MASTERARBEIT

Titel der Masterarbeit
Essay on Oil Price Dynamics

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angestrebter akademischer Grad
Master of Science (MSc)

Wien, 2015

Studienkennzahl lt. Studienblatt: A 066 914
Studienrichtung lt. Studienblatt: Masterstudium Internationale Betriebswirtschaft UG2002
Betreut von: Prof. Dr. Franz Wirl
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I. Introduction

Oil is a commodity, which is deeply enrooted in the global economy. The global oil market, with its numerous layers, has evolved over the years to a complex, constantly developing system, which binds together players, e.g. large companies, governments and individuals, from all over the world. Given this importance of the oil market to the global economy, reliable forecasts on the price development of the commodity and analytical assessments on the development of the oil pricing framework are detrimental to the welfare of all involved parties.

In the following essay we outline the constituting fundamentals of the global oil market, e.g. supply, demand and other key oil characteristics. Having analysed these aspects, we turn to assess the price formation process on the key Brent and Dubai markets. In addition to this we also assess price formation processes, trend and volatility indicators as well as an outlook of the driving factors on the future oil market. Furthermore, we provide the reader to some forecast models with an empirical and mathematical focus.

In order to optimally assess the abovementioned aspects, we divide this paper into two sections: a theoretical section and an empirical/mathematical section.

The first part of the theoretical section will lay down the constituting characteristics of crude oil as commodity. In this section we analyse the physical, chemical and economical characteristics of crude oil. Furthermore, we present an insightful overview of the development of global oil supply and demand, focusing on the future development of these two segments and its impact on future oil prices.

In the second part of the theoretical section we discuss the historical development of crude prices, e.g. the driving factors, which shaped the evolution of oil price formation over the years. Having assessed this section, we turn our view to the key Brent and Dubai markets. Here we analyse how these have developed over time. In addition to this, we also analyse the different financial layers of these market, e.g. spot, Futures and Forwards, and the way these layers interact between each other.
In the second section of the paper, we will examine various mathematical and empirical models and tools for assessing the development and providing a forecast for crude oil prices. The former section will include the notions of various mathematical forecasting concepts based on Futures contracts, the spread between Futures and spot prices, Parsimonious Mathematica forecasting models, such as the no-change rule, and volatility and trend indicators. The empirical section will deal with analysing price time series, taking into account key scientific findings on this topic. We will base this section on simple and multiple regression models and Vector Autoregression Models, which we will analyse both from a conceptual and academics perspective.
II. Theoretical Section

1. The Nature of Crude Oil

Crude oil, or petroleum, can be viewed under different perspectives, the compound of which represents the fundamentals, on which price formation is built. As a physical commodity, oil has both chemical and physical properties, which serve as a building block of the price formation process. Furthermore, oil can be viewed also as a financial/hedging tool, i.e. economic properties.

1.1. Physical and Chemical Properties of Crude Oil

From a chemical perspective, crude oil is a liquid mixture of hydrocarbons of various weight and length. In addition to hydrocarbons, oil also contains other chemical molecules, such as sulphur, nitrogen, oxygen and metals (Speight 1998, p. 39). Usually, around 83-87% of the volume of the crude oil mixture is composed of carbon, whilst hydrogen, sulphur and other substances account for 10-14%, 0-6% and 0-6% respectively. This characteristic means that, opposed to the common public misbelief, crude oil is not a single and homogenous substance. Thus there are several hundred grades of crude oil, differentiated with regards to key chemical characteristics, which are usually depicted in a Crude Oil Assay. For example, the Crude Oil Assay of one of world’s benchmark grade, namely Brent Blend, provides a breakdown of the chemical characteristics of this crude grade.
Some of the crude oil features, outlined in its assay, are the expected yields of numerous finished products (naphtha, gasoline, jet/kero, gas oil, residual fuel oil, etc), acidity, viscosity, density and sulphur content. We turn to analyse the latter two characteristics, as these are considered to be the most important when defining the quality of a crude oil grade. Thus, mainly depending on their quality, different crudes will get different prices on the global market.
We start with density. Density is a characteristic of crude oil, which depicts the size of hydrocarbon molecules of the crude oil. For instance, heavy crudes have larger hydrocarbon molecules, which hold more atoms. The contrary argument applies to light crudes. In general, light crude grades are more valuable for a refiner, as they yield more light-end products, such as liquefied petroleum gas (LPG), naphtha and gasoline, when produced via simple refining processes. In order to obtain the same amount of high-values petroleum products, heavier crude grades have to undergo more complex refining processes, such as cracking and coking, which require investments into costly secondary refining capacities. Density of crude oil is measured in three ways: API gravity (the abbreviation stands for the American Petroleum Institute), Specific Gravity and Metric Density. Of the three measurements the first is most widely spread. The API gravity measures the density of crude oil to the density of water (water has a density of 10° API).

<table>
<thead>
<tr>
<th>API Density Classification</th>
<th>API Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate/Extra Light</td>
<td>&gt;50°</td>
</tr>
<tr>
<td>Light</td>
<td>34°&lt; &gt;50°</td>
</tr>
<tr>
<td>Medium</td>
<td>33.9°&lt; &gt;28.1°</td>
</tr>
<tr>
<td>Heavy</td>
<td>28°&lt; &gt;20.1°</td>
</tr>
<tr>
<td>Extra Heavy</td>
<td>20°&lt; &gt;10.1°</td>
</tr>
<tr>
<td>Ultra Heavy</td>
<td>&lt;10°</td>
</tr>
</tbody>
</table>

We continue with sulphur content. In an earlier paragraph we described that crude grades, also contain other chemical molecules, such as sulphur. The volume of sulphur in a particular crude grade plays an important role in the pricing mechanism. Typically, the sulphur content is in negative relation to the value on the crude grade, i.e. higher sulphur content lowers the grade’s value. This inverse relation comes on the back of several factors: 1) the higher the sulphur content, the lower the energy content of the crude, as hydrocarbon molecules are displaced by sulphur molecules (Downey 2009, p. 35); 2) when burned, either during a direct crude-burning process (usually for power generation) or via high sulphur gas oil (e.g. 350 ppm) or fuel oil, sulphur becomes a precarious pollutant to the surrounding environment; 3) sulphur causes corrosion to metals. As metal plays an important role in the oil industry, e.g. pipelines, storage tanks, refining facilities are usually constructed with
metals, high sulphur crudes cause damage to such facilities, which increases the need for maintenance and consequently raises operating costs.

Sulphur content of a given crude grade is measured in percentage (%) of its weight. Thus higher percentage values indicate higher sulphur content. A typical classification of crude grades, with regards to their sulphur content is depicted in the following data-table.

<table>
<thead>
<tr>
<th>Sulfur Content Classification</th>
<th>(% by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>Medium Sour</td>
<td>0.5%&lt; &gt;1.5%</td>
</tr>
<tr>
<td>Sour</td>
<td>&gt;1.5%</td>
</tr>
</tbody>
</table>

NB: Classifications can differ
Source: Various

In the next paragraph we analyse the relationship between sulphur content and API gravity. Due to its chemical characteristics, sulphur connects easier with heavy and complex hydrocarbons. Thus, heavier crudes, i.e. lower API gravity index, typically have higher sulphur content. The same principle applies to finished products. Gasoline and naphtha usually have lower sulphur content than heavy products (larger hydrocarbon molecules) such as fuel oil and bitumen.

In a typical setup, from a refiner’s perspective, light sweet crude grades are easily processed to high-value petroleum products such as LPG, naphtha and gasoline. In a separate note, in order to achieve a lower yield of less economically attractive petroleum products such as fuel oil these, when refining more sulphurous and heavy grades (which are usually traded at lower prices), a refiner needs to utilise secondary refining units, such as hydrotreating, hydrocracking and visbreaking units, which substantially add up to the overall production costs of the refiner.

Therefore, generally light and sweet crude grades are more expensive than heavy sour grades. A refiner often has to face the following trade-off: invest into costly secondary capacities, which allow the more effective processing of heavy sour crude grades, or pay a premium to process light-sweet crude grades, without significant investments into secondary
units. The determinants of a final decision between these two options are the overall capacity for processing these two crude types within a refining industry, as well as the relative demand and supply of heavy-sour/light-sweet.

1.2 Oil Liquids Components

When speaking about crude oil one can refer to a different mixture of hydrocarbons. In this section of our analysis, we assess the different hydrocarbon components, which comprise crude oil.

- Crude oil (including field condensate/lease condensate)
This is unprocessed oil recovered from a reservoir and typically ranges between 10° and 50° API. According to various reports (IEA, EIA, BP Statistical Review etc.), crude oil production will continue increasing in the upcoming years (in absolute terms). Nonetheless, the share of crude oil in total oil liquids production will decline, as production natural gas liquids (NGLs) and other oil liquids will increase at a higher pace than total oil liquids production.

(Field) Condensates are hydrocarbons with high API index (above 50°API). Given their density and very low sulphur content, these hydrocarbons are very valuable to refiners. Apart from being used in a refinery (typically blended into a heavy crude grade in order to increase its quality), condensates are also processed at condensate splitters, which mostly produce light end products for the chemical industry (e.g. naphtha).

- Natural Gas Liquids (NGLs)
  - NGLs are by-products of natural gas production. These hydrocarbons are produced from natural gas in separation facilities or gas processing plants (Downey 2009, p. 42). Consequently, countries with high natural gas production have high NGLs output. Natural gas liquids are typically comprised of ethane, liquefied petroleum gas (LPG; propane and butanes), but not of methane, the main component of natural gas. Here, it is important to note that NGLs do not fall within the OPEC target production (EIA, What Drives Crude Oil Prices), meaning that OPEC member countries can produce and export as much NGLs as they find necessary. As outlined in the aforementioned paragraph, the share of NGLs in total oil liquids production will increase, intact with rising natural gas production (see chart).
• Other Liquids
  
  o Several liquids fall within this category.
    
    ▪ Gas to liquids (GTL): As natural gas is built also by hydrocarbons, it can be converted into liquid fuels. For example, Qatar utilises this unconventional process, as it has abundant natural gas reserves. According to BP’s Statistical Review for 2013, the Persian Gulf country holds 13.3% of total gas reserves worldwide, or around 24.7 trillion cubic meters; The shared South-Pars gas field (with Iran) is an example of a large-scale gas field within the borders of Qatar.
    
    ▪ Coal-to-liquids (CTL): This process converts coal into liquids by utilization of the Fischer-Tropsch process (Meyers 2004, p. 15.3). Coal to liquids is currently used in South Africa, as form a historical perspective the country fell under international isolation during the
apartheid regime, and could not trade on the international oil market. This process was also widely used in Germany in the 1930/40s.

- Biofuels are also another component of total liquids. Biofuels are used mainly in Brazil and the US, and can be separated into Ethanol and Biodiesel, the latter of which is used mainly in the EU for blending into diesel.

- Processing/Refining Gains
  - During the refining process more complex hydrocarbon molecules are cracked to lighter molecules. Thus, total products output from the refinery occupy more space than the liquids input. This means that the volume after the refining process has increased, although the weight (i.e. energy content) remains unchanged (Downey 2009, p.42). This volume difference between input and output is referred to as processing/refining gains.

Different players have different definitions of the term crude oil. OPEC defines crude, which is subject to the production quotas, as hydrocarbons with API density below 50°. On the other hand US producers enclose not only crude with API of above 50° to the term crude, but also lease condensate. In addition to the US components, Russia also includes LPG to the term crude (see data table). Thus, when analysing crude production data from different sources, it is important to take into account these differences in the definition of crude, in order to be able to correctly assess oil price dynamics.
Nowadays, hydrocarbons and crude oil in particular, have become an integral part of the global economy, due to their key characteristic. Oil is a concentrated form of energy and contains more energy per volume than any other form of hydrocarbon mixture: 1 metric tonne of coal contains only around 67% of the energy equivalent of 1 metric tonne of crude oil. One metric tonne of crude oil is roughly equal to 7.3 barrels, or 42 Gigajoules (GJ) of energy. The conversion factor between metric tonnes (weight) and barrels (volume) depends on the density (API Gravity) of the selected crude grade and can be approximated by the following formula:

\[
Conversion \ Factor = 1/((141.5 \times 0.159)/(API \ Gravity + 131.5))
\]
2. Evolution of the Global Oil Market

In this section we will assess the foundations of oil trading, in the context of the historical development of the oil pricing system on the global market. Over time, this system has been shaped by various political, economic and other factors.

When we talk about oil trading it is important to distinguish between trade of physical and paper markets. The former form could be further separated into term supply and spot supply contracts, which are discussed at a later stage in this chapter.

Historical Development of Oil Pricing

Posted Prices

From a historical perspective, until 1970s almost all physical deliveries of crude oil were done via term contracts with fixed volumes and fixed prices (see data-table). Prices of these contracts were relatively stable over time and sometimes remained constant for as long as several months. During that period, almost every aspect of the term contract was constant: the oil producer supplied cargoes on a FOB basis at certain export outlet (e.g. port), over a fixed timeframe with a fixed price per barrel for all customers at that outlet (Fattouh 2011).

In the era of Posted Prices, the local governments, on which territory oil was produced, usually did not participate in the extraction of crude oil, but received a royalty payment usually done by a company from the Seven Sisters group. This group controlled the majority of oil exports on a global basis and thus could prevent oil prices from declining (Penrose 1968, p. 54).

This set-up of term contracts, although with little room for manoeuvres, provided a high degree of security to the buyer. Therefore risk management in global oil trade played a rather minor role in the period of posted prices. Furthermore, this pricing system facilitated a quick and easy mechanism for the calculation of revenues from oil sales to host governments, a fiscal role which spot prices could not take as efficiently, in the dynamics of that time.
(Fattouh 2011, p. 14). As a fiscal parameter, oil prices did not follow the economic laws of supply and demand, in the sense of an allocation property (Mabro 1984, p. 6-17).

The importance of posted prices began gradually decreasing, as independent oil companies, i.e. other than oil majors, began playing a more important role in the global upstream sector, in particular in Venezuela, Iran, Libya and Saudi Arabia (Parra 2004, p. 132). Nonetheless, until the late 1960s oil majors remained dominant on the global oil market. Furthermore, over that period OPEC evolved into an organisation, which was setting the posed prices unilaterally (Terzian 1985, p. 150-173).

In the early 1970s ideas for nationalisation of oil ventures in the Arabian Gulf states become more popular amongst national governments there. Later, this eventually led to partial/full nationalization. This gave national governments access to vast crude oil supplies, which they had to market. In the new market set-up another pricing concept, the one of Official Selling Prices, was adopted (Mabro 1984, p. 18). During the first half of the 1970s, three different pricing schemes were in place on the global oil market: posted price, official selling price and buyback principle. This market position was not efficient, as a buyer could obtain a barrel of crude at three different prices, amidst lack of transparency and information (Fattouh 2011, p. 16)

With the introduction of spot prices in the first half of the 1970s, term suppliers began taking into account this element. Nonetheless, during that period risk management instruments were not common in the market, as both buyers and sellers enjoyed stable market fundamentals. Prior to the 1980s, term contracts with fixed volume and price dominated the global oil market. During that period trading had been done by only few companies.

These market conditions changed in late 1970, when other players like independent oil companies/refiners, trading houses and oil traders emerged. Furthermore, the change of regime in Iran, in the late 1970s/early 1980s, accelerated the shift to a different dominant pricing regime. During that period spot prices, which already had been introduced to the market, were increasing quicker than official selling prices (Fattouh 2011, p. 16). This opened arbitrage opportunities: buying crude at official selling prices via long-term contracts and selling it for the spot price would yield low risk profits. Thus OPEC producers had an incentive to abandon selling their oil via long-term contracts (see chart).
With increasing supplies from outside OPEC countries, official selling prices, which were administrated by OPEC, were steadily losing popularity amongst market players. This was also due to the fact that non-OPEC producers were selling their oil in line with market conditions, i.e. spot prices, which were more favourable to buyers than OPEC administrated prices.

With market pricing gaining popularity amongst market players, the industry gradually shifted to a more sophisticated market position, where term contracts take into account benchmark prices, thus reflecting more closely the movement and dynamics of the volatile spot markets. This shift to spot market linked term contracts was triggered by the disadvantages of term contracts outlined in the previous paragraph: each contract part (buyer, seller) had an incentive to break the all-fixed term contract, as soon as the price on the competitive spot market moved into a more favourable direction, thus allowing the one party to acquire crude at a more lucrative terms.
Saudi Arabia, the stringiest proponent of the official pricing mechanism, moved to market pricing sometimes in 1987, marking a new chapter in the global oil pricing framework. With this step pricing power shifted from OPEC to the actual market.

Following higher importance the spot market and more volatile oil prices, due to the newly adopted linkage to spot pricing, OPEC member countries could no longer set the prices of their crude grades, without respecting current market conditions. Thus OPEC members shifted from directly defining the price of their oil output, to setting it via production quotas. OPEC producers started producing regulated volumes of oil and let the market clear these volumes and determine the price. Thus oil buyers were driven to compete for the marginal OPEC barrel, which then determined the price. The new OPEC policy also aimed at reducing the volatility of prices, by bringing global supply and demand into equilibrium, a goal which is also currently the primal objective of the Organisation of the Petroleum Exporting Countries. This policy prevented any substantial damages to the world economy caused by high price fluctuations.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price Type</strong></td>
<td>Posted Prices</td>
<td>Mixture between Official Selling Price and Posted Price</td>
<td>Market Price</td>
<td></td>
</tr>
<tr>
<td><strong>Market Type</strong></td>
<td>Physical Oil Market</td>
<td></td>
<td>Paper Oil Market defined by risk management instruments (derivatives), such as futures, forwards, options</td>
<td></td>
</tr>
<tr>
<td><strong>Trade Contracts Type</strong></td>
<td>Long term contracts with regards to both volume and price; prices remain constant over long periods (months) of time</td>
<td>Long term contracts with regards to volume; Price defined on a spot basis</td>
<td>Volume both long term and spot; Market linked prices</td>
<td></td>
</tr>
<tr>
<td><strong>Pricing Framework</strong></td>
<td>CIF Prices: determined by the &quot;Seven Sisters&quot;, following the Achnacarry agreement on production quotas; Prices also take into account royalty payments to concession countries</td>
<td>FOB selling prices set by OPEC</td>
<td>Competition on the global oil market defines prices</td>
<td></td>
</tr>
<tr>
<td><strong>Oil Price (in USD per barrel)</strong></td>
<td>Roughly 2 USD/barrel</td>
<td>On average at around 20 USD/barrel</td>
<td>High volatility of oil price change; Prices spike and drop rapidly; Current level at around 107 USD/barrel</td>
<td></td>
</tr>
</tbody>
</table>

Source: Energy Charter Secretariat, Various
Present Day Oil Pricing Mechanism

As discussed in the section above, market-based oil pricing had begun to gain popularity in the late 1980s, and is the most important pricing mechanism nowadays.

The oil pricing mechanism nowadays better depicts market dynamics and it also allows for the utilisation of risk management instruments such as derivatives. Today’s market structure is built on a complex interaction between the physical and paper (futures, forwards and swaps) market layers. At the same time, physical deliveries of crude oil occur either via the spot market (directly or indirectly via EFPs or CFDs, which are discussed in the next section) or via long-term contracts.

Term and Spot Agreements

The most important characteristic of the present-day term contract, which distinguishes it from a spot market contract, is a longer lasting relationship between buyers and sellers. This bond implies operational predictability for both parties of the term contract, which in terms suggests a high degree of certainty, compared to more versatile, but also more unpredictable and volatile spot agreements. Furthermore, pricing of present day term contracts is linked to the spot market.

Thus nowadays, a term contract could be viewed as a hybrid agreement, which combines elements of the former term contracts with features of the spot market (Energy Intelligence 2009, p. 1).

The price of a long-term contract cargo is usually derived by a formulae-pricing mechanism, which is discussed at a late stage in this analysis.

Returning to term contracts, these agreements are used by numerous key players in the market like Saudi Aramco, the national oil company of currently the biggest exporter of crude oil worldwide, namely Saudi Arabia and Pemex of Mexico.
The differential, set by oil producers depends on many market variables. For example, for the Asian market this differential depends on the difference between Dubai 3rd Month and Dubai 1st Month. Other variables also play a role here. For example field maintenance in the country is also considered in addition to the Gross Product Worth value the particular crude yields in the particular region (Fattouh 2011, p. 21).

Furthermore, when setting crude differentials an exporting country also takes into account how other competitive crudes perform in the market. For example, when Saudi Aramco markets its Arab Light grade to Europe, the company considers also how Russia’s flagship grade Urals is performing on that market, as the two crude grades have similar qualities/product yields and are thus competitors.

Usually, the differentials are set one month before the actual loading of the cargo. This means that the information, used to derive the differential is outdated at the time of loading and might not fully mirror the market at that time. Thus, differentials adjusted each over regular periods, e.g. month/quarter etc.

Spot supply contracts are agreements for physical delivery of crude oil between a buyer and a seller as soon as it is operationally possible. On a global scale, spot supply contracts account for significantly less actual oil deliveries than term supply contracts. Nonetheless, agreements on the spot market have a much higher accuracy of depicting the current position on the global oil market, as these are done practically on an ad-hoc basis and this serve as the cornerstone of the modern day pricing mechanism.

Benchmarks in Formula Pricing

The daily spot prices of markers or benchmark grades, such as WTI, ASCI, Dated Brent and Dubai, are issued by pricing reporting agencies (or also referred to as trade journals). Currently, the two most widely used trade journals which issue daily spot prices are Platts and Argus. Here it is imperative to note, that these agencies have different price discovery methodologies. Thus, the prices for the same benchmark, which they report, often differ slightly from each other.
Futures quotations are also an important ingredient in the present day pricing mechanism. Futures quotations are done by trading hubs, with the NYMEX (New York Mercantile Exchange), ICE (Inter-continental Exchange) and the DME (Dubai Mercantile Exchange) being the three most important futures exchanges in the world, which are the trading hubs for WTI, ICE Brent and Dubai respectively. Altogether, spot and futures prices are widely used as benchmarks by oil exporting countries (see data-table).

<table>
<thead>
<tr>
<th>Exporting Country</th>
<th>Asia</th>
<th>Europe</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>Oman/Dubai</td>
<td>BWAVE</td>
<td>ASCI</td>
</tr>
<tr>
<td>Iran</td>
<td>Oman/Dubai</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kuwait</td>
<td>Oman/Dubai</td>
<td>BWAVE</td>
<td>ASCI</td>
</tr>
<tr>
<td>Iraq (Basrah Light)</td>
<td>Oman/Dubai</td>
<td>-</td>
<td>ASCI</td>
</tr>
</tbody>
</table>

Source: Various

Trade journals closely follow another form of oil trade, namely the OTC (Over the Counter) market, and derive a snapshot of the spot price of key global benchmarks.

The daily prices of oil benchmarks are utilised to define the price of all almost all other crude grades. The premium/discount of all the other global grades to the benchmark grades is a function of different market variables, such as transportation costs, taxes, quality difference, etc. There are several key methods for determining the price formation of these grades. The three key methods are:

1. **Formula Pricing**

Formula pricing is a common method for marketing a non-benchmark crude grade to the global market. The formula pricing concept takes into account dynamics of underlying market fundamentals (e.g. refining cracks, relative demand for sweet/sour grades, etc.) in order to assess the premium/discount of the grade to the underlying benchmark for a given period in time (typically either a day or a month). After each period, formulas are revised in order to follow the market dynamics more closely. For instance, OPEC producers use formula pricing when placing their crudes on the global market. By using formula pricing these producers derive the Official Selling Price (OSP) of their crudes to the underlying benchmark
grade (marker). By using the formulae pricing the price of the cargo is linked to the spot price (Fattouh 2011, p. 21). The formulae pricing mechanism typically has the following form:

$$P_x = P_R \pm D$$

Where:

- \(P_x\) = the price of the agreed crude in the long-term contract
- \(P_R\) = Price of the benchmark crude grade, usually Brent, WTI or Oman/Dubai
- \(D\) = Differential

The differential is usually agreed upfront between the two parties, by price reporting agencies or is set unilaterally by the suppler. This type of formulae pricing is used not only for pricing term-cargoes, but also for spot cargoes of non-benchmark grades. A major advantage of formulae pricing is that it reduces the risk exposure to the buyer/seller of a cargo, as the final price of the cargo is linked to the benchmark price at the time of delivery (Fattouh 2011, p. 21-22).

For example, each month Saudi Aramco, sets the differentials for its various oil grades in that month at a premium/discount/flat against a crude marker for the particular marketing region, i.e. BWAVE for Europe, ASCI for the US and Oman/Dubai for Asia. This means that Saudi Aramco fixes each month the differential to these crude markers, whilst the outright delivery price for the buyer of Saudi Arabian crude depends also on the movement of the particular marker (we assess pricing of marker grades in the next section of our analysis).

Another version of formula pricing can give the outright price of the non-benchmark grade by taking into account several relevant benchmark prices. This version of formula pricing gives an outright price, and not the differential.

For example, Pemex of Mexico uses the following formula to market its three key crude grades to the US (source: PMI Comercio Internacional):

- Isthmus Crude = 0.40(WTS + LLS) + 0.20(Dated Brent) + constant
- Maya Crude = 0.40(WTS + US Gulf #6 oil 3%) + 0.10(LLS + Dated Brent) – constant
\[ \text{Olmeca Crude} = 0.333(\text{WTS} + \text{LLS} + \text{Dated Brent}) + \text{constant} \]

As we can see from the second equation above, the outright price of Maya crude does not depend only on the price of key crude oil grades, but also on oil products. In this case a grade of residual fuel oil, as Maya is a heavy-sour grade with API° of around 21 and sulfur content of 3.6%, which is similar in quality to this fuel oil grade. Furthermore, the constant above, or as K-factor, as PEMEX calls it, is a number, derived after the assessment of key market variables and competing grades.

2. Netback Pricing

Netback pricing is another method for pricing crude oil on the global market (Energy Charter Secretariat 2007, p. 73), which was used by Saudi Arabia in the mid-1980s. Prior to the adoption of the netback pricing method, the Middle Eastern country was suffering from decreasing market share, as non-OPEC oil supplies were increasing at that time, whilst global oil demand declined. In an attempt to regain its lost market share, Saudi Arabia dropped the Official Selling Price System, which had become too rigid, due to its strict conditions (see insight on Saudi Arabian pricing history in the paragraphs above), and adopted the netback pricing mechanism. The netback mechanism derived oil FOB prices from product prices, adjusted for transportation costs and refining margins.

Netback pricing, for a brief moment in history, was widely adopted by OPEC producers. Soon after Saudi Arabia started using this principle and consequently regained its lost market share, other OPEC producers also priced their oil using the netback principle. However, as in that period oil prices had collapsed, the netback principle was disregarded by OPEC countries. Nonetheless, this principle was a factor in the transition of global oil pricing from the rigid official selling prices system to the current international oil pricing framework, which is mainly based on spot prices.

In general a netback pricing formula takes into account the gross worth of all end products a barrel of oil yields, as well as all the costs, associated with bringing this barrel to a given refinery. The following equation represents a simple netback mechanism:

\[ \text{Crude Oil Price (FOB)} = \text{GPW} - \text{Fixed Refining Margin} - \text{Transportation Costs} \]
Where: GPW is the Gross Product Worth of all end products of a barrel of oil

Transportation Costs are logistic charges from the export outlet of the oil supplying country to the refinery of the oil buyer (Energy Charter Secretariat 2007, p. 73). From the viewpoint of the oil buyer, the netback principle secures profit margins, whilst marketing the crude according to what a barrel earns via end products at the market.

Robert Mabro of the Oxford Institute for Energy Studies further argues in his paper “On Oil Price Concepts” that the netback mechanism does not derive the price of an oil barrel. It rather estimates what this barrel is worth to a refiner, given the refiner’s specific product yields as well as the transportation and refining costs. Furthermore, the Mabro (1984) argues that the netback method should not be referred to as measure of profitability, as this calculation is made for the marginal barrel and because it does not allow for “normal returns on capital”. A further flaw of the netback method is that its underlying assumption is that a barrel of crude is bought at a certain price, whilst the end products are sold instantaneously at the spot market. However, this assumption does not fully mirror the reality, as refiners usually tend to choose from supply a term market, to increase inventories, or to sell only a selection of the products produced.

Currently, the netback mechanism for crude oil prices is not commonly spread in the global oil industry. Nonetheless, this principle is incorporated into the Russian oil industry, one of the most important on the global scale. In Russia, sales of crude oil and oil products on the domestic market follow the “export parity model”, which has the same features as the netback mechanism. According to this method, domestic prices in Russia (for both crude oil and oil products) are a function of the price of the commodity on the respective international market, “netted back to a delivery basis in Russia” (Argus 2014, Argus Russian Netbacks, p. 2). The Russian government can steer these prices by altering its hydrocarbons taxation framework, e.g. changing the export duty for crude and oil products, which consequently increases or decreases domestic prices.

The netback index for placing oil and products on the Russian domestic market is calculated as follows (Argus 2014, Argus Russian Netbacks, p. 2):

\[ N = P - F - D - S + T \]
Where:

N: Netback Index

P: Price assessment of crude or oil products at competitive international markets, e.g. NW Europe, Mediterranean, etc.

F: Tanker costs, including insurance, and other freight-associated costs

D: Export duty

S: Costs of loading, storage, transportation, etc.

T: Russian VAT and excise duty

This way, by calculating the netback to the wellhead, e.g. Nizhnevartovsk, and compare this figure to the domestic market price, one can judge if the domestic market is at premium/discount to the international market.
3. The Brent Benchmark

In this section of our analysis we will assess global crude benchmarks and their key fundamentals with focus on the Brent benchmark.

**Crude Oil Benchmarks: Key Regions**

The Brent market is paramount to international oil trading. Nowadays, the Brent complex (see map) is regarded as the main crude oil benchmark worldwide, which is the base for almost 2/3 of global oil trades (The ICE). From a historical perspective, in the early 1980 the Brent market consisted of a spot market (Dated Brent) and an informal forward (OTC) market (Fattouh 2011, p. 36). Since that period, the Brent market has evolved rapidly according to the needs and shapes of the global oil market (Horsnell 2000, p. 1-3) and has developed into a highly sophisticated market, with highly liquid futures and swaps segments.
Prerequisites for the Formation of a Crude Benchmark

First we consider several key factors, which helped promote Brent to evolve over time to be a global benchmark.

- **Ownership Diversification:** Horsnell and Mabro (1993, Chapter: The Historical Development of the Brent Market) discuss that one of the most important properties of an oil benchmark is a wide range of sellers. If the crude is supplied by a monopolistic constellation of producers or a single producer, then the probability of manipulations rises, which in turn increases the risk exposure of buyers (Newbery 1984, Chapter 2). For example, the absence of a wide range of producers prevented many key grades, such as Arabian Light (Saudi Arabia) and Urals (Russia), from becoming benchmarks. With regards to Brent, the addition of a further stream (Ekofisk) to the initial BFO blend further contributed to the high ownership diversification.

- **Geographical Location:** Another major characteristic of an oil benchmark is the geographical location of the oil producing fields near an oil demand centre. The Brent Blend is physically produced in the North Sea (see map), which is in the vicinity of a key demand region, namely North West Europe. Furthermore, the production area of the Brent Blend is also near North America’s Gulf Coast, the refining hub of the United States.

- **Physical Liquidity:** In addition to the other key characteristics, the Brent Blend has also a relatively high production rate of around 800,000 b/d (EIA August 29, 2013: Summer Maintenance Affects North Sea Crude Oil Production and Prices), which provides enough physical liquidity for trading.

- **Judicial Framework:** Furthermore, benchmark traded volumes (both physical and paper) should be subject to a stable and transparent judicial framework. In particular, the Brent Blend enjoys a high degree of judicial stringency in terms of legal, tax and regulatory issues.
Historical Production Overview of Brent

Initially, Brent, which consists of grades from different fields all of which are collected via a pipeline system offloading at Sullom Voe in the Shetland Islands, UK, served as a fundamental to pricing of other North Sea crudes, such as Ninian, Forties, Flotta, Statjord, etc. With a physical decline of production of the Brent stream in the mid-1980s, the possibility of price distortions increased (see Physical Liquidity point above). In order to avoid any possibly manipulations, the Ninian stream was added to the Brent stream, forming the Brent Blend. This alleviated the problem for some years. In the beginning of the new millennia physical production of the Blend was once more on a decline, threatening its position as a benchmark.
In July 2002, Platts added two new crude streams to the Brent Blend, namely Forties, originating from the UK section of the North Sea, and Oseberg, produced at the Norwegian section of the North Sea. The new blend, referred to as BFO (Brent-Forties-Oseberg) was used for assessment purposes instead of the former Brent Blend and the tree grades were assumed deliverable in the context of Brent Forward contracts. As production of these three streams gradually decreased over time, in 2007 a new stream, Ekofisk, complemented the compound, forming the BFOE Blend. Thus, the BFOE price, or also currently referred to as Brent Blend, should not be associated with a single physical crude stream, but could be rather referred to as indexation. BFOE is widely referred in the industry as Brent or simply North Sea.

An interesting feature of the pricing mechanism of BFOE is a quality “de-escalator”, which was introduced by Platts in July 2007 (Platts 2013, p. 2). Since any of the four BFOE grades can be delivered against a BFOE contract (i.e. for the BFOE price), sellers prefer to deliver the cheapest of the four grades to buyers. The cheapest of the four is typically Forties, due to its physical qualities. Thus, Forties usually sets the price of the BFOE benchmark, or Brent. In 2007 the Buzzard field, which has a relatively high sulphur content, was adopted
into the Forties stream, which deteriorated the overall quality of this stream, relative to the Brent, Ekofisk and Oseberg streams (see data-table). Thus Platts introduced the abovementioned quality “de-escalator”, which postulates that the higher the sulphur content of a cargos, which is sold to a buyer (above a certain threshold), the higher the discount of this cargo.

Another interesting feature of BFOE is the Quality Premium (QP). The QP is an instrument, which binds the buyers of Ecofisk and Oseberg to pay a certain quality premium, in cases when lower quality Forties sets the price. This way the liquidity of the BFOE market is increased, as the QP makes the two aforementioned grades more competitive, i.e. increases the probability of these grades to be price setters instead of Forties. This increases volumes of the price setting grade, and thus increases liquidity (Platts 2013, p.2).

### Brent Market Layers

**The Spot Brent Market**

In the following paragraphs we will analyse the different constituting layers of Brent: the spot and paper (Futures, Forward and Swaps) markets. Furthermore, in the context of price risk management, it is important to note that these layers are interconnected.

Spot Brent, or also North Sea Brent and Dated Brent, constitutes the Brent market for physical deliveries. Dated Brent is a crude blend, which consists of different four crude streams: Brent, Forties, Oseberg and Ekofisk (see previous paragraph). According to the pricing methodology, the spot price of Brent is set by the cheapest of the four constituting

<table>
<thead>
<tr>
<th>API Gravity and Sulfur Content of BFOE Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>API Gravity</td>
</tr>
<tr>
<td>Sulfur Content</td>
</tr>
</tbody>
</table>

Source: BP, Statoil, Eni
grades. When looking at the time frame of loading a Brent cargo (see chart), we see that cargoes loading in the next ten days from today are referred to as distressed cargoes. Thus, from a time perspective, the Dated Brent market occurs between the 10th and the 25th day from today. Physical cargoes of the Brent are loaded during that period. The time frame after the 25th day from today serves as a starting point for the forward Brent market (see chart).

The Brent Forward Market

The Forward Brent market is referred to as 25-day Brent, or simply 25-day. Price assessments at this forward market are done by several key trade journals, such as Platts, PVM and Argus (price assessments of the Brent Futures market are done by The ICE). Forward deals are OTC (Over-the-Counter) deals, many of which are unreported due to the nature of the forward market. This feature raises problems when comparing the different layers/markets of Brent.

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It is important to note that forward contracts specify only the month of loading, but not the exact date. Furthermore, Forward Brent prices are often assessed for the next three months from the current date. Before settlement, a 25-day BFOE contract can be transferred between
numerous buyers and sellers through a so-called “daisy chain” of notices (Fattouh 2011, p. 41). A 25-day BFOE contract ends either by a cash-settlement, i.e. no physical delivery of crude, or by an actual physical delivery of a cargo (physical settlement). The latter of the two options occurs rather seldom in comparison to the former. Furthermore, the Forward Brent market typically assumes a nominal trading volume of a minimum of 600,000 barrels. This figure comes from the SUKO 90 Terms and Conditions of Shell UK Limited, which are adopted by the majority of players on the forward market (Agreement for the Sale of Brent Blend Crude Oil on 15 day terms Part 2 General Conditions Shell U.K. Limited July 1990).

Taking into account the features of the forward market (large size of cargoes of usually 600,000 barrels, compared to a typical futures contract assumes a 1,000 barrels cargo, competing against time (25-day notice, and a swift exchange of contracts between many players), trading at the forward market is considered by many market players as a risky endeavour. Thus, many market participants opt to switch to a more secure marketplace for trading, namely the futures market.

The Brent Futures Market

Brent Futures are traded on the InterContinental Exchange, or the ICE, which was launched in 1988. Thus Brent Futures are often referred to as ICE Brent. Like many other futures contracts, ICE Brent contracts are highly standardised and have all the features of a future contract: Clearing House, brokers, high degree of security and no direct interaction between buyer and seller. An ICE Brent Future contract has a minimum lot size of 1,000 barrels, meaning that the units of trading are a multiple of these 1,000 barrels. The smaller futures contract (compared to the usually 600,000 barrels cargoes at the forward market) reduces the entry costs. Consequently, the smaller contract size also makes the market more accessible, which in terms increases its transparency.

Thus the Futures Brent market is considered to be highly liquid and its forward curve goes long into the future (this curve is also used as a hedging tool). The level of the Average Daily Volumes of ICE Brent Futures contracts (see chart) is an indication of the high liquidity observed on the futures market. In fact, Daily Average Volumes of ICE Brent Futures
Contracts stood at almost 600 million barrels per day over 2012, which was more than 6 times the daily oil consumption worldwide in that year (BP Statistical Review 2014, p. 9).

Trading of Brent Futures contracts happens on an electronic platform, which anonymously matches bids and offers. Termination of an ICE Brent Futures contract occurs via cash settlement, which also has the feature of a physical delivery, although used rarely, via the Exchange for Physicals (EFP) system.

Brent Futures contracts are used to facilitate the transfer of price risks between different market players. One of the key aspects of such a mechanism is convergence, i.e. the linkage of the futures market to the underlying physical commodity. In theory such a mechanism would allow market participants to exchange their Futures contracts after expiry for actual physical deliveries. This will then drive Futures prices to converge to physical prices.

The ICE has successfully incorporated this feature of the Futures markets to the ICE Brent Futures. This happens by linking ICE Futures to the Brent Forward market, which implies physical delivery. At the date of expiry an ICE Brent Futures contract cash settles
against the **ICE Brent Futures Index** (Brent Index), which is derived from the 25-day BFOE market, i.e. **Brent Forward market** (The ICE). The 25-day BFOE base implies that the price of the Brent Futures contracts converges to the price of the Brent Forward contracts. Thus, reliability of the futures market for price discovery is linked to the forward market and its liquidity (Fattouh 2011, p. 42).

**The Brent Futures Index**

The Brent Futures Index is calculated by taking into account:

1. A weighted average of first month (i.e. next calendar month) cargo trades in the 25-day BFOE market.
2. A weighted average of second month cargo trades in the 25-day BFOE market plus a straight average of the spread trades between the first and second months.
3. A straight average of designated assessments published in media reports.

**1. First Month Weighted Average**

The weighted average of first month cargo trades in the 25-day BFOE market is calculated by determining the average of the cargo trade prices reported. These are then weighted by volume in order to include multiple trades at any one price level. The following data table depicts the first month average from the prices of different pricing agencies. In our calculation we follow the approach and data, which are provided by the ICE (The ICE Futures Europe: The Brent Index). With only the figures provided by the ICE however, one cannot calculate the first/second month weighted average, as the number of trades of each price is omitted from ICE’s data.
2. Second Month Deals Plus Spread Trades

The second step of calculating the ICE Brent Futures Index is by determining the implied price for the first month on the 25-day BFOE market. This implied price is simply the weighted average of the second month 25-day BFOE market discounted, i.e. plus/minus, the spread between these two months. The price of the second month 25-day BFOE market is calculated the same way as with the first month, i.e. by calculating the weighted averages.

<table>
<thead>
<tr>
<th>Price</th>
<th>Media Source 1</th>
<th>Media Source 2</th>
<th>Media Source 3</th>
<th>Media Source 4</th>
<th>Media Source 5</th>
<th>ICE Summary</th>
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<td></td>
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<td>111.66</td>
</tr>
</tbody>
</table>

First Month Weighted Average = 111.610

NB: The actual number of trades behind each price of each media source is not reported.
Source: The ICE

The average spread trade prices are essential in finding the implied first month price level. The spread is calculated by averaging the 25-day trades for the first-second month spread. In a backwardated market (i.e. price today is higher than the future price) this spread is in positive territory. In a Contango market (i.e. price today is lower than the future price), this spread is negative. The following data-table depicts a calculation of the first-second month spread for 25-day trades.

<table>
<thead>
<tr>
<th>Price</th>
<th>Media Source 1</th>
<th>Media Source 2</th>
<th>Media Source 3</th>
<th>Media Source 4</th>
<th>Media Source 5</th>
<th>ICE Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>111.51</td>
<td>111.7</td>
<td>111.53</td>
<td>111.51</td>
<td>111.53</td>
<td>111.51</td>
</tr>
<tr>
<td>111.53</td>
<td>111.53</td>
<td>111.68</td>
<td>111.53</td>
<td>111.58</td>
<td>111.53</td>
<td>111.53</td>
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<tr>
<td>111.53</td>
<td>111.53</td>
<td>111.68</td>
<td>111.53</td>
<td>111.68</td>
<td>111.58</td>
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<td></td>
<td></td>
<td></td>
<td>111.7</td>
<td></td>
<td></td>
<td>111.68</td>
</tr>
</tbody>
</table>

First Month Weighted Average = 111.588

NB: The actual number of trades behind each price of each media source is not reported.
Source: The ICE
Average Spread Trade Price = \frac{(6 \times 0.04) + (4 \times 0.03)}{10} = +0.036

This average spread is to be added to the weighted average trade price for the second month, which will yield the implied first month price.

3. Intra-Day Price Assessment

Different industry media sources (PVM, Argus, Platts, etc.) publish their 25-day BFOE price assessments through the trading day. In order to calculate the average for the whole trading day, the mid-point of each quote is used.

The Brent Futures Index is then calculated by finding the average of the 3 prices outlined above:
The Brent Futures Index is then rounded to only two figures after the decimal point: $111.63. The Brent Futures Index provides the essential link of the Futures market to the physical market via the Forward market through the Exchange of Futures for Physicals mechanism.

### The Exchange for Physicals

The Exchange of Futures for Physicals (EFP) links the ICE Brent Futures to the physical oil market in the North Sea via the Forward BFOE contracts. The EFP allows market players to exchange their ICE Brent Futures positions for an actual physical position. The EFP is depicted as a differential between the two markets, i.e. ICE Brent Futures market and the underlying physical market. These deals are done via a broker of ICE’s Clearing House (The ICE: Exchange Futures for Physical for ICE Brent Futures, 2008, p. 1). Furthermore, when EFPs are registered, their volume is counted for that trading day, whilst the actual price is not published to the market, as the price is agreed between the two parties and is usually different from the price prevailing at the futures market (Fattouh 2011, p. 44).

In this paragraph we illustrate the mechanism of the EFP system with the help of the following example:

- **Oil Producer:** Holds 500,000 barrels of unsold oil. Believes the market is in Contango and the price of oil will increase.
- **Oil Buyer (e.g. Refiner):** The Refiners is short 500,000 barrels on the 10th of December. As this volume is below the allowed minimum of 600,000 barrels at the

### Calculating the Brent Futures Index

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>First Month Average Price</td>
<td>$111.610</td>
</tr>
<tr>
<td>2.</td>
<td>Implied First Month Average Price (Second Month Average Price adjusted by Spread Value)</td>
<td>$111.624</td>
</tr>
<tr>
<td>3.</td>
<td>The average Market assessment</td>
<td>$111.632</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>$111.632</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: The ICE
25-day BFOE market, the refiner turns to the Futures market to hedge the price risk. There he buys 500 ICE Brent Crude Futures at the price of $100 per barrel. The refiner also assumes the market is in Contango and expects the price of crude oil to increase by the 10th of December.

- **Mechanism:** The two parties agree to exchange their positions. This occurs on the following manner: One month prior to the 10th of December, i.e. on the 10th of November, the oil producer sells his 500,000 barrels of crude at the ICE December Brent Futures market. The settlement price is the one of that trading day. After the two parties have agreed to exchange their positions, they will get in touch with their respective brokers at the ICE Clearing House, who will then proceed with the execution of this EFP. The ICE Brent Futures settlement price for the 10th of November is $80.50 per barrel.

- **Positions After the EFP:**
  - Producer:
    - Short 500,000 barrels of crude at $80.50 per barrel
    - Long 500 December Brent Futures at $80.50 per barrel
  - Refiner:
    - Sold 500 December Brent Futures at $80.50 per barrel ⇒ Profit of $0.50 per barrel
    - Long 500,000 barrels of crude at $80.50 per barrel
Hedging Tools

As discussed before, the commodity traded on the spot market for Brent is referred as Dated Brent, or Dated BFOE. The term Dated is derived from the fact that a cargo is sold with a specific loading slot.

Under a classic assumption-framework, a spot market is defined as an ad-hoc agreement between a buyer and seller on the price of the commodity, for an immediate delivery of the cargo. However, the spot Brent market is not a spot market in the classical sense of the aforementioned definition. The Brent spot market adopts certain elements and features of the Forward Brent market and because of this it is also referred to as a “short-term Forward market affected by CFDs derived from the Forward curve of Brent Futures and short-dated cash market options” (The ICE, ICE Crude Oil, p. 2). This feature comes from the fact that cargoes on the spot Brent market are traded not ad-hoc, but rather at least 10 days ahead. Thus, the price of Dated Brent is quoted for the next 10-21 days, according to the current methodology. In order to manage the risk, implied by this element of forwardness, i.e. price risk between the time when the cargo is sold and delivered, physical cargoes of Dated Brent are priced off a differential to the forward market (25-days BFOE), instead of off an outright price.

Contract for Differences (CFD)

We will further supplement our spot Brent analysis with the introduction of Contract for Differences, or CFDs. CFDs are a paramount circuit of the complex Brent market, as these represent a link between the spot Brent market and the forward market (Fattouh 2011, p. 45-46). CFDs are cash swaps on the price differential between Dated Brent and Forward Brent (25-day BFOE). The swap contract is employed in order to manage the risk of aforementioned price volatility. The CFDs determine the settlement Dated Brent (The ICE, ICE Crude Oil, p. 2). For instance, if the Forward Brent market is in backwardation, i.e. each next futures contract is priced lower than its predecessor, the CFDs will have a positive value, and vice-versa.
Furthermore, we provide an example of the calculation and importance of CFDs for the Brent market. The example, which is based on the works of Fattouh 2011, will also include some critical remarks and considerations.

We assume that on the 19th of March 2010 a refinery binds himself to acquire a cargo of Brent Blend, which will load sometimes between the 21st and the 23rd of April the same year. At the time of loading, the refiner will pay for the cargo the average price of Dated Brent over a five-day period prior to the loading date, i.e. average Dated Brent price over the 19th-23rd of April. Furthermore, the refiner expects that the price of Dated Brent might increase from today’s going forward. This means that the refiner assumes that the Dated Brent market is in Contango, i.e. he would have to pay a higher price for the cargo in April, relatively to today. The refiner considers how to hedge this price risk.

There are several ways for the refiner to hedge. First, on the 19th of March 2010 the refiner might buy an April Forward. Thus the refiner “locks” the forward contract at the price on the 19th of March. The next step of the refiner is to sell this 25-day contract in April (in the period of loading) and with the funds of this sell to acquire the cargo at the average Dated Brent price over the 19th and the 23rd of April, which by that time would be already Dated. However, there is a risk that the two price series, i.e. Dated Brent and Forward Brent develop differently and thus the refiner would still be exposed to price risk. This kind of risk is referred to as basis risk.

A second way to hedge this risk would be to buy a second month Forward contract (i.e. May BFOE) and a CFD for the loading week (i.e. 19th-23rd of April). The role of the CDF here is crucial. The CFD enables the refiner to receive the Dated Brent price by paying the Forward price. This means that on the 19th of March, the refiner has secured his cargo loading during 19th-23rd of April at the Dated Brent price today. Here it is important to explain the logical chain of conclusion. The cargo of the refiner is a “spot” cargo, meaning that after being loaded on the 19th-23rd of April, it will arrive in the next 10 to 25 days, i.e. in May. This is why the refiners buys second month forward on the 19th of March.

This deal develops as follows. The price of the May Forward stands at $79.53 per barrel on the 19th of March. The price of the CDF for the week between 19th and 23rd of April is -$0.57 per barrel. In the period between the 19th and the 23rd of April (when the cargo is
loaded) the refiner sells the Forward May contract. Assume that on the day of sell this 25-day BFOE contract settles at $84.78 per barrel on the 23rd of April, which means that the refiner makes a profit of $5.25 per barrel ($84.78-$79.53).

The final position of the refiner as of the 23rd of April is as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>Dated Brent</th>
<th>BFOE May</th>
<th>Loss/Gain CFD</th>
<th>Loss/Gain CFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-04-10</td>
<td>$83.19</td>
<td>$83.53</td>
<td>0.2*(83.19-83.53)</td>
<td>-0.068</td>
</tr>
<tr>
<td>20-04-10</td>
<td>$84.74</td>
<td>$84.86</td>
<td>0.2*(84.74-84.86)</td>
<td>-0.024</td>
</tr>
<tr>
<td>21-04-10</td>
<td>$84.47</td>
<td>$84.62</td>
<td>0.2*(84.47-84.62)</td>
<td>-0.03</td>
</tr>
<tr>
<td>22-04-10</td>
<td>$84.64</td>
<td>$84.78</td>
<td>0.2*(84.64-84.78)</td>
<td>-0.028</td>
</tr>
<tr>
<td>23-04-10</td>
<td>$86.49</td>
<td>$86.43</td>
<td>0.2*(86.49-86.43)</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Total Loss/Gain: $-0.138

Source: Fattouh: An Anatomy of the Crude Oil Pricing System

Here an important notice should be made, namely that the CDF should not be considered as the difference between the current price of Dated Brent and the Forward Brent contract, but rather as a difference between the Dated Brent at some point in the future and the Second Month Forward Brent

Dated-to-Frontline (DFL)
Another tool, commonly used by traders, to hedge the Brent price risk is a Dated-to-Frontline swap, or a DFL. A DFL is the difference between the daily Platts Dated Brent price and the ICE Brent price of the expiring ICE Future Brent contract for the same time (Platts, 2013, Forward Curve-Oil, p. 3).

The following table provides us with a summary of the different layers of the Brent market.

<table>
<thead>
<tr>
<th>Trading Instrument</th>
<th>Objective</th>
<th>Trading Period</th>
<th>Market where Traded</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFOE 25-day Contract</td>
<td>Obtain Brent cargoes, Hedge, Speculate</td>
<td>Up to 25 days before loading at Sullom Voe terminal</td>
<td>OTC Market</td>
</tr>
<tr>
<td>Dated Brent</td>
<td>Obtain Brent cargoes</td>
<td>Within 10 to 25 days</td>
<td>&quot;Spot*&quot; Market</td>
</tr>
<tr>
<td>ICE Futures Brent</td>
<td>Hedge, Speculate</td>
<td>Until expiry of contract in month prior to loading month</td>
<td>Futures Exchange: The ICE, NYMEX</td>
</tr>
<tr>
<td>CFD, DFL Swaps</td>
<td>Hedge, Speculate</td>
<td>Weeks prior to loading</td>
<td>OTC Market</td>
</tr>
</tbody>
</table>

"Spot*" refers to the fact that the Spot Brent market is derived from the Forward Brent Market

Source: Various
4. The Dubai Benchmark

Market Background

The Dubai market has developed around 1984, amidst declining spot trading in Arabian Light, which until that time served as the main Middle East spot crude benchmark. The Dubai Blend (API° of around 30 and sulphur content or around 2.13%) was also one of the few types of crude from the Persian Gulf available on the spot market. The promotion of Dubai to being crude marker for grades into the Asia-Pacific region is to be attributed to a one main factor: Dubai production was managed by an international oil company (Conoco-Phillips), unlike oil production in other Persian Gulf countries, like Saudi Arabia, Iran and Kuwait, which is managed by a national oil company. Thus, in 1988 OPEC member countries gave up the posted pricing system (see previous chapters) and moved towards the utilization of Dubai for the pricing of their Asia-bound oil exports.

Like other international crude oil benchmarks, Dubai’s role as a marker crude is a function of actual physical availability, i.e. production levels. With time, physical output of the Dubai crude decreased, i.e. production decreased from around 400,000 b/d between 1990-1995 to only 80,000 b/d by 2009 (see chart). This lower production was of a scale of only a handful of cargoes per month.

In a previous chapter of this analysis, we discussed the qualities usually required for a crude grade/blend to become a global benchmark. Two of these are physical availability and diversification of the production/ownership structure. The Dubai crude did not satisfy these two requirements: 1) actual production volumes fall to below 100,000 b/d by 2009 and 2) in 2007 Dubai’s government did not renew the oil production concession of the oil crude, which meant that production of this grade fell into governmental hands.

This development was a “call” for another crude grade in the region, namely Oman, to join the Dubai setup as the main marker in at the Asia-Pacific region. The Oman grade satisfied the two aforementioned qualities, which Dubai failed to achieve: 1) production had been averaging between 700,000-800,000 b/d; 2) production was managed by the Petroleum
Development Oman (PDO) consortium, which constituted by the Government of Oman (60%), Royal Dutch Shell (34%), Total (4%) and Partex (2%) (http://www.pdo.co.om/).

Nowadays, the majority of Persian Gulf oil exports to Asia are priced off Platts’ Dubai/Oman average. Additionally, Russia’s East Siberia-Pacific Ocean (ESPO) Blend is also traded at a differential to Platts’ Dubai/Oman average. Furthermore, Platts’ Dubai/Oman instrument is a Forward, opposed to the DME Oman, which is a Futures instrument.

In the following paragraph we turn to analyse the pricing process on the Forward market, i.e. Platts’ Oman/Dubai average.

With declining physical production of Dubai, the credibility of the grade on the Forward market was undermined (see Dubai production chart). In order to counterbalance this trend, Platts has introduced the partials mechanism (http://www.platts.com/price-assessments/oil/dubai-crude), which allows a Dubai/Oman cargo to be cut into small parcels, which increases cargo numbers. Thus, trading is promoted, which in terms maintains the viability of the crude oil benchmark. The smallest lot size allowed is 25,000 barrels, whilst in cases of actual physical deliveries these are at 500,000 barrels, or 20 parcels. Moreover, any amounts below the 500,000 cannot be delivered and should be cash-settled.
The additions of Oman to Platts’ Dubai assessment created a problem, as the two grades have different quality aspects: Dubai has higher sulphur content than Oman, whilst Oman has higher API gravity. This discrepancy means that the two grades should differ in prices.

As outlined in the previous paragraphs, in the Asia Pacific region the majority of crude are priced off Platts’ Oman/Dubai average. Nonetheless, some minor volumes of mainly sweet grades are priced off Malaysia’s Tapis and Indonesia’s Minas.
As the physical oil production of these two countries is declining, whilst domestic demand increases (see charts), physical availability of the two aforementioned grades at the export market is declining, which dents the reputation of the two grades as price setters. In such an environment, trades of sweet crudes against Dated Brent are increasing in the Asia Pacific region. Looking forward, such a trend could cause market imperfections, as the Dated Brent structure does not necessarily depict the underlying market conditions (supply/demand) at the Asia Pacific market.

In 2011 Malaysia had become a net oil importer. The country had never been an OPEC member, but has the status of an "Observer" since 1984.

Source: BP Statistical Review 2014
Dubai’s Financial Layers

The Dubai market has developed a much simpler market structure, compared to the complex Brent market (see Brent section). From a historical perspective, the Forward market of Dubai was in focus, as a successful Futures market failed to develop in the early 1990s. The Forward market of Dubai has similarities to the Brent forward market, given that the two grades are seaborne. Nonetheless, the two Forward markets (Dubai and Brent) differ in terms of information process, loading schedule announcement, book-out process duration (Horsnell and Mabro 1993, Chapter on the Dubai Market).

Nowadays, the Dubai market is defined mainly by two central financial instruments: the Brent/Dubai Exchange of Futures for Swaps (EFS) and the Dubai inter-month swaps market, with both instruments traded Over the Counter (OTC). More recently, in 2007, an Oman Crude Oil Futures Contract was launched on the Dubai Mercantile Exchange (DME).

The Brent/Dubai EFS

The Brent/Dubai EFS is similar to the Brent Exchange of Futures for Physicals (EFP). The EFS converts Future Brent to a Forward Dubai Swap, plus a quality premium, as Brent has better physical characteristics compared to Dubai. The EFS provides players on the Asian market the linkage to the highly liquid Brent market and therefore allows them to better manage their Dubai price exposure by converting it into Brent price exposure. The latter exposure is easier to manage, given the aforementioned high liquidity on the Brent market.

The level of the Brent/Dubai EFS, which is reported as a differential to ICE Brent, is important for crude trade flows from the Brent basin to the Dubai basin. For instance, a narrow Brent/Dubai EFS, e.g. around 2 USD per barrel, is a signal for high oil demand in the Asia Pacific region, relative to the Brent region. The spread should in almost all times average in positive territory, due to the aforementioned quality difference between Brent and Dubai. In a separate note, this quality spread, which can also be referred to a sweet-sour spread, is set to narrow in the future, on the back of the global refining industry becoming more complex, i.e.
being able to throughput more efficiently more heavy-sour crudes, and thus demanding more heavy-sour crudes by taking advantage of the discount at which these are usually traded. Consequently, a narrow spread incentivizes more Atlantic Basin crudes, which are priced off Brent, to sail to Asia. Taking this market structure into account, one could consider the Dubai market as an additional layer of the Brent market.

**The Dubai Inter-Month Swaps Market**

The Dubai inter-month swap is the differential between two swaps, which allows traders on that market to hedge their position month over month. These inter-month swaps are crucial for the price formation on the Dubai Forward market. Trading spots of Dubai inter-month swaps are London and Singapore.

**The Oman Futures Market**

In the 1990s, after several attempts to launch a futures market for crudes into the Asia Pacific region have failed, in June 2007 the Dubai Mercantile Exchange (DME) was commissioned, aiming to deliver adequate price discovery and efficient risk management in the East of Suez region. Since then, the DME supervises the Oman Crude Oil Futures Contracts, which is considered to be “the explicit and sole benchmark for Oman and Dubai crude oil Official Selling Prices (OSPs) - historically established markers for Middle Eastern crude oil exports to Asia” (www.dubaimerc.com, About DME). Oman oil futures issued by the DME can be settled for a physical delivery of Oman crude. Both Oman and Dubai use DME’s Futures quotations to market their crudes to Asia. In Oman’s case the Official Selling Price (OSP) of the country’s crude bound for physical delivery is equal to the average of the daily settlement prices over a month for physical delivery in two months. However, none of the big Persian Gulf producers, e.g. Saudi Arabia, Iran, Qatar, Kuwait, has yet shifted from using Platts’ Oman/Dubai average to DME’s Futures.

Ever since its inauguration in 2007 the DME handles increasing volumes of the Oman Crude Oil Futures Contract. While in the first two years these volumes were in the vicinity of around 1,000-2,000 lots (1 lot = 1,000 barrels), over 2014 daily volumes started crossing the 10,000 lots mark more frequently. However, on a monthly basis, since the existing of the DME, only in February 2014 Futures volumes averaged above 10,000 lots (see chart). The
10,000 lots mark is crucial, as Saudi Arabia, the world’s biggest crude exporter, has often been quoting to have argued that this volume is important for them to shift from Platts’ Oman/Dubai average to DME’s Futures for pricing their crudes to Asia. Saudi Arabia considers this volume as a landmark, as it is roughly equal to the volume of transactions for Dubai, i.e. Dubai inter-month swaps and the Brent/Dubai EFS.

![Dubai Mercantile Exchange: Monthly Averages ['000 lots; $/bbl]](image)

Even though Futures contracts volumes traded on the DME are on the increase, so far these have not crossed the 10,000 lots mark on a sustainable basis. In addition to this, we see that daily Futures volumes are highly volatile (see next chart).
Thus, relatively low number of Oman futures contracts traded on the DME (still below 10,000 lots), coupled with high volatility of daily volumes of contracts means that Oman DME Futures still have a long way before being used by big exporting countries, such as Saudi Arabia, for pricing their crude exports to the Asia Pacific region.
5. Outlook of Oil Pricing

Based on the ideas and topics discussed so far, we can identify several key trends and driving factors, which will shape the future of crude oil benchmarks. One of the key aspects is oil demand.

Oil Demand

According to data provided by BP, liquids are and will be the world’s primal energy source in the next couple of decades (see chart).

Indeed, total liquids will lose some percentage points in the share of the global energy consumption by declining from almost 40% in the early 1990s to around 27% in 2035. Nonetheless, total liquids will remain the leading source of energy worldwide in the short-run (next 20 years). This decline will come on the back of an increasing importance of other
energy sources, namely natural gas, renewables and coal. Other energy sources, such as hydroelectricity and nuclear power will only grow with nearly the growth rate of global demand, thus keeping their relative share in total global demand at around 7% and 5% respectively (see chart).

Thus, despite a decreasing share (including crude oil), liquids will continue to be the main energy source in the global economy. This means that with regards to financial layers of oil prices, the mechanisms there will continue playing an important role globally and will thus continue evolving.

What will be the structure of this evolution? To understand this, we need to have a look at historical oil demand data. The following charts depict the top 10 oil consuming countries in the years 2000 and 2013. According to the data, Non-OECD countries, with China leading the pack, were the main drivers of oil demand since the beginning of the new millennia. According to data provided by BP, non-OECD demand growth will be the main driver of oil demand growth.
This shift of demand from the established OECD centres to non-OECD regions has an effect on oil trade flows. For instance, Saudi Arabian exports to the US have declined in the last few years, compared to the mid-2000s. Russian crude exports are also undergoing a shift-phase, with the Kremlin turning its focus from the established European market, eastwards to Asia. Until 2040 the EIA projects that petroleum and other liquid fuels consumption will increase to around 120 million b/d. This increase will be mainly driven by strong demand growth in the non-OECD Asian countries, with the Middle East following closely. This development will have a strong effect on oil pricing in that region. As we have discussed already, whilst Tapis and Minas are gradually losing market power, DME Oman futures are so far still a long way before being used by big players, who export to the Asia-Pacific region. At the same time market participants in that region are not seeing Russia’s ESPO, although supplies of this blend are on the increase, as an alternative pricing benchmark for Asia.

Staying with consumption, whilst total world energy consumption is set to increase from currently around 13 billion tonnes of oil equivalent per year to around 17.5 billion in 2035 years, total liquids demand will raise from currently around 4.1 billion toe per year to nearly 5 billion toe over the same period. This increase will largely be attributed to demand growth from the Asia Pacific and Middle East regions, whilst the current high demand regions like North America and Europe & Eurasia will lose in relative terms (see chart). Thus, looking forward the Asian market and the oil pricing mechanism there, be it either directly via DME or Dubai/Oman average or indirectly via the Brent link, will gain in importance.
Turning to global oil consumption by sector, here we identify several trends. First and foremost, transportation will remain the world’s biggest consumer of crude oil over the next 20 years. Oil demand growth will be driven mainly by the industry and transportation sectors, with these two posting an average annual growth rate of 5.5% and 3.7% between 2015 and 2035 respectively. Although this trend might not have a direct effect on the dynamics of crude oil prices, high demand for transportation fuels, such as gasoline and diesel, might indirectly influence the price of oil through Gross Product Worth (GPW), which influences posted differentials to the market crude of crudes of many Persian Gulf countries (see Brent section).
In addition to oil demand, oil supply will also be a factor to watch out for, when discussing future oil pricing mechanism.
Oil Supply

On a global scale the Middle East as a region is by far the world’s largest crude oil supplier, accounting currently for nearly 1/3 or nearly 29 million b/d of global supplies. This region is followed by Europe and Eurasia, which accommodate major oil producing countries such as Russia, Kazakhstan, Azerbaijan, Norway and the United Kingdom. In North America, the US is the biggest oil producer (10 million b/d in 2013), followed by Canada (nearly 4 million b/d in 2013) and Mexico (2.9 million b/d in 2013), according to the BP Statistical Review for 2014.

Looking forward, the Middle East will remain the world’s largest oil supplier until 2035. Over the same period North America, which is currently ranked at 3rd place, will overtake Europe and Eurasia and will become the world’s second biggest producing region in the second half of this decade (see chart). In that period increasing North American oil production will be driven by higher unconventional crude output in the US (light tight oil) and Canada (oil sands).

With regards to US production, it is worth commenting that this will have an impact on the pricing framework of WTI, one of the key world grades, which serves as a benchmark in the Americas region. Almost 40 years ago, on the 22nd of December 1975, US president Gerald Ford signed into law the Energy Policy and Conservation Act, which since than bans the export of almost all US produced oil. Even though WTI is a global crude pricing benchmark, players cannot export physical volumes out of the US (they still can trade WTI futures/forwards on the NYMEX, as long as these are not concluded as physical deliveries). With rising US crude production, US refiners will have lower import requirements for lighter and sweeter crude grades, which are and will further be displaced by light tight oil. Here it is worth noting that the US already imports less light sweet barrels, i.e. West African grades (see chart). This means that future higher shale oil output would rather displace imports of heavier barrels. Nonetheless, given the high complexity of US refiners, such a move will be difficult to implement (the more modern the refinery, the heavier (cheaper) grades it can process). Looking forward, considering the dynamics of the US oil market, WTI’s pricing framework would undergo a change, which would aim to better mirror the rising light tight oil output.
Looking at the proved oil reserves by region also yields conclusions about the future variables, which will shape the pricing framework of global crude benchmarks. First, European and Eurasian oil reserves are so far significantly lower than oil reserves in the Americas (North and South America) and the Middle East. In Europe, Norway and the UK are battling with decreasing North Sea crude production, which is also the basis for the global crude price benchmark Brent. As physical barrels of Brent decrease, due to lower production, so will the liquidity of the benchmark be undermined. This process has a negative effect on the reliability of Brent as a global benchmark (the issue is discussed in greater detail in the Brent section of this analysis). Oil reserves of Norway and the UK are estimated to be at 8.7 and 3.0 thousand million barrels respectively (BP Statistical Review of 2013). Taking into account the relative low level of reserves and the declining Brent production the pricing mechanism of Brent will be exposed to rising pressure in the future.

On a global basis the Middle East as a region holds the largest oil reserves. In that region, all countries, apart from Oman, Syria and Yemen, which have small oil reserves compared to the other countries, are OPEC member countries. In a breakdown of figures Saudi Arabia holds the largest oil reserves, estimated at 266 thousand million barrels. These
are by far the largest reserves in the Middle East and the second largest in the world, after Venezuela’s. Iran and Iraq follow Saudi Arabia, as the two countries have around 160 and 150 thousand million barrels of oil reserves. Altogether, Middle Easts’ large oil reserves, in addition to large oil reserves of other OPEC member countries (Venezuela, Ecuador, Angola, Nigeria, Libya and Algeria) means that OPEC (and its Crude Oil Basket Price), will continue to have a paramount role in equilibrating the global oil market via prices, which are influenced by the Group’s production quotas (see next section).
Finally, physical trade in oil undergoes a shift from the Atlantic region (North-West Europe and the US), the main demand region historically, to Asia, where rapid economic development has boosted regional oil import requirements. Historically, the US and Europe have accounted for the bulk of imported crude until 2007, when the two regions combined imported less barrels than all other regions altogether. Ever since 2007, Europe and the US are importing less oil as 1) European refiners struggle with meagre demand growth and competition from other regions (Russia, India, etc.), which dents refining margins and 2) the US uses more domestic oil production, amidst rising light tight oil production and thus relies less on imports.

Looking forward, Europe will likely import less crude as 1) product demand in the region is stagnating and 2) more sophisticated and complex refiners from other regions will put further pressure on Europe’s refining industry (e.g. big and modern refineries in the Middle East (Ruwais, Yanbu, Jizan) will pressure their European counterparts).
Rising trade share indicates that demand growth (China, India) happens at countries, which produce less oil than they consume.

Rapid economic expansion in key Asian countries like China and India, which have negative import/export balances, increases trade flows.

US shale boom decreases the country’s oil.

Source: BP Statistical Review 2014

Oil Trade Movements: Imports [million b/d]
III. Empirical Section

In this section we provide further scientific foundations on the dynamics of crude oil prices. In comparison to the first section, where we assessed the dynamics of oil prices and in particular Brent prices in light of physical and paper markets and their evolutionary development, in this section we introduce the reader to empirical research. This chapter will be based on current empirical works of oil price dynamics.

The issue of forecasting crude oil prices has been assessed in several key scientific papers, like Alquist, Kilian and Vigfusson (2011), Baumeister and Kilian (2012), Fattouh (2007) and Yanagisawa (2009). All these scientific papers have a common aspect: by utilising empirical valuation methods, they try to derive a forecasting method for the future development of crude oil prices.

For instance, Alquist, Kilian and Vigfusson (2011) argue that forecasting the price of oil is paramount in a macroeconomic policy framework of every country, as this commodity is deeply rooted in the country’s economy. These authors further argue that Central Banks often try to assess the future movement of the crude oil price, as these are often responsible for numerous key macroeconomic policies. This statement of the two authors finds support in a paper by the European Central Bank (ECB) on the drivers of the oil futures prices: Fundamentals versus Speculations, by Isabel Vansteenkiste (2011).

Furthermore, Alquist, Kilian and Vigfusson (2011) provide an in-depth assessment of the issues of oil price forecasting by employing different empirical tools, like out-of-sample forecasting methods for the nominal price of oil. This mechanism takes into account daily and monthly oil futures prices. The authors contemplate that forecasting models, which take into account the USD exchange rate of oil exporting countries, Hotelling-rule models and other simple time-series regression models, have little predictability potential.
Before turning to the actual empirical section, Alquist, Kilian and Vigfusson (2011) derive several key aspects of the preference of nominal oil prices over real oil prices, when making forecasts:

- For the USA-case, the nominal price of oil is exogenously given.
- The nominal oil price could be taken as exogenous after 1973, when OPEC started posting set prices.
- Consumers of oil products are much more sensitive to positive fluctuations of the nominal oil price, rather than such of the real oil price. The authors argue that likely this is the case because the nominal oil price is more “on-hand” and more visible to consumers (money-illusion disease of consumers).

In their study Alquist, Kilian and Vigfusson (2011) first consider linear forecasting methods for the nominal oil price. Before commencing with the actual linear forecasting methods, the authors test for a predictable relationship between the price of oil and macroeconomic aggregates by utilising Ganger non-causality tests. The authors distinguish between two time-series, namely before 1973 and after 1973.

1. Nominal Oil Price Predictability

In the pre-1973 period, the authors stick to the findings of Hamilton (1983), who argues that domestic macroeconomic aggregates in the US do not have Granger causality to the percentage change in the nominal price of oil during 1948-1972.

The assessment of the post-1973 period is more complex. Here Alquist, Kilian and Vigfusson (2011) test for predictability, considering a linear vector autoregression model, by using Granger causality tests on key nominal macroeconomic variables, such as:

- the Consumer Price Index (CPI)
- Money Supply Bases (M1 and M2)
- Commodity Research Bureau (CRB) Industrial Raw Materials Index
- CRB Metals Index
- 3-Month T-Bill Rate and a Trade-Weighted Exchange Rate.
The nominal oil price can be attributed to four time series:

- WTI price
- Refiner Acquisitions Costs (RAC) Oil Imports price
- RAC Domestic Oil price
- RAC composite price

Conducting the Granger causality test yields the following results: The CPI index (inflation) is significant for predicting the percent change in the nominal WTI oil price. The test results also show that the M1 measure for money supply has a significant explanatory power on the three price time series of the Refiner Acquisition Costs (RAC), as well as on the WTI price on the period between 1975 and 2009.

Opposed to the above results, both the short-term lending rate (3-Month T-Bill Rate) and the Trade-Weighted Exchange Rate do not significantly predict the nominal price of oil (see date-table).

### Table: Predictability from Selected Nominal U.S. Aggregates to the Nominal Price of Oil (p-values of the Wald test statistic for Granger Non-Causality)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Price Index (CPI)</td>
<td></td>
<td>WTI</td>
</tr>
<tr>
<td></td>
<td>0.004</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RAC Oil Imports</td>
</tr>
<tr>
<td></td>
<td>0.021</td>
<td>0.320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RAC Domestic Oil</td>
</tr>
<tr>
<td></td>
<td>0.010</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RAC Composite</td>
</tr>
<tr>
<td></td>
<td>0.181</td>
<td>0.000</td>
</tr>
<tr>
<td>M1 Money Supply</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>0.039</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>0.234</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td>0.318</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>0.629</td>
<td>0.209</td>
</tr>
<tr>
<td>CRB Industrial Raw Materials Index</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>CRB Metals Index</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>3-Month T-Bill Rate</td>
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<td>0.001</td>
</tr>
<tr>
<td>Trade-Weighted Exchange Rate</td>
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<td>0.006</td>
</tr>
<tr>
<td></td>
<td>0.409</td>
<td>0.712</td>
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<td></td>
<td>0.009</td>
<td>0.880</td>
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<tr>
<td></td>
<td>0.799</td>
<td>0.896</td>
</tr>
<tr>
<td></td>
<td>0.740</td>
<td>0.746</td>
</tr>
</tbody>
</table>

NB: Bolded figures are statistically significant at the 10% level.
All variables are depicted in percentage changes (apart from the interest rate).
Source: Alquist, Kilian and Vigfusson-Forecasting the Price of Oil (2011)
2. Real Oil Price Predictability

In this section we follow Alquist, Kilian and Vigfusson (2011) and their analysis on the predictability of the real price of oil. Before commencing with the actual analysis, we provide a brief explanation of the real price of oil. The real price of oil is obtained by deflating the nominal price of oil by the US consumer price index (Baumeister and Kilian 2011, p. 328). The scientific literature often refers to the real price of oil as being more important to policymakers such as, central banks and other governmental regulatory bodies, than the nominal price of oil.

Alquist, Kilian and Vigfusson (2011) quote Barsky and Kilian (2002) by arguing that the real price of oil moves up responding to expectations of low interest rates and high real aggregate output. This deduction is in line with classical economic theory, which implies that low expected interest rates trigger an uptick in investments, which consequently drive oil demand up and thus the oil price also up.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WTI</td>
<td>WTI</td>
</tr>
<tr>
<td><strong>U.S. Real GDP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT</td>
<td>0.353</td>
<td>0.852</td>
<td>0.676</td>
</tr>
<tr>
<td>HP</td>
<td>0.253</td>
<td>0.821</td>
<td>0.653</td>
</tr>
<tr>
<td>DIF</td>
<td>0.493</td>
<td>0.948</td>
<td>0.705</td>
</tr>
<tr>
<td><strong>World Industrial Production</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT</td>
<td>0.032</td>
<td>0.095</td>
<td>0.141</td>
</tr>
<tr>
<td>HP</td>
<td>0.511</td>
<td>0.766</td>
<td>0.800</td>
</tr>
<tr>
<td>DIF</td>
<td>0.544</td>
<td>0.722</td>
<td>0.722</td>
</tr>
</tbody>
</table>

NB: Bolded figures are statistically significant at the 10% level. LT=Linear Detrending; HP=Hodrick-Prescott-filtering with smoothing parameter $\lambda=1600$; DIF=Log Differencing

Source: Alquist, Kilian and Vigfusson-Forecasting the Price of Oil (2011)

We analyse the two quarterly predictors, namely U.S. Real GDP and World Industrial Production. Classical economic theory suggests that both real GDP and the real price of oil
are exogenous and that an unexpected increase of the former factor will trigger higher oil demand and consequently an uptick of the real price of oil, if all other economic factors remain unchanged.

However, here we need to make a remark, which is linked to the insights provided in the first section of this paper. In the first section we discussed that the spot price of Brent, i.e. Dated Brent, is derived by using elements of the classical Forwards market, i.e. Contract for Differentials (CFDs). Furthermore, Dated Brent loads in a time window of 10 to 25 days, which is also a feature of the classical Forward market. Thus if we assume that the Dated Brent (spot price) is expressed as the real price of oil, it means that the real price of oil is forward looking, due to the 10-25 days loading window, and would thus already incorporate the insight on the future real GDP.

Alquist, Kilian and Vigfusson (2011) derive the same conclusion, but for the US-WTI case. In such a case, the authors suggest utilising lagged estimators. In their study, the U.S. real GDP in all cases fails to reject the null-hypothesis of no predictability. This might be the case, as the real price of oil is determined on the global market, as outlined by Kilian and Murphy 2010. This explains why the variable real U.S. GDP, which does not take into consideration real GDP in the reminder of the world, could not reject the null hypothesis. Furthermore, Alquist, Kilian and Vigfusson argue that only when real GDP fluctuations are highly correlated globally, then the real U.S. GDP could be an indicator for world real GDP.

An indicator, which takes into account the aforementioned issue, is the index on World Industrial Production, which is obtained from the U.N. Monthly Bulletin of Statistics. This is also statistically shown in the table above, where in some cases the World Industrial Production Index, opposed to the real U.S. GDP, rejects the null hypothesis of no-predictability.
3. The Role of Futures in Oil Price Forecasts

Numerous scientific papers have analysed the role of futures as predictors for the short-run price of oil, i.e. spot price. Some of these include Alquist and Kilian (2010) and Hamilton (2009).

Hamilton (2009) argues that in equilibrium conditions the following equation should hold:

\[ F_t = E_t P_{t+1} + H_t^# \]

where

\[ F_t = \text{Future Price of Oil} \]

\[ E_t P_{t+1} = \text{General Public Expectations for the Spot Price in Period } t + 1 \]

\[ H_t^# = \text{risk premium, complications, unexpected occurences as seen in period } t \]

Furthermore, Hamilton (2008) discusses that if we do not consider the risk premium, then the Futures price should follow the current spot price, i.e. \( F_t = P_t \).

A common belief is that Futures contracts represent a better proxy for the future spot price of oil, than forecasting models, based on various indicators. Various key institutions use Futures prices to construct their policies. For instance, the European Central Bank uses prices of Futures as a proxy for the future spot price of oil, on the basis of which the European institution adjusts its monetary policy (Svensson 2005, p. 2-4). The IMF and the Federal Reserve Board also follow the same pattern and base their policies on the Futures prices being proxy of the future spot price (Alquist, Kilian and Vigfusson 2011, p.19).
Forecasting Methods of the Spot Oil Price, Using Monthly Futures Prices

Alquist, Kilian and Vigfusson (2011, p. 20-21) discuss several forecasting methods, which aim at forecasting the spot oil price by utilising monthly oil Futures prices. Considering scientific findings, which have empirically proven that Futures prices have forecasting ability for spot prices only on the short-term, the authors restrict the forecasting period to one year. We assume that:

- The current nominal price of Futures contracts that matures in \( h \) periods is denoted by \( F_t^{(h)} \).
- The nominal spot price of oil is equal to \( S_t \).
- The expected future spot price at date \( t + h \) is denoted by \( E_t[S_{t+h}] \).

Here it should be noted that this expected futures spot price is conditional of the information available in moment \( t \). Given these variables, Alquist, Kilian and Vigfusson (2011) assess several forecasting methods:

- **Random Walk Model Without Drift:** Such models are used when handling time series, which have irregular growth, i.e. no drift. This feature is also common for oil spot prices. The core-assumption of this model is that spot prices are unpredictable (random walk without drift). In a random walk model without drift the best forecast for the spot price of oil is the current oil price, i.e. a no-change forecast:
  \[
  \hat{S}_{t+h|t} = S_t
  \]

- **Futures Prices Model:** The Futures prices model assumes that the best forecaster for the future oil spot price are the Futures prices:
  \[
  \hat{S}_{t+h|t} = F_t^{(h)}
  \]

- **Spread Between Futures Price and Spot Prices:** This forecasting model is used to derive the movement of spot oil prices, i.e. whether these will increase or decrease. The central assumption of this model is that Futures prices forecast future spot prices. One of the simplest such models takes the following form:
\[
\hat{S}_{t+h|t} = S_t(1 + \ln \left( \frac{F_t^{(h)}}{S_t} \right))
\]

Alquist, Kilian and Vigfusson (2011, p. 22) empirically test the predictability power of the No-Change and Futures models. Empirical test are based on the WTI time series during the period 1983-2009. The authors demonstrate that the two models have roughly the same accuracy in the sense of the Mean Squared Prediction Error (MSPE).

### 4. Parsimonious Econometric Forecasts

Parsimonious regression-based forecasting models are defined by a small number of explanatory parameters. Such forecasting models are usually employed because they are easy to explain and understand (Ledolter and Abraham 1981, p.1).

In the case of forecasting the price of oil, classical examples for parsimonious models include a random walk model without drift (discussed above), a double-differenced forecasting model and a random walk model with drift.

The double-differenced forecasting model postulates that the future sport price of oil can be predicted by taking into account the most recent percentage growth rate of the spot price. It is debateable if such approach is suitable whenever time series are subject to infrequent trend changes. Taking these considerations into account Alquist, Kilian and Vigfusson (2011) derive the following parsimonious forecasting model, which is similar to the no-change model, in a sense that here the growth rate is constant over time:

\[
\hat{S}_{t+h|t} = S_t(1 + \Delta s_t)^h
\]

where

\[ h = 1, 3, 6, 9, 12 \]

\[ \Delta s_t = \text{the percent growth rate of the oil spot price between } t - 1 \text{ and } t \]

Alquist, Kilian and Vigfusson (2011) note that this model is not suitable for forecasting the oil spot price in the long-run.
Another parsimonious forecasting model is the random walk model with drift, which extrapolates the futures spot price from longer-term trends, i.e. the drift. The drift can be estimated by using simple rolling regression (Alquist, Kilian and Vigfusson 2011, p. 24):

\[
\hat{S}_{t+h|t} = S_t \left( 1 + \Delta s_t^{-(h)} \right),
\]

where

\[ h = 1, 3, 6, 9, 12 \]

\[ \hat{S}_{t+h|t} = \text{the forecasted spot price in period } t + h \]

\[ \Delta s_t^{-(h)} = \text{the percent change in the spot price over the most recent month } h \]

5. Hotelling-Rule Forecasts

In his work “The Economics of Exhaustible Resources” Hotelling (1931, p. 141) derived a price-development model of exhaustible resources, based on the rate of return. After analysing the model, we can say that it is a parsimonious forecasting tool, i.e. a simple forecasting model with only a small number of explanatory variables. Hotelling (1931) assumes the following conditions:

- Perfect competition between oil suppliers
- No arbitrage opportunities
- No uncertainty

Considering Hotelling’s work, Alquist, Kilian and Vigfusson (2011) derive the following forecasting formula for the spot oil price in the future:

\[
\hat{S}_{t+h|t} = S_t \left( 1 + i_{t,h} \right)^{\frac{h}{12}}
\]

where

\[ h \text{ (time of maturity)} = 3, 6, 12 \]
\[ i_{t,h} = \text{annualized risk} - \text{fee interest rate at the time of maturity} \ h \]

Here, the annualised risk-fee interest rate could be the Federal Reserve’s 3-month, 6-month and 12-month constant maturity T-Bill rates.

6. The Role of Forwards in Oil Price Forecasts

In his essay on the Usefulness of the Forward Curve in Forecasting Oil Prices, Mr. Akira Yanigisawa of Japan’s Institute of Energy Economics, a research entity at the country’s Ministry of International Trade and Industry, empirically proves that the forward curve is of use when forecasting one week to one month ahead oil prices. It proves rather limited explanatory power for longer-term forecasting periods. One explanation for this result is that the majority of deals on the Forward market are stacked in the nearest few months, while volume further away in time are relatively small.

Like Alquist, Kilian and Vigfusson (2011), Yanigisawa (2009) also employs the Granger causality test in determining the usefulness of the Forward curve in forecasting oil spot prices in his empirical study. This test is usually used when dealing with time series and cross-effect relationships (Berzuini, Dawid and Bernardinelli 2012, p.332). The Grander causality test is based on two insights (Ashley, Granger and Schmalensee 1980):

1) The effect does not precede its cause in time. In the case of Alquist, Kilian and Vigfusson (2011) an increase of the spot price, or lagged spot price should not precede an unexpected increase of the World Industrial Production Index.

2) The causal series contains unique information about the series being caused that is not available otherwise.

After having briefly assessed the Granger causality, we continue with our analysis of the usefulness of the Forward curve in prediction the spot price. After testing the second, third and fourth front months (i.e. forwards) for granger causality on WTI spot oil prices, Yanigisawa (2009, p. 3) concludes that only in some cases the forward curve is helpful for forecasting daily and weekly spot WTI prices. Empirical evidence point that the forward curve is only of little use in long-term forecasts, because:
• The forward curve cannot fully incorporate information of unexpected future events (e.g. natural disasters, political instabilities, etc.)
• Price inelastic supply and demand trigger huge price fluctuations, with small supply/demand changes

7. Volatility and Trend Indicators

In line with our goal to define and critically assess oil price forecasting methods and models, in this section of our analysis we provide the reader to a wide range of volatility and trend analysis instruments. These tools are used to provide forecasts of for the future price development of an asset, based on historical market data such as high, low, close and open prices, as well as volumes. In this section of our analysis we will use various volatility and trend analysis tools on the price series of ICE Brent 1st Month Futures, which is widely referred in the industry as the oil price (see ICE Brent section).

The underlying assumption behind these volatility and trend analysis instruments is that historical development influences future trends. This foundation is in contradiction to what we have discussed at other places in this paper, namely that oil prices follow a random walk pattern. Furthermore, these instruments are also in contrast to fundamental analysis, which assesses the economic factors behind price movements. These volatility and trend indicators argue that all relevant information is already reflected in the price dynamics. Even though such assumption is subject to debate, in this section we discuss several key volatility and trend analysis tools.

Volatility Indicators

Oil prices, e.g. futures, spot, forward, fluctuate on a daily basis. Understanding these movements, under the light of volatility measurements, is key to developing an estimator for the development of future oil prices.

When discussing volatility, it is important to distinguish between several benchmark calculation methods. Implied volatility, which is usually used in financial statistics, mirrors
the volatility of an underlying asset, subject to the market price of the option. Historical volatility is calculated on the basis of historical data.

**Parkinson Volatility**

For the purpose of our analysis we will use **historical volatility** of oil prices, i.e. 1st month Futures. With regards to historical volatility, we can distinguish between several types of volatility estimators. All these types are suitable to give an estimate for volatility of random walk time series, which oil prices are argued to be (see Random Walk with/without Drift paragraph).

- **Close-Close Volatility Estimator**: This volatility estimator is calculated by using log close, or settlement prices, which implies its simplicity. However, it does not incorporate important data such as open, high and low prices.

- **High-Low Volatility Estimator**: In his paper “The Extreme Value Method for Estimating the Variance of the Rate of Return” from 1980, Michael Parkinson developed a more sophisticated historical volatility estimator than the abovementioned Close-Close Method. Parkinson’s volatility estimator takes into account high and low price data and has the following form (annualized):

  \[
  \sigma_{HL} = \sqrt{\frac{1}{4 n^2} \cdot 252 \cdot \sum_{i=1}^{n} \ln \left( \frac{H_i}{L_i} \right)^2}
  \]

  Parkinson volatility does not measure \((x_t - \bar{X})\) of the traditional formula of historical volatility (variance). Instead, it measures the difference between the maximum and the minimum prices during the same time interval.

- **High-Low-Open-Close Volatility Estimator**: This volatility estimator was developed by Garman and Klass (1980) using Parkinson’s insights by adding historical open and close prices to his High-Low analysis.

  We have calculated the Parkinson Volatility of ICE Brent 1st month and plotted it in
the next chart. Input data for the chart was obtained from the ICE, which then served as the basis for our calculations of Parkinson volatility. We compared the obtained results for Parkinson volatility of 1st month Brent to Parkinson volatility of S&P 500 Index. The S&P 500 index is a key equity index for 500 large companies listed on the NYSE or NASDAQ. Thus, volatility of this index could be used as a benchmark tool for comparing volatilities of other assets, in our case ICE Brent 1st month. By examining the chart, we can see that the Parkinson volatility of oil prices is greater in almost every occasion over the past 4 years than the Parkinson volatility of the S&P 500 index. One possible explanation for this difference is the fact that the S&P 500 Index is comprised by stocks of companies from different economy sectors, which also implies lower risk exposure. Another explanation lies in the market volume of the two indices: the one of S&P 500 exceeds the one of ICE Brent 1st month, with also implies lower risk exposure.

In addition to these volatility estimates, the Chicago Board Options Exchange (CBOE) issues the Crude Oil Volatility Index (OVX), which provides a measurement for the market’s expectation of 30-day volatility of crude oil prices. This is done by utilising a model, i.e. VIX, developed by Harvey and Whaley (1992) to United States Oil Fund, LP
options. The VIX methodology is considered to be a key measurement for market volatility. The following chart plots OVX Oil Price Volatility and daily Parkinson volatility of ICE Brent 1\textsuperscript{st} month. When examining the chart, we see that the two oil price volatility measurements tend to move in the same direction. Nonetheless, there is a difference in the pace of the movement. This discrepancy is likely to be attributed to the structural difference of the two underlying time series for these two oil price volatility measurements. Namely, on the one hand we have ICE Brent 1\textsuperscript{st} month data (Parkinson), whilst the OVX depicts a volatility calculation on the United States Oil Fund, LP options time series.

Comparing NYMEX WTI 1\textsuperscript{st} month Futures Parkinson volatility to ICE Brent 1\textsuperscript{st} month Futures Parkinson volatility yields the following plot. When comparing yearly volumes of the former Parkinson volatility series to the one of the latter, we see that WTI time series (1\textsuperscript{st} month Futures) are more volatile than their ICE Brent counterparts (see chart). One possible explanation for this is the higher trade volume of ICE Brent front month, compared to WTI 1\textsuperscript{st} month futures.

![ICE Brent 1st Month Parkinson Volatility and OVX Oil Price Volatility Index [\%; % Points]](image-url)

Source: The ICE, CBOE
The Average True Range

The Average True Range was developed by Welles Wilder as a volatility measurement. This instrument considers high and low prices, subject to previous close prices. The Average True Range is only a volatility measurement; it does not say anything about the direction of the price movement (J. Welles Wilder, Jr. (1978), Section IV: Directional Movement). The Range is usually calculated on 14 periods (as is the case in this analysis) on a daily basis.
Average True Range of ICE Brent 1st Month

Close price of ICE Brent 1st month [USD per barrel]

Source: The ICE
Bollinger Bands

Bollinger bands are also a volatility indicator used to measure. As the Bollinger Bands consider the volatility of the time series, these adjust themselves, i.e. widen or narrow, when the market becomes more/less volatile respectively.

Bollinger Bands for ICE Brent 1st Month [USD per barrel]
The Average Directional Moving Index

The Average Directional Moving (ADX) Index method was developed by Welles Wilder in the late 1970s. The Index gives an indication of the strength of a price series trend, regardless of the direction of the movement. The ADX Index is based on lagged values, i.e. a trend must be established before it is mirrored by the index (J. Welles Wilder, Jr. (1978), Section IV: Directional Movement). The positive/negative directional indicators are complementary to the ADX. The ADX is widely used as a trend analysis tool by traders of financial instruments. In General, ADX values below 20 mirror trend weaknesses, whilst values above 40 are usually considered to depict trend strength. Over the first 8 months (Jan-August), the ADX index averaged below 40. Nonetheless, with falling oil prices (ICE Brent first month), the Index has moved up (see chart). On a broader perspective, the ADX was averaging more below 20 than above 40 over the last four years, indicating weak price movement trends on the international oil market.
The Alligator Index

The Index was developed by Bill Williams in the mid-1990s. It consists of three lines, which are calculated by using lagged smooth moving averages. These lines (often referred to as Jaw, Teeth, Lips), help confirm a trend in the market. When the three lines are...
crossed or intertwined, the market is flat, whilst when these lines are not crossed or intertwined, depending on the position of the outright price, there is an upward (outright price is above three lines) or downward (outright price is below the three lines) trend (see chart).

The Commodity Channel Index

The Commodity Channel Index (CCI) was developed by Donald Lambert in the year 1980 with an aim to identify new trends and extreme conditions of commodity price movements by measuring the current price with an average price level over a given period in the past (Lambert 1980, p. 3). Thus, when current prices are above/below the historically defined average, values of the CCI are high/low (above 100 and below -100 are typically considered to be the threshold high/low values). Lambert also argues that this also gives an indication if the commodity is overbought, or oversold, i.e. if the CCI averages above the 100 mark, this a signal that prices are trending higher.

One crucial point of the CC Index is the period length of the historical average: if this period is too long, then the response time to any extremes of price developments will be slower.
The DeMarker Index

The DeMarker Index was developed by Thomas DeMarker as a momentum oscillator for identifying buying and selling opportunities for traders. By assessing intraday price minimum and maximum levels, the DeMarker Index provides information about overbought and oversold volumes. The usual time span for the DeMarker Index is 14 periods (also used for our calculations). Like with other momentum analysis tools, longer time periods cause slower swings of the oscillator and vice versa. If the DeMarker Index is based on a shorter period, it is more suitable for identifying overbought and oversold trends (the overbought and oversold lines are usually at 0.7 and 0.3 respectively). Thus, when the DeMarker Index falls below 0.3 (oversold line) this is a signal for traders to go long on a position, whereas when the index rises above 0.7 (overbought line) traders should opt for taking a short position. If the time period is longer, the DeMarker Index is more suitable for assessing price patterns (DeMarker, Thomas (1994) p. 49).
The Moving Average Envelopes Index

The Moving Average Envelopes Index is used as a trend following indicator. The Index is built on a simple moving average. The upper and lower envelopes are then set at the same percentage above or below this simple moving average. Thus, moves above or below the upper and lower envelope respectively, should be assessed more closely: surges above the upper envelop signal extraordinary strength, whilst those below the lower bound mirror extraordinary weakness. Usually, such moves are a signal for an end of a trend, i.e. surge/drop.

Source: Input date: The ICE; Calculations done by Mihni Mihnev
Time Frame: 15 Periods
Deviation: 2.5%
The Fractals Index

Fractals are a tool used to identify price trend reversals. Usually, fractals are composed of five or more bars, where a bullish turning point (here up arrow) occurs. This is the case when a high price is higher than two previous and two future high prices. The adverse logic applies for a bearish turning point (see chart). The Fractals index is often used complementary to the Alligator Index (discussed above).

ICE Brent 1st Month Fractials [USD per barrel]

Summary of Key Volatility and Trend Analysis Tools

<table>
<thead>
<tr>
<th>Family</th>
<th>Index</th>
<th>Purpose</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatility Indicators</td>
<td>Parkinson Volatility</td>
<td>High-Low Volatility Estimator</td>
<td>Does not say anything about the direction of the price movement</td>
</tr>
<tr>
<td></td>
<td>Bollinger Bands</td>
<td>High-Low Close Volatility Estimator</td>
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<tr>
<td></td>
<td>Average Directional Index</td>
<td>Movement strength indicator</td>
<td></td>
</tr>
<tr>
<td>Movement and Trend Indicators</td>
<td>Alligator Index</td>
<td>Price Trend Indicator</td>
<td>Close price above 3 lines: Uptrend</td>
</tr>
<tr>
<td></td>
<td>Commodity Channel Index</td>
<td>Identify new trends and extreme conditions</td>
<td>Close price below 3 lines: Downtrend</td>
</tr>
<tr>
<td></td>
<td>DeMarker Index</td>
<td>Provides information about overbought and oversold positions</td>
<td>Overbought positions: Above 0.7</td>
</tr>
<tr>
<td></td>
<td>Moving Average Envelopes</td>
<td>Trend following indicator</td>
<td>Oversold positions: Below 0.3</td>
</tr>
<tr>
<td></td>
<td>Fractals Index</td>
<td>Identity price trend reversals</td>
<td></td>
</tr>
</tbody>
</table>

Source: Various
8. Regression Models

Simple Linear Regression

Regression models are commonly used for analysing data sets and the interaction between variables. A regression model (static) usually has the following form:

\[ y_t = \beta_0 + \beta_1 z_1 + u_t \]

Usually, such models with only one explanatory variable, i.e. low coefficient of determination- \( R^2 \). For example, a simple linear regression of the oil demand growth (explanatory variable) and oil price (dependent variable) between 1987 and 2013 yields the following chart:

From the chart we can see that the coefficient of determination is equal to around 73% (coefficient equal to 1 would imply that all points be on a line and thus residual will be equal to 0).
A polynomial regression of 2\textsuperscript{nd} order yields an equation (see chart above), which has a higher $R^2$ (94.04\%) than the simple linear regression (in general when we increase the order of the polynomial, the coefficient of determination increases).

We should consider the possibility that all factors, including global oil demand, change over time. This issue has been assessed with regards to natural gas prices in a paper called “The Weak Tie between Natural Gas and Oil Prices” by Ramberg and Parsons. In this work, the authors argue that variables, determining a cointegration relation, change with time. Thus, the authors suggest dividing a long period into two, or more, sub periods. After analysing the scale of the error term (historical difference between actual oil prices and these predicted by the simple linear regression equation; for the exact calculations refer to the excel file) we divide our data set into two different subsets:

- Between 1987 and 1998. During that time the line of the simple linear regression will have an $R^2$ of only 4.1\%
Between 1999 and 2013. In difference to the first data set, a simple linear regression between global oil demand and Brent spot price yields a much higher $R^2$ (89.2%).

One of the underlying reasons, which might be behind this significant shift of the explanatory strength of the simple linear regression model, could be a shift in fundamentals, which define the oil price.
Multiple Linear Regression

A multivariate linear regression model is used to determine the relationship between one dependent variable and two or more independent variables.

When we run a multiple regression with the annualised oil price (independent variable) and world oil demand, global GDP growth rate and global population growth rate (independent variables) we receive the following outcome:

Here, we see that the $R^2$ is around 90%, i.e. the three independent variables explain around 90% of the variation of the oil price. Standard error, or the sample estimate of the standard deviation of the error $u$, takes the value $10.8$ per barrel.

The output in the ANOVA table suggests that the model is significant. The column labelled F depicts the F-Test of the two hypothesis: H0 (the three slope parameters are all equal to 0) vs H1 (at least one of the three slope parameters does not equal 0). The adjacent column (here labelled significance F) depicts the P-Value of the F-Test. Because this value is smaller than 0.05, the H0 hypothesis is rejected and we have reliable results (Wooldridge 2002: Multiple Regression Analysis section).

The first column in the last table gives the intercepts and slopes of the three independent variables. The value of the intercept is a negative number, which contradicts the basics of the classic economic theory, which postulates positive commodity prices. Both Global Oil Demand and World Population growth rate have positive least square estimates for their slope parameters, i.e. higher global demand and higher population growth rate result in higher oil price. At this point we have to make the remark that, from a logical perspective,
Global Oil Demand might not be independent, but rather a function of the Global Population Growth Rate variable. The table also shows that, contradictory to common belief, higher GDP growth rates negatively influence the level of oil prices.

Looking at the P-Values (two-sided test) of the three independent variables, we see that only two of them are statistically significant: Global Oil Demand and World Population Growth Rate. World GDP Growth Rate is not statistically significant.

Running a regression analysis of just Global Oil Demand and World Population Growth Rate as explanatory variables yields the following result:

```
SUMMARY OUTPUT

Regression Statistics
Multiple R 0.945266025
R Square 0.893527858
Adjusted R Square 0.88465518
Standard Error 11.34359873
Observations 27

ANOVA

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<th>df</th>
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Coefficients

<table>
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<th>Lower 95%</th>
<th>Upper 95%</th>
<th>Lower 95.0%</th>
<th>Upper 95.0%</th>
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<td>-630.9704868</td>
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<td>0.00623459</td>
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<tr>
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<td>13833.93899</td>
<td>28676.66794</td>
<td>13833.93899</td>
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```
Vector Autoregression

In the case of oil price forecasts, simple and multiple regression models are not widely used, as it is often the case that the \( E(u_{t+1}|I_t) = 0 \) assumption of the model is usually not valid in reality (Woodridge: Introductory Econometrics).

Another forecasting method takes into account the lagged values of the dependent and explanatory variables. Such a model would have the following form:

\[
\begin{align*}
y_{1,t} &= \delta_0 + \alpha_1 y_{1,t-1} + \alpha_2 y_{1,t-2} + \cdots + u_{1,t} \\
y_{2,t} &= \delta_0 + \alpha_1 y_{2,t-1} + \alpha_2 y_{2,t-2} + \cdots + u_{1,t} \\
&\vdots \\
y_{n,t} &= \delta_0 + \alpha_1 y_{n,t-1} + \alpha_2 y_{n,t-2} + \cdots + u_{1,t}
\end{align*}
\]

In a matrix form the VAR model has the following form:

\[
K_t = \delta + \alpha_1 K_{t-1} + \alpha_2 K_{t-2} + \cdots + u_t
\]

\( E(u_{t+1}|I_t) = 0 \)

with

\[
E[u_t, u_t'] = \Omega \text{ equal to the contemporaneous covariance matrix}
\]

This form can also be extended to include more lags of \( y \) and \( z \) and lags of other explanatory variables. The equation above represents one equation in a vector autoregressive model (VAR). With a VAR model we forecast the development of a variable based on the lags of the series (own and also of other variables). This means that past occurrences of the dependent variable are utilised also on the right hand side of the regression equation, i.e. they become explanatory variables.
Furthermore, one important advantage of VAR models is that it eliminates the need to determine which variables are exogenous: on the right side of the VAR equation we have only lagged-variables and all variables are endogenous (Green 2002, p. 587). This is also the reason why we need to test the variables for Granger causality.

Green (2002) also discusses the underlying factors, which supported a wide-spread adoption of VAR models in the 1980s-1990s. From a historical perspective, large structural equations designed in the 1950s-1960s did not provide accurate forecasts. Such large models failed to predict the high inflation-high unemployment period in the 1970s in the USA. Thus, researchers moved away from employing structured equation systems for forecasting. Over the same time, research had shown that small-scale VAR models (without errors in their theoretical framework) are better in forecasting than the abovementioned large-scale structural equation systems.

Nonetheless, VAR models also have significant disadvantages. Green (2002, p. 585) argues that the “proliferation of variables in the vector Autoregression models” is the main disadvantage of these models.

In a complete VAR analysis we model several time series, on the basis of their past occurrences (Woodridge 2002, p. 598). In our case, we are interested in forecasting the future oil price. Before we can utilise the above described equation to forecast the future spot price, we need to test, whether past values of $y_t$ help to forecast $y_t$.

Here we need to note that Granger causality is not equal to the classical term of causality between two variables. In our case $z$ will be the global demand for crude. We can extend our analysis and also add the global GDP growth rate and the global crude supply in addition to $z$.

At this stage to utilise a Johansen’s test to find the optimal number of lags of our VAR model. After implementing this in STATA we receive the following output:
From the output above we see that the optimal number of lags is 3. The outcome is also consistent with empirical studies: Here conduct our analysis with yearly data. In such cases the number of lags tends to be small (Woodridge 2002, p. 599).

After having derived the optimal number of lags, we can proceed and test our variables for Granger causality. In that test, our null-hypothesis will be that global oil demand does not Granger cause the spot price of oil, i.e. \( z \) does not Granger cause \( y \).

The VAR model requires that response and explanatory variables are covariance stationary. This feature implies that the first two moments of these variables (mean and variance) exist and are time invariant (STATA: Time Series Guide). Furthermore, the VAR model treats all variables identically and is considered to be non-structural, which contributes to a good fit of the data.

In STATA we develop of VAR model, where the explanatory variables (independent variables) are only lags of the dependent variable, i.e. lagged price and demand data. The time frame of our study is between 1987 and 2013.

After having entered the data into the Data Editor of the programme, we declare it as a time series set. In STATA we run the Vector Error Correction Model (VECM). Furthermore, we run the model function with three lags, as discussed in the paragraphs above. This means that our model will have the following form:

\[
\text{Oil Spot Price}_{1,t} = \delta_0 + \alpha_1 \text{Oil Spot Price}_{1,t-1} + \alpha_2 \text{Oil Spot Price}_{1,t-2} + \beta_1 \text{Global Oil Demand}_{1,t-1} + \beta_2 \text{Global Oil Demand}_{1,t-2} + u_t
\]
Oil Spot Price \(2_t\)
\[
= \delta_0 + \alpha_1 \text{Oil Spot Price}_{2,t-1} + \alpha_2 \text{Oil Spot Price}_{2,t-2} \\
+ \beta_1 \text{Global Oil Demand}_{2,t-1} + \beta_2 \text{Global Oil Demand}_{2,t-2} + u_t
\]

Oil Spot Price \(n,t\)
\[
= \delta_0 + \alpha_1 \text{Oil Spot Price}_{n,t-1} + \alpha_2 \text{Oil Spot Price}_{n,t-2} \\
+ \beta_1 \text{Global Oil Demand}_{n,t-1} + \beta_2 \text{Global Oil Demand}_{n,t-2} + u_t
\]

After running the VEC Model in STATA, we get the following output tables.
We will consider several coefficients from these tables. We see that only the second lag of price, as well as the first lag of demand is significant for our price equation of the VECM.

Before proceeding with forecasting, we must check if the model assumptions are satisfied. First we check if the model has serial correlation. From STATA we receive the following result of the Lagrange-multiplier test, with H0: there is no autocorrelation at lag order and H1: there is autocorrelation at lag order. In both lags the P-values are above the 5% mark, which means that we cannot reject the null hypothesis, i.e. there is no serial correlation in our model.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Parms</th>
<th>RMSE</th>
<th>R-sq</th>
<th>chi2</th>
<th>P&gt;chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_Price</td>
<td>6</td>
<td>7.35692</td>
<td>0.7544</td>
<td>55.29425</td>
<td>0.0000</td>
</tr>
<tr>
<td>D_Demand</td>
<td>6</td>
<td>0.931521</td>
<td>0.7211</td>
<td>46.53605</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

| Coef.    | Std. Err. | z    | P>|z|   | [95% Conf. Interval] |
|----------|------------|------|-------|-------------------|
| D_Price  | _cel_      |
| L1.      | 0.0276803  | 0.0087881 | 3.15 | 0.002 | 0.010456 | 0.0449046 |
| Price    |
| L1.      | -0.3577914 | 0.2177481 | -1.64 | 0.100 | -0.7845698 | 0.068971 |
| L2D.     | -0.4222394 | 0.1449553 | -2.91 | 0.004 | -0.7063466 | 0.1381322 |
| Demand   |
| L1.      | 7.462574  | 1.670391 | 4.47 | 0.000 | 4.188667 | 10.73648 |
| L2D.     | -0.198124 | 2.503469 | -0.08 | 0.937 | -5.104833 | 4.708585 |
| _cons    | 0.1202385 | 3.932279 | 0.03 | 0.976 | -7.586887 | 7.827364 |

Cointegrating equations

<table>
<thead>
<tr>
<th>Equation</th>
<th>_Parms</th>
<th>chi2</th>
<th>P&gt;chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>cel</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Identification: beta is exactly identified

Johansen normalization restriction imposed

| beta  | Coef. | Std. Err. | z    | P>|z|   | [95% Conf. Interval] |
|-------|-------|------------|------|-------|-------------------|
| _cel_ |
| Price |
| _cons |
| Demand |
| _cons |

We will consider several coefficients from these tables. We see that only the second lag of price, as well as the first lag of demand is significant for our price equation of the VECM.

Before proceeding with forecasting, we must check if the model assumptions are satisfied. First we check if the model has serial correlation. From STATA we receive the following result of the Lagrange-multiplier test, with H0: there is no autocorrelation at lag order and H1: there is autocorrelation at lag order. In both lags the P-values are above the 5% mark, which means that we cannot reject the null hypothesis, i.e. there is no serial correlation in our model.

We will consider several coefficients from these tables. We see that only the second lag of price, as well as the first lag of demand is significant for our price equation of the VECM.

Before proceeding with forecasting, we must check if the model assumptions are satisfied. First we check if the model has serial correlation. From STATA we receive the following result of the Lagrange-multiplier test, with H0: there is no autocorrelation at lag order and H1: there is autocorrelation at lag order. In both lags the P-values are above the 5% mark, which means that we cannot reject the null hypothesis, i.e. there is no serial correlation in our model.
Then, we check if our model residuals are normally distributed. Our null-hypothesis is: residuals are normally distributed, whereas the alternative-hypothesis reads: residuals are not normally distributed. In the table, the first equation (Price) is relevant for us, as we are interested in the VAR model on oil prices, rather than the one on demand. The P-value in that equation is 97%, which means that we cannot reject our null-hypothesis, i.e. residuals are normally distributed.

    . varnorm, jbera

    Jarque-Bera test

<table>
<thead>
<tr>
<th>Equation</th>
<th>chi2</th>
<th>df</th>
<th>Prob &gt; chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>0.055</td>
<td>2</td>
<td>0.97301</td>
</tr>
<tr>
<td>Demand</td>
<td>1.234</td>
<td>2</td>
<td>0.53956</td>
</tr>
<tr>
<td>ALL</td>
<td>1.289</td>
<td>4</td>
<td>0.86329</td>
</tr>
</tbody>
</table>

Now, we can proceed with forecasting, as our model has passed the diagnostic checking. We will forecast the development of oil prices in the next 5 years, i.e. until 2018.

Computing this in STATA yields the following result:
From the chart we can see that our forecast for the price of oil is upwards sloping, i.e. the model projects increasing oil price. Furthermore, the stretch of 95% confidence interval expands as we move further into the future. This occurrence should be attributed to the fact that, as we move further away from the last historical data point (2013), the forecast becomes less reliable, which in terms increases the 95% confidence interval.

Our model forecasts an oil price of nearly $118 per barrel in 2014 and almost $140 per barrel in 2018. When comparing the actual development of the oil price in 2014 to the model’s forecast, we see that, even though in the second half of 2014 the oil price decreased (i.e. Brent Spot FOB), moving to nearly $80 per barrel on November 11th, the average for 2014 until November 11th is equal to $103.8 per barrel, which is still in the 95% confidence interval of the model (lower interval of the model is around $100 per barrel). However, our model predicts and upwards sloping oil price, i.e. increasing for all years y-o-y between 2013 and 2018, whilst currently (November 2014) this is not the case (oil prices are decreasing, with also futures contracts for upcoming years settling at levels, which do not fall in the 95% confidence interval).
9. Critical Comparison of Empirical Forecast Instruments

Oil prices have been on an increase ever since 2001 (2009 was the sole exception, whilst in 2013 prices edged down marginally y-o-y). All the regression parameters, which we discussed in this section take this historical development into account and produce projections for the future oil price development, based on this historical data. We deliberately conducted all regression analysis (simple linear full history, simple linear at the two different cases, multiple linear, VAR) starting 2014, as we wanted to see if all the aforementioned forecast models would predict the drop of international oil prices, observed in the second half of 2014, or at least a downwards trend. The chart below shows that all regression models predicted increasing oil prices from 2014 onwards. All models, apart from the VAR model and the simple linear regression (1999-2013 trend) indeed predicted a decline in oil prices in 2014, compared to 2013 (see chart). Furthermore, all models, apart from the simple linear regression (full history case), ICE Brent Futures scenario and simple linear regression (1987-1998 case), are bullish in their price forecasts, i.e. these forecast oil prices at above $120 per barrel (nominal terms) as soon as 2015 (VAR case).
Comparison of Different Oil Price Forecasting Instruments [USD per barrel]

- Brent Spot FOB
- ICE Brent Futures
- Simple Linear Regression Full History Trend
- Simple Linear Regression 1987-1998 Trend
- Simple Linear Regression 1999-2013 Trend
- Multiple Linear Regression Projection
- VAR Projection


ICE Brent curve constructed using ICE Brent Futures contracts as of November 14, 2014
IV. Critical Remarks

In this analysis we assessed different formation and forecast aspects of oil prices. With regards to hedging tools, we saw that the Brent market provides sufficient instruments (CFDs, EFPs) to hedge the basic risk on that market. Here it is worth noting that even though the Brent market is currently the leading oil market worldwide in terms of pricing, its reputation is threatened by declining physical output of the Brent Blend complex. In the future this development might lead to the addition of other North Sea streams to the Brent Complex. With regards to the DME Oman Futures market, we concluded that this market still has not evolved to a position, where leading crude exporters to Asia will substitute the current Bret/Dubai average issued by Platts with it.

With regards to mathematical and empirical methods, we analysed different forecast models and approaches. Some of these models are based entirely on historical data, e.g. volatility and trend indicators, whilst other are based on structural relations, e.g. Hotelling rule, different regression analysis, etc. With regards to the latter approaches, we saw that any long-term forecast (e.g. further away than a couple of months), provide rather skewed results (e.g. based on historical figures, none of the regression models predicted the 2014 drop in prices). This might be attributed to the fact that in the longer term crude oil prices are often subject to non-structural variables (e.g. black swan events), which are often of a geo-political, weather or even economic nature. Thus, when analysing the mid and short term development of oil prices one should not only consider the historical development of this time series, but also take into account various economic and other, e.g. political, etc., variables, which have influence on the oil price (for instance, according to the IEA global oil demand growth this year will be at a multi-year low of 680,000 b/d (www.iea.org/oilmarketreport/omrpublic/currentreport/#Demand), which was especially pronounced in Q2 and Q3 this year. This event coincided with the steep decline in oil prices.)
V. Conclusion

In this analysis provided insights on the historical development of the pricing regime on the global oil market. This evolution to the spot market system is induced by the need to have a pricing scheme, which follows free market principles. Nowadays, the key Brent market is not only important on a regional basis (in the Atlantic Basin), but it also provides Asian buyers the possibility to have access to the Atlantic Basin market via the Brent Dubai EFS (Exchange Physicals for Swaps). This makes the Brent market, with its complex layers (physical and paper markets), key to the global oil pricing scheme.

We also analysed different methods for forecasting the future development of spot oil prices. Here we assessed several key methods, such as the employment of Futures and Forwards, parsimonious forecasting models such as the random walk without drift, trend and volatility indicators and the various regression models, including the Vector Autoregression model. We derived the conclusion that forecasts, based on the aforementioned methods are useful only in the short-term.
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• Yanagisava, Akira (2009): Usefulness of the Forward Curve in Forecasting Oil Prices, The Institute of Energy Economics, Japan
VIII. Deutschsprachiges Abstrakt

IX. Lebenslauf

Education

10.2011-01.2015  University of Vienna
Master of Science in International Business Administration
Specialisation: Energy Management
Master Thesis: Empirical Analysis of Oil Price Dynamics

09.2007-07.2011  University of Mannheim
Bachelor of Science in Economics
Specialisation: Mathematics, Energy Economics, Statistics
Bachelor Thesis: The Market for Electricity: Industry Structure and Regulation

09.2002-07.2007  Foreign Language High School, Dobrich, Bulgaria
German and English Language Studies
German Language Final Thesis (DSDII): Fundamentals of Renewable Energy Technologies

Professional Experience

Since 02.2013  JBC Energy
Position: Energy Market Analyst
➢ Part of JBC Energy’s Upstream and Statistical Modelling Teams
➢ Focus: Energy Markets of Former Soviet Union (FSU) Countries, Energy Modelling, Oil Pricing, Tanker Freight
07.2012-10.2012 **EVN AG**  
Position: Internship at Maria Enzersdorf Headquarters  
- Elaborating on an empirical foundation of an alteration of the pricing structure of EVN’s Bulgarian subsidiary, with regards to the structure of electricity tariffs in the country and the market liberalisation.

02.2012-03.2012 **Bulgarian National Electric Company**  
Position: Internship  
- Analysis of the pricing framework of the Bulgarian electricity market.

01.2011-03.2011 **Ministry of Energy and Economy of Bulgaria**  
Position: Internship  
- Part of the team, which executed the transposition of Directive 2009/28/EU (promotion of the use of energy from renewable sources) into Bulgarian legislation.

07.2010-08.2010 **Bulgarian National Bank**  
Position: Internship  
- Assessing the monetary policy tools of the Bulgarian National Bank under the Currency Board Arrangements.

07.2006-09.2006 **Allianz Bulgaria**  
Position: Internship  
- Working closely with company agents in the Property Insurance/Damage Liquidation Departments.
Language Skills

Bulgarian      Native  German      Fluent
English        Fluent    Russian     Excellent
Serbian and Macedonian  Basic

Computer Skills

Statistical Software: Microsoft Excel, Stata, SPSS, R
Energy Information Providers: Thomson Reuters Eikon, Argus Media, Energy Intelligence, IEA MODS, McQuilling, DME, The ICE
Word Processing/Presentation/Desktop Publishing: Word, LyX/Power Point/Publisher
E-Mail/Communications: Microsoft Outlook/Customer Relationship Manager (CMR)
Technical Instruments for Time Series Analysis