



UNIVERSITY OF PIRAEUS  
DEPARTMENT OF INTERNATIONAL  
AND EUROPEAN STUDIES

# **AN ASSESSMENT OF OPEC'S STRATEGY AND MARKET FACTORS ON CRUDE OIL PRICING**

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## PhD Main points

The PhD dissertation aims to explore:

- **the determinants and the nature of crude oil price.**
  - **focusing on the crude oil price explosive periods**
  - **examining also its interlinkage with natural gas prices**
- **the role and strategy of main crude oil producers**
  - **focusing on the Organization of the Petroleum Exporting Countries (OPEC) and its swing producer, Saudi Arabia**

the main findings are provided below:

### A. Crude oil price drivers:

- Demand is significant and elastic (+1.35).
- Demand's elasticity implies lack of substitution.
- Shale production also deflates prices but in less intensive way (-0.16).
- Shale production even if it is inelastic, it smooths political influence.
- Shale production should be considered as the marginal production.
- Days ahead of future consumption (inventories) deflate prices but inelastically (-0.45). Last, inventories act as "production buffers".
- Terrorist attacks (Islamic State, wars in Middle East and North Africa etc.) did not have any influence on oil prices.
- Trading (speculation or "paper oil") elasticity (+1.28) adds to the market volatility.
- Further, market regulation might not help since pricing is mostly fundamentally driven.

- Current oil pricing is based on market fundamentals.
- Glut will prevail due to negative demand shocks (global recession, epidemics like coronavirus and etc.) and oversupply.
- Consumers and Producers have common interest to keep prices at reasonable levels (disinvestment, employment, global slow down etc.).

#### **Nature of crude oil prices:**

- Oil prices prior to 1973 were very stable, while they are volatile since then.
- Explosive episodes (“bubble periods”) are fundamentally driven.
- The two oil crises 1973/74, 1978/1981, and the periods between 2005 and 2008 (up to the financial crisis) are explosive.

#### **Interlinkage of crude oil with natural gas markets:**

##### **Henry Hub:**

- Market decoupling between oil and gas.
- Traders adjust gas prices faster when there are oil price increases.
- Oil price innovations have greater impacts than those of gas.
- Oil and gas markets in the US are highly liquid and financialized.

##### **NBP, TTF and JKM:**

- There are only transient spillovers from gas to oil in the British market.
- There are only transient spillovers from oil to gas in the JKM market.
- European gas hubs have close to zero impacts from oil, market decoupling.
- European gas hubs have low correlation with oil.

- JKM gas market was coupled with oil prices between the Fukushima accident and until the nuclear power generation rebound.

## **B. Role and strategy of Major Producers:**

### **Saudi Arabia:**

- Saudi Arabia covers demand increases but leaves volumes to the other producers.
- Saudi Arabia does not overreact since fully covering demand increases would reduce revenues and disrupt relationship with other producers.
- Saudi Arabia does not want to keep prices high for long periods since this would harm future demand (substitution by other sources, declining demand).
- Saudi Arabia has the same production strategy irrespectively of the time horizon (long/short term) and the market developments (price changes etc.).
- Saudi Arabia does not change production strategy in respect to the inventories (long-run), while in the short-run, it has a competitive behavior (+0.05) to constitute them less cost effective.
- Trade-off dilemma (High Prices/Low volumes or Low prices/High Volumes) confirmed i.e. Saudi Arabia increases production in low price environment to keep market share (exports).

### **Russian Federation:**

- Russian GDP is not only dependent on oil prices.
- Russian GDP is more dependent on other than oil prices factors in the short-run.
- Crude prices have the same elasticity in the long and short-run for the Russian GDP.
- Russian GDP is dependent on state expenditure.

- However, state expenditure has an elastic relationship with GDP (+2.30).
- Oil dependence might not come directly from the prices for state expenditure, but from the elastic relationship with GDP (+2.30) in the long-run.
- State expenditure is only influenced by oil production in the short-run implying technological and production limitations. Sectors other than oil do not help much.
- No Dutch disease but oil dependence detected.

#### **OPEC:**

- OPEC production deflates prices (adding supply) and its elastic (-1.32)
- OPEC is institutionalized and can provide strong signals to the market.
- OPEC ready and able to cooperate with other major producers.
- OECD production (-3.97) is more important than that of OPEC (-2.63) in the long-run, and this is why OPEC seeks multilateral cooperation. However, OECD production is not important in the short-run, while OPEC's production elasticity remains important and almost identical (-2.59). This is explained by the exporting infrastructure bottlenecks of OECD, while OPEC is more export ready.
- Other products will use less oil prices as benchmark. A great example is that of natural gas since long-term and oil-linked contracts will not be the mainstream in the future. Trading and spot prices will become more important through the creation of gas hubs.

#### **OPEC policy implications**

- OPEC continues to signal and monitor the market (experience in production decisions, credible statistics and etc.).

- OPEC could prevent market failures like financial crises in a highly financialized world where commodity exchanges might influence or be influenced by other economic developments.
- OPEC continues to hold experience on cooperation with other institutions and countries.
- It should be transformed into an open forum where producers and consumers could meet and exchange opinions.
- OPEC could form a map of good practices and due diligence for economic diversification and oil revenues' management for its member.
- OPEC should consider price volatility as the main threat to economies, investment, and future demand

## **Abstract**

The main aim of this dissertation is to explore and discover the main crude price drivers. While oil is seen as a commodity, its market structure is much more complex. It is not a commodity which can be produced in abundance from each country, even if in our era there are multiple sources other than the conventional ones. As a result, the countries are separated into producers and consumers with many new producers to claim their market share. Along with the oil price determinants, we try to best describe the role and strategy of major producers like those of Saudi Arabia and the Russian Federation, and then focus on OPEC.

Our main result is that demand is the main determinant, something which implies lack of substitution. However, shale production and inventories play a deflationary role but in a much lesser way than what is widely conceived. Financial speculation plays a contributory role to market's volatility. However, pricing is fundamentally explained. On the contrary, negative shocks in supply are not possible since we had incidents like the surge of the Islamic State which did not cause disruptions. Predominantly, the glut could prevail due to negative demand shocks like recessions or epidemics like the COVID. Further, it is proposed that consumers and producers have common interest to keep prices at reasonable levels and dialogue could be achieved.

As for the linkage between the natural gas and oil markets, we find strong evidence of market decoupling in several markets. In the US (Henry Hub), UK (National Balancing Point or NBP) and continental Europe (Title Transfer Facility or TTF in Netherlands) the natural gas market is a completely separate market. And even when there are linkages, these are only transient. However, in the Japanese-Korean market or Japan Korea Market (JKM), when the nuclear power plants were turned off after the Fukushima accident, oil drove the LNG prices.

We consider the Saudi Arabia as the swing producer, which covers most of the demand increases, but leaves space to the others. Saudi Arabia does not want to keep prices at extreme levels as this would harm future demand. In addition, Saudi Arabia

keeps the same production strategy irrespectively of the time-horizon, prices and inventories. Especially, in the short-run the major producer tries to make inventories less cost effective.

In addition, the Russian Federation is not solely dependent on oil prices. The Russian GDP is more dependent on state expenditure. However, the oil dependence might come from the relationship between the state expenditure and GDP. We find that there is a level of dependency but not Dutch disease.

We also find that OPEC production can deflate prices, however, OECD production is more significant in the long-run. On the contrary, OPEC's production has the same influence on the short-run, while OECD has insignificant impact. The last shows the production and export bottlenecks OECD countries face.

Finally, OPEC continues to be capable of sending strong signals to the market. Its production profile can prevent market failures. Further, it can be transformed into a forum between producers and consumers. Many OPEC countries could help in drafting a manual of good practice since they are in their effort to diversify their economy. Last, oil price volatility is considered as the main threat for both consumers and producers.

# Table of Contents

1	Foreword .....	20
1.1	Crude oil price developments .....	27
2	Crude oil price determinants.....	34
2.1	Introduction.....	34
2.1.1	Demand .....	34
2.1.2	Supply .....	39
2.1.3	Inventories.....	44
2.1.4	Speculation .....	47
2.1.5	Investments .....	50
2.1.6	Uncertainty.....	52
2.2	Econometrics analysis .....	54
2.2.1	Oil price determinants data.....	54
2.3	Results .....	61
2.4	Conclusions.....	69
3	Crude oil price effects.....	73
3.1	GDP .....	74
3.2	Fiscal .....	75
3.3	Monetary .....	76
3.4	Oil demand .....	78
3.5	Natural gas.....	80
3.6	Renewable Energy .....	81
3.7	Financial Markets .....	81
3.8	Commodities .....	84
4	Crude oil price explosive periods .....	86
4.1	Introduction.....	86
4.2	Data .....	92
4.3	Methodology .....	94
4.3.1	The PWY (2011) test for bubbles.....	94
4.3.2	The PSY (2015) test for bubbles .....	94
4.3.3	Date-stamping strategies .....	95
4.4	Results .....	98
		10

4.5	Conclusions.....	103
5	Crude oil price and production countries.....	107
5.1	Saudi Arabia and OPEC.....	107
5.1.1	Introduction.....	107
5.1.2	Data .....	110
5.1.3	Methodology .....	115
5.1.3.1	Saudi Arabia’s crude production .....	116
5.1.3.2	Crude oil price.....	117
5.1.3.3	World crude oil demand.....	117
5.1.4	Results .....	117
5.1.4.1	Saudi Arabia’s crude oil production, long-run model.....	117
5.1.4.2	Saudi Arabia’s crude oil production, short-run model.....	119
5.1.4.3	Crude oil price, long-run model.....	120
5.1.4.4	Crude oil price, short-run model. ....	122
5.1.4.5	World crude oil demand, long-run model.....	123
5.1.4.6	World crude oil demand, short-run model. ....	124
5.1.5	Conclusions.....	125
5.2	Russian Federation .....	128
5.2.1	Introduction.....	128
5.2.2	Data .....	131
5.2.3	Methodology .....	132
5.2.4	Results .....	134
5.2.4.1	Long-run models.....	134
5.2.4.2	Short-run models.....	135
5.2.5	Conclusions.....	142
6	Crude oil price relation with LNG markets .....	144
6.1	Introduction.....	144
6.2	US market .....	152
6.2.1	Data .....	152
6.2.2	Methodology .....	153
6.2.2.1	Time domain causality tests .....	154
6.2.2.2	Asymmetric Price Transmission.....	155
6.2.2.3	In and Out of sample forecasting ability tests.....	157

6.2.2.4	Long-term impacts.....	157
6.2.2.5	Volatility transmission .....	158
6.2.3	Results .....	160
6.2.3.1	Time domain causality tests .....	160
6.2.3.2	Asymmetric Price Transmission.....	164
6.2.3.3	In and out-of-sample forecasting ability tests.....	166
6.2.3.4	Long-term impacts.....	169
6.2.3.5	Volatility transmission .....	171
6.2.4	Conclusions.....	177
6.3	European and Asian gas markets .....	180
6.3.1	Introduction.....	180
6.3.2	Data .....	181
6.3.3	Methodology .....	185
6.3.4	Results .....	185
6.3.4.1	Time domain causality tests .....	185
6.3.4.2	In and out-of-sample forecasting ability tests.....	192
6.3.4.3	Long-Term impacts .....	198
6.3.4.4	Volatility transmission .....	203
6.3.5	Conclusions.....	214
6.4	Natural gas policy suggestions towards fundamental pricing.....	217
7	Conclusions.....	220
	References.....	225
	R packages used in this dissertation.....	245
	Dissemination work.....	246

## List of Tables

Table 2.1 Uncertainty categories in the crude oil price.....	54
Table 2.2 Variable description and data sources.....	56
Table 2.3 Test for unit roots. Period 2008-2017.....	57
Table 2.4 Cointegration test for variables of Model 3.1 .....	59
Table 2.5 Cointegration test for variables of Model 3.2.....	60
Table 2.6 Cointegration test for variables of Model 3.3.....	62
Table 2.7 Estimation results for Model 3.1.....	62
Table 2.8 Estimation results for Model 3.2.....	63
Table 2.9 Estimation results for Model 3.3.....	64
Table 4.1. Descriptive Statistics.....	93
Table 4.2 Unit root tests for the WTI real price between 1/1/1947 and 1/9/2018.....	93
Table 4.3 Structural oil price breakpoints and important events.....	99
Table 4.4 The SADF TEST and the GSADF TEST of the West Texas Intermediate (WTI) Price.....	99
Table 4.5 Bubble periods.....	105
Table 5.1.1 Test for unit roots 1980-2017.....	112
Table 5.1.2 Johansen’s maximum likelihood method test for cointegration relationship Saudi production model.....	113
Table 5.1.3 Johansen’s maximum likelihood method test for cointegration relationship Crude Price Model.....	114
Table 5.1.4 Johansen’s maximum likelihood method test for cointegration relationship World Demand.....	115
Table 5.1.5 Saudi crude oil production model – Long Run and Short run.....	119
Table 5.1.6 Crude oil price model – Long Run and Short run.....	122
Table 5.1.7 World crude oil demand model -Long Run and Short run.....	124
Table 5.2.1 Stationarity tests.....	132

Table 5.2.2 Johansen’s maximum likelihood method test for cointegration relationship for the GDPRI model.....	133
Table 5.2.3 Johansen’s maximum likelihood method test for cointegration relationship for the Government Expenditure model.....	133
Table 5.2.4 VECM and short-run elasticities for the GDPRI model.....	135
Table 5.2.5 VECM and short-run elasticities for the Government expenditure model.....	136
Table 5.2.6 Impulse response functions of the VAR for the GDPRI model.....	139
Table 5.2.7 Impulse response functions of the VAR for the government Expenditure model....	141
Table 6.1.1 Test for unit roots 1990–2017.....	160
Table 6.1.2 Full sample causality tests.....	161
Table 6.1.3 Asymmetric Price Transmission- ECM or Oil to Gas Transmission-Dependent $\Delta$ Gas.	166
Table 6.1.4 Diebold and Mariano tests – Full Sample.....	167
Table 6.1.5 Bivariate VAR.....	173
Table 6.1.6 Symmetrical DCC GARCH (1,1).....	174
Table 6.1.7 Asymmetrical DCC GARCH (1,1).....	175
Table 6.2.1 Test for unit roots 2/2/2019-28/6/2019.....	183
Table 6.2.2 Johansen’s maximum likelihood method test for cointegration relationship without linear trend and with a constant. NBP and Brent prices.....	184
Table 6.2.3 Johansen’s maximum likelihood method test for cointegration relationship without linear trend and with a constant. TTF and Brent prices.....	184
Table 6.2.4 Johansen’s maximum likelihood method test for cointegration relationship without linear trend and with a constant. JKM and Brent prices.....	185
Table 6.2.5 Full sample causality tests.....	186
Table 6.2.6 Diebold and Mariano tests – In Sample.....	193
Table 6.2.7. NBP Bivariate VAR.....	203
Table 6.2.8. TTF Bivariate VAR.....	204
Table 6.2.9. JKM Bivariate VAR.....	206
Table 6.2.10 NBP Symmetrical DCC GARCH (1,1).....	207
Table 6.2.11 NBP Asymmetrical DCC GARCH (1,1).....	208

Table 6.2.12 TTF Symmetrical DCC GARCH (1,1).....	210
Table 6.2.13 TTF Asymmetrical DCC GARCH (1,1).....	211
Table 6.2.14 JKM Symmetrical DCC GARCH (1,1).....	213
Table 6.2.15 JKM Asymmetrical DCC GARCH (1,1).....	214

## List of Figures

Figure 1-1 Total World Proved Reserves in Billion Barrels (source: BP Statistical Review of World Energy 2019).....	28
Figure 1-2 Real WTI Price - Nominal WTI CPI deflated (source: FRED) .....	31
Figure 2-1 World Oil Demand in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019).....	38
Figure 2-2 Oil Refining Capacity in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019).....	38
Figure 2-3 Oil Production in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019).....	44
Figure 3-1 Depicts the effects of oil prices on several sectors. ....	74
Figure 4-1 Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the SADF Test, Author's calculations. ....	100
Figure 4-2 Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the GSADF Test, Author's calculations. ....	101
Figure 6-1 Probability Gas returns do not Granger cause Oil returns (in %). ....	162
Figure 6-2 Probability Oil returns do not Granger cause Gas returns (in %). ....	162
Figure 6-3 The Diebold-Mariano test for predictive ability from Gas to Oil. ....	167
Figure 6-4 The Diebold-Mariano test for predictive ability from Oil to Gas. ....	168
Figure 6-5 10-day horizon AIRF from Gas to Oil (in %). ....	170
Figure 6-6 10-day horizon AIRF from Oil to Gas (in %). ....	171
Figure 6-7 Time varying Correlation between Gas and Oil. ....	176
Figure 6-8 NBP Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations. ....	187
Figure 6-9 NBP Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations. ....	187
Figure 6-10 TTF Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations. ....	189
Figure 6-11 TTF Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations. ....	189
Figure 6-12 JKM Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations. ....	191
Figure 6-13 JKM Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations. ....	192
Figure 6-14 NBP The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculations. ....	194
Figure 6-15 NBP The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations. ....	194
Figure 6-16 TTF The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculation. ....	195
Figure 6-17 TTF The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations. ....	196

Figure 6-18 JKM The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculations. ....	197
Figure 6-19 JKM The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations. ....	197
Figure 6-20 NBP Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.....	199
Figure 6-21 NBP Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.....	199
Figure 6-22 TTF Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.....	200
Figure 6-23 TTF Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.....	200
Figure 6-24 JKM Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.....	201
Figure 6-25 JKM Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.....	202
Figure 6-26 NBP Time varying correlation between Oil and Gas. Source: Authors' calculations. ....	209
Figure 6-27 TTF Time varying correlation between Oil and Gas. Authors' calculations.....	212

## Abbreviations

AIC: Akaike Information Criterion

AIRF: Accumulated Impulse Response Functions

AR: AutoRegressive

BTU: British Thermal Units

DCC: Dynamic Conditional Correlation

DM: Diebold and Mariano

DOC: Declaration Of Cooperation

ECM: Error Correction Model

ECT: Error Correction Term

EV: Electric Vehicle

FID: Final Investment Decision

GARCH: Generalized AutoRegressive Conditional Heteroscedasticity

GRP: Gas Release Program

ICE: Intercontinental Exchange

IO: Industrial Organization

IOC: International Oil Company

JCC: Japanese Customs-Cleared Crude Oil

JKM: Japan/Korea Marker

LNG: Liquefied Natural Gas

LTO: Light Tight Oil

LTS: Long Term Strategy

MA: Moving Average

MENA: Middle East and North Africa  
MSFE: Mean Squared Forecast Errors  
NBP: National Balancing Point  
NOC: National Oil Company  
PCI: Projects of Common Interest  
PRA: Price Reporting Agency  
QE: Quantitative Easing  
TPA: Third Party Access  
TTF: Title Transfer Facility  
VAR: Vector Autoregressive  
VTP: Virtual Trading Point  
VTP: Virtual Trading Points  
WTI: West Texas Intermediate

# 1 Foreword

Oil remains the most used energy source around the globe. First, its unique utility and its high energy density perplex its nature. Second, oil is not evenly distributed among the states. Thus, there are oil-rich and oil-poor countries. Third, oil is easily transported around the globe as it is liquid. It requires low infrastructure and transport costs are minimum.

Its importance grew with the industrial revolution. The British government for example bought the 51% of the Anglo-Persian Oil Company (1914) -later named as British Petroleum- when its navy turned from coal to oil. The victorious Allies empowered their efforts after the World War I to secure their oil supplies. The then new oil discoveries of the 1920s and 1930s in the Middle East intensified the struggle between the British Empire and the US. The US oil companies succeeded to secure a stake in Saudi, Iraqi, Kuwaiti, and Bahraini plays. By the late 1930s almost all of the Middle Eastern reserves were under Anglo-American companies' control. Oil became even more important during the World War II. The American efforts for oil supply security culminated in the 1945 agreement between Franklin Roosevelt and Ibn Saud for Lend-Lease aid and military bases' construction. The Anglo-American companies' dominance secured cheap oil for the West. Furthermore, oil continues since then to be priced in US dollars while Western countries kept trying to keep balance between cheap oil imports and domestic production when the last was existent. A great example was Eisenhower's decision to impose quotas on oil imports to protect US production. Moreover, a separate balance should have been kept with the oil exporting countries. Oil prices were not fundamentally formed and were stable from late 1940s to late 1960s, while the exporting countries were requiring a fair share. To alleviate concerns, the US encouraged oil companies to evenly share their revenues with the oil exporting countries. The "fifty-fifty" deals were specially treated by the US government, which allowed the payments' deduction from oil companies' balance sheets. However, this was not enough to alleviate the dominance of international oil companies. The "Seven Sisters" continued to impose their terms in the oil market. In the

1950s, this small group of companies controlled 90% of oil production and sales excluding the US market. Their vertical integration made them almost necessary for any oil development.

All the above drove the developments in the following decades. The strong oligopoly by oil companies was highlighted in 1959 when they unilaterally decreased the royalties by 10%. In addition, their new oil discoveries in Middle East and Africa suppressed oil prices. Oil revenues became even lower and host countries became even more unsatisfied with the prevailing conditions. The aforementioned motivated some of the oil exporting countries to form OPEC in 1960. The founder members are Islamic Republic of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. Later other countries joined while others withdrew. After the formation of OPEC, the Seven Sisters had to bargain with a block of countries. Initially OPEC had successes like the inclusion of royalties in the total cost calculations, and the decrease of marketing costs for oil companies.

The depreciation and the declaration of the US dollar as a floating currency in 1971 decreased oil revenues. OPEC replied with a conference whose result was a production reduction increasing oil prices by 70%. In 1973, a month later, there was the outbreak of the War of Yom Kippur. The first oil embargo on the supporting countries of Israel was announced. As a consequence, the first Oil Crisis erupted and the price of a barrel quadrupled from 3 to 12\$/bbl. The oil revenues for the OPEC members sharply increased but the increase in consumption and as a result in imports, along with the necessity for industrial and infrastructure development did not help the sustainment of oil revenues. Consumer countries suffered for a short period but, in return, they gained from the oil revenues increase.

The second oil crisis erupted in 1978/1979 when the Islamic Revolution of 1979 in Iran took place. Iranian exports were curtailed and prices doubled from 15\$/bbl. to 30\$/bbl. The consecutive crises highlighted the role of OPEC. Further, the oil market stopped to be stable as used to be. The two oil shocks provoked increased prices (inflation) and long-term unemployment to the importing countries. The phenomenon was named as

“stagflation” and influenced the industrialized countries. In order to tackle potential oil crises, the industrialized countries formed the International Energy Agency (IEA) in 1974 and later the G7 and G8 summits. IEA inaugurated the permanent holding of inventories for its members capable enough to satisfy oil demand for 3 months in each country.

However, there were not only periods of high prices. In 1986, the oil prices collapsed. Increased oil supply from the North Sea, namely by the United Kingdom and Norway, reduced prices. OPEC members in their effort to keep revenues high further increased their supply. The oil glut decreased prices. Competitive production reached new heights and continued to break the OPEC ceilings. Finally, OPEC’s members insisted on production cuts and stabilized the market. Since then, the oil market moved in a certain bandwidth with two exceptions. The first was a temporary increase in 1990-1991 due to the first Gulf and the second was a decrease in 1999.

Since 2000 and up to 2008 the price followed an ascending course due to the growing demand by the emerging economies. This course was halted by a sudden financial crisis in 2008. The price fully recovered and reached its peak in 2014 when again collapsed. In 2016 reached its lowest levels, and then OPEC took the initiative with other non-OPEC members to curtail production. Oil price rebounded and moved between 60\$/bbl. and 80\$/bbl. until the coronavirus spread (2020). The last decade is of increased volatility and uncertainty. Conventional consumers like the US turned to net exporters as the hydraulic fracturing and horizontal drilling defied the established exploitation technology.

However, it is difficult to conclude which are the absolute drivers of oil prices. Oil prices have not constant drivers throughout the whole period. The main fundamental drivers are the supply and demand. Supply was once limited. Few countries had enough exploitable reserves. In contrast, this has already changed by technological advancements. The conception for oil changed from a commodity in scarcity to a commodity in abundance. This is the reason why now many do not consider oil prices as supply driven. Negative oil shocks like those of 1973 and 1978/79 hardly will ever be repeated. An argument against the aforementioned is the price war which reached its

peak in 2016. The supply shock was positive i.e. more oil was produced than needed. So, oil prices may be affected, as they already are in some periods, by excessive production. Positive supply shocks might be one of the main drivers.

Demand has received a lot of attention recently. Due to the large-scale economic development in Asia (China, India and etc.), oil demand increased and thus prices were influenced. Emerging economies drove demand's evolution since their transformation required energy intensive operations. Moreover, developing countries' consumers altered their habits which further increased energy demand. Many argue that oil price shocks are largely demand driven. Last, many argue that both demand and supply are driven by geopolitics. This is true in many occasions. However, large consensus might be required by consumers and producers to alleviate geopolitics' disturbances. This is not feasible especially in the short-term. Oil prices fundamentals after all might be the aftermath of geopolitics developments.

Moreover, oil prices are now posted in commodity exchanges. Many market participants do not trade to hedge physical deliveries. Speculation and arbitrage opportunities might also influence prices. Excessive trading might result in volatility explosions. This might not have fundamental reasoning. Uncertainty is also among the determinants which might increase volatility in commodity exchanges. Trading is one the factors which is researched on whether influences pricing.

Inventories and investments also take part in oil pricing. Oil glut is concentrated in inventories. If supply surpasses demand, then excess production is headed to inventories which form a buffer. Now, pricing considers inventories among the major drivers according to some market participants. Suppliers also follow inventory levels. Our research presents evidence that suppliers try to make inventory holding less cost effective. Last, investments influence future supply. Present low prices remove investment and this in turn limits future supply driving prices up. Investment plays a significant role since oil production is capital intensive with long lead times from research to production.

In this volatile market OPEC remains a “permanent intergovernmental organization” with the objective of “coordinating and unifying petroleum policies among Member Countries in order to secure fair and stable prices for petroleum producers; an efficient economic and regular supply of petroleum to consuming nations; and a fair return on capital to those investing in the industry”<sup>1</sup>. In order to fulfill the objective, OPEC developed a Long-Term Strategy (LTS). First, the organization acknowledges the increased volatility of the oil market and its financialization. It is stated that “as oil has increasingly emerged as an asset class with excessive speculation adding appreciably to market volatility and with significant changes underway in terms of financial regulations” and “oil market, which is now exposed to the broader financial markets. As a result, the oil market has experienced greater volatility and the price of crude has been impacted by a growing number of factors, which are not directly related to supply and demand. These factors include exchange rates fluctuations, portfolio management and risk hedging strategies on the part of non-commercial market participants, and arbitrage between various assets”. But the excess volatility is restrained by spare capacity and production swiftness by the producers. OPEC further states “The organization will continue making investments to expand its production capacity to not only meet perceived demand for its crude, but also maintain an adequate level of spare capacity”. The LTS becomes even more complex as the “OPEC will continue to expand and strengthen its dialogue with all producing and consuming countries as well as regional groups, UN institutions and other energy-related international organizations” while “it is crucial to constantly adhere to the principle of the permanent sovereignty of nations over their natural resources, and the use of comparative advantage provided by this resource”.<sup>2</sup>

Finally, it is interesting in this complex world where world demand and developments are not certain, while exchanges’ volatility entered global oil market to study OPEC’s

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<sup>1</sup> [https://www.opec.org/opec\\_web/en/about\\_us/24.htm](https://www.opec.org/opec_web/en/about_us/24.htm)

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[https://www.opec.org/opec\\_web/static\\_files\\_project/media/downloads/publications/OPECLTS.pdf](https://www.opec.org/opec_web/static_files_project/media/downloads/publications/OPECLTS.pdf)

strategy and the factors affecting oil prices with their repercussions. OPEC's strategy is formed by the oil price determinants, their effects and broader political factors. OPEC is the most powerful permanent intergovernmental organization for a resource. It remains a question whether it can drive oil prices, and whether its future will be bright. Further, many consider that there is no space for cartels in the era of liquid financial markets. What others consider is that OPEC will continue to play an important role in the future, but after reforms and reorganization. The present dissertation studies the contemporary prevailing conditions in the market (oil price determinants, their effects and etc.) and asserts to estimate the potential future developments of the organization. However, OPEC's strategy is not formed in strict silos. It is not a study of the past, since precedent does not guarantee future outcomes. Oil pricing is now complex affecting many market stakeholders. We study how the prices and their determinants and OPEC's strategy jointly affect the market. The potential future options can help today's decision making. The decision making can be either in the political or economic sphere affecting several aspects of peoples' lives.

The above analysis indicates that it is an always challenging issue to explore the determinants and the nature of crude oil price, as well as its interlinkage with other energy commodities, especially with natural gas. Moreover, to explore the role and strategy of main crude oil producers, with special focus on the Organization of the Petroleum Exporting Countries (OPEC) and its swing producer, Saudi Arabia. This is the aim of the PhD dissertation.

Section 1.1 provide the crude oil price developments, aiming to provide the background of the analysis. Chapter 2 examines the crude oil prices determinants, aiming to identify the main drivers of international oil prices. Chapter 3 examines the effects of crude oil prices on different sectors, providing further evidence on the importance of major producers to form initiatives, such as OPEC and OPEC+ to affect crude oil pricing. Chapter 4 focuses on crude oil price explosive periods, aiming to explore the nature of crude oil prices. Chapter 5 examines the role and strategy of major oil producers, with special focus on OPEC and Saudi Arabia, which stands as its swing producer, namely adjust

its production to implement OPEC strategy. It explores the role of other producers, such as Russia, a major pillar of the OPEC+ initiative. Finally, Chapter 6 focuses on the interactions of crude oil prices with natural gas prices, aiming to provide evidence on their interlinkage. Chapter 7 provides the concluding remarks. Last, we would like to add that most of the research was done by R programming language. We have a different section citing the language and the packages.

## ***1.1 Crude oil price developments***

There are several reasons why crude oil market is so volatile since 1973. Market fundamentals in conjunction with new reserves discoveries and technological advancements drove the oil market during its ups and downs. There are certain milestones in the oil market history with the most significant to be the two oil crises of 1973 and 1978/79, the near OPEC collapse in 1986, the First Gulf War, the ascending oil price course until the financial crisis (2008), the high levels of 2014, the emergence of unconventional exploitation and the rebound from the “Declaration of Cooperation” in 2016<sup>3</sup> to today’s levels. There were several repercussions on the global economy and corporations. The perception over oil has changed from a commodity in scarcity to a commodity in abundance. The new discoveries are not unevenly distributed as it were in the past. The new discoveries increased oil supply transforming the market into a liquid one where no stakeholder has dominant market power affecting the oil price course. Now market participants adjust to information flow over fundamentals. Information is not available to the market at the same time with the market facts and there is a lag in adjustment, let alone information asymmetries. Further, the adjustment is not always under strict economic criteria. Market perception is what drives the futures prices. Whether stakeholders perceive market as tight or loose, great lead times will continue to exist adding to the uncertainty.

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[https://www.opec.org/opec\\_web/static\\_files\\_project/media/downloads/publications/Declaration%20of%20Cooperation.pdf](https://www.opec.org/opec_web/static_files_project/media/downloads/publications/Declaration%20of%20Cooperation.pdf)

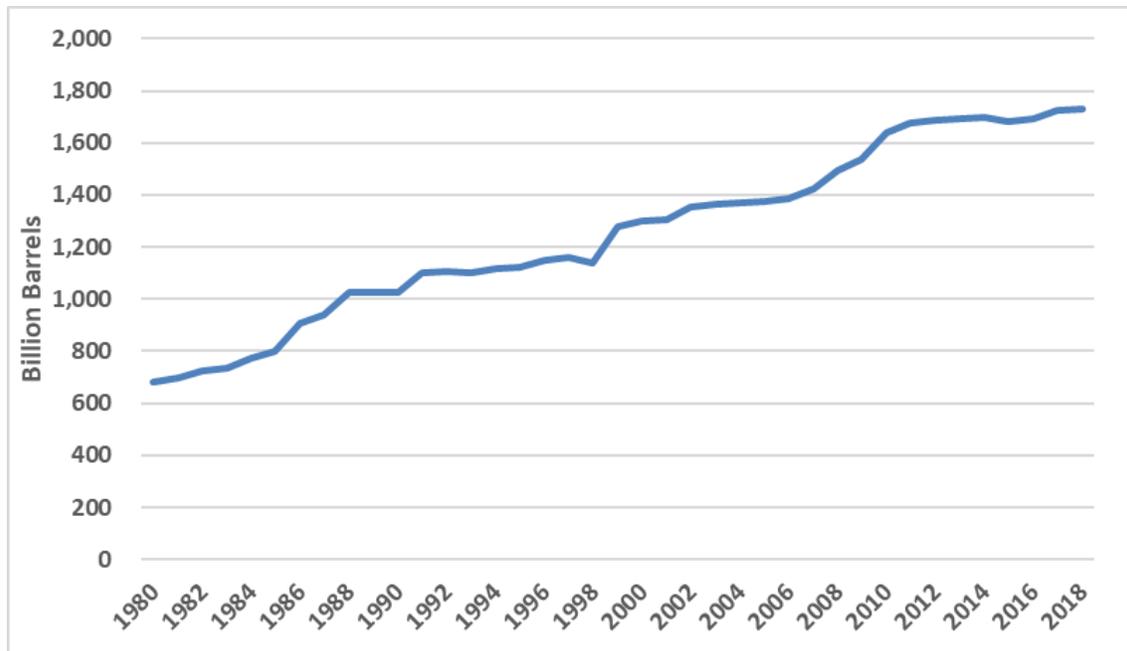


Figure 1-1 Total World Proved Reserves in Billion Barrels (source: BP Statistical Review of World Energy 2019)

During the last decade, oil price formulation was under many influences. The excess volatility was present for reasons other than market fundamentals. The collapse of 2008 was due to the great financial crisis caused by bank collapses. The incident was exogenous to the oil market, but raised concerns over global development. Moreover, traditional consumers like the US turned into producers with the tight revolution. Oil prices reached levels of 28\$/bbl. in 2016 for WTI as a consequence. The extremely low-price levels halted the majority of the oil-related projects causing concerns over future supply. Oil investments had negative net present values and as a result they were rejected. The investment stagnation was horizontal leaving room for disputes between International Oil Companies (IOC) and governments. National Oil Companies (NOC) followed the same course but this had broader implications to sovereign balance sheets. Deep-water investments were among the first victims of disinvestment. The direct repercussion was high unemployment in the oil sector, and many companies filed for bankruptcy. Corporate and governmental revenues also suffered. However, supply continued uninterrupted by the major players in the market. This was due to their effort to defend

their market share. The trade-off dilemma which urges a supplier to decide between high prices/low supply and low prices/high supply became a mainstream in production decision making. The oil glut was prevalent because traditional suppliers like Saudi Arabia and the Russian Federation tried to drive new private companies out of the supply chain. High inventories added to the supply pressure driving prices even lower. However, the US private companies hedged against a reverse oil price shock and were resilient. Tight oil supply has low breakeven points. Further, the low cost of halting and then restarting production casted tight oil producers as the swing ones. Weak economic development did not add volumes to the demand side empowering the downward pressure.

One of the most popular theories in energy economics is that of Peak Oil Demand. Under this theory, demand growth will go to zero and total demand will have its maximum. Since its peak, then oil demand will have high negative growth rate and will collapse. The peak point and its timing are attempted to be identified by several researchers. Dale and Fattouh (2018) acknowledge this difficulty since new assumptions greatly alter the results. However, if global demand reaches its peak, then it is not certain whether it will collapse soon afterwards. This is further suggested since low cost suppliers will continue to choose the large market share/low price option until they diversify their portfolio. Large deficits are not bearable by oil-depending governments and corporations. This is the reason why state fiscal breakpoints will form oil prices and not commodity's cost.

The tight revolution casted doubts over market fundamentals, investments and market power of the traditional producers. The US increased its production 70.10% or from 5,478kbbbl/day in 2010 to 9,352kbbbl/day in 2017. This was the aftermath of the hydraulic fracturing and horizontal drilling. The technology developments were the consequence of the 2008 financial crisis. Vast funds were exiting the financial markets and were in search of new investing opportunities. Light Tight Oil (LTO) was among the investment options according to a CIEP/KAPSARC/OIES report. Moreover, Quantitative Easing (QE) made borrowing even easier and with favored terms. The opportunity was exploited by the small private companies which specialized in the horizontal drilling and

hydraulic fracturing. In most of the companies, private equity firms were among the shareholders. Private equity demanded by companies to hedge against adverse price courses. This is the explaining reason for resilience of the private companies. Under Mnasri et al. (2017), companies hedge with non-linear contracts when they have or will have high capital expenditures. In addition, put options are the favorite ones when oil prices and quantities are highly correlated. Spot prices and market volatility influence the preferred hedging instruments. Production uncertainty is related to linear hedging. The loose strategy followed by the FED and the US government, and as a consequence the weak dollar, made the shale oil blend even more attractive. However, until 2015, there was an oil export ban in the US. One way to divert this ban was through refined products which were allowed to be exported. It was the infrastructure which kept the augmented volumes as inventories. But this started to change since the ban was lifted. Moreover, drilling activity continues to be the measure for production since rig count is the benchmark. However, the rigs become even more productive and cheap<sup>4</sup>. The new shale production is complex due to its unprecedented characteristics. Fattouh and Sen (2015) study its behavior through downward cycles. Tight oil expenditure, both capital and operating one, is highly adjustable casting shale producers as the new swing producers, instead of Saudi Arabia.

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<sup>4</sup> EIA, 2019 (May). US Drilling Productivity Report. Energy Inf. Adm.

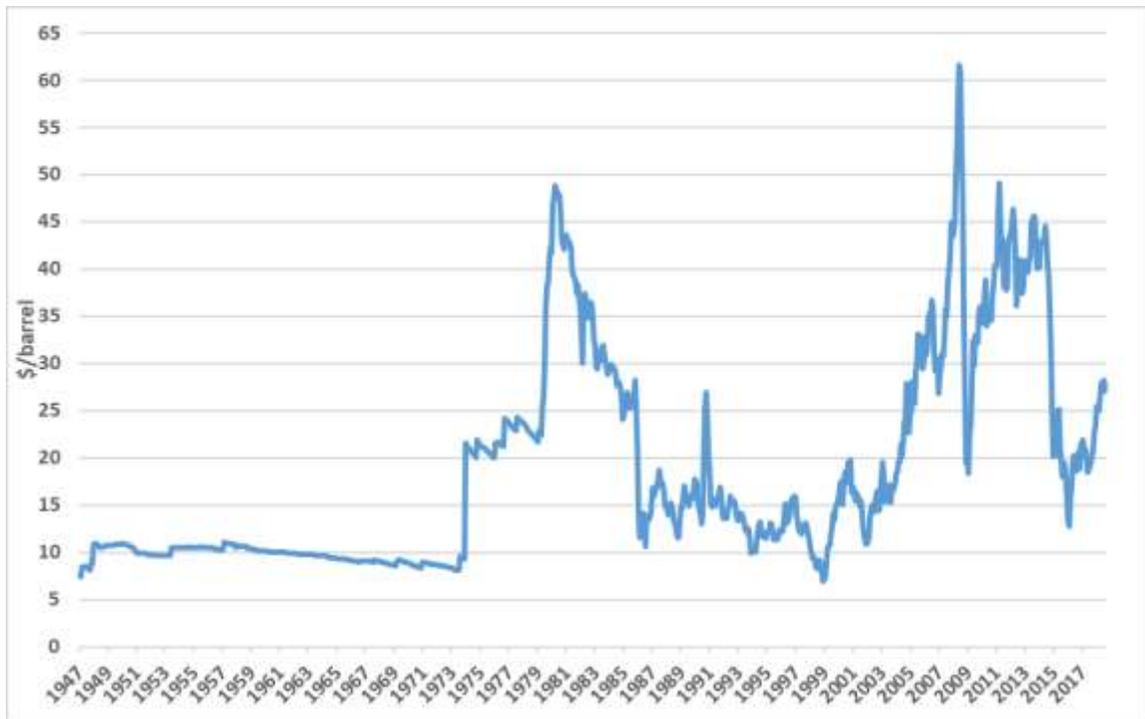


Figure 1-2 Real WTI Price - Nominal WTI CPI deflated (source: FRED)

The aforementioned leave place for concerns on how traditional producers will react to increased competition, technological advancements and climate policy regulations. Consumers like China try to fortify their energy supply from countries like Iran whom sanctions are imposed to. Sanctions are also imposed on Russia which is closely related to energy revenues (Perifanis and Dagoumas 2017). The state-owned energy companies payed a 50% of their profits as dividend in order Russia to tackle the fiscal problems. The same was applied also for Transneft which almost completely manages the energy pipeline network<sup>5</sup>. Saudi Arabia and OPEC as a whole have already perceived their less dominant role in the global energy market. Oil price can not be easily maintained in a narrow band while satisfying both demand and producers. A sudden production cut would challenge future demand (Fattouh and Economou 2018). To diversify itself from oil

<sup>5</sup> U.S. Energy Information Administration, 2017. Country Analysis Brief: Russia, Independent Statistics and Analysis.

revenues, Saudi Arabia took the initiative to implement the “Vision 2030” project<sup>6</sup> and to make Saudi Aramco public (Fattouh and Harris 2017). Until then the kingdom will remain oil revenues dependent. Revenues maximization will be the utter goal by keeping the market share and production output constant (Dagoumas et al. 2018). In the same time, societies turn their focus to cheaper energy sources than hydrocarbons. The last challenges the future of oil related investments, which are capital intensive and with long lead times. This changes the investors’ appetite for carbon investments (Fattouh et al. 2019). Their focus is more on short payback periods while harvesting is better than exploitation. The extremely low prices of 2016, the diversification mandate and the energy transition caught OPEC by surprise. To face the hardships OPEC did what is good at. It held a meeting for both members and non-members. The 170<sup>th</sup> Extraordinary Meeting of OPEC states “Based on the above observations and analysis, OPEC Member Countries have decided to conduct a serious and constructive dialogue with non-member producing countries, with the objective to stabilize the oil market and avoid the adverse impacts in the short- and medium-term.” and “oil market stability in the interest of all oil producers and consumers”<sup>7</sup>. The meeting was fruitful as the “Declaration of Cooperation” (DOC)<sup>8</sup> was achieved, a milestone for the oil industry. The meeting was all about production cuts which would remove the oil glut and would limit inventories. Since then oil price had an upward course. The decided framework also coordinates long-term investments as excess infrastructure destabilizes the market.

Environment becomes an increasingly important factor for oil pricing. The new International Maritime Organization (IMO) low sulfur oxide emission rule<sup>9</sup> which will be imposed in 2020 widens the imbalance between heavy sour and light sweet blends. Sweet oil is stored as the US can not drive their blend into the refineries (Fattouh and Economou

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<sup>6</sup> <https://vision2030.gov.sa/en>

<sup>7</sup> [http://www.opec.org/opec\\_web/en/press\\_room/3706.htm](http://www.opec.org/opec_web/en/press_room/3706.htm)

<sup>8</sup>

[https://www.opec.org/opec\\_web/static\\_files\\_project/media/downloads/publications/Declaration%20of%20Cooperation.pdf](https://www.opec.org/opec_web/static_files_project/media/downloads/publications/Declaration%20of%20Cooperation.pdf)

<sup>9</sup> <http://www.imo.org/en/mediacentre/hottopics/pages/sulphur-2020.aspx>

2019), while oil price benchmarks are mostly for heavy sour oil blends. As a consequence, pricing is not effective. Energy transition and decarbonization do not have certain dates in the future adding to the overall uncertainty and speculation. Most of advanced economies already have seen the future in Electric Vehicles (EVs). Many economies have already designed economic and energy transitory projects to lead them in a safe and secure environment<sup>10</sup>.

Oil market has a binary nature as pricing is affected by several endogenous and exogenous factors while in turn oil pricing affects global economy. Increased volatility attracts speculation and hedge funds. Initially, we start with a literature review over the oil price determinants, and in the last chapter we describe the effects of oil prices. An extensive literature review over oil pricing highlights the potential determinants, while sets the framework within OPEC operates.

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<sup>10</sup> <https://www.imf.org/external/np/pp/eng/2016/042916.pdf>

## **2 Crude oil price determinants**

### **2.1 Introduction**

Crude oil price determinants have attracted several researchers who try to explain the fluctuations over different periods. Perifanis and Dagoumas (2019) suggest that now oil prices are influenced by market fundamentals. In the past they were affected by more political factors such as OPEC production decisions. We try to classify these factors which were or are important in specific periods or throughout the whole period. For example, the “Supply” category includes both OPEC and non-OPEC production. “Technology developments” includes shale oil revolution which have made its significant appearance since 2008/2009. “Demand” and “Supply” are the main market fundamentals, while “Inventories” includes research for oil stocks held initially as strategic and later as a safety buffer to OPEC supply shocks. As it is already mentioned, oil has been quite a liquid market with active trading in financial markets. This is why we include “Speculation” as an oil price determinant, since not all traders are physical hedgers. Crude oil price signals initiate or halt investments in crude oil exploitations. Therefore, we include “Investment” as a separate determinant. However, investments have long lead times and influence the market with a lag. Finally, “Uncertainty” is among our determinants since oil is a highly related commodity to political or economic instability.

#### **2.1.1 Demand**

Oil is related to global economic development. It is the energy source for all economies to grow. Figure 2.1 presents how global demand evolved in the past. It has a relative steady growth with only a temporary recession after the two Oil Crises. Our world is energy intensive and a low to medium growth would require the respective energy consumption. He et al. (2009) suggest that real economic activity (Kilian Index), the US dollar index, and real futures prices are cointegrated. They also add that real oil prices increase 0.98% if there is economic growth of 1%. On the contrary, real oil price declines

0.70% to a 1% increase of the US dollar index. The short-run elasticities are 0.14% and -0.51%, respectively. Jadidzadeh and Serletis (2017) suggest that aggregate demand and specific demand shocks contributed more to oil prices than the supply shocks. Aggregate demand shocks provoke long-term swings, while oil market specific demand shocks provoke short-term fluctuations. Guntner (2014) separates demand shocks into flow demand and speculative demand shocks. Increased demand caused by business cycles provokes flow demand shocks. As a consequence, increased demand increases oil prices. Within these cycles both OPEC and non-OPEC producers keep their production strategies. Only Saudi Arabia and United Arab Emirates increase their production when the demand is high. This is explained by the ample spare capacity both countries hold. Furthermore, Russia and Mexico also increase their production. Perifanis and Dagoumas (2019) also suggest that demand increases crude oil price. Crude price would increase 1.35% to a 1% increase of demand. The elasticity is over unity implying that oil prices are heavily influenced by economic growth. Bataa et al. (2016) recognize two structural breaks in oil prices. The first in May 1988, and the second in October 1994. Volatility breaks have almost identical dates as there is one in February 1986, and one in September 1998. They coincide with the period when producers fiercely competed against each other leading to the near collapse of OPEC in 1986. Oil experienced relatively low volatility in the first half of the 1980s. Moreover, the price responded less to demand shocks between late 1980s and mid-1990s, but it reached its precedent levels afterwards. Demand shocks influence oil prices more since 1994. Further, demand shocks cause longer and more intense influence. A positive demand shock between 1988 and 1994 decreases oil prices a few months later. Oil specific demand shocks become the major driver for oil price variance as they are held accountable for more than 90% of the variance since October 1994 in the six-month and two-year periods. Lorusso and Pieroni (2018) find zero influence of supply shortages caused by exogenous political events in the Middle East since mid-1970s. The important factor is the precautionary demand shifts. Liu et al. (2016) consider demand as the main driver of crude oil pricing. Precautionary demand has only transient and not persistent effects. The US and Chinese demand have more persistent character. The US

demand shocks last for seven months while the Chinese demand shocks last for four months. The Chinese and precautionary demand explain 51.28% and 26.64% of oil price variance respectively. Precautionary demand has a fading influence as horizon is extended. In contrast, the US demand shocks have more influence the longer the horizon. Specifically, the US demand shock explain 27.97% of the variance even 24 month later. The Chinese shocks are accountable for between 46.55% and 68.94% of the oil price variation, irrespectively of the time horizon. Along with the US demand shocks contribute even 70% of the oil price variation. The aforementioned constitute Chinese demand as the major oil price determinant. Chevillon and Riffart (2009) suggest that between 2002 and 2008 increased demand by non-OECD countries and low OPEC production quotas are responsible for the oil price increase. Further, physical volumes could not fully justify the oil price increase of 2004 and 2005. Developing countries' demand can not justify the increase on its own. Drachal (2016) proposes the significant role of economic growth in 2009, and then afterwards it lost part of its significance to pre-2009 levels. Economic activity has a steadily significant role with rapid short-lived peaks of effect. China's demand was also a constantly significant factor of oil price formulation. Moreover, OECD demand was significant until 2000. Since then emerging economies took over. Byrne et al. (2018) propose the time-varying influence of demand due to economic activity. The real oil price did not react to demand with the same magnitude throughout the whole period. This kind of influence has become more abrupt since mid-2000s due to the developing countries. Caldara et al. (2016) estimate elasticity at -0.017. The value changes to -0.031 with narrow instrumental variables, when with broad instrumental variables is -0.08. Further, impulse response functions cast shocks responsible for 6% increase in oil prices. Positive shocks in real economic activity and commodity metal prices increase oil prices and oil production. Developing countries' real economic activity along with positive metal price shocks provoke persistent increase. Instead, advanced economies provoke short-lived and medium-run increases. Market fundamentals are the main drivers since supply and demand are responsible for 64% of the price variance. Kim (2018) holds demand collapse responsible for the oil price drop of 2008. Global economic recession

caused by the subprime financial meltdown was the main determinant for the oil price decline. Grownwald (2016) finds explosive periods for oil prices in 1990/1991, 2006/2006 and 2007/2008. He further adds that these extreme oil price moves can be fundamentally explained as supply and demand in conjunction with low elasticities are well capable of explaining oil price fluctuations. Juvenal and Petrella (2015) propose demand as the major determinant of oil price. Although speculation reinforced the oil price surge until 2008, it was the negative demand shock since then that deflated prices. In contrast, Wang and Sun (2017) find consumption insignificant while economic activity is significant. The justification is the price inelasticity of consumption. This is something hard to explain as economic activity increases consumption. Authors add the low influence of economic activity on consumption, as consumption is an endogenous reaction. Second, while consumption increases in emerging economies due to economic growth, in other decreases, offsetting any effects. Third, speculation could also be a reason. Prest (2018) suggests that economic activity proxies can explain the 2014-2016 collapse. Copper prices, US interest and exchange rates can explain the \$31 out of the \$65 collapse. The 52% of the collapse can be explained from other variables catching the demand side. Under his results shale revolution is not accountable for the collapse but demand is. D' Ecclesia et al. (2014) proposes that refinery utilization decreases oil prices as producers prefer heavier and more sour blends to satisfy consumption. Figure 2.2 highlights the ascending refining capacity trajectory in 1970s and 1980s, while there is a stalemate after the second oil crisis, and then increases again.

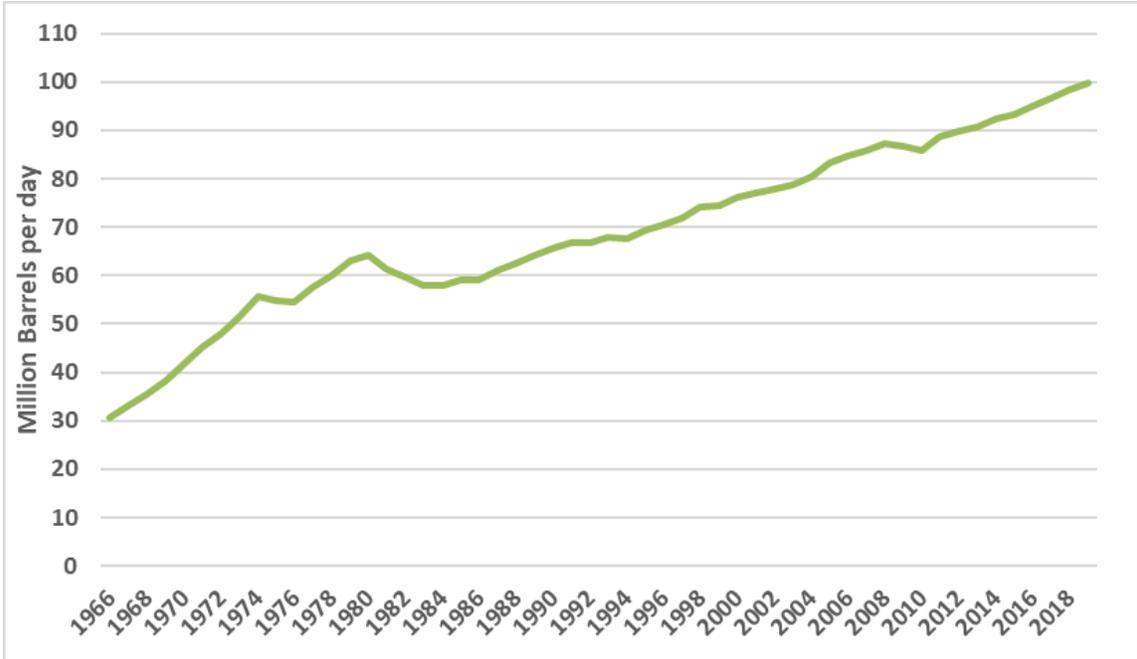


Figure 2-1 World Oil Demand in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019)

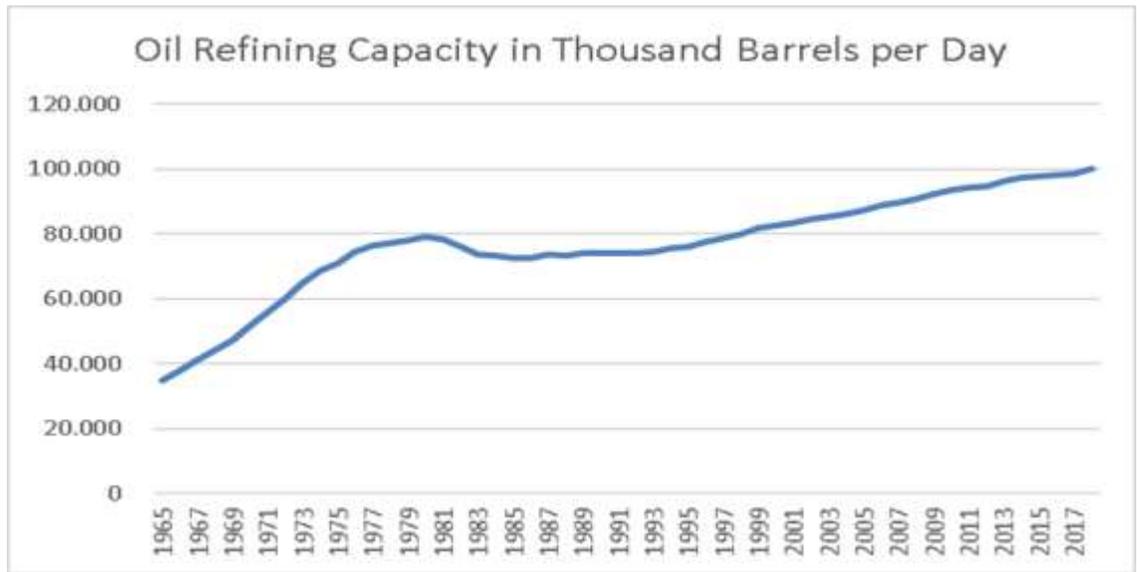


Figure 2-2 Oil Refining Capacity in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019)

### **2.1.2 Supply**

Supply as a determinant can include both technological advancements and OPEC decisions. In this dissertation supply is considered from a market fundamental perspective. Figure 2.3 depicts the supply side evolution. Supply is comprised by strong stakeholders like OPEC, US private or public oil companies, Russia and African production. “Declaration of Cooperation” between OPEC and non-OPEC members was a milestone for oil industry. Actually, production decision making can be distinguished into before and after that. Beccue et al. (2018) attempt to estimate the probability of a negative supply shock and its magnitude. According to them world production is divided into five regions, Saudi Arabia, other Persian Gulf states, African, Latin American and Russian/Caspian states. The probability of a supply shock has increased since 1996, while the risk profile of 2005 keeps constant since then. In addition, low prices add to the possibility of an oil disruption. They calculate that the probability of a supply shock of 2MMbbl/day or over lasting at least two months is 80% between 2016 and 2025. Pierru et al. (2018) consider OPEC as the market stabilizing force. Its spare capacity, under their model, can offset potential price disruptions. They conclude that OPEC’s strength to stabilize the market is dependable on short-run demand and supply elasticities. Even more impressively, OPEC’s ability to offset price disruptions is capable enough to reduce market’s volatility by half. Their research studies the oil market until October 2014 leaving the lowest levels of 2016 out. The central role of OPEC in the supply chain is recognized by Reza (1984) and Wood et al. (2016). Further, Dees et al. (2007) construct a model of the global oil market including demand, inventories and potential OPEC behaviors. Chevillon and Riffart (2009) find two cointegrating relations with oil prices. It is OPEC’s behavior controlling pricing with production quotas (the first one), while the length of OECD inventories future demand coverage is the second. Cologni and Manera (2014) propose a cointegration between oil production levels and demand for many producing countries. Further, they conclude that demand levels strongly influence production in both OPEC (Algeria, Iran, Kuwait, Saudi Arabia and Venezuela) and non-OPEC members (Mexico, Norway, Russia and the US) countries. The reason is that economic growth increases consumption and

producers follow suit to maximize their revenues. This is the condition if there is spare production capacity and production is elastic. Instead, Angola, Brazil and Canada have production levels unaffected by global demand. Moreover, high demand increased prices but the production elasticity of many OPEC countries is zero. Saudi Arabia with its ample spare capacity sharply increases production to maximize revenues during periods of high prices. Further, during periods of extreme high prices, Saudi Arabia acts as “swing producer” aligning OPEC actions to alleviate the pressure. Norway and Mexico to reduce their revenues’ volatility adjust their production negatively to price levels due to their smaller reserves. The general conclusion is that Saudi Arabia and Kuwait act as “swing producers” with their ample spare capacity to accommodate demand. Last OPEC and non-OPEC countries do not produce competitively. This why the production elasticities are not negative and significant to prices with Mexico and Norway as the only exemptions. Kisswani (2016) suggests that OPEC does not act as a supply cartel, and that OPEC production does not cause the prices but rather the prices cause OPEC production. Loutia et al. (2016) suggest that OPEC’s decision effect is not constant and its influence is determined by production decisions and oil prices. The least influence is when oil prices are high and unconventional production is viable. Kaufmann (2011) suggests that it is the growth in OPEC utilization, i.e. supply side, which increases prices and speculative pressures reinforce it. Increased demand for oil met with slow OPEC capacity increase caused price inflation. D’Ecclesia et al. (2014) consider both fundamental and speculation variables for oil prices. They find that OPEC utilization alters between two thresholds. OPEC countries do not change their production when prices are low because fixed costs are disproportionate to operating costs. From a certain production level and up (high threshold), high prices are required since high utilization requires increased maintenance and puts long-lived production into danger. Dagoumas et al. (2018) suggest that there is production sharing and the trade-off theory hold for Saudi Arabia. Arabia exports enough volumes to accommodate demand. However, it does not try to cover all of the demand increase and leaves space for the rest of the producers. This kind of strategy increases revenues while preserves good relations with other producers (production sharing

strategy). Further, production sharing does not leave prices to reach extreme levels putting future demand in danger. Moreover, the reluctance to curtail production during the low-price environment presents evidence for the trade-off theory. Saudi Arabia programs its production within the high production/low price or low production/high price dilemma. Furthermore, OPEC production has a stronger price deflating behavior than shale production. OPEC has an elastic coefficient (-1.32), while shale production an inelastic (-0.16). The last can be explained by the fact that OPEC is a well-established club consisted of few strong producers, while shale production is comprised by main small producers. So, the market turns its attention to OPEC whose signals define the market. This is not possible due to the dispersed nature of the US production. Okullo and Reynes (2016) find that OPEC is not a perfect cartel, and that smaller countries are allocated with higher quotas as to be bribed. Further, OPEC's heterogeneity and non-OPEC fringe cause incentives of non-collusion. However, OPEC's supply strategy is found to be more restrictive than the Cournot-Nash oligopoly equilibrium. Behar and Ritz (2017) suggest that OPEC should accommodate the growing US shale production and then follow a market-sharing strategy.

Bataa et al. (2016) also date the structural and volatility breaks in the fundamental variables. For the supply, they detect a structural break around December 1980 with 90% probability to be between October 1980 and February 1981. Volatility experiences two breaks, one in 1990, and one in 2004. These volatility breaks signal decreasing volatilities for production shocks. Oil prices respond less abruptly to negative supply shocks. The relation becomes inelastic (-0.42), when it was elastic (-1.81) until mid-1990s. Until 1980, production loss was temporary and extinct in two years, when it was caused by a negative supply shock. Since 1980, production losses its temporary character becoming permanent. Supply shock effects alter throughout the period. Prices sharply respond between 1988 and 1994, a period close to the near OPEC collapse. The influence becomes less intense a few months later. The last might be explained by the ample spare capacity which producers held at the time. The effect on oil prices turns into permanent since 1994. Variance decomposition suggests that supply is held responsible only for 2% of

economic activity's variance. Supply shocks explain 50% of oil price variance until 1981. Demand shocks also play a crucial role since they explain 40% of oil price variation. Both variance decomposition results are for the two-year horizon. For shorter horizons like the six-month, supply can explain 70% of oil price variation for the first half of the 1980s. During the second half of the 1980s, demand shocks take up the significant role since they explain over 80% of the oil price variation in the six-month, two-year and five-year horizons. The near collapse of OPEC could be held accountable. In 1986, there was low demand and high supply creating glut. However, supply shocks recapture their prominent role in 1988 and remain significant until 1990. One good reason of explanation is the pre-Iraqi invasion period. Demand becomes the major oil price determinant since 1990.

Drachal (2016) proposes the steady role of production for the whole period. Only in 2009, production increased its importance but soon afterwards returned to its precedent importance. The US oil imports increased their importance before mid-2000s. Caldara et al. (2016) insist that supply enjoys an increased role on oil prices. The supply elasticity is 0.021, under different methodologies can reach values between 0.054 and 0.081. The influence remains strong even if more extended supply disturbances are added. But not all producers respond in the same way. Saudi Arabia, OPEC members excluding Saudi Arabia, and non-OPEC members have supply elasticities of 0.212, 0.191 and 0.004 respectively. OPEC maintains the amplest spare capacity which stabilizes extreme oil fluctuations. Oil production increases 0.6% from an oil demand shock. Oil production mainly reacts to supply and demand shocks. Oil production volatility is 36% explained by demand shocks and 43% by supply shocks. Instead, Liu et al. (2016) suggest that supply shocks only have transient influence as their effect lasts for only one month. This is explained by the steady world oil production. There were not significantly negative oil supply shocks even if there were massive strikes in Venezuela in 2002-2003, or when the Second Gulf War started in 2003. The absence of new investments between 2005 and 2008 kept production constant. Supply shocks do not have constant effects on oil prices, and these effects are dependable on the time horizon. Oil supply shocks explain between 0.22% and 20.45% of oil prices' variance. A combination of low demand and high

production explains the since 2014 oil price decline. Byrne et al. (2018) suggest that oil supply shocks had less influence on real oil prices in 1990s and 2000s than in the past. The lesser influence becomes even weaker as shale oil adds more quantities. Su et al. (2018) insert the implied volatility index (NVIX) in conjunction with the fundamentals. Supply shocks influence oil prices until 2002. Since then their influence becomes negligible. Supply shocks greatly influence the implied volatility in 2008 and 2009. The NVIX index is positively influenced by supply shocks. In addition, in 2002 and between 2007 and 2012, supply shocks drive the NVIX's course. Prest (2018) makes the assumption that if oil glut influenced oil prices then oversupply and oil prices should have been negatively correlated. His initial results suggest that crude prices are exogenous to drilling activity and US production. This implies that the US oversupply did not decrease the oil prices between 2014 and 2016. When he tests the hypothesis with regressions, he finds that supply variables like those of US oil production and rig count suggest that the shale revolution preceded the oil price collapse, and that the US production decreased during the low-price environment. However, Kim (2018) disagrees with Prest (2018) and proposes that shale supply and definitely not OPEC supply was behind the oil price decrease. Further, under his results, real and speculative demand were among the oil price determinants.

Bataa et al. (2016) find that demand influences oil production. In detail, demand shocks declined oil production until 1980. Variance decomposition reveals that demand can explain oil price's variation from 0.2% in the 1980s to 20% between 2004 and 2008. Espinasa et al. (2017) find Saudi Arabia's production extremely sensitive to oil price fluctuations in all horizons but especially in the six-month horizon. Production variation is 84% explained by oil price fluctuation, and 15% by drilling. This kind of production profile can be explained by the vast reserves the country holds. Further, almost all of them are operated by the NOC Saudi Aramco. Saudi Arabia enjoys ample spare capacity. This why the Saudi side can alter its production quite easily. Drilling activity is included in medium to long perspective and it is not that sensitive to oil price fluctuations. The US production, on the contrary, has a much different behavior. Demand can explain 53% of production's

variation while drilling activity can explain 36% in the first six months. For longer horizons, drilling activity can explain 62% of production increases when demand can be accountable only for 31%. Global production is 47% influenced by the prices' course, while 23% by drilling activity. When the horizon becomes 1 year, then global production is 72% explained by demand, while 27% is explained price changes. The drilling activity is statistically insignificant. His final suggestion is that the oil price course is dependable on fundamentals and not on speculation.

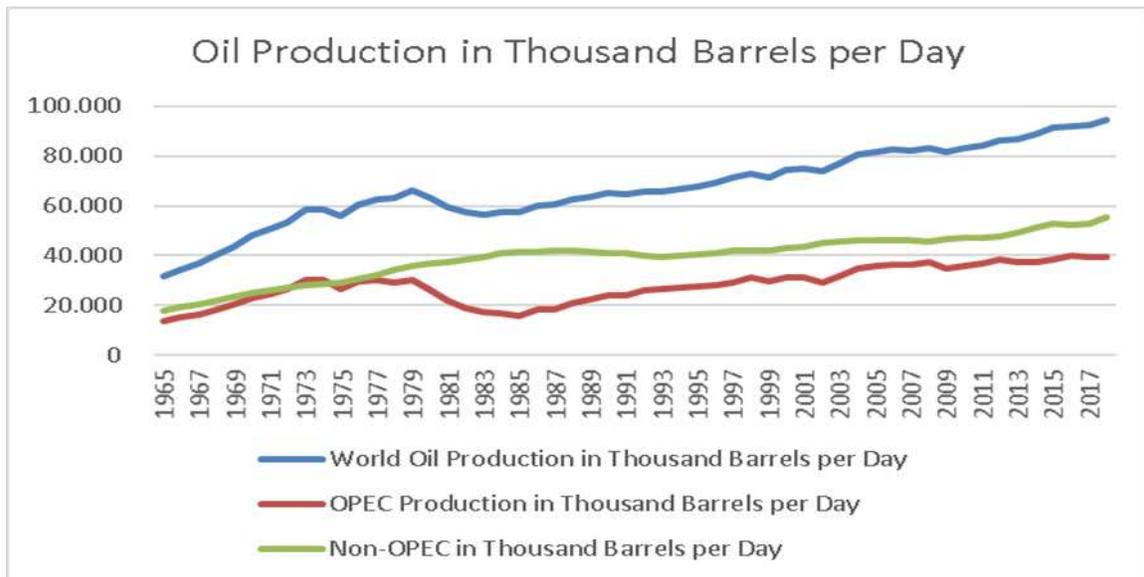


Figure 2-3 Oil Production in Thousand Barrels per Day (source: BP Statistical Review of World Energy 2019)

### 2.1.3 Inventories

Inventories play a crucial role as volatility buffers. Their role is lately highlighted as the US glut is concentrated there. For many years, inventories were treated as “speculative” i.e. a demand increase would increase prices. Many suggest that this reversed since the shale revolution. Oil is storable and can restrain price increases. But, if the exporting infrastructure improves, then inventories might decrease making the market tighter.

Drachal (2016) reject the hypothesis that oil inventories are important only lately since he finds that they were also important in 1991. Specifically, their effect is heavier than that between 2005 and 2010. Bataa’s et al. (2016) find that speculative demand is

not accountable for the oil price increase between 2003 and 2008, since even if they remove the inventories and emerging economies components from demand, demand's influence remains constant. There is a volatility break in 1998. Perifanis and Dagoumas (2019) suggest that a 1% increase in inventories would increase demand by 0.45%. The relationship is inelastic. Nikitopoulos et al. (2017) examines storage theory with the spread between futures and spot oil prices. When the spread is positive, then the market is in contango. When it is negative, then it is in backwardation. They conclude that there is bidirectional causality between the spread and the US or OECD inventories (storage theory is confirmed). Further, consumption shocks are only transmitted through inventories to futures spread. The inventories either US or OECD cause both positive and negative spreads. Negative spreads cause US and OECD inventories, when the positive spreads have less influence on OECD storages and no influence at all on US inventories. The aforementioned do not verify the storage theory under which traders buy at low spot prices and sell at higher futures prices. They find that infrastructure bottlenecks and low demand may explain that positive spreads do not cause any increase in inventories. When consumption and inventories are studied in continuous models then there is no causal relationship. When the spreads are divided into positive and negative ones, then OECD consumption causes negative spreads. Negative oil price spreads are preceded by OECD consumption shocks in backwardation environment. Positive spreads are caused by lagged US petroleum demand. The US demand shocks have both negative and positive influence over positive spreads. US inventories influence historical volatility. The last becomes more important since most traders turn their attention to the US glut. Oil price spreads are in close relationship with lagged implied volatility. Lagged volatility forecasts oil spreads and their forecasting ability is best at the twelve-month horizon. This can be explained by the shale oil revolution which decreases spot prices but has almost zero influence on futures oil prices. Scheitrum et al. (2018) verify the storage theory for oil. They study this by examining the Brent-WTI spread. The spread has a structural break in January 2011. This can be attributed to the shock revolution in conjunction with the oil exports ban in the US and several European supply disruptions. Storage bottlenecks in the

US drove the WTI prices even lower. But this can not be continued in the future since the oil export ban was lifted in 2015 and new infrastructure was added in the pipeline. Finally, they conclude that since WTI is considered as mainly a US blend, then Brent will continue to be the world benchmark. Chevillon and Riffart (2009) suggest the inventories' tightening in conjunction with demand as one of the cointegrating equations when oil prices become fundamentally determined.

Guntner (2014) propose the difference between producers' reaction and flow demand shocks, when they do not react. Countries like Saudi Arabia and Canada instantly react to speculative demand shocks when the rest remain reluctant. However, in the long run OPEC balances the market with production cuts. Countries not belonging to OPEC react differently. Egypt augments production during the first years after a shock, when the US, Norway and Canada keep their production constant. The UK, Mexico, and Russia boost their production between the first and second year after a speculative demand shock. The reaction reverses when the demand shock stems from inventories. In contrast, Dagoumas et al. (2018) propose that OECD inventories influence Saudi production only the short-run. In the long-run Saudis keep their production strategy unchanged in order to make storage keeping cost ineffective and out of the money.

Last, storage keeping can be instrumentally used for trading purposes by oil companies. Diaz-Rainey et al. (2017) suggest that until 2000 the Index of Scaled Physical Inventories (ISPI) had negative growth since companies tried to be more cost effective. Instead, ISPI started to have a positive growth since inventories were used as a speculative instrument from 2001 and onwards. In addition, ISPI standard deviation increased since 2000 revealing the heterogeneity of storages. BP, Royal Dutch Shell, Statoil, and Total used their inventories for speculative purposes, as their inventories had structural positive breaks in the speculative period. Last, only Royal Dutch Shell and Total used inventories to improve their financial condition.

#### **2.1.4 Speculation**

Not all market participants trading oil are physical buyers or suppliers. Among them there are also hedgers and speculators. Speculation has come into spotlight due to the financialization of the market.

According to Drachal (2016) financial markets do influence oil prices and their role gained importance between 1995 and 2000. It was only in 2009 that financial markets lost their significance. This was because investors turned to safer assets like the Treasury bills. Treasury bills lost part of their significance but they do enjoy a more central role than that before the crisis. Under Ji and Fan (2016) financial markets had a cointegrating course and confirm the theory of “one great pool” for oil. They divided the global market into three regions namely the US, the African, and that of Middle East. The US market maintained its core status while Africa improved its market status due to political and production stability. Middle East did not enjoy a lot of stability to follow suit. China remains dependent on the Middle East market, while it continues to be the price taker. Many of their results can be explained by the market integration, trading liquidity and information transmission. Consumers and producers face higher systematic risk due to the increased correlation between regional financial markets. According to Fattouh (2009) blend spreads are stationary irrespectively of the blend quality implying the market’s integration. This does not imply that price information is transmitted the same way between the oil blends. Price spreads adjust non-linearly as there are certain threshold bandwidths, where they have different behavior. Market decoupling is still present when arbitrage costs are high for low spreads. Active futures markets minimize price spreads and accelerate adjustments.

Many suspect that futures contracts are the speculative instrument for traders. Since they are not physically settled, nor require high cash outflow, then price speculation should be initiated from there. Instead, if oil is fundamentally priced, then spot prices should be the innovators. Kaufmann and Ullman (2009) find one spot and one futures price as innovators. The spot price is for Dubai-Fateh blend, while the futures contract is for the WTI blend. Emerging economies’ demand might explain the result for the spot

price, while speculation might explain for the WTI blend. Emerging economies used Dubai-Fateh spot as a benchmark for their contracts. WTI is traded specifically in advanced commodity markets. The price spread between the two blends drifts apart in August/September 2004 when it increases from 0-5\$/bbl. to 5-10\$/bbl. The extended spread might be attributed to speculation. Both speculation and fundamentals drove the prices up until 2008. Speculation had an additive role in the oil price increase. Under D' Ecclesia et al. (2014), there is a negative relationship between oil price and risk. They verify the leverage effect since most traders are not physical hedgers. Real oil prices are increased by open interests in futures, something that can be called "hedging pressure". The increased "hedging pressure" might drive to market failures. Büyükşahin and Robe (2014a&b) propose that oil prices are also determined by fund activity while hedge funds have lower predictive ability during stress periods. They further add that hedge fund activity, macroeconomic fundamentals and the Treasury-Eurodollar (TED) spread (a proxy for financial market stress) are capable of predicting long-run fluctuations in commodity-equity correlations.

Kilian and Murphy (2010) suggest that speculative demand had a significant impact in 1979, 1986, and 1999, and not from 2003 to 2008 when the oil price surge was caused by demand. They find that further regulation would not add to the market since if demand grows then oil price will follow. Several episodes of speculation driven prices are suggested by Kilian and Lee (2014). Episodes like the Iranian Revolution in 1979, the Invasion of Kuwait in 1990, the Iraqi War in 2003, the Libyan crisis in 2011 and the Iranian crisis in 2012 were increasing ones. On the contrary, the near OPEC collapse in 1986 and the financial crisis of 2008/09 were decreasing episodes. Speculation can not increase or decrease the price unless inventory demand is changed. Financialization alone did not drive the prices. It only worked as an additive component. The index funds investing in the commodity markets turned their attention to the fundamentals. Supply and demand shifts had as an aftermath the market trends. Demand is the main driver for the real oil price increase between 2003 and 2008. Speculation had a minor contributory role (5-14\$/bbl.) between March 2008 and July 2008. Increased demand stemmed from the

emerging economies. Since 2010, increased demand played its inflationary role. During the Libyan revolution speculative demand increased prices between 3 and 13\$/bbl., and this was temporary. Asian inventories do not increase prices. Further, supply is not a key factor for real oil prices. The 29-dollar decrease can be divided into demand's shocks contribution (20 to 23\$/bbl. decrease) and supply's contribution, -2 to 3\$/bbl. from the 2008 highest point. Since oil is fundamentally driven, increasing market regulation would not provide any benefits. Alquist and Gervais (2011) propose that speculation had a modest role in the price surge of 2003 to 2008. Cifarelli and Paladino (2009) suggest, on the contrary, that speculation drives the oil market and that the regulatory bodies should monitor speculative activities. Sornette et al. (2009) further agree with the existence of speculative pressures between 2006 and 2008. Chevillon and Riffart (2009) estimate the risk premium for uncertainty as half of the 2000 to 2005 price increase. Investor Fear Gauge (IFG) used by Gong and Lin (2018) can be a good traders' irrational behavior proxy. IFG has a significantly important forecasting ability of price returns volatility. Perifanis and Dagoumas (2019) suggest that speculation is a main price determinant as it has an elastic relationship with prices (1.28).

Espinasa et al. (2017) propose that oil price volatility is heavily influenced by itself in the short-term. They go even further suggesting that speculation is not responsible for the 1998-2008 surge. Speculation has short-lived cycles which disappear in a two-year horizon, and they are serially correlated. Speculative shocks have seen their volatility to increase as their variance has been the double in the decade from 1998 to 2008. The aforementioned do not hold speculation free of the hypothesis that is not accountable of the oil price formulation. Under Liu et al. (2016) speculation contributes only less than 10% to price variation. They go on further to cast the Chinese demand as the main determinant behind oil price formulation. Avdulaj and Barunic et al. (2015) suggest that oil is not a hedging instrument against stock markets.

### **2.1.5 Investments**

Investments are appraised by their net cash flows. Future prices have to be somehow forecasted. This is extremely difficult as there is volatility in the market. Negative appraisals damage future supply, while excess investments might cause future oversupply increasing volatility. Further, investments to final production have long lead times. Finally, the capital structure and the ownership play a significant role in the investment appraisal, since oil supply is consisted by both National Oil Companies and International Oil Companies.

Osmundsen et al. (2010) research drilling productivity (meters per day) to draw conclusions on oil investment. Water depth has a strong negative effect on drilling activity. Technological difficulties are also in conjunction with water depth negative factors for drilling activity. High temperatures have a negative influence on drilling productivity. This is why high temperatures require advanced equipment, which increases well costs. Oil prices deflate drilling productivity as personnel and equipment become scarcer. Technological advancements decrease the negative influence of the aforementioned factors. Wildcat drills are faster than the Appraisal drills. North Sea is between Barents Sea (lowest) and Norwegian Sea (highest) when it comes to productivity. Wells that end with low gas and oil results (dry wells) are faster than discovery wells. However, drilling facility experience is equally important for drilling productivity. Apergis et al. (2016) suggest that the rig count in the US has a positive influence on total production in the long-term. The rig coefficient is between 0.905 and 3.893 dependable on the region. There is a bidirectional causality between rig count and production in Bakken, Eagle Ford, and Haynesville region, while there is causality from rig count to total production in Marcellus, Niobrara and Permian. For short-term horizons, there is a bidirectional causality between rig count and production in Eagle Ford and Haynesville plays when there is only causality from rig count to production in Marcellus, Permian and Niobrara. There is causality from production to rig count in Bakken. Berntsen et al. (2018) find that the most important factors for investments in the Norwegian Self are the oil prices, the geological variables and the size of the reserves. The reserve size also

determines the duration of the investment decisions for oil companies. Oil price volatility leaves uninfluenced the previously mentioned.

Since the perspective for investments is profit maximizing, commodity prices might be the most significant determinant. Chen and Lin (2017) find that futures prices influence drilling activity more than spot prices. The same result holds even if rig productivity is controlled. What is impressive is that in regions where National Oil Companies operate, commodity prices do not influence investment decisions. This is especially prevalent in regions like the Middle East and OPEC members. When the National Oil Companies cooperate with International Oil Companies like in Latin America, then commodity prices do shape investment decisions. Espinasa et al. (2017) find that the price course leaves Saudi Arabia's drilling activity free of any influence in the short-term. Oil price becomes significant only two years later and is responsible only for 10% of the drilling activity. It seems that the Saudi drilling activity is self-explained and neither fundamentals like supply and demand, nor crude oil prices are determinants in the short and medium-run. The US drilling activity is heavily influenced by the crude prices. Price signals explain 82% of the drilling activity's variation in the first six months. A year later, price signals account for 86% of the drilling variation. This is a huge difference between the two producers. For Saudi Arabia, all activities are held by the state-owned Saudi Aramco, while in the US, drilling activities are mainly conducted by small private companies. For the rest of the world, price signals account for 66% of the drilling activity's variation in the first month. However, the response is even more elastic in the full year horizon. Drilling variation is 86% influenced by the price signals. Khalifa et al. (2017) use linear and non-linear analysis to find that a positive influence of oil returns on rig count exists. However, this effect comes with a lag. Further, the relationship between oil returns and the rig count becomes steadier and stronger since 2005 under the linear analysis. The quantile regression reveals the lag between the two factors. The influence of oil returns is heavier when low prices prevail.

### **2.1.6 Uncertainty**

Highly liquid markets might be affected by increased uncertainty. Uncertainty might stem from political or economic factors and became highly noticed after the 2008 crisis. Wei et al. (2017) study uncertainty and its ability to explain price volatility. They find that two aggregate and six country-specific Economic Policy Uncertainty (EPU) positively influence long-run oil price volatility. The Japanese and US EPU indices have the greatest influence over oil prices when the British, Chinese and Russian EPUs have less effect. The last implies that the countries should turn their attention on fundamentals and less on their uncertainty. Under their results, EPUs become the main determinants of oil prices. Wang and Sun (2017) suggest that EPUs have a moderate influence over prices. The moderate effect should be alternatively explained by the fact that uncertainty is also included in the economic activity coefficient. Wars are also significant but they do cause supply disruptions, something incorporated in the supply coefficient. Le Coleman (2012) suggests it is the number of US troops and the frequency of terrorist attacks in the Middle East significant apart from the speculative activity, OPEC market share, OECD import dependence, and bond yields. Perifanis and Dagoumas (2019) propose that terrorist attacks do not have any influence on crude oil prices. Under Bekiros et al. (2015), EPUs can be a good instrument for price forecast, while Time-Varying VAR are preferable to standard and Bayesian VAR methodologies. Kim and Jung (2018) study the dependence structure among oil prices, exchange rates and the US interest rates.

Su et al. (2018) suggest that spot prices influence the implied volatility (NVIX) between 2000 and 2004. Further, the Brent and WTI spot prices follow different courses from 2011 to 2014, while the WTI prices have heavier effect on NVIX. The last might be attributed to the shale revolution and that the NVIX index is an index published in the Wall Street Journal. Further, oil prices influence uncertainty since 2004. The WTI aggregate demand shocks had stronger connection with implied volatility than Brent. NVIX has significant influence over specific demand shocks between 2007 and 2011. This is why the financialization of the market was already extended and deep. The NVIX holds a negative

influence on specific demand. For long-term periods, between 2004 and 2008, NVIX has less influence on oil specific demand shocks.

Corporate executives do not hold control over the full supply chain. This lesser control is depicted in their mobility to determine real oil price in the early 1990s (Iraq-Kuwait war). Byrne et al. (2018) find that the Business Confidence Index (BCI) has a weak influence in their Time-Varying Parameter model. Instead, corporate leaders have a clear view and influence over demand. This is why their expectations influence oil prices especially in periods of high demand like the one between 2002 and 2008. The BCI index holds a firm influence over price after the financial crisis of 2008. The effect ends in 2014 when the shale revolution took place making business leaders' expectations less influential.

**Table 2.1** Uncertainty categories in the crude oil price

<i>Economic</i>	<i>Policy/regulatory</i>
✓ Global GDP growth	✓ Geopolitics
✓ Carbon prices evolution	✓ Terrorism in producing countries
✓ Competitive fuel prices evolution	✓ Taxation regime
✓ Evolution of costs on renewables, energy storage and electric vehicles	✓ National energy and industrial policies
✓ Demand and consumption pattern evolution	✓ Energy security
	✓ Environmental regulation
<i>Technical/operational</i>	<i>Social/environmental</i>
✓ New discoveries and new infrastructure	✓ International climate agreements
✓ Shale oil developments	✓ Decarbonization and renewable energy targets
✓ Ageing infrastructure, outages	✓ Social acceptance, behavioral shift
✓ Increasing interdependence with other sectors (gas, maritime, renewables)	✓ Shale oil environmental concerns
✓ Integration of competitive technologies (LNG, renewables, storage, electric vehicles)	✓ Public health and other externalities
	✓ Climate change, extreme climatic events
	✓ Natural disasters

## **2.2 Econometrics analysis**

### **2.2.1 Oil price determinants data**

We attempt to discover the main drivers of oil prices and their influence. We use econometrics to derive our results. We consider that the crude oil price is determined by market fundamentals and political factors. We use the WTI real crude oil price from MacroTrends to account for inflation. We use the interpolated world demand by the Kilian Index in thousand barrels per day by Knoema database. Kilian Index is a proxy for monthly economic activity and it is derived by ocean freight rates. The supply is included by EIA's

OPEC crude oil production in thousand barrels per day and total US shale production which is derived by the sum of each region's consumption. Further, in order to include stocks, we calculate the days ahead of OECD consumption supported by OECD inventories. We divide OECD stocks by OECD consumption per day. We also include the S&P GSCI Crude Oil index to account for speculative trading or "paper oil" as Buyuksahin and Robe (2014a & b) account too. We add the Chicago Board Options Exchange (CBOE) volatility index or VIX index which incorporates market and political instability. We add the number of terrorist attacks in the Middle East North Africa (MENA) region supplied by the Global Terrorism Database (GTD) by the US National Consortium for the Study of Terrorism and Response to Terrorism (START). However, the last two variables did not have any significant influence over crude oil prices. Table 2.2 provides the description of the variables.

**Table 2.2** Variable description and data sources

Variables	Description	Data source
WCP	Monthly crude oil prices in real US dollars	MacroTrends data
WCONS	World oil consumption interpolated by Kilian global real economic activity index	Knoema database and <a href="http://www-personal.umich.edu/~lkilian/reaupdate.txt">http://www-personal.umich.edu/~lkilian/reaupdate.txt</a>
OPECPRO	OPEC production in thousand barrels per day	EIA
SHALE	Shale production in thousand barrels per day by the regions Anadarko, Appalachia, Bakken, Eagle, Haynesville, Niobrara and Permian.	EIA
OECD	Days the OECD oil stocks can cover the OECD consumption	EIA
SPGSC	S&P GSCI Crude Oil Index	Standard and Poor's
NINC	Numbers of terrorist attacks	Global Terrorism Database <a href="https://start.umd.edu/gtd/">https://start.umd.edu/gtd/</a>

Our studied period is between 2008 and 2017, and our data are monthly. Our data are transformed into natural logarithms to derive the respective elasticities. We test for stationarity with the Augmented Dickey Fuller (1984) test and the Phillips-Perron (1988) test. The result is that our data are not stationary at levels while their first differences are stationary I(1).

**Table 2.3** Test for unit roots. Period 2008-2017

Level	ADF	Phillips-Perron	First difference	ADF	Phillips-Perron
WCP	-0.57 <sup>a</sup>	-0.65 <sup>a</sup>	$\Delta(\text{WCP})$	-5.68	-7.97
WCONS	1.26 <sup>a</sup>	4.39 <sup>a</sup>	$\Delta(\text{WCONS})$	-1.88 <sup>b</sup>	-1.95 <sup>c</sup>
OPECPRO	0.47 <sup>a</sup>	0.59 <sup>a</sup>	$\Delta(\text{OPECPRO})$	-6.96	-9.23
SHALE	4.50 <sup>a</sup>	3.91 <sup>a</sup>	$\Delta(\text{SHALE})$	-3.81	-7.31
OECD	0.65 <sup>a</sup>	0.65 <sup>a</sup>	$\Delta(\text{OECD})$	-12.02	-20.72
SPGSCL	-0.49 <sup>a</sup>	-0.44 <sup>a</sup>	$\Delta(\text{SPGSCL})$	-5.57	-7.40
VIX	-0.75 <sup>a</sup>	-0.83 <sup>a</sup>	$\Delta(\text{VIX})$	-14.81	-17.16
NINC	0.16 <sup>a</sup>	0.47 <sup>a</sup>	$\Delta(\text{NINC})$	-16.63	-18.95

Notes: The null hypothesis of the ADF and Phillips-Perron test is that a unit root exists. The first difference of the series is indicated by  $\Delta$ .

<sup>a</sup> Indicates acceptance of the null hypothesis at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates acceptance of the null hypothesis at 1% and 5%.

<sup>c</sup> Indicates acceptance of the null hypothesis at 1%.

Our regression models are the following:

$$WCP_t = WCONS_t + OPECPRO_t + SHALE_t + OECD_t + SPGSCL_t + NINC_t \quad (3.1)$$

$$WCP_t = WCONS_t + OPECPRO_t + SHALE_t + OECD_t + SPGSCL_t + VIX_t \quad (3.2)$$

$$WCP_t = WCONS_t + OPECPRO_t + SHALE_t + OECD_t + SPGSCL_t \quad (3.3)$$

We do not include a constant term (intercept) in our models as we take advantage of the Green's (2003) suggestion which states "This does not suggest that there is a potential problem in models without constant terms". Further, we use ARMA methodology which makes our models dynamic adding to our decision.

First, we test our variables for cointegration in order to avoid spurious models. We test for cointegration with the Johansen test with several specifications:

None data trend

No intercept no trend.

With intercept no trend.

Linear data trend

With intercept no trend.

With intercept and trend.

Quadratic data trend

With intercept and trend.

We do so to test whether a long-run relationship exists for our models. All of our cointegration tests suggest that a long-run relationship exists. We present our results for linear deterministic trend in Tables 3.4 to 3.6.

**Table 2.4** Cointegration test for variables of Model 3.1

Johansen's maximum likelihood method test for cointegration relationship

Linear deterministic trend (Lag intervals 1 to 3) Model 3.1

Null Hypothesis, $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum Eigen values			
$r=0$	$r=1$	77.03	46.23
$r\leq 1$	$r=2$	31.07	40.07
Trace statistics			
$r=0$	$r\geq 1$	173.80	125.61
$r\leq 1$	$r\geq 2$	96.77	95.75
$r\leq 2$	$r\geq 3$	65.69	69.81

Maximum Eigen suggest 1 and Trace value indicate 2 CE at 0.05 level

**Table 2.5** Cointegration test for variables of Model 3.2

Johansen's maximum likelihood method test for cointegration relationship

Linear deterministic trend (Lag intervals 1 to 3) Model 3.2

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	61.18	46.23
$r\leq 1$	$r=2$	42.03	40.07
$r\leq 2$	$r=3$	21.27	33.87
Trace statistics			
$r=0$	$r\geq 1$	168.39	125.61
$r\leq 1$	$r\geq 2$	106.21	95.75
$r\leq 2$	$r\geq 3$	64.18	69.81

Maximum Eigen and Trace value indicate 2 CE at 0.05 level

**Table 2.6** Cointegration test for variables of Model 3.3

Johansen's maximum likelihood method test for cointegration relationship

Linear deterministic trend (Lag intervals 1 to 3) Model 3.3

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	61.16	40.07
$r\leq 1$	$r=2$	27.32	33.87
Trace statistics			
$r=0$	$r\geq 1$	128.69	95.75
$r\leq 1$	$r\geq 2$	67.53	69.81

Maximum Eigen and Trace value indicate 1 CE at 0.05 level

## 2.3 Results

We attempt to investigate the major oil price determinants by examining different combinations among our variables. Our regression results are presented in Tables 3.7, 3.8, and 3.9. We use Autoregression (AR) and Moving Average (MA) methodology to avoid serial correlation. Box et al. (2013) suggest that the normal conditional likelihood function might be maximized by minimizing the sum of squares of the innovations under the condition of pre-sample values for the AR and MA errors. In order to have a good fitting and also avoid heteroscedasticity, we apply the Huber White methodology (Huber 1967 and White 1980).

**Table 2.7** Estimation results for Model 3.1

Variable	Coefficients	Std. Error	Probability	Probability F	Probability Chi sq.
WCONS	1.31	0.55	0.0194 <sup>b</sup>		
OPECPRO	-1.30	0.57	0.0248 <sup>b</sup>		
SHALE	-0.19	0.06	0.0038 <sup>a</sup>		
OECD	-0.35	0.27	0.2021		
SPGSCL	1.24	0.38	0.0017 <sup>a</sup>		
NINC	0.02	0.03	0.4689		
P <sub>t-1</sub>	-0.32	0.37	0.3892		
MA	0.19	0.09	0.0310 <sup>b</sup>		
LM test				0.0889	0.0722
Breusch- Pagan- Godfrey				0.1246	0.1256
Adj R <sup>2</sup>	0.9322				
Durbin Watson	1.9204				

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 2.8** Estimation results for Model 3.2

Variable	Coefficients	Std. Error	Probability	Probability F	Probability Chi sq.
WCONS	1.40	0.53	0.0108 <sup>b</sup>		
OPECPRO	-1.25	0.54	0.0230 <sup>b</sup>		
SHALE	-0.19	0.05	0.0003 <sup>a</sup>		
OECD	-0.54	0.23	0.0220 <sup>b</sup>		
SPGSCL	1.15	0.39	0.0045 <sup>a</sup>		
VIX	-0.06	0.04	0.1518		
P <sub>t-1</sub>	-0.25	0.38	0.5072		
MA	0.17	0.08	0.0541 <sup>c</sup>		
LM test				0.1030	0.0861
Breusch-Pagan-Godfrey				0.1582	0.1575
Adj R <sup>2</sup>	0.9396				
Durbin Watson	1.9355				

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 2.9** Estimation results for Model 3.3

Variable	Coefficients	Std. Error	Probability	Probability F	Probability Chi sq.
WCONS	1.35	0.54	0.0134 <sup>b</sup>		
OPECPRO	-1.32	0.57	0.0217 <sup>b</sup>		
SHALE	-0.16	0.04	0.0005 <sup>a</sup>		
OECD	-0.45	0.23	0.0547 <sup>c</sup>		
SPGSCL	1.28	0.40	0.0018 <sup>a</sup>		
P <sub>t-1</sub>	-0.35	0.38	0.3586		
MA	0.16	0.09	0.0766 <sup>c</sup>		
LM test				0.0778	0.0661
Breusch-Pagan-Godfrey				0.1155	0.1161
Adj R <sup>2</sup>	0.9391				
Durbin Watson	1.8771				

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

Our results by Models (3.1) and (3.2) suggest that political uncertainty determinants like the number of terrorist attacks incidents and market uncertainty determinants like the VIX index are statistically insignificant. The most robust model is Model (3.3) since it gives statistically significant results and passes residual tests for serial correlation and heteroscedasticity. We present Model (3.3) with the respective standard errors in parentheses.

$$WCp_t = 1.35 WCONS_t - 1.32 OPECPRO_t - 0.16 SHALE_t - 0.45 OECD_t + 1.28 SPGSCL_t$$

$$(0.54) \quad (0.57) \quad (0.04) \quad (0.23) \quad (0.40)$$

The results verify economic theory as consumption positively influences prices. Our coefficients are also the respective elasticities. Crude prices will increase 1.35% if consumption is increased by 1%. The elastic relationship suggests the low substitution between the energy sources. Further, it makes apparent the energy intensive world we live in. The global oil demand increase mainly comes from Asia and it is expected to continue. Asian low income classes will emerge to middle and higher classes, and new consumers with higher energy demand will appear. The last is more apparent as half of the growth in global economy will come from China and India<sup>11</sup>.

OPEC crude oil supply negatively influences oil prices as it should be. More volumes mean lower prices. The relationship is again elastic (-1.32). The elastic relationship highlights the ability of OPEC to smooth oil prices easily. Most of its members have large reserves while upstream costs are low. This makes it easy for them to add volumes in the short-term. This kind of ability was apparent before the 170<sup>th</sup> Extraordinary Meeting. OPEC members tried to keep their market share constant and drive new private companies out of the market. This led to a sharp decrease of oil prices since there was a glut. Further, few countries like Saudi Arabia keep ample spare capacity to intervene into the market when they consider it proper. But this kind of power should not be considered as monolithic. OPEC cooperated with other non-members to stabilize the market after the 170<sup>th</sup> Extraordinary Meeting and the Declaration for Cooperation. OPEC can institutionally collaborate with other major market participants, while shale producers

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<sup>11</sup> <https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf>

should be considered as the marginal producers affected by market developments. Another determinant that could make more apparent the relationship between oil prices and OPEC would be the capacity utilization. However, these kind of data are only available in yearly basis and most of time they are not published.

Shale revolution started in late 2000s. Hydraulic and horizontal drilling or more known as fracking took mainly place in the US. This is why most of the oil glut is concentrated in the US. We summed the shale production of the most prolific US regions to account for the unconventional production. We have a second factor of the supply side. The coefficient is negative (correct sign) and lower than 1. An increase of 1% in shale production would decrease prices by only 0.16%. The contrast between the elastic influence of the OPEC and the inelastic influence of the US shale is apparent. This might be explained by the spare capacity and the low upstream costs that OPEC enjoys, while the US shale is the marginal producer. Moreover, OPEC is more of a fully and vertically integrated exporter, while the US shale is consisted of small privately own companies. The US lifted the oil exports only in 2015. Until then shale oil influenced more the WTI blend (Kilian 2016) rather than the global pricing. This is why the absence of exporting infrastructure kept the excess production as glut in the US making the Brent-WTI spread wider.

The competition between conventional and unconventional producers continued between 2014 and 2016. Oil glut was stored even in tankers since none of the producers agreed to curtail quantities strengthening the contango phenomenon. We divided the OECD stocks by the daily consumption to have the days ahead of consumption stocks can

cover. Stocks are highly monitored by traders lately. Our assumption was confirmed since the respective coefficient has the correct sign (negative). The elasticity is -0.45% meaning that a 1% increase in the days stocks can cover will deflate prices by 0.45%. The relationship is lower than 1 i.e. inelastic. Further, stocks are concentrated in the US as the shale production and increase the influence the US oil market has on oil prices. In 2016, OPEC took the initiative to balance the market and reduce production due to the oil glut. OECD stocks drove OPEC decisions.

We further add one more determinant to account for speculation in the market. We use the S&P GSCI Crude Oil index to account for the “paper oil” as it is referred in the market. This is for the reason that “paper oil” does not have to do with physical delivery i.e. it is cash settled. We do find evidence of speculation’s presence in the market since the elasticity is significant and positive (+1.28). The elastic relationship confirms that speculation is among the major oil price determinants. Speculation makes increases steeper and decreases deeper for oil prices. We agree with Les Coleman shoe also finds that speculation influences oil prices. The volatility which prevailed during the last ten years might be explained by increased speculative activities. But, increased oil price variance further attracts speculators like hedge funds which are after price fluctuations. These kind of cycles should be further studied and considered. We continued by studying volatility transmission between market indices and crude oil prices. We used the S&P GSCI crude oil index and the VIX index. However, our bivariate VAR methodology and bivariate GARCH models (DCC, Copula GARCH) did not give firm results. The last might be explained by the examined period since a shorter iteration such as that of 2007 to 2009 might give

results of volatility transmission by speculation.

To sum up our results do not agree with Kisswani (2016), Okullo and Raynes (2016) in relationship with OPEC's ability to affect oil prices over the last ten years. Our study does not focus on whether OPEC acts as a perfect cartel, but on whether its total production can influence market fundamentals. We provide evidence that OPEC's production can still affect prices and this is elastic. OPEC continues to sustain a significant production share and as a result can still influence a large part of the market. We contributed to the research by providing results for shale oil as Behar and Ritz (2017) and Khalifa et al. (2017) did. We suggest that the relationship between oil prices and shale production is inelastic i.e. shale oil has less influence than that of OPEC. We propose that shale production has taken the role of the marginal producer. Moreover, OPEC continues to enjoy a reinforced role as it has the institutional capability to collectively act with important non-OPEC producers like the Russian Federation to stabilize the market.

Moreover, OECD stocks have a significant influence on oil price formulation. Oil glut stored as inventories make the market less tight. This has a deflationary role for oil prices. This stored oil glut is fought by OPEC since 2016 and the Declaration for Cooperation. We are in agreement with Buyuksahin and Robe (2014a) who propose that hedge funds drive the oil prices. Our elasticity is elastic making apparent the heavy influence of speculative activities. However, market fundamentals continue to be the critical factors for the oil price course.

Last, we tried to use several variables and methodologies to include political and economic uncertainty. We used the VIX index as a regressor in bivariate VARs, and

bivariate GARCH modelling (DCC GARCH, Copula GARCH) but we did not have significant results. We also used University of Maryland's Study of Terrorism and Responses to Terrorism (START) for the MENA region where most of the production and reserves exist. Our results were not statistically significant. Our analysis did not include dummies as Les Coleman (2012) did. We did so because we consider that this would not be fully objective as data long monitored by well-established bodies. The last does not mean that we do not consider political events or uncertainty as important, but our effort was to quantify the influence of every determinant.

## **2.4 Conclusions**

Our chapter targets at identifying and quantifying the price drivers of crude oil prices. We include drivers from different sectors like market fundamentals, financials and political. We use variables like world crude consumption, OPEC production, the US shale oil production, days ahead of consumption which the OECD stocks can cover. In order to catch the impact of market speculation or "paper oil", we include the S&P GSCI crude oil index. To include political instability in the region of Middle East and North Africa, we use the number of terrorist attacks in oil producing countries by the University of Maryland's Study of Terrorism and Responses to Terrorism (START). Further, we use the Chicago Board Options Exchange (CBOE) Volatility Index or VIX index which engulfs market and political instability. On the contrary, we do not include dummies as political indicators since this might jeopardize the results.

We study the period between January 2008 and December 2017 when oil prices experienced high volatility. We tried several methodologies such as the bivariate VAR and GARCH methodology (DCC and Copula GARCH) and we found that the most appropriate methodology is the simple regression. We excluded the other than linear regression

methodologies since they did not give satisfactory results on volatility relationship between our variables.

Our results confirm that the market fundamentals are the main drivers explaining the recent oil prices' course during the last decade. We find that world oil consumption or demand is statistically significant. Further, the elasticity is positive and over one (+1.35). The elastic relationship may suggest the lack of substitution between energy sources, especially in the emerging economies. In addition, OPEC's production plays a price deflationary role since its elasticity is -1.32. The relationship is elastic implying that OPEC volumes have a significant role. The same deflationary role is also played by the US shale production less intensively since the elasticity is inelastic (-0.16). This might be explained by the lack of exporting infrastructure in the US. The number of days of future OECD consumption has again an inelastic relationship with oil prices (-0.45). This is important since a production buffer is created influencing oil pricing.

We incorporate variables which engulf political and economic instability in an attempt to detect whether they influence oil prices. We use the number of terrorist attacks in oil producing countries and a volatility index as VIX. However, we did not find any statistically significant influence over oil prices during the last decade. We do not use dummy variables since they might be subjective. Although they are used in other research papers, we consider that they are prompt to "biased" research since authors consider some events or facts as a priori significant. The last does not mean that we ignore the political factors. On the contrary, we tried to researched them in the best possible way. However, the used variables did not give significant results. What is also important is the influence of "paper oil" in the market which is included in our models with the S&P GSCI crude oil index. Trading contributes in the oil market volatility since the elasticity is positive, and over one (+1.28). The elastic relationship reveals that speculation is a major oil price determinant. The results confirm other research which suggest the additive role of market speculation in the commodity markets.

To further investigate volatility transmission between oil prices and market indices, we used variables like the S&P GSCI crude oil index and the VIX index. This was not possible since our bivariate VAR and GARCH models (DCC, Cupola GARCH models) did not give reliable evidence for volatility transmission. This might be altered for different periods, since the role of paper oil might have been important between 2007 and 2009 when there was a lot of volatility in the market due to the financial crisis.

From our analysis, we can suggest that oil prices are formulated mostly by market fundamentals such as demand, supply and inventories. Especially demand and supply influence oil prices. In contrast, we find no evidence indicating political effects since variables like the VIX index or the GTD indicator are not significant. The last is very important since we study a period when the Arab spring and the Islamic State occurred in many oil producing countries. Their presence was not transitory since they lasted for several years. We agree with MacAvoy (1982) who suggests that oil prices are fundamentally explained. However, we do not use dummy variables in our research which could drive to opposite results since we use widely accepted variables. Further, we confirm the findings of Kaufmann et al. (2004) for the significance of inventories and Kaufmann and Ullman (2009) over fundamentals' importance. The deflationary role of shale production may verify Loutia's et al. (2016) results as even low oil prices might bring enough profits restraining OPEC's market power. However, OPEC's production continues to preserve an important role in the oil market since it has an elastic relationship. The influence of OPEC's volumes is much heavier than that of shale production, and even if shale was revolutionary for the oil market, it might be the marginal production. The major influence of OPEC is highlighted by the fact that it refused to curtail volumes in a price declining environment to push shale out of the market. Further, prices increased when OPEC put the hand on the pump.

Since we find evidence of the fundamentally priced oil, then we do not agree with the suggestion of LesColeman (2012) who suggests that political or instability drivers play a significant role. However, the researched period is different. Speculation in our analysis also plays a significant role.

Our research might be useful for policymaking. The importance of supply in price formulation might be a significant aspect for oil producers like OPEC for their revenues and balance sheets. However, shale production is a game changer altering the market fundamentals and smoothing political influence. However, marginal production constitutes shale profits vulnerable to price changes. OPEC continues to enjoy a highly institutional role since it retains the ability to cooperate with other major producers like the Russian Federation. In the 170<sup>th</sup> (Extraordinary) Meeting of OPEC it is stated that to “to conduct a serious and constructive dialogue with non-member producing countries, with the objective to stabilize the oil market and avoid the adverse impacts in the short- and medium-term.” (OPEC 2016).

We expect that demand will continue to have a significant role since economic development will be among the main drivers. However, oil glut will continue to prevail due to oversupply by competitive producers. Even if low prices prevail then many oil dependent economies will face deficits and additional debts which may result in political instability and regime changes. Economic diversification is crucial for those producers in order to avoid dependency on oil revenues and as thus recession, deficits, and potential intense political instabilities.

Further, natural gas markets are influenced by oil price changes since some gas contracts continue to be oil benchmarked. Gas producers are seriously affected by the oil price course. This is the reason why countries or regions attempt to form liquid natural gas hubs like those in Europe and Japan-Korea. From the point gas markets will develop their own dynamics and prices are fundamentally formulated, then this condition will be irreversible to go back to oil-indexed pricing. This trend is obvious since natural gas hubs become even more liquid. Moreover, gas is even more used as an energy source and dominant suppliers like Gazprom move to hub-linked contracts. Gazprom for example has set its contract policy to be one third oil-benchmarked, one third hub benchmarked and one third hybrid (Henderson and Sharples 2018). Last, European Union’s Energy Union and target model set as an aim a liquid, dynamic, non-oil-linked gas market priced by its own dynamics.

### 3 Crude oil price effects

In our attempt to frame the nature of oil prices and the strategy which the OPEC can employ with its limitations, we consider the effects oil prices have on several aspects of economic life. In the past, crude oil had heavy influence on macroeconomic figures causing phenomena like stagflation in the 1970s. Further, it was such the challenge for macroeconomic models that a whole critique arose like the “Lucas critique” (Lucas 1976). Moreover, the two oil crises casted doubts on the validation of the Phillips curve (Alberro 1981), which connects inflation and unemployment (Phillips 1958). Crude prices also influence the balance sheets of producing countries (Dagoumas et al. 2018) and Perifanis and Dagoumas (2017). GDP has long been perceived as the most significant macroeconomic indicator for oil price changes. Additionally, one of the most difficult concerns is the calculation of demand’s price elasticity. Demand is heavily influenced by the commodity’s price and potential shocks. The financial markets are among the main followers of energy price adjustments. This is why we dedicate a section for the interdependencies between oil prices and financial markets. Commodities are also a section we dedicated since they are influenced. We separated the literature into the relationship between Natural, and renewables with oil. These sectors are competitors to oil and take part in the energy transition. This is the reason why we develop two different sections for these two energy sources. Further, we develop the subsidies and interest rates sections, since they constitute two sectors also affected by oil prices. Oil subsidies and energy taxation can form policies which include revenues raising, indirect taxation and environmental taxation. However, interest rates indicate the perceived country risk. Further, they are a cornerstone of monetary policy since they affect foreign direct investments (FDI) and consequently economic development. Oil dependence can take the form of exports (for producing countries) or imports (for consuming countries).

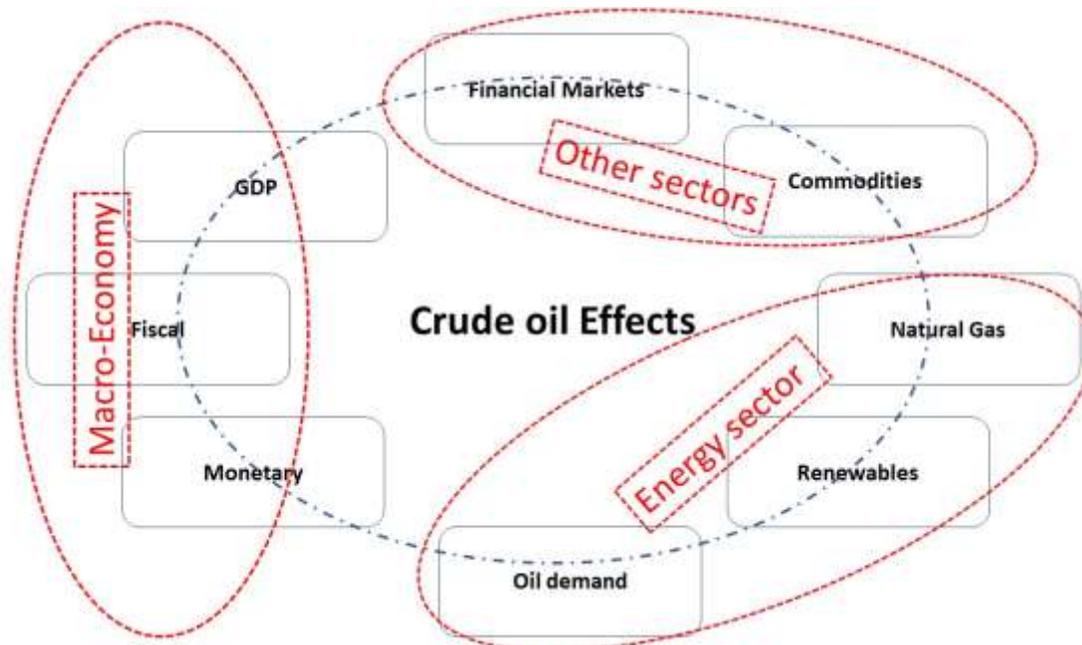


Figure 3-1 Depicts the effects of oil prices on several sectors.

### 3.1 GDP

Oil shocks influence total output. Economies can be divided into oil exporting or importing, or divided by the level of revenues' dependence or consuming expenditures. It comes as a consequence that the kind of reaction to oil price shocks and its magnitude vary depending on the kind of the economy.

Cashin et al. (2014) find that only during supply shocks, there is a difference between oil importers and exporters. During a negative supply shock oil exporters' economy are booming while oil importers' economies experience long-lived slowdown. Demand-driven shocks do not have different effects on countries depending on their production profile since they increase GDP and inflation. Lorusso and Pieroni (2018) find that the UK GDP is immediately negatively influenced after a negative oil supply shock. The UK inflation increase is permanent after an oil price shock. Further, the Bank of England does not directly react to oil price shocks, but instead to the reasons they stem from. Aggregate and oil market specific demand shocks increase interest rates. When there is a negative

oil supply shock, then the nominal interest rates increase. Wei and Guo (2016) find a complex relationship between oil shocks and the Chinese macro-economy. An oil shock augments Chinese output, contrary to what would be expected. Further, the increase is permanent since it is during the second, fourth and eighth quarter after the shock. A possible explanation for this might be the following. A possible oil price shock is related with increased global demand and the Chinese output is mainly focused on exports. One more result is that exports increase during the first four quarters after the shock. State-owned exporting corporations are more influenced than private-owned corporations after a shock since the former are concentrated on less efficient economic sectors. Importantly, there is no asymmetry in effects since an oil price shock will have of the same magnitude effect, whether it is positive or negative. Oladosu et al. (2018) calculate lower GDP elasticity to oil prices than a decade ago. The US economy has the most elastic response to oil price changes since it is the most dependent on oil prices.

### **3.2 Fiscal**

Fiscal policy is closely related to oil prices. Due to the inelastic demand to energy prices, taxing oil is a safe option for revenues increase. In addition, oil subsidies redistribute these tax revenues to broader social groups. However, subsidies increase local demand and economic growth, while they are a burden in periods of low oil prices. Oil revenues' redistribution is a difficult issue since due diligence policies should be implemented, while at the same time satisfy local needs.

It is not rare that oil production is considered as a curse for the economies by many. Mazaheri (2017) assesses the relation between oil revenues and fresh water, sanitation, education, health care and infrastructure provision. Oil revenues are not directly headed to local societies. Public services are better supplied to societies with peaceful and non-continuous discord rather in societies which do not appear any dissent. In addition, nonviolent movements have access to better public services than what violent do. More

importantly, the proximity to oil production infrastructure does not help local societies automatically. The spillover effect requires a lot of effort, time and persuasion.

Moghaddam and Wirl (2018) propose that the gradual removal of oil refined products' subsidies help consumers to adopt the new reality (energy transition), while delaying the transition to the new consumption behavior does not help. Political stability does not help elastically the gasoline subsidies' removal since 1% more political stability will lower oil subsidies by 0.094%. Price declines are more important. Contrary, CO<sub>2</sub> emissions do not influence gasoline subsidies. Oil prices play an important role since their increase augments oil revenues which are distributed as subsidies to alleviate the higher consumer prices. This is why oil prices negatively influence subsidies withdrawal. Further, when oil prices are high, producing governments start projects which are financed by state balance sheets. On the contrary, when oil prices fall these investments are funded by foreign assets and subsidies can no longer be available. This is why foreign assets negatively influence subsidies.

Further, oil subsidies influence oil corporations too. Alhassan et al. (2018) research the stock valuation of oil using companies in net oil-exporting countries. This kind of corporations are benefited by oil subsidies when oil prices rise. However, oil subsidies do not mitigate the risks of high oil price volatility. Importantly, the subsidy/GDP ratio remains constant and between 5.77% and 3.56% for the period between 2004 and 2015 for almost all countries. Finally, the more oil prices increase, the more oil using companies' stocks are benefited. However, stocks are not immune to oil price volatility.

### **3.3 Monetary**

Oil price changes and levels affect monetary policy. This influence is more profound on the interest rates. In addition, countries which have strong dependency on oil exports or imports are sensitive to increased oil price volatility affecting the country risk. Interest rates are in close relation with country risk since they depict the premium one investor

would like to receive to lend his funds to an economy. Furthermore, central banks adjust their interest rates to signal their monetary policy. Uncertainty is also included in the offered interests.

Kang and Ratti (2013) research the interdependency between global oil production, global real aggregate demand, oil-market specific demand and US economic policy uncertainty. Economic policy uncertainty increases when precautionary demand leads the oil prices up. Global real aggregate demand increases real oil prices, and as a consequence economic policy uncertainty. Instead, global oil production shocks do not influence the US economic policy uncertainty. Oil market specific demand is responsible for 31% of the variation of economic policy uncertainty, while it is 22.9% for the conditional variation of Consumer Price Index's forecast 24 months later. Global real aggregate demand influences federal expenditure and tax code expiration uncertainties.

Wei and Guo (2016) find mixed responses to oil price shocks by Chinese interest rates. The Chinese interest rates decrease during the second and third quarter and later increase. The mixed responses might be explained by that oil shocks are in close relationship with unexpected events like financial crises and wars. The Chinese Central Bank as many other banks lower interest rates to increase liquidity and money supply. Zhu et al. (2014) suggest that Chinese bond rates remain uninfluenced by global oil prices. This is the consequence of governmental decisions over interest rates, which do not adjust to commodity markets.

Lee et al. (2017) research the relationship between risk and oil price levels for both producing and importing countries. Canada's country risk is heavily affected by oil price changes. An aggregate demand shock or an oil specific demand shock lowers country risk by 0.091% and 0.093% respectively. An increase in risk rating means a decrease in country risk. Oil exporting countries are benefited when oil prices increase. An excellent example is that of the UK. Importing countries like Germany, France and Italy have mixed reactions to oil price changes. Aggregate demand shocks increase country risk for short periods in France and Italy. The risk rating declines 0.11% three months after the shock. Germany

has a mixed reaction as its country rating increases initially and later decreases. The last might be explained by the exporting nature of the German economy. Initially, the increased demand means increased exports for the German economy lowering the country risk and increasing the risk rating. However, soon afterwards inflation appears increasing the country risk. Further, the driver of an oil shock might be demand or supply. Aggregate demand shocks are the most influential for both importing and exporting countries. The relationship between country risk and oil production is also researched. When the country risk falls in the US and Canada, oil production increases with a lag. Further, aggregate demand is the most influential factor for country risk variance's in oil exporting countries. In oil exporting countries, specific demand is the most important factor. Last, oil exporting countries experience longer and heavier country risk rating changes compared to that of the oil exporting countries.

Bouri et al. (2018) use the 5-year CDS spread for each BRICS country as a proxy for sovereign risk. Oil volatility exposure is dangerous for both oil-exporting and importing countries. However, oil exporters are more sensitive to positive shocks, while oil importers are more sensitive to negative shocks. Further, there is a positive relationship between low oil volatility which predicts low sovereign risk, and high volatility which forecasts higher sovereign risk.

### ***3.4 Oil demand***

Oil demand consists the cornerstone of modern-day consumption. Oil is necessary for petrochemicals, pharmaceuticals, transportation fuels, agricultural fertilizers and etc. The supply chain is easily influenced by price shocks.

Cooper (2003) calculates the price elasticities for 23 countries. His results are statistically significant and only China and Portugal have positive signs and are insignificant. In agreement with the Le Chatelier Principle, the long-run elasticities are higher than the short-run ones. They move between -0.18 and -0.45. Instead, Dagoumas

et al. (2018) calculate both long and short run demand elasticities which are low and identical implying the low substitutability of oil. Genc (2017) calculated the corresponding price elasticities in different ranges of marginal cost of production. His calculations are between -0.755 and -0.438 before the financial crisis, while the reaction to prices doubles after the crisis (from 2009 to 2014). He further employs the Residual Supply Index (RSI) and the Lerner Index (LI) to calculate the market power of OPEC and non-OPEC countries. His calculations reveal the negative sign of correlation which is in accordance with the theory. This is because the price-cost markup decreases when OPEC's influence declines and RSI increases since non-OPEC supply reaction increases to demand. Hamilton (2008) assumes the magnitude of demand elasticities by the already calculated elasticities for gasoline. The demand elasticities for gasoline are around -0.25 in the short run and range between -0.5 and -0.75 for the long-run. Since crude oil consists 50% of the gasoline's cost, then the elasticity for crude will be around half of the aforementioned values.

Haugom et al. (2016) forecasts the real crude oil price in different supply and demand elasticity combinations. Given the current price elasticities, real oil price is expected to increase by 1.4% and up to 12.5% per year for the coming decades. The result is calculated with and without scarcity rent. Scarcity rent will become even more crucial for the price formulation. However, it is almost impossible for a price decline to appear even if scarcity rent is included in the price formula. The continuous price increases will turn consumption into more efficient technologies. Atil et al. (2013) find an asymmetry of the pass-through effect from oil to gasoline prices in the short-run. Gasoline prices will increase 0.483% if oil prices increase by 1%, while they will decrease by 1.095% if oil prices decrease by the same (1%) percentage. Gasoline is 60% consisted of oil which explains the asymmetry. Natural gas has a more regional character than gasoline and mostly reacts to regional factors rather than global. The broader factors which influence oil prices and as a consequence gasoline cause the asymmetry in demand.

### **3.5 Natural gas**

Natural gas prices were long oil-indexed. However, there is an ongoing debate on whether cointegration still exists between the two commodities. The debate on market decoupling or the timing of the market decoupling or what drove the market decoupling, if this is existent, continues with research trying to shed light on the topic.

Brigida (2014) suggests that the US oil and gas markets continue to be integrated and not permanently decoupled. In the early 2000s the markets temporarily decoupled, but if endogenously regime switching is accounted, then cointegration is still existent. Atil et al. (2013) present the non-linear and asymmetric nature of oil spillovers to natural gas and gasoline prices. Further, there is a long-run asymmetric influence on natural gas prices. The relationship is positive since a 1% increase in oil prices would increase natural gas prices by 1.247% and an equal decrease would lower gas prices by 1.666%.

Jadidzadeh and Serletis (2017) suggest that there is a positive relationship between real gas prices and precautionary oil demand. Further, one structural shock in oil prices (supply shock, aggregate demand shock, oil-specific demand shock) provokes natural gas real prices volatility. However, natural gas prices follow an independent course when there are strong natural gas fundamentals' changes like weather conditions, seasonal effects, storage activity or imports. For the up to 2000 period, oil shocks account for 69% of the natural gas long-run variation. During the post 2000 era, the influence falls close to 52%. This fall is well-explained by the institutional and technological developments in the US markets. Perifanis and Dagoumas (2018) propose that the US oil and natural gas prices are decoupled. Market decoupling was already present in the US markets and shale revolution only increased commodities' independence. Further, only bidirectional spillovers for very short-lived periods existed. During these periods, there is an asymmetry between oil price increases and decreases on gas returns. The asymmetric relationship is existent when a certain threshold is overpassed. Positive oil shocks cause faster adjustments. Last, natural gas prices have negligible effect on oil prices.

### ***3.6 Renewable Energy***

Energy transition is a crucial factor for crude oil market. The entrance of electric vehicles challenges the gasoline/diesel domination. The decarbonization encourages the development of environmentally friendly technologies like renewables, especially if their market penetration is in conjunction with electric storage development. Further, oil price fluctuations either encourage the research on those fields (if oil prices are high, then substitution is sought) or discourage the evolution (if oil prices are low, then energy transition is not cost effective). As a consequence, investment in renewable energy is dependable on oil prices.

Renewable energy investments are the competitors to oil investments. Renewable energy investments are mainly concentrated on power systems. Further, more sectors enter electrification like that of transportation. Shah et al. (2018) research the heterogeneity of approaches in energy investing between three energy intensive countries (UK, USA, and Norway). There are two factors shaping the different investment policies. The first is whether the economy is an oil net importer or exporter. The second is the level of state intervention in renewable energy investments. Liberalized energy markets and oil importers like the US appraise renewable energy investments in relation with the oil market. Renewable investments' variance is explained 22% by oil prices in the US. However, when renewable energy is driven by the state as in the UK, then oil price volatility is less important for renewable investments.

### ***3.7 Financial Markets***

The connection between oil prices and capital markets is obvious since most of the trading is in the futures market. Further, participants in the oil market also participate in the stocks and other commodities. It is of great interest to discover whether spillovers exist, and whether they are of large magnitude.

Feng et al. (2017) research the influence of oil volatility's risk premium on G7 equity markets. There is a connection since oil volatility's risk premium well forecasts daily stock volatilities in the developed economies. The result is close to 0.004 for all G7 economies. The results hold for both realized and implied volatilities. During high and low levels of stock indices, volatility's risk premium has even better forecasting ability. Reboredo and Ugolini (2016) research the influence of oil prices on the US, UK, European Monetary Union, and BRICS equity markets before and after the 2008 crisis. They suggest that oil and stock prices were cointegrated even before the outburst of the financial crisis. This kind of relationship became even stronger since 2008. Moreover, vast price shifts had asymmetric and limited influence on extreme equity changes, while interquantile oil price changes had no influence. In addition, large upward (downward) oil price changes significantly influenced large upward (downward) equity price quantiles. Influence is even greater during lower rather than upper quantiles. Oil price spillovers to be transmitted need to overpass a threshold, if this is not the case then they are insignificant. Ewing et al. (2018) research the connection between supply shocks and the US upstream companies. The real return for the US upstream equities has increased for both the US and non-US supply shocks. Real returns' response to a negative non-US supply shock increases from 0.70% (2006) to 6.16% between 2008 and 2010. The greatest returns are in 2014 and are 6.81%. When there is a US negative shock, then the real returns for the US upstream equities are 3.60%. The non-US supply shocks (negative ones) increase global oil prices and as a consequence the US domestic production and earnings. Last, the negative supply shocks augment the US refiner's acquisition costs and again boost earnings.

Shahzad et al. (2017) highlight the investors' inability to diversify their portfolios during falling oil prices. In addition, the Islamic stock returns are not uninfluenced by global financial turbulences or oil prices changes. Moreover, the bidirectional risk spillovers from oil prices to Islamic equities are asymmetric and more intense since the financial crisis. Badeeb and Lean (2018) apply the non-linear Autoregressive Distributed Lag methodology to research the influence of oil price changes on Islamic equities. Their

conclusion is that the composite index is immune to oil price changes. However, not all equity sectors respond in the same way to oil price changes. Equities and oil price changes do not have a linear relationship in the long-run. When the research is focused on sector indices which consist the behavior of the composite index, they find that the composite's behavior is oil prices immune. More analytically, equity indices are positively and linearly influenced by price changes in the short-run, while their sensitivity is more intense to oil price decreases rather than oil price increases in the long-run. A quite interesting finding since Islamic equities come out stronger from oil price decreases. Indices like those of materials, oil and gas and utilities are positively influenced by oil price increases. Instead, indices like those of consumer goods and industry equities have a negative correlation with oil price returns and should be preferred during falling prices. Sectors like those of financial services, healthcare, and consumer services are immune to oil price changes and remain unaffected. Pan et al. (2016) suggest strong asymmetric correlations between oil and equities' returns. The relationships are stronger in oil-exporting countries. Last, they propose that the Asymmetric Dynamic Equi-Correlation (ADECO) model is better than the Dynamic Conditional Correlation (DCC) model for portfolio hedging between energy futures and equity indices.

Outstandingly, the Chinese equities have a significant correlation with oil prices. Kirkulak-Uludag and Safarzadeh (2018) suggest that there are significant spillovers from oil prices to the Chinese equities, while the vice-versa are not so much apparent. In addition, the past oil price shocks influence significantly and negatively the Construction, Machinery, Automobile, Military and Agriculture stock sectors. On the contrary, only the Military sector influences the oil price volatility. You et al. (2017) suggest that during bearish markets, negative oil shocks influence stock returns greater than positive ones. During normal and bullish periods, negative and positive oil price shocks have symmetrical influence on equities. Interestingly, negative and positive shocks have non-linear influence. Positive oil price shocks have significant and negative influence before the financial crisis, while after the crisis their influence is positive. Negative oil price shocks lower equities' returns before the outbreak of the financial crisis when the market

is either normal or bullish, while they decrease equities whatever the market after the financial crisis. The last for the post crisis period holds for every market condition except for the extreme bullish. Last, Economic Policy Uncertainty is always negative for equities' returns.

### **3.8 Commodities**

Refiq and Bloch (2016) apply the ARDL and NARDL methodologies to present the long-run influence of oil price changes. Their results suggest that a positive oil price shock would increase 20 commodity prices, with their elasticities to range between 0.23% and 0.88%. Instead, a negative oil price shock would only decrease the prices of wheat, maize, and aluminum with their elasticities to range between -0.37% and 0.68%. However, negative oil price shocks influence more commodities in the short-run. Their asymmetric Granger tests suggest that a positive shock only increases the prices of three commodities in the short-run, while an oil price decrease will cause negative returns for at least 13 commodities. Moreover, not all sectors are heavily influenced like those of metal prices and food agricultural commodities. Beverages and cereal are less affected by the oil price changes than the other sectors. The asymmetries between the nature of the shock (positive or negative), and between the sectors' influence can be employed for portfolio diversification by both producers and consumers. Uddin et al. (2018) enhance the suggestion that oil price changes have asymmetrical influence on precious metals. Oil price shocks are separated into demand, supply and risk shocks. All kind of shocks can be held responsible for metal returns but their nature changes across regimes. Even if there is switching between low and high volatility regimes, supply and demand shocks are positively related with metal returns whatever the regime. Instead, risk shocks have different effects (sign and magnitude) depending on the regime.

Zhu et al. (2014) propose that global oil prices affect Chinese precious metals' prices both in the short and long-run. The vice-versa relationship or precious metals' influence

on global oil prices is positive only in the short-run. This is explained by the fact that when Chinese demand increases, then oil prices increase, and as a consequence inflation increases. In turn, inflation lowers liquid asset valuations, and investors turn to precious metals as a safe heaven and thus increase their prices. The vice-versa relationship could not hold since the Chinese precious metal market is a regional one, while the oil market is a global one. Further, 6% of Chinese precious metals' variation can be attributed to the oil price changes.

## **4 Crude oil price explosive periods**

### **4.1 Introduction**

Oil price's course is characterized by a succession of oil price bursts after hikes. The course with several structural breaks, either upward or downward or either wise jumps is the consequence of increased volatility. The duration of high volatility periods is also not the same. For example, it took only three months for oil prices to reach their highest levels in 1991, but seven years to reach the highest levels of 2008.

Researchers have always studied the consecutive hikes and bursts to detect bubbles in the market. The main question is whether financial markets are fundamentally driven or speculatively driven. Market stakeholders might be confused sometimes on whether a period of extreme upward or downward pressures is the result of rational expectations. Regulatory bodies try to detect bubble periods and are in need of robust empirical tools in the quest of prompt actions. The literature uses the term "bubble" to describe periods of explosiveness. Explosive periods are the ones when an asset's price increases rapidly until a sudden collapse follows. However, the main question remains. What is the real value of oil? There is not a single answer to the question and it is not constant since new information constantly enters the market. Further, there is not a single appraisal methodology. Nevertheless, oil is a storable commodity. Stocks and oil glut have a major role as Perifanis and Dagoumas (2019) propose. In addition, Pindyck's (1992) methodology is widely accepted where the convenience yield is calculated as the sum of discounted oil inflows or dividends or else the total benefit of inventories to the physical holder against the holder of a financial contract.

In addition, there is still debate over the oil price determinants even if it is known that the market is in state of exuberance. The exuberance might be justified either by fundamentals' swift or speculative activities. Kaufman and Ullman (2009) suggest that price innovations start from both spot and futures markets depending on the studied blend. Polanco-Martinez and Abadie (2016) agree for the bidirectional causality between

spot and futures prices. Irwin and Sanders (2012) propose that there is no causal relationship between returns or volatility and the positions of exchange-traded index funds. Kilian and Murphy (2014) as it is already mentioned reject the assumption that speculation had any role in the 2003 to 2008 surge. Consequently, any additional regulation will not bring results. Under Juvenal and Petrella (2015) only demand determines oil prices. However, speculation contributed to the increase between 2004 and 2008. Demand collapsed in 2008 and speculation drove many market participants to curtail demand for commodity assets. Knittel and Pindyck (2016) propose that the sharp changes since 2004 were the result of fundamentals' changes.

Oil bubbles will not stop to appear in the future, since even if speculation is driven out, sharp changes in supply and demand can make their appearance. Supply and demand may also alter the price course if their respective elasticities are low. Bubbles have a dominant role in the literature review. Diba and Grossman (1988) suggest that non-stationarity of the means of differenced time series imply rational bubble existence. Their assumption is that if there are rational bubbles then their time-series should be of higher order non-stationary. Their results suggest low order non-stationarity for stock prices i.e. there are no bubbles. They go further suggesting unit root cointegration tests fail to detect exuberance periods when periodical bubbles bursts occur. Tirole (1985) suggests that Overlapping-Generations (OLG) models are the most appropriate for bubble investigation. Evans (1991) proposes that traditional tests are unable to identify periodically collapsing bubbles. Kirman and Teyssiere (2005) identify self-reinforced expectation switching by individuals' forecasting rule changes behind bubbles. They continue by suggesting that standard unit root tests underperform. Long memory and switching regime effects act together in their bubble detection analysis. Last, volatility persistence is the consequence of regime changes and long-range dependence.

Barberis et al. (2018) propose the positive news over fundamentals can start a bubble period, and that bubble periods are concurrent with increased trading volumes which in turn will be increased with past returns. Bao et al. (2019) suggest that bubbles occur in swallow markets. In addition, market stakeholders coordinate following trends to

forecast asset prices and initiating bubble opportunities. Bubbles have long been connected with credit expansion. Werner (2014) proposes that debt constraints can not stop an asset price bubble. Jorda et al. (2015) find that bubbles are not the same every time. They continue by claiming that credit is the major factor for a bubble episode. Martin and Ventura (2015) propose that low interest rates initiate credit expansions which in turn result into inefficient cash flows. Albuquerque et al. (2015) suggest that fundamentals are highly correlated with bull and bear periods. Hirano et al. (2015) suggest that government guarantees provoke riskier bubbles. Miao et al. (2015) propose that Tobin's taxes, macro-prudential policy, property taxes and prompt credit policy are preventive factors for bubbles. Instead, useless collaterals can relax credit constraints and create bubbles.

Kunieda and Shibata (2016) suggest that even useless assets which can spread investors' credit can initiate bubbles. Asset purchases is the second most prompt action to deter a bubble. The most prudent action before asset purchases is depositors' taxing and investors' subsidizing. Nemoto (2017) connects credit availability to assets prices as thus the more credit is given, the higher the assets prices go. Acharya and Naqvi (2018) suggest that the more the monetary policy is loosened the more investors are induced to higher returns and as a consequence to bubbles. Wang et al. (2019) propose that deposit insurance and limited liability induce banks to hold bubble assets for risk premium purposes. In turn, risk premium is influenced by supervisory intensity, leverage ratio and credit spread. If banks have such assets in their portfolio, then internal leverage, cash withdrawal, credit friction and network effects will deteriorate their stability. There is no segregation whether a bubble shock is domestic or foreign since banking stability is fundamental to economic growth. Wang and Chen (2019) verify that trading volume and price volatility are the drivers of equity bubbles. Further, monetary policies drive the bubble episodes. Credit expansion contributes to bubble episodes too, but with a lag.

Gronwald (2016) by applying a forward recursive Augmented Dickey Fuller test suggests that the 2005/2006 and 2007/2008 periods are explosive for oil. Fantazzini (2016) suggests a negative bubble for the period between 2014 and 2015. Phillips and Yu

(2011) suggest a bubble dating procedure with recursive right sided unit root tests. Phillips, Wu and Yu (2011) (for our convenience referred as PWY) return to suggest a new methodology with recursive regression right sided unit root tests and confidence interval calculation for the growth parameter in market explosiveness. Their results suggest exuberance during the 90s for NASDAQ, when they can date-stamp the episode with accuracy. Phillips Shi and Yu (2015) (or PSY) go further by suggesting an even more accurate date-stamping procedure for multiple bubbles. The Generalized Sup ADF (GSADF) test is a rolling window right-sided ADF test with double-sup window selection criteria. This improvement detects multiple bubble episodes while the previous SADF not. GSADF is more sensitive than the PWY (2011) because it can detect a second bubble in the sample. They tested their methodology for the S&P 500 price-dividend ratio between 1871 and 2010.

Harvey et al. (2017) propose a complementary methodology for date-stamping. Bubble periods are recognized by experienced traders. Shestakova et al. (2019) suggest that market efficiency is heavily influenced by the prior success of experienced traders in mixed-experienced markets. However, in all-experienced and all-inexperienced markets the experience's effect is not significant since markets have almost the same efficiency. Greenwood et al. (2019) study the Fama (2014) suggestions. They agree with Fama that high returns do not precede low future returns. The explanation is that in a diversified portfolio, assets with positive returns can coexist with assets exhibiting vast increases and bursts. However, abrupt increases are positively related to increased burst probabilities. Last, future returns and as a result bubbles can be forecasted by volatility, turnover, issuance and run-up's price course.

Gilbert (2010) proposes that one can not be definite on whether oil prices experienced explosiveness, since results are mixed and they can be differently interpreted. He continues with that index-based investments on energy is between 3% and 5% in 2006 to 2007, but expand to 20 to 25% in the first half of 2008. Shi and Arora (2012) apply the regime models of Brooks and Katsaris (2005), and Schaller and Van Norden (2002) for oil prices. Their results suggest that the probability of a sudden bubble burst is increased

during the late 2008 and early 2009. They continue with suggesting that the probability for both expansion and collapse regimes for short periods is increased i.e. most bubbles live short. Lammerding et al. (2013) propose that speculative bubbles exist in oil price dynamics. Fan and Xu (2011) date-stamp the structural breaks when fundamentals and speculation had great influence. They detect 2004 and 2008 as years of great swifts. In 2004, we had increased demand by emerging economies and the entrance of speculative funds in the market. In 2008, we had the financial crisis. They further add that speculation and episodic events were the major determinants between 2000 and 2004, while speculation on its own was the major determinant between 2004 and 2008.

Market fundamentals drove the market after 2008 and the financial crisis. Corbet et al. (2018) applied the Phillips et al. (2011) methodology with fundamentals to study whether Bitcoin and Ethereum had bubble episodes. Their results suggest that Bitcoin experienced explosiveness when its price was over \$1,000. Pan (2018) suggest that gold and silver experienced bubble episodes between 2007 and 2009 when the subprime crisis and the European sovereign debt crisis unfolded. Pessimist sentiment augments the probability of a bubble in the gold market. Hu and Oxley (2018) find that there were asset bubbles in the Japanese markets in the 80s and 90s. They add that there was contagion from the equity to the real estate market. Geuder et al. (2018) apply the Phillips et al. (2015) methodology to suggest that Bitcoin experienced several bubbles in 2017 when it experienced none since January 2018. Chaim and Laurini (2019) confirm that Bitcoin experienced bubble episodes between early 2003 and mid-2014, while this was not the case in 2017.

Matsuoka and Shibata (2012) propose that bubbles do not lead to optimal productivity technology choices. Hirano et al. (2015) propose that the size of bubbles and production levels do not have a monotonic relationship i.e. bubble episodes increase production levels until a certain level. If a certain threshold is passed, then production levels decrease. The direct implication is that state bailouts augment production efficiency in the beginning, but after a certain threshold they augment the boom-burst cycles which in turn require even more money by taxpayers. Partial bailouts are the

optimal policy. Narayan et al. (2016) suggest that asset bubbles affect economic welfare both positively and negatively, but there is an asymmetry since bubbles affect welfare more positively.

Wan (2018) suggests capital gain taxes, transaction or property taxes, rebate options, and fixed periods of asset usage as means to avoid explosive episodes. Further, regulators and policymakers have to choose between hard and soft landing. Hard landing refers to financial or tax tools that can burst a bubble. If a hard landing is chosen, then the asset value after the burst might be lower than its fundamental, which is a second regulatory failure. Soft landing, instead, is when capital gain taxes are chosen to stop bubble growth. He further adds that heterogeneous beliefs, market frictions and speculative trading motives are responsible for bubbles' occurrence. Fenig et al. (2018), on the contrary, claim that leverage constraints do not help a lot in asset bubbles' avoidance. This is justified by market participants supplying more labor to concentrate a wealth buffer stock. This kind of wealth is then flowed into asset markets driving prices higher, and thus making assets distant from fundamental values. Inflation targeting is a prompter action against bubbles. Ciccarone et al. (2019) propose that the adjustment of the nominal rate, in quest of preventing the formation of asset bubbles, is the best action when the adjustments to inflation and output deviations are not great. If this is not the case, then the regulatory body puts economy into danger since it increases bubble's volatility.

Zhang and Yao (2016) detect oil price bubbles between 2001 and 2008. They distinguish several oil products that were driven by bubbles like Brent, WTI and diesel prices. On the contrary, gasoline was driven by fundamentals. Zhang and Wang (2015) suggest that WTI's fundamentals do not cause oil market volatility. They go further with that as a speculative bubble occurred prior to the 2008 burst. Figuerola-Ferretti et al. (2019) propose that the WTI and Brent blends experienced two bubbles periods. One positive prior to the 2008 crisis, and one negative afterwards. Global economic activity can explain the positive one. As for the second (negative bubble), shale oil contributed to the oil price decline but it is not the main determinant. Additionally, the VIX index did not affect oil prices. Su et al. (2017) identify bubbles in 1990, 2005, 2006, 2008 and 2015.

Speculation drives long-term bubble episodes in WTI prices. Episodic events like wars influence prices prior their outbreak and until their end. As a consequence, they have limited implications. Garcia-Carranco et al. (2016) propose that explosive episodes do not affect the intrinsic time of volatility. However, they do affect the metric of volatility horizons.

We continue by applying the PWY(2011) and PSY (2015) statistics and date-stamping methodology to detect possible bubbles on their drivers.

## **4.2 Data**

We use the monthly spot WTI prices by the Federal Reserve Economic Data (FRED) for the period from January 1947 to September 2018. The nominal spot prices are deflated by the seasonally adjusted monthly Consumer Price Index by the FRED. We use the monthly and not the spot daily price due to the fact that the CPI is only calculated on a monthly basis. Therefore, the derived 861 observations of our sample are the real oil prices. Oil prices experienced several peaks and crashes through this period. Oil price was spectacularly stable from 1947 to 1973. Since the first oil crisis of 1973, oil prices experience high volatility. The summary statistics are presented in Table 4.1.

**Table 4.1.** Descriptive Statistics

Mean	18.6531
Median	14.1688
Maximum	61.5874
Minimum	6.8613
Std. Deviation	11.1339
Skewness	1.2091
Kurtosis	3.5496
Jarque-Bera	220.6267
Probability	0.0000

*The positive skewness means that our data's distribution has a long right tail. Kurtosis is over 3 (of the normal distribution), and as a result is peaked (leptokurtic).*

Our data are tested for stationarity with the ADF (Said and Dickey 1984) and the Zivot and Andrews (1992) tests. The last test allows for one structural break. Both tests confirm that our data are I(1) or stationary at their first difference (Table 4.2)

**Table 4.2** Unit root tests for the WTI real price between 1/1/1947 and 1/9/2018

	ADF test	Critical Values			Zivot and Andrews (1992) test	Critical Values		
		1%	5%	10%		1%	5%	10%
WTI real oil prices	-1.1941 <sup>a</sup>	-2.58	-1.95	-1.62	-3.2715 <sup>a</sup>	-5.34	-4.80	-4.58
$\Delta$ (WTI real oil prices)	-16.1597 <sup>b</sup>				-20.8989 <sup>b</sup>			

*Both tests have as a null hypothesis ( $H_0$ ) that a unit root exists.*

<sup>a</sup> *Acceptance of the null hypothesis for 1%, 5% and 10%.*

<sup>b</sup> *Rejection of the null hypothesis for 1%, 5% and 10%.*

## 4.3 Methodology

### 4.3.1 The PWY (2011) test for bubbles

Our first test is the PWY (2011) test for bubbles which is a repeatedly conducted ADF test on a forward expanding sample sequence. The test statistic is the sup value of the ADF sequence. The sample window size is denoted as  $r_w$ . It is in between  $r_0$ , which is the minimum sample, and 1 which the total sample size. The starting point for the test is  $r_1$  of the sample sequence at 0, and  $r_2$  is the endpoint of each sample. Together equal  $r_w$ . The  $r_2$  of each sample goes from  $r_0$  to 1. The first ADF test from 0 to  $r_2$  is the  $ADF_0^{r_2}$ . Then we have a sequence of ADF statistics and PWY (2011) is the sup statistic of the forward recursive regression.

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2} \quad (4.1)$$

There is a comparative research by Homm and Breitung (2012) on Bhargava (1986), Kim (2000), and Busseti and Taylor (2004) methodologies for speculative bubbles. These methodologies are not far from the SADF of PWY (2011) but they are not of the same level. Homm and Breitung (2012) suggest that the PWY (2011) is the best.

### 4.3.2 The PSY (2015) test for bubbles

The PSY (2015) test is an improvement of the previous PWY (2011) test with the rolling window GSADF statistic. The test is calculated on repeated ADF tests on subsamples in a recursive mode. The regression model is written as:

$$\Delta y_t = \hat{\alpha}_{r_1, r_2} + \hat{\beta}_{r_1, r_2} y_{t-1} + \sum_{i=1}^k \hat{\psi}_{r_1, r_2}^i \Delta y_{t-i} + \hat{\varepsilon}_t \quad (4.2)$$

Where  $k$  is the lag order.

The regression is calculated with  $r_1$  in (4.2) changing from 0 to  $r_2 - r_0$  for all the feasible ranges. The largest ADF value in all feasible ranges from  $r_1$  to  $r_2$  by the double recursion calculation is the GSADF statistic. The GSADF ( $r_0$ ) can then be rewritten

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\} \quad (4.3)$$

The result (GSADF statistic) is compared to the respective critical statistic to test the existence of bubbles or not. PSY (2015) suggest that the asymptotic GSADF distribution is influenced by the smallest window size  $r_0$ . Its size depends on the sample size. For small samples has to be relatively large, while for large samples has to be relatively small. After many simulations PSY (2015) conclude that the best possible way to suggest the minimum window  $r_0$  based on a lower bound of 1% of the full sample can be given by the type:

$$r_0 = 0.01 + 1.8/\sqrt{T} \quad (4.4)$$

Where T is the number of sample observations.

### **4.3.3 Date-stamping strategies**

The PWY (2011) methodology for bubble date stamping is the calculation of a right-tailed recursive ADF test from the start of the sample to latest chronological observation. Evans (1991) emphasizes the disadvantages of these kind of methodologies, as that of Diba and Grossman (1988), because pseudo stationarity behavior might be exhibited due

to multiple collapsing bubble episodes. PSY (2015) differs from the previous methodology as the calculation is conducted with a double recursive test with a flexible window named Backward Sup ADF.

The Backward Sup ADF is the calculation of the sup ADF tests on a backward expanding sample sequence. The starting points for the samples are the 0 to  $r_2 - r_0$  observations when  $r_2$  is the respective endpoint of each sample. The ADF statistic sequence can be written as

$$\left\{ ADF_{r_1}^{r_2} \right\}_{r_1 \in [0, r_2 - r_0]} . \text{ The sup value of the ADF statistic sequence is the backward SADF}$$

statistic:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \left\{ ADF_{r_1}^{r_2} \right\} \quad (4.5)$$

The PWY (2011) methodology can then be restated as the recursive ADF when the Backward Sup ADF test is calculated with  $r_1=0$ . The duration of the bubble can be detected between the start, which is the first chronological observation where the ADF statistic surpasses the critical value, and the end which is the last chronological observation where the ADF statistic is under the critical value. The start of the bubble can be written as  $[T\hat{r}_e]$ , and the end as  $[T\hat{r}_e] + L_T$ , where  $L_T = \log(T)$ , to exclude short-lived jumps. The start and the end points of the PWY (2011) can then be written as:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : ADF_{r_2} > cv_{r_2}^{\beta_T} \right\} \quad (4.6)$$

and

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \{r_2 : ADF_{r_2} < cv_{r_2}^{\beta_T}\} \quad (4.7)$$

When  $cv_{r_2}^{\beta_T}$  is the  $100(1 - \beta_T)\%$  critical value sequence of the ADF statistic depending on the  $[Tr_2]$  sample observations.

The start and end points for the PSY (2015) methodology can be then written as  $[T\hat{r}_e] + \delta \log(T)$ , when  $\delta \log(T)$  is the least bubble duration with  $\delta$  being a frequency-dependent parameter. The bubble duration for the GSADF method is between the observation's points where:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \{r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T}\} \quad (4.8)$$

and

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \{r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T}\} \quad (4.9)$$

with  $scv_{r_2}^{\beta_T}$  to be the  $100(1 - \beta_T)\%$  critical value sequence of the sup ADF statistic.

The SADF test statistic is calculated by the repeated implementation of the ADF test for each  $r_2 \in [r_0, 1]$ , when the GSADF test statistic implements the repeated backward sup ADF test for each  $r_2 \in [r_0, 1]$ . The PWY (2011) and PSY (2015) date stamping methodologies then be respectively written as:

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ ADF_{r_2} \right\} \quad (4.10)$$

and

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\} \quad (4.11)$$

For a more detailed description of the methodologies please see PSY (2015).

#### **4.4 Results**

WTI prices are tested for bubble episodes between 1947 and 2018. This is an extended period when oil had a considerably stable price until 1973, while it experiences high volatility since then. Oil had two spectacular positive shocks in 1973 and 1978/79. Oil prices also collapsed in 1986, when we almost had the near OPEC collapse, and in 2008 when the subprime crisis emerged. Since oil prices experience high volatility, while in a prior long period were stable, it is expected to have non-stationary properties (non-constant mean, variance, and autocorrelation). This is confirmed by both stationarity tests. The non-stationary properties do not preclude bubbles in our sample. However, the sudden increases and collapse of the prices guarantee for structural breaks. An initial detection of the structural breaks and their potential drivers is presented in Table 4.2. What is presented is that structural breaks are caused by high volatility, which in turn was the consequence of significant market events.

**Table 4.3** Structural oil price breakpoints and important events.

Date	Important Events in the Oil Market
1/2/1973	First Oil Crisis
1/7/1979	Second Oil Crisis
1/12/1985	Near OPEC collapse
1/2/2005	Beginning of Oil price surge until Financial Crisis
1/3/2012	Oil price rebound until 2014

Events are presented in conjunction with breakpoints. Events' dates are not identical with that of breakpoints. Author's calculations.

We continue with the SADF and BSADF test statistics for the full sample. We continue with the comparison of the statistics with their respective critical values. The finite sample critical values are derived by Monte Carlo simulation of 2000 replications. Our sample size is 861 observations. We apply the rule of  $r_0 = 0.01 + 1.8/\sqrt{861}$  for the smallest window. The smallest window has the size of 61 observations. Our SADF and BSADF statistics for the full sample suggest that oil prices experienced bubble periods since they both exceed their 1% right-tail critical dynamic lag order (Table 4.3).

**Table 4.4** The SADF TEST and the GSADF TEST of the West Texas Intermediate (WTI) Price.

	Test Stat.	Finite Sample Critical Values		
		90%	95%	99%
SADF	4.91	1.25	1.49	1.99
GSADF	5.01	2.07	2.28	2.70

Notes: Critical values calculated by 2000 replications of Monte Carlo simulation and sample size of 861 observations. The minimum window has 61 observations. Author's calculations.

We continue with the date-stamping procedures to detect when these periods existed. We apply the PWY (2011) date-stamping methodology first. Bubble periods are when the BADF sequence is over the 95% critical value sequence. Our PWY (2011) date-

stamping procedure detects two bubble episodes for oil prices. These periods lasted between July 1979 and January 1982, and between May 2008 and July 2008. The first period is coinciding with the second oil crisis, while the second is coinciding with the course that led oil prices to their highest level until the financial crisis erupted. As PSY (2015) state, the PWY (2011) date-stamping methodology is conservative that fails to detect multiple episodes of exuberance. Our first date-stamping procedure might miss the 1973 oil crisis and the 1986 collapse. Our sequences are presented in Figure 4.1.

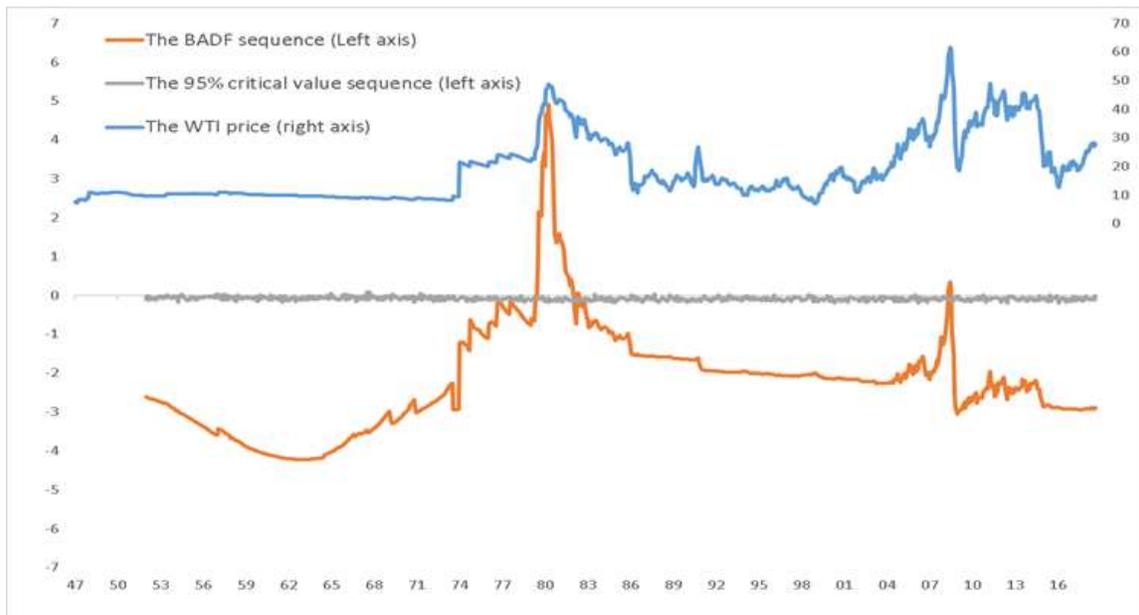
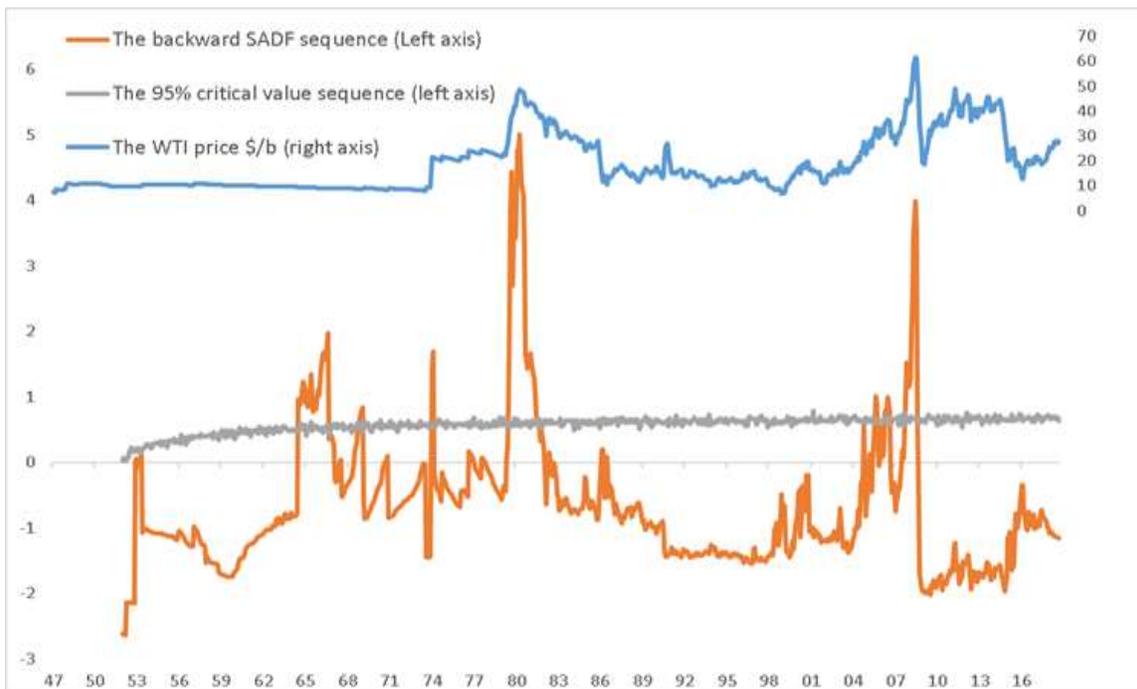


Figure 4-1 Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the SADF Test, Author's calculations.

The PSY (2015) date-stamping procedure suggests more episodes of exuberance. It detects seven periods. These are between July 1964 and August 1966, December 1968 and February 1969, January 1974 and February 1974, July 1979 and July 1981, August 2005 and September 2005, April 2006 and August 2006, and October 2007 and August 2008. Both methods suggest two almost identical episodes of exuberance. PWY (2011) suggests that of July 1979 to January 1982, while PSY (2015) suggests one from July 1979 to 1981. The second episode is between May 2008 and July 2008 for PWY (2011), while for PSY (2015) is between October 2007 and August 2008. However, the PSY (2015) date-

stamping procedure is more sensitive since it suggests five additional episodes. The episode between January 1974 and February 1974 coincides with the first oil crisis of 1973. The periods between August 2005 and August 2008 coincide with the long period between 2004 and 2008 when oil prices were increasing until the financial crisis. The sensitivity of the methodology also suggests two episodes prior the era of high volatility. The date-stamping procedure results are presented in Figure 4.2.

Figure 4-2 Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the GSADF Test, Author's calculations.



The episodes must be separately examined to identify their drivers. The explosive episodes of 1974 and 1978 are mainly explained by the supply shocks of the two crises. Cremer and Weitzman (1976) and Pindyck (1978) suggest that OPEC is a powerful monopolist. Johany (1980) proposed that OPEC just refused to expand its production. Pierru et al. (2018) study OPEC's behavior as a world price stabilizer. OPEC maintains ample spare capacity and can alter its production vastly. The influence of OPEC is dependent on short-term demand and price elasticity. Pierru et al. (2018) suggest that OPEC can play the role of the swing producer by adjusting production without

considerable costs. In 1973, there was a sudden supply shock and consumers did not have strategic inventories as supply buffers. Chevillon and Riffart (2009) suggest that two cointegrating relationships influence oil prices. They continue by proposing that OPEC quotas and OECD inventories have long term relationships with prices. Cologni and Manera (2014) suggest a long-term relationship between production levels and demand. D' Ecclesia et al. (2014) find two thresholds for OPEC. OPEC leaves production levels unchanged under a threshold to cover fixed costs, and refuses to augment production levels over a threshold since this would mean increased maintenance costs and faster depletion. Dagoumas et al. (2018) suggest production sharing strategy for Saudi Arabia. Bataa et al. (2016) propose that supply shocks do not permanently influence production levels prior to 1980, when their influence totally disappears two years later. Demand is affected by production. Production decreases after demand shocks until 1990. Espinasa (2017) suggests the Saudi sensitivity to price changes, while Drachal (2016) propose that inventories have deflationary effects even in 1991. Perifanis and Dagoumas (2019) suggest that inventories decrease prices by 0.45%. All in all, the two bubbles can be largely explained by the supply shocks of the two oil crises. The combination of increased demand, low substitutability and the absence of strategic inventories was the driving factor behind the explosive episodes of 1974 and 1979-1981. Our research suggests that two detected periods are fundamentally explained. Moreover, the following explosive episodes can also be fundamentally explained. Our research detects three explosive episodes from 2005 to 2008, when the financial crisis occurred. He et al. (2009) propose the cointegration between futures prices real economic activity (Kilian Index) and the US dollar index. Jadidzadeh and Serletis (2017) suggest that aggregate and specific demand shocks contributed more than supply shocks to oil prices. Guntner (2014) divides demand shocks into flow and speculative ones. The first ones are caused by increased demand. OPEC and non-OPEC countries keep their production constant when demand increases. The only exceptions are that of Saudi Arabia and the U.A.E which increase their production levels. Both of them hold ample spare capacity. Perifanis and Dagoumas (2019) suggest the contributory role of demand. Lorusso and Pierroni (2018) suggest that

political events and their following supply shocks did not influence prices since the mid-70s. On the contrary, the precautionary oil demand is among the main drivers for oil prices. Liu et al. (2016) propose the Chinese and the US demand as the main oil price fundamentals. Byrne et al. (2018) propose that the relationship between demand and oil prices is time-varying. There was always an adjustment to demand changes and this became even more prevalent since the mid-2000s due to the increased demand by the emerging economies. World economic activity is the main determinant for oil prices since economic development is energy intensive. The 2008 financial crisis halted economic development and drove many economies into recession. The explosive episodes coincide with severe demand shocks which were driven by economic development.

Gronwald (2016) applied a forward recursive ADF test to detect explosive periods in 2005/2006 and 2007/2008. His results verify ours. Gronwald (2016) further claims that the term bubble should not be used as no one knows the precise fundamental value for oil. He further adds that oil is fundamentally driven. Fantazzini (2016) suggests a negative bubble in 2014/2015. This was due to other than the fundamentals. The last does not verify our results as no bubble is detected in 2014/2015. The difference might be explained by the nature of our time-series where there is a period of no volatility and one of high volatility. The high volatility period starts from 1973. It is advised to apply both of our used methods for real time bubble detection. Finally, both methods were applied with different specifications like lags, constant and without trend, and the results were identical.

## ***4.5 Conclusions***

We investigate the existence of bubble periods between 1/1/1947 and 1/9/2018. The period can be divided into two sub-periods. The one with zero volatility prior the 1973 oil crisis, and the other of high volatility since 1973. Both of them have their own unique characteristics. After the 1973 oil crisis many researchers attempted to examine whether

the market was in exuberance or when the market was either fundamentally, politically or speculatively driven.

We employ two econometric methodologies to detect and date-stamp potential bubbles in the oil prices. We apply the PWY (2011) and PSY (2015). The new GSADF test is the improvement to the previously proposed method (SADF), and it is a rolling window right-sided ADF test with double-sup window criteria. SADF test was not always able to detect numerous bubbles in the sample. SADF and GSADF tests suggest that there are periods of exuberance.

We also date-stamp these periods of exuberance. The PWY (2011) suggest less periods in contrast with the PSY (2015). This is due to the reason that the PSY (2015) is a more sensitive method compared to the PWY (2011). Their results are presented in Table 4.4. Both methodologies suggest the second oil crisis (1978-1979) as explosive. Totally, the PWY (2011) date-stamping process suggests two bubbles while the PSY (2015) seven. Further, the PSY (2015) suggests three periods between 2005 and 2008, when oil prices followed an ascending course until the great financial crisis. However, the PWY (2011) suggests only one short-lived bubble period in 2008. The PSY (2015) does not fail to suggest the first oil crisis also. Additionally, the explosive periods coincide with the structural breakpoints (Tables 4.2 and 4.4), something further strengthening our results. The PWY (2011) and the PSY (2015) engulf one and three structural breakpoints respectively. What can be suggested is that the later methodology is more sensitive and better at following volatility explosions. However, it can be too sensitive and suggests even periods that they might be not explosive like the two explosive periods when oil prices experienced zero volatility.

**Table 4.5** Bubble periods.

<b>PWY (2011)</b>	<b>PSY (2015)</b>
July 1979–January 1982	July 1964-August 1966
May 2008-July2008	December 1968-February 1969
	January 1974-February 1974
	July 1979-July 1981
	August 2005-September 2005
	April 2006-August 2006
	October 2007-August 2008

We suggest the application of both methodologies in a complementary way. Then compare their results with structural breaks and find similarities. We contribute by not only suggesting the explosive periods, but also by suggesting their causal drivers. Our results confirm Gronwald (2016) but not Fantazzini (2016). We suggest that the explosive periods are fundamentally explained. Fundamentals swifts caused the hikes and bursts. The sensitiveness of the PSY (2015) should be combined with the conservatism of the PWY (2011). What is more important than the bubble detection itself is the discovery of the causal drivers. Hamilton (2003) and Hamilton (1983) highlight the negative consequences of oil price swifts. Additionally, there is an asymmetry between oil price hikes and bursts. Any failed market perception can lead into wrong policy decisions and market hardships. Bernanke et al. (1997) attribute the output declines during the periods of high oil prices to the failed monetary policies. Kilian and Murphy (2014) propose that further regulations would not improve market efficiency as speculation has minor effects.

Last, the paper can contribute to the market dynamics' understanding and their causal drivers. Liquid and effective markets are achieved by applying prudent policies. Market failures lead in output collapses. Market volatility is even more prevalent since the shale revolution, and policymakers and stakeholders should target transparency and efficiency.

Since explosive periods are fundamentally explained, robust market analysis can result into prudent decision making.

Finally, supplementary research should be conducted by taking into account inflation (real against nominal prices). Volatility modelling could also be used, but it needs daily and not aggregated data (weekly, monthly etc.).

## **5 Crude oil price and production countries**

### **5.1 Saudi Arabia and OPEC**

#### **5.1.1 Introduction**

We study whether Saudi Arabia decides between the price/market-share perspective and not whether it suffers from the Dutch disease as Perifanis and Dagoumas (2017) do. Fattouh et al. (2016) describe Saudi Arabia as a rational market player trying to maximize its revenues. Under this perspective, crude oil is a commodity in scarcity and a producer would have the inclination to pump-out low quantities to keep prices high. This would help profit maximization if demand elasticity is low. However, Mabro (1991) challenged this idea arguing that producers could never maximize their revenues and that they only enjoyed increased revenues to those revenues they would realize in competitive markets. Pindyck (1978) suggests that oil monopolists were earning enough just to cover cartelization costs. Santis (2003) suggests the dominant role of Saudi Arabia and export quotas to explain crude prices and output changes. Further, the inelastic production curve of Saudi Arabia can explain the short-run price fluctuations. In addition, a negative demand shock would incline Saudi production to decrease. In contrast, when there is a significant positive demand shock, then the Saudis will not increase their production.

Further, oil revenues are realized by countries with different production and reserves profiles. This is why Eckbo (1976) separated countries by their earnings time preference and endowment. Then the countries were characterized as price pushers, hard-core and expansionist fringe. Since Saudi Arabia has large reserves, ample spare capacity, low production costs and low borrowing costs, then it would favor lower present prices, while other producers would prefer earlier profit maximization. However, Kaufmann et al. (2004) propose that production quotas and capacity utilization, cheating (production over production quotas) and OECD inventories can explain crude oil changes. Kaufmann et al. (2008) propose that OPEC's behavior is not limited to a single industrial organization model since this would leave out real world complexities. Further, not all countries have

the same profile to follow the same policy, even if they constitute a producers' organization.

However, Industrial Organization (IO) theory continues to suggest that a producer has to decide between price and volume. This has to do with the revenues one producer enjoys either by volume or price. If a market share increase does not compensate for the lower prices, then lowering production is the best action. Oil production changes follow demand changes with a lag. Demand is not monitored or posted every day or monthly with absolute accuracy. The result is that both elasticities are lower than one in the short-run. Mabro (1998) suggest that if a producer increases its market share during a low-price environment, then its earnings decline. However, Alkathlan et al. (2014) challenge Mabro's (1998) suggestion as monolithic. Under their claim, production periods are divided into "normal" and those with disruptions. Saudi Arabia swings between two policies. During "normal" periods it cooperates with the rest of the OPEC members, while the kingdom intervenes when there are disruptions. The Saudi policy is to keep OPEC's quantities constant. Saudi Arabia has the incentive to keep prices constant, if not increase them due to the local capital markets and welfare. Mohanty et al. (2011) suggest that there is significantly positive correlation between price and Saudi stock market returns. Alhassan et al. (2018) suggest that oil-using companies experience positive returns with lagged oil price returns, while they decrease with lagged oil volatility.

The crucial is who among the oil exporters and at what extent will cut production. Saudi Arabia, long-perceived as the swing producer, denies its priority for production cuts. Saudi Arabia further promotes collective action against adverse price changes. Collective acting also includes non-OPEC members. However, this is extremely difficult since coordination proved extremely difficult between OPEC members in the past. Furthermore, numerous efforts to designate volumes based on country specifics failed. But even if volumes are allocated, an instant monitoring procedure does not exist, nevertheless a certain punishment for the cheater. If cheating becomes prevalent, then this will be identified months later. All the aforementioned are described by Kohl (2002), and Libecap and Smith (2004).

Geroski et al. (1987) had added that perfect collusion is impossible since competitors' decisions are also determinants. Almoguera et al. (2011) suggest that producers constantly choose between collusion and non-cooperation. However, MacAvoy (1982) denounces cartel models and suggests that oil price changes can be attributed to fundamentals. Griffin (1985) used several models like the competitive cartel, target revenue and property rights for eleven countries participating in OPEC. Teece (1982) and Griffin and Nielson (1994) suggest that Saudi Arabia only prefers profits over than those of the Cournot equilibrium. However, if OPEC's members largely deviate from allocated production quotas, then Saudi Arabia intervenes with production increases punishing the rest of the producers and bringing profits back to Cournot equilibrium.

However, it is unquestionable that Saudi Arabia denounces price wars, Stigler (1964) using game theory recognizes price wars as the signs of collusion. Porter in a series of papers (Porter 1983a, 1983b and Green and Porter 1984) finds price wars as the aftermath of non-cooperation games. Every producer utilizes his full capacity when prices are high and does not want to decrease production since this would mean even higher prices for the rest. If the prices decline then a producer considers the trade-off between short-term revenues and competitors' decisions in an effort to increase market share. Haltwinger and Harrington (1991) find that collusion is difficult when demand is decreasing. The last might explain the ample spare capacity kept by the Saudi Arabia. If an exporting country tries to exploit any market development, Saudi Arabia punishes the disruption with increased production as the discipline enforcer.

Hamilton (1983, 2003) suggests that positive oil price shocks have a significantly negative influence on economies. Further, Hamilton (2003) proposes an asymmetry since negative price shocks have greater influence than positive ones. However, Hamilton (2005) proposes that oil shocks have a diminishing influence. Mory (1993) calculated the GNP elasticity at -0.0551. Instead, Hooker (1996) rejects that oil price shocks have the same influence they had in the past, and suggests a structural break in 1975. Since then GDP and unemployment remain neutral to oil price changes. Bernanke et al. (1997) propose that energy costs constitute a small portion of total costs in an economy. They

further suggest that it was the monetary policy which had a negative impact on the economy during periods of high prices. Gault (2011) calculates that a 10\$/bbl. increase at 100\$/bbl. would significantly influence price index and disposable income. Gault (2011) further adds that increased oil prices reduce income in related sectors driving to deeper GDP decline.

Difiglio (2014) proposes that the negative effects caused by positive oil price shocks can be severely mitigated if countries release volumes from their stocks in time. Further, the US should increase their strategic reserves and tanker loading capacity, while strategic reserves should be sold directly to oil refineries. Bai et al. (2016) calculate the appropriate size acquisition, drawdown and refiling policy of strategic inventories. They conclude that in order to avoid GDP declines, countries should release all of their inventories in some cases. Bai and Dahl (2018) find that strategic reserves work as an insurance. They calculate that the cost for holding the inventories is 219\$ billion for the US, while the total benefit is close to 122\$ billion. The calculation does not include the risk decline, which is not negligible. They add that OPEC effects can be mitigated by governmental stockpiles. However, OPEC should be still considered as the dominant player in the oil market. OPEC's influence can be even mild if OECD drawdowns take place, let alone if other major emerging economies contribute. Rose et al. (2017) add that in a 90-day oil disruption, reserves have significantly resilient properties.

We continue our dissertation with data, methodology and results sections.

### **5.1.2 Data**

Saudi oil production is influenced by market fundamentals like global demand and supply. This is why we try to set a framework with three Error Correction Models (ECMs). The first for Saudi Arabia's production, the second for crude oil prices and the third for global demand. Our data are annual and for the period 1980-2017 by the Energy Information Agency (EIA), World Bank and OPEC annual statistical bulletin.

Our variables are used with the following abbreviations:

WD: World demand

GDPPC: GDP Per Capita

PRA: Real Price of crude average

OECD: days that OECD crude oil stocks can cover OECD crude oil demand

OECDP: OECD crude oil production

OPECP: OPEC crude oil production

SCOP: Saudi Arabia's crude oil production

SCEXP: Saudi Arabia's crude oil exports

STEXP: Saudi Arabia's total petroleum exports (crude oil and refined products)

We used the EIA database for global crude demand, Saudi Arabia's total petroleum exports (both crude oil and refined products), OECD crude production and OPEC production. Knoema database supplied Saudi Arabia's total oil exports and Saudi Arabia's crude oil production. All our variables are in thousand barrels per day (bbl./d). In order to calculate the days ahead of consumption, we divide OECD crude oil stocks by OECD crude oil consumption. World Bank supplied the average real 2010 \$/bbl. price, which is derived from the average of Brent, Dubai, and WTI. Additionally, the 2010-dollar World GDP per Capita is supplied by World Bank. All variables are transformed into natural logarithms.

We test all our data for stationarity. All of them are non-stationary at levels, but their first differences are stationary. We use the Zivot and Andrews (1992) test. The results for stationarity are presented in Table 5.1.1. Since our data are stationary at  $I(1)$ , then we test the levels for cointegration i.e. if a long-term relationship exists between our variables. We test for cointegration with the Johansen Cointegration test in order to avoid spurious models. The test is conducted at 5% level and we use both Trace and Eigen

values. The lags for the cointegration test are determined by the Akaike and Schwarz criteria.

**Table 5.1.1** Test for unit roots 1980-2017

Level	Zivot and Andrews test	First difference	Zivot and Andrews test
WD	-4.66b	$\Delta$ (WD)	-5.73
GDPPC	-3.89a	$\Delta$ (GDPPC)	-5.18
PRA	-3.27a	$\Delta$ (PRA)	-6.84
OECD	-3.55a	$\Delta$ (OECD)	-5.88
OECDP	-4.14a	$\Delta$ (OECDP)	-4.82c
OPECP	-4.20a	$\Delta$ (OPECP)	-6.21
SCOP	-4.71b	$\Delta$ (SCOP)	-11.59
SCEXP	-4.40a	$\Delta$ (SCEXP)	-10.18
STEXP	-4.46a	$\Delta$ (STEXP)	-10.39

Notes: The null hypothesis of the Zivot and Andrews (1992) test is that the variable is stationary. The first difference of the series is indicated by  $\Delta$ .

<sup>a</sup> Indicates rejection of the null hypothesis at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates rejection of the null hypothesis at 1% and 5%.

<sup>c</sup> Indicates rejection of the null hypothesis at 1%.

**Table 5.1.2**

Johansen's maximum likelihood method test for cointegration relationship

Saudi production model

Intercept no trend

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	49.29	33.87
$r\leq 1$	$r=2$	22.51	27.58
Trace statistics			
$r=0$	$r\geq 1$	89.31	69.81
$r\leq 1$	$r\geq 1$	40.02	47.85

Trace indicates 1 CE at 5% level

\*\*MacKinnon-Haug-Michelis (1999) p-values

**Table 5.1.3**

Johansen's maximum likelihood method test for cointegration relationship

Crude Price Model

Intercept no trend

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	49.37	33.87
$r\leq 1$	$r=2$	28.69	27.58
$r\leq 2$	$r=3$	18.70	21.13
Trace statistics			
$r=0$	$r\geq 1$	105.53	69.81
$r\leq 1$	$r\geq 2$	56.15	47.85
$r\leq 2$	$r\geq 3$	27.46	29.79

Trace indicates 2 CE at 5% level

\*\*MacKinnon-Haug-Michelis (1999) p-values

**Table 5.1.4**

Johansen's maximum likelihood method test for cointegration relationship

World Demand

Intercept no trend

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	30.76	27.58
$r \leq 1$	$r=2$	14.32	21.13
Trace statistics			
$r=0$	$r \geq 1$	57.67	47.85
$r \leq 1$	$r \geq 2$	26.91	29.79

Trace indicates 1 CE at 5% level

\*\*MacKinnon-Haug-Michelis (1999) p-values

### 5.1.3 Methodology

We apply the Engle and Granger (1987) methodology to derive both short and long-term elasticities. The elasticities are the respective coefficients since our variables are in natural logarithms. Further, we use the residuals ( $u_t$ ) from the long-term models lagged by a single period as time series. This is the Error Correction Term and written as  $ECT_{-1}$  in the short-term models. In our short-term models, we use the first differences of our models.

We test our fittings, since we have the residuals from the long and short-term models, for homoscedasticity, serial correlation, and normal distribution. Furthermore, we attempt to model our relationships with the highest  $R^2$  and adjusted  $R^2$ .

Finally, we use the Auto Regressive Moving Average (ARMA) methodology to avoid correlation. Conditional Least Square (CLS), and Gauss-Newton methodologies were also applied.

### 5.1.3.1 Saudi Arabia's crude production

We assume that the crude oil production of Saudi Arabia is determined by the signals the kingdom receives. Saudi Arabia must react to signals like the world oil demand, crude oil price, stocks and its own petroleum exports. We also studied models with OECD crude production, Saudi crude exports, and market shares but did not have the best explanatory ability giving insignificant coefficients.

We presume that Saudi Arabia will attempt to satisfy demand increases. This will help profit maximization since one can make up profits either by increasing prices (low volumes) or increasing market share (low price). This is the trade-off dilemma a producer faces.

Our long-term model is:

$$SCOP = c + b_1 * WD + b_2 * PRA + b_3 * OECDD + b_4 * STEXP + u_{t1} \quad (5.1)$$

Where all variables are in natural logarithms. Saudi crude oil production is SCOP, World crude demand is WD, the annual aggregate 2010 US \$/bbl. price is PRA, the number of days of consumption the stocks can cover is OECDD, and the Saudi total exports including crude oil and refined products is STEXP. The  $u_t$  is the residuals or disturbance term. It is further lagged as the  $ECT_{-1}$  in the short-term models. The short-term model is:

$$\Delta(SCOP) = b_1 * \Delta(WD) + b_2 * \Delta(PRA) + b_3 * \Delta(OECDD) + b_4 * \Delta(STEXP) + ECT_{-1} \quad (5.2)$$

### 5.1.3.2 Crude oil price

For the pricing of the crude oil, we apply the third model which also includes OECD's crude production (OECDP) and OPEC's crude oil production (OPECP):

$$PRA = c + b_1 * WD + b_2 * OECDD + b_3 * OECDP + b_4 * OPECP + u_{t2} \quad (5.3)$$

With again apply the same principles as in model (4.2):

$$\Delta(PRA) = b_1 * \Delta(WD) + b_2 * \Delta(OECDD) + b_3 * \Delta(OECDP) + b_4 * \Delta(OPECP) + ECT_{-1} \quad (5.4)$$

### 5.1.3.3 World crude oil demand

The basic assumption is that world crude oil demand is influenced by global crude price and economic growth. We incorporate the total Saudi crude oil exports to investigate the kingdom's power over demand so we have the long-run model:

$$WD = b_1 * PRA + b_2 * GDPPC + b_3 * SCEXP + u_{t3} \quad (5.5)$$

And the short-run model is:

$$\Delta(WD) = b_1 * \Delta(PRA) + b_2 * \Delta(GDPPC) + b_3 * \Delta(SCEXP) + ECT_{-1} \quad (5.6)$$

Where GDPPC is the global GDP per capita in 2010 US dollars and SCEXP is the Saudi crude exports.  $\Delta$  again is the first differences.

## 5.1.4 Results

### 5.1.4.1 Saudi Arabia's crude oil production, long-run model.

The long-run coefficient for demand is lower than 1 (0.56) and positive. World oil demand positively affects the Saudi production meaning that Saudi Arabia tries to satisfy more than half of a demand increase but also leaves space for the rest of the producers. Satisfying almost all of a demand increase would cause disruption with other oil producers. If the kingdom over satisfied the demand, then oil prices would decrease. The

inelastic reaction also protects oil reserves from depletion. The days ahead of OECD stocks could cover consumption are insignificant implying that Saudi Arabia follows a production strategy irrespectively of the customers' stocks. Further, this is in accordance with the characterization of the inventories as "Strategic" implying that they are drawdown only in cases of supply disruptions. The elasticity of Saudi production to oil price is again positive and very low (0.02) implying that the kingdom follows a long-term strategy to maintain earnings and market share constant. In addition, the kingdom is sensitive to oil exports, and can easily respond, as it holds ample spare capacity. Saudi Arabia's production must be intensified only 0.74% to increase total exports by 1%. The ability to increase total exports more than production highlights the importance of high reserves, low production costs, and infrastructure for Saudi Arabia. The elasticity is close to 1 but lower meaning that their production strategy is not monolithic. They will not start to produce and export without considering the repercussions. This is in accordance with the trade-off theory (low volumes-high price or high volumes-low price). We would like to mention that our models with the Saudi market share did not provide results with statistically significant results. This might be explained by the Saudi ignorance to the market share.

**Table 5.1.5** Saudi crude oil production model – Long Run and Short run (SCOP)

Variables	Coefficients	Std. Error	Coefficients	Std. Error
C	-3.99 <sup>a</sup>	0.44		
WD	0.56 <sup>a</sup>	0.05		
PRA	0.02 <sup>b</sup>	0.009		
OECD	0.01	0.02		
STEXP	0.74 <sup>a</sup>	0.01		
$\Delta(WD)$			0.53 <sup>b</sup>	0.19
$\Delta(PRA)$			0.01	0.01
$\Delta(OECD)$			0.05 <sup>b</sup>	0.02
$\Delta(STEXP)$			0.75 <sup>a</sup>	0.02
ECT <sub>-1</sub>			-0.73 <sup>a</sup>	0.19

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

#### 5.1.4.2 Saudi Arabia's crude oil production, short-run model.

The short run elasticity is almost identical to that of the long-run model (0.53). The short-run elasticity is lower than the long-run model implying the inconvenience to adjust at the same levels as the kingdom does in the long-run. This is in accordance with the Le-Chatelier principle (Milgrom and Roberts 1996). Saudi Arabia, more or less, follows the same strategy in the long and short-run. This will keep its earnings constant, while maintaining its ample spare capacity. The advantage of ample spare capacity keeps the long and short-run elasticity constant. The oil kingdom can keep its production strategy unchanged against demand swifts. Moreover, the lower than 1 elasticity implies the production sharing policy which avoids the disruption with other producers. Saudi Arabia avoids unilateral actions or decision making in silos. The elasticity to price is half of that in the long-run (0.01). The sign is positive meaning that the exporter intensifies its production when prices rise. However, this is extremely low since an abrupt response would jeopardize equilibrium. The significantly low price elasticity does confirm that Saudi Arabia is a price smoother, especially in the short-run. In conjunction with the demand

elasticity, the kingdom tries to catch price increases but avoids to overproduce since this would bring prices down. This would be verified if we had elastic elasticities. Further, the Saudi production is competitive to OECD stocks since the respective elasticity is significant, positive, and low (0.05). The last implies that Saudi Arabia attempts to drive oil glut out-of-money making inventory holding cost ineffective. Since oil glut is driven out of the market, then the market is tighter. Saudi Arabia considers stocks only in the short-run as it may have not the resources to do the same in the long-run. As for the total exports, the coefficient is almost identical (0.75) meaning the Saudi persistence to keep its absolute exports constant. The last implies that Saudi production strategy does not change irrespectively of the horizon, and that there is an optimal level where revenues are satisfactory without causing disruptions. Moreover, the positive sign and the close distance to 1 implies that Saudi Arabia is eager to defend its total exports. The persistence explains why traditional oil exporters kept up exporting in a decreasing price environment between 2014 and 2016. The  $ECT_{-1}$  or speed of adjustment is 73% implying that the short-run model adjusts 73% in a year to the long-run model.

#### *5.1.4.3 Crude oil price, long-run model.*

We use as determinants global demand, days ahead of OECD consumption for oil stocks, OECD production, and OPEC production for crude oil prices. Further, in order to have a good fit, we used ARMA methodology and the Berndt-Hall-Hall-Hausman likelihood optimization method.

Almost all of our coefficients are significant. Only the autoregressive coefficient is statistically insignificant. The world demand is a heavy influencer of price. The elasticity is as expected positive and high (8.04). This might be also explained by the strong demand by emerging economies. Price is mainly demand-driven. Further, the assumption of an energy-intensive demand is verified. The coefficient for the stocks is negative and less than 1 (-0.78). Stocks are deflating oil prices. Our results are in agreement with Difiglio

(2014), Bai et al. (2016), Bai and Dahl (2018), and Rose et al. (2018). Stocks mitigate oil supply disruptions.

Further, OECD production again has deflating principles. The elasticity is -3.97 meaning that a 1% increase would deflate crude prices by 3.97%. Among OECD countries are the US where the shale revolution took place. The relation is elastic meaning that crude prices respond over OECD production. This might be explained by the transformation of some OECD countries from net importers to exporters making more volumes available to other countries. The result is that the market is less tight and oil glut prevails. Moreover, OPEC production has an elasticity of -2.63. The negative sign again confirms theory as supply decreases prices. The relationship is again elastic. However, OPEC production influences prices less than that of OECD. OPEC's less influence implies the less dominant role of the oil cartel in the modern world. Saudi Arabia is a key player within the organization, and the lesser role of OPEC results in the mandate of more multilateral decisions. The last explains the later summits with non-OPEC members, where collective action was decided.

Last, all of our elasticities are high enough (except for the day-ahead consumption of OECD inventories) implying abrupt responses and as a result more volatility for the oil market. Crude oil information absorption is faster in the modern eras.

**Table 5.1.6** Crude oil price model – Long Run and Short run (PRA)

ARMA Maximum Likelihood (OPG-BHHH)

Variables	Coefficients	Std. Error	Coefficients	Std. Error
C	-16.38 <sup>c</sup>	8.17		
WD	8.04 <sup>a</sup>	1.80		
OECD	-0.78 <sup>b</sup>	0.34		
OECDP	-3.97 <sup>a</sup>	1.00		
OPEC	-2.63 <sup>a</sup>	1.04		
AR(1)	0.03	0.32		
MA(1)	0.51 <sup>c</sup>	0.27		
$\Sigma Q$	0.04 <sup>a</sup>	0.01		
$\Delta(WD)$			3.36	4.98
$\Delta(OECD)$			-0.35 <sup>c</sup>	0.20
$\Delta(OECDP)$			-0.67	1.78
$\Delta(OPEC)$			-2.59 <sup>c</sup>	1.35
AR(1)			-0.47	0.37
MA(1)			1.00	4208
$\Sigma Q$			0.03	2.88
ECT-1			-0.83 <sup>a</sup>	0.25

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

#### 5.1.4.4 Crude oil price, short-run model.

In the short-run model, demand is statistically insignificant implying the difficulty in monitoring the global demand. The days-ahead OECD inventories can cover demand are statistically significant at 10% but they lose half of their magnitude (-0.35). This is hard to explain as they should have more power in the short-run. The last might be explained by the fact that the drawdowns are not easily reported in the short-run. Further, this might also imply infrastructure bottlenecks and inability by inventories to reach fast enough the market. The OECD production coefficient is insignificant while the OPEC production is significant at 10%. In addition, OPEC production's elasticity is almost identical to that of the long-run model. The OPEC production has the same influence highlighting the

advantages of ample spare capacity, big reserves and low production costs. The significance of OPEC, in contrast to the OECD production in the short-run, makes apparent that the oil organization can act instantly mitigating supply disruptions. But it also highlights the power and the influence the traditional producers have. OPEC is playing a crucial role both in the short and long-run and this power is only mitigated by the OECD production only in the long horizon.

The  $ECT_{-1}$  is high (-0.83) again implying that the short run results adjust to the long-run equilibrium by 83% in the first year. A very fast adjustment.

#### 5.1.4.5 *World crude oil demand, long-run model.*

Additionally, we examine the determinants of global oil demand. We use as factors the oil price, World GDP per capita and Saudi crude exports.

The demand elasticity to price is -0.01, which is something expected. A price increase decreases demand but the elasticity is extremely low. This is justified by the energy intensity and the global dependence on oil. The relationship is inelastic and demand does not overreact to price fluctuations. This makes apparent that there is low substitution between the energy sources. Further, emerging economies add to oil demand as they develop. Our results confirm previous works by Hamilton (1983, 2003, and 2005) and Gault (2011) who suggest the negative relationship.

The elasticity to global GDP is inelastic (0.70). Demand will increase 0.70% if GDP increases by 1%. The positive relationship between output and demand is expected as new consumers alter their habits, let alone global development requires energy fueling. The last is in agreement with Kumhof and Muir (2014) who suggest that income elasticity is almost 1. Our elasticity is less than 1 implying increased energy efficiency. The elasticity to the Saudi exports is low and positive (0.02). The positive relationship implies the assurance that the kingdom provides to demand. However, is low implying that the whole demand can not be left on Saudi Arabia's exports only.

**Table 5.1.7** World crude oil demand model -Long Run and Short run (WD)

ARMA Conditional Least Squares (Gauss-Newton)

Variables	Coefficients	Std. Error	Coefficients	Std. Error
PRA	-0.01 <sup>c</sup>	0.006		
WGDPPC	0.70 <sup>a</sup>	0.13		
SCEXP	0.02 <sup>b</sup>	0.008		
AR(2)	1.00 <sup>a</sup>	0.0007		
MA(1)	0.99	1.19e <sup>-5</sup>		
$\Delta$ (PRA)			-0.01 <sup>a</sup>	0.004
$\Delta$ (WGDPPC)			0.93 <sup>a</sup>	0.08
$\Delta$ (SCEXP)			0.006	0.007
AR(2)			-0.28	0.18
MA(1)			0.97 <sup>a</sup>	0.02
ECT <sub>-1</sub>			-0.62 <sup>a</sup>	0.10

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

#### 5.1.4.6 World crude oil demand, short-run model.

The short-run model has the same elasticity to price (-0.01). The elasticity to GDP per capita is higher (0.93) but remains inelastic. The higher elasticity might be explained by the increased short-run demand for oil in emerging economies. This is not in compliance with the Le Chatelier principle. The main conclusion is that demand will continue to grow since global development requires energy and consumers change habits in emerging economies, while there is low substitution. The higher absolute value might also imply the transportation expansion in emerging economies. The elasticity to Saudi crude exports is almost zero. The even lower positive elasticity in the short-run makes apparent the lesser role of Saudi exports for demand. Demand is less sensitive in the short-run. Last, the  $ECT_{-1}$  or the speed of adjustment is high implying that 62.33% of the change occurs in a single year.

### **5.1.5 Conclusions**

Saudi Arabia holds intensive interest in keeping oil prices high. High oil prices imply limited supply. This balance supply is designated to OPEC. However, OPEC members do not stick to their production quotas due to production mismanagement and earnings targets. Further, shale production in the US influences oil prices, OPEC's revenues and market shares. Saudi Arabia as a major producer has to consider all the market developments for a production strategy.

The chapter investigates Saudi Arabia's crude oil strategy in conjunction with the market fundamentals and macro-economic factors. We developed three models accounting for Saudi Arabia's oil production, crude pricing and world oil demand. Our models provide evidence on Saudi Arabia's strategy in conjunction with OECD stocks, oil prices, oil demand, OECD crude oil production and Saudi total exports.

First, the Saudi kingdom attempts to comfort world crude oil demand by increasing its production. When oil demand increases, then Saudi Arabia attempts to catch higher prices with larger volumes. However, it does not catch all of the demand since it leaves almost half of the increased demand. Our results confirm production sharing strategy. Saudi Arabia does not prefer to overreact as this would bring prices down. This also keeps reserves' production life at high levels. On the contrary, if Saudi Arabia was abruptly adjusting its production levels, it would decrease its available reserves. In addition, Saudi Arabia tries to achieve a pivotal role in global oil production. The kingdom tries to exploit demand hikes without putting long-term demand under threat. What is important is that Saudi Arabia is following the same strategy in the short-run. The short-run elasticity is almost identical to the long-run implying that the oil kingdom keeps its production strategy constant. The production strategy is not responsive to market developments. The stability of the production strategy does not disrupt the relations with other producers. Additionally, Saudi Arabia does not overreact to price fluctuations and this is why it has a very low elasticity. The short-run elasticity is even lower. Production levels

remain constant irrespective of the long and short-run price fluctuations. Keeping production levels stable preserve employment and welfare allowance at high levels. Saudi Arabia's production is unaffected by OECD stocks in the long-run, while in the short-run it barely adjusts (+0.05). The statistical significance and the positive sign of OECD stocks only in the short-run imply competitive production behavior. By augmenting production, and thus reducing oil prices, stock holding becomes less cost effective. Saudi Arabia attempts to balance the market. OECD countries have agreed to keep strategic inventories and by doing so they pay for wages and infrastructure. The dilemma for oil consumers is whether they should hold stocks or just import oil. Our results confirm the trade-off dilemma (low production-high price or high production-low price) since Saudi Arabia increases production to defend its exports. This explains the reason why Saudi Arabia kept its production high in a low-price environment due to the shale revolution. Saudi Arabia can keep or increase its exports due to the ample spare capacity it holds, low upstream costs and large reserves. Short and long-run elasticities are identical for total exports since the country enjoys low costs at increased production levels.

Crude prices are more sensitive to OECD production than OPEC's in the long-run. Saudi Arabia is a prominent member of OPEC. This is the reason why Saudi Arabia seeks multilateral decisions since the opposite would decline production share in a low-price environment. Our result is further strengthened by the OPEC's conclusion "to conduct a serious and constructive dialogue with non-member producing countries, with the objective to stabilize the oil market and avoid the adverse impacts in the short- and medium-term.". New global producers limit the influence of Saudi Arabia and OPEC in general in the long-run. However, only OPEC production is significant in the short- run implying that for OPEC is easier to reach the markets. Traditional oil exporting countries have enough infrastructure and expertise to reach markets timely. On the contrary, OECD countries have not yet the infrastructure to export quantities, and as thus their production is not important in the short-term. OPEC's production still has the advantage in the short-run, while in the long-run it sees its role to shrink. In the long and short-run, demand has an important influence on world prices (elasticities well over than one).

LeChatelier principle is confirmed since short-run elasticity is lower than the long-run. The high elasticities confirm the low substitution of oil since prices overreact to demand shifts. Demand can spread volatility since minor changes can have great impact on oil prices. OECD stocks play an important role since they decrease prices but their influence is greater in the short-run.

Low substitution between energy sources is again confirmed both in the long and short-run since demand elasticity to prices is very low (-0.01). Our results confirm Hamilton (2005, 2003, and 1983) and Gault (2011), who suggest that economies are negatively affected by oil prices. Increased energy efficiency and lower energy intensity can tackle oil dependence and its negative side effects. Saudi exports are perceived as a guarantee for undisrupted consumption and they have a positive sign increasing demand. The main driver for global oil demand is global economy. Global development requires more oil (positive sign). When global economy is in recession, world oil demand declines. However, the elasticity of demand to global GDP is higher in the short-run implying the changing consumption habits in the emerging world. Consumers in emerging economies as soon as they have an income capable of conserving some habits turn their consumption to oil (cars etc.).

Finally, Saudi Arabia does not decide in strictly economic terms but rather it has more extended targets. Geopolitical targets or long-term share issues might make the price-share dilemma to coincide. This is why Saudi Arabia might set its production levels not at optimal levels but to more politically oriented targets such as the preservation of petroleum exports and its total market share.

## **5.2 Russian Federation**

### **5.2.1 Introduction**

The most prominent non-OPEC member which signed the Declaration of Cooperation is the Russian Federation. The Russian Federation and its predecessor USSR are always among the top producers. Oil exports and revenues are important since they account as major contributors to the country's balance sheet. Gaidar (2007) suggests that the collapse of the Soviet Union is the aftermath of oil prices' collapse. It was in 1986 and 1988 when oil prices collapsed and a few years later the superpower tumbled. Falling oil prices was again the reality between 2014 and 2016. The reality is clearly depicted by the report of the World Bank (2017) as demand continued to decrease due to the decreasing real income. Consumers' demand decreased 2.4% in a year. Fixed capital investment also decreased by 1.2% in 2016. Poverty rate increased 0.2% in 2016. Even if the ruble depreciated, the output growth was not backed by investment growth. The primary deficit grew from 1.7% of GDP in 2015 to 2.7% in 2017. Russia curtailed expenditures and proceeded with partial privatizations like that of the Rosneft. Moreover, civil servants' payroll was kept constant, while pensions were posted below inflation. Most of government spending decreased in real terms. Finally, a three-year federal budget law passed, and currency interventions were introduced. In 2017 oil prices increased rising federal revenues. Oil revenues constituted 7.6% of GDP from 2.2% in the respective period of January to March 2016.

It is easily understood that oil revenues account for a very significant portion of the Russian budget. Though it is extreme to conclude whether one economy suffers from the Dutch disease or not. Dependence does not necessarily mean suffering from the Dutch disease. We refer to the Dutch disease as the condition when one sector of the economy consists most of the exports or inflows. The inflows drive currency appreciation and high inflation. Since development is mainly concentrated in a particular sector, then capital and workforce follow. The rest of the economy remains undeveloped. When the undiversified economy receives a windfall in the developed sector, then the whole

economy suffers from high prices, manufacturing underdevelopment, high unemployment rates and deficits.

However, the Dutch disease is hard to be detected in an economy, especially before the economic blow. Pegg (2010) suggests the decoupled wages from productivity, infrastructure, underdevelopment, and income inequality as the main drivers for Botswana's economic hardships. The Dutch disease might be also suspected for Botswana's economy. Sosunov and Zamulin (2006) suggest that even if ruble appreciates due to exports' growth, the balance of payments will remain secure. Rajan and Subramanian (2009) suggest that developing countries should receive financial aid until they cover their absorptive capacity and not exceed it. If they do exceed it, then they will suffer from adverse exchange rates and the Dutch disease. Ahrend et al. (2007) blame ruble's appreciation for the weak industry growth. Brahmbhatt et al. (2010) warn that even if inflation targeting is a prompt policy, it is risky when commodities see their prices rising due to exchange appreciation. Egert (2012) studies the majority of the ex-Soviet countries to conclude that high oil prices drive nominal and real exchange rates' appreciation, and thus to economic underdevelopment. Habib and Kalamova (2007) suggest the ruble's exchange rates are oil price driven. Tabata (2013) suggests that the Russian economy suffered from the Dutch disease but its effects were mitigated by:

1. The elimination of the non-competitive manufacturing in the 90s leaving the fittest to survive.
2. Oil revenues and as a result increased domestic demand turned to domestic products.
3. Low energy costs for Russian industry
4. Central bank's monetary policy

Many argue that is not the Dutch disease which is present in the Russian economy but the transition process from the state economy to the free market. The transitory phase was coupled with recession which many anticipated. Beck et al. (2007) suggest that there were mixed signs since the Russian Federation attempted to decouple its economy from

oil prices, and hydrocarbons constituted only a small part of the economy while holding a developed industrial and human capital base. Oomes and Kalcheva (2007) agree on the mixed signs of the Dutch disease's presence even if they find all of the symptoms of the suffering i.e. manufacturing and employment slow down, increased role of the services sector and exchange rate appreciation. These might also be cast on the transition from the Soviet era to the free market. Dobrynskaya and Turkish (2010) conclude that Russia increased its industrial production between 1999 and 2007 even though signs of the Dutch disease existed. They further add that the Balassa-Samuelson effect (Balassa 1964 and Samuelson 1964) is to account for the ruble's appreciation. Egert (2012) suggests that the oil price increase is not transmitted to the nominal and real exchange rates of the post-Soviet countries until one to two years pass. Further, oil exports had a negative effect initially which turned to positive lately. Kerkela (2004) proposes that the subsidies are to blame for the most part of the economic distortion.

Usui (1998) studies Mexico and Indonesia in avoiding the Dutch disease. Usui (1998) proposes that Indonesia proceeded with due diligence, while Mexico followed a non-optimal policy. Basdevant (2000) finds that capital flights and structural reforms are equally important to public investment for private investment development. Beine et al. (2014) suggest that immigration has mitigating principles to the Dutch disease effects.

Finally, it is important to study whether there are incentives for the Russian Federation to cooperate as it did with OPEC. Russia remains the most prominent non-OPEC member of the Declaration of Cooperation. Its production magnitude, along with that of Saudi Arabia's, shapes the production strategy of many other countries. Furthermore, Russian production along with that of OPEC constitutes the majority of traditional exploitation and a significant part of the global production. We research that complexities of the Russian economy by studying two macroeconomic figures, GDP Real Index and government expenditure.

### **5.2.2 Data**

We use data from 1<sup>st</sup> of January 1995 to 31<sup>st</sup> of December 2014. Oil prices started to decrease from 2014 (highest level) to 2016. Our variables are the GDP real Index for Russia (DPPRI), the government expenditure (EXPD), the Industrial Production Index (IPI), the crude oil (petroleum) price (COPW), and unemployment (UNEMP) for the first model. For the second, we use the government expenditure (EXPD), the crude oil (petroleum) price index (COPIW), the Russian oil production (PRUSSIA) and the GDP real Index for Russia (DPPRI). The Russian production is in thousand barrels per day and from the EIA database. The government expenditure is from Knoema database and in nominal currency after the removal of inflation. The rest are from the IMF database. The GDPRI is the real index. Industrial production is again an index, COPW is in US dollars and COPIW is again an index. Unemployment is the respective rate. Our data are for year quarters and transformed in natural logarithms.

We proceed with the Augmented Dickey Fuller (ADF), Phillips-Perron (PP) and KPSS tests for stationarity. All of our variables are stationary at their first differences (Table 5.2.1). We then proceed with the Johansen cointegration test. If our data are cointegrated, then a long-run relationship exists. Since our data are cointegrated, then we can proceed, even if our data are not stationary at levels, and our results will not be spurious. The cointegrating equation accounts for the long-run model, while the VECM is for the short-run equilibrium.

**Table 5.2.1** Stationarity tests

Level	ADF	Phillips-Perron	KPSS	First difference	ADF	Phillips-Perron	KPSS	Order of integration
GDPRI	-0.7443	-0.963	1.20 <sup>a</sup>	D(GDPRI)	-4.081 <sup>a</sup>	-14.375 <sup>a</sup>	0.072	I(1)
IPI	-1.028	-1.099	1.089 <sup>a</sup>	D(IPI)	-4.393 <sup>a</sup>	-14.710 <sup>a</sup>	0.126	I(1)
EXP	-3.30	-3.30	1.237 <sup>a</sup>	D(EXP)	-8.287 <sup>a</sup>	-8.327 <sup>a</sup>	0.584	I(1)
COPW	-1.604	-1.657	1.034 <sup>a</sup>	D(COPW)	-7.469 <sup>a</sup>	-7.303 <sup>a</sup>	0.175	I(1)
UNEMP	-1.615	-1.618	0.847 <sup>a</sup>	D(UNEMP)	-2.576 <sup>a</sup>	-10.722 <sup>a</sup>	0.337	I(1)
COPIW	-1.397	-1.164	-5.746 <sup>a</sup>	D(COPIW)	-6.116 <sup>a</sup>	-1.164 <sup>a</sup>	-1.167	I(1)
PRUSSIA	-1.032	-0.434	-1.152 <sup>a</sup>	D(PRUSSIA)	-2.110 <sup>a</sup>	-6.320 <sup>a</sup>	-0.209	I(1)

Notes: The null hypothesis of the ADF and Phillips-Perron tests is that a variable has a unit root, and the null hypothesis for the KPSS test is that a variable is stationary. The first difference of the series is indicated by  $\Delta$ .

<sup>a</sup> Indicates rejection of the null hypothesis at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates rejection of the null hypothesis at 5% and 10%.

<sup>c</sup> Indicates rejection of the null hypothesis at 10%.

### 5.2.3 Methodology

Our research focuses on the relationship between major macroeconomics and oil revenues. All our data are non-stationary at levels, while they are stationary at their first difference. We proceed with the Johansen test for cointegration. Johansen's test suggests whether there is long-run relationship between the variables. If the variables are cointegrated, then our models will not be spurious. We then model the relationships with Vector Autoregressive (VAR) models of second order, and then with Vector Error Correction Models (VECM). Since our VAR models are of second order (two lags), we can tell with confidence that they are white noise i.e. Gaussian Errors. Our VAR models are also with a constant. Further, we tested whether there was any polynomial root outside the unit circle (stability test). All of our models do not have a unit root outside the circle.

Tables 5.2.2 and 5.2.3 suggest that there is one cointegrating equation for each of our models or more simply there is a long-run relationship between the data and as a result the models are not spurious. Both Trace and Eigen statistics suggest that there is one cointegrating vector. We set the cointegrating equation equal to zero.

**Table 5.2.2**

Johansen's maximum likelihood method test for cointegration relationship for the GDPRI model

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5% critical value
Maximum eigenvalues			
$r=0$	$r=1$	43.98	33.87
$r \leq 1$	$r=2$	20.80	27.58
Trace statistics			
$r=0$	$r \geq 1$	86.48	69.81
$r \leq 1$	$r \geq 2$	42.50	47.85

Trace indicates 1 CE at 5% level

\*\*MacKinnon-Haug-Michelis (1999) p-values

**Table 5.2.3**

Johansen's maximum likelihood method test for cointegration relationship for the Government Expenditure model

Null Hypothesis $H_0$	Alternative Hypothesis, $H_1$	Eigen Value	5 % critical value
Maximum eigenvalues			
$r=0$	$r=1$	39.92	30.81
$r \leq 1$	$r=2$	19.18	24.25
Trace statistics			
$r=0$	$r \geq 1$	69.15	55.24
$r \leq 1$	$r \geq 2$	29.22	35.01

Trace indicates 1 CE at 5% level

\*\*MacKinnon-Haug-Michelis (1999) p-values

## 5.2.4 Results

### 5.2.4.1 Long-run models

Our normalized cointegrating coefficients by the cointegrating equation have the expected signs.

$$\text{GDPRI} = 0.5438 \text{IPI} + 0.1102 \text{EXPD} + 0.0315 \text{COPW} + 0.0153 \text{UNEMP} \quad (5.7)$$

(0.08807)      (0.00902)      (0.01995)      (0.02976)

The parentheses are the respective standard errors. The GDPRI is positively influenced by the Industrial Production index, expenditure and crude oil prices. Unemployment is statistically insignificant. We would expect a negative sign and to be significant. Since our data are logarithms, then our coefficients are the respective elasticities. All of our elasticities are inelastic. Industrial production contributes 0.54% if increased by 1%. Crude oil price inflates GDP by 0.03% if it is increased by 1%. Expenditure contributes to GDP by 0.11%. All in all, our first long-run model has correct signs and inelastic elasticities. GDP does not overreact to the changes of these macroeconomic factors. We continue with our second long-run model.

$$\text{EXPD} = 0.3808 \text{COPIW} + 0.1003 \text{PRussia} + 2.3038 \text{GDPRI} \quad (5.8)$$

(0.15353)      (0.51265)      (0.79015)

Our model for the government expenditure suggests that crude oil prices have a positive influence. The relationship is inelastic. Crude prices add to expenditure 0.28% if increased by 1%. The Russian oil production is statistically insignificant, while an increase of 1% of GDP real index positively influences expenditure by 2.30% (elastic). The relationship between GDP and expenditure is elastic meaning that expenditure is strongly influenced. The examined period is between 1995 and 2014. Through this period, the Russian Federation transformed from an ex-Soviet country to its current state. Massive changes and reforms took place. Due to the full sample modelling, our results are the aggregate of different transformative sub-periods.

### 5.2.4.2 Short-run models

We can now proceed with the short-run models. This is achieved by the VECM. Tables 5.2.4 and 5.2.5 present the respective results. We include a lagged term in our models to avoid autocorrelation.

**Table 5.2.4** VECM and short-run elasticities for the GDPRI model

Variables	Coefficients	Std. Error
C	0.0005	0.0011
D(IPI)	0.4780	0.0468
D(EXP)	0.0486	0.0121
D(COPW)	0.0301	0.0079
D(UNEMP)	0.0300	0.0162
D(GDPRI(-1))	0.1771	0.0565
ECT	-0.2389	0.0479
R <sup>2</sup>	0.8273	
Adj R <sup>2</sup>	0.8127	
Durbin Watson	2.0542	
BG LM test	0.5433 (0.5048)	
Arch test	0.9892 (0.9890)	
Jarque Bera	18.03 (0.0002)	

**Table 5.2.5** VECM and short-run elasticities for the Government expenditure model

Variables	Coefficients	Std. Error
C	0.0622	0.0192
Trend(95Q1)	-0.0008	0.0003
D(COPIW)	-0.0924	0.0638
D(PRUSSIA)	3.6657	0.9234
D(GDPRI)	0.7214	0.4892
D(EXP(-1))	-0.0520	0.0894
ECT	-0.3300	0.0517
R <sup>2</sup>	0.4363	
Adj R <sup>2</sup>	0.3887	
Durbin Watson	2.0240	
BG LM test	0.9274 (0.9184)	
Arch test	0.4673 (0.4608)	
Jarque Bera	29.4955 (0.0000)	

Our fitting for the first model is good since it can explain over 80% of our data (R<sup>2</sup>). For our first VECM, unemployment is statistically insignificant as it was also in the long-run. Industrial production positively influences GDP. GDP would increase 0.47% if industrial production was increased by 1%. The government expenditure also positively influences GDP. If expenditure is increased by 1% then GDP increases by 0.048%. The crude price elasticity is almost identical to that of the long-run model (0.03). Lagged term of GDP is also statistically significant. Last, the Error Correction Term is negative as it should be and is the speed of adjustment from the short to long-run equilibrium. The speed is relative slow as the adjustment will be 23.89% in the first year. Our short-run elasticities are lower than their respective long-run elasticities. This is in compliance with the Le-Chatelier principle.

Our second VECM has many insignificant coefficients. Russian crude oil production is significant meaning that government expenditure is influenced by it. Crude oil price is statistically insignificant implying that state expenditure is not adjusted due to short-run

crude oil shifts. The same holds for GDP since the Russian Federation do not adopt to the output in the short-run. Further, GDP is a hard to monitor macro-variable and it is not day-to-day posted. It is further highlighted that government expenditure is only adjusted to crude oil production. An increase in crude production by 1% would increase expenditure by 3.66%. The relationship is very elastic since a temporary crude production increase would heavily influence expenditure. The coefficient is even higher than the long-run model implying that production increases to boost expenditure are not sustainable in the long-run. The speed of adjustment is again slow as it is only 33%. What is highly mentioned by the low speed of adjustment is that the Russian macroeconomic indices are not easily adjusted. Our short-run elasticities are in agreement with theory.

Our analysis has not revealed the relationship between our variables in pairs. We only shed light on the short and long-run relationships between two variables and two groups of determinants. This is the reason why we apply the impulse response functions. Our results are presented in Tables 5.2.6 and 5.2.7. The IRFs are derived by our unrestricted VARs. They present the response of one variable to one standard deviation shock of the other. Our IRFs are for 12 periods ahead meaning 3-year horizons. In Table 5.2.6, we present the GDP's reaction to a standard deviation shock of industrial production. The response is a fading in time and positive. The greatest influence is two quarters later and it is less than 0.01%.

Government expenditure causes also a positive reaction in GDPRI. However, seven quarters are needed for the effect to reach its maximum level. This is again in agreement with our previous results since expenditure has a much lower coefficient than that of industrial production. Further, crude oil prices cause a mixed reaction to GDP. Initially, they cause a positive reaction with the peak reached two quarters later, but this turns into negative from the fourth quarter and onwards. It is implied that even if oil prices initially have a positive effect on output, the overall influence is mixed since it later becomes negative.

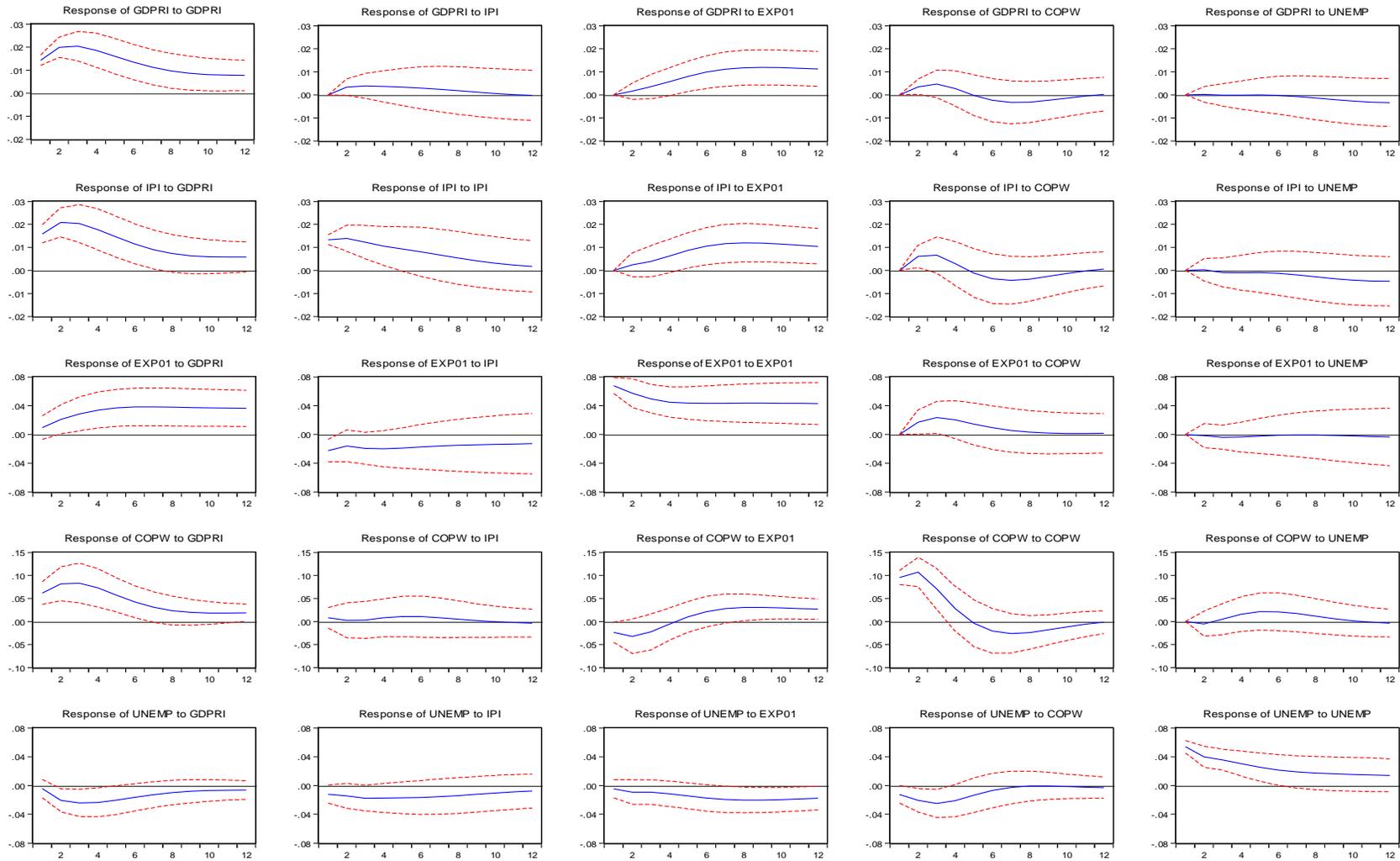
Moreover, the Russian industrial sector is mainly concentrated in the hydrocarbons. This is why the industrial index is influenced by crude oil prices in the same way as GDP. The response's peak is again after two quarters from the standard deviation shock and turns negative from the fourth quarter.

Expenditure has an almost instant response to crude oil prices since the relation is positive. The impulse reaches its peak in the fourth quarter and it is 0.4% after one standard deviation shock. However, after that it follows a fading course reaching zero levels.

Furthermore, GDP has a positive effect on state expenditure. This is in agreement with our expectations since expenditure would increase after an output's increase. Four quarters are needed for GDP's influence to reach its peak and then remains at the same level implying that the effect is permanent. Expenditure is also positively related to crude oil price since it has a positive response until the eighth quarter when it totally fades out. The IRF methodology confirms that state expenditure has zero response to unemployment. The result is verified by the expanding bounds of confidence.

**Table 5.2.6** Impulse response functions of the VAR for the GDPRI model

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.



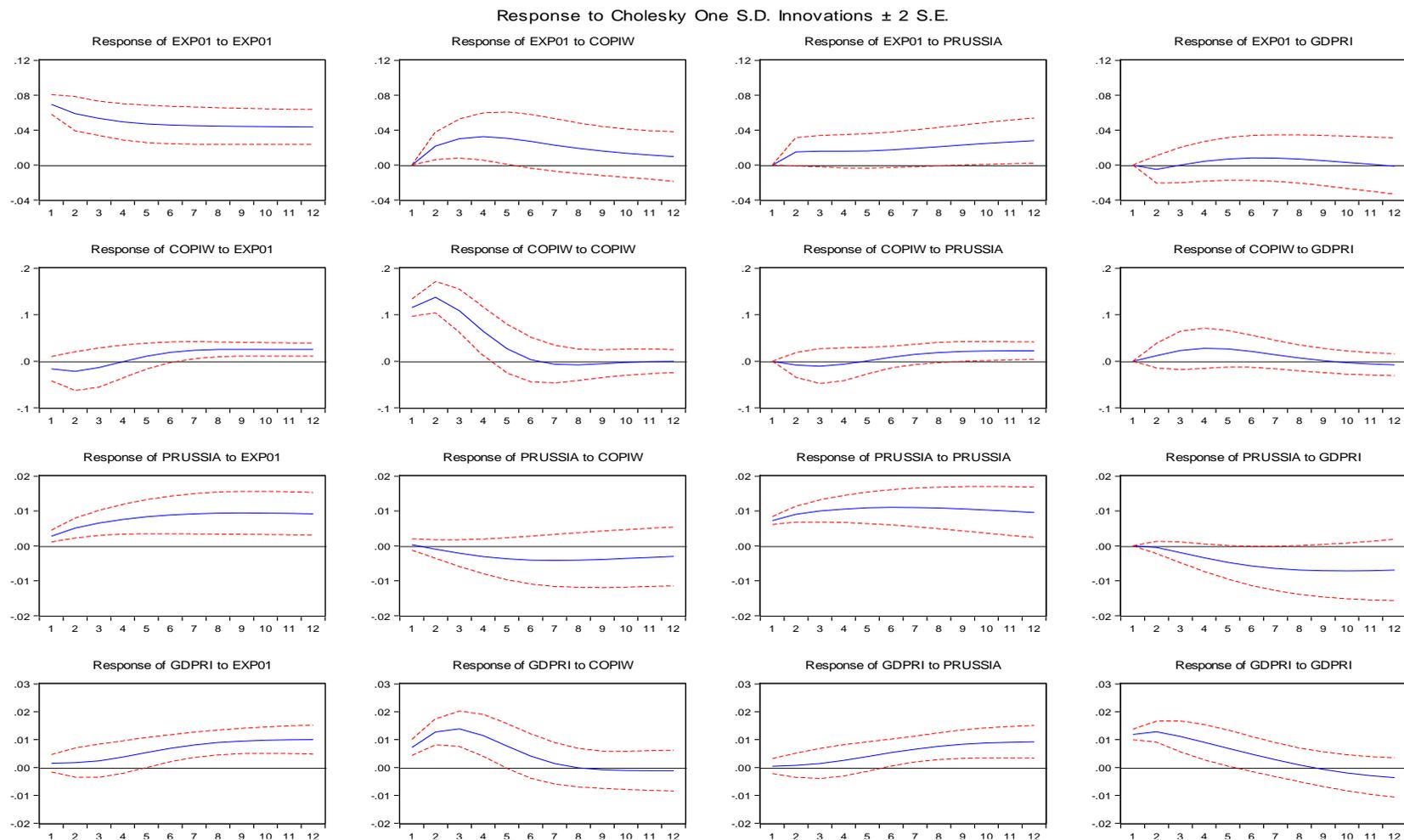
By our Table 5.2.7, we can present the response of state expenditure to a standard deviation shock of Russian production. The response is always positive since production revenues augment government expenditure. This is a suggestion that the Russian Federation is dependent on oil revenues. There is an ascending response until the second quarter. Since then it has a constant low growth.

The response of crude price to the Russian production is mixed. Initially, the response is negative since an increase in volumes is translated into a price decline. However, the relationship becomes positive from the fourth quarter and onwards. This confirms our models' results since production increases are not sustainable in the long-run.

Russia manages its resources as in scarcity. This is implied by the response of Russian production to a standard deviation shock of crude oil prices. The response remains always negative as Russia decreases production when prices increase. However, since the third quarter, the bounds of confidence turn extremely wide, something that makes harder to say the same continues for longer horizons.

Since Russia manages hydrocarbons as scarce and the exporting sector is mainly concentrated in that area, we would expect a negative response of Russian production to a GDP increase. This is our result by the IRF between Russian production and GDP. As GDP increases, oil production decreases to save reserves. However, the confidence intervals become wide from the third quarter implying that it is difficult to claim the same for longer horizons. Last, the IRF of GDP to Russian production remains always positive confirming that crude production has a positive influence over Russian GDP.

**Table 5.2.7** Impulse response functions of the VAR for the government Expenditure model



Finally, we can claim that Russian GDP is influenced by crude oil prices but it is also influenced by other economic factors. Further, in the short-term, Russian GDP is more sensitive to other determinants than crude prices. The elasticities of crude oil prices are inelastic and low both in the long and short-run. However, Russian GDP is also affected by the government expenditure, which in turn is affected by crude oil prices in the long - run. This confirms the dependence of GDP to hydrocarbon revenues. However, the expenditure is not influenced by the produced oil volumes. This might be explained by the inability to hold production at high levels in the long-term. Sustainable production might imply treating oil as a commodity in scarcity. Oil dependence might be implied by expenditure results and through expenditure to total output. Finally, we find results of at least oil dependency, but we can not claim the same for the existence of the Dutch disease.

#### **5.2.5 Conclusions**

The Russian Federation is researched on whether it is dependent on oil revenues or whether it is already suffering from the Dutch disease. The Dutch disease is present when one economy has one sector overdeveloped concentrating most of its resources there. The resources' inflow in one sector appreciates the exchange rate and increases inflation. When there is a blow for the overdeveloped sector, then the whole economy suffers.

In contrast to the already literature, we did not use the exchange rate as the main sign of oil revenue dependence. However, we use the total output and the government expenditure in order to research oil dependency. This allows us to examine the general oil dependency and not only the presence of the Dutch disease. The GDP is not only dependent on crude prices but also on other factors in the long-run. On the contrary, in the short-run the GDP is more sensitive to all other economic factors. Crude price elasticity is statistically significant and low (lower than one) and identical to that of the long-run model implying that the role of crude prices does not change irrespectively of the time horizon.

In addition, the Russian GDP is dependent on state expenditure. In the long-run, crude prices elasticity is significant and lower than 1 for capital expenditure. However, oil dependency might be present by the higher than 1 GDP elasticity (+2.30) for the state expenditure. In addition, in the short-run government expenditure is only influenced by oil production. The importance of oil production only in the short-run might imply the potential technological and production limitations of oil production. Produced volumes might not be retained for long periods.

All in all, even if we do not find evidence of the Dutch disease in the Russian economy, we do find evidence of dependency on oil revenues. This reason might explain the imminent response of the Russian Central Bank with a flexible exchange rate and expenditure curtailment to the oil prices' decline. Since prices rebounded, then the signs of the Dutch disease might be even less apparent. Our research confirms that the Dutch disease consequences are not present in the Russian economy due to prudent policymaking, while oil revenues dependence exists.

## 6 Crude oil price relation with LNG markets

### 6.1 Introduction

Crude oil remains the most traded commodity in the globe along with gold. This is the reason why oil, even if it is traded on different blend basis, is used as a pricing benchmark for other commodities. Apart from its own byproducts as the gasoline and heating oil, oil is a benchmark for natural gas. Natural gas does not belong to oil's supply chain. However, the two commodities are considered as substitutes. Initially, natural gas pricing was performed by long-term oil-indexed contracts. This was common for inter-state pipeline contracts pricing natural gas. However, the increasing natural gas traded volumes, and the decision to consider the commodity as the bridge fuel to the energy transition have altered the oil-indexed market. The dynamics make many consider that a global fully integrated market is achievable.

The relationship between oil and natural gas is challenged by the market dynamics which have been liberated by the shale revolution. The increase of the unconventional production, while OPEC refused to curtail production, drove oil prices to extremely low levels in 2016 (26\$/bbl.). This forced US producers to reduce operating costs, improve efficiency in all phases of research and exploitation, or even mothball wells. On the contrary, the US shale gas producers kept their production constant and uninterrupted as the US Lower 48 Production only decreased by just over one billion cubic feet per day. This was explained by the increasing demand for power generation since natural gas overtook coal.

BP energy outlook 2018 considers that energy demand will continue to increase in the US as well globally<sup>12</sup>. Global demand for oil will continue to grow as demand from emerging economies and their middle classes will rise. Liquids' demand will stop to grow with increasing ratios. The increase will be about 10 Mbbbl./d and the demand will plateau

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<sup>12</sup> <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf>

around 108 Mbbl./d in the 2030s. The US tight oil will initially cover most of the increase, and the OPEC will continue after shale oil increase. The OPEC will contribute 4Mbbl/d but all of the growth will be in the 2030s. Oil demand will be significant even until 2040. Further, global natural gas will continue to grow. The growth is led by industry and the power sector. Supply will also increase with North America in the forefront. The US along with Qatar will account for around 40% of LNG exports by 2040. The diversity of gas exports will lead to stronger competition between LNG and pipeline gas. The gas-to-gas competition and pricing will be the main scenario for Europe and China, two of the largest importers. Unless there is a global fully integrated market, supply will be tight.

EIA in its long-term outlook suggests that the US crude oil production will continue to rise through 2030, and will plateau at 14 Mbbl./d until 2040. Lower 48 on Shore will continue to account for 68% of total domestic production. The US natural gas production will increase by 1% per year after 2020 since domestic consumption will start to slow. Although the growing demand in domestic and export market will drive Henry Hub spot prices up. Natural gas prices will remain lower than 4\$ per Million British Thermal Units (MBTU) until 2035 and lower than 5\$ per MBTU until 2050. Tight and shale resources will account for almost 90% of dry natural gas production in 2050<sup>13</sup>.

The specific profile of the US market is very interesting since the market has undergone several developments. The transformation from an energy importer to an exporter and the tight revolution set new standards to the whole supply and demand chain. Additionally, to the supply shock the market made great steps to integration with the packages for interstate gas pipeline deregulation by the Federal Energy Regulatory Commission (FERC) in 2000<sup>14</sup>. However, the oil and gas exporting facilities remain largely underdeveloped adding to the supply glut. Infrastructure's development will help for a more integrated and fully operational global energy market, but it will make the US market tighter. Bernstein et al. (2016) propose that the US gas exports are non-competitive in the short-term, while they will become important when there will be

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<sup>13</sup> <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>

<sup>14</sup> <https://www.ferc.gov/legal/maj-ord-reg/land-docs/RM99-2A.pdf>

natural gas oversupply. The US gas exports are competitive only when there will be Russian supply disruptions or demand shocks (Asian). Nikhalat-Jahromi et al. (2016) suggest that LNG exporters could take decisions under their proposed profit maximizing model which takes into consideration the type of tanker, routing, inventory management, contract obligations, arbitrage and uncommitted LNG. Valle et al. (2017) research the drivers forming shippers' decision making in relation with natural gas hubs. They propose that virtual trading hubs offset shippers' marginal cost with the transparent gas hub price. This in turn increase shippers' earnings as it intensifies their flexibility. However, a gas hub alone is not sufficient enough to increase competition or discourage anticompetitive behavior. A report by Oxford Institute for Energy Studies divides gas hub markets into different categories according to five criteria over liquidity and transparency<sup>15</sup>. The criteria are the number of participants, the traded products, volumes, the tradability index, and the churn rates. Henry Hub is on top of the criteria for a fully integrated market and can be considered as a role model for other regional markets. The European Union has implemented the European Gas Target Model<sup>16</sup> which includes as targets the security of supply, the evolution of the market to a fully functioning natural gas market and the complementarily flexible role for gas in the power generation. Under all criteria the US gas market has been transformed into the most integrated and mature market in the region. We intent to study whether this stands and whether the two hydrocarbon commodities are priced independently.

There is significant research over the interdependencies (if they exist) between oil and other commodities. The price and volatility spillovers are time-varying since new information constantly enters the market. We try to catch even the slightest causality between the two commodities.

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<sup>15</sup> <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/05/European-traded-gas-hubs-an-updated-analysis-on-liquidity-maturity-and-barriers-to-market-integration-OIES-Energy-Insight.pdf>

<sup>16</sup> <http://www.acer.europa.eu/events/presentation-of-acer-gas-target-model-/documents/european%20gas%20target%20model%20review%20and%20update.pdf>

Villar and Joutz (2006) propose the cointegrating relationship between oil and gas i.e. there is a long-run relationship between oil and gas. Erdos (2012) suggests that oil and gas prices co-moved in the short-run while they were cointegrated in the long-run between 1997 and 2008. The US natural gas prices decoupled from the European ones and oil prices since 2009. He points that until 2008, there were imports from Europe to the US as the prices were higher. This condition has been completely altered due to the glut in the US and the limited supply diversification in Europe. The US gas market decoupled from the European and Asian oil-indexed markets due to the exporting facilities bottlenecks and the domestic oversupply. Asche et al. (2012) proposes the existence of large differences between oil and gas prices in the short-run. The last is explained by the long-run equilibrium and the substitution between the two commodities. Kumar et al. (2019) propose that crude oil, natural gas, and Indian stock prices are not cointegrated while the VARMA DCC GARCH methodology best models the correlations.

Lin and Li (2015) propose that there is cointegration between the European and Japanese markets with crude oil prices. Instead, this does not hold for the US market. The difference is that the European and Japanese markets remain oil-indexed. The US gas market is more fundamentally based with supply and demand to formulate prices. However, even if the US oil and gas markets are decoupled, there are still spillovers from oil to gas prices. Wei-Kao and Wan (2009) suggest that the spot and futures prices are fundamentally driven. Further, they add that futures contribute to price discovery in the UK and the US. Goor and Scholtens (2014) suggest that the UK gas market experiences seasonal effects between October 2001 and September 2005. Jadidzadeh and Serletis (2017) suggest that the gas prices' response depends on the nature of the oil price shock. They, further, propose that 45% of the gas price variation is explained by the aggregate supply and demand shocks. Their conclusion is that oil and gas are decoupled. Nick and Thoenes (2014) suggest that gas fluctuations are explained by abnormal temperatures and supply shocks. However, oil and coal are responsible for the gas price course in the

long-run. The German gas markets is heavily influenced by the supply shocks while demand exacerbated their volatility.

Malik and Ewing (2009) suggest the existence of interdependencies between oil price volatility and other market sectors implying that these interdependencies can be applied as hedging instruments. Since many financial instruments are index-based, volatility spillovers might be exploited for optimal portfolio allocation. Wakamatsu and Aruga (2013) identify 2005 as the year when the Japanese and the US gas markets decoupled due to the shale gas revolution. Since then the US gas market followed a more independent course. The independent course might be lost if exports grow and the US market becomes tighter. Further, if exports are headed to the Japanese market, then the relationship might be restored. Finally, the income-gas consumption elasticity is lower than 1 meaning that gas is among the necessary goods. Geng et al. (2016a) propose that the seasonal effect for gas in the US market is lost due to the shale oversupply. Further, Henry Hub is decoupled from the WTI price after the shale revolution, while prior to the shale revolution they were cointegrated. On the contrary, Scarciuffolo and Etienne (2019) propose that there is not enough evidence of market decoupling between US oil and natural gas markets. Huang and Etienne (2019) add that gas prices are less sensitive to Gulf State incidents, when shale production has greater influence since the shale revolution. Duangnate and Mjelde (2019) suggest that the Henry Hub and AECO prices are easier to forecast since they are in excess supply zones. Instead, Chicago and Illinois prices are harder to predict since they are in areas of excess demand. However, the European gas markets remain cointegrated with oil prices since they are not influenced by the shale glut. The dependence might be lost if European markets are diversified with multiplied supply sources and pricing formulas. Geng et al. (2016b) propose that the WTI and Brent prices heavily influenced Henry Hub and National Balancing Point (NBP) prices. However, this does no longer apply to Henry Hub since the shale revolution, while the European gas markets largely remain exposed to crude's volatility. In addition, for medium- and long-term horizons, the impact of crude to gas has been disappeared. Further, WTI price shocks have been more effective on Henry Hub high frequency price

changes. However, after the shale revolution, Henry Hub price changes are more sensitive to crude price shocks. Moreover, there are indirect volatility spillovers between gas and oil, and they are bidirectional. Last there is direct volatility spillover from gas to oil returns. Batten et al. (2017) suggest that oil and gas markets are decoupled since 2007 and therefore the commodities can no longer be used as hedging instruments against each other. Until 2007, there was a causal relationship from gas to oil. Hydraulic fracturing and horizontal drilling were the main drivers for the markets' decoupling. Zhu et al. (2018) suggest that there are no volatility linkages between the two commodities since 2007, while causal relationships can be detected in the put options in a subsample.

Brown and Yucel (2008a) research the US market which was endowed with a dense pipeline system and early deregulated implying arbitrage opportunities. However, demand overpassed pipeline system upgrades capacity causing supply bottlenecks. The consequence was for regional, operational and technical factors to be more influential than Henry Hub prices or arbitrage. Brown and Yucel (2008b) suggest that gas inventories affect US gas prices. Moreover, regional inventories can act as increased transmission capacity. However, if there are not regional storages, or if they are not substantial, demand peaks can cause sharp price increases. Further, Geman and Ohana (2009) propose that both oil (volatility) and gas spot prices and inventories have negative correlation, while spot gas prices experience negative correlation with inventories when inventories are low. Ergen and Rizvanoglu (2016) suggest that inventories have asymmetric influence when they are low in winter, while when they are high, they cause volatility during the no winter months.

Shaikh et al. (2016) confirm that Japan and Korea have gone ahead with source and route diversification to secure supply. Vivoda (2014) suggests that Asian importers' cooperation did not have the expected results on regional pricing, while Japan's LNG decoupling strategy (diversion from oil-index contracts) will bring results from 2020 and onwards. Shi (2016) describes the gas pricing and trading in East Asia, while Shi et al. (2019) suggest that country-specific heterogeneities determine the drivers of LNG pricing. Zhang et al. (2018) suggest that the Asian premium in gas markets is the consequence of

oil indexation, and proposes that an Asian benchmark price should be developed based on its own fundamentals. Shi and Variam (2016) propose that the relaxation of clauses would decline importing costs for East Asian LNG importers. Shi and Variam (2018) study the key drivers of East Asia's gas hub pricing by using the European Federation of Energy Traders (EFET). Jensen (2004) suggests that gas market should be distinguished into regional markets due the high transportation costs and the required infrastructure. Bachmeir and Griffin (2006) and Li et al. (2014) confirm that the global gas market is fragmented into three segments (European, North American, and Japanese/Korean). They also add that only NBP and JKM are integrated due to oil indexation and not by fundamental pricing. Stern (2014) suggests that oil indexation in Asian markets did not reflect pricing by fundamentals. Barnes and Bosworth (2015) suggest that the gas markets become more and more integrated. Geng et al. (2014) propose that the North American, European and Asian markets are not integrated and that gas trade globalization requires more steps towards integration. Hulshof et al. (2016) propose the TTF price was little positively influenced by oil prices and that the day-ahead prices are fundamentally driven.

Honarvar (2009) finds asymmetries between oil and gas byproducts. He adds that while keeping the gasoline price constant, a positive crude oil shock would only be transitory. Further, there is a long-term asymmetry which is assigned to consumers' responses to technological changes. Ji et al. (2014) propose that oil prices are more influential than global economic activity on natural gas prices. However, the crude volatility has different impact on natural gas prices depending on the studied market. The US gas market is not heavily influenced by crude's volatility. The European markets are influenced with a lag in the short-term and with a limited magnitude. Atil et al. (2013) suggest that natural gas and gasoline are affected by oil prices. They add that gas does not instantly adjust as regional factors play an important role. Negative oil shocks have greater influence than positive ones. Pal and Mitra (2015) apply a multiple threshold nonlinear autoregressive distributed lag model to detect asymmetries between oil and its byproducts. They find that there are asymmetries between positive and negative shocks and of magnitude. They go further by suggesting that negative oil price shocks are not

fully transmitted to byproducts' prices. Wiggins and Etienne (2017) suggest that natural gas prices have different responses to supply and demand shocks. Supply and aggregate demand shocks have heavier influence than precautionary inventory shocks. Consumers can now diversify their energy sources and as a consequence demand's elasticity becomes more elastic. Last, demand and supply shocks are responsible for 20% of the post-deregulation price volatility. Lin and Wesseh (2013) propose a regime switching for natural gas prices and as a consequence their volatility is not predictable.

The US natural gas market is very important since deregulation and shale revolution pose the question of markets' decoupling from oil. The literature review is extended. The relationship is not constant over time and as a result is dynamic. Further, it is important to detect whether asymmetries exist.

Our research section studies the time-varying price and volatility spillovers between the US gas and oil markets for the period 1990-2017 with several econometric methodologies. The result is that both markets are largely decoupled in contrast with the results of Villar and Joutz (2007) and Brown and Yucel (2008b). Further, we argue that the shale revolution did not decouple the markets since they were already decoupled, and that there is only causality from oil to gas if certain conditions prevail. As a consequence, we argue with Geng et al. (2016). Our research is conducted without exogeneity assumptions as those of Nick and Thoenes (2014). Our research studies the interdependencies between the two commodities without any presumptions as the preceding literature, and it is updated since it covers data up to 2017. We include a whole decade of unconventional production.

We apply Bivariate Vector Autoregressive (VAR) models with the assumption that oil and gas are endogenous, Momentum Threshold Autoregressive (MTAR) cointegration and ECM modeling, out-of-sample and in-sample methodologies and we compare their forecasting ability with the Diebold and Mariano test, Accumulated Impulse Response Functions (AIRF), and Dynamic Conditional Covariance (DCC) Generalized Autoregressive Conditional Heteroscedasticity (GARCH) methodologies. Batten et al. (2017) also used the

Bivariate VAR approach to study the spillovers between oil and gas, when Ferraro et al. (2015) also applied it in research between crude oil and exchange rates. The application of MTAR and DCC GARCH approaches studies the asymmetric dependencies and volatility linkages between the two commodities. The DCC-GARCH is also used by Chavellier (2012), Wei (2016), and Singhal and Ghosh (2016).

Our study continues with Data description, Methodology, Results and Conclusions.

## **6.2 US market**

### **6.2.1 Data**

We use the daily closing crude oil Futures prices of the New York Mercantile Exchange (NYMEX) and the daily Henry Hub prices by again NYMEX. Crude oil prices are in dollar per barrel and gas prices are in dollars per Million British Thermal Units (MMBTU). Our data are between 3/4/1990 and 31/12/2017 and constitute 6975 price pairs.

We include full years from the first time NYMEX started offering natural gas futures with physical delivery at the Henry Hub. We use futures prices as they are instantly adjusted to new information, and not spot prices which tend to be slower. For convenience NYMEX crude oil futures will be referred as oil prices and NYMEX Henry Hub prices will be referred as gas prices.

Our study in this section is focused on the US wholesale natural gas and crude oil markets. Oil-indexed gas contracts have been disappeared to almost 0% for domestic production and imports as presented in the International Gas Union. In addition, the deregulation of interstate pipeline system took place along with the shale revolution. However, there was not an export option since oil and gas exporting infrastructure was not existent while the regulatory framework was not developed. The US followed a different path from other oil and gas producers like Russia, Norway, Qatar and Algeria. While the rest of the producers expanded their exporting options with pipelines, and long-term oil-indexed contracts, the US waited until the glut to start exports. This is why the

US market is considered as the most advanced competitive and integrated natural gas market in the world. Our long-studied period covers 28 years within significant events took place. Wars in oil rich regions like the Gulf War in 1991 (Archer et al. 1990), OPEC production quotas, technological evolutions like hydraulic fracking and horizontal drilling (Sandrea 2014), the gas market deregulation, the financial crisis of 2008, the Deepwater Horizon destruction in the Gulf of Mexico, the Katrina hurricane (Stern and Rogers 2014), and the destruction of the Fukushima power plant in 2011 (Miyamoto et al. 2012) which could have a major impact on the price formulation. All might seem as extremely important but the statistical importance on their time series is primarily tested with the existence of structural breaks. We apply the Bai and Perron (1998) test for multiple structural breakpoints on our time-series, and we detect several structural breaks. There is a structural break on 10/9/1988 for the gas time series. Several structural breakpoints were identified for oil prices which suggested a refinement process from the sequential to the repartition dates. Finally, we suggest the periods from 3/4/1990 to 27/11/2001, 28/11/2001 to 31/3/2009, and 1/4/2009 to 29/12/2017. Unfortunately, we could not identify particular events that could explain our results. We added dummy variables for several aforementioned events but we did not have cointegrating events or statistical significance in our VARs.

Finally, it is easily understood that we study the global market of oil in conjunction with the regional market of gas. Oil is priced under the fundamental prism, while gas under more regional factors as infrastructure bottlenecks, pipeline capacity and other supply determinants (Brown and Yucel 2008a and 2008b) like exporting facilities (EIA 2012). Production glut and inventories may accommodate demand disruptions. Our research continues with methodology, results and conclusions.

### **6.2.2 Methodology**

In our attempt to detect even the slightest spillover, we apply as more methodological approaches as possible. Further, in order to detect even transient spillovers between the

two commodities, we employ our approaches with rolling iterations, except for the Asymmetric Price Transmission (ECT) and the DCC-GARCH. Our methodology approach is consisted of Time domain causality tests, Asymmetric Price Transmission (ECT) methodology, In and out of sample causality tests, Long-term impacts (AIRF) methodology, and Volatility Transmission (DCC-GARCH).

### 6.2.2.1 Time domain causality tests

We begin with our time-domain causality tests which are the Granger (1969) causality tests or Wald tests conducted on our VARs. We test both prices as causal. If a commodity is leading the information process, then it would Granger cause the second's commodity price. Granger causality tests have the inherent assumption of symmetry over the effect and information transmission between the two variables i.e. an increase will inflict the same influence and will have the same speed with the respective decrease.

Our tests are implemented as in-sample F statistics or as VAR Wald tests. We proceed with our "unrestricted" models which contain both commodity prices. If there is statistical significance of one's commodity coefficient explaining other's price course, then there are price spillovers. The "unrestricted" models are:

$$\Delta Oil_t = \alpha_0 + a_1 \Delta Oil_{t-1} + \dots + a_p \Delta Oil_{t-p} + \beta_1 \Delta Gas_{t-1} + \dots + \beta_p \Delta Gas_{t-p} + \varepsilon_{st} \quad (6.1)$$

$$\Delta Gas_t = a_0 + a_1 \Delta Oil_{t-1} + \dots + a_p \Delta Oil_{t-p} + b_1 \Delta Gas_{t-1} + \dots + b_p \Delta Gas_{t-p} + \varepsilon_{ot} \quad (6.2)$$

We first test for cointegration and we have negative results i.e. there is no long-term relationship. As a result, we use the  $\Delta Oil_t$  and  $\Delta Gas_t$  coefficients or the first differences of our data at time t for our VAR modelling. Our VAR order is suggested by the Akaike criterion which determines the  $\Delta Oil_{t-p}$  and  $\Delta Gas_{t-p}$  lagged differences. Our data are in natural logarithms and as a result their first differences are the respective returns. Further, we assume that both variables are endogenous avoiding structural assumptions like those of Kilian (2009) for Structural VAR or SVAR models. Our first hypothesis is:

$$H_0 : \beta_1 = \beta_2 = \dots = \beta_p = 0 \quad (6.3)$$

And for the second model, the hypothesis is:

$$H_1 : a_1 = a_2 = \dots = a_p = 0 \quad (6.4)$$

If our assumption is rejected then one commodity price explain the other's, and there is information transmission i.e. spillovers. The direct implication is that the first commodity price can forecast the second's price.

Initially, we use the full sample for our hypotheses which is the aggregate result. Since we want to detect even the transient spillovers, we conduct our Granger causality tests for shorter iterations. We use a rolling window for our observations. We conduct the test for 250 observations, which consists a trading year, and every 100<sup>th</sup> observation.

#### 6.2.2.2 *Asymmetric Price Transmission*

Symmetry is inherent in the Wald tests i.e. a price increase will have the same influence with a decrease. This is quite restrictive since markets might be related not in the same way always. Price transmission might be vertical or horizontal, or positive or negative. When the two markets belong in the same vector, we have a vertical transmission, while horizontal is for different sectors. We consider the two commodities as of different marketing chains since their fundamentals could price them differently. In addition, asymmetry can be positive if the second commodity reacts heavier or faster to the first's positive change, in contrast to a negative shock. Negative asymmetry is when the second's reaction is greater to a negative shock than that to a positive shock.

We denote the price of the transmitting commodity as  $p_t^{in}$ , while  $p_t^{out}$  is the second's commodity price. We apply the Error Correction Model (ECM) suggested by Engle and Granger (1987). We begin with Granger's and Newbold's (1974) concern over the non-stationary data and the spurious models they produce. We test their stationarity with the ADF (Said and Dickey 1984) test and the Phillips and Perron (1988) test. We find that our

data are stationary at their first differences and not at levels. Engle and Granger (1987) suggest that for I(1) data, if they are cointegrated, then there is a linear stationary relationship between them. We apply a threshold cointegration test before our first formula:

$$p_t^{out} = a + \beta p_t^{in} + u_t \quad (6.5)$$

Since our  $p_t^{in}$  and  $p_t^{out}$  are cointegrated, then the model (6.5) is the long-term model which is not spurious.

Our ECM uses the lagged residuals of the long-run model as an Error Correction Term, which are the deviations from the long-term model between  $p_t^{in}$  and  $p_t^{out}$ . The deviations can be positive or negative ones. Then, we can rewrite the short-run model as:

$$\Delta p_t^{out} = \alpha + \beta \sum_{j=1}^k \Delta p_{t-j+1}^{in} + \varphi^+ ECT_{t-1}^+ + \varphi^- ECT_{t-1}^- + j_t, \quad (6.6)$$

when  $\Delta p_t^{out}$  and  $\Delta p_t^{in}$  are the first differences and  $j_t$  the residuals.

As it is aforementioned a long-run relationship between the two commodities must exist. This kind of long-run relationship is tested with threshold cointegration as suggested by Tong (1983). He contributed that price adjustments are favored when a certain threshold is passed. If the ECT is between the two points constituting the threshold, then no adjustment is occurring. This band is when adjustments are costlier than no adjustments. This bandwidth is named by Goodwing and Piggot (2001) as “neutral”.

We apply the Momentum Threshold Autoregression (MTAR) cointegration methodology suggested by Ender and Granger (1998). To calculate the optimal threshold value with the lowest Sum of Squared Errors (SSE), we exclude some observations. We fit our models with the best threshold value. We conduct all our steps with MTAR

methodology (threshold value, lag selection, threshold cointegration test, and ECM modelling). We use both prices as  $p_t^{in}$  and  $p_t^{out}$ .

### 6.2.2.3 In and Out of sample forecasting ability tests

Price spillovers can also be detected by comparing the forecasting ability of different models. If one commodity price precedes in the information process, then the unrestricted models (6.1) and (6.2) will have better forecasting ability than that of the restricted models (6.7) and (6.8). The restricted models are the (6.7) and (6.8):

$$\Delta Oil_t = \alpha_0 + a_1 \Delta Oil_{t-1} + \dots + a_p \Delta Oil_{t-p} + \varepsilon_{st} \quad (6.7)$$

$$\Delta Gas_t = a_0 + a_1 \Delta Gas_{t-1} + \dots + a_p \Delta Gas_{t-p} + \varepsilon_{ot} \quad (6.8)$$

Forecasts by both the unrestricted and restricted models are derived for one step ahead and then compared for their forecasting ability with the Diebold and Mariano (1995) test. The null hypothesis of the test is that both models give forecasts of same Mean Squared Forecast Errors (MSFE) or that they have the same forecasting ability. If the null hypothesis is rejected then one of the two has better forecasting ability.

We proceed with the Diebold and Mariano (1995) test for the full sample (in-sample) and for shorter iterations or a trading year (out-of-sample).

### 6.2.2.4 Long-term impacts

We try to quantify the accumulated effect of one commodity price on another. Causality tests only calculate the probability of a price spillover. Both markets are futures markets and we consider them as both highly liquid. Since both markets are highly liquid, then price spillovers would be instantly transmitted. We use a ten-day horizon (two trading weeks) to quantify the potential spillovers. The horizon is fair enough for arbitrage opportunities. If a commodity is preceding in information process, then traders will jump

to the opportunity for profits. High liquidity will cancel this kind of trading profits since information is soon revealed.

We calculate the Accumulated Impulse Response Functions (AIRFs) from our rolling VARs in order to derive the impulse response coefficients with their respective bootstrapped error bands with 95% confidence intervals. We derive the orthogonalized impulse responses. Again, our rolling window is of 250 observations which consist a trading year.

#### 6.2.2.5 Volatility transmission

Volatility transmission is one form of information transmission. Initially, we test our bivariate VARs with Pormanteau and Breusch-Godfrey statistics. Since we reject the hypothesis of serial correlation, we proceed with the ARCH LM test. We do have ARCH effects. We apply the Dynamic Conditional Covariance (DCC) GARCH (1,1) methodology suggested by Engle and Sheppard (2001). The methodology allows for non-constant correlation between the two variables as Engle et al. (1990) and Bollerslev (1990) suggested that this is not the case in most of the times. Later, Cappiello et al. (2006) improved the model by including asymmetries. Engle (2002) starts with Dynamic Conditional Correlation with:

$$H_t = D_t R_t D_t \quad (6.9)$$

With  $H_t$  and  $D_t$  to be the conditional correlation matrix and the  $k \times k$  diagonal matrix of the time varying standard deviations from the GARCH with  $(\sigma_{i,t}^2)^{1/2}$  on the  $i^{\text{th}}$  diagonal respectively.

$$D_t = \begin{bmatrix} \sqrt{\sigma_{o,t}^2} & 0 \\ 0 & \sqrt{\sigma_{s,t}^2} \end{bmatrix} \quad (6.10)$$

The time-varying components are included in the  $R_t$

$$R_t = \begin{bmatrix} \varepsilon_{oo,t} & \varepsilon_{os,t} \\ \varepsilon_{so,t} & \varepsilon_{ss,t} \end{bmatrix} \quad (6.11)$$

When  $R_t$  is

$$R_t = Q_{os,t}^{*-1} Q_{os,t} Q_{os,t}^{*-1} \quad (6.12)$$

And  $Q_{os,t}$  is

$$Q_{os,t} = (1 - \theta_1 - \theta_2) Q^* + \theta_1 (\varepsilon_{o,t-1} \varepsilon_{s,t-1}) + \theta_2 (Q_{os,t-1}) \quad (6.13)$$

$Q_{os,t}$  denotes the unconditional variance of the  $i$  and  $j$  following a GARCH, while  $Q^*$  is the unconditional covariance, while  $\theta_1$  and  $\theta_2$  are the positive parameters with their sum to be less than 1:  $\theta_1 + \theta_2 < 1$

The maximization of the log-likelihood function (6.14) gives the parameters:

$$L(0) = -\frac{1}{2} \sum_{t=1}^T (k \log(2\pi)) + 2 \log(|D_t|) + \log(|R_t|) + \varepsilon_t' R_t^{-1} \varepsilon_t \quad (6.14)$$

Last Cappiello et al. (2006) include the term  $\theta_3$  for asymmetry with  $Q_{os,t}$  to be:

$$Q_{os,t} = (1 - \theta_1 - \theta_2) Q^- - \theta_3 \bar{\xi}_t + \theta_1 (\varepsilon_{o,t} \varepsilon_{s,t-1}) + \theta_2 (Q_{os,t-1}) \quad (6.15)$$

With  $\bar{\xi}_t = E + \theta_3 (\varphi_{t-1} \varphi'_{t-1})$  and

$$|\overline{\varphi_{ot} \varphi'_{st}}| \text{ and } \overline{\varphi_{ot}} = (I [\bar{\varepsilon}_{ot} < 0]) \circ \bar{\varepsilon}_{ot}$$

the last denotes the Hadamard product of the residuals in case the returns are negative and otherwise  $\overline{\varphi_{ot}} = 0$ . Finally,  $\theta_3$  contains the time periods when the information inflow is negative with  $|\overline{\varphi_{ot} \varphi'_{st}}| = I_t$ .

### 6.2.3 Results

#### 6.2.3.1 Time domain causality tests

We attempt to study both the aggregate and time-varying spillovers between the US oil and gas markets. We employ bivariate VARs to conduct Wald tests. Before that we test the stationarity properties of our data. Our data are  $I(1)$  i.e. stationary at first difference. Since our data are transformed into natural logarithms, then their first differences are the respective returns.

**Table 6.1.1** Test for unit roots 1990–2017.

Level.	ADF	PP test	First difference	ADF	PP test
Oil	0.2632	-1.4978	$\Delta(\text{Oil})$	-62.9597 <sup>a</sup>	-86.3383 <sup>a</sup>
Gas	-0.9279	-2.6679	$\Delta(\text{Gas})$	-61.7458 <sup>a</sup>	-88.7742 <sup>a</sup>

Notes: The null hypothesis of the ADF and Phillips Perron test is that the variable has a unit root. The first difference of the series is indicated by  $\Delta$ .

<sup>a</sup> Indicates rejection of the null hypothesis at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates rejection of the null hypothesis at 5% and 10%.

<sup>c</sup> Indicates rejection of the null hypothesis at 10%.

The order of our VARs is determined by the Akaike criterion and it is order of six. The width of the lag length helps our residuals to be White noise (Gaussian errors) ruling out the possibility of autocorrelation, something verified by our tests. We further test the stability of our VARs as a root may lie outside the unit circle. Our test confirms that no root lies outside the unit circle.

Our first test is whether there is a causal relationship from natural gas to oil, and if this is existent, then the inclusion of “gas” coefficients should improve the statistical properties of the model. Our aggregate or full sample model suggests that there is a

unilateral causal relationship from gas to oil returns. However, this is not accepted as strong evidence since the probability of accepting the null hypothesis of no causality is very close to our 5% threshold. The instantaneous causality between oil and gas returns is firm accepted since the probability is very low (Table 6.1.2)

**Table 6.1.2** Full sample causality tests.

<b>Null Hypothesis H0 No causality</b>	<b>P value</b>	<b>Critical value</b>
<b>From Gas to Oil</b>		
Wald test	0.0422	0.05
Instantaneous	$<2.2e^{-16}$	0.05
<b>From Oil to Gas</b>		
Wald test	0.1535	0.05
Instantaneous	$<2.2e^{-16}$	0.05

When we test the causality from oil returns to gas returns, we have the results of no causality. The results well verify no causal relationship since the probability is over our threshold.

From our aggregate Wald test, we find that there is a unilateral causality from natural gas to oil returns i.e. the natural gas market precedes in the information process. But this result is close to the rejection threshold and it is only marginally accepted. Our preliminary results seem to verify Batten’s et al. (2007) results. However, this is only the aggregate result and it is not firmly accepted. We proceed with the rolling VAR methodology and we conduct the Wald test for each respective bivariate VAR. We create series of p-values and we depict them with the acceptance threshold in our Figures 6-1 and 6-2.

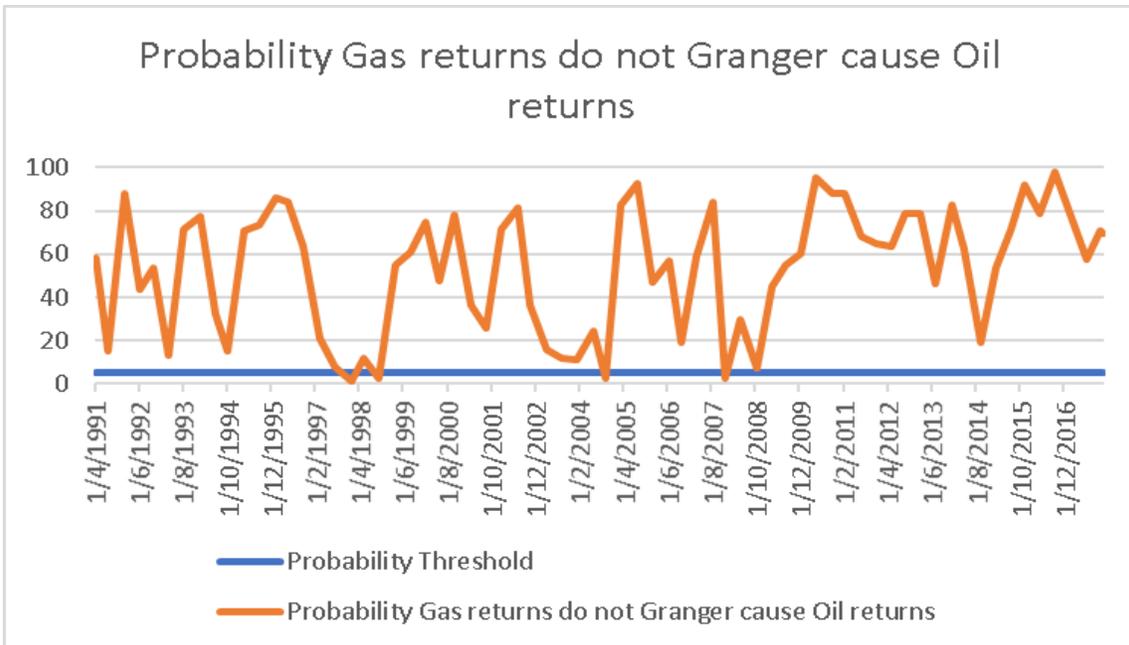


Figure 6-1 Probability Gas returns do not Granger cause Oil returns (in %).

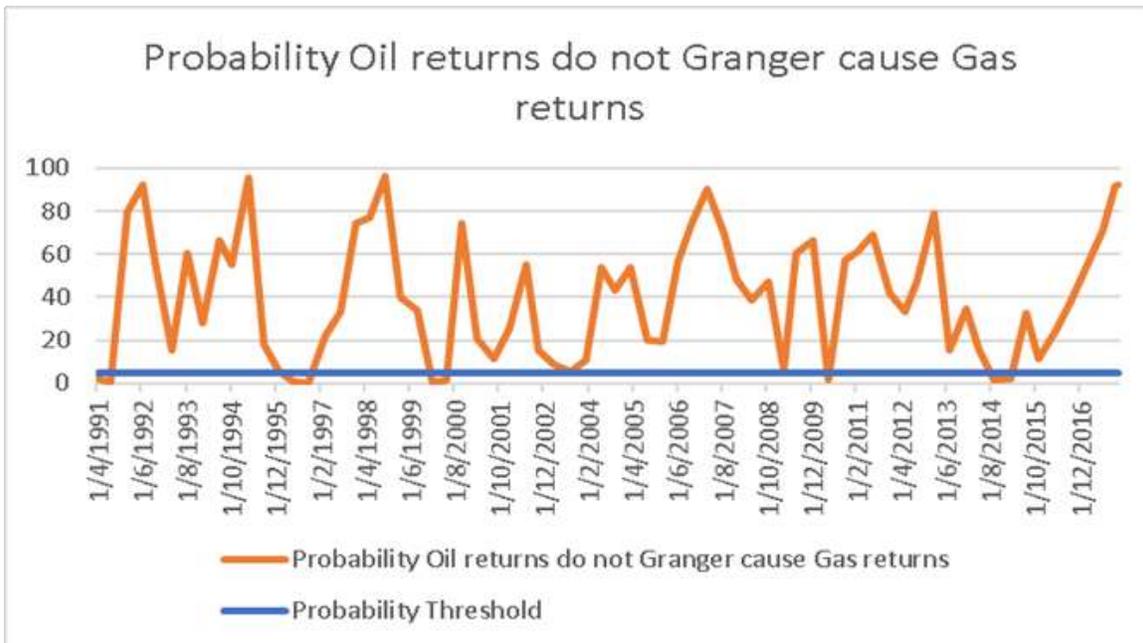


Figure 6-2 Probability Oil returns do not Granger cause Gas returns (in %).

Our initial result is that the unilateral causality from gas returns to oil returns is not confirmed. The null hypothesis that gas returns do not cause oil returns is only rejected in four instances. This is the reason why the aggregate result is only marginally accepted.

We can conclude that there is not consecutive causality, let alone stable causality, as our iterations suggest only few short-lived causality periods from gas returns to oil returns.

Further our rolling VAR results confirm the aggregate result of no causality from oil. There is no causality from oil to gas returns since the null hypothesis of no causality is confirmed for almost all short iterations. There is persistence in no causality from oil to gas.

Our first method suggests that there are no long-lived causal relationships between the two commodities. Gas returns cause oil returns only for short periods. These periods are between 5/1/1998 and 20/10/1998, and 26/10/2004 and 24/12/2007. The periods are short. For oil's causality, we have more periods. These are between 1/4/1991 and 21/8/1991, 31/5/1996 and 23/10/1996, 4/1/2000 and 26/5/2000, 13/5/2010 and 22/9/14 and 13/2/2015. There are no consecutive periods and their duration is also short.

Again, we highlight that our iteration framework is very short. We only use 250 observations for each bivariate VAR which constitutes them as a very sensitive tool. The short-lived causality from gas to oil in 1998 can be explained by the OPEC production cuts announced in March 1998 and March 1999. Again, the causality close to 3/6/2004 is attributed to the OPEC curtail production decisions in February 2004<sup>17</sup>.

The spillover from oil returns to gas returns in 1991 can be attributed to the Gulf War and the uncertainty caused by supply incidents like the ceased Iraqi and Kuwaiti production, OPEC cuts in March 1991 and the then Kuwaiti claim to the Cooperation Council for the Arab States of the Gulf to supply 800.000 bbl./d to cover demand. The spillover of 1996 can be again attributed to Iraq's volatile agreement for "Oil for food" program since there were several setbacks from its start. The 2000 spillover can be explained by the gas trade deregulation of the interstate gas pipeline system by the Federal Energy Regulatory Commission (FERC) since regionality was further weakened<sup>18</sup>.

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<sup>17</sup>

<https://www.opec.org/library/Annual%20Statistical%20Bulletin/interactive/2004/FileZ/XL/CEILING.HTM>

<sup>18</sup> <https://www.ferc.gov/legal/maj-ord-reg/land-docs/RM99-2A.pdf>

Middle East tensions in 2015 can explain the same year spillover from oil to gas. The tensions were in conjunction with inventory levels, demand projections and King Abdullah's death<sup>19</sup>.

### 6.2.3.2 *Asymmetric Price Transmission*

Initially, we attempted to detect symmetrical spillovers since Wald tests assume symmetrical effects. The influence one price will have on the second will be the same whether this will be caused by an increase or a decrease. Information process might have differences in magnitude and speed of transmission. Our asymmetric price model is for the full sample, and therefore the aggregate. First, we calculate the best threshold value and then we calculate the appropriate number of lags suggested by the Akaike Information Criterion. Then we test for threshold cointegration and we finally construct our ECM model.

When we consider gas price as  $p_t^{in}$ , then we find no cointegration between the two commodities i.e. there is no long-term adjustment. Our result does not let us proceed with the ECM calculation. The absence of any adjustment would not produce any model of stable statistical significance.

Instead, when we investigate for asymmetries with oil prices as  $p_t^{in}$ , we result in useful conclusions. Initially, we calculate the best threshold value which is 0.1 and that threshold cointegration exists. When we calculate our ECM model, we find a positive asymmetric price transmission from oil to gas. Positive oil price shocks are transmitted to gas prices much faster than negative ones. The speed of adjustment or the  $ECT_{t-1}^+$  is higher than the respective correction term for decreases, and they are both statistically significant (Table 6.1.3)

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<sup>19</sup> <https://www.reuters.com/article/us-saudi-succession/saudi-king-abdullah-dies-new-ruler-is-salman-idUSKBN0KV2RQ20150123>

Our results confirm that there is threshold cointegration from oil to gas prices, while there is a positive asymmetry. Oil price increases have heavier influence than oil price decreases. This might be attributed to the global character of the oil market, since oil is the most traded commodity, and affected by global fundamentals and political factors. On the contrary, the gas market is more of a regional character. Our results are calculated with the Momentum Threshold Autoregressive method. All our processes like the best threshold value, lags, cointegration and ECM modelling are conducted with this method.

Our results confirm Villar and Joutz (2006) since there is a threshold cointegration between the two commodities. Further, the cointegration from oil to gas when there is none for the vice-versa relationship confirms the assumption of oil spillovers. Lin and Li (2015) are partially confirmed since oil is influenced more by market fundamentals. We contribute that there is cointegration from oil to gas when certain costs are covered for the price adjustment to be effective. Their research might have missed the asymmetry since they used the Johansen test. However, they suggested that there is an asymmetry from oil to gas prices, when the vice-versa relationship does not hold. Last, they did use ECM models like us. Our contribution was the split of the Error Correction Term into two components for increases and decreases. Erdos (2012) applied Vector Error Correction models to confirm that oil and gas co-moved between 1997 and 2008 in the short-run. This can not be said for the commodity prices after 2009. We do not confirm his results as we suggest that gas prices remained decoupled for the whole period, and that they were influenced if certain conditions prevailed. Our asymmetric ECM model confirms Honarvar's (2009) who proposed that oil price increases have different effect than decreases. The result is derived by applying an Error Correction Model which is capable of identifying asymmetries in the cointegrating vectors by cumulative positive and negative changes. Pal and Mitra (2015) also confirm the asymmetry with their Nonlinear Autoregressive Distributed Lag models. We conclude that asymmetric price theory is appropriate since it can unravel potential complexities among commodity prices.

**Table 6.1.3** Asymmetric Price Transmission- ECM or Oil to Gas Transmission- Dependent  $\Delta$ Gas.

Variables	Coefficients	Std. Error	t Value	Probability
C	0.0001	0.0004	0.2960	0.7675
$\Delta(\text{Oil})_{t-1}$	-0.0389	0.0174	-2.2310	0.0256 <sup>b</sup>
$\Delta(\text{Gas})_{t-1}$	-0.0453	0.0122	-3.696	0.0002 <sup>a</sup>
$\text{ECT}^+_{t-1}$	-0.0339	0.0099	-3.4090	0.0006 <sup>a</sup>
$\text{ECT}^-_{t-1}$	-0.0029	0.0010	2.8570	0.0428 <sup>b</sup>

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%). <sup>b</sup> Indicates significance at 5% and 10%. <sup>c</sup> Indicates significance at 10%.

### 6.2.3.3 *In and out-of-sample forecasting ability tests*

Ashley et al. (1980) propose this kind of method for causal relationships. Initially, we start with the full sample or the in-sample forecasting ability of our models. We compare the forecasting ability with the Diebold and Mariano (1995) test. We use both prices, either gas or oil as dependent or as coefficients for the vice-versa relationship. Then we use the out-of-sample methodology or otherwise for shorter iterations to examine their time-varying relationship.

The predictive accuracy is tested for a single step ahead between models (6.1) and (6.7) and (6.2) and (6.8). If the inclusion of gas coefficients does not improve the forecasting ability, then the two models have equal predictive ability. Our test value is the absolute 1.96 for the DM test. Both our test absolute values do not overpass 1.96 meaning that the unrestricted and the restricted model have forecasting ability of equal value. The forecasting ability's comparison of pairs (6.1) and (6.7), and (6.2) and (6.8) imply that there are no spillovers among the two commodity prices. The full sample results which are the aggregates suggest that the two prices are decoupled and move independently.

**Table 6.1.4** Diebold and Mariano tests – Full Sample.

<b>H<sub>0</sub> Equal Predictive ability</b>	<b>Value</b>	<b>1.96 and 0.05 critical values</b>
<b>From Gas to Oil</b>		
DM test	-1.7319	
P value	0.04169	
<b>From Oil to Gas</b>		
DM test	-1.24857	
P value	0.1059	

We also attempt to detect time-varying spillovers between the two commodities. We divide our full sample not by 250 observations, but in a way to have full exact trading years. Our out-of-sample results suggest that there is not a single point when the unrestricted model has better forecasting ability than that of the restricted model, and gas coefficients do have any sort of contribution. The DM value tests are within the bandwidth of the critical absolute values implying no spillovers from the gas to the oil market.

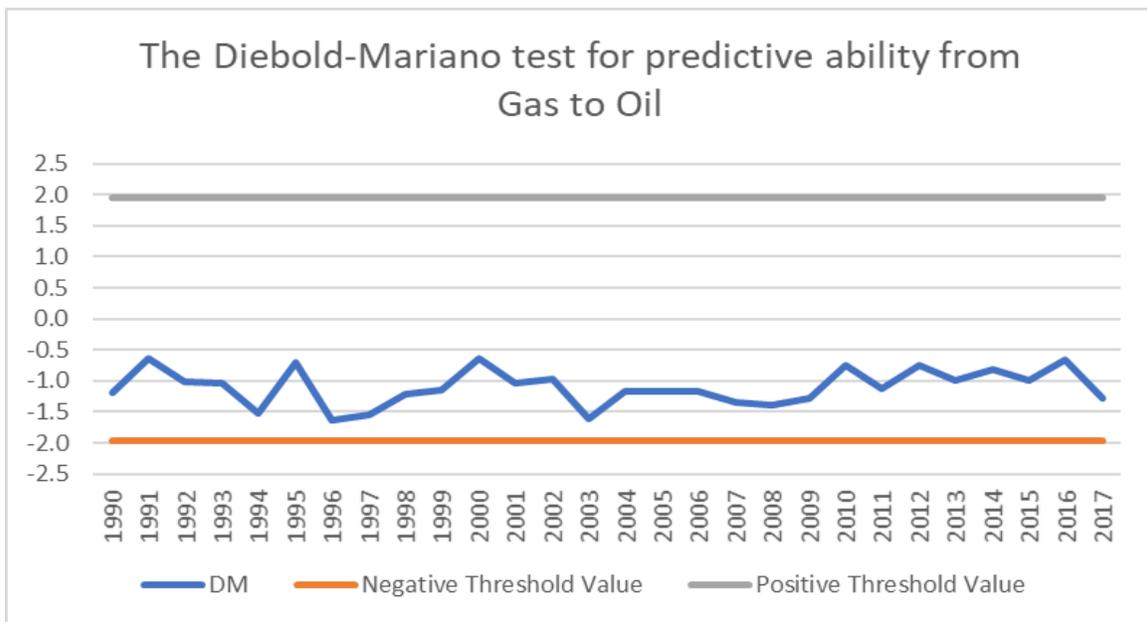


Figure 6-3 The Diebold-Mariano test for predictive ability from Gas to Oil.

On the contrary, when we research the out-of-sample causality from oil to gas, we find that there is a single instance when the inclusion of oil coefficients improves the forecasting ability of our model. This is for the year 1999 (Figure 6.4). This spillover can be attributed to the anticipation the public had for the FERC's decision. In addition, our test results are close to the acceptance threshold for the years 2005 and 2008. However, they are not higher to have firm results. Our time-varying results confirm that both markets largely move independently and that spillovers are mainly short-lived.

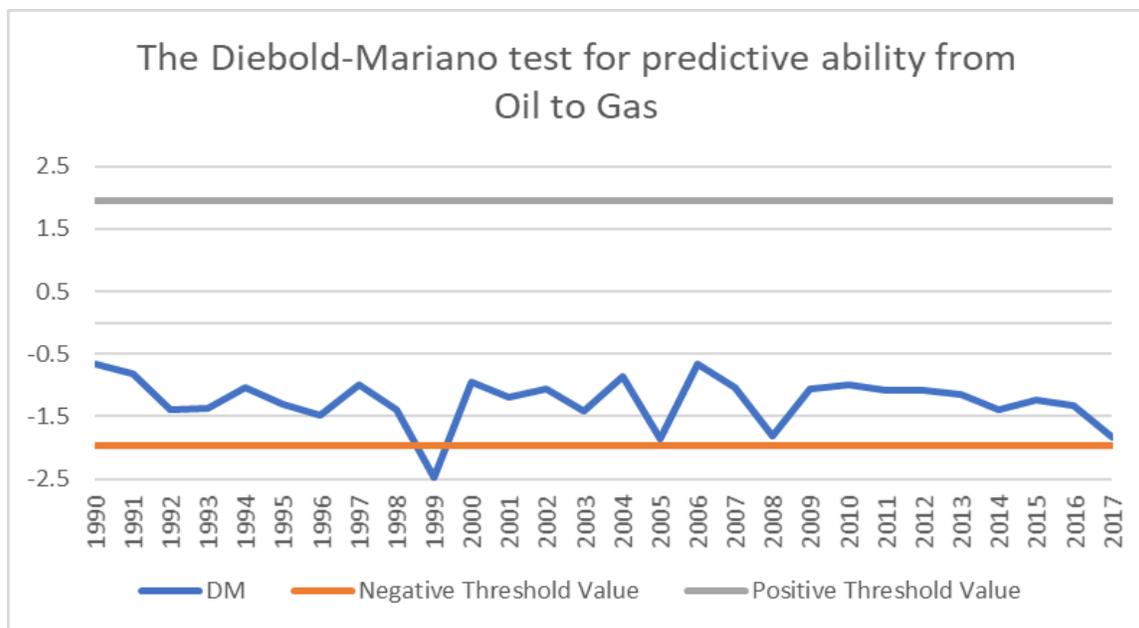


Figure 6-4 The Diebold-Mariano test for predictive ability from Oil to Gas.

Last, we suggest that both energy commodities are priced independently without constant spillovers among them. The two markets were already independent and shale revolution only added to the precedent state. The oil and gas glut in the US market did not influence the pricing process. Our results contradict the results of Batten et al. (2017) since only oil could predict gas prices in 1999 and not the vice-versa as they claim. However, Batten et al. (2017) reach their results by applying a different window of 1.000 trading days, while their results for shorter iterations (750 and 250 trading days) only

confirmed those of 1.000 trading days. The extended data windows might lead to aggregations. Malik and Ewing's (2009) results are not confirmed since no interdependencies are detected. We argue that since commodities move independently, then there is no possibility of using them as hedging instruments against each other. Malik and Ewing (2009) study the period between 1992 and 2008 which is only a sub-period of ours and does not include the shale revolution.

#### *6.2.3.4 Long-term impacts*

Our so far rolling VAR methodology only calculated the probability of a price spillover between the two energy commodity prices. We have not yet calculated the impact one price change had on the second's commodity price. Since we discuss for highly liquid markets, we consider a ten-day horizon or otherwise two trading weeks as a fair enough period for effects to be detected. The two futures markets absorb information pretty fast and eliminate any arbitrage opportunities. We derive the Accumulated Impulse Response Functions (AIRF) by our bivariate VARs.

We collect the AIRFs to create series and then comment them. We calculate our results for the orthogonalized impulse response coefficients, and we also derive their bootstrapped error bands with 95% confidence intervals. As it is aforementioned, the bivariate VARs have a window of 250 observations. We use short iterations to detect even the most sensitive spillovers between the two commodities. Our accumulated impulse response function coefficients form a series of long-run effects, which then are graphed in our figures.

We graph our results in Figures 6.5 and 6.6. When we study the accumulated impact of gas to oil returns, we can pretty tell that these are negligible. The impacts move very close to zero. A standard deviation shock causes less than 0.005% change in oil prices. The peaks are almost contemporary to the Granger results as gas returns cause oil returns in the periods around 1/4/1998, 9/1/2004 and 9/10/2008. We can argue that gas spillovers are short-lived and of low impact. Oil price shocks, instead, provoke higher long-run

impacts. Except for three periods when the accumulated impacts are negative, we have always positive impacts. The peaks of the accumulated impact response functions coincide with the spillover periods suggested by the Wald tests. The higher impacts are in years 1996, 2003, 2006, 2008, 2009, 2014 and 2016. They are way higher than those caused by gas and are between 0.01% and 0.02%. The high impact is attributed to several incidents. The 2008 and 2009 increased impacts can be explained by the evolving financial crisis, while those of 2014 and 2016 can be attributed to the OPEC decision to defend its market share and drive shale production out of the market. However, even if the oil returns have greater impact than that of gas returns, they remain low verifying our results of market decoupling. As a general conclusion, we tell that gas returns have extremely low impact on oil returns, while oil returns' influence move between 0.01% and 0.02% and is almost positive.

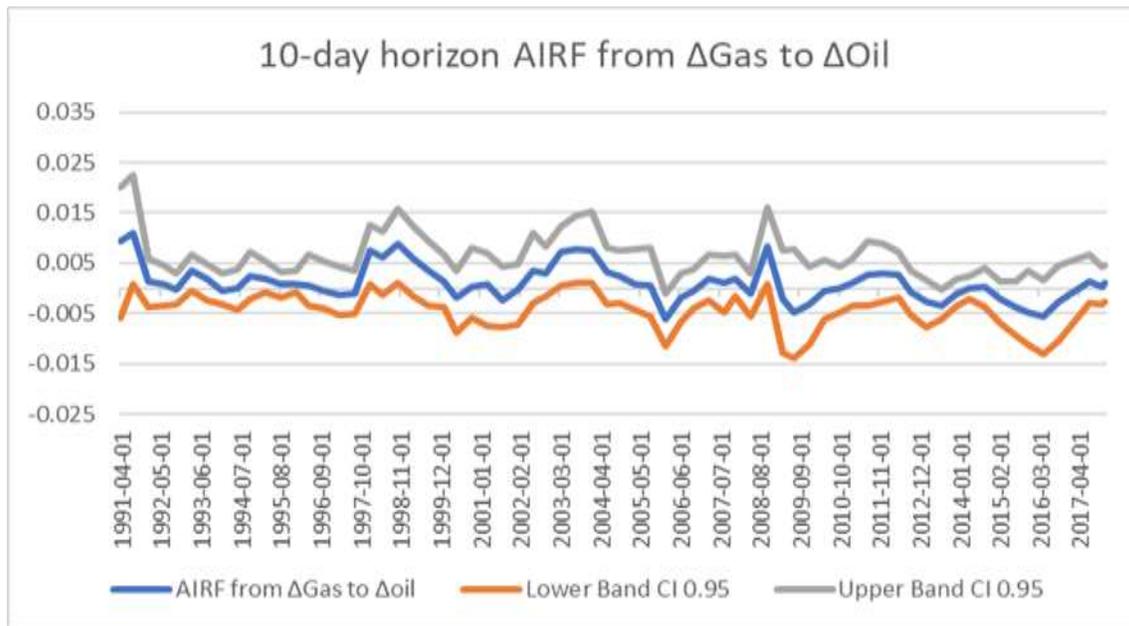


Figure 6-5 10-day horizon AIRF from Gas to Oil (in %).

Our findings contradict those of Batten et al. (2017) who suggest heavier influence by gas returns (0.3000%). Further, they suggest that they are statistically significant and persistent. Moreover, we find the impact of oil on gas returns around 0.0250%, while Batten et al. (2017) calculate it up to 0.4000%. The different impulse levels reveal the different conceptions of the markets. Low impulses mean more liquid markets, and high impulses imply shallow markets. Low effects agree with Geng et al. (2016b) who claim that the WTI's influence on gas pricing is fading. We expect longer time horizons to have even lower impulses. This again verify Geng et al. (2016b). Honarvar (2009) also argues of low impulse responses from oil to unleaded retail premium gasoline price (0.0100%).

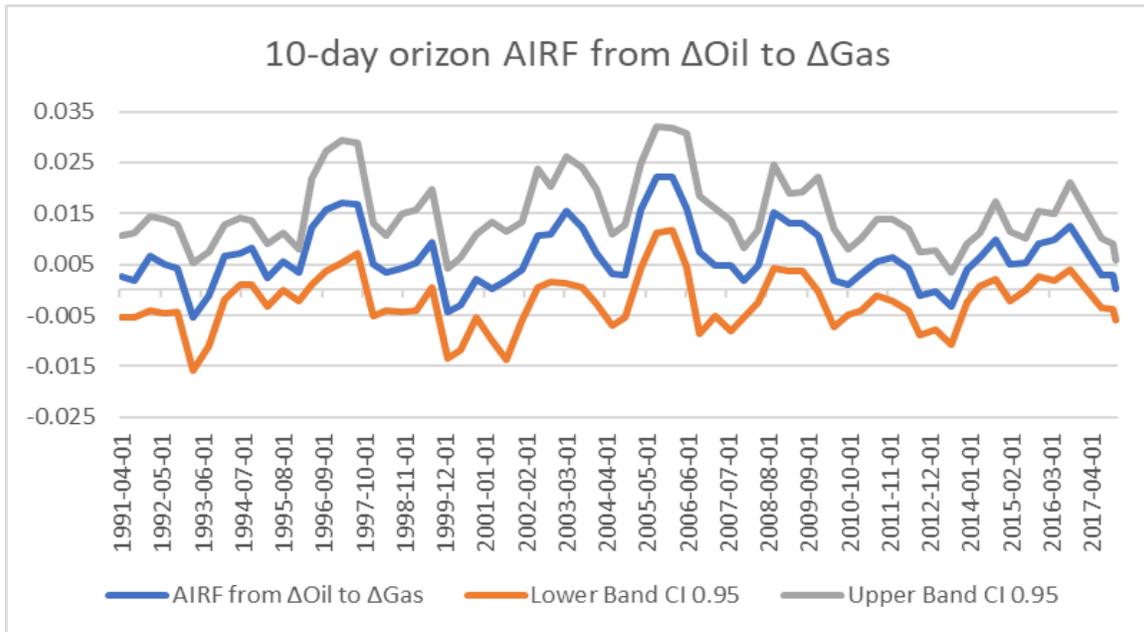


Figure 6-6 10-day horizon AIRF from Oil to Gas (in %).

### 6.2.3.5 Volatility transmission

We further extent our research with the volatility transmission. Even if a commodity does not influence other's pricing, it might affect the price bandwidth it moves within. Moreover, volatility transmission research can shed led light on whether the two commodities can be used as hedging instruments against each other.

Initially, we use the bivariate VAR for the full sample to detect volatility spillovers as Singhal and Ghosh (2016) do. We test our VAR model for serial correlation with the Portmanteau and Breusch-Godfrey tests and the results are negative (Table 6.1.5). Further, the ARCH LM test confirms the ARCH effects (Table 6.1.5). We detect that the  $\Delta\text{Gas}_{t-2}$  is statistically significant at 1% and as a consequence there is gas volatility transmission from oil to gas. Oil prices transmit volatility too since  $\Delta\text{Oil}_{t-1}$  and  $\Delta\text{Oil}_{t-4}$  are statistically significant at 5% and 10% levels respectively. Our initial results verify the bilateral nature of volatility transmission between the two commodities. This confirms that no single commodity price leads the information process alone.

**Table 6.1.5** Bivariate VAR.

Variables	$\Delta Oil_t$	$\Delta Gas_t$	Std. Error	t Value	Probability
C	0.0001		0.0002	0.5680	0.5703
$\Delta Oil_{t-1}$	-0.0325		0.0122	-2.6670	0.0076 <sup>c</sup>
$\Delta Gas_{t-1}$	0.0080		0.0085	0.9800	0.3447
$\Delta Oil_{t-2}$	-0.0582		0.0122	-4.7250	0.0000 <sup>a</sup>
$\Delta Gas_{t-2}$	0.0245		0.0085	2.8627	0.0036 <sup>a</sup>
$\Delta Oil_{t-3}$	-0.0271		0.0122	-2.2220	0.0263 <sup>b</sup>
$\Delta Gas_{t-3}$	0.0069		0.0085	0.8150	0.4153
$\Delta Oil_{t-4}$	0.0112		0.0122	0.9200	0.3574
$\Delta Gas_{t-4}$	-0.0074		0.0085	-0.8740	0.3821
$\Delta Oil_{t-5}$	-0.0291		0.0122	-2.3880	0.0169 <sup>b</sup>
$\Delta Gas_{t-5}$	0.0122		0.0085	1.4370	0.1508
$\Delta Oil_{t-6}$	-0.0264		0.0122	-2.1700	0.0300 <sup>b</sup>
$\Delta Gas_{t-6}$	0.0080		0.0085	0.9390	0.3476
C		0.0009	0.0004	0.2370	0.8125
$\Delta Oil_{t-1}$		-0.0352	0.0175	-2.0120	0.0442 <sup>b</sup>
$\Delta Gas_{t-1}$		-0.0541	0.0122	-4.4330	0.0000 <sup>a</sup>
$\Delta Oil_{t-2}$		0.0004	0.0171	0.0230	0.9815
$\Delta Gas_{t-2}$		-0.0186	0.0122	-1.5260	0.1271
$\Delta Oil_{t-3}$		0.0181	0.0173	1.0330	0.3018
$\Delta Gas_{t-3}$		-0.0235	0.0124	-1.9240	0.0544 <sup>c</sup>
$\Delta Oil_{t-4}$		0.0295	0.0173	1.6860	0.0918 <sup>c</sup>
$\Delta Gas_{t-4}$		-0.0032	0.0122	-0.2690	0.7877
$\Delta Oil_{t-5}$		0.0019	0.0175	0.109	0.9133
$\Delta Gas_{t-5}$		-0.0225	0.0122	-1.839	0.0660 <sup>c</sup>
$\Delta Oil_{t-6}$		0.0192	0.0175	1.1000	0.2713
$\Delta Gas_{t-6}$		-0.0293	0.0122	-2.4060	0.0161 <sup>b</sup>
Portmanteau Test (asymptotic)					0.2446
Breusch-Godfrey LM test					0.7745
ARCH (multivariate)					2.2e <sup>-16</sup>

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

We apply a DCC GARCH (1,1) model for our stationary data (returns). We apply both the symmetrical (DCC) and asymmetrical (ADCC) approaches of the DCC GARCH (1,1) methodology (Tables 6.1.6 and 6.1.7). Our results are statistically significant at 5% level. Moreover, our coefficients alpha and beta for both commodities are positive and significant. Further, the sum of alpha and beta coefficients for each commodity is very close to one meaning that the shocks to the conditional variance are highly persistent. The sign and the sum of alpha and beta confirm the stationarity of the covariance.

**Table 6.1.6** Symmetrical DCC GARCH (1,1).

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t Value	Probability
M.U	0.0002			1.1065	0.3116
Ar	0.8357			8.8125	0.0000 <sup>a</sup>
M.A	-0.8538			-9.4428	0.0000 <sup>a</sup>
$\omega$	0.0000			0.6429	0.5202
$\alpha$	0.0727			2.0281	0.0425 <sup>b</sup>
$\beta$	0.9233			23.9219	0.0000 <sup>a</sup>
M.U		-0.0001		-0.5814	0.5609
Ar		0.5312		2.2434	0.0248 <sup>b</sup>
M.A		-0.5529		-2.3671	0.0179 <sup>b</sup>
$\omega$		0.0000		2.9584	0.0030 <sup>a</sup>
$\alpha$		0.0825		6.4104	0.0000 <sup>a</sup>
$\beta$		0.9088		142.7623	0.0000 <sup>a</sup>
$\lambda$		4.9426		14.1085	0.0000 <sup>a</sup>
DCC $\alpha$			0.0089	4.1526	0.0000 <sup>a</sup>
DCC $\beta$			0.9833	170.4483	0.0000 <sup>a</sup>
Q(50)r	44.8682				0.6803
Q(50)r <sup>2</sup>	63.6792				0.0925
Q(50)r		66.1342			0.0627
Q(50)r <sup>2</sup>		47.1342			0.5890
Akaike					-8.9426

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.1.7** Asymmetrical DCC GARCH (1,1).

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t -Value	Probability
M.U	0.0002			1.3120	0.1894
Ar	0.8357			8.8109	0.0000 <sup>a</sup>
M.A	-0.8538			-9.4414	0.0000 <sup>a</sup>
$\omega$	0.0000			0.6416	0.5210
$\alpha$	0.0727			2.0248	0.0428 <sup>b</sup>
$\beta$	0.9233			23.8856	0.0000 <sup>a</sup>
M.U		-0.0001		-0.5814	0.5609
Ar		0.5312		2.2434	0.0248 <sup>b</sup>
M.A		-0.5529		-2.3672	0.0179 <sup>b</sup>
$\omega$		0.0000		2.9563	0.0031 <sup>b</sup>
$\alpha$		0.0825		6.3942	0.0000 <sup>a</sup>
$\beta$		0.9088		142.6651	0.0000 <sup>a</sup>
$\lambda$		4.9426		13.8312	0.0000 <sup>a</sup>
DCC $\alpha$			0.0089	4.1828	0.0000 <sup>a</sup>
DCC $\beta$			0.9833	167.8860	0.0000 <sup>a</sup>
DCC $\gamma$			0.0000	0.0000	0.9999
Q(50)r	44.8296				0.6803
Q(50)r <sup>2</sup>	63.6792				0.0925
Q(50)r		66.1342			0.0627
Q(50)r <sup>2</sup>		47.1343			0.5890
Akaike					-8.9424

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residual with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

Volatility persistence of shocks on the dynamic conditional correlation is divided into the long and short-run coefficients for DCC GARCH models. The DCC coefficients for the symmetrical model are statistically significant, while the asymmetrical coefficient of the ADCC is not. Moreover, the Akaike criterion suggests that the symmetrical fitting is better. The dynamic volatility or DCC $\alpha$  coefficient is close to 0.1, while the DCC $\beta$  is very close to 1. The size of the two coefficients means that there is a systematic correlation between them, while their joint significance means that the conditional correlation is not constant.

We graph the time-varying correlation between oil and gas returns in Figure 6.7. The correlation collapses between 2005 and 2009 when oil reached its lowest levels while gas price reached its peak. The two prices followed a different path. Low correlation is also the case in 2010 when oil prices increased when gas prices receded. The last might mean that the shale revolution affected the volatility spillovers, as low correlation means price formulation independence. The markets are decoupled but the bilateral volatility spillovers and their substitutability could be held as important for optimal portfolio allocation. Singhal and Ghosh (2016) and Malik and Ewing (2009) use similar results for volatility transmission between oil and other equity sectors.

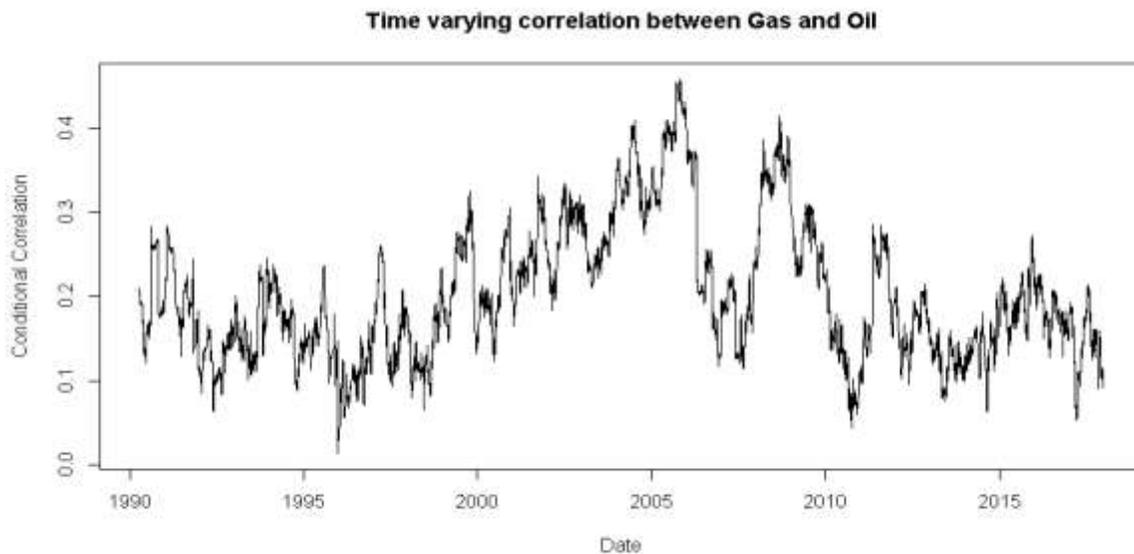


Figure 6-7 Time varying Correlation between Gas and Oil.

Finally, we would like to highlight that our research takes into account the latest data from the energy commodity markets covering the period up to 2017. We apply several econometric methodologies to detect spillovers. Our analysis suggests that the two commodities were already decoupled, something that can assist investors and policymakers. Our research does not confirm Batten et al. (2017) who suggest a unilateral causality from gas to oil. Neither do we agree with Wakamatsu and Aruga (2013), who suggest that shale revolution decoupled the two markets. Geng et al. (2016a) and Geng

et al. (2016b) propose that the two markets had a long-run relationship prior to the shale revolution. We claim that for a cointegration to exist, a certain threshold must be passed. We further find that shale revolution only added to the market independence. We can agree with Wiggins and Etienne (2017) who suggest that demand elasticity is higher since we can expect higher substitution between the two commodities. Augmenting volumes in an already deep market helps substitution to be more efficient. We do not confirm Atil et al. (2013) that the US natural gas market adjusts to oil prices. Last, we find bilateral spillovers which are short-lived and without great magnitude.

#### **6.2.4 Conclusions**

We attempt to research the time-varying price and volatility spillovers between the Henry Hub (natural gas) and New York Mercantile Exchange (NYMEX) oil prices, between 1990 and 2017. We use 6975 observations of futures closing prices since futures prices absorb faster information than spot prices. Our contribution is that we update the literature review with recent data by applying different methodologies. We suggest that there is market decoupling between oil and gas even before the shale revolution and for the whole period.

We apply bivariate VARs, the Momentum Threshold Autoregressive (MTAR) cointegration for asymmetric price transmission, in and out-of-sample causality tests like the Diebold and Mariano test, the Accumulated Impulse Response Functions (AIRF), and the Dynamic Conditional Covariance (DCC) GARCH model.

Our approach is to apply Wald tests for the whole period and for shorter iterations. We would like to remember that the Wald tests are symmetrical implying that an increase of the first commodity price will have the same effect as a decrease on the second commodity price. In the beginning, we found weak evidence of unilateral causality from natural gas to oil for the whole period. However, when we study shorter periods, we find that there is bilateral causality from oil to gas, and that these periods of causality are very

few and without long duration. For the most of our 28-year period, we find that the two commodities follow different and independent courses.

When we research for asymmetric price transmission, we find that there is positive asymmetry from oil to gas implying that oil price increases provoke faster adjustments to natural gas than those of oil price declines. We considered the two markets as independent and thus we have spatial asymmetry. Traders absorb information and adjust prices faster when there are oil price increases.

When we compare the forecasting ability of models containing other than the same commodity coefficients, we find that the inclusion of the second commodity's coefficients does not provide any improvement. We find causality only in a single year (1999) from oil to gas implying that the two markets are decoupled.

To quantify the long-run effects, we apply AIRFs for two trading weeks i.e. 10 days. The horizon is quite short since we consider two highly liquid markets. We consider one standard deviation shock for one commodity price and we account for the second's reaction. From gas to oil the effects are very close to zero and few times (3) is over 0.0005%, while the influence of oil is much greater, since it is between 0.01% and 0.02%.

When we study the volatility transmission, we find that there are bidirectional volatility spillovers and that they are mainly attributed to the long-term component and not to the dynamic. We find that there is a systematic correlation between the two commodities but this is variant. In relevance, the two markets can be considered as decoupled. The US markets are highly financialized and liquid. Many market participants trade large volumes many times resulting in a high churn ratio. The deep liquidity of the NYMEX exchange certifies the market decoupling between the two commodities.

We use data between 1990 and 2017, and we suggest that there is market decoupling. Our contribution has major implications for policymakers and investors. Market decoupling means that the two commodities can not be used as hedging instruments against each other. However, the bidirectional volatility transmission and the high

substitutability can diversify portfolios. This is in accordance with the rest literature review discussing volatility transmission between oil and other equity sectors' returns.

The market follows different paths since there is gas oversupply or high inventories. If gas exports become dominant, then substantial quantities might be removed driving to potential cross-market spillovers. Further, if demand continues to grow, then we might see a re-coupling between the two commodities. In addition, potential bottlenecks might be present requiring additional infrastructure. Last, both oil and gas are fundamentally priced, which is not the case in other regional gas markets. Traders cannot hedge against each other since there is no linkage between them. Trading forms the commodities' prices, and not long-term oil-indexed contracts, making the US market different from other regional markets.

Our research studies the price and volatility spillovers between oil and gas. But our analysis could be improved if the rolling periods were determined under an optimal criterion, and not by ourselves who considered a full year. Shorter periods could capture even more transient effects. Longer periods could aggregate results and supplementary methodologies should be used in compensation.

We continue to study other gas markets since many consider them as regional. Hub pricing is targeted by several policymakers and regulatory authorities. Market design is crucial for fully integrated markets. The European Union has set the initiative of the Energy Union. Maturity could lead into liquid and fully functional markets away of market failures.

## **6.3 European and Asian gas markets**

### **6.3.1 Introduction**

We continue our research for price spillovers in other gas markets around the globe. Gas hubs are considered as highly dynamic. Crude oil pricing is fundamentally driven (Perifanis and Dagoumas 2019). Many products were linked to oil prices. These were not necessarily oil byproducts. A great example was that of long-term gas pipeline contracts which were oil-benchmarked. This was considered as an efficient solution since allowed oil substitution, transparency and disruption avoidance.

However, the long-standing contracts of gas supply were challenged by the shale revolution, and the availability of LNG. The sudden increase in oil and gas production by unconventional sources in the US drove the evolution. Brent declined from 114\$/bbl. (June 2014) to 28\$/bbl. (January 2016). The US turned from a net importer to a self-sufficient market, and the ban of oil exports created a glut due to overproduction. In turn, oil glut and commodity over-stockpiling pushed prices further down leading to oil sector downsizing. This was not the case for the gas industry which saw its share to increase due to the new developments, market evolution and policy and regulatory initiatives.

The global gas market moves away from oil-indexation. To achieve that, many countries constructed gas hubs to procure volumes away from oil-linked contracts. In addition, the Russian Federation and Qatar evolved as swing producers between Europe and Asia. The Asian markets gained importance as China and Japan/Korea increased imports rapidly. Gas hubs offer suppliers' diversification since they do not have the limitations of pipelines. Gas pricing allows fundamentals like supply and demand to function or this is the goal. However, the gas sector is grid bound and requires a lot of infrastructure. Gas markets are still considered as regional since they are not integrated. To overcome limited integration and no physical trading across markets, countries built virtual trading points where market stakeholders exchange volumes.

Regulatory authorities and policy initiatives encourage the transition from oil to gas. European Union initiated the European Gas target model which targets at supply security,

a fully integrated wholesale market with upstream competition and gas' flexible complementing role to renewable production<sup>20</sup>. This leads to the development of gas hubs which deviate from oil-linked contracts. European Gas hubs like the NBP (National Balancing Point), TTF (Title Transfer Facility) and the CEGH (Central European Gas Hub or formerly Gas Hub Baumgartner) play the role of arbitrators since European production will decline and be replaced by imports.

Another important gas market is that of Japan/Korea which had its volumes utterly altered after the Fukushima Daiichi nuclear power plant accident in 2011. Japan changed its energy mix since the gas share increased. The Japanese natural gas demand increased 42% between 2005 and 2015. Further, Japan is the largest LNG importer and constitutes 32% of global LNG purchases in 2016. The sudden increase in imports made the global gas market even tighter. This is why the imports drove the prices from 10\$/MMBTU to 17\$/MMBTU in 2012. This was explained by the Japan's decision to completely shut down nuclear power plants in 2011.

We again claim that environmental concerns, transition from oil to gas, security of energy supply, gas market maturity and energy source diversification altered the global gas market.

We extend our research following the methodological approach we already used for the Henry Hub. We do not conduct asymmetric price transmission methodology. We try to shed light on the liquidity's depth of each market, their maturity and how they reacted to different events such as the Fukushima nuclear accident.

### **6.3.2 Data**

We start with the gas market of the United Kingdom. The natural gas hub is named as National Balancing Point or most commonly NBP and it is a virtual trading point. It offers

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<sup>20</sup> <http://www.acer.europa.eu/events/presentation-of-acer-gas-target-model-/documents/european%20gas%20target%20model%20review%20and%20update.pdf>

several standardized contracts like the within-day, day ahead, months, quarters, summers (April to September) and winters (October to March). It is the longest-standing gas hub. It is different from the majority of the gas hubs since it does not require trades to be balanced, and thus there is no fixed penalty for trading imbalances. When a trading side is out of balance, then the “cash-out” process starts with the trader to buy or sell quantities at the marginal system price, which is almost the spot price. We use the Intercontinental Exchange UK Natural Gas Continuous Futures prices as data. The price is Sterling per Therm.

Second is the Dutch market of Title Transfer Facility (TTF). It is also a virtual trading point. It is now the leading gas hub and its prices are used as benchmark for contracts. It is widely considered as the most liquid hub after that of Henry Hub. Didier Magne considered the TTF price as the real market price, even if the NBP was considered as the price setter. Further, he claimed that the TTF is the only trading point where you can hedge the importing US LNG into Europe. Patrick Barouki, Uniper Global Commodities trading and origination head, claimed that there are occasions when the TTF movement can be explained by the forex changes signaling the increased link between the US LNG and European pricing<sup>21</sup>. We use the Platts Day-Ahead Futures closure prices and they are posted in Euros per Mwh.

We continue with our last market which is that of Japan Korea Marker or JKM. It is the benchmark for LNG spot physical cargoes. The Japanese and Korean markets combinedly account for the largest share of gas imports globally. It is also a key market since many events drove the global LNG evolution. There are many economies in the region which are developing quite rapidly. Further, 51% of the Australian LNG exports are to Japan<sup>22</sup>. In addition, the exporting contracts are long-term. Last, the Fukushima disaster and the complete nuclear power shut down increased the imports for Japan. Our prices are the Platts Spot Cargo price in USD per MMBTU.

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<sup>21</sup> <https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/051117-dutch-ttf-natural-gas-hub-now-the-henry-hub-for-europe-flame-panel>

<sup>22</sup> <https://www.eia.gov/international/analysis/country/AUS>

All our gas prices are researched in conjunction with the Intercontinental Exchange (ICE) Brent Crude Continuous Futures contract. We consider the European blend as the most appropriate since we study two European markets. However, Japan Korea Marker and the rest of LNG contracting in Asia use the Japanese Customs-Cleared Crude Oil (JCC) as benchmark. We continue to use the Brent blend to research the Asian market since Kaufmann and Ullman (2009) recognize it as the price Granger causing other blends. In addition, Fattouh (2009) proposes that the price differentials between different blends are stationary implying that the blends are integrated in the long-run. The last confirms the law of “one great pool” since the opposite would give arbitrage occurrences. Our research uses daily data between 2/2/2009 and 28/6/2019. We use the natural logarithms of our data and thus their first differences are the respective returns. Our data are stationary at first differences I(1). Last, there is no cointegration between the three pairs (Tables 6.2.1 to 6.2.4).

**Table 6.2.1** Test for unit roots 2/2/2009-28/6/2019.

<b>Level.</b>	<b>ADF</b>	<b>PP test</b>	<b>First difference</b>	<b>ADF</b>	<b>PP test</b>
Brent Oil	0.2572	-1.8566	Brent $\Delta$ (Oil)	-37.2574 <sup>a</sup>	-54.4199 <sup>a</sup>
NBP Gas	-0.7599	-1.7877	NBP $\Delta$ (Gas)	-37.4909 <sup>a</sup>	-50.2464 <sup>a</sup>
TTF Gas	-0.7637	-2.5089	TTF $\Delta$ (Gas)	-39.2390 <sup>a</sup>	-52.9523 <sup>a</sup>
JKM Gas	-0.5298	0.9782	JKM $\Delta$ (Gas)	-29.6525 <sup>a</sup>	-45.8495 <sup>a</sup>

Notes: The null hypothesis of the ADF and Phillips Perron test is that a variable and has a unit root. The first difference of the series is indicated by  $\Delta$ .

<sup>a</sup> Indicates rejection of the null hypothesis at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates rejection of the null hypothesis at 5% and 10%.

<sup>c</sup> Indicates rejection of the null hypothesis at 10%.

**Table 6.2.2** Johansen's maximum likelihood method test for cointegration relationship without linear trend and with a constant.

NBP and Brent prices

Result no cointegration

<b>Null Hypothesis: No cointegration</b>	<b>Alternative <math>H_1</math></b>	<b>Eigen values</b>	<b>5% Critical value</b>
Maximum Eigen values			
$r=0$	$r=1$	13.89	15.67
$r \leq 1$	$r=2$	4.10	9.24
Trace statistics			
$r=0$	$r \geq 1$	17.99	19.96
$r \leq 1$	$r \geq 2$	4.10	9.24

**Table 6.2.3** Johansen's maximum likelihood method test for cointegration relationship without linear trend and with a constant.

TTF and Brent prices

Result no cointegration

<b>Null Hypothesis: No cointegration</b>	<b>Alternative <math>H_1</math></b>	<b>Eigen values</b>	<b>5% Critical value</b>
Maximum Eigen values			
$r=0$	$r=1$	13.45	15.67
$r \leq 1$	$r=2$	5.53	9.24
Trace statistics			
$r=0$	$r \geq 1$	18.98	19.96
$r \leq 1$	$r \geq 2$	5.53	9.24

**Table 6.2.4** Johansen’s maximum likelihood method test for cointegration relationship without linear trend and with a constant.

JKM and Brent prices

Result no cointegration

<b>Null Hypothesis: No cointegration</b>	<b>Hypothesis <math>H_1</math></b>	<b>Eigen values</b>	<b>5% Critical value</b>
<b>Maximum Eigen values</b>			
r=0	r=1	15.33	15.67
r≤1	r=2	4.37	9.24
<b>Trace statistics</b>			
r=0	r≥1	19.70	19.96
r≤1	r≥2	4.37	9.24

### 6.3.3 Methodology

We use the same methodology with the previous chapter apart from the asymmetric price transmission.

### 6.3.4 Results

#### 6.3.4.1 Time domain causality tests

Time domain causality tests are conducted first. We devise bivariate models for each market to Granger test for the whole period and for shorter iterations. The lag order for our models is determined by the Akaike Information Criterion (AIC). The lag order is two for NBP, ten for TTF and four for JKM. Further, we test our VARs for stability and none of their roots lies outside the unit cycle. We again have results which allow us to proceed.

We begin with the NBP which is the oldest gas trading point. Further, we test price spillovers between 2009 and 2019, which is the whole period. Our significance level, or when we reject or do not reject the hypothesis of price spillovers is that of 5%. Our hypothesis (null) is that there are no price spillovers between the two commodities. The aggregate of the full sample suggests that the National Balancing Point is a fundamentally

priced gas hub i.e. there are no price spillovers from none commodity. The probability for oil not causing gas prices is 7.85% and the vice versa probability is 16.28%. Our first results confirm that the NBP is an integrated market and there are not price spillovers between the two commodities.

**Table 6.2.5** Full sample causality tests.

<b>Null Hypothesis H<sub>0</sub> No causality</b>	<b>NBP</b>	<b>TTF</b>	<b>JKM</b>	<b>Critical value</b>
<b><i>From Oil to Gas</i></b>	<b>p value</b>	<b>p value</b>	<b>p value</b>	
Wald test	0.0785	0.1407	0.0002	0.05
<b><i>From Gas to Oil</i></b>				
Wald test	0.1628	0.7538	0.0083	0.05

To investigate further whether transient spillovers exist, we use rolling iterations of 250 observations every 100<sup>th</sup> observation. We graph our results in the following figures (Figures 6-8 and Figure 6-9). We have no price spillovers from oil to gas. The successive probabilities that oil returns do not Granger cause gas returns are all over our rejection threshold. This confirms our aggregate results. There are only three time points when the probabilities reach but also do not pass under the rejection threshold and these are between 2010 and 2011, 2016 and 2017 and 2018 and 2019 (Figure 6-8). These instances might explain the statistically significant  $\Delta Oil_{t-2}$  in Table 6.2.7 for the gas returns.

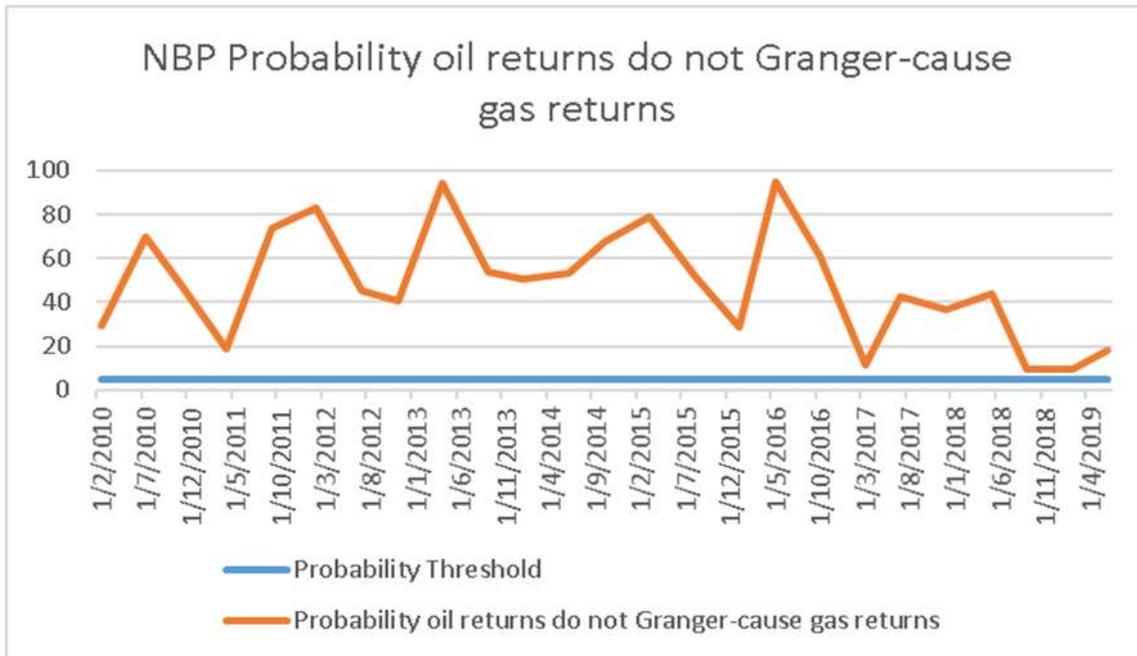


Figure 6-8 NBP Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations.

When we investigate the vice-versa causality, we find instances when we have transient spillovers from gas to oil. These are only three short periods between 2010 and 2011, 2012 and 2013, and 2015. These are the only instances when the gas pricing is driving the oil pricing i.e. it leads the information process (Figure 6-9).

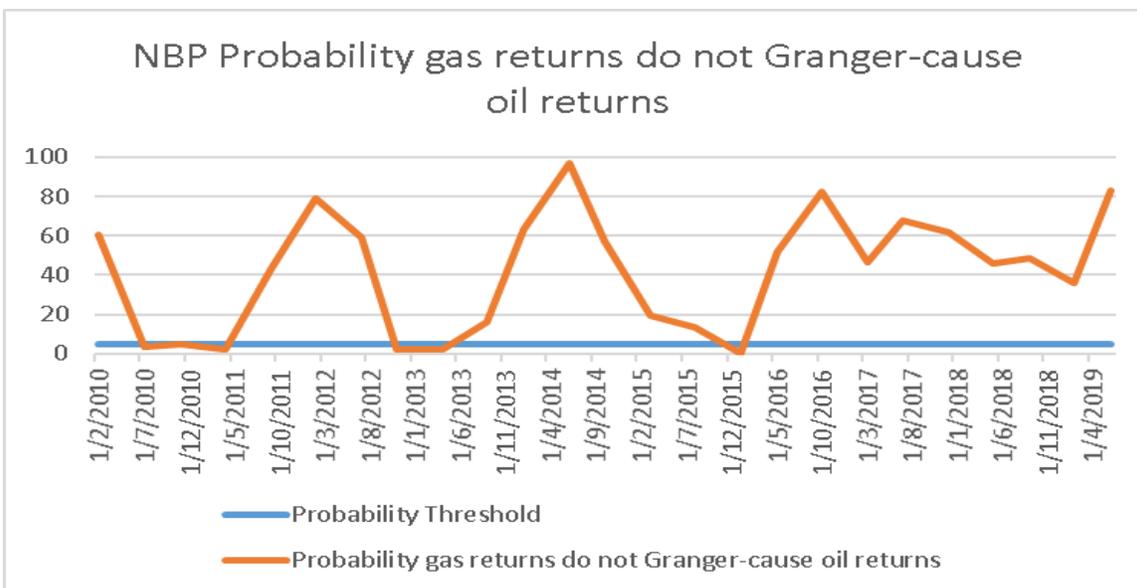


Figure 6-9 NBP Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations.

In conclusion, we consider the British market as fully operational and integrated since the two commodities are priced by the fundamentals. There are only transient effects from gas to oil while the aggregate remains unaffected. The market can be well characterized as efficient.

Our second gas hub is that of the TTF which is considered as the most liquid in the recent years. For the aggregate of the whole period, we can deny that there are price spillovers from oil to gas returns since the probability of no causality is 14.07%. In addition, the vice versa causality does not hold and the probability is quite high 75.38%. We can tell with confidence that the causality between the two commodities irrespectively of the direction does not hold. Our aggregate of the full sample confirms the consideration that the two commodities are not co-integrated in the long-run.

Further, oil returns do not drive the pricing process in the TTF market (rolling VAR). The probability series remain well above the rejection threshold. There are only two instances when the probabilities reach the threshold but never pass it. These points are not enough to suggest causality among the commodities. Our rolling VAR results confirm the whole period results. Instead, gas causes oil returns only for one instance between 2013 and 2014 (Figure 6-11).

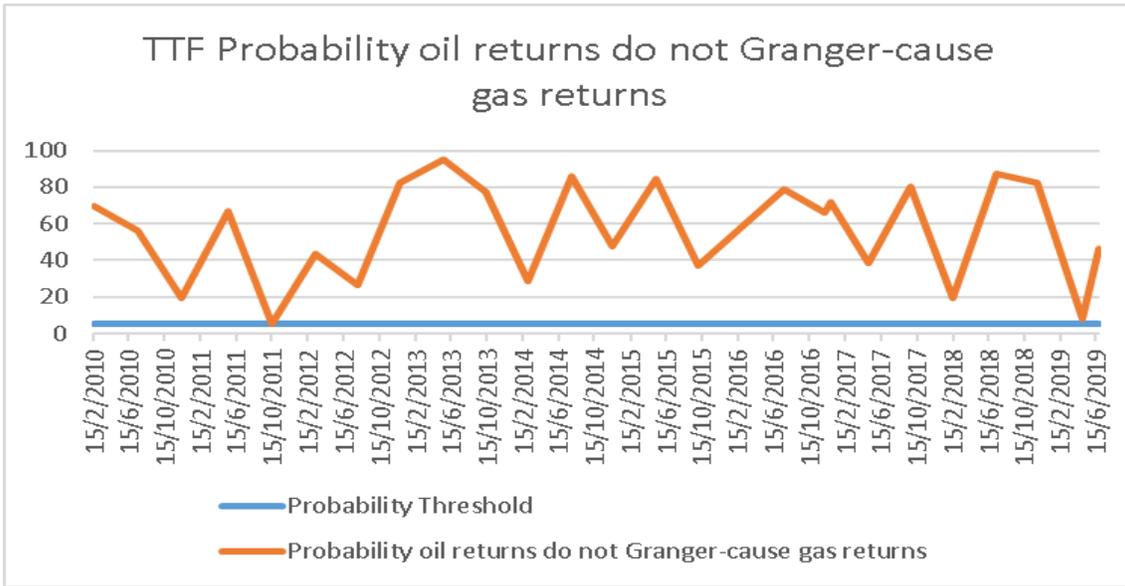


Figure 6-10 TTF Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations.

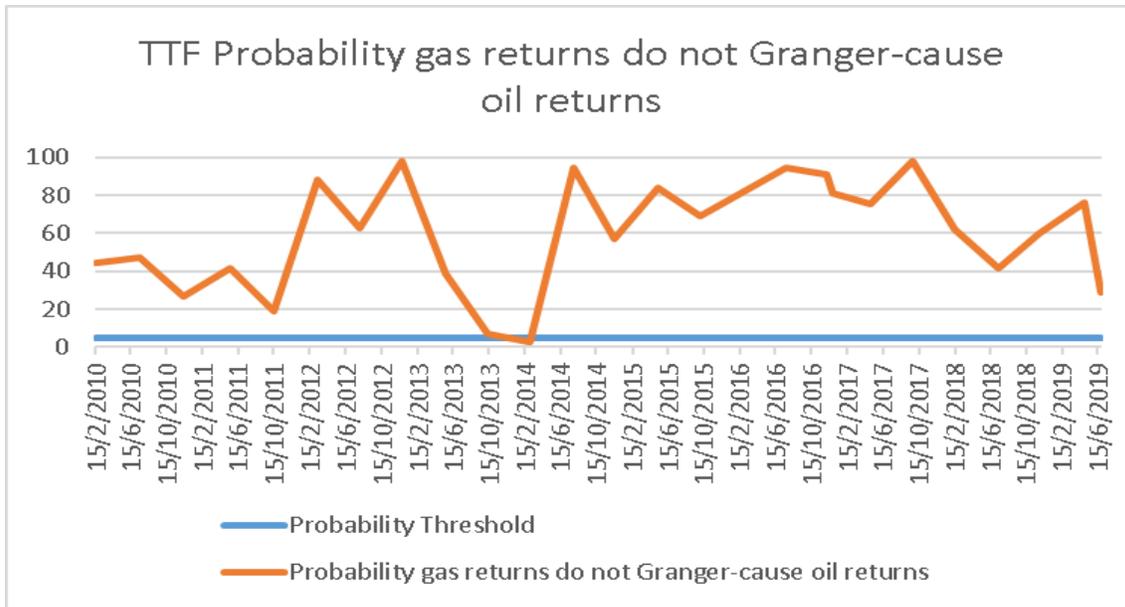


Figure 6-11 TTF Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations.

A single period does not confirm causality from gas returns to oil returns, something confirming our full sample results. Largely, the two European gas hubs are fully efficient, not allowing any commodity to drive the pricing process.

Japan Korean Market is the largest gas market in the region since the majority of the imports are conducted there. China also increases its imports. The pricing process can be challenged since several events tightened the market. Our causality tests for the whole period confirm that there is a bilateral causality between the two commodities. The null hypothesis of oil returns not causing gas returns is rejected since the probability is 0.02%. Further, gas returns also cause oil returns. The probability of gas returns not causing oil returns is 0.83%. The bidirectional causality between the two commodities is something to be better researched by the shorter iteration causality tests.

We continue with the rolling VAR process to investigate the time-varying process. We confirm that there are long-lasting periods when oil returns cause gas returns. Oil leads the information process between 2012 and 2014, and between 2015 and 2016. The two periods can present evidence of the causal drivers which existed then. An earthquake of 9.0 Richter caused one of the largest nuclear accidents. A tsunami (giant wave) hit a nuclear power plant (Fukushima Daiichi) causing a radioactivity accident. Japan lost 10 Gigawatt (GW) of its power capacity. The Japanese government shut down the whole nuclear power generation and not only the damaged plants between 2013 and 2015. Japan was dependent on nuclear power since it consisted 27% of its capacity before 2011. The shut-down led to fossil fuel imports and constituted the market as the price taker. To replace nuclear power generation, Japan started importing LNG. The LNG importers hedged their commodity purchases with mid to long-term contracts but the Japanese currency was already depreciating against the US dollar making imports more expensive. Further, oil and gas prices were high until 2014. The high import prices caused losses and deficits in turn<sup>23</sup>. Japan initiated a program of nuclear power rebound starting in 2015. Both periods when the oil returns guided the gas returns can be attributed to this period

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<sup>23</sup> [https://www.eia.gov/beta/international/analysis\\_includes/countries\\_long/Japan/japan.pdf](https://www.eia.gov/beta/international/analysis_includes/countries_long/Japan/japan.pdf)

of market tightening. Oil linked contracts drove the LNG imports until the nuclear power rebounded. The mid to long-term import contracts hedge against price fluctuations in conjunction with the tight power market are accountable for our results (Figure 6-12).

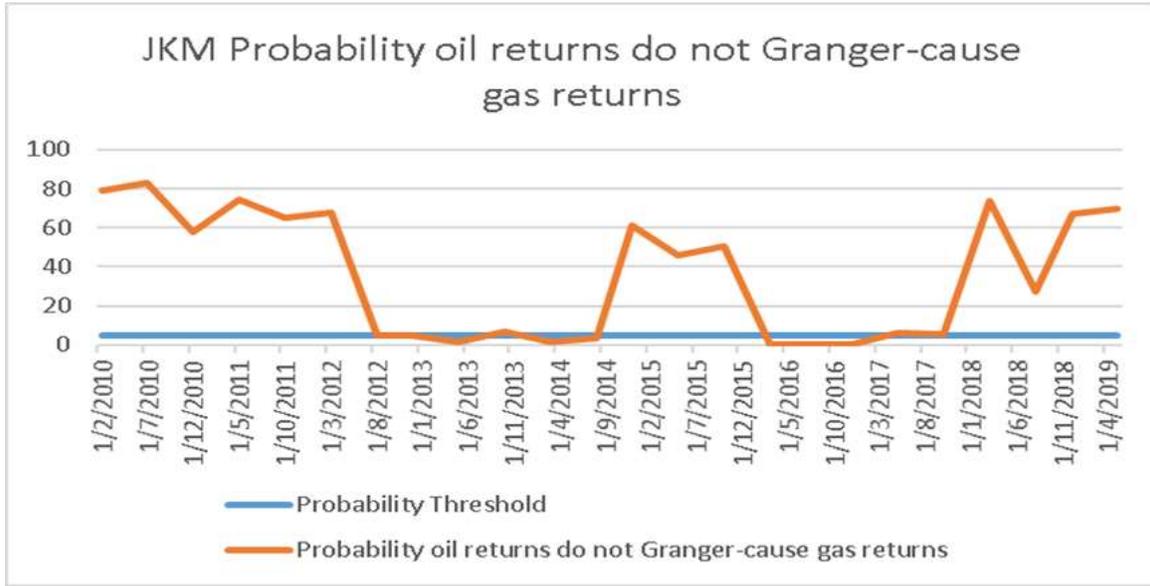


Figure 6-12 JKM Probability (%) oil returns do not Granger-cause gas returns. Source: Authors' calculations.

Instead, our results do not suggest causality from gas to oil (Figure 6-13). Only in one instance gas prices cause oil returns and it is in 2010. The rolling VAR process does not confirm the whole period result.

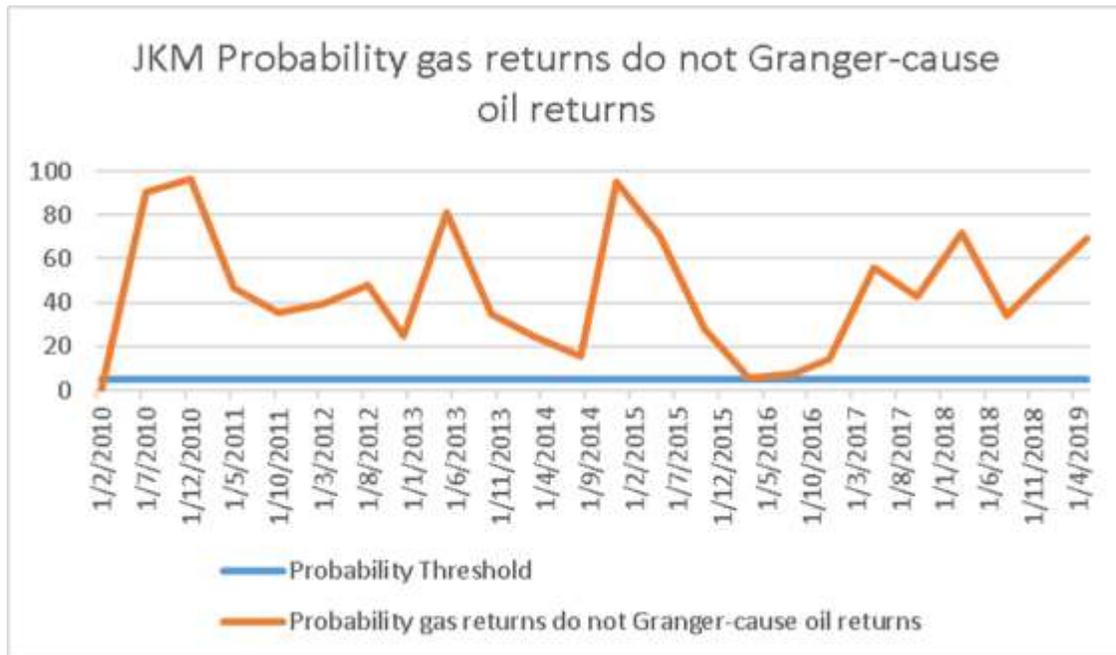


Figure 6-13 JKM Probability (%) gas returns do not Granger-cause oil returns. Source: Authors' calculations.

Finally, our so far research confirms that there is unilateral causality from oil to gas for the JKM gas hub. The oil prices drove the LNG import prices. Our results are also confirmed by our bivariate VARs since oil coefficients well explain gas returns (Table 6.2.9).

#### 6.3.4.2 In and out-of-sample forecasting ability tests

We employ the Ashley et al. (1980) methodology to test whether the inclusion of one's commodity price forecasts the other's course. Actually, we compare the forecasting ability of two models. One with only the coefficients of a single commodity price and the other with both commodities' price coefficients. We test the forecasting ability for the full sample (in-sample) and for shorter iterations (out-of-sample).

We compare the predictive ability of one-step ahead forecasts of models (6.1) and (6.2) to the models (6.7) and (6.8) for all the researched markets. If the inclusion of

another than the same commodity price coefficient improves the forecasting ability, then we have causality. If the predictive ability remains the same, then there are no price spillovers. We use the DM test with the absolute value of 1.96 as a threshold. If our models have less than 1.96 DM value, then the models have equal predictive ability i.e. no price spillovers.

Initially, the in-sample tests for the NBP propose equal predictive ability between the restricted and unrestricted models implying no causality between the two commodities (Table 6.2.6). Our test values are lower than 1.96 verifying the assumption that the NBP is an efficient and integrated market.

**Table 6.2.6** Diebold and Mariano tests – In Sample.

<b>Null Hypothesis H<sub>0</sub> No causality</b>	<b>NBP</b>	<b>TTF</b>	<b>JKM</b>	<b>Critical value 1.96</b>
<b><i>From Oil to Gas</i></b>	<b>D-M value</b>	<b>D-M value</b>	<b>D-M value</b>	
	-0.8954	-2.2638	-1.8897	
<b><i>From Gas to Oil</i></b>				
	-0.7763	-1.5045	-1.5166	

We reach the same conclusions when we conduct the out-of-sample tests. The DM tests values never surpass the absolute value 1.96 moving within the negative and positive thresholds. Our results suggest market decoupling (Figures 6-14 and Figures 6-15).

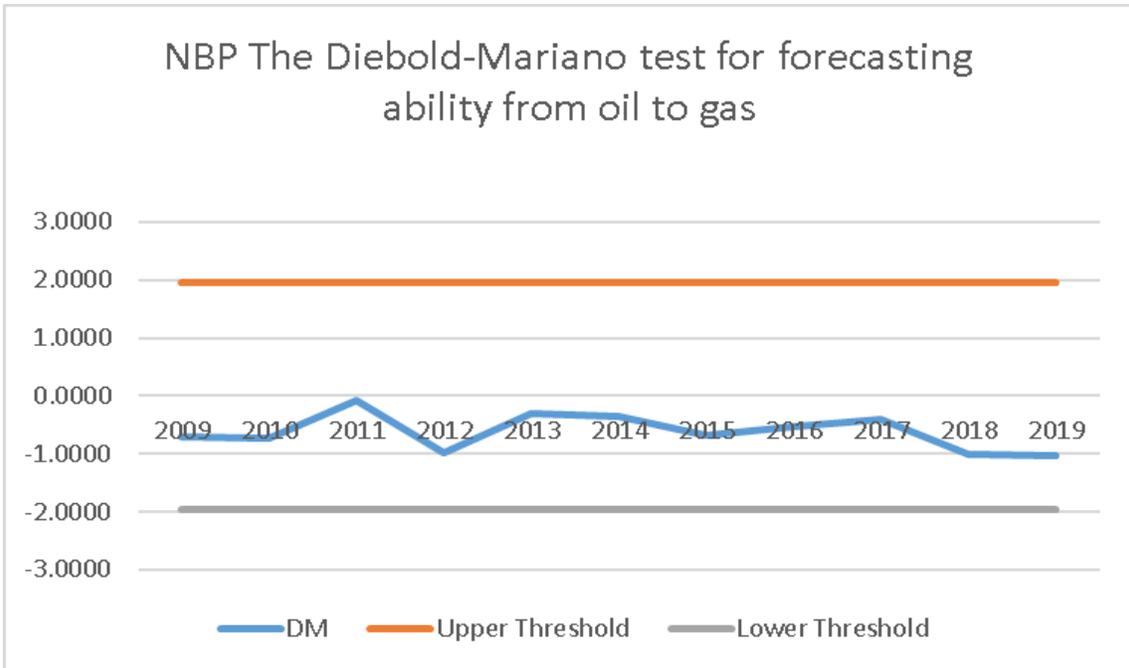


Figure 6-14 NBP The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculations.

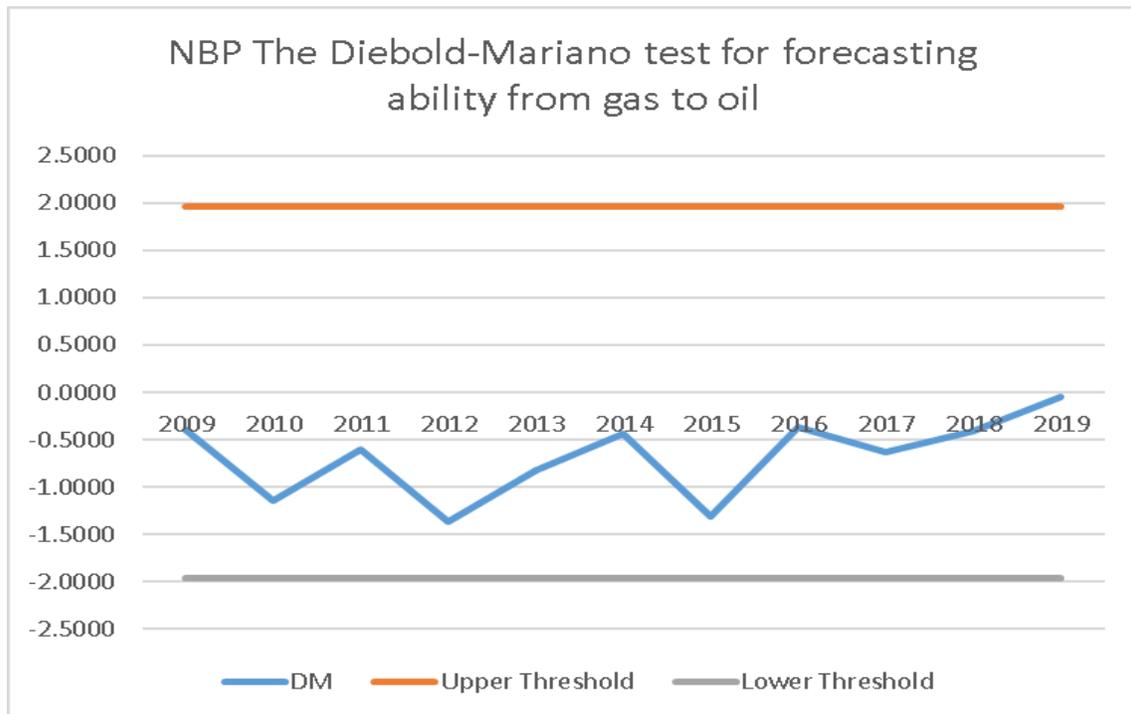


Figure 6-15 NBP The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations.

On the contrary, for the TTF, we have causality from oil to gas for the full sample. Our in-sample methodology is -2.2638, which is higher in absolute terms than 1.96 (Table 6.2.6). This is a unilateral causality since we do not find causality from gas to oil by our in-sample tests. However, the full sample tests are only the aggregates.

Our out-of-sample tests propose a bilateral causality, and that only during two instances oil returns better forecast gas prices and vice versa (Figures 6-16 and 6.17). Our out-of-sample predictive ability tests suggest that there is a bilateral causality between the two commodities. However, these instances are not successive and as a result we can propose only transient causal effects. Our suggestions by this methodology further enhance our previous results. Our suggestion is that the TTF is well decoupled from the oil market and it is integrated and efficient.

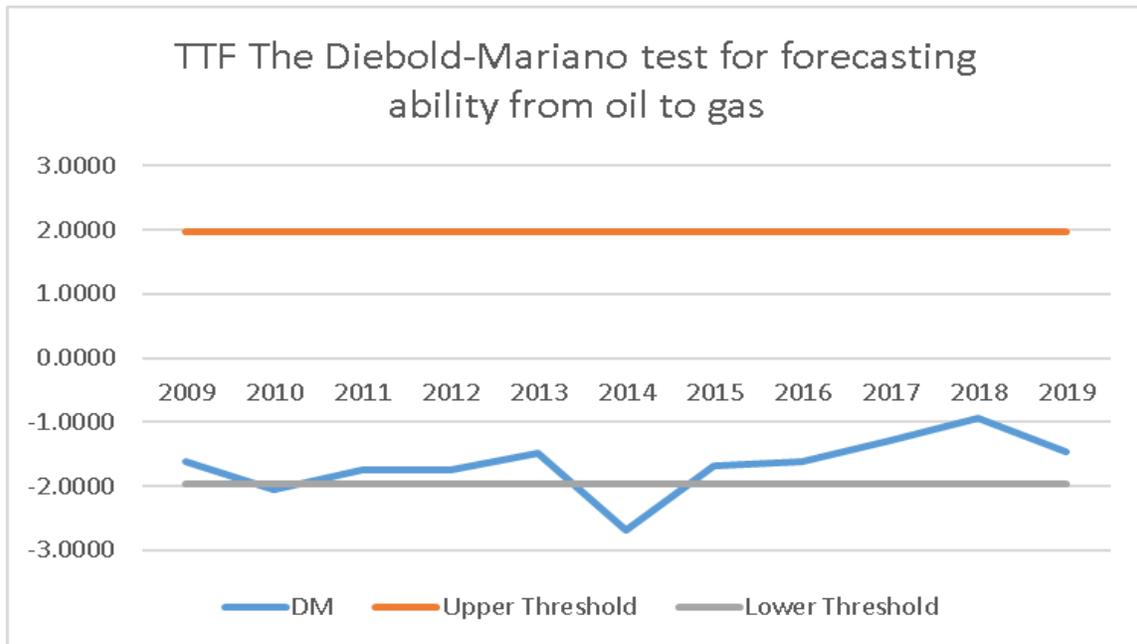


Figure 6-16 TTF The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculation.

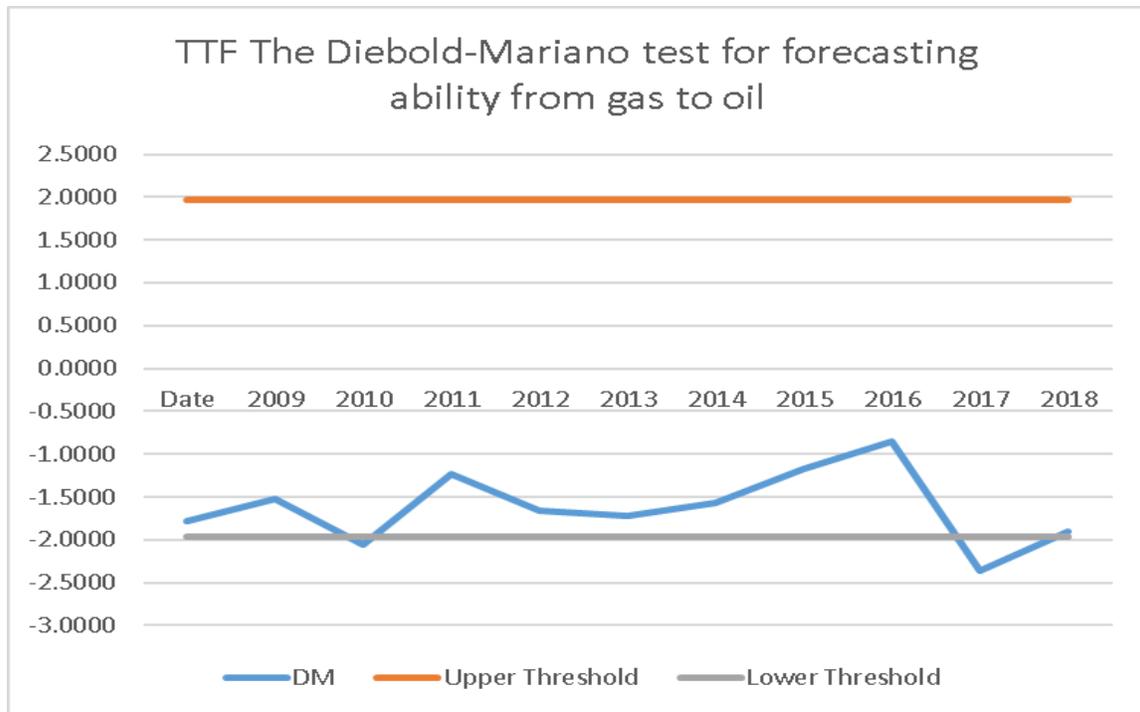


Figure 6-17 TTF The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations.

In addition, the in-sample results for the JKM market suggest even if there is a value that it is close to our threshold that there are no price spillovers between two commodities (-1.8897 and -1.5166 respectively). However, the close to 1.96 value (-1.8897) does not allow us to accept it with confidence. We continue with our out-of-sample tests to test our in-sample results.

Our out-of-sample tests again suggest market decoupling but the DM value series have points well close to our threshold. Only in one instance we have gas returns to better forecast oil returns.

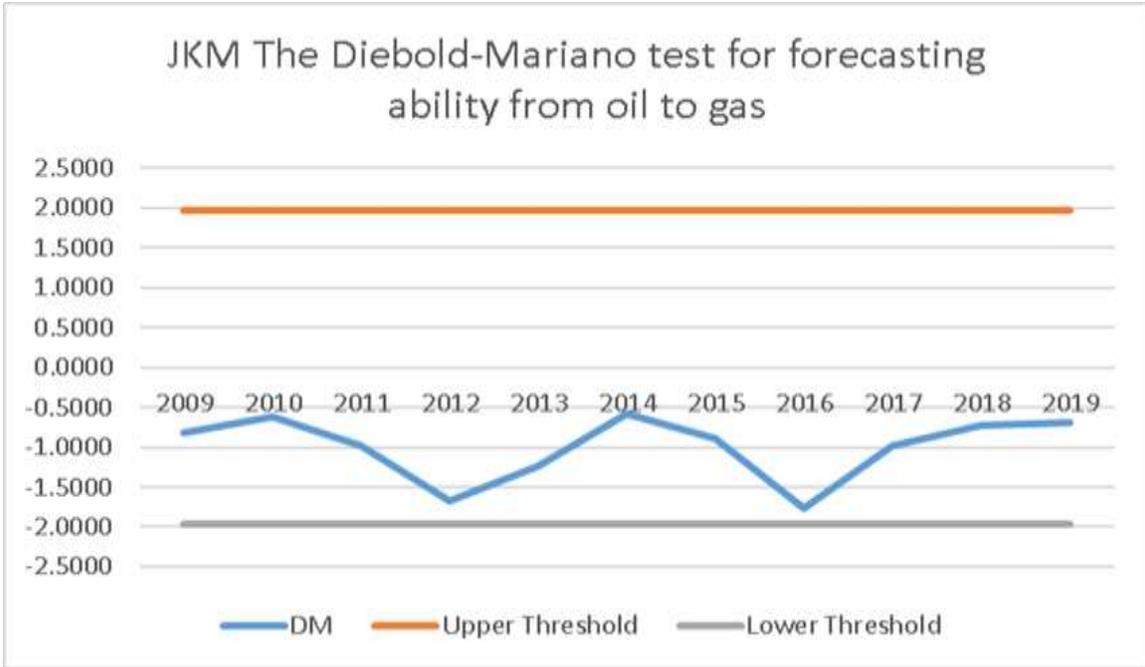


Figure 6-18 JKM The Diebold-Mariano test for forecasting ability from oil to gas. Source: Authors' calculations.

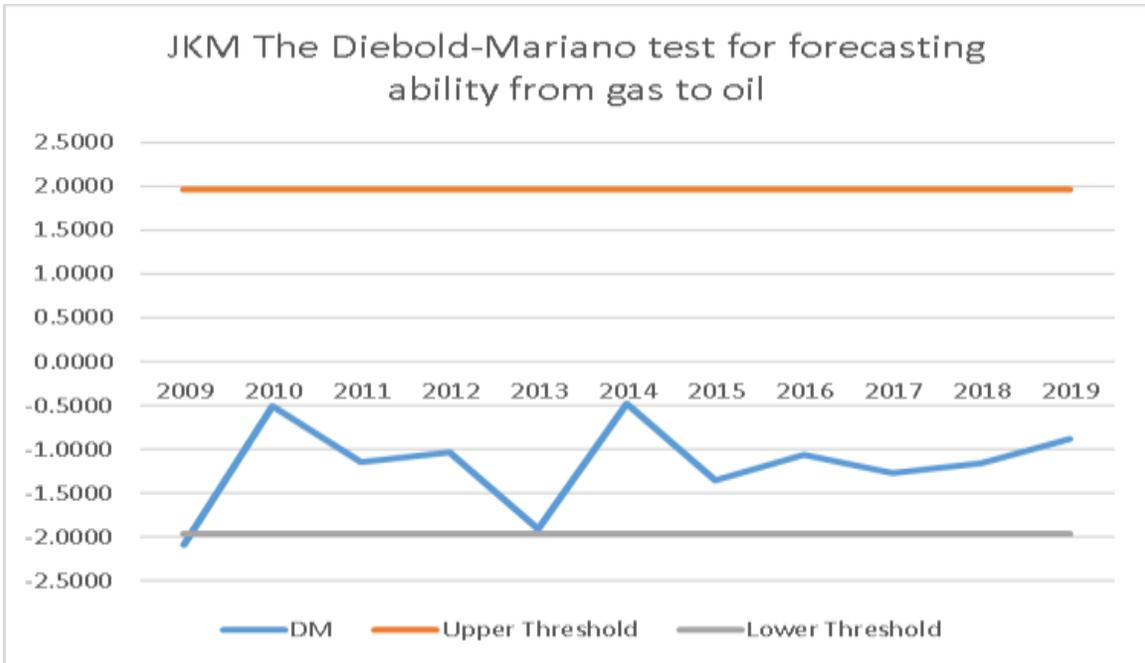


Figure 6-19 JKM The Diebold-Mariano test for forecasting ability from gas to oil. Source: Authors' calculations.

Last, our results for the European markets well propose market decoupling while we can not tell the same for the JKM market.

#### *6.3.4.3 Long-Term impacts*

We calculate the influence's magnitude when there are spillovers. We consider the futures markets as highly liquid. Information will be fast absorbed by traders. This is why we consider only two trading weeks (10 days) as a fair horizon to calculate the Accumulated Impulse Response Functions (AIRFs).

We obtain the AIRFs by our bivariate rolling VARs and we derive series. We calculate the orthogonalized impulse response coefficients with the respective bootstrapped error bands with 95% confidence intervals. We notice that the bivariate VARs cover a whole trading year. With this we capture even the most transient effects.

We start again with the NBP and we notice that the accumulated influences are almost zero. After one standard deviation shock in oil prices, gas' influence is between zero and 0.0050, while for one standard deviation shock in gas prices the influence over oil returns is almost zero (Figures 6-20 and 6-21 respectively). The low impacts among the commodities' returns confirm the hypothesis of market decoupling. A shock in a commodity price does not affect other's returns allowing the fundamentals of each commodity to formulate their pricing.

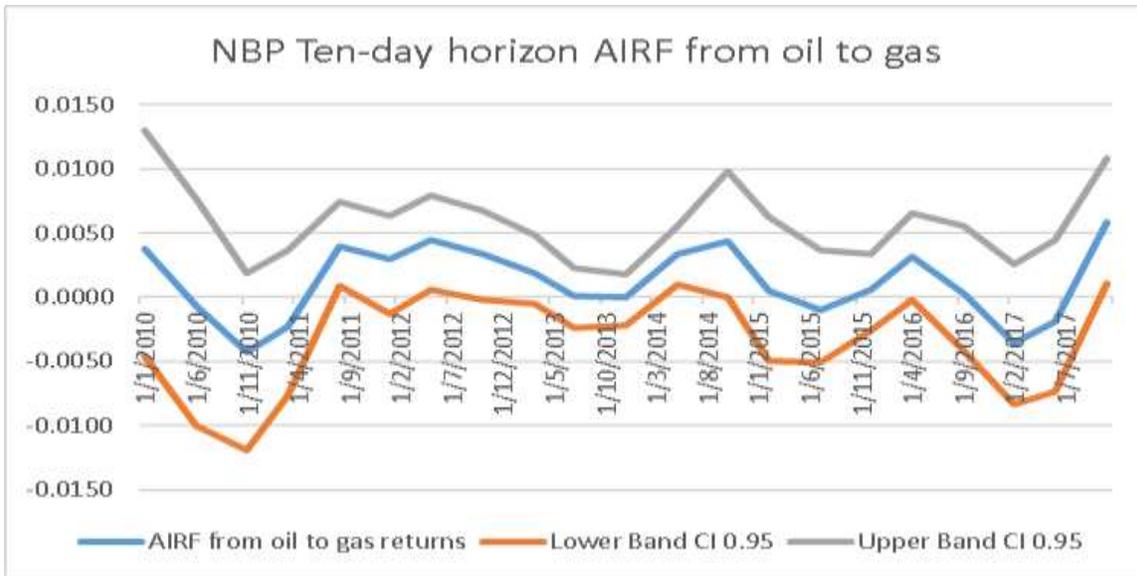


Figure 6-20 NBP Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.

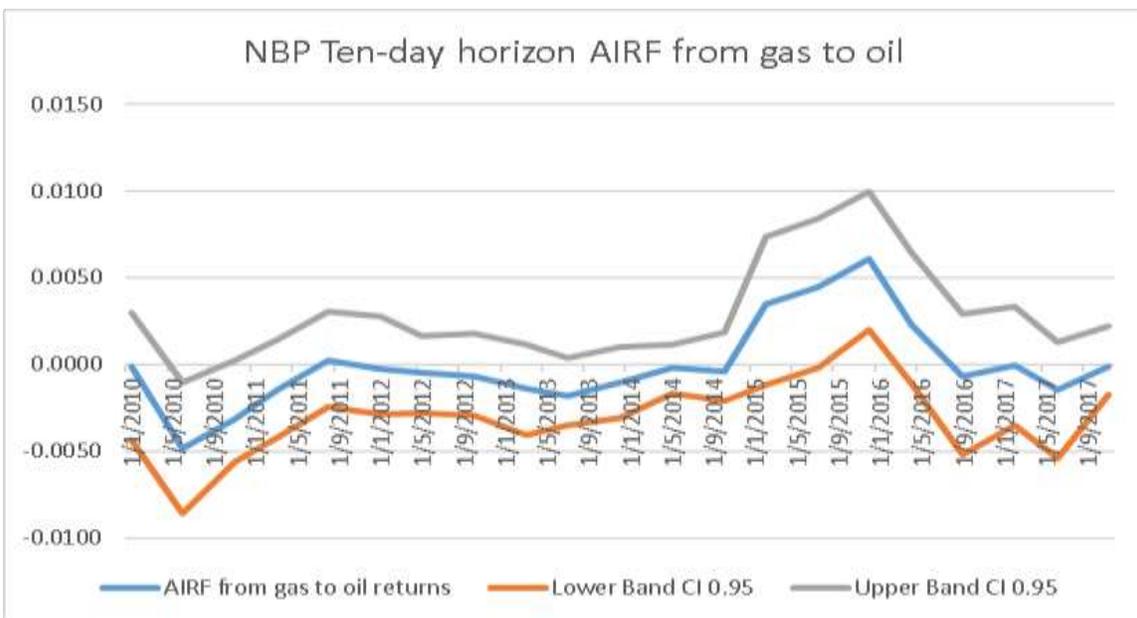


Figure 6-21 NBP Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.

Our results are similar for the TTF market. Oil returns have greater influence on gas rather than the vice versa. The accumulated effect is 0.0100 on gas returns (Figure 6-22). The gas price shocks cause almost zero effect (Figure 6-23). The low accumulated impacts

confirm market decoupling for the second European market (TTF) i.e. commodity prices do not have interdependencies.

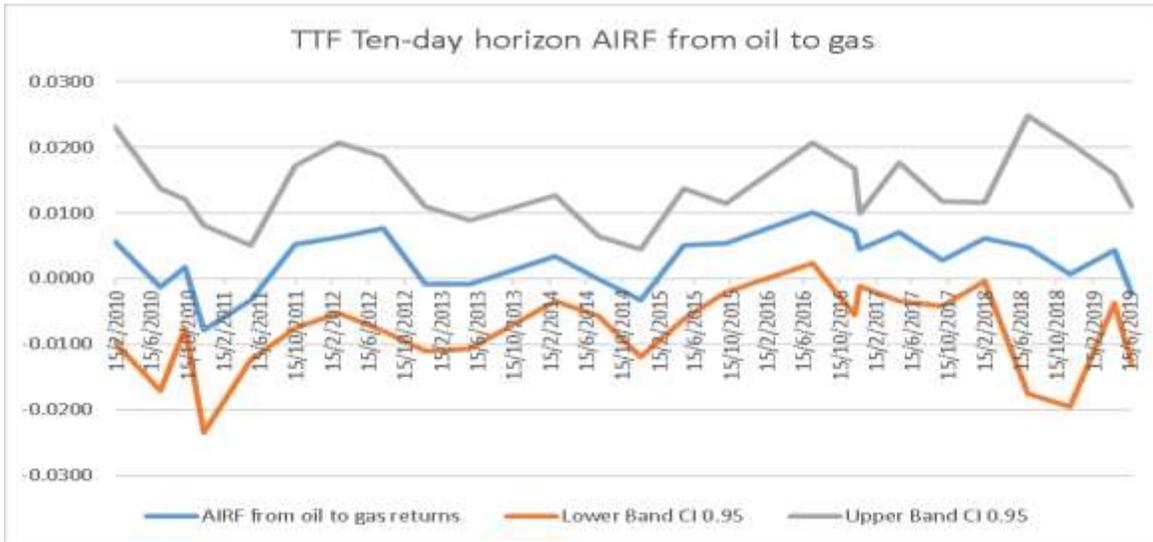


Figure 6-23 TTF Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.

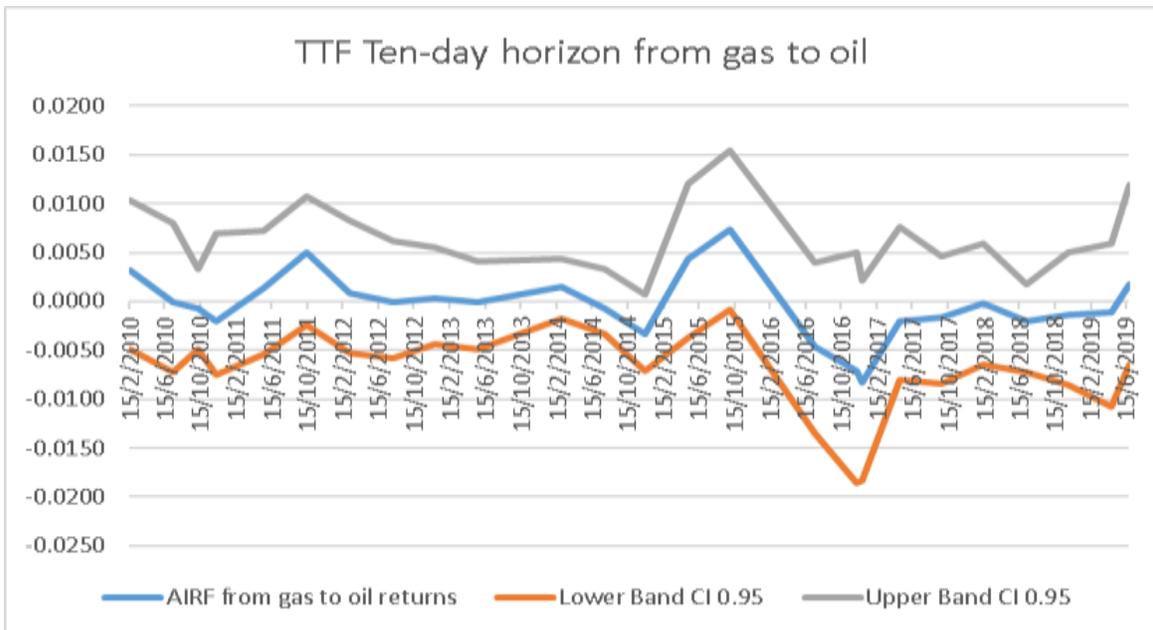


Figure 6-22 TTF Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.

However, the JKM market has different characteristics. The influence of one standard deviation shock in oil prices is even 0.0150, which is three times that of NBP and 50% higher than that of TTF. The high impact periods are between 2015 and 2018. Before that the influence of oil returns is almost zero and follows the pattern of the other two gas hubs. This is justified by the hedging strategy which was followed with mid to long-term contracts. Oil price fluctuations were negligible due to the contracting. However, the partial nuclear power generation rebound led to the less available capacity for other fuels, and traders turned to more short-term contracts. Between 2014 and 2016, oil prices experienced a sharp decline. The short-term oil linked contracts increased the influence oil prices had on gas prices.

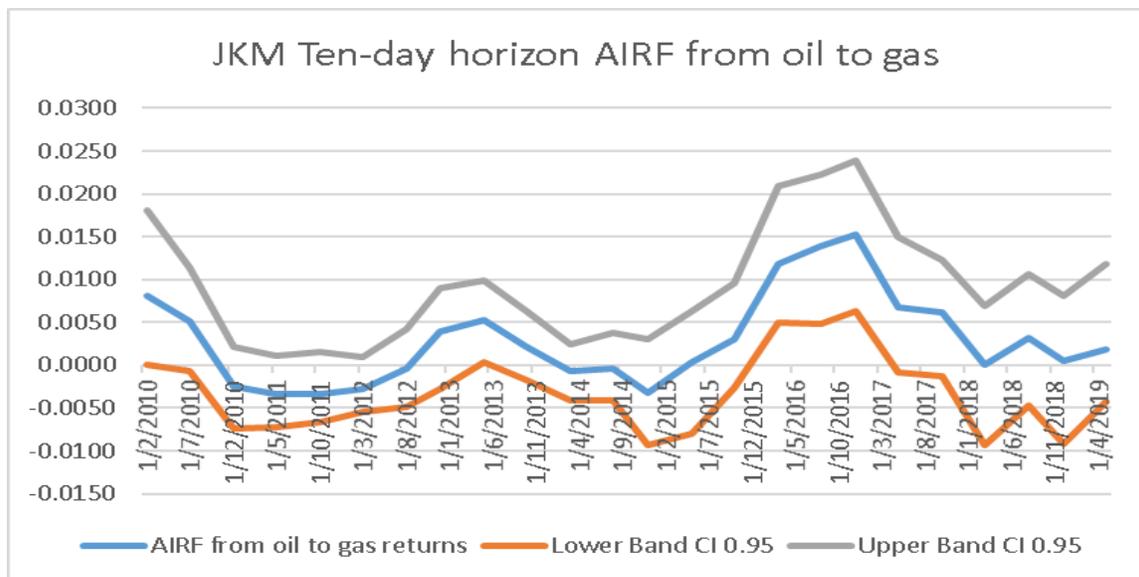


Figure 6-24 JKM Ten-day horizon AIRF from oil to gas. Source: Authors' calculations.

Instead, gas returns had almost zero effect on oil returns. The accumulated impulse response functions have a parallel course to the x axis before 2015. Since then and up to 2018, nuclear power rebounded, gas price shocks have negative impacts on oil returns since the commodity is considered as a substitute to nuclear energy and oil (bridge fuel).

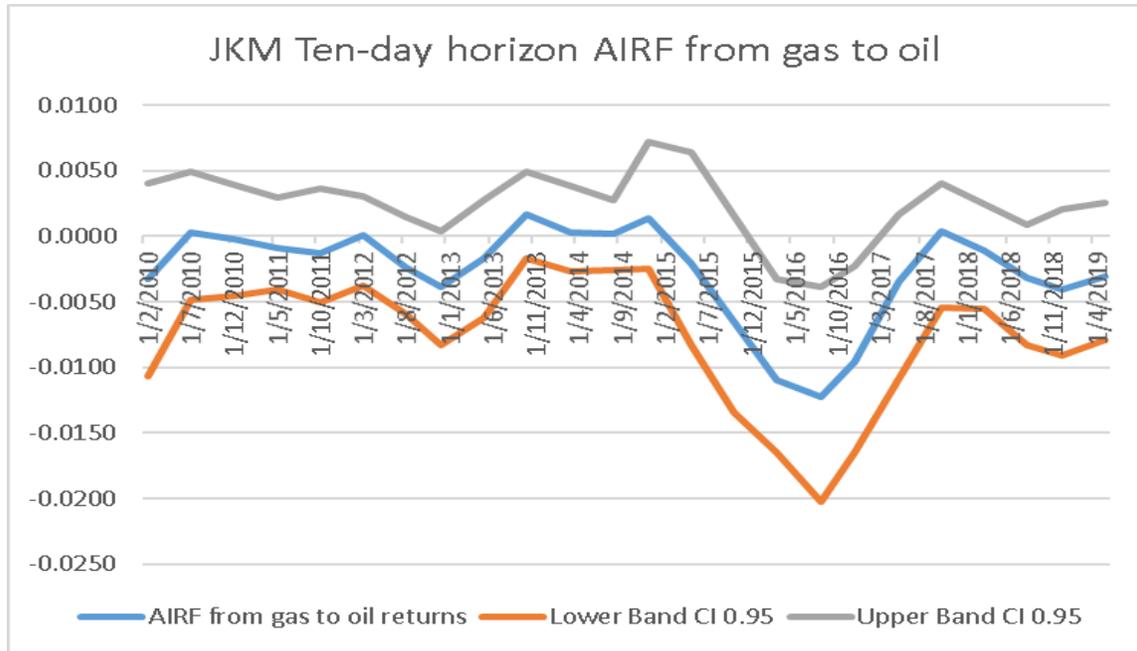


Figure 6-25 JKM Ten-day horizon AIRF from gas to oil. Source: Authors' calculations.

#### 6.3.4.4 Volatility transmission

Our effort to detect linkages between the two commodities could not leave out potential volatility spillovers. One commodity might not influence other's pricing, but could influence volatility. Volatility transmission can potentially cast the two commodities as hedging instruments against each other. We use the Singhad and Gosh (2016) methodology and we start with the bivariate VARs. The Breusch-Godfrey LM tests suggest that serial correlation is non-existent in our residuals while the ARCH tests suggest clustered volatility (Tables 6.2.7, 6.2.8, and 6.2.9). Both of our results allow us to proceed with volatility modelling.

**Table 6.2.7. NBP Bivariate VAR.**

Variables	$\Delta Oil_t$	$\Delta Gas_t$	Std. Error	t-Value	Probability
C	0.0001		0.0004	0.3950	0.6931
$\Delta Oil_{t-1}$	-0.0538 <sup>a</sup>		0.0195	-2.750	0.0060
$\Delta Gas_{t-1}$	-0.0225-		0.0151	-1.4900	0.1363
$\Delta Oil_{t-2}$	0.0013		0.0195	0.0660	0.9469
$\Delta Gas_{t-2}$	0.0186		0.0151	1.2280	0.2196
C		-0.0003	0.0004	-0.6160	0.5382
$\Delta Oil_{t-1}$		-0.0007	0.0252	-0.0300	0.9763
$\Delta Gas_{t-1}$		0.0252	0.0195	1.2910	0.1968
$\Delta Oil_{t-2}$		-0.0567 <sup>b</sup>	0.0251	-2.2550	0.0242
$\Delta Gas_{t-2}$		-0.0381 <sup>c</sup>	0.0195	-1.9510	0.0512
Breusch-Godfrey LM test					0.2297
ARCH (multivariate)					2.2e <sup>-16</sup>

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.2.8. TTF Bivariate VAR.**

Variables	$\Delta Oil_t$	$\Delta Gas_t$	Std. Error	t-Value	Probability
C	0.0001		0.0003	0.4350	0.6639
$\Delta Oil_{t-1}$	-0.520 <sup>a</sup>		0.0197	-2.6320	0.0085
$\Delta Gas_{t-1}$	0.0009		0.0096	0.0980	0.9215
$\Delta Oil_{t-2}$	-0.0033		0.0197	-0.1680	0.8667
$\Delta Gas_{t-2}$	0.0087		0.0096	0.9070	0.3646
$\Delta Oil_{t-3}$	0.0210		0.0197	1.0620	0.2884
$\Delta Gas_{t-3}$	0.0102		0.0096	1.0550	0.2913
$\Delta Oil_{t-4}$	0.0123		0.0197	0.6250	0.5321
$\Delta Gas_{t-4}$	-0.0105		0.0097	-1.0850	0.2778
$\Delta Oil_{t-5}$	0.0132		0.0197	0.6710	0.5024
$\Delta Gas_{t-5}$	-0.0035		0.0096	-0.3670	0.7139
$\Delta Oil_{t-6}$	0.0139		0.0198	0.7030	0.4822
$\Delta Gas_{t-6}$	0.0016		0.0096	0.1740	0.8615
$\Delta Oil_{t-7}$	-0.0218		0.0198	-1.104	0.2698
$\Delta Gas_{t-7}$	-0.0040		0.0097	-0.4130	0.6798
$\Delta Oil_{t-8}$	-0.0048		0.0197	-0.2470	0.8050
$\Delta Gas_{t-8}$	-0.0136		0.0096	-1.4100	0.1586
$\Delta Oil_{t-9}$	0.0028		0.0197	0.1410	0.8877
$\Delta Gas_{t-9}$	-0.0004		0.0096	-0.0480	0.9614
$\Delta Oil_{t-10}$	0.0316		0.0197	1.6101	0.1096
$\Delta Gas_{t-10}$	-0.0095		0.0096	-0.9930	0.3207
C		-0.0003	0.0007	-0.4530	0.6508
$\Delta Oil_{t-1}$		-0.0277	0.0403	-0.6880	0.4916
$\Delta Gas_{t-1}$		-0.0345 <sup>c</sup>	0.0197	-1.7480	0.0806
$\Delta Oil_{t-2}$		-0.0120	0.0403	-0.2980	0.7659
$\Delta Gas_{t-2}$		0.0996 <sup>a</sup>	0.0196	-5.0650	4.38e <sup>-7</sup>
$\Delta Oil_{t-3}$		0.0682 <sup>c</sup>	0.0403	1.6920	0.0908
$\Delta Gas_{t-3}$		-0.0963 <sup>a</sup>	0.0197	-4.8740	1.16e <sup>-6</sup>
$\Delta Oil_{t-4}$		0.0847 <sup>b</sup>	0.0403	2.0980	0.0359
$\Delta Gas_{t-4}$		-0.0511 <sup>a</sup>	0.0198	-2.5830	0.0098
$\Delta Oil_{t-5}$		0.0138	0.0403	0.3420	0.7324
$\Delta Gas_{t-5}$		-0.0683 <sup>a</sup>	0.0197	-3.4610	-0.0005
$\Delta Oil_{t-6}$		0.0469	0.0403	1.1610	0.2455
$\Delta Gas_{t-6}$		-0.1000 <sup>a</sup>	0.0197	-5.0670	4.32e <sup>-7</sup>
$\Delta Oil_{t-7}$		0.0043	0.0404	0.1070	0.9144
$\Delta Gas_{t-7}$		0.0262	0.0198	1.3240	0.1856
$\Delta Oil_{t-8}$		0.0509	0.0403	1.2620	0.2069
$\Delta Gas_{t-8}$		-0.0265	0.0197	-1.3480	0.1778
$\Delta Oil_{t-9}$		0.0654	0.0403	1.6220	0.1050

$\Delta\text{Gas}_{t-9}$	-0.0128	0.0196	-0.6540	0.5129
$\Delta\text{Oil}_{t-10}$	-0.0805 <sup>b</sup>	0.0403	-1.9970	0.0458
$\Delta\text{Gas}_{t-10}$	0.01115	0.0196	0.5910	0.5549
Breusch- Godfrey LM test				0.1083
ARCH (multivariate)				2.2e <sup>-16</sup>

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<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.2.9. JKM Bivariate VAR.**

Variables	$\Delta Oil_t$	$\Delta Gas_t$	Std. Error	t-Value	Probability
C	0.0001		0.0003	0.3030	0.7616
$\Delta Oil_{t-1}$	-0.0468 <sup>b</sup>		0.0197	-2.3670	0.0180
$\Delta Gas_{t-1}$	0.0268		0.0230	1.1650	0.2440
$\Delta Oil_{t-2}$	-0.0108		0.0197	-0.5480	0.5834
$\Delta Gas_{t-2}$	-0.0506 <sup>b</sup>		0.0231	-2.1870	0.0288
$\Delta Oil_{t-3}$	0.0087		0.0197	0.4440	0.6573
$\Delta Gas_{t-3}$	-0.0543 <sup>b</sup>		0.0231	-2.3460	0.0191
$\Delta Oil_{t-4}$	0.0235		0.0197	1.1930	0.2329
$\Delta Gas_{t-4}$	-0.0177		0.0230	-0.7690	0.4417
C		-0.0001	0.0003	-0.3220	0.7471
$\Delta Oil_{t-1}$		0.0512 <sup>a</sup>	0.0168	3.0340	0.0024
$\Delta Gas_{t-1}$		0.1166	0.0196	5.9340	3.35e <sup>-9</sup>
$\Delta Oil_{t-2}$		-0.0144	0.0168	-0.8550	0.3928
$\Delta Gas_{t-2}$		0.0933 <sup>a</sup>	0.0197	4.7220	2.46e-6
$\Delta Oil_{t-3}$		0.0117	0.0168	0.6960	0.4862
$\Delta Gas_{t-3}$		0.0550 <sup>a</sup>	0.0197	2.7840	0.0054
$\Delta Oil_{t-4}$		0.0568 <sup>a</sup>	0.0168	3.3730	0.0007
$\Delta Gas_{t-4}$		0.0831	0.0196	4.2280	2.44e <sup>-5</sup>
Breusch- Godfrey LM test					0.0584
ARCH (multivariate)					2.2e <sup>-16</sup>

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

As for the NBP gas hub, we can tell that only oil transfers volatility to gas returns. Oil returns are also explained by lagged oil coefficients (Bivariate VAR).  $\Delta Oil_{t-2}$  is significant for gas returns. The coefficient is negative and low, while it is significant at 5% and 10% levels. The result suggests unilateral volatility transmission from oil to gas returns and its sign suggests substitutability, while its low magnitude (-0.0567) constitutes the suggestion weak (Table 6.2.7).

Our stationary data (returns) allow us to proceed with DCC GARCH modelling. We model with both the symmetrical (DCC) and asymmetrical (ADCC) versions our data. The results for NBP are presented in Tables 6.2.10 and 6.2.11.

**Table 6.2.10 NBP Symmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.3234	0.1856
Ar	-0.0987			-0.2380	0.8118
M.A	0.0510			0.1225	0.9024
$\omega$	0.0000			0.5259	0.5989
$\alpha$	0.0622 <sup>a</sup>			2.7277	0.0063
$\beta$	0.9359 <sup>a</sup>			39.8777	0.0000
M.U		0.0000		0.1383	0.8899
Ar		-0.7962 <sup>a</sup>		-6.1000	0.0000
M.A		0.8221 <sup>a</sup>		6.5669	0.0000
$\omega$		0.0000		1.0368	0.2998
$\alpha$		0.1307 <sup>a</sup>		4.7521	0.0000
$\beta$		0.8682 <sup>a</sup>		29.7702	0.0000
$\lambda$	5.8114 <sup>a</sup>			7.9441	0.0000
DCC $\alpha$			0.0098 <sup>b</sup>	2.0604	0.0393
DCC $\beta$			0.9682 <sup>a</sup>	113.3988	0.0000
Q(50)r		0.8156			0.3665
Q(50)r <sup>2</sup>		0.1663			0.6834
Q(50)r	2.1645				0.1412
Q(50)r <sup>2</sup>	0.5006				0.4792
Akaike					-10.0550

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.2.11 NBP Asymmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.3233	0.1857
Ar	-0.0987			-0.2380	0.8118
M.A	0.0510			0.1225	0.9024
$\omega$	0.0000			0.5256	0.5991
$\alpha$	0.0622 <sup>a</sup>			2.7263	0.0064
$\beta$	0.9359 <sup>a</sup>			39.8585	0.0000
M.U		0.0000		0.1383	0.8899
Ar		-0.7962 <sup>a</sup>		-6.1037	0.0000
M.A		0.8221 <sup>a</sup>		6.5716	0.0000
$\omega$		0.0000		1.0354	0.2998
$\alpha$		0.1307 <sup>a</sup>		4.7516	0.0000
$\beta$		0.8682 <sup>a</sup>		29.7473	0.0000
$\lambda$	5.8114 <sup>a</sup>			7.9458	0.0000
DCC $\alpha$			0.0098 <sup>b</sup>	2.0346	0.0418
DCC $\beta$			0.9682 <sup>a</sup>	113.0994	0.0000
DCC $\gamma$			0,0000	0,0010	0,0000
Q(50)r		0.8156			0.3665
Q(50)r <sup>2</sup>		0.1663			0.6834
Q(50)r	2.1645				0.1412
Q(50)r <sup>2</sup>	0.5006				0.4792
Akaike					-10,0540

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

For our versions both alphas (ARCH coefficients) and betas (GARCH coefficients) are statistically significant at 1% for both commodities. Further, their sum (for each commodity) is close to one (1) suggesting that volatility shocks have long memory i.e. shock to the conditional variance are highly persistent.

We apply the DCC GARCH methodology because it separates shock's volatility persistence on the dynamic conditional correlation into short and long-term parts. Our DCC coefficients are statistically significant in both symmetrical and asymmetrical models.

However, the asymmetric DCC coefficient ( $DCC\gamma$ ) is zero (Table 6.2.11). Additionally, the Akaike criterion suggests the symmetrical modelling as better. The dynamic component of the volatility ( $DCC\alpha$ ) is close to 0.01 (0.0098), while the long-term persistence of the shock ( $DCC\beta$ ) is close to one (1). Their statistical significance suggest that the conditional volatility is not the same through time. The coefficients are high enough to suggest a systematic correlation between the two commodities.

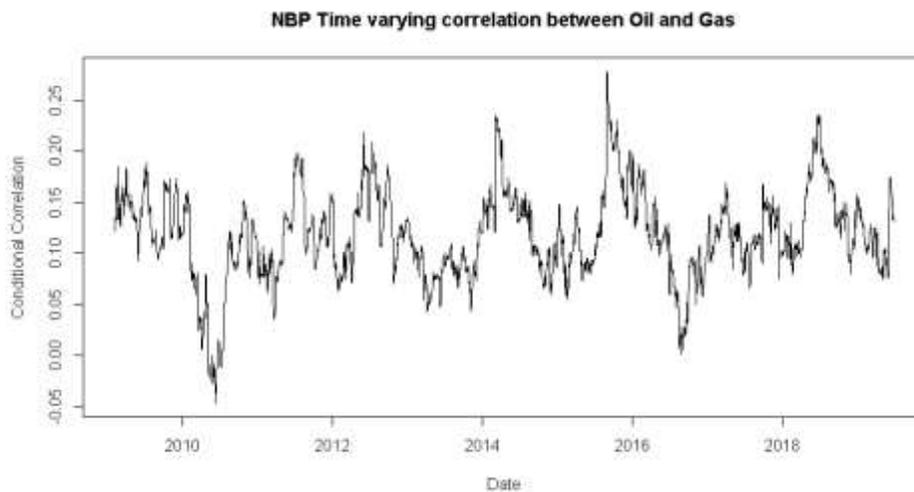


Figure 6-26 NBP Time varying correlation between Oil and Gas. Source: Authors' calculations.

The correlation's course does not have vast fluctuations. Only in 2011 and 2016 declines reaching zero. In 2011, oil had fully rebounded from the 2008 crisis and reached its highest level in 2014. Profoundly, the oil price course had no connection with the European gas prices. The sign change may imply the competitive character of the two commodities among them. In 2016, oil reached its lowest levels while gas prices increased suggesting a different pricing mechanism.

The results for the Dutch market, which is considered as the continental price benchmark, are similar to those of the NBP.

**Table 6.2.12 TTF Symmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.3326	0.1826
Ar	-0.0581			-0.1478	0.8824
M.A	0.0126			0.0320	0.9744
$\omega$	0.0000			0.5757	0.5648
$\alpha$	0.0559 <sup>a</sup>			3.1854	0.0014
$\beta$	0.9420 <sup>a</sup>			51.5940	0.0000
M.U		-0.0006 <sup>c</sup>		-1.7221	0.0850
Ar		0.4075		1.4771	0.1396
M.A		-0.4761 <sup>c</sup>		-1.7895	0.0735
$\omega$		0.0000 <sup>a</sup>		3.1575	0.0015
$\alpha$		0.1772 <sup>a</sup>		9.0067	0.0000
$\beta$		0.8217 <sup>a</sup>		43.6667	0.0000
$\lambda$	5.9547 <sup>a</sup>			8.0420	0.0000
DCC $\alpha$			0.0082 <sup>b</sup>	2.1491	0.0316
DCC $\beta$			0.9806 <sup>a</sup>	107.2759	0.0000
Q(50)r		1.4473			0.2290
Q(50)r <sup>2</sup>		1.1556			0.2824
Q(50)r	2.119				0.1455
Q(50)r <sup>2</sup>	0.2516				0.6159
Akaike					-9.6304

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.2.13 TTF Asymmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.3322	0.1827
Ar	-0.0581			-0.1478	0.8824
M.A	0.0126			0.0320	0.9744
$\omega$	0.0000			0.5765	0.5642
$\alpha$	0.0559 <sup>a</sup>			3.1905	0.0014
$\beta$	0.9420 <sup>a</sup>			51.6934	0.0000
M.U		-0.0006 <sup>c</sup>		-1.7221	0.0850
Ar		0.4075		1.4765	0.1398
M.A		-0.4761 <sup>c</sup>		-1.7887	0.0736
$\omega$		0.0000 <sup>a</sup>		3.1558	0.0016
$\alpha$		0.1772 <sup>a</sup>		9.0044	0.0000
$\beta$		0.8217 <sup>a</sup>		43.6667	0.0000
$\lambda$	5.9547 <sup>a</sup>			8.0428	0.0000
DCC $\alpha$			0.0082 <sup>b</sup>	2.0884	0.0367
DCC $\beta$			0.9806 <sup>a</sup>	107.7581	0.0000
DCC $\gamma$			0.0000	0.0001	0.9998
Q(50)r		1.4473			0.2290
Q(50)r <sup>2</sup>		1.1557			0.2824
Q(50)r	2.1190				0.1455
Q(50)r <sup>2</sup>	0.2516				0.6159
Akaike					-9.6297

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

It again plummets from positive to zero in 2010 like that of NBP and it should have the same driving forces (oil rebounded and it was irrelevant to the gas price). It again reaches zero levels between 2013 and 2014. The zero correlation can be explained by the Ukraine crisis which pushed prices higher due to the imports decline. Europe had to import volumes from different sources. This profoundly diminished the correlation between the two commodities. Additionally, in 2018 oil prices remained stable while gas prices increased. This is why we have a separate correlation decline to zero levels.

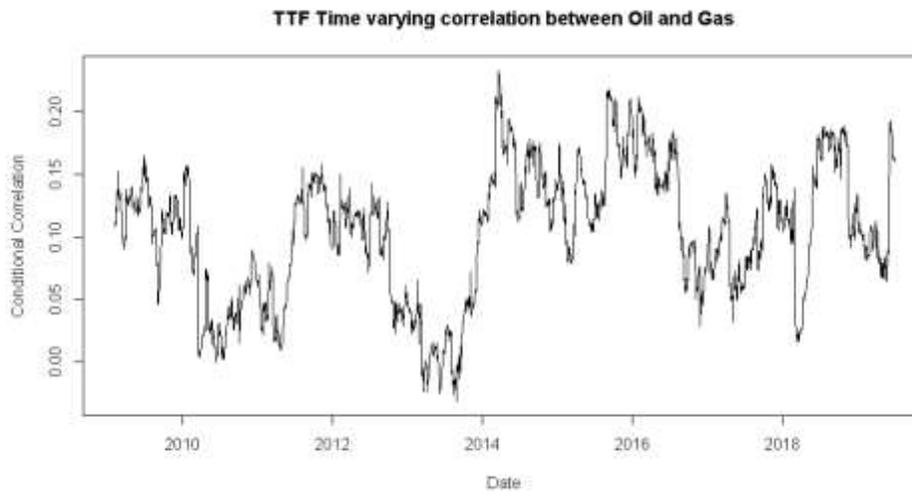


Figure 6-27 TTF Time varying correlation between Oil and Gas. Authors' calculations.

Our results further strengthen our suggestions about NBP and TTF. Gas pricing in those hubs follows the fundamentals and remains unaffected by oil prices. There is market decoupling, and demand and supply price the commodity. As a matter of fact, the commodities can not be used as hedging instruments against each other since there is no strong negative correlation between them. We can suggest that none commodity leads the information process.

Our results for the JKM market are not statistically significant (DCC modelling) and it is impossible to present evidence over the time varying correlation. We present our results in 6.2.14 and 6.2.15.

**Table 6.2.14 JKM Symmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.2009	0.2297
Ar	0.2231			0.0462	0.9631
M.A	-0.0578			-0.1199	0.9045
$\omega$	0.0000			0.5987	0.5493
$\alpha$	0.0581 <sup>a</sup>			3.2072	0.0013
$\beta$	0.9398 <sup>a</sup>			49.9102	0.0000
M.U		0.0001		0.1113	0.9113
Ar		0.9171 <sup>a</sup>		32.7122	0.0000
M.A		-0.7806 <sup>a</sup>		-17.6889	0.0000
$\omega$		0.0000		0.1970	0.8438
$\alpha$		0.0325		1.3131	0.1891
$\beta$		0.9611 <sup>a</sup>		74.4590	0.0000
$\lambda$	5.8613 <sup>a</sup>			8.2082	0.0000
DCC $\alpha$			0.0020	0.9314	0.3516
DCC $\beta$			0.9935 <sup>a</sup>	433.6515	0.0000
Q(50)r		0.3639			0.5463
Q(50)r <sup>2</sup>		1.7999			0.1797
Q(50)r	1.7725				0.1831
Q(50)r <sup>2</sup>	0.3011				0.5832
Akaike					-10.7110

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

**Table 6.2.15 JKM Asymmetrical DCC GARCH (1,1).**

Coefficient	GARCH (Oil)	GARCH (Gas)	Joint	t-Value	Probability
M.U	0.0003			1.2011	0.2297
Ar	0.2231			0.0462	0.9631
M.A	-0.0578			-0.1199	0.9045
$\omega$	0.0000			0.5985	0.5494
$\alpha$	0.0581 <sup>a</sup>			3.2070	0.0013
$\beta$	0.9398 <sup>a</sup>			49.9054	0.0000
M.U		0.0001		0.1114	0.9112
Ar		0.9171 <sup>a</sup>		32.7098	0.0000
M.A		-0.7806 <sup>a</sup>		-17.6891	0.0000
$\omega$		0.0000		0.1970	0.8438
$\alpha$		0.0325		1.3135	0.1889
$\beta$		0.9611 <sup>a</sup>		74.4539	0.0000
$\lambda$	5.8613 <sup>a</sup>			8.2081	0.0000
DCC $\alpha$			0.0020	0.9311	0.3517
DCC $\beta$			0.9935 <sup>a</sup>	254.3939	0.0000
DCC $\gamma$			0.0000	0.0000	1.0000
Q(50)r		0.36391			0.5463
Q(50)r <sup>2</sup>		1.7999			0.1797
Q(50)r	1.7725				0.1831
Q(50)r <sup>2</sup>	0.3011				0.5832
Akaike					-10.7100

Note: Ljung – Box q statistics correspond to a test of the null of no autocorrelation in residuals, and squared residuals with h=50.

<sup>a</sup> Indicates significance at all levels (1%, 5% and 10%).

<sup>b</sup> Indicates significance at 5% and 10%.

<sup>c</sup> Indicates significance at 10%.

### 6.3.5 Conclusions

We continue to research other markets to investigate whether price and volatility transmission exists between oil and gas. In particular, we research the NBP, the TTF and the JKM markets for price spillovers. We can suggest that in the British market there are only transient spillovers from gas to oil. On the contrary, the JKM market experienced only unidirectional spillovers from oil to gas. The accumulated impacts between Brent and the European gas hub prices were close to zero, an evidence of market decoupling.

Instead, the JKM experienced higher accumulated impacts from oil further adding evidence of unilateral spillover from oil to gas. In addition, both NBP and TTF had low correlations between oil and gas. TTF was influenced by the Ukraine Crisis, while the NBP had no effect at all. The TTF can be considered as the European Continental gas benchmark. Something that can bring the regionality of the markets upfront. This might also imply the grid bound nature of the gas markets.

Our results do not suggest volatility transmission in the European Gas markets from oil to gas as Lovcha and Perez-Laborda (2019) do. Further, we do not find bidirectional volatility spillovers between oil and gas as Perifanis and Dagoumas (2018) do for the Henry Hub. We agree with Dahl et al. (2011) who suggest that there are no spillovers between Brent and NBP prices. Our results strengthen Misund and Oglend's (2016) suggestion that the UK gas system is endowed with interconnections which mute causal relationships. The efficient market design supplements the hard infrastructure of the market. Nick and Thoenes (2014), Geng et al. (2016), Geng et al. (2016b), Villar and Joutz (2016) suggest that there are oil spillovers in the long-run gas pricing for the Henry Hub. We do not agree with all the aforementioned for the European markets as they did not fail in moving from the oil-indexed contracts to fundamental pricing without the shale revolution as the Henry hub did (Erdos 2012). As for the Asian markets, the relationship will fade since nuclear power rebounds. We further disagree with Karali and Ramirez (2014). For the European gas markets, we find low correlations between the two commodities and we can say that we agree with Erdos (2012) who suggest market decoupling since 2009. We confirm Batten's et al. (2017) results who propose that the two commodities can not be used as hedging instruments against each other since 2007. Low correlations do not agree with Asche et al. (2012) who propose that a long-run equilibrium relationship exists, while there might be great differences in the short-run. We confirm Shaikh's et al. (2016) results who suggest the importance of source and route diversification for the JKM market, since we find single causality from oil to gas. However, the decision makers' efforts did not bring the desired results, or will bring in the near future as Vivoda (2014) proposes. The Asian market did not use gas fundamentals as a

hedging strategy, something which complies with Stern's (2014) results. We agree with Barnes and Bosworth (2015) who propose that the gas market became more integrated. However, integration comes with different pace around the world. We suggest that the NBP and TTF are fully integrated while the JKM moves toward the integration after the nuclear power generation rebounds. This strengthens Jensen's (2004), Bachmeir and Griffin's (2006), and Li's et al. (2014) findings who suggest that the world gas market should be separated into regional ones. The European gas markets are more efficient and transparent than the Asian, and this is why they became price leaders. Kim and Kim (2019) are confirmed. Europe's success confirms Brown and Yucel (2008) and Brown and Yucel (2008b) who consider infrastructure as the cornerstone for gas pricing. Since oil and gas are separately priced, then the "one price law" does not hold for the European markets, and for the JKM after the nuclear power rebound.

The success of the European markets might propose their market design as the prototype for other gas markets or other commodity markets. Their success suggests policy recommendations for even further transparency, integration, and functionality. The elements adopted by the European countries are:

1. Establishment of Entry-Exit systems.
2. Definition of the role of hub operators.
3. Establishment of exchanges.
4. Standardization of contracts.
5. Transparency in price reporting agencies (PRAs) and
6. Provision of access to market makers, brokers and non-physical traders.

These elements in conjunction with critical infrastructure's development, grid operational optimization ,and coordination are drivers for fully functional gas markets.

In conclusion, the efforts for common functional gas markets and infrastructure paved the way for success for the European gas pricing. Within the European Union, the main intra-regional gas hubs are coupled. Grid interconnections, regional hubs and shared energy strategy succeeded the initial regionalization.

If these regions are interconnected, then the Energy Union will be reality. Then a European fully integrated market might be reality. Fundamentals will be freed to price energy commodities leaving no space for exogenous innovations. This process requires further infrastructure, such as the Projects of Common Interests (PCIs), in regions like the South East Europe and the Baltics. In Japan, the complete nuclear power generation shut down drove to less market pricing and efficiency. The last proposes that the transition to new energy sources should be adopted if this is smooth and well organized. Source diversification, as well supplier diversification is fundamental for pricing. Fundamental pricing and energy security are better served when energy sources (fossil fuels, nuclear and renewables), and suppliers (gas pipelines from different sources, LNG with increased liquefaction capacity, storage facilities and etc.) are added to the already existent.

#### ***6.4 Natural gas policy suggestions towards fundamental pricing***

Several policy steps should be taken in order for natural gas to be priced as a completely different commodity and under its fundamentals. Specific proposals are made by Joskow (1996) and Newbery (2002) who provide toolboxes towards this direction. The most important among the tools are services' unbundling, Third-Party-Access to network, and network pricing regulation.

Initially, unbundling has taken the forms of administrative or accounting i.e. network activities are separately financially monitored compared to sales and upstream activities, while they are sharing operations within the same corporation. A step further is management unbundling which entails different business divisions independently operating under the same company. The third form which goes even further is that of legal unbundling. Different entities (networks) operate in parallel with production or sales subsidiaries under the same holding company. The last form is that of ownership unbundling when assets are separated from the dominant corporation and form a completely different entity.

Fundamental pricing can be encouraged by Third-Party-Access (TPA) to the network. It can be separated into the Regulated and the Negotiated one. Under the Regulated TPA, the network owner posts major terms of transactions' and tariffs. This allows the entrance of new competitors in the network. Last, costs are published and no anti-competition behavior can be expressed by any stakeholder.

Market opening enables consumers to use the infrastructure with different suppliers and this strengthens market pricing. This allows competition to work and eliminates potential premiums dominant companies might charge.

Regulatory bodies must also exist to implement competitive behavior among market participants. Independent regulatory authorities have to be fully free of any conflict of interest or potential relationship which would lead to compromises. Last, they should be stuffed with competent personnel to monitor market conditions.

The European countries encouraged the establishment of entry-exit zones with Virtual Trading Points. These zones allow volumes to be directed where they are mostly priced. If there is enough investment, price differentials are eliminated, and pricing becomes fundamental depending on the particular market conditions. These entry-exit zones can well be developed to energy exchanges. Fundamental pricing can be even more encouraged since spot and futures prices will be daily posted and standardized contracts will decrease information asymmetries.

Furthermore, the lift of gas price controls even more strengthens market pricing. Regulatory-determined pricing can be replaced by the fundamental pricing of supply and demand. On the contrary, when prices are pre-defined, monopolistic behaviors can prevail. Moreover, Gas Release Programs (GRPs) allow new entry competitors to buy volumes from dominant participants at determined prices strengthening competition. Cost burdens are removed for market participants entering the market.

The application of all the aforementioned should also consider the particularities of each region. When it comes to market design, "one size does not fit all". The implementation of certain toolbox items does not guarantee transparency and efficiency

immediately. All policy recommendations should not be applied on a stand-alone basis. The market transition requires in depth study of the current market conditions. This is important for an effective roadmap to the desired market design. Oil-indexation has long been used as the main gas practice and switching to market pricing requires a lot of concern.

The Energy Union by the European Union is a good example of gas market decoupling. The European markets have moved from oil-indexation to fundamental pricing. This success is credited to the grid interconnections, regional hubs and shared energy strategy, which first regionalized energy pricing. Further, market interconnection will encourage market integration and efficiency. Fundamentals are liberated to play their own roles and are uninfluenced by exogenous innovations. However, supply bottlenecks should be removed with critical infrastructure. Projects of Common Interest (PCIs) are of crucial importance for regions without the appropriate networks (regions of Balkans and Baltics). The transition to the new reality should be smooth and organized. Fully efficient gas hubs are part of this transition. Supply diversification is a component of fully operational markets. Different energy sources (fossil fuels, nuclear, renewables) and diversification of suppliers (pipelines, LNG with increased liquefaction capacity, storage facilities) strengthen market fundamentals eliminating information asymmetries and extreme incidences' impact. Last, energy security can be achieved by cautious policy making which includes all the above.

## 7 Conclusions

Crude oil prices have experienced great volatility especially in the recent decades. Prices had an abrupt course from the rally up to 2008 highs to the same year's financial crisis, and from the rebound to the 2014 highest to the 2016 lowest. Understanding what drives oil prices is of great importance since it would unravel the dynamics that move the markets. These are not constant and do not have the same influence all over the time. Researching the causal drivers and their influence helps market participants to have a better picture of the prevailing conditions, while they can adjust their responses. Price forecasting remains difficult, but deviations become narrower if we understand what affects oil prices. This kind of course is attempted to be explained by this dissertation, and then describe the framework within OPEC will follow its strategy. OPEC as a global institution does not implement a strategy in "strict silos", but rather adapts to market evolutions. This is why OPEC's strategy is of great importance since it has to adjust rapidly, while its production decisions are considered as the strongest market signals. OPEC signals what a great share of suppliers considers as the most appropriate action for the market.

Further, current and future challenges create a different framework than that of the past. Long-standing beliefs like that of the peak oil demand do not seem to be verified since demand changes rapidly rather than follow an increasing pattern until its highest point. Consumers in emerging economies change their habits and choices, especially in transportation. This increases demand for oil and its byproducts. Instead, energy transition in the developed world might contract considerable volumes. Electronic Vehicles (EVs) and power generation by renewables and natural gas pose a serious threat to future demand. Environmental considerations over the current state of global economy may also alter the business conduct. Circular economy with increased efficiency and decreased energy intensity may also challenge demand. New regulations like those of IMO 2020 challenge the level of required investment and infrastructure. However, under the prism of so many challenges and uncertainties, countries and companies are

hesitant to proceed with their Final Investment Decisions (FIDs), as their investment appraisals are not solid. The current infrastructure has to cope with the imbalance of the Light/Sweet-Heavy/Sour blends. This kind of imbalance is created by the new producers which enter the market. Shale revolution turned the US from a net importer to an exporter, while the volumes were stockpiled as inventories due to the lack of exporting and refinery infrastructure. Last commodities like natural gas obtain their own trading hubs with the aspiration to distant themselves from long-term oil-benchmarked contracts.

Oil prices experienced no volatility until 1973, while since then they have a volatile price course. The explosive periods are those of the First Oil Crisis 1973/1974, the Second Oil Crisis 1978/1979 and from 2005 to 2008. While the two oil crises can be explained by the feared supply shocks, the later oil price course can be explained by demand. Demand is lately elastic implying the lack of substitution, especially in the developing world. Demand drives prices since incidents like the global slow-down (2008) and coronavirus (2020) caused negative demand shocks and as a consequence price declines. Shale production and inventories deflate prices inelastically. However, shale production smooths the political influence of traditional suppliers, while it should be considered as the marginal production. Further, terrorist attacks or wars, in major oil producing regions, did not have any effect on prices. Islamic state's rising for example did not increase prices due to fears over supply in 2016. On the contrary, prices reached their lowest levels. All the above strengthen our view that oil is now fundamentally driven. Our results confirm that speculation, even if elastically, adds to the market volatility due to supply and demand concerns. This is the reason why further market regulation would not add anything to transparency and efficiency. Speculation or "paper oil" is an additive to price changes and not a driver.

OPEC should consider all the above before forming or updating its strategy. Major producers like Saudi Arabia and Russia have formed a consensus over production quotas lately. Saudi Arabia has for example ample spare capacity and this is why it partially covers demand increases. It partially covers them to leave volumes for the rest of the producers

(production sharing strategy) and not cause disruptions. Saudi Arabia, further, does not want to keep prices at extreme levels as this would damage future demand. However, Saudi Arabia does not respond to price changes both in long and short-term, while it only pushes inventories to be less cost-effective in the short-run. The trade-off dilemma (High Prices/Low Volumes or Low Prices/High Volumes) is verified since Saudi Arabia attempts to keep its market share constant even in a declining price environment. Additionally, the Russian Federation is not only dependent on oil earnings, while its state expenditure is elastically dependent on GDP. Oil dependence might come indirectly from the relationship between state expenditure and GDP. Further, state expenditure is only influenced by oil production in the short-run. OPEC should balance the considerations of major producers over earnings, balance sheets, and state expenditure or welfare.

In addition, mature markets like Henry Hub, NBP and TTF do not experience effects from oil price changes. Traders adjust faster to oil price increases in Henry Hub, and their oil innovations cause greater impacts on gas returns. On the contrary, JKM experiences spillovers from oil to gas but this is only until the nuclear power generation rebounds. The mature European hubs have low correlation with oil, a sign that fundamentals work. Generally, only the JKM coupled with oil prices after the Fukushima accident.

All the aforementioned frame the strategy that OPEC can follow. First, OPEC should consider which is the sustainable price for its members. Many members depend on oil revenues. Their welfare and development are in direct relationship with oil prices. It is extremely difficult to manage whole country economies if there is volatility in the oil market. Sovereign funds act like buffers to negative earnings shocks, but they are not endless. Many countries were highly optimistic and did not create shock absorption mechanisms like wealthy sovereign funds or well diversified economies. Many members ran high deficits from 2014 and onwards. OPEC should consider establishing a map of good practice and due diligence for its members over oil revenues management. It should advise members on how to avoid price setbacks. Practices of economic diversification should be shared between members in order to avoid separate failures in this field.

OPEC is still able to elastically deflate prices, and its production volumes remain significantly important both in the long and short-run. Its production is the institutionalized one since its member states agree on quotas. Coordination is easier between states which control National Oil Companies (NOCs) than between International Oil Companies (IOCs). OPEC remains the main signaling mechanism in the global market. These advantages cast OPEC as one of the major supply players. OPEC has advantages over other stakeholders due to low costs, sufficient investment, timely information, credible statistics and etc. What is not timely posted is the demand data. This is why OPEC could be turned into an open forum where major producers and consumers could meet. Increased volatility damaged not only producers who disinvested in new upstream infrastructure, but also consumers who supply oil services to producers (exploitation, construction services and etc.). Commodity markets in developed economies suffered by low wages, increased unemployment and financial institutions' bankruptcies. Consumers do not gain by extremely low oil prices since some of their sectors are dependent on them.

Last, since commodities are traded in highly financialized markets, OPEC could continue to play the role of the price smoother. Highly connected markets could lead to market failures. OPEC as the institutionalized supplier with its ample spare capacity could alleviate the consequences of market downturns. Financial crises like that of 2008 are reminders and initiatives for broader cooperation. OPEC has the experience of cooperation with other non-member countries, and this could be a toolbox against future economic downturns.

OPEC can be perceived as one major market stakeholder and not as a hard cartel. To continue in preserving this role, it should be transformed into a more open organization. Transparency in decision making would make financial appraisals, FIDs and economic cooperation and development even more inclusive. Last, the challenges that lay ahead are numerous and go beyond the reach of a single state. As for the field of International Relations, we can tell that the interests will continue to be colluding and contrasting at the same time for many countries. Producers will continue to try to take advantage of higher prices, but at the same time they will be reluctant to disrupt future demand. On

the other hand, consumers will continue to aim at fundamental pricing and energy security but they will not force energy transition at the highest pace. It will be not strange to see coalitions between parts that were previously thought with conflicting interests. The Declaration of Cooperation is a first example. Fundamental pricing will continue to be sought. However, our research presented that in Japan, after the Fukushima accident, fundamental pricing was deviated with long-term contracts for hedging-purposes. The country was profoundly uncertain for the global LNG prices and their neighbors' demand in the hydrocarbon. It would not be bold to claim that the future of energy will swift to the East, as both major consumers and producers will concentrate there. Energy security will continue to be one of states' priorities since this will classify them in the international system. As a result, countries, state or publicly owned companies or other energy stakeholders will continue to be deeply involved in every aspect.

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## Dissemination work

### Published journal papers

- Perifanis, T., Dagoumas, A., 2017. An econometric model for the oil dependence of the Russian economy. *Int. J. Energy Econ. Policy* 7, 7–13.
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### Under review journal papers

- Perifanis T. Dagoumas A., Crude oil price determinants and multi-sectoral effects: A review, submitted to the *Energy Sources Part B: Economics, Planning and Policy*.
- Perifanis T. Dagoumas A., Paravantis J., Do market fundamentals flatten Peak Oil in case of US shale oil?, submitted to the *Energy Sources Part B: Economics, Planning and Policy*.

### Conference papers

- Perifanis T. 2019, Are West Texas Intermediate (WTI) Prices Explosive? 42nd International Association for Energy Economics (IAEE) Annual Conference, 29 May-1 June, 2019, Montréal, Canada
- Panapakidis I., Perifanis T., Dagoumas A., 2018, The Effect of Dimensionality Reduction Methods in Short-Term Load Forecasting Performance, 15th International Conference on European Energy Market (EEM 2018), 27-29 June 2018, Łódź, Poland
- Perifanis T., Panapakidis I., Dagoumas A., 2018, The relationship between the Brent crude oil and the National Balancing Point natural gas prices, 15th International Conference on European Energy Market (EEM 2018), 27-29 June 2018, Łódź, Poland