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Optimization of oil production by OPEC countries

Bachelor thesis Prague 2018

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Academic Year: 2017/2018

Bibliographic note

PILÁTOVÁ, Markéta. *Optimization of oil production by OPEC countries.* Prague 2018. 35 pp. Bachelor thesis (Bc.) Charles University, Faculty of Social Sciences, Institute of Economic Studies. Thesis supervisor RNDr. Michal Červinka, Ph.D.

Abstract

Almost 4 years of low oil prices and excess supply call the relevance of OPEC for current oil market into question. Therefore to investigate its role, this thesis examines the optimum oil production of individual OPEC countries accenting the consequent profit. Firstly, Cournot's model is employed to find equilibrium price and output on the oligopolistic market. Secondly, model considering OPEC and Russia as the Stackelberg leader with competitors forming oligopolistic fringe helps to uncover the potential of the recent cartel of OPEC and Russia. In both models, data from the year 2016 with different levels of elasticity ranging from -0.1 to -0.2 are utilized. Our research suggests that all OPEC members could have increased their profits by forming a non-cooperative oligopolistic market, where prices would reach up to 81.7 USD/bbl. Moreover, as a part of the cartel with Russia, OPEC could increase its joint profits by almost 27 % compared to the oligopolistic market, benefiting from coordinated output cuts followed by a steep growth in price. Thus we can conclude that either OPEC lost its power over the oil market or attempted to maintain its market share and drive higher-cost producers out of the market.

Abstrakt

Po téměř 4 roky vídáme na ropném trhu nízké ceny a převis nabídky, což značně zpochybňuje relevanci OPECu. Abychom zjistili jeho roli, rozebereme v této práci optimální produkci ropy jednotlivých zemí OPECu s důrazem na zisk, kterého by jednotlivé země mohly dosahovat. Nejprve použijeme Cournotův model, abychom našli rovnovážnou cenu a výstup na oligopolním trhu. Následně pomocí modelu, považujícího OPEC a Rusko za Stackelbergova vůdce, jehož konkurenti tvoří oligopolní lem, odhalíme potenciál nedávno utvořeného kartelu OPECu a Ruska. V obou modelech uplatníme data z roku 2016 s různými mírami elasticity poptávky na škále od -0.1 do -0.2. Naše zkoumání ukazuje, že všichni členové OPECu mohli mít vyšší zisk, pokud by participovali na nekooperativním oligopolním trhu, na kterém by se cena vyšplhala až na 81.7 USD/bbl. V případě vytvoření kartelu s Ruskem by společný profit OPECu mohl být ještě o 27 % vyšší, a to díky koordinovanému snižování výstupu a následnému prudkému nárůstu cen. Z toho lze usuzovat, že buď OPEC ztratil kontrolu nad trhem s ropou nebo se pokusil vytlačit z trhu konkurenty, jejichž produkční náklady jsou relativně vyšší.

Keywords

OPEC, oil production, oligopolistic market, cartel, equilibrium price

Klíčová slova

OPEC, produkce ropy, oligopolní trh, kartel, rovnovážná cena

Declaration of Authorship

I hereby proclaim that I wrote my bachelor thesis on my own under the leadership of my supervisor and that the references include all resources and literature I have used.

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Prague, 11 May 2018

Signature

Acknowledgement

I would like to express my deepest gratitude to RNDr. Michal Červinka, Ph.D. for his kindness and tireless commenting on the thesis. A special thanks belong to Dawud Ansari, M.Sc., who provided me with crucial data and gave some priceless advice. I would also like to thank my family and friends for always supporting me, especially to my father who helped me to carry out the modelling part of this thesis. Finally, I would like to thank our dearest teacher Ing. Ivo Koubek for encouraging our curiosity and love for microeconomics.

Bachelor's Thesis Proposal

Author's name:	**Markéta Pilátová**
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Academic year:	**2017/2018**

Topic: Optimization of oil production by OPEC countries

Research question and motivation

This thesis primarily examines the optimal oil production levels for individual OPEC member countries in an oligopolistic market (disregarding the existence of OPEC as an economic agent) and the equilibrium price linked to such market structure. The obtained data of production and price is then juxtaposed with current state on the market that accounts for the existence of OPEC. The resulting profits are used to determine to what extent is the membership beneficial for individual countries. Such analysis is subsequently used to discuss current role of OPEC and its optimal behaviour.

In light of recent changes in prices that put exporters under high pressure as a result of decreased profits, the issue of oil market and OPEC becomes vastly important. Since OPEC presumably abandoned its previously upheld position of decreasing produced quantity to maximize prices, many now question its relevance and ability to improve the conditions of the member states. This study grows even more significant, given that, to our best knowledge, there is no recent relevant literature dealing with such problematics.

Contribution

Economic literature scarcely covers the optimization problems of oil exporting countries. Al-Qahtani (2008) conducted an analysis of optimal oil production of Saudi Arabia in 2004, but no comprehensive study of all OPEC members optimization has been conveyed. Most of the literature concentrates solely on the market power of OPEC (Huppmann, 2013) and development of prices (Jobling and Jamasb, 2015). While a lot of work has

been done also in the area of optimizing production of particular fields (Gunnerud and Foss, 2010), these studies are of limited relevance to the global oil market.

The research is therefore of major importance for both the individual members of OPEC and the organisation itself, as it enables them to make fully informed decisions about increasing or limiting oil production. Moreover, the study allows for balancing of negotiation positions within OPEC and improvement of the distribution of production quotas. Finally, this paper develops our understanding of cartels, as there are limited environments in which we can study such behaviour.

Methodology

Firstly, cost functions of individual countries' production will be obtained, using model as proposed by Huppmann (2013). Secondly, an inverse demand function will be derived based on the Cambridge working paper on price volatility of oil (Jobling and Jamasb, 2015). Finally, the optimization problem for individual countries will be solved utilizing Nash equilibrium theory and mathematical programming as suggested by Murphy et al. (1982). Two major sources of data on consumption and production of oil are available: IEA Quarterly statistics and OPEC Annual Statistical Bulletin.

Outline

1. Introduction
2. Characteristics of oil market and its recent development
3. Literature review
4. Methodology
5. Numerical results and interpretation
6. Conclusion

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Contents

Introduction

Oil has become vital for economies all over the world especially due to its wide range of possible utilization. Among others, it is chiefly used as a fuel currently powering almost all motor vehicles as well as for manufacturing of plastic. According to International Energy Outlook 2017, petroleum products satisfy approximately one-third of world energy consumption. Moreover, the petroleum is unlikely to lose such prominent position in foreseeable future despite the possibility of sharp price increase (EIA, 2017).

The exploration of oil market has always been exceptionally engaging owing to the existence of the *Organisation of petroleum exporting countries (OPEC)*, the only publicly declared cartel in the world. Especially after the two oil shocks in the 1970s, numerous studies examining its functioning and power were published. However, the attention was fading away during the first decade of the 21st century as prices of oil were high and OPEC seldom took action.

The situation changed rapidly at the turn of the year 2014 when over course of few months the price of oil halved. Especially countries heavily dependent on incomes from oil production need to consider their further actions. Even more so, OPEC is now facing a severe threat to its position as a prime price-setter on the oil market by US shale producers. It has to search for solution beneficial for its members with often very contradictory preferences. For example, poverty-stricken Venezuela on the verge of civil war urges current profit maximization much more than wealthy Qatar.

Since we acknowledge the importance of oil not only to its producers but to the global economy, modelling the oil market is of major significance. Thorough examination enables not only predicting future price development but also allows for informed choices of individual producers and consumers.

So far, little attention has been paid to optimization of individual countries producing oil. Especially for OPEC members, this may be used to set jointly optimal price and production levels or as a ground to fairly assign production quotas. Alternatively, it may be used to infer current and future

relevance of OPEC.

This thesis aims at helping to fill in the gap. Firstly, we will model oil market as a non-cooperative oligopolistic market and deduce the benefits, if any, OPEC brought to individual cartel members. Further, in reaction to the recent cooperation of OPEC and Russia, we will calculate optimization of their joint cartel facing oligopolistic fringe of other producers. That should provide us with an idea of what can be reached if OPEC and Russia fully exert their market power. Prices corresponding to such optimization problems may also provide valuable insight to the functioning of the oil market.

The bachelor thesis is organised in the following manner. Firstly, we start out with the characteristics of oil market including the vital role of OPEC. Additionally, some discussion of recent development is conducted. Then a literature review summarizing the most influential works in the field of oil market modelling and OPEC's behaviour is provided. The following chapter is dedicated to methodology, which includes a description of cost and demand functions as well as analysis of the two methods employed to model the oil market. Finally, the numerical results are provided alongside their interpretation.

1 The oil market characteristics

Every day 75.7 million barrels (bbl) of crude oil are produced all over the world (OPEC, 2018b), which translates into almost 4 barrels per person and year. Considering that 1 barrel corresponds to nearly 120 litres, we consume approximately 480 litres yearly.

Despite tendencies to support ecological energy sources, this number keeps on growing. The year-on-year increase from 2016 to 2017 was approximately 1.67 %, mostly drawn by higher consumption in China (accounting for more than 10 % of total world oil consumption). Similar tendencies are expected in the next years, with a gradually intensifying role of Indian imports (OPEC, 2018c).

The suppliers of crude oil can be divided into two subgroups: OPEC and non-OPEC producers. Currently, there are 14 members of OPEC: Algeria, Angola, Ecuador, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. Together, OPEC members produce 32.3 mbbl of crude oil daily (OPEC, 2018b). Non-OPEC producers extract 43.4 mbbl per day, with an increasing tendency mostly caused by the higher output of the United States of America (OPEC, 2018c).

Other important information include proved crude oil reserves or reserve-to-production ratio. Proved reserves show how much oil each country is expected to own based on geological research and other data. On the other hand, reserve-to-production ratio estimates the how long could country continue with its current production given the proved reserves. This is vital for estimating an appropriate time horizon for policies and planning.

Table 1 shows proved reserves as well as the current daily production of main oil producers. For brevity, only countries with reserves of at least 10 billion barrels are included. Data were taken over from CIA World Factbook for both oil production (World Factbook, 2018a) and proved reserves (World Factbook, 2018b). The provided information is sufficient to estimate the reserve-to-production ratio.

Country	**Proved reserves** (1 000 000 bbl)	**Production** (1 000 bbl)
Venezuela	300 900	2 277
Saudi Arabia	266 500	10 460
Canada	169 700	3 679
Iran	158 400	4 068
Iraq	142 500	4 452
Kuwait	101 500	2 924
United Arab Emirates	97 800	3 106
Russia	80 000	10 550
Libya	48 360	385
Nigeria	37 060	1 871
United States	36 520	8 853
Kazakhstan	30 000	1 595
China	25 620	3 981
Qatar	25 240	1 523
Brazil	13 000	2 515
Algeria	12 200	1 348

Table 1: Proved reserves and daily oil production

Crucial issue connected with oil market and its equilibrium is price elasticity of demand. Importantly, the contrast between short and long-term substitutability is vast. As for the short run elasticity, many studies endorse the view of oil demand as very inelastic with values closer to zero than -0.1. For example, Fawcett and Price (2012) estimate it to be approximately -0.1 and Cooper (2003) obtains result -0.06. The situation is even more complicated in developing countries, with limited access to technologies that could potentially replace oil but serious financial constraints.

The long-run elasticity was proven much higher as switching to alternative sources of energy as well as increasing efficiency of current usage becomes more beneficial and also feasible. Cooper (2003) in his aforementioned study estimates the long run price elasticity to be -0.46. Hence although higher prices could temporarily increase profits, long run substitution may under-

mine future crude oil demand.

Furthermore, the oil market evinces many characteristics that make it specific. First and foremost, similarly to other natural resources, the entry to the market is strictly limited by the availability of oil reserves. That backs the tendencies towards oligopolistic market structure since little fear of competition occurs. Furthermore, leaving the oil in the ground incurs only minor costs to the producer, whereas costs connected to storing are rather high for the buyers and issues associated with lack of oil are immense. Therefore oil-rich countries are in a much better negotiating position with little to lose but much to seize from oil-dependent customers.

Besides, oil is traded at highly liquid spot markets. The very opposite can be observed for example at coal market with prevailing long-term contracts (Huppmann and Holz, 2009). Thus trading and investing in crude oil is less costly, which makes it prone to speculative purchases. In addition, that may also cause significant price volatility.

Another key element of the market is that oil can be purchased almost exclusively with dollars (Mileva and Sigfried, 2012), presumably as a result of a deal between the United States and OPEC members. However, the situation is changing sluggishly: Russia agreed to sell oil to China for yuans (Farchy, 2015) or Iran's deal with its European customers to accept euro payments (Verma, 2016), mostly as a result of the US sanctions. Those changes may significantly influence the price of oil, as it hinges less upon the value of the US dollar.

Finally, the role of infrastructure should not be overlooked. Although there are some alternatives such as oil tankers, most of the countries, especially the landlocked ones, rely on the pipelines. In case of Eastern Europe, this causes heavy dependency on Russian oil as no other source is available (Cambridge Econometrics, 2016). Building new infrastructure is both financially demanding and time-consuming, which once again strengthens the position of oil producers.

1.1 The role of OPEC

With its prominent reserves and exports, OPEC plays a central role in the crude oil market. Its members produce almost 40 percent of global oil output (OPEC, 2018c) and have been proven to own 81 percent of worlds oil reserves (CNN, 2017).

Since the establishment in September 1960 in Bagdad, the OPEC's stated mission has been to "co-ordinate and unify 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" (OPEC, 2018a). Such results are reached mainly through production quotas, striving to ensure the well-being of the cartel.

OPEC came into public knowledge mostly after the first oil shock in 1973 reacting to US support of Israel in Yom Kippur war. The oil price quadrupled and cutting exports to the United States caused a severe shortage of gasoline. Despite lifting the embargo year later, grave economic crisis followed. Many countries, especially the United States underwent numerous reforms to decrease oil dependency including the creation of large oil stockpiles, instituting daylight saving time, investment into renewable sources of energy and so on (History, 2010b).

The first oil shock was shortly followed by another one caused by Iranian revolution in 1979 and the price of oil more than doubled due to supply disruption (History, 2010a). Once again, attempts to save and replace oil together with an exploration of new non-OPEC oil wells intensified. After the two oil shocks, the demand for oil from OPEC members would not recover mostly due to the increasing market share of other suppliers (Mileva and Sigfried, 2012).

At the turn of the century, the oil market was relatively stable. However, as many states, most notably China, faced favourable economic conditions in the mid-2000s, the demand for oil was increasing rapidly. In combination with decreasing supply caused by violence in Iraq and Nigeria, the prices of

oil surged to 123 dollars per barrel (BBC, 2008). After reaching an all-time high, the price of oil slumped in 2008 as a result of economic crisis. The slow recuperation of the world economy, as well as output loss due to the uprising in Lybia, contributed to the recovery of oil prices (Darbouche, 2011).

Over the course of its functioning, OPEC has changed its way to manage production multiple times. In the beginning, prices of oil were observed and policies were formed in a way to keep them at acceptable levels. Towards the end of the 1970s, OPEC set the production solely based on individually assigned quotas without considering other indicators. Finally, the end of the 1980s was marked by a change in favour of preserving a stable market share (Grundy, 2017). This aim seems to prevail up until recent months, despite facing very low oil prices.

In general, OPEC members have a lot in common. Firstly, their costs to produce a barrel of oil are significantly lower than those of other producers such as the United States or Norway (Mileva and Sigfried, 2012). Therefore, they have the ability to push the prices down to squeeze higher-cost producers out of the market.

Furthermore, after a wave of nationalizations in the 1970s, most of the oil in OPEC countries is produced by governments' companies (Griffin, 1985). It is thus important to realize the difference between solely profit-driven companies and nationalized enterprises, whose aims are much more complex. According to Kisswani (2014), the possibility of social unrests calls for policies that raise popular support. For many OPEC members, this means an attempt to harm western nations by cutting oil supplies or increasing prices. To do that countries are willing to sacrifice 10 to 20 percent of their revenues, which is unlikely to happen in private companies.

On the other hand, there are also some dissimilarities among the OPEC members. Those differences can cause disagreement among the OPEC members and make its functioning more difficult. A very important instance consists in the extent to which countries depend on oil. All 3 countries with the highest share of oil production in GDP belong to OPEC. Contrarily, some

members' output accounts for much less than 10 percent of GDP (World Bank, 2016b) and hence rely on high prices of oil to a much lower extent.

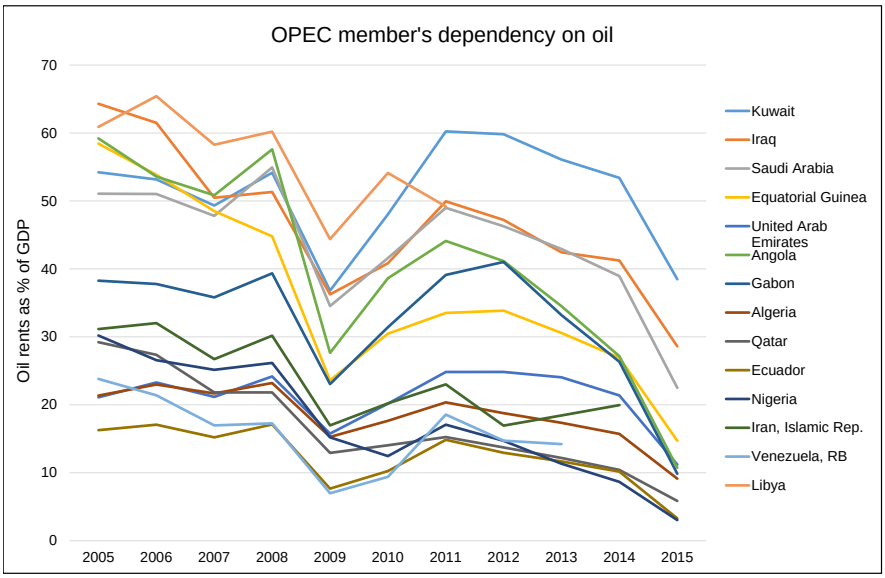

Figure 1: Share of oil rents on GDP (World Bank, 2016b)

Traditionally, there is a large controversy concerning strategical decisions in OPEC among its members. The largest producers are divided into groups so-called Doves and Hawks. Countries in the former group include Saudi Arabia, United Arab Emirates and Kuwait. Contrarily, Venezuela, Iraq and Iran belong to the latter one. Doves are known to aim at a well-supplied market with moderate prices and higher market share, while Hawks strive to increase oil prices (Defterios, 2011). The strategy of Hawks prevailed for quite a while, but the events of late 2014 and forth call its rationality into question.

1.2 Recent developement

A sharp downturn in the second half of 2014 severely affected the oil market, as prices halved in just a few months. Multiple factors presumably influenced the price, most notably the increase in production of US shale gas by 3.5 million barrels per day over the preceding 5 years (Onour, 2017), global economic slowdown or shifts towards renewable energy. The development of

prices since 2005 is depicted in the graph below:

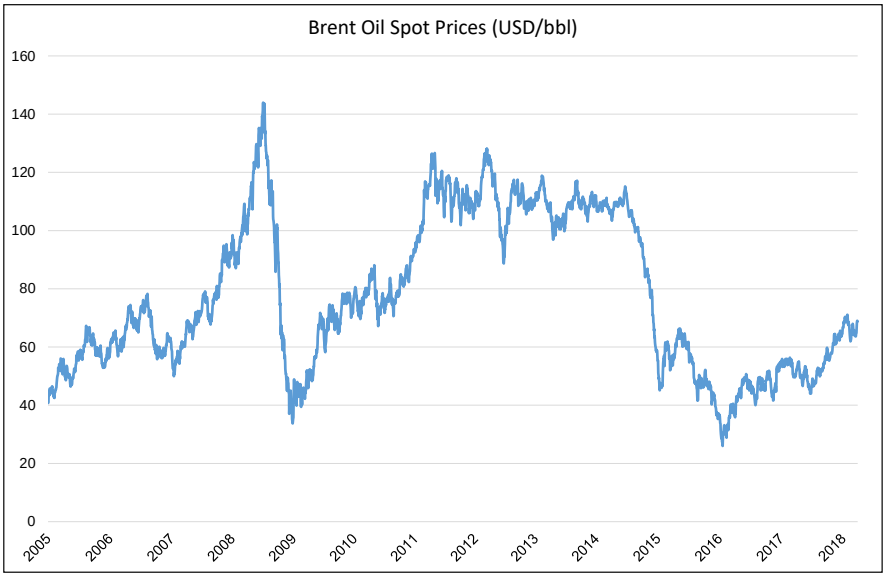

Figure 2: Brent oil price 2005 to 2018 (EIA, 2018)

OPEC's reaction to such a change in the oil market was awaited. Surprisingly, contrary to the previous Hawk's tendencies, OPEC lead by Saudi Arabia declared a price war on the U.S. shale oil producers. They decided not to cut output at all, in order not to lose market share and prevent rendering their profits to the rest of the producers (Lawler, Bakr and Zhadnnikov, 2014).

A vehement reaction of oil and gas producers lead to 40 percent decrease in capital expenditures over the first two years after the price crash. Both blanket layoffs of almost a quarter of workers and cancellation of less profitable projects took place. Although at first, the price fall seemed damaging, it leads to significant decrease in costs in the oil industry (Biscardini, 2017).

The limited effect of a price war on oil market may largely be caused by its late declaration as many investments unprofitable under low oil prices were already made. Their complete elimination is hence impossible and instead, we observe investors attempting to increase the efficiency rather than writing off their investments.

Another noteworthy moment in the recent history of the oil market is

the lift of US ban on oil exports at the beginning of 2016, flooding the market with even more oil and pushing the price of oil to its new low of 26 dollars (EIA, 2018). The supply by US producers increased over the last 2 years (England, 2018) as well as their capital expenditures, with year-on-year growth of 7.3 percent from 2016 to 2017 (Biscardini, 2017).

After almost 2 years of low oil prices, OPEC decided to take action and together with Russia agreed on output cuts. The decrease of 1.8 million barrels per day should last at least by the end of 2018 if prices do not get to a more acceptable level sooner. Additionally, Libya and Nigeria agreed not to raise their outputs, as those 2 countries were previously a source of increasing excess supply (Lawler, Gamal and Nasralla, 2017). Those policies proved to be at least partially effective as the market seems to slowly recover (England, 2018).

The cuts may have many adverse effects to be seen in years to come. The belief that especially letting go of so many employees resulted in severe loss of skills and knowledge is widespread. Therefore we may see the costs of future expansionary projects grow large as oil industry now lacks experienced workers (Biscardini, 2017).

The future of oil market is rather uncertain. Common cuts of OPEC and Russia seem to positively affect the prices and investors steadily return. Furthermore, some claim prices could rise quickly as a result of break down of conflict in Iraq, Libya, Nigeria and Venezuela or as a result of political conflict with Iran or Saudi Arabia (Lawler, Gamal and Nasralla, 2017). However, growing excess supply and modest demand are likely to prevent prices to return to the pre-2014 levels in the near future.

2 Literature review

Extraction and exchange of vital resources including oil had been an attractive topic well before the OPEC was established. Long prevailing theory on this topic was invented by Hotelling (1931). He proposed that under competitive market, profit (i.e. the difference between price and marginal costs) from the resource sale should grow at the same pace as the discount rate. Although some studies (Slade (1982), Moazzami and Anderson (1994) and Lin (2009)) confirm the validity of Hotelling's rule for energy and oil markets while others (Heal and Barrow (1980), Krautkraemer (1998)) claim its relevance is very low, it is still vital for modelling markets with exhaustible resources.

During the 1980s, OPEC got into the spotlight because of its presumably high influence on the two oil shocks that happened in the previous decade. Therefore many economists started to describe and model the oil market, with special attention devoted to the power of OPEC and its ability to influence oil prices.

An early work containing a thorough description of the oil market over the period 1973 to 1983 was published by Gately (1984). Most importantly, he analysed the reasons why OPEC behaved in the way it did and what effects on the economy could have been observed. Gately also speculated to what extent can the oil shocks be attributed to OPEC, considering whether competitive market models could explain them. However, he did not do any original empirical research to prove one of the alternatives correct.

The extent to which OPEC influences the oil market became one of the major questions diving the community of researchers in the field. Since Gately's article, countless studies testing behaviour and power of OPEC have been published. Some of them favour the notion of strong OPEC with a vast ability to influence the market, while others deny it and support the idea of individual optimization. Works of proponents of both views are presented below.

To reveal whether collusive or non-cooperative behaviour dominated the

oil market, authors use various methods. These include modelling the market and juxtaposing it to reality, comparing OPEC and non-OPEC producers or generally revealing a causal relationship between OPEC behaviour and situation on the market.

2.1 OPEC exercising market power

A pivotal work proving the importance of OPEC was written by Griffin (1985). He describes four different models that can be used to simulate oil market. Firstly, he presents Adelman's idea (Adelman, 1982), which regards OPEC as a cartel and whose level of cooperation is to be measured by the extent to which they share residual demand for oil. Then, MacAvoy's approach (Macavoy, 1982), which is close to a competitive market theory, is discussed. Next, the Ezzati's target revenue model (Ezzati, 1976) is examined, the underlying idea is that once a certain level of income is reached, countries will not produce more oil no matter the price. Finally, property rights explanation provided by Johany (1978) was also reviewed, introducing the idea that national oil companies have lower discount rates compared to the international ones. Therefore after the transfer of rights to the nations which occurred multiple times in the 1970s, production would decrease which explains the observed growth in prices.

Not only did Griffin provide a review of the available models, he also made a comprehensive theoretical test using data from 1971 to 1983 to prove which one of the theories is correct. He proved that model suggesting that OPEC is partially sharing the oil market cannot be rejected for any OPEC member and furthermore, such model has a solid predictive power, superior to all the other models. Additionally, competitive market behaviour can be conclusively rejected for most of the OPEC members, while for non-OPEC producers competitive behaviour cannot be rejected for 10 out of 11 countries. As for the other models, some weaker form of target revenue may be valid, whereas property rights explanation yields very different results for individual OPEC members. For example, Iraq directly clashes this idea

with state increasing production capacity 2.5 times after nationalization.

Another paper concluding that OPEC behaves as a cartel was written by Danielsen and Kim (1988). They use the concept of capacity and reserve ratio, which measures to what extent individual members of OPEC limit the production in comparison to their capacity or reserves. Under competitive setup, countries with the highest reserves and cheapest production would produce the most to make use of high oil prices on the market. However, the evidence from years 1973 to 1985 proves that contrary to the expectations, such countries have relatively higher sacrifice ratio which supports the cooperative scheme.

Similar results were reached by Kaufmann (2004) for period 1986 to 2000. The idea behind his work is that the main characteristic of a cartel is its ability to increase prices. Kaufmann proved, that through strategic handling of production, capacity decisions and quotas OPEC managed to change prices in their favour. Even more importantly, he also concluded that such relation is Granger causal and that non-OPEC producers act as price takers and produce close to capacity.

There were further studies proving that the behaviour of OPEC members was collusive over certain periods of time. Those include for example Loderer (1985), Youhanna (1994), Gulen (1996) and many others. Overall, those papers prove that the situation on the market and behaviour of OPEC members are very different from the competitive ones and therefore they conclude cooperation is present on the oil market.

2.2 Oligopolistic or competitive oil market

The literature questioning the relevance of Organisation of the Petroleum Exporting Countries is no less common. Especially papers proposing gradual weakening of OPEC and slow transition of oil market towards competitive scenario are emerging swiftly.

One of the works proving the feebleness of cooperation of OPEC members was written by Huppmann and Holz (2009). They perceived oil market

as multipool rather than bilateral, with prices set at pool nodes with a possibility of arbitrage. The main results of the paper are that actual prices in 2006 are double those that would be in a perfectly competitive market but only a third of those that would occur under a cartel setup. The prices predicted for Nash-Cournot equilibrium are much closer to 2006 values with only 50 percent higher prices. However, the most suitable and accurate model is OPEC members forming a non-cooperative oligopoly with non-OPEC members as competitive fringe.

Three years later, the same duo has presented another article with similar methodology and updated figures (Huppmann and Holz, 2012). For the first period, the results differed slightly, suggesting the market is closer to Saudi Arabia as a Stackelberg leader and other OPEC members forming a non-cooperative oligopoly. However, after the crisis and volatility in 2008 prices got closer to the situation on the competitive market. Importantly, both of those works conclusively reject cartel behaviour.

In 2014, a paper concluding that over the period 1994 to 2014 no co-ordination that would suggest cartel behaviour of OPEC is observed was published by Kisswani (2014). Major explanation presented by Kisswani is that discovery of large oil reserves in the Gulf of Mexico and the North Sea together with the liberalization of Russia radically decreased the dependency on OPEC supplies and thereby limited the power it has previously had.

A thesis concentrated solely on the position of Saudi Arabia was written by Al-Qahtani (2008). The study proves that if the whole OPEC optimized its oil production in 2004, it would decrease production by 1.4 million barrels per day, which would lead to 7 percent price increase. Profits of Saudi Arabia would grow by 4 billion US dollars per year and the rest of OPEC would gain additional profit of 28 billion US dollars per year. It follows that the cartel is not fully using its potential to influence the oil market and maximize its member's profits. However, the situation is still very different from the one that would occur in a competitive market.

One of the pioneering works proposing the OPEC behaviour and nature

might have switched over time was written by Almoguera et al. (2011). Compared to previous literature such as (Griffin, 1985), multiple changes were present: they took a very long period from 1974 to 2004, used simultaneous equation and optimized for OPEC as a whole rather than for individual members. Almoguera et. al. tested for changes from collusive to non-cooperative behaviour and backwards.

They revealed that in late 1970a and early 1980s collusive behaviour among OPEC members was present, which upholds the results presented later in the literature review. However, later in the mid-1980s and mid-2000s, the situation changed in favour of non-cooperative conduct with observable price wars. All in all for OPEC members Cournot competition dominated the period accounting for approximately 65 percent of it. Nonetheless, when colluding, OPEC was able to increase prices by 69 percent by mere 11 percent decrease in quantity.

Similarly, Grundy (2017) focuses on behavioural dissimilarities between OPEC and non-OPEC producers since cartel members should presumably act differently based on their cooperative deals. For period 1973 to 1990 the behaviour of the two groups is very different with a distinctively high volatility of OPEC members' production, while in period 1991 to 2010 the differences diminished and oil producers now form one large cluster suggesting the low future relevance of OPEC.

Finally, Onour (2017) published a study comparing the power of OPEC and US shale producers to influence the price of oil. He concludes that if OPEC increases its production by 1 % prices would decrease by 0.12%. On the other hand, if the US did the same, prices would drop by 1.03 %. Therefore oil prices react approximately 8 times more to the behaviour of US producers. Not only does this suggest OPEC has become very weak and barely able to influence prices of oil, it seems that the US has taken over the role of swing producer and controls the oil market.

Although no clear conclusion has been reached across the scientific community, it seems that during the early years of OPEC existence its ability

to influence prices was immense. However, over course of last few decades, its power has slowly vanished, which calls into question its future role as a leader in the oil market.

2.3 Reaction of OPEC to 2014 price downfall

The situation changed considerably since the price drop towards the end of 2014 from over 100 dollars in September to less than 50 in January 2015. The decision of OPEC not to cut production in face of such slump in oil price has been hotly debated and further examined in the literature.

Behar and Ritz (2017) compare two possible strategies OPEC has: to "accommodate" or "squeeze". The former strategy reconciles to the US shale producers supplying a certain amount of oil and maximizes its profit within the new situation. On the other hand, OPEC could attempt to increase production, decrease price and squeeze the new producers out of the market. Thereby it would secure higher future profits and defend its market share.

The results of the empirical analysis suggest that up until late 2014, the optimal strategy of OPEC was to accommodate. However, with the change of circumstances, the squeeze strategy became more beneficial. The factors include lower demand for oil products, increasing supply of non-OPEC producers (especially US shale) or poor cooperation among OPEC members. The situation or available information may well change again and prompt another switch to accommodate.

Fattouh et al. (2016) concentrated solely on the situation of Saudi Arabia, explaining its dilemma between short-term profit maximization and securing long-term demand. Using a game-theoretic framework, they examine costs and benefits of decreasing production to raise prices contrary to not acting at all. The situation is further split based on the elasticity of shale oil supply. It turns out that for inelastic supply curve, the optimum reaction of Saudi Arabia is to cut the production. By contrast, for elastic supply, it is better not to adjust the output.

Comparing outcome of different reactions, Fattouh et al. conclude that under uncertainty it is best for Saudi Arabia to act as if the supply of shale was elastic and hence no change in oil output shall take place. Nonetheless, as they get additional information about the elasticity of shale oil supply, they may adjust their production accordingly. So far it seems that US shale producers sharply decrease capital investments and a number of rigs. However, the effect on the amount of oil produced is not so high since the efficiency increases and costs of shale oil production decrease.

To summarize, the prevailing opinion in the current literature is that OPEC and its members are undergoing the right steps to deal with the current situation. However, it is nearly impossible to distinguish whether this is a well thought-through strategy or rather an inability of OPEC to act collectively as pointed out by Huppmann and Holz (2015).

3 Methodology

In this thesis, we search for an equilibrium of the oil market in a single time period. We presume purely current profit maximizing behaviour since it is hard to predict the future as there are too many factors that can influence the demand and the price of oil. For example, in the future, technologies can even eliminate the dependency on oil and significantly slash its value. Therefore the assumption of maximizing present profits is frequently used in the literature, namely for instance by Huppman and Holz (2012).

The following 29 countries are included in the optimization: Algeria, Angola, Argentina, Azerbaijan, Brazil, Canada, China, Colombia, Ecuador, Egypt, India, Indonesia, Iran, Iraq, Kazakhstan, Kuwait, Libya, Malaysia, Mexico, Nigeria, Norway, Oman, Qatar, Russian Federation, Saudi Arabia, United Arab Emirates, United Kingdom, United States and Venezuela. Their total production represents approximately 95 % of the global oil output (OPEC, 2018b), meaning we only exclude few minor producers. In order to prevent possible distortion of the results (especially prices), we add output corresponding to the missing 5 % of producers to the total quantity available on the market.

Some simplifying assumptions, such as oil being a perfectly homogenous product, are made. Hence the differences in quality of oil are not accounted for, as for most oil producers no significant price differences occur. A similar approach was used for example by Huppmann and Holz (2012). In like manner, we will not consider the differences in transportation costs.

3.1 Cost and inverse demand function

To approximate the total costs of individual oil producing countries, we employ the function proposed by Ansari (2017). We consider the total cost function C_i of producer $i, i = 1, \ldots, 29$, in the form

$$C_i\left(q_i\right) = \gamma_{1i} q_i + \gamma_{2i} q_i^2 - \gamma_{3i}\left(q_i - \kappa_i\right)\left(ln\left(1 - \frac{q_i}{\kappa_i}\right) - 1\right), \tag{1}$$

where γ_{1i}, γ_{2i} and γ_{3i} are parameters tailoring the function to fit individual producers and κ_i are their respective capacities. Additionally, q_i represents the quantities produced.

The parameters γ_{1i}, γ_{2i} and γ_{3i} determining the shape of cost function were taken over from Ansari's work (Ansari, 2017). To ascertain the production capacities $\kappa_i, i = 1, \ldots 29$, we use two different methods. For members of OPEC, we have an estimation by *International Energy Agency*, which annually publishes its Market Report Series (IEA, 2017). It includes data on sustainable crude oil production capacity of all OPEC members. For the rest of the oil producers, such data is not available. Thus we build on the assumption that other producers choose outputs close to their capacities. We take the maximum production over the last 5 years from the OPEC Annual Statistical Bulletin (OPEC, 2018b) and consider it to represent 97 percent of the capacity, from which we can easily derive the total crude oil production capacity of all non-OPEC countries. This approached is based on the method used by Ansari (2017).

There are many essential features of those functions. First and foremost, they are convex and increasing on the whole feasible interval ($0 \leq q_i \leq \kappa_i$). Furthermore, each of them is continuously differentiable and thus suitable for finding a solution to the optimization problem. Finally, because of the logarithmic term, the functions approach infinity as the production gets close to the capacity. By that, we get a natural production limit without the need to explicitly including it in the optimization problem.

To proceed, we also need an inverse demand function, which depends on the total quantity consumed on the market

$$Q = \sum_{i=1}^{29} q_i. \tag{2}$$

A general linear function depicting demand for oil declares

$$Q\left(p\right) = a - bp, \tag{3}$$

with p being the equilibrium price of oil. Parameters a and b signify the intercept and slope of the demand function, respectively. Hence if we want

to express the price, we get:

$$p\left(Q\right) = \frac{a - Q}{b}. \tag{4}$$

That is an inverse demand function showing the market equilibrium price for a given quantity.

To determine the values of parameters a and b, we use the price elasticity of demand as well as base values of price and quantity actually observed. First, we look at the elasticity ϵ, which is calculated in the following way:

$$\epsilon = Q'(p)\frac{p}{Q}. \tag{5}$$

Since the elasticity cannot be exactly determined, we will model the market for more levels of elasticity, specifically -0.1, -0.15 and -0.2.

Additionally, we also use the information from the market in 2016. We know the average price (EIA, 2018) and production of crude oil (OPEC, 2018b), which can be plugged into the equation (3). Furthermore, we assume that the demand attains the given elasticity exactly at the equilibrium levels from 2016. The ascertained information is sufficient to calculate the parameters and obtain the inverse demand function. The graph is shown below:

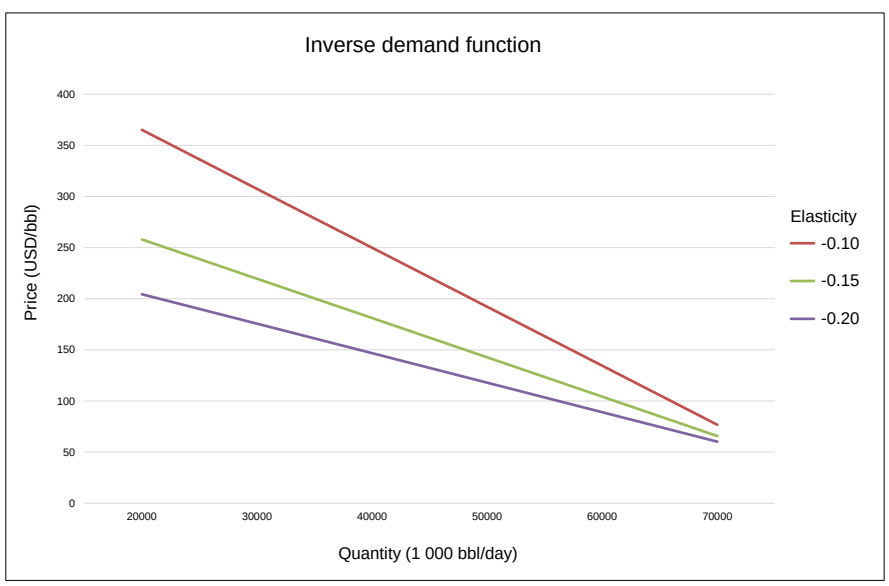

Figure 3: Inverse demand function for different elasticities

3.2 Cournot model of the oligopolistic market

We will examine what would the oil market look like under the oligopolistic setup disregarding the existence of OPEC. The model fitting the situation on the oil market is the Cournot oligopoly, where individual oil-producing countries aim to maximize their profits through an appropriate set of output. Characteristically, all countries play a simultaneous game, meaning they all have to determine their production at the same time. For such a decision, they also need to estimate outputs of their competitors.

The assumption underlying the Cournot model include homogeneity of products, perfect information, profit-maximizing behaviour with no cooperation among the oligopolists and each player having market power. Furthermore, we presume there is no market leader and that the players compete by setting quantities rather than prices. All of those conditions are likely to hold at the oil market.

The fulfilment of the first two assumptions relies on the aforementioned definition and simplification of the optimization problem. Secondly, although there currently exists some coordination among the OPEC members, the incentives to break the cartel and increase one's profit are omnipresent and we frequently witness cheating on the quotas. Therefore we conclude that individual profits are the main goals of the production and especially in a non-repeated game, cooperation is not likely. Additionally, as there is a limited number of players with rather large outputs (even more so after leaving out the minor producers in our setup), we see that manipulation with the productions significantly influences the price of oil. Finally, the nature of the market supports the preference of the output to the price setting. The reason is, that oil is usually traded at stock markets where prices are set based on the available quantities and demand.

The Cournot-Nash problem to be solved is

$$\max_{q_i \geq 0} \{p(Q)\, q_i - C_i(q_i)\}, i = 1, \ldots, 29. \tag{6}$$

To find the Cournot-Nash equilibrium, we use the aforementioned cost and inverse demand functions.

An important feature of the Cournot oligopoly model is the creation of the Nash equilibrium. The reason is that producers maximize profits through output setting based on the knowledge of the profit functions of the other players. Therefore their profits are the highest when choosing to produce at the levels calculated above and no one has an incentive to deviate from the equilibrium, which makes it stable.

3.3 Coalition of OPEC and Russia as a Stackelberg leader

In addition to Cournot oligopoly, we will also look at the functioning of oil market under the existence of the cartel. To react to the newly formed alliance, we will model the market as a cartel of OPEC and Russia. There, countries again maximize their profits through output optimization. However, the cartel aims at maximizing its profit as a whole rather than its individual members. That means that some of the countries may have lower profit as a sacrifice for a higher profit of the whole group.

Furthermore, the game is no longer simultaneous. At first, cartel chooses its output considering reaction functions of the followers. Then, the producers outside the cartel react with a Cournot game as described above, taking into account the decision made by the cartel in the first stage.

Similar assumption to the Cournot oligopoly apply also for the Stackelberg game, but we allow for the existence of the market leader. We also add the assumption of trustworthiness of the cartel and knowledge of its output decisions. Generally, the credibility of OPEC was not fundamentally undermined. Additionally, after each of their meeting, now also with Russia, they commit to producing a certain amount of oil, usually accomplished with just minor deviations. Hence such assumptions are arguably realistic ones.

The Stackelberg model has two consequtive stages expressed by

$$\begin{aligned}
&\max_{q_l,\, l\in L} \left\{ p\left(\sum_{l\in L} q_l + \sum_{f\in F} q_f\right) \sum_{l\in L} q_l - \sum_{l\in L} C_l\left(q_l\right) \right\} \\
&s.t. \quad q_l \geq 0,\, \forall l \in L, \\
&\qquad q_f \in \arg\max_{q_f \geq 0} \left\{ p\left(\sum_{l\in L} q_l + \sum_{f\in F} q_f\right) q_f - C_f\left(q_f\right) \right\} \forall f \in F,
\end{aligned} \tag{7}$$

where L is the set of the market leaders (OPEC members and Russia) and F is the set of the followers. We also use the cost and inverse demand functions formulated previously.

Properties of the problem ensure the existence of a single solution, as the maximized profit function is strictly concave. Firstly, the revenue is a result of multiplication of inverse demand function and quantity of the given producer. Since quantities of other countries are included only as parameters, we get a strictly concave function. The convexity of cost function has been established previously and hence with a negative sign we also have a concave function. Finally, as the sum of two concave functions is also concave, we get a single maximum.

In case of Stackelberg game, we get a Subgame Perfect Nash Equilibrium. In the first stage, the market leader chooses his output, anticipating a certain reaction of the follower. Then in the second stage, follower knows the production level chosen by the leader and performs his optimum reaction it. Once again, if the information is available and players are trustworthy, there is no chance to improve one's situation by deviating from the calculated strategy.

4 Numerical results and interpretation

In this chapter, we will look at the result of both the Cournot-Nash problem and Stackelberg leader model. Firstly, we inspect the equilibrium price linked to the oligopolistic as well as cartelized market and juxtapose it with the actual price at the time. Special attention will be paid to the effects of different price elasticities. Additionally, we analyse the total optimum quantity to be produced once again in comparison with the status quo. Finally, we look at some of the OPEC members including the contrast of their current and prospective situation.

4.1 Equilibrium price

The average price of the barrel of crude oil on the market in 2016 was approximately 43.68 USD. The prices on the modelled Cournot oligopolistic market are notably higher for all employed levels of elasticity and range from 59.8 to 81.7 USD/bbl. The overview of equilibrium prices for different elasticities is provided below:

Elasticity	**Price (USD/bbl)**
-0.10	81.7
-0.15	67.0
-0.20	59.8

Table 2: Equilibrium price of oil in Cournot oligopoly

Now, we can look at the way in which elasticity influences equilibrium price - the more elastic demand, the lower the price. Such result is in line with the economic understanding of the problematics: if elasticity in absolute value is higher, customers respond to price changes with a larger slash of demand. Hence it is less beneficial for the supplier to increase prices. Contrarily, for small elasticity little drop in demand occurs and it is more profitable to increase the price. As we can observe, the differences in elasticity caused almost 27 % change in the equilibrium price.

Additionally, the results clearly suggest the low significance of OPEC in those times, as prices should be significantly higher at the market under the effect of a large cartel. Similar results have been reached by other studies on the topic. Two main theories can help to clarify the issues - either OPEC grew toothless or it had other reasons not to act.

Firstly, as some propose, OPEC may have lost its power and become unable to coordinate output cuts across its members. Therefore it would no longer be able to influence the oil market. However, such claims are to a large extent incompatible with the late development of the market. In recent months, the price of oil has been constantly growing and in March 2018 it almost reached 70 USD/bbl presumably as a result of the cooperation of Russia and OPEC on decreasing the production. Hence we can conclude that the cartel is still able to efficiently push the prices up.

The other and arguably more likely alternative is that OPEC was declaring a price war on more expensive oil producers to squeeze them out of the market. Thus, rather than pursuing current economic profits they chose to prefer long-term benefit in form of securing their market share. Especially for countries with sizeable reserves compared to production, eliminating competition will enable them to keep the prices as well as profits high. That makes sacrificing contemporary benefits strategically reasonable. Since these potential considerations are hardly quantifiable, they were not included in the model. Thus they may cause the actual price and production to differ from our expectations.

However, a noticeable space still remains for prices to grow, as more competition is present on the non-cartelized market. That is a result of dispersion of market shares and incentives to free-ride on potential output cuts of other players. Without collusion, the producer choosing to decrease his output to increase prices is likely to lose his position on the market since he may be replaced by others and the price may not change anyway.

Those theories are supported by the results of equilibrium prices on markets accounting for the existence and cooperation of OPEC and Russia.

Prices vary from 80.3 to 124.8 USD/bbl, which means a substantial increase in price compared to the Cournot-Nash equilibrium. Table 3 summarizes results of market organised as a cartel of OPEC and Russia with other countries forming an oligopoly.

Elasticity	**OPEC & Russia price** (USD/bbl)
−0.10	148.1
−0.15	108.7
−0.20	89.9

Table 3: Equilibrium price of oil under cartel of OPEC and Russia

Therefore, shall OPEC and Russia regard it beneficial, the cartel may exert its market power and get the price of oil close to the pre-2014 level.

4.2 Equilibrium quantity

Expectedly, the quantities estimated to be produced on the oligopolistic market were smaller than the real production in 2016, which was 75 476 thousand bbl/day. Since we only model 29 oil producing countries, we have to extrapolate the output of the whole industry. The table below summarizes the equilibrium quantities of the 29 producers as well as the total amount of oil produced:

Elasticity	**Quantity of the 29** (1 000 bbl/day)	**Quantity of all** (1 000 bbl/day)
−0.10	65697	69155
−0.15	66191	69675
−0.20	66652	70160

Table 4: Equilibrium quantity of oil in Cournot oligopoly

It is important to notice that for less elastic demand price is higher, while quantity goes down. From the perspective of producers, it is more beneficial to cut production in order to raise the price if the absolute value

of elasticity is smaller. A similar logic about the behaviour of customers as for the equilibrium prices applies here as well.

Generally, the results suggest that most of the countries should produce very close to their capacities. The reasons are twofold: firstly, most of them produce oil so cheaply that their marginal costs are well below the oil price level and hence they are motivated to produce as much as they can as it increases their profit. Even more importantly, especially for smaller producers, other players are mostly able to replace the production of someone who decides to cut it. Therefore, if no cooperation is present, competition pushes countries to produce extensively, because otherwise their profits may be hindered.

Major exceptions from the situation described above are the three largest oil producers: Saudi Arabia, Russia and the United States. Depending on the elasticity, they on average utilize 65.6 to 67.7 percent of their total capacities. The reason is, that their own capacities are so immense that the production cannot be replaced and when exerting market power, they are better off choosing lower outputs.

On a market with a cartel, the quantity cuts are even more extensive. With cooperation, individual players do not have to worry about other producers increasing their outputs and losing market share. However, implementing such coordination in the real world may be a bit complicated. Every single player would benefit from deviating from the agreed upon quantities and producing more while benefiting from concessions made by others.

The problem grows even more significant as it is difficult to find out whether and who broke the deal. The reason is that it is nearly impossible to obtain information about the country of origin on the market and incentive to misreport information is overt. Therefore, even under a repeated game scenario, punishments are scarcely feasible. Additionally, all countries outside the cartel benefit without a need to participate in limiting production, which may be demotivating for cartel members.

The following table summarizes optimum utilization of capacity under the

cartel of OPEC and Russia, as they are currently cooperating on limiting common output. The US production is introduced as a reference value and also to reveal the impact of cartel on other producers. Additionally, the total quantity produced by the whole cartelized market is included.

Elasticity	**Capacity Utilization**		**Quantity**
	OPEC & Russia	USA	(1 000 bbl/day)
−0.10	80.2%	99.0%	57634
−0.15	84.5%	92.9%	58838
−0.20	87.5%	83.9%	59711

Table 5: Capacity utilization under cartel of OPEC and Russia

We can clearly conclude, that cartel is better able to utilize their quantity to manipulate price and profits. Especially with lower elasticity cartel is able to effectively make use of small slash of demand as a result of a price increase. As anticipated, the total quantity produced on the market dropped even further due to cartel's output cuts. However, we see that other producers represented by the United States produce much more than previously, as they can enjoy the high price caused by the cartel.

4.3 Situation of individual OPEC members

Now that we understand the development of oil market as a whole, we look at positions and roles of individual countries. The overview of their profits is visible in Figure 4 below.

As we see, all of the countries except for Saudi Arabia would gain the most if they were part of the OPEC and Russia cartel. For some, the profits on the cartelized market may be three times higher than those actually obtained in 2016. The reason is that their oil production is very cheap and thus with high oil prices caused by cartel's coordinated output cuts their profits rise rapidly. Overall for the mean elasticity, the profit of OPEC alone rose by 560.6 million USD/day.

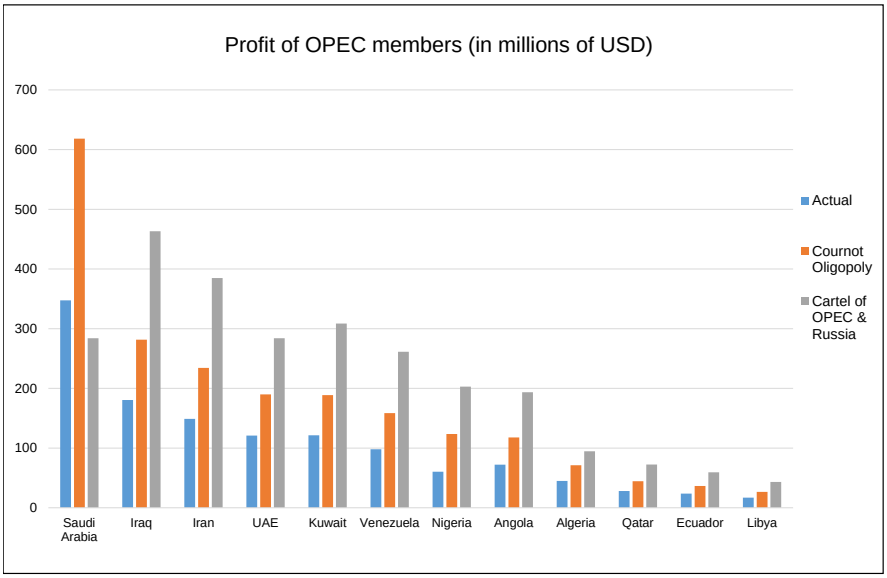

Figure 4: Profits of OPEC members under different setups

The following five countries will be further analysed: Saudi Arabia, Qatar, Nigeria, Venezuela and Iran. Those countries represent different kinds of OPEC members and serve well to understand impacts on individual countries based on their specifics.

We start in the Kingdom of Saudi Arabia, a country with the highest production and second largest proved reserves of oil. Furthermore, it is one of the leading countries of OPEC and has extensive spare capacities of approximately 2 000 bbl/day, which means the kingdom has immense power over the oil market.

Currently, Saudi Arabia produces 10 460 thousand bbl/day and its profit from oil sales is approximately 347 million USD/day. However, based on the calculation of equilibrium on the oligopolistic market it could earn somewhere between 569 and 725 million USD/day due to elasticity differences. Interestingly, as the kingdom's oil production is relatively expensive compared to other OPEC members, in cartel its outputs would be lower. Hence its profits would decrease as a sacrifice for the good of the whole cartel and would only reach 313 million USD/day.

Saudi Arabia is known to be one of the players supporting lower prices

aimed at preserving OPEC's market share. However, as financial reserves vanish, it may have to reconsider the stance. OPEC is now cooperating on production cuts, which should increase price and thereby the oil profits. Furthermore, the recent introduction of 5 % value-added tax or cuts of government subsidies (Kerr and Omran, 2018) nicely illustrate the situation in Saudi Arabia.

Let us now look at the position of Qatar, the richest country in OPEC and country with one of the highest GDP per capita in the world. As much as all the other oil-exporting countries, its financial conditions changed significantly after the price drop in 2014. In 2013 oil rents accounted for 26.1 % of its GDP while over the following 2 years later the ratio almost halved (World Bank, 2016b). Moreover, over the same period, Qatar's GDP per capita fell from 88 305 USD to 66 347 USD and continued dropping in 2016 to 59 324 USD. Despite the adverse economic movements, Qatar never left its prominent position in the 7 richest countries of the world (World Bank, 2016a)

In 2016, Qatar made a daily profit of circa 28 million USD, but it could make considerably more if fully enjoying the oligopolistic nature of the market. The model indicates that depending on elasticity, profits of Qatar would vary from 39.6 to 54.2 million USD/day. Even more, if the cartel was exerting its market power, 98.8 million USD/day. Although Qatar could earn higher profits under oligopolistic or efficiently cartelized market, its situation is still more than satisfactory and low oil prices could not fundamentally endanger the citizen's wellbeing.

In contrast, the poorest OPEC member Nigeria with 2016 GDP per capita of 2 176 USD suffered much more as its GDP slashed by one third since the start of oil price collapse. Similarly, the percentage of oil rents in Nigerian GDP decreased to one-third of its original value (World Bank, 2016a). With the history of military conflicts, ethnic fragmentation and countless terrorist attacks by Boko Haram, Nigeria desperately needs the oil money to improve conditions in the country.

Nigeria's net profits from oil production reached 60.3 million USD per day in 2016. From our calculation, we can infer that on an oligopolistic market, with favourable elasticity they could earn as much as 151.4 million USD daily Interestingly, Nigeria was losing the most money from lack of current profit maximization. Its actual profits were 45 % lower than in case of the oligopolistic market, while for example Qatar only lost 29 % of its profits as a result of OPEC's production decisions. Since Nigeria's oil production is relatively cheap, it would extensively benefit from participation in a cartel of OPEC and Russia, where its profits could reach 277.8 million USD/day.

Contrary to the richer OPEC members such as Saudi Arabia or Kuwait, the following 2 countries were always in favour of keeping the price of oil high. However, their voices within OPEC were not strong enough imminently after the oil price downswing in 2014. Therefore they both had to subordinate to the strategy aimed at preserving future market share which significantly hampers their oil incomes.

As a result of abovementioned, Venezuela is now facing an unpleasant situation and could use any money potentially available. Its GDP decreased by 10 % in 2016 and inflation was expected to reach 1 600 % in 2017. Furthermore, Venezualeans suffer from lack of food and as a result in the year 2016 the poorest 74 % on average lost weight of 8.7 kg. As a share of oil on exports used to exceeded 90 %, the oil price drop posed a significant threat to import-dependent Venezuela. Furthermore, lack of government revenues leads to cuts in subsidies which primarily hurt the already impoverished parts of society. (The Economist, 2017)

Nowadays, Venezuela owns largest proved crude oil reserves and its 2016 production brought profits exceeding 98 million USD/day. Nonetheless, oligopolistic market and low elasticity would enable Venezuela to almost double its oil rents. This would not only bring resources to the government to help the poor but also it would improve Venezuela's balance of trade and enable its currency to appreciate. The earnings of Venezuela could grow even higher if it took part in the cartel of OPEC and Russia - its daily profits may reach

310.8 million USD.

Finally, we look at the situation in Iran. Previously, sanctions including oil exports were imposed on Iran due to its nuclear programme, but they were lifted at the beginning of 2016. Then, the share of oil rents on Iranian GDP reached 13.6 percent (World Bank, 2016b) and GDP grew to 5 219 USD per capita (World Bank, 2016a) with a year-on-year increase of more than 7 percent.

In 2016, Iran's profits from oil production were close to 149 million USD/day. Depending on elasticity, its daily earnings on the oligopolistic market could vary between 208 to 287 million USD. The profits would grow even more on the cartelized market, where Iran could use its advantage of producing cheap oil for higher prices. Its profit could be as high as half billion dollars per day, even outpacing Saudi Arabia.

Other countries have similar fates to those mentioned above, all of them were severely weakened by the oil price drop. The most important conclusion remains, that profit for all of the states in 2016 was far from the one expected for a non-cooperative oligopolistic market. Furthermore, with the existence of the cartel, profits could have been even higher. Especially for the members who direly needed them, OPEC decisions was substantially damaging.

Conclusion

In this thesis, we have looked at the optimization of oil production from the perspective of individual OPEC members. We have modelled oligopolistic and cartelized market under the leadership of OPEC and Russia. For the Cournot oligopoly, prices would range from 59.8 to 81.7 USD/bbl, with corresponding quantities between 70 160 and 69 155 thousand barrels per day depending on elasticity. The coalition of OPEC and Russia could lead to prices as high as 148.1 USD/bbl and quantity below 58 million barrels a day. We can clearly conclude, that compared to the actual situation, modelled prices are significantly higher while quantities slumped.

To a large extent, our findings are compatible with the previous studies. Ansari (2017) concludes that at the end of 2015 the price on the oligopolistic market should be close to 80 USD/bbl mark, while on the cartelized market price of barrel exceeds 100 USD. The difference in price on the cartelized market can mostly be explained by the omission of Russia from the cartel but also by yearly changes, as for example in 2014 the prices on the market with cartel were also reported close to 150 USD/bbl. Huppmann and Holz (2012) calculate the equilibrium price on 2009 market for both oligopolistic and cartel setup, with a result of approximately 150 USD/bbl and 170 USD/bbl respectively. Despite not including Russia in the cartel the prices are much higher in both setups, presumably as a result of a substantial loss of market power due to US capacity rise and following oil glut. Since profits and quantities of individual countries are not examined in the works, we cannot compare them to our values.

In line with the microeconomic theory, we observe the effect of elasticity on the prices and quantities. Low elasticity marking a small decrease in demand in response to growing prices results in much higher prices and lower quantities. Especially cartel of OPEC and Russia can effectively utilize such situation, as they have vast power over the market.

Moreover, we have discovered that unlike Saudi Arabia, other members of OPEC would benefit significantly from the formation of the cartel with

Russia. Additionally, the situation in 2016 was far from optimum for all of OPEC members and led to major financial losses, which were hardly bearable for the poorer members of OPEC. Interestingly, poverty-stricken countries such as Nigeria were oftentimes forced to sacrifice more of their profits than the richer members.

Importantly, there are many limitations to this particular as well as general modelling of the oil market. Many simplifying assumptions such as linearity of demand function or homogeneity of oil production were included. Those can be accounted for in the model and thus provide space for further research.

However, there are other matters that cannot be easily covered. Most importantly, long-term considerations are included in state's optimization but can hardly be quantified. Furthermore, the extent to which high prices of oil bring new competition and substitution methods is unknown. The subjective importance of future lack of demand also differs based on the reserves compared to current production, as countries with output sustainable for just 10 years do not really have to worry about it. Finally, the preference of current profits must be considered as poorer countries cannot afford to postpone their incomes even with the promise of larger future revenues.

The situation is complicated by the lack of reliable and complete data on countries' production costs or elasticity, which makes the results of the models arguable as they are merely approximations of the reality. Additionally, as much as for OPEC members the optimization of production for the whole country makes sense, the application in countries with dispersed and privately owned companies is limited.

Thorough discussions analysing the behaviour of OPEC and low profits of its members are led. Either the problem could lie in the inability of OPEC to influence the market or it may be a well-elaborated strategy aimed at maintaining market share and squeezing high-cost producers out of the market. Recent events on the oil market seem to prove the first theory wrong, as OPEC is now pushing on prices to increase. However, it has to

pay the price in form of losing market share due to output cuts and attracting potential new investments into higher-cost production.

Based on our research the power of OPEC especially in connection with Russia is undeniable. The cartel may help to increase prices and profits on the whole oil market and get it close to the pre-2014 levels. However, the sustainability of such behaviour in reality is to be tested. Cartel sacrifices a lot to increase the price, effectively paying for the immense US or Chinese profits, which many of its members dislike. Furthermore, any renegade deviating from the agreed upon quantities in the cartel may increase his profits. Particularly the inability of OPEC to reveal breaches of the deal makes the stability of coordinated output cuts unlikely.

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