GE/M2 – Major in Finance

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Application of game theory to oil producing countries

Forecasting market players behavior in the current new oil order

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PUBLIC REPORT

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Abstract

The aim of this paper is to further study the application of game theory to world oil market. A first part focused exclusively to a deep analysis of the current situation and of future prospects for the main players involved allows to select the best theoretical framework to represent it in a model. In the second half, based on our assessment and forecast of the main variables and on the tools offered by game theory, projections on the evolution of oil price for the coming years are computed for different scenarios. Moreover, the main weaknesses are studied in order to offer possible improvements for future models.

Glossary

API gravity: American Petroleum Institute gravity. It is a measure of how heavy or light a variety of crude oil is compared to water. Higher API gravity implies lower density.

AV: autonomous vehicle.

Bbl: abbreviation for blue barrel, representing a 42 U.S. gallon barrel.

Breakeven point: required market price for which the net present value of the future cash flows of a project is zero, only taking into account the cost of oil production. A 10% required rate of return is usually taken.

Brent Blend: sweet light crude oil extracted from the North Sea. It is widely used as a benchmark for crude oil price.

BTM: Russian big tax manoeuver. Set of reforms to incentivize export of crude oil, energy efficiency growth and stimulate the sector's modernization. Measures included a reduction in crude oil exports custom duties.

Call on OPEC: difference between oil demand and non-OPEC supply.

Car sharing: short-term car rental.

Carpooling: sharing of car journeys.

CED: Russian crude oil export duties.

CIF: abbreviation for cost, insurance, and freight. It is a transportation contract where the seller is responsible for insurance and transportation costs to the destination.

CNOOC: China National Offshore Oil Corporation, a national oil company in China focusing on the exploration and development of oil and natural gas in offshore fields.

CNPC: China National Petroleum Company. National oil and gas Chinese company ranked among the largest energy groups in the world and covering the whole value chain of oil and gas.

Cournot game: economic model employed to represent a structure in which every player decides independently its output. Under this framework, every player considers as given the sales path of the rest, which means that the decisions taken by a player do not affect the strategies of the rest.

Dubai crude: medium sour crude oil produced in Dubai. It is widely used as a benchmark for crude oil price.

Elasticity: change in the demand or supply of a given good following a change in its price.

Energy intensity: measure of the energy efficiency of a nation. A decrease in energy intensity is equivalent to an increase in energy efficiency.

EOR: Enhanced oil recovery. Refers to the development of techniques allowing an increase in the amount of crude oil extracted from an oil field. It includes three techniques: thermal recovery, gas injection, and chemical injection.

ESPO: Eastern Siberian-Pacific Ocean pipeline allowing exports of Russian crude oil to Asian clients.

EV: electric vehicle.

Free on Board: transportation contract where the buyer is responsible for the goods once they are shipped.

Full cycle breakeven point: required market price for which the net present value of the future cash flows of a project is zero, including all expenses of developing a new field. It is the most comprehensive measure of the cost of oil.

Future contract: financial instrument enabling to lock in a pre-specified price and quantity of oil for delivery at a pre-determined date in the future.

Game equilibrium: solution for a game defined as the situation where no player has no incentive to change its own strategy.

Half cycle breakeven point: required market price for which the net present value of the future cash flows of a project is zero. It takes into account the cost of oil production, including lifting costs, the expense of current well workers, and of drilling, completing and stimulating additional wells in a developed field, with the goal of maintaining the production level. It also includes the related financial costs.

ICE: internal combustion engine. Refers to vehicles relying on fuel burning to create power.

Improved Oil Recovery techniques: cf. EOR (Enhanced oil recovery).

Inelasticity of demand: changes in the demanded quantity of a good following a change in its price. It represents the unwillingness or inability of oil consumers to move away from oil.

IOC: International (or Investor-owned) Oil Company.

IPC: Iran Petroleum Contract. New framework deployed by the National Iranian Oil Company to attract foreign investment.

JCPOA: Joint Comprehensive Plan of Action. Iran nuclear deal struck in 2015 between the five permanent members of the United Nations Security Council, Iran, and the European Union that resulted in the lifting of part of the international sanctions.

KRG: Kurdistan Regional Government. Ruling body of the Kurdistan Region of Iraq (KRI), located in the North of the country.

KRI: Kurdistan Region of Iraq. Autonomous region in Northern Iraq ruled by the Kurdistan Regional Government (KRG).

Lifting costs: incremental cost of producing one additional barrel of crude oil from an existing well in an existing field. It includes corporate overheads.

LTO: Light Tight Oil (cf. Tight Oil).

Mbd: million barrels per day.

Monopoly: theoretical market structure in which there is only one seller for a good.

MRET: Mineral Resources Extraction Tax in Russia.

New Policies Scenario: baseline employed by IEA scenario that takes into account current policies as well as announced targets and plans.

NIOC: National Iranian Oil Company. Iranian government-owned company responsible for the production and distribution of national oil and natural gas.

NOC: National Oil Company. Oil company owned by a national government. It can be seen as the opposite of International Oil Companies (IOC).

OECD: Organization for Economic Co-Operation and Development.

Oil shales: organic-rich fine-grained sedimentary rocks containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons called shale oils can be produced.

OIL: Oil India Limited. Indian national company engaged in the whole value chain: exploration, development, production, transportation, and refining of crude oil and natural gas.

Oligopoly: theoretical market structure defined by limited competition as there is a small number of sellers.

ONGC: Oil and Natural Gas Corporation. Indian government-owned company that is India´s largest one engaged in oil and gas exploration and production.

OPEC: Organization of the Petroleum Exporting Countries.

Perfect competition: theoretical market structure in which the price of a good is beyond the control of individual buyers or sellers.

PPP: Purchasing Power Parity. Economic theory that states that the exchange rate is the rate that makes the price levels in two countries equal.

Proven reserves: (EIA definition) estimated quantities of all liquids defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

Reference case: baseline case employed by the U.S. Energy Information Administration that only takes into account current policies in place, leaving aside proposed legislation.

Reserves: cf. Proven reserves.

Reserves-to-production ratio: remaining amount of a non-renewable resource divided by the amount consumed per year. Expressed in years.

Ride pooling: cf. Carpooling.

Shale oil: unconventional oil produced from oil shales by pyrolysis, hydrogenation, or thermal dissolution.

Sinopec: China Petroleum and Chemical Corporation. Listed Chinese company focusing in oil and gas exploration, refining and marketing.

Spare capacity: (EIA definition) volume of production that can be brought on within 30 days and sustained for at least 90 days.

Spot price: price at which a commodity could be bought or sold and delivered now.

Stackelberg game: economic model employed to represent a structure in which a dominant firm (or leader) can use its power to maximize its profit by anticipating the reaction of its competitors. Under this framework, the leader is a price-maker as it takes into account the reaction of the competitors when setting the prices policy, while the other player, the competitive fringe, becomes a price-taker because it adapts its own maximization problem to the price path set by the leader.

Sulphur content: measure of the impurity Sulphur that allows to classify crude oil varieties between sour (Sulphur content above 0.5%) and sweet.

TaaS: Transport-as-a-service. Shift in the traditional concept of mobility: from individually owned modes of transportation to solutions sold as services.

Tight oil: oil located in relatively low-porosity and permeability shales. Its extraction is possible thanks to advanced drilling techniques and hydraulic fracturing.

Toe: tonne of oil equivalent. Unit of energy representing the energy released by burning one tonne of crude oil

Unproven reserves: estimated quantities of all liquids defined as crude oil based on geological and engineering data, but current technical, contractual, or regulatory uncertainties do not allow classifying them as proven.

West Texas Intermediate (WTI): light sweet crude oil traded in U.S.'s oil hub in Cushing, Oklahoma. It is widely used as a benchmark for crude oil price.

1. Introduction

The oil industry is one of the world's largest, most complex and most important industries in global economy. Our daily life relies heavily on its main products, including transportation, heating and electricity, but also on other articles that we would not link to the industry ranging from eyeglasses to clothing. The role that oil plays in modern society is such that it impacts national elections and international conflicts and geopolitics. Needless to justify then why the price of crude oil is one of the most watched commodity price in the world.

Following the 1973 oil shock and the impact it had on society, both the industry big players and academia supported by governments tried to explain the main dynamics of the industry and to predict future prices to try to bring some certainty. Since then, models and assumptions have evolved continously, reflecting the underlying complexity, but also the importance of gaining deeper knowledge.

These articles conclude that, as it is the case for any good, the price movements can essentially be explained by the interaction between supply and demand. However, oil industry presents two particularities. First, the variety of players involved in the decision making process, including supra national organizations, legislators, international companies, speculators and even final consumers. This diversity necessary implies the existence of some sort of hierarchy in the market, which translates in complex relations, and of course, in divergent goals. Secondly, it is important to highlight that oil cannot be treated as any other commodity. Indeed, besides the fundamental market forces of supply and demand, oil is also subject to political and geopolitical powers, which are harder to understand. These include the role oil plays in energy security matters as there is no clear substitute, the importance of crude oil price to balance national budgets or the pressure to reduce oil consumption due to environmental considerations.

With all this in mind, the aim of this project is to present an application of game theory to the global oil industry as it is the most powerful tool to try to predict the evolution of crude oil prices. To do so, the purpose of this thesis is threefold. The first part will focus on an introduction to oil pricing describing the main forces behind it, as well as reviewing the historical evolution of oil price. Secondly, as it is fundamental to understand the structure of the industry, light will be shed on the main consumers and producers of the industry. This is an essential step to puzzle out their motivations, comprehend the nature and complexity of their goals and interactions, but also to review forecasts and assess the impact of technological disruption and new policies. These two first analysis pave the way for the application of game theory to world oil market. In this last section, a literature review along with theoretical and numerical analysis will support the application to current and future market conditions.

2. Introduction to oil pricing

The first step in order to forecast market players' behaviour in the current new oil order through the application of game theory is to understand the key factors that drive crude oil prices. This will enable us not only to select the most relevant elements to incorporate into our models later on in our study but also to get a better understanding of their combined effects in oil pricing dynamics.

Given the obvious relevance of oil prices for the global economy, there are a vast number of research papers covering the determination of the most relevant variables explaining oil price behaviour in a quantitative and analytical manner (most of the times with an ultimate forecasting purpose). Although similar variables appearing repeatedly (which will be analysed later on in this section), there are other factors whose causality is highly debatable and seem to be driven by a third hidden variable not included in the model. Moreover, statistically significant variables are extremely sensitive to the specific data sample used, as defined by its time horizon, making it extremely difficult to reach a definite conclusion on the main variables that drive oil prices through these quantitative methods. Hence, we will dig into those main factors influencing oil prices in a broad scale and that persistently show up in both qualitative or quantitative analysis and reports.

Taking EIA's views into consideration, we find five different factors driving crude oil prices: spot prices, oil balance, financial markets, supply, and demand. Needless to say that these factors have not been presented in order of relevance.

2.1. Spot prices

There are multiple different crude oil streams brought into the market with differences in qualities and coming from different geographical locations. Crude oil benchmarks serve as a reference price for a particular oil produced in a given region. For instance, the Brent Blend refers to light sweet crude oil extracted from the North Sea, the West Texas Intermediate (WTI) represents light sweet crude oil traded in U.S.'s oil hub in Cushing, Oklahoma, and the Dubai crude englobes medium sour crude oil produced in Dubai.

Thanks to a generally efficient market integration, and because crude oil prices are traded in global markets, prices of different crude oil benchmarks tend to co-move (see Figure 1), despite persistent price spreads explained by quality or location differences. Notwithstanding, temporary transportation infrastructure or refinery capacity constraints might lead to certain oversupply, increased oil inventories at the oil hub, and a final downward pressure on that particular oil price benchmark.

Petroleum products and crude oil prices also tend to move together, given that the latter is the most significant driver of product prices (see Figure 2). Certain breaks can be seen, however, after periods of refinery or transportation outages.

Oil market prices factor in both current and expected oil market conditions, such as the anticipated net balance between supply and demand. As historical review clearly reveals, both crude oil and petroleum products prices are notoriously susceptible to events that generate or bring the possibility of disruptions to the crude oil or petroleum products expected supplies.

Those events tend to be geopolitical, economic or weather-related events and will be further analyzed in the third section. Other factors, such as refinery and transportation constraints can temporarily generate a supply disruption as mentioned above.

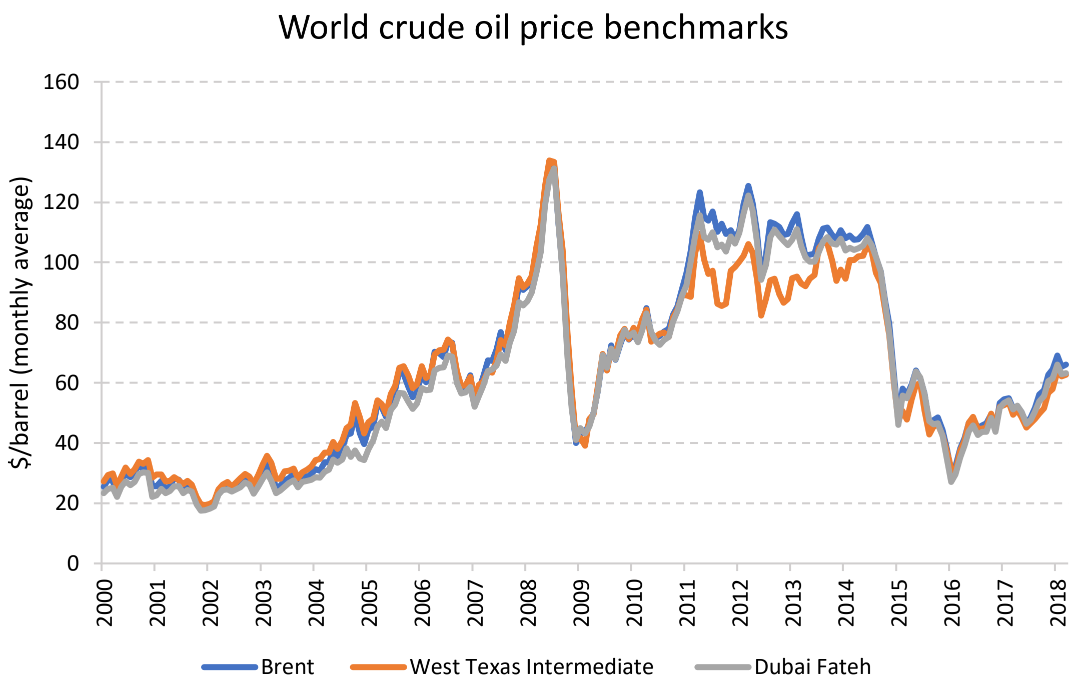

Figure 1. World crude oil price benchmarks, in real 2010 dollar terms. Source: Bloomberg.

We must bear in mind that volatility is, in many cases, inherently built in oil prices given the low responsiveness or inelasticity of demand and supply to short-term oil price movements.

On the one hand, oil consumers cannot quickly change to alternative energy sources and it takes time to make their manufacturing equipment more energy efficient. On the other hand, oil producers' capacity is relatively fixed in the short run as new oil flows take years to develop. Consequently, a large oil price swing might be necessary in order to achieve the physical rebalancing of supply and demand following a market disruption.

Spare capacity appears also as a fundamental factor driving oil prices. This parameter gives comfort that supply can be maintained and demand can be met over the short term.

Market participants constantly evaluate risks of oil supply shocks given the historical evidence of these event's relevant effects on oil price movements. The analysis tends to include not only the potential size and duration of the disruption but also the ability of the market to offset a given shock (i.e. available inventories to provide extra oil flows in an event of a negative supply shock).

If spare capacity or inventories are low, then market participants will be concerned about the market inability to digest a possible negative oil production shock and will incorporate their concerns into oil pricing with a given "fear premium" that can be significantly high as we will see in the third section.

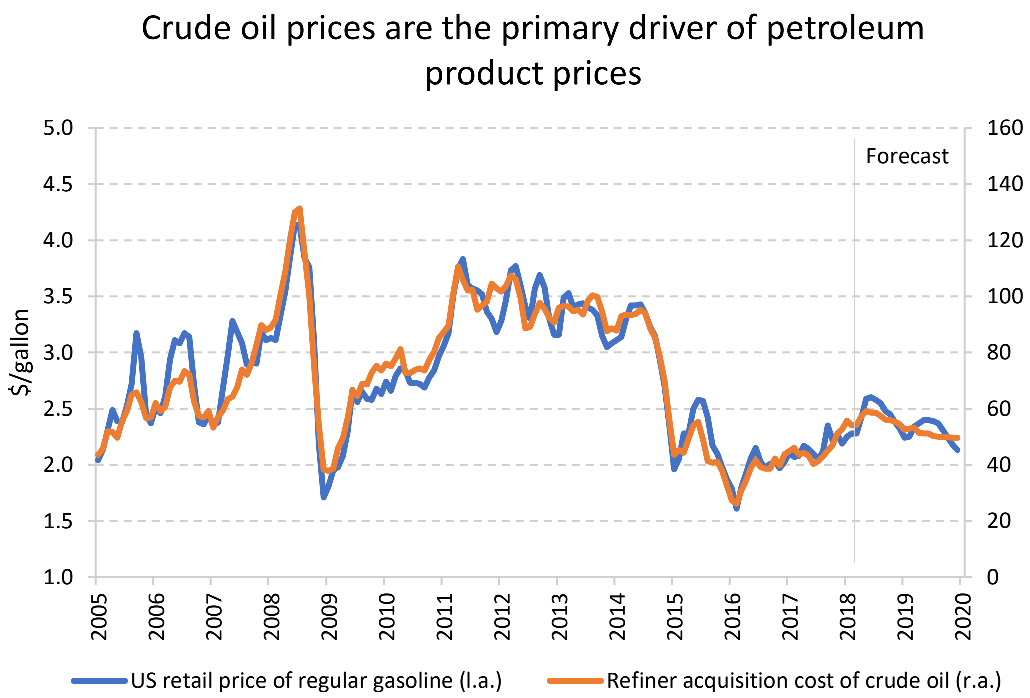

Figure 2. Crude oil prices are the primary driver of petroleum product prices: U.S. retail regular gasoline price versus refiner acquisition cost of crude oil. Source: U.S. Energy Information Administration.

2.2. Oil balance

Commercial oil inventories appear as a key factor balancing not only supply and demand, but also current and future oil prices.

On the one hand, inventory builds up when actual crude oil or petroleum products supply exceeds demand in a given period. Conversely, inventories serve crude oil or petroleum products supply shortages when consumption exceeds actual production. Hence, inventories act as a precautionary cushion that fills supply-demand imbalances.

On the other hand, inventory levels can, and do, influence oil prices. In actual fact, as can be observed in Figure 3, inventory builds generally occur together with rises in the price of crude oil futures relative to current prices (and vice versa).

In the first case, future and current price imbalances affect inventories. Here, refineries and storage terminals check next month's future oil prices with respect to current oil prices. If futures prices are higher than current prices, then the market expects the net balance to decrease, and inventory holders will be incentivized to increase inventories (either to cover for the upcoming excess demand or in order to sell later, profiting from higher prices).

In the second case, inventories affect future and current price imbalances. Here, crude oil and petroleum product traders and market participants notice a rise in inventory levels. The storage increase implies a current supply surplus at the prevailing price, which will follow a spot price decrease to rebalance production and consumption levels.

Hence, physical inventory levels and price spreads over time act as market signals between current market participants and those with long-term exposures, and these market signals influence oil pricing.

It is important to note that despite OECD countries being considerably transparent in their inventories' frequent reporting practices, non-OECD players inventory reports are significantly less recurrent and reliable (even sometimes inexistent). This uncertainty regarding real available global oil inventories can increase price volatility under a fragile oil market environment.

Finally, apart from commercial inventories, countries also hold strategic oil reserves that can be drawn upon in case of a supply shock hitting oil markets (meeting certain statutory criteria).

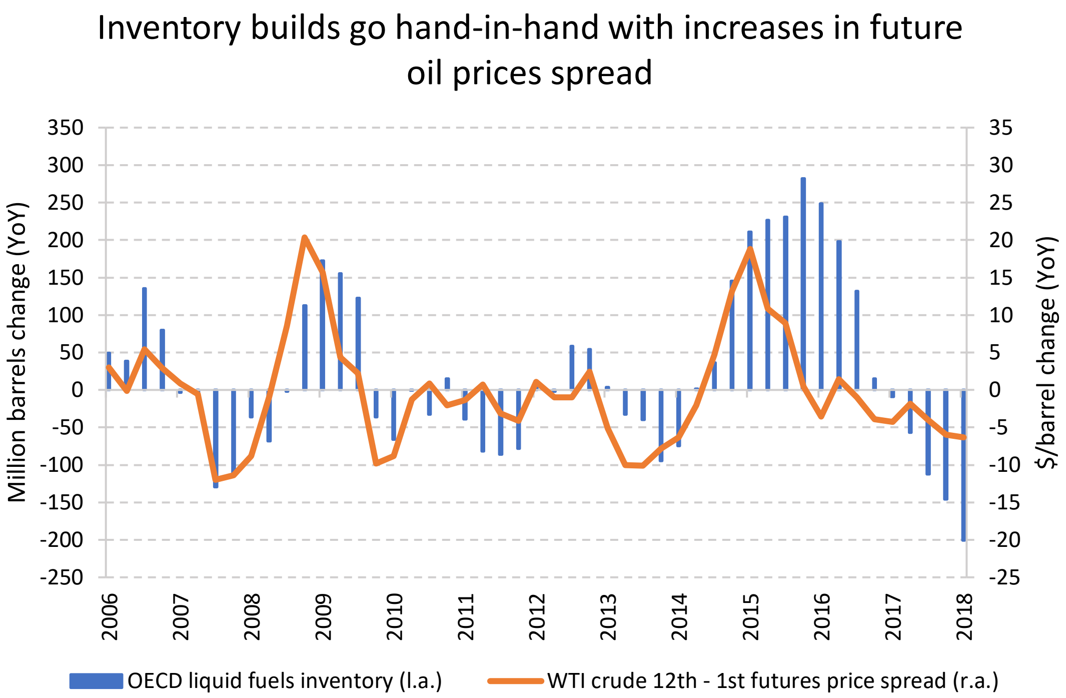

Figure 3. Inventory builds tend to go hand-in-hand with increases in future oil prices relative to current prices (and vice versa): OECD liquid fuels inventories versus WTI futures spread. Source: U.S. Energy Information Administration.

2.3. Financial markets

Market participants within oil markets get involved not only in physical oil trades, but also in future contract transactions, which are financial instruments that enable them to lock in a pre-specified price and quantity of oil for delivery at a pre-determined date in the future. Given than one of the principal roles of the futures markets involves price discovery, these financial markets have the ability to influence oil prices.

Market participants involved in oil trading activity are of diverse nature and do not necessarily seek similar goals. They can be divided in two main groups: commercial investors and non-commercial investors.

The first group is characterized by having a direct interest in the production, consumption, or trade of physical oil. These commercial investors generally trade in order to hedge oil price volatility risk by buying or selling derivative products (such as futures or options).

The second group is formed by money managers, banks, hedge funds, commodity trading advisors, etc. Their activity within financial markets involving oil contracts aims at profiting from oil price changes (speculative motives), portfolio diversification, inflation hedge, and others.

Activity in commodity exchange contracts has risen dramatically in recent years (see Figure 4), primarily driven by a growing interest of non-commercial investors to participate in oil financial markets. The positive or negative effects of the insurgence of these non-commercial investors in oil price dynamics has generated significant debate.

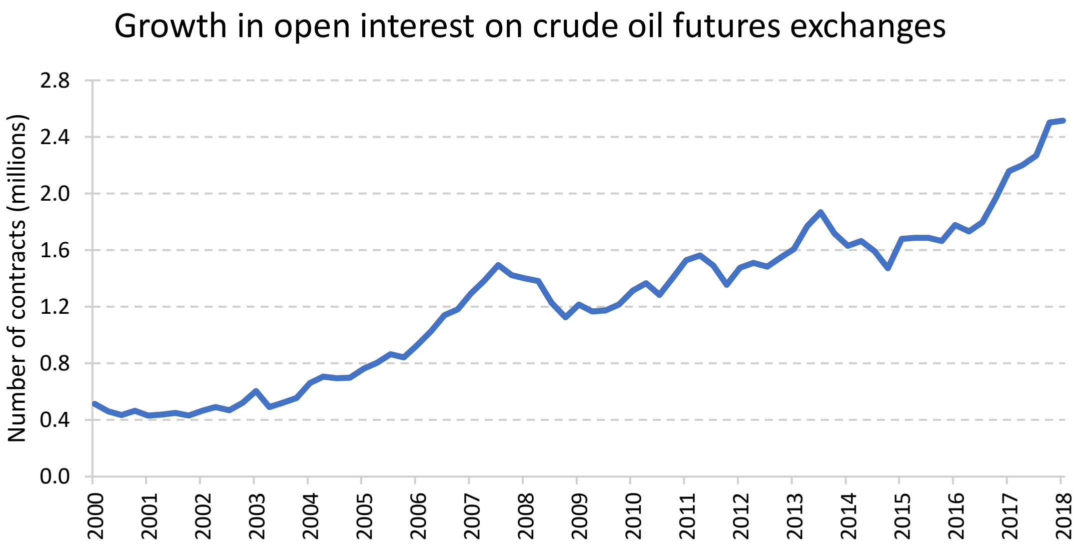

Figure 4. Open interest on crude oil futures exchanges grew over the last decade as more participants entered the market: average daily open interest in crude oil futures on U.S. exchanges. Source: U.S. Energy Information Administration.

On the one hand, given their differing motivations with commercial investors, these emerging market participants can bring liquidity to financial markets by taking the opposite position in, for example, futures and derivatives transactions. The extra liquidity brought into the system should diminish oil spot and futures price volatility.

On the other hand, some market observers have shown their concerns over non-commercial commodity trading and investment justifying that they "use up" liquidity and amplify oil price movements. This is especially true when momentum is running strongly in a particular direction. However, despite increasing research being conducted towards this issue, no formal evidence that demonstrates or debunks causality between non-commercial trading and increased oil price volatility in the recent past has been reached.

Correlations between daily returns on crude oil futures and other financial market instruments have also strengthened in the recent past. One must bear in mind that correlation does not mean causality, as a third hidden variable might explain the observed co-movement between selected parameters. However, persistent unidirectional correlations might help uncover interesting factors influencing oil prices within financial markets.

Amongst the most relevant asset classes to which crude oil futures prices are correlated, we would like to point out commodities, stocks, bonds and currencies. Figure 5 and Figure 6 have been built in order to shed some light on the historical evolution, and variability, of correlations with the aforementioned financial assets.

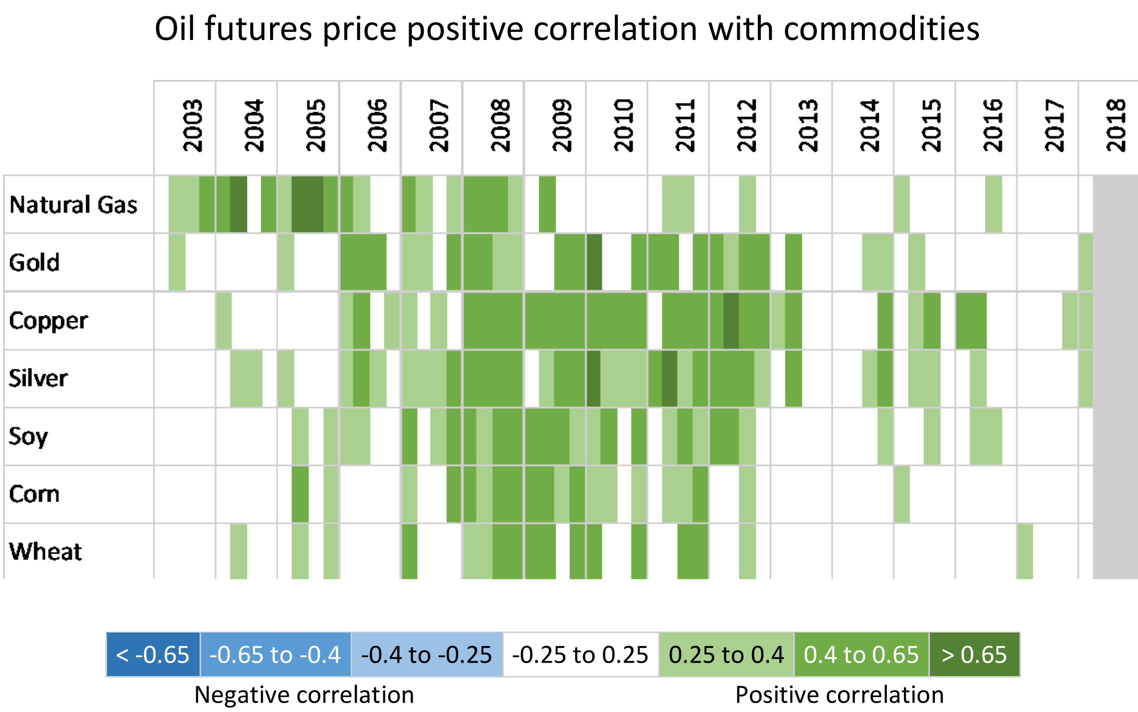

Figure 5. Correlations between daily futures price changes of crude oil and other commodities generally rose in recent years. Source: U.S. Energy Information Administration.

On the one hand, commodities and stocks show a clear, and generally persistent, positive correlation with oil futures prices. These correlations strengthened amidst the global financial crisis. The same can be said for bonds, except that in this case we observe a negative correlation with oil futures prices. While analytical results might point out to statistically significant relationships, we believe that the observed co-movements with the aforementioned financial instruments are in fact driven by a third hidden common factor: economic growth expectations. It is needless to say that the 2008 great financial crisis abolished investor risk appetite, leading to capital flying away from risky assets into bond-like instruments that offered, despite lower returns, a lower chance of losing principal. The expected high volatility and returns of oil prices resembles that of commodities and stocks, which explains the strong positive correlation that appeared after the great recession. The reverse is also true for bonds asset class.

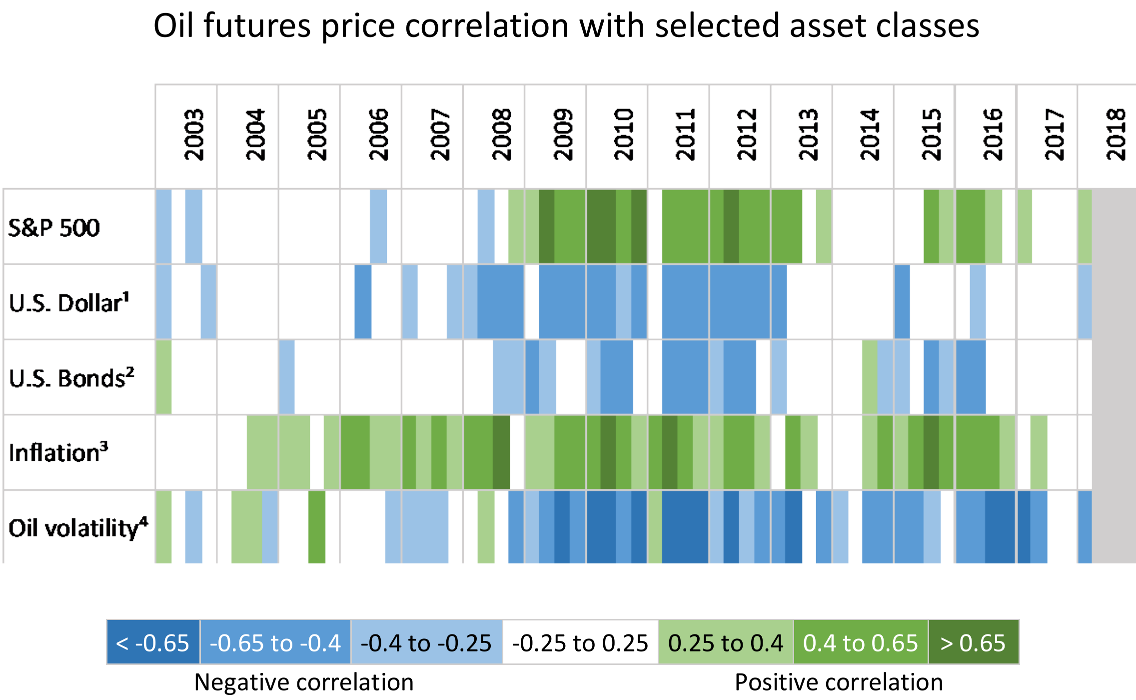

Figure 6. Correlations between daily returns on crude oil futures and financial investments have also strengthened. Source: U.S. Energy Information Administration. [1][2][3][4]

On the other hand, currencies appear as a key factor driving oil prices. In particular, there is a relatively strong and continuous negative correlation between the U.S. Dollar Index (DXY), which is the weighted index of a basket of currencies per U.S. dollar (such that as the collar strengthens against other currencies, the value of the index rises), with oil futures prices. Several hypotheses explain this inverse relationship nature. The most intuitive one comes from the fact that as the U.S. dollar strengthens, the oil becomes more expensive for foreign non-U.S. oil consumers (their purchasing power has been

[1] U.S. Dollar Index (DXY), which is a weighted index of a basket of currencies, per U.S. dollar. As the dollar strengthens against other currencies, the value of the index rises.
[2] U.S. bonds is based on the negative of the change in yield on 30-year U.S. government bonds because as yields rise, bond prices fall.
[3] Inflation Expectations are based on daily changes in the 5 year Treasury - TIPS (Treasury Inflation Protected Securities) spread.
[4] Oil volatility refers to WTI implied volatility.

reduced), which in turn decreases overall demand for oil leading to eventual downward pressure on oil futures prices. The reciprocal event also holds.

2.4. Supply

Despite the complexity behind oil price dynamics and forecasting, oil price is fundamentally derived by the classic interaction of supply and demand market forces. Therefore, it is fundamental to understand the structure and nature that define oil producing players, puzzle out their motivations, identify their strengths and weaknesses, and comprehend how they interact in order to serve global oil demand.

While we will further develop on each key oil producing country in section 4, the following analysis will provide a broad overview on important features that define the current oil supply force.

Oil producing countries can be split up in two main groups: OPEC and non-OPEC players.

On the one hand, OPEC (or Organization of Oil Producing Countries) represents an intragovernmental organization of 14 nations, most of which control the vast majority of proven oil reserves. OPEC's oil production accounts for c. 40% of global oil output and c. 60% of global oil exports. The organization actively manages oil prices by setting oil production targets (or quotas) within their member countries, which makes them a critical power driving oil price movements. Key players within this group are Persian Gulf countries such as Iran, Iraq and, most prominently, Saudi Arabia. It is important to remark Saudi Arabia's position of dominant supplier being able to drastically influence oil prices. Historical evidence proves this reality, which can be observed in Figure 7.

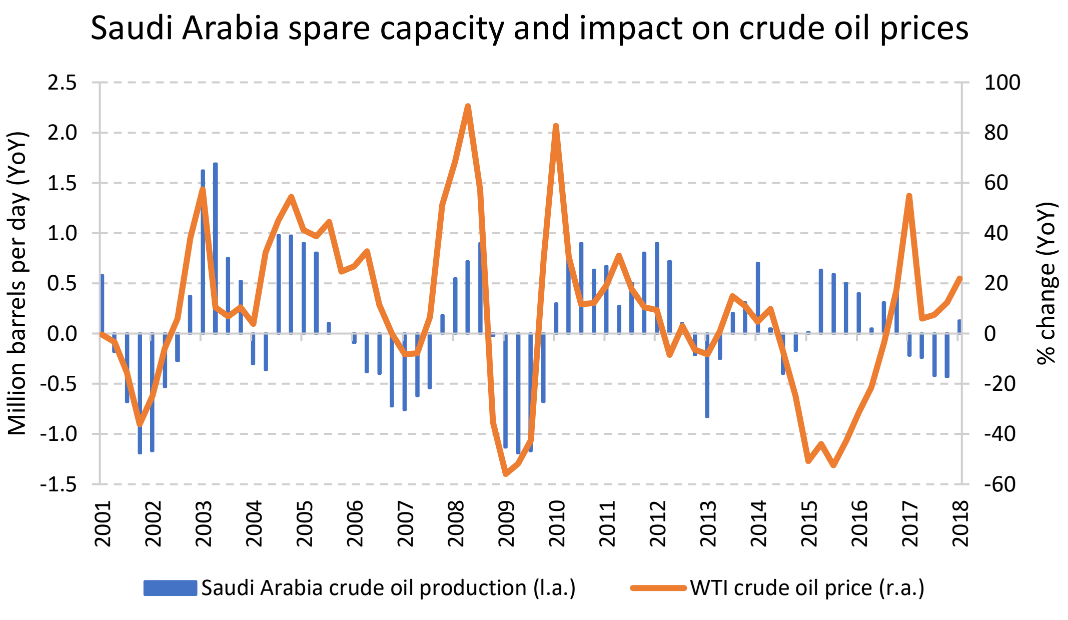

Figure 7. Saudi spare capacity and its impact on crude oil prices: changes in Saudi Arabia crude oil production versus WTI crude oil price. Source: U.S. Energy Information Administration.

On the other hand, non-OPEC key players are North America, Russia, and the North Sea. Non-OPEC production accounts for c. 60% of world oil output, a share that is expected to rise following U.S.'s shale oil boom and Canada's oil sands developments in Alberta. While OPEC's oil output is set by central coordination, non-OPEC supply comes as a result of many independent decisions made by unconnected oil producers, which abolishes their ability to set oil prices individually.

Moreover, significant motivation differences arise when evaluating the ownership nature of OPEC versus non-OPEC players.

Non-OPEC supply is primarily in control of IOCs (International or Investor-owned Oil Companies), whose interests are fundamentally to maximise shareholder value. These players make most of their investment decisions according to economic variables and, consequently, tend to respond more readily to changes strictly in market conditions.

Alternatively, OPEC oil production is in hands of NOCs (National Oil Companies). Government involvement make these player's goals much more complex and diverse, which may include providing employment, infrastructure, or revenue to their respective countries. Significant geopolitical interests influence their investment decisions in a broader sense, in many cases, to gain political and market power.

As mentioned earlier, OPEC has proven its ability to manage oil prices in the past. Three factors determine its effectiveness in driving oil markets:

- *Inelasticity of demand,* which is the unwillingness or inability of oil consumers to move away from oil
- *Non-OPEC competitiveness*, which expresses how competitive alternative oil producers become following changes in oil prices (generally in terms of bankability or breakeven point economics)
- *Non-OPEC flexibility*, which represents how efficiently alternative oil producers can supply oil to global oil markets (generally in terms of responsiveness and available national and international transportation infrastructure)

Non-OPEC oil production competitive power is relatively low compared to OPEC. While non-OPEC supplies come from areas with high finding and producing costs (such as deep-water offshore and unconventional resources), OPEC countries own the vast majority of lower cost conventional oil resources. This creates a cost disadvantage for non-OPEC players relative to OPEC members (see Figure 8).

Notwithstanding, non-OPEC's desire to gain certain oil independence have made them lead the way in developing revolutionary technology. Even if these innovative developments have resulted in high costs supplies, technological advancement and efficiency improvements are achieving significant reductions in unconventional resources' breakeven prices. In a competitive environment, as costs go down, certain downward pressure can be expected in oil prices in the long run.

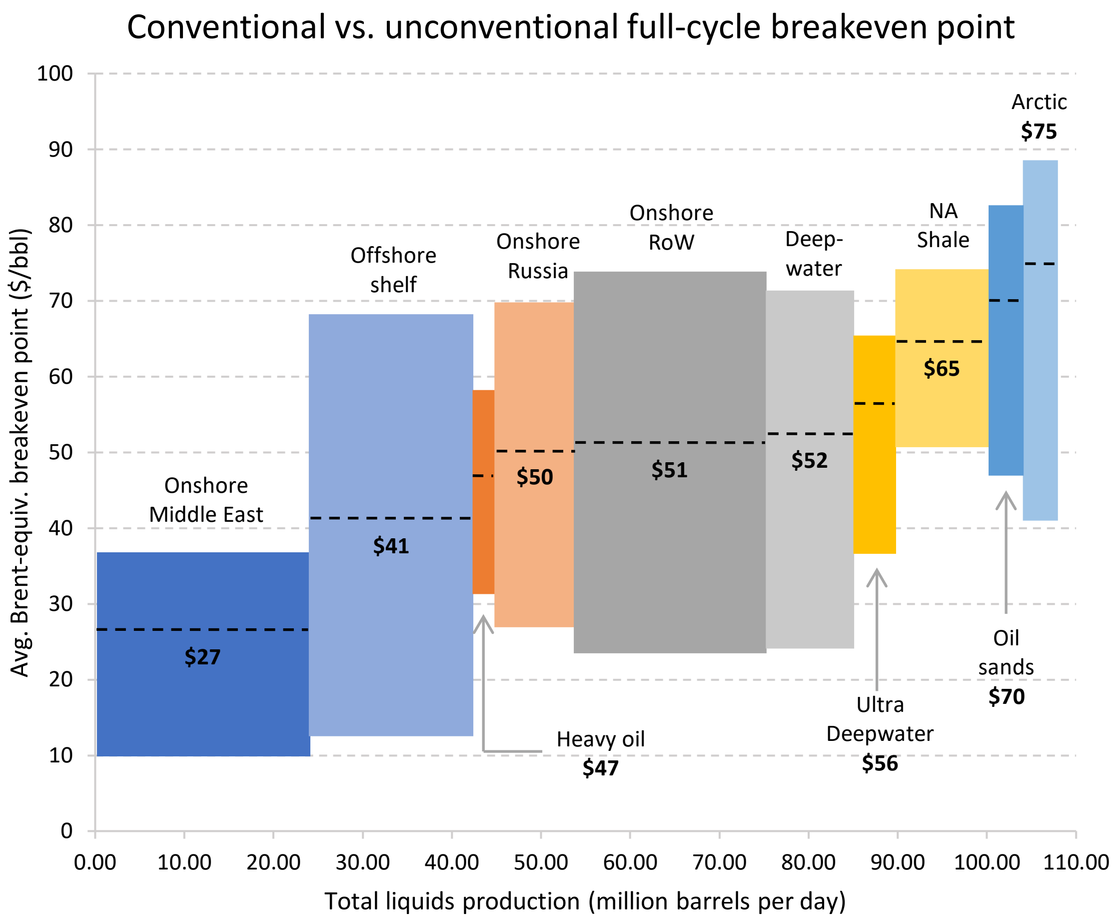

Figure 8. Conventional versus unconventional average Brent-equivalent full-cycle breakeven points. Source: Rystad Energy, Morgan Stanley Commodity Research estimates.

Two important concepts arise when defining how supply players interact in order to serve global oil demand: call on OPEC and spare capacity.

- *Call on OPEC*, which is the difference between oil demand and non-OPEC supply
- *Spare capacity*, as mentioned earlier, is the potential oil production that could be generated in a given point in time considering oil suppliers' production capacity. The EIA formally defines spare capacity in oil markets as: "*the volume of production that can be brought on within 30 days and sustained for at least 90 days*"

Non-OPEC producers will generally produce at or near full capacity, which limits their ability to build up spare capacity. This is logical bearing in mind that developing and maintaining idle spare production capacity is not cost-effective for IOCs, as their business model aims at maximising revenue by producing oil as long as oil's market price trades above the marginal cost of supplying an additional barrel of oil to the market.

Consequently, OPEC players generally maintain world's entire crude oil spare capacity, and are the ones expected to equilibrate demand and supply imbalances by using up their idle capacity in a supply disruption occurs. But then, and as a result of their derived relatively weak market power, non-OPEC producers have become price takers: they can only react to oil market prices rather than seek to alter them by managing their supplies.

Under this supply scheme, the level of the call on OPEC relative to available spare capacity is an indicator of tightness of the market and also reflects the extent to which OPEC is exerting upward pressure on prices (see Figure 9 and Figure 10).

Moreover, and other things being equal, lower levels of non-OPEC production can also influence crude oil prices as this reduces global oil supply, increases the call on OPEC, and decreases global available spare capacity. In actual fact, non-OPEC likelihood and ability to affect prices through supply shocks increases in parallel to call on OPEC's magnitude or, in other words, as the market becomes tighter.

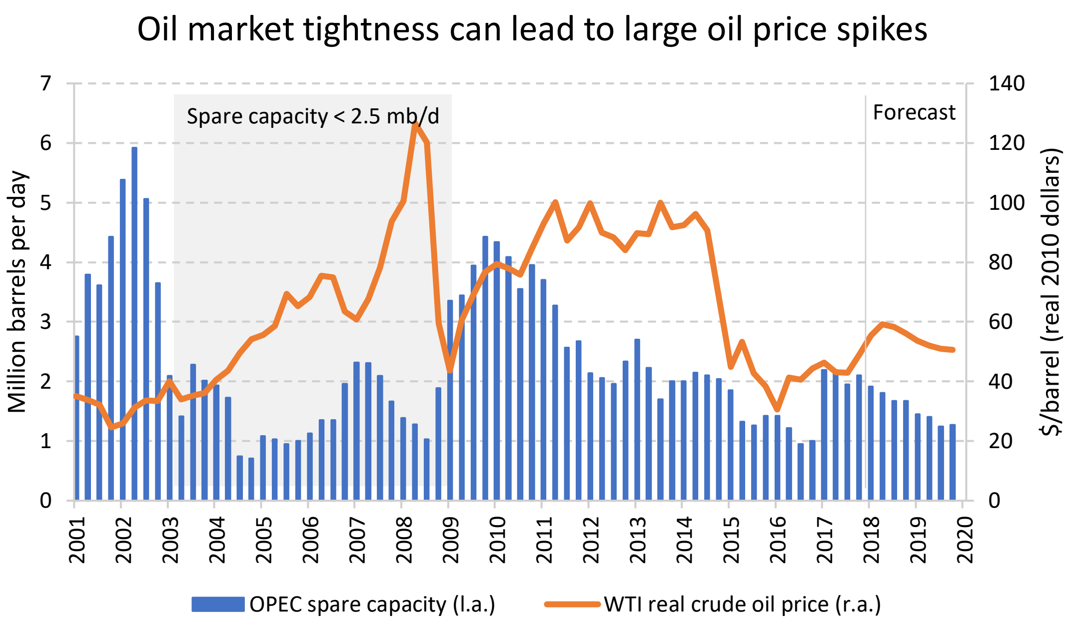

Figure 9. During 2003-2008, OPEC's spare production levels were low, limiting its ability to respond to demand and price increases: OPEC spare production capacity versus WTI real crude oil prices (GDP deflated). Source: U.S. Energy Information Administration.

World oil prices are not solely influenced by actual supply levels, but also by changes in anticipated future production. Despite OPEC's effort to effectively manage quotas, there are many occasions when member countries do not fully comply with the pre-established production targets. Unanticipated supply outages from OPEC and non-OPEC players can also occur due to motley reasons (see Figure 11).

The generally low responsiveness to quickly changing oil market environment has consequences on oil pricing, and the same holds true for production target adjustments, which take time to be implemented. All in all, these events drive oil prices by putting upward pressure on current levels.

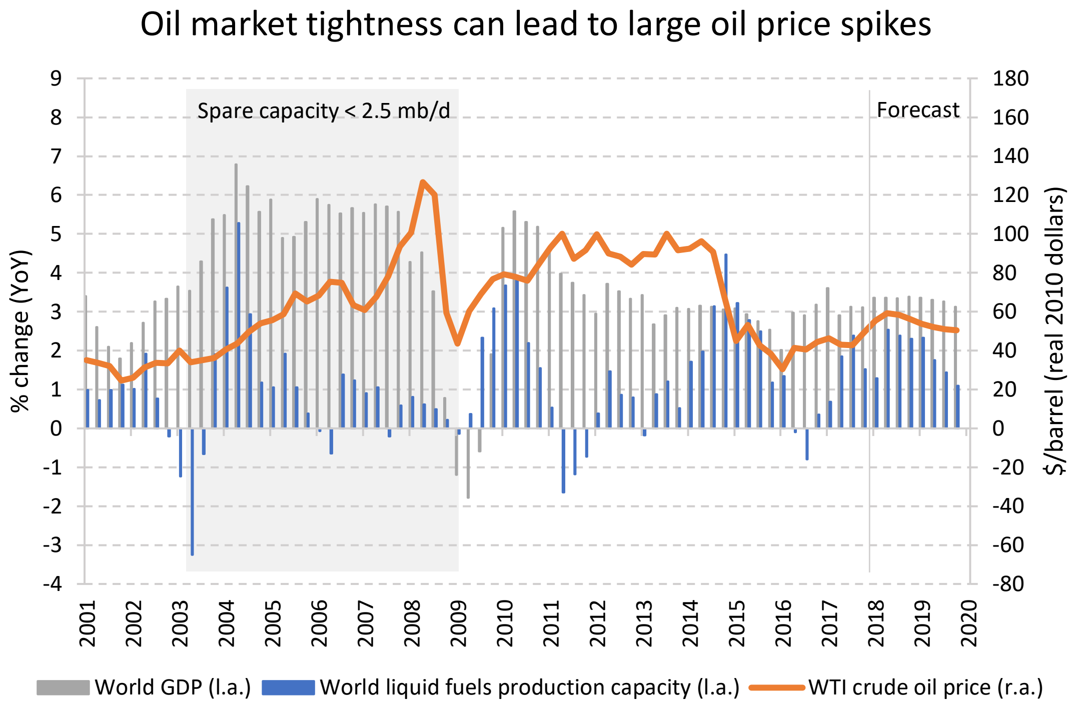

Figure 10. The years 2003-2008 experienced periods of very strong economic and oil demand growth, slow supply growth and tight spare capacity: changes in world liquid fuels production capacity, GDP and WTI crude oil prices. Source: U.S. Energy Information Administration.

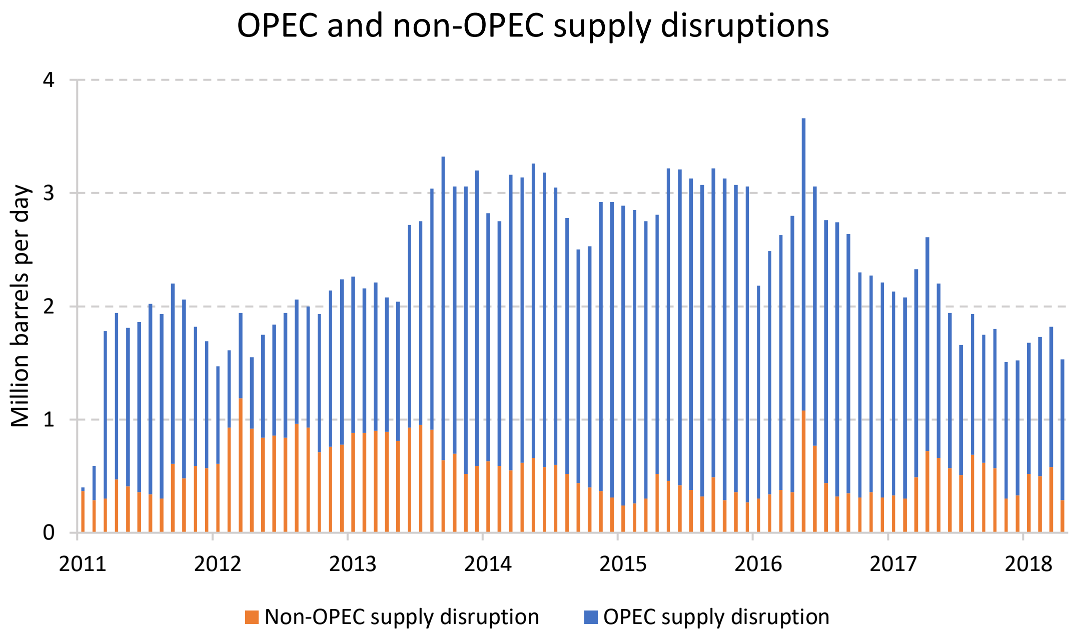

Figure 11. Unplanned supply disruptions tighten world oil markets and push prices higher: OPEC and non-OPEC supply disruptions. Source: U.S. Energy Information Administration.

Finally, we would also like to emphasize the circumstances under which the tightness of the market will severely affect oil prices. As seen in previous Figure 9, low levels of spare capacity before 2008 played a major role in driving prices over $120/bbl. However, an avid reader would have noticed that the same low levels of spare capacity from 2012 onwards (specially from 2015 to 2017) did not derive to the same result.

Figure 12 can shed some light and help us prove that certain structural break occurred after 2008 with respect to the relationship between oil prices and OPEC's spare capacity.

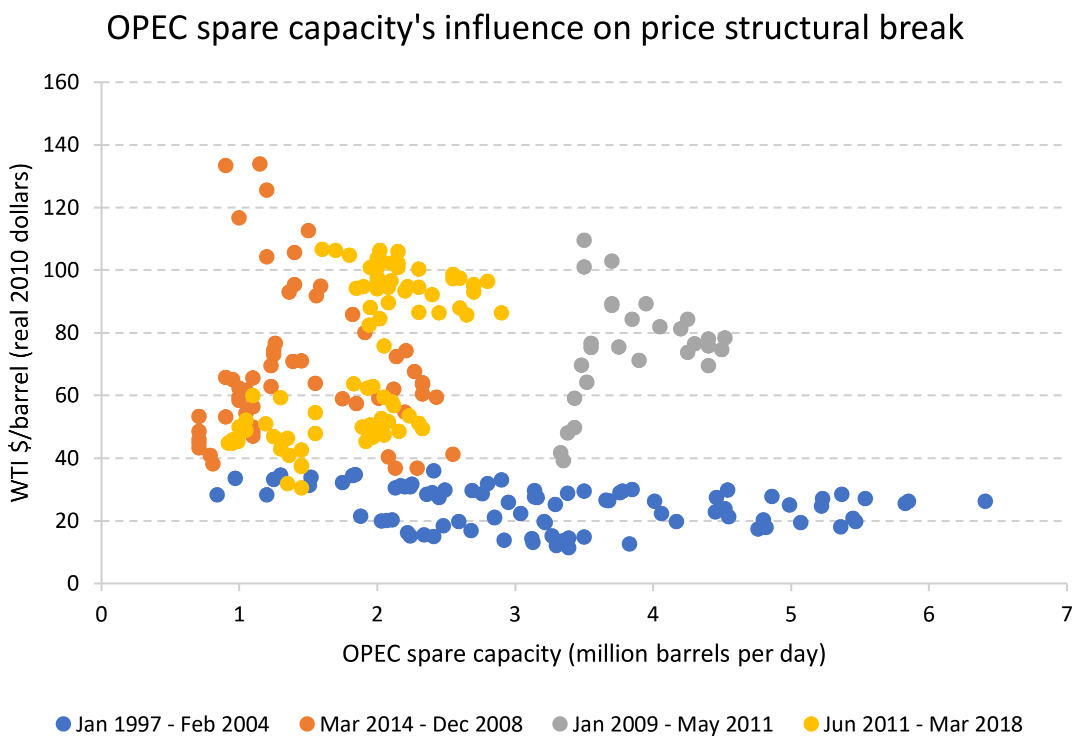

Figure 12. Structural break in OPEC spare capacity's influence on oil prices: WTI real spot price versus OPEC spare capacity. Source: U.S. Energy Information Administration.

The steep inverse relationship between both variables appears clear for the period between January 1997 to December 2008. However, the following periods show an unclear correlation between OPEC spare capacity and oil prices.

Apart from certain decrease in world GDP growth rates, the reason behind this sudden lack of causality comes from the existence of a third variable which makes oil markets less susceptible to market tightness: the existence of enough proprietary inventories piled up ready to be drawn down.

And here is where U.S. tight oil and other additional supply sources (such as Canada's oil sands in Alberta) come into play. As we will see in section 4.1.2, significant oil inventories have been built in the U.S. from 2012 onwards (ultimately causing the 2014 oil glut in Cushing). These high inventory levels help explain why the market has not been driven by OPEC's spare capacity in recent years (Till, 2015).

2.5. Demand

Now that we have described the nature of supply forces within oil markets, we must introduce the demand side in oil pricing.

Oil consuming countries can be split up in two main groups: OECD and non-OECD countries.

On the one hand, OECD (standing for Organization for Economic Co-operation and Development) is an intragovernmental economic organization of 35 nations, most of which represent the highest developed economies. Key players within this group are the U.S., Europe and Japan. OECD's oil consumption accounts for c. 53% of global oil demand. Historically, the U.S. has been characterized by its high dependence on oil, being the largest both importer and oil consuming country worldwide. On the other hand, non-OECD countries represent developing or emerging countries. Key players are China, India, and Russia.

Broadly speaking, three long term rules define expected global oil demand and, as a result, oil prices: increases in world population, increases in GDP (economic growth) and a decrease of energy intensity (or increase of energy efficiency). Multiple differences arise between OECD and non-OECD players with respect to these long-term rules.

While OECD oil demand is the largest, consumption growth is expected to be sluggish, so that they should not generate upward pressure in oil prices in the long run. On the contrary, non-OECD countries have lead the way on oil consumption thanks to their fast economic development. Rapid economic growth translates into rising commercial, manufacturing and transportation activities, which require energy to function (either as fuel or feedstock). The subsequent crude oil and petroleum products consumption increase generated significant upward pressure on oil prices, particularly during 2003 to 2008, before the great financial crisis (as we will see in section 3).

Asymmetric structural conditions of OECD and non-OECD countries economies also exist. While developing countries' economy relies more heavily on energy intensive industries (such as manufacturing), OECD nations have slowly evolved towards the tertiary sector development (services). All things being equal, economic growth in the latter countries won't generate the same impact on global oil consumption as non-OECD's economic development does.

Energy policy appears also as an important factor to bear in mind. Non-OECD countries subsidize oil prices to end-consumers to insulate its micro-economy from large oil price swings and sustain economic activity levels. This protectionism leads to a considerable increase in inelasticity of non-OECD demand, and further amplifies their key role in sustaining global oil prices. Conversely, periods of price increases have coincided with lower OECD consumption due to end-consumers bearing all the burden when prices rise.

Additionally, non-OECD countries are facing fast population growth, which adds to the global increase in oil consumption and further helps explain why the EIA projects nearly all oil consumption growth stemming from these countries in the foreseeable future.

Technological disruption can have significant effects on oil consumption, and will affect OECD countries first. This is evidenced by the fact that, not only are these innovative technologies being tested and developed at OECD countries (i.e. self-driving cars), but also have the potential to higher vehicle ownership per capita.

3. Historical oil price evolution analysis

In this section, we will first analyse the different events that led to structural breaks in oil price behaviour in the past. Then, we will take a quick look at the main historical events that drove the movement of oil prices under OPEC's cartel supremacy.

3.1. Breaks in oil market structure

Most studies regarding oil price behaviour following relevant geopolitical events, supply or demand disruptions, or major economic downturns, have been focused on the 1970s onwards due to the existence of high-frequency data. However, very interesting conclusions can be reached by taking a longer-term view of oil prices historical evolution.

A study published in 2010 by the National Bureau of Economic Research, "The Three Epochs of Oil", analyses oil price persistence and volatility from 1861 to 2009 and formerly shows that real oil price reaction to oil market shocks changes significantly, not depending on whether if it originated in the demand or supply side, but rather because of the existence of a key force or player with the power to limit access to supply to oil consumers.

They found that periods of intense industrialization (with persistent demand growth shocks) along with uncertainty regarding access to supply coincided with periods of extremely high persistence, high oil market volatility, and generally high prices. On the contrary, whenever this key prominent supply settler was missing, then the oil market showed remarkably high flexibility, significantly less volatility, and generally lower oil prices.

Finally, the study remarks that, although not usual, changes in the oil industry structure can happen and are fundamental to identify when trying to predict oil price's most likely evolution, as they lead to structural breaks in oil price behaviour.

This is relevant to bear in mind in our case, given that this project aims to predict oil prices under the new oil order, which has the potential to bring a change in today's world oil industry structure. Consequently, it will be fundamental to determine whether if OPEC's supremacy in setting significant supply limits is under real threat in both the shorter or longer term.

The aforementioned study found three clearly defined periods with considerable different oil price evolution behaviour (see Figure 13). The estimated change points signify a relevant change in market structure and happened around 1877-8 and 1972-3.

The first change point, around 1877-8, was a consequence of the end of rail transport oligopoly following the insurgence of long-distance pipeline distribution systems in an environment of rapidly growing demand. By the time, most of the commercial oil production was located in the Oil Regions of northern Pennsylvania and transport was carried out by three distinct railroads. Railroad operators acted as an oligopoly, while oil producers and refiners experienced considerable rivalry between players. To illustrate these facts, the rail transport "open fare" from the Oil Regions to New York amounted $1.40 per barrel in 1877, representing a 58% of crude oil price at the time. Margins for railroad firms were high considering an estimated cost per barrel of $0.40, which prove their market power to fix prices and, consequently, restrict supply.

Oil producers ended rail transport monopoly with the construction of Tidewater, the first long-distance pipeline, followed by other pipelines built by refiners to avoid a new transport monopoly from oil producers' side. Having invested in their own infrastructure, and due to considerably lower transportation costs by pipeline (c. $0.12 to $0.20 per barrel), both refiners and operators' strategy was to sell as much as possible to recoup initial capital expenditures, which ended the first period of restricted supply.

These events happened amidst highly growing oil demand both in the U.S. and abroad. In actual fact, from 1860 onwards, the U.S. manufacturing output increased by a factor of three and eight in 1880 and 1900, respectively.

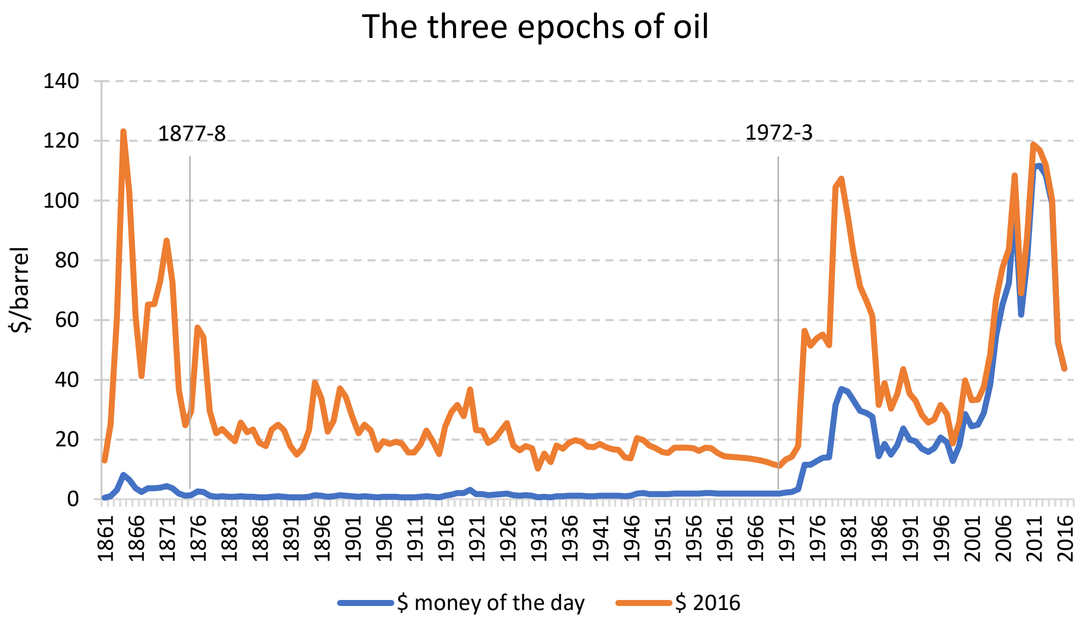

Figure 13. The three epochs of oil, crude oil prices historical evolution from 1861 to 2016 in dollars per barrel. 1861-1944 represent US average, 1945-1983 represent Arabian Light posted at Ras Tanura, and 1984-2016 are Brent dated. Series $2016 has been deflated using the Consumer Price Index for the US. Source: BP.

During the middle period, after the first and before the second change points, the inexistence of a controller of supply and spare capacity caused oil markets volatility, persistence and prices to decrease notably. Note that this was despite very large supply and demand shocks suffered worldwide in the meantime: two world wars, the U.S. and western Europe's steep post-war industrial growth, and periodic crisis in the Middle East.

The second change point, around 1972-3, brought OPEC's prominence into play once the U.S. supply peaked in 1970, again against a backdrop of ever-rising demand. The U.S.

production peak meant that excess capacity was fully controlled by the Middle East, which gave these players a similar power to that observed in the first period by railroad operators: the ability to charge higher prices by limiting supply to oil consumers.

Moreover, the Gulf experienced a significant increase of state participation (ownership transfer) in their easily-exploitable oil reserves in 1972. This transfer of power to governments meant that oil production would be driven to offer financial and strategic support to their state programs and budgets, with their objectives not necessarily aligned with global oil market's goals.

During this period, demand was mainly driven by East Asia's rapid industrialization. As examples, Japan saw its GDP per capita three-fold from 1960 to 1980 and China, from 1970 to 2000, saw its industrial output multiply by a factor of 21.

Hence, the features characterizing the oil market environment that prevailed in the U.S. a century ago, are now governing oil markets in a much broader scope: the combination of relatively high demand growth (at least at the beginning of the last period) and the presence of an oil access restrictor.

As the National Bureau of Economic Research's study puts it: *"The persistence in the price of oil can be reasonably expected to continue as long as demand shocks are persistent, or until the ability of OPEC to effectively limit access to supplies no longer exists, either due to an independent source of oil, or to an alternative source of energy"* (Dvir & Rogoff, 2010).

3.2. Historical oil disruptions

The analysis of oil price's historical evolution under OPEC's supremacy (or the third period according to the first section) can be useful to uncover not only oil market's behaviour to certain supply or demand shocks, but also key player's reaction to these disruptions.

The most relevant demand or supply shocks have been illustrated in Figure 14. We can divide oil price shocks in two main groups depending on whether if they provoke a rise or a fall in oil prices tendency.

In green, we can see the events that put downward pressure on real oil prices. It is interesting to observe how there is a clear tendency to see abrupt free falls of oil prices when these events take place. Generally, they represent non-supply shocks in a sense that they come from a persistent decrease of oil demand from consumers (rather than from oil supply shortages).

Moreover, as can be observed from the graph, these demand-driven events mostly occur once oil prices have reached significant high levels, which contributes or even leads to a temporary economic recession (led by OECD countries most of the times as explained in section 2) followed by an industrial activity slowdown, which prompts oil demand to fall.

Several exceptions exist, such as Saudi Arabia's price war in 1985 and 2014, which are examples of supply-side disruptions. In these cases, Saudi Arabia abandoned its role of swing producer in an attempt to regain market share from competitors by oversupplying oil markets.

It is important to highlight Saudi Arabia's historical power as a dominant producer. In a similar way to OPEC in global oil markets, Saudi Arabia has had the power to influence OPECs' actions in its best interests.

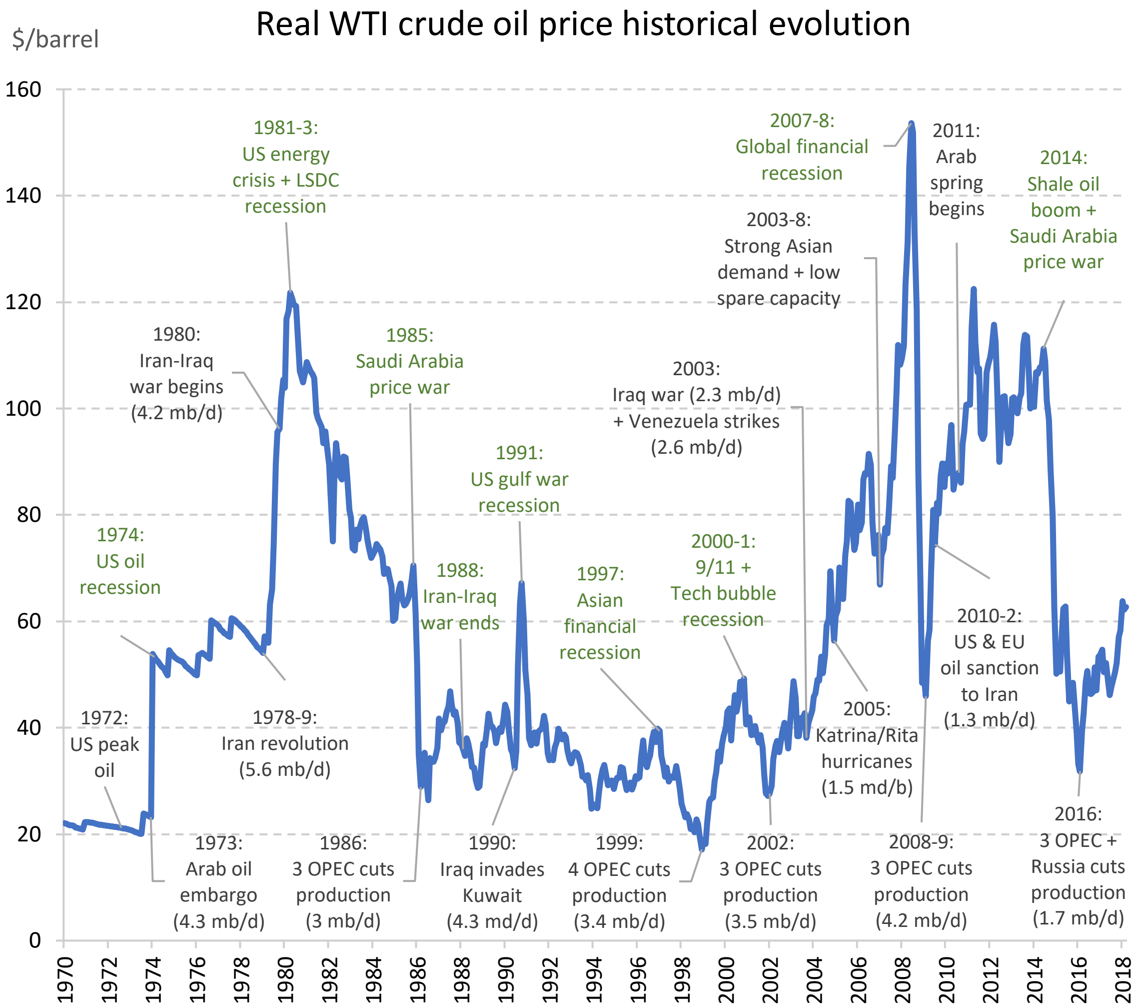

Figure 14. Real West Texas Intermediate crude oil price historical evolution, from 1970 to 2018 in dollars per barrel. Nominal WTI prices have been deflated using Consumer Price Index for the US, obtaining prices rebased to 2018. Source: Federal Reserve Bank of St. Louis Economic Data.

In black, we can see the events that put upward pressure on real oil prices. We observe a clear likelihood of supply disruptions leading to abrupt reversals of oil price tendency, while persistent positive demand shocks would lead to smoothly increasing oil prices (which is logical considering the reduced speed at which industrialization and GDP growth occurs).

The most common supply shocks are of two different natures: either they are a consequence of a geopolitical conflict (such as a war) or they come as a premeditated result of a supply settler (in this case OPEC) to restore plunging oil prices. Either way, oil market's access to certain amount of supply is suddenly restricted, which leads to a quick increase of oil prices.

In actual fact, there are studies that prove that supply disruptions coming from OPEC member countries or in the Persian Gulf (prominently Saudi Arabia) have unusually large effects on oil prices: a 10% cut in world oil production arising from abrupt and large monthly disruptions from OPEC members generally lead to a 35-43% increase in real oil prices (Huntington, 2018).

In either case, spare capacity appears as a fundamental factor driving oil prices as mentioned in the second section. When spare capacity decreases below a certain threshold, oil markets become fragile and events that indicate a possible supply disruption or shortage lead to significant oil price spikes. An example of this "fear premium" that oil participants incorporate into oil markets was seen in 2008, when OPEC's spare capacity reached one million barrels per day at the same time that Iran was testing missiles towards Israel (rising concerns of supply disruption), which sent oil prices over $125/bbl.

4. Current Situation in Oil Markets

4.1. Supply

4.1.1. OPEC

OPEC was founded in 1960 and has proven to be the most influential non-corporate organization in oil markets. The creation of the organization, during a wave of nationalization of crude oil producing companies of International Oil Companies, represents government intervention at a global scale with the objective to shift bargaining power to the producing countries and away from international oil companies.

OPEC's organization and objectives are focused on the management of oil prices. As stated in its statute, the principal aim of the Organization shall be the coordination and unification of the petroleum policies of Member Countries and the determination of the best means for safeguarding their interests, individually and collectively. But it also takes into account other stakeholders, as it also seeks to secure an efficient, economic and regular supply of petroleum to consumers, and a fair return on capital to those investing in the petroleum industry. To do so, the organization shall devise ways and means of ensuring the stabilization of prices in international oil markets with a view to eliminating harmful and unnecessary fluctuations.

As of 2018, OPEC members are 14: Algeria, Angola, Ecuador, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, Unit Arab Emirates and Venezuela.

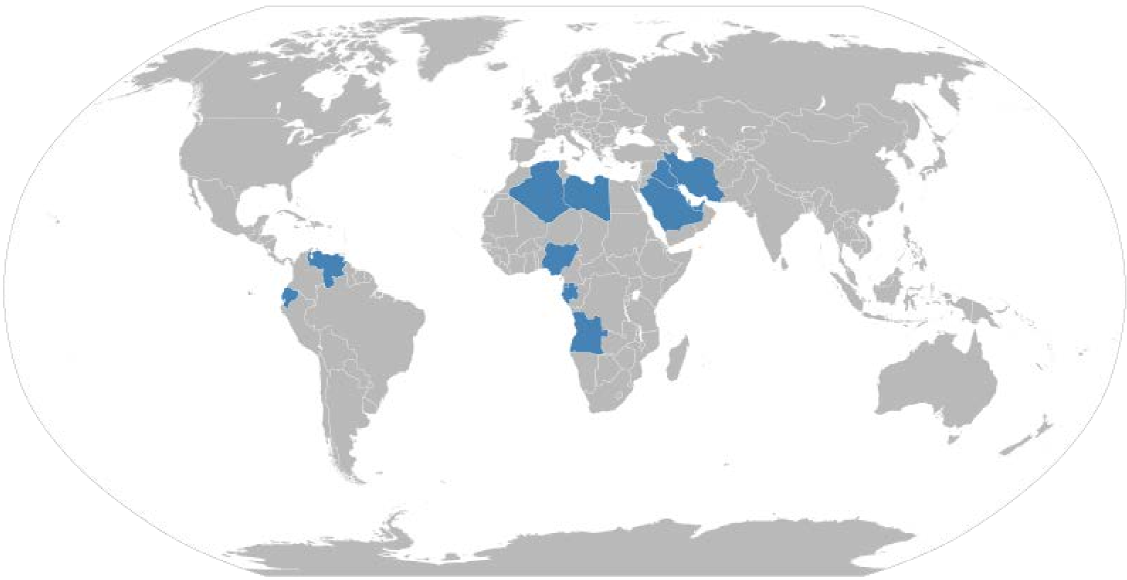

Figure 15. Current OPEC members. Source: OPEC

As an organization, the power OPEC stems essentially from the reserves it has. Indeed, OPEC has proven reserves of 1220.5 thousand million barrels, which represent 71.5% of the total global reserves (BP, 2017). Higher proven reserves also mean higher production, and this has been the historical trend as it can be seen in Figure 16.

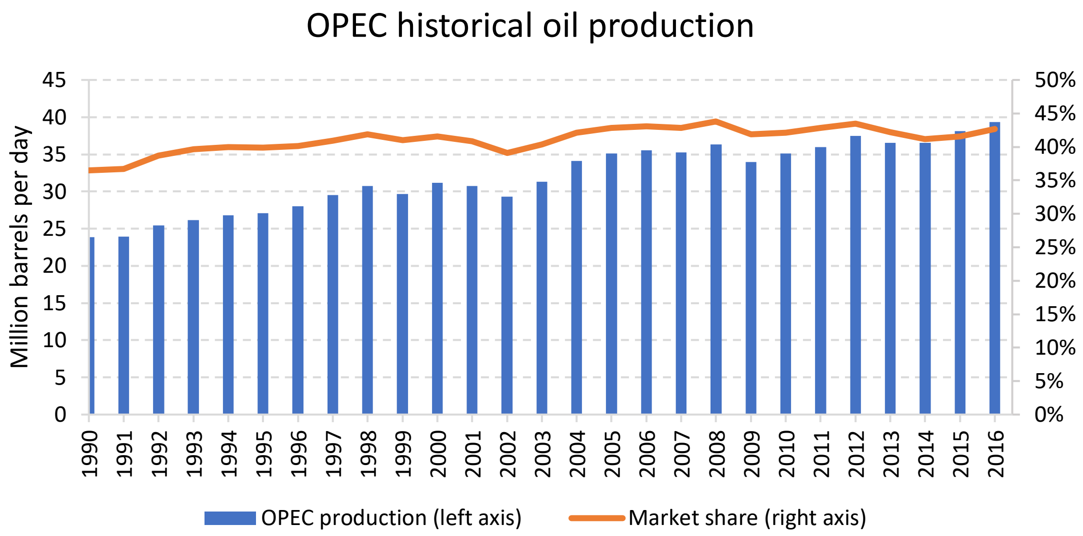

Figure 16. OPEC historical oil production. Source: BP.

Interpretation of the above figure leaves little room to doubt. Historically OPEC has been adapting its production to demand growth in order to keep a market share above 40%, which has been fairly stable over time. The small fluctuations around these figures also show us that the power OPEC can exert on the market does not only come from its larger reserves, but also from its ability to shift production in specific periods in order to smooth temporary shocks. Indeed, if OPEC were able to face permanent shocks, the variations in its market share would be more important.

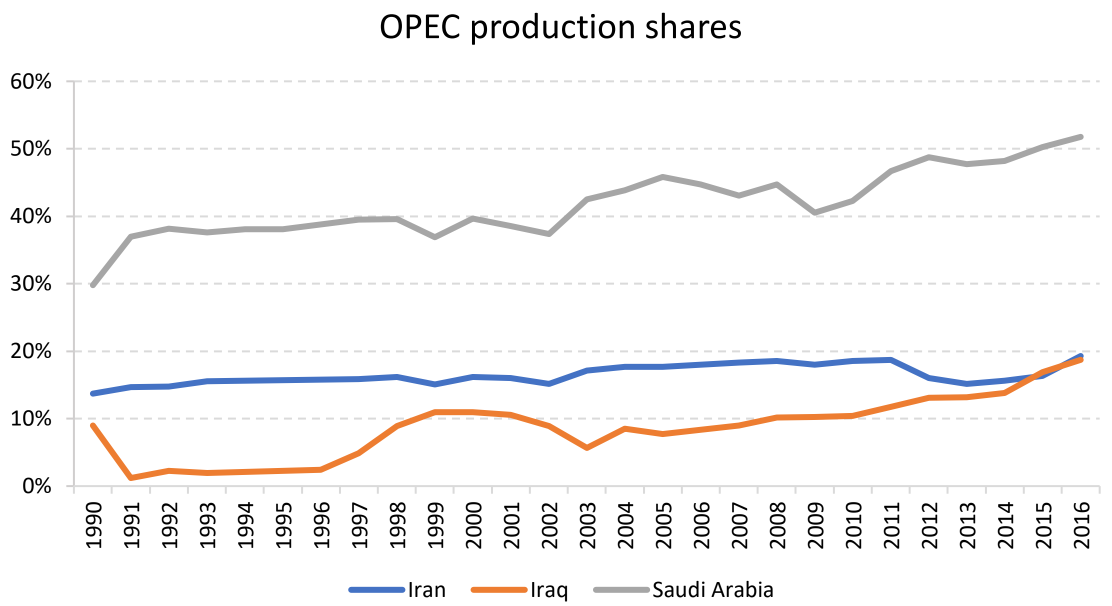

Figure 17. OPEC production shares. Source: BP.

Even though the OPEC is treated as an organization, it is important to know who are the main players behind. Based on the share of OPEC production shown in Figure 17, Saudi Arabia followed by Iraq and Iran are the most prominent producers within the organization. Other countries such as the United Arab Emirates are leaving aside mainly due to its close diplomatic relations with Saudi Arabia. Indeed, the way OPEC operates and takes its decisions is very complex and obscure. The variety of factors behind and the political and social differences among its members lead us to question the way the organization works and whether it can be considered a cartel.

4.1.1.1. OPEC: is it a cartel?

A cartel is defined as a group of firms that gets together to make output and price decisions. Even if described by its members as a market stabilization force, its main goals according to OPEC's website seem the ones of a cartel ("coordinate and unify the petroleum policies of its Member Countries and ensure the stabilization of oil markets in order to secure [⋯] a steady income to producers"). Nevertheless, strictly speaking, OPEC cannot be considered a perfect cartel, as it does not control all the volumes of crude oil. Moreover, after analysing its decisions, there is no consensus among academics on the economic nature of the organization, and it should not be regarded as a perfect colluding cartel.

To control oil supply, OPEC has a quota system in which each member is assigned a production level (measured in thousand barrels per day) for the coming months depending on individual reserves. From a theoretical point of view, quotas should be allocated so that marginal revenues are the same for all members (Schmalensee, 1987). This implies that least efficient countries, such as Venezuela, would have a smaller production than more efficient members like Saudi Arabia. When full marginal costs of the extraction are in line for both countries, production shares will also be in line. Notwithstanding, what really happens is the opposite: less efficient countries are given unproportionally larger quotas as if to bribe their participation in the cartel (Okullo & Reynès, 2016).

Leaving aside the purely theoretical issues of a cartel, OPEC faces constantly two main problems. First of all, as stated before, quotas are assigned depending on individual reserves, which generates an incentive for members to overstate them in order to have a larger quota. Secondly, and more importantly, the main challenge of OPEC since its inception has been enforcement of quotas: oil production is difficult to track and producing more than the established quota is a common practice, and is also usually tolerated by the organization. By establishing quotas and controlling the flow of crude oil to the market, OPEC seeks to exert control on price. This generates an incentive for countries under budgetary pressure to take advantage of higher prices by producing more than the established without assuming a big risk as a slightly higher supply will not have an important impact on market prices. Indeed, from 1993 to 2005, non-compliance was common among members as the quota was on average over-produced by 6.7% (Ghodussi, Nili, & Rastad, 2017). This situation, which is the main danger for OPEC control of the market, is known as tit-for-tat strategy in game theory: if one member deviates from its quota to gain higher profits in the short-term, the rest of the members will also abandon the collusive strategy and long-term profits of the cartel will be significantly reduced.

The question now is what are the motivations of the different members to produce above the established quota even if it is known that it is detrimental in the long-term. First, it is important to note that OPEC is not a common cartel only driven by profit maximization: it is an intergovernmental organization run by politicians having both economic and political ambitions, which is definitely way more complex. This implies that political arguments play an important role when setting individual quotas. Indeed, OPEC members try to find an equilibrium between production limits, which are set collectively, and internal policies to maximize welfare, which are discussed internally. These measures are not independent at all: some countries rely heavily on crude oil to balance their budgets, and in all of them downstream products are subsidized. This leads us to an important conclusion: OPEC is a political organization essentially defined by the heterogeneity of its members. This heterogeneity is not exclusively relative to the reserves or the quality of the crude oil, it also depends on the macroeconomic and geopolitical situation of each member. Therefore, to further understand how OPEC works and the impact it has as a player in the crude oil market, which can be seen as a game, the situation of the most important members will be analysed and discussed.

In the next sections, we will analyse the main drivers shaping the oil policy of the largest three members of OPEC, which are Saudi Arabia, Iran, and Iraq. As we will see, these three countries face different internal challenges, but given the importance of oil for their economy as a group, conflicts take a regional dimension, and therefore, the social and political situation of the region as a whole, as well as the ongoing geopolitical relations, are also important when setting the output policy.

4.1.1.2. The political situation following the Arab Spring

Before analysing the situation of the main players from OPEC, we need to understand the current political situation. This is essentially defined by the ripples of the Arab Spring that started seven years ago, and these uprisings, besides the political and social changes, brought important implications for the oil market.

The Arab Spring started with the Jasmine Revolution, which was initially ignited by the protests following the self-immolation of a Tunisian vegetable seller. Protests erupted likewise in Egypt, Yemen, Lebanon, Palestine, Libya, and Syria. Leaving aside the description of the conflicts, we can say that the main effects of the Arab Spring were:

- Change in many regimes overthrowing long-term leaders, particularly in Tunisia, Egypt, Libya, and Yemen. This situation led to the birth of many transitional governments that were again contested

- Civil wars. Especially in Syria, where the conflict is far from being resolved and threatens to expand to neighbours like Iraq where the political system is not strong enough
- Sabotage against energy infrastructure. Recently, a surge of terrorist and politically motivated attacks against energy infrastructure has taken place. Algeria and Yemen were particularly affected by these attacks

Even if this region of the world has suffered many conflicts in recent history, and therefore disruptions in the oil supply, Arab Springs are a brand new event as they shook the political, economic and social foundations. Even if Gulf members have remained relatively unaffected by the conflicts, the implications on the oil market have impacted every producer of the region. These effects will be analysed separately: first, the short-term implications, and then the long-term consequences which are key to drill down in the players' policies.

4.1.1.2.1. Short-term effects of the Arab Springs

The main impact of the Arab Spring has been the disruption in the oil supply. Notwithstanding, as the uprisings affected in different ways different regimes, some countries oil supply chain were more impacted than others. In that sense, the most significant impact took place in Libya, where crude production was reduced to virtually zero during its civil war.

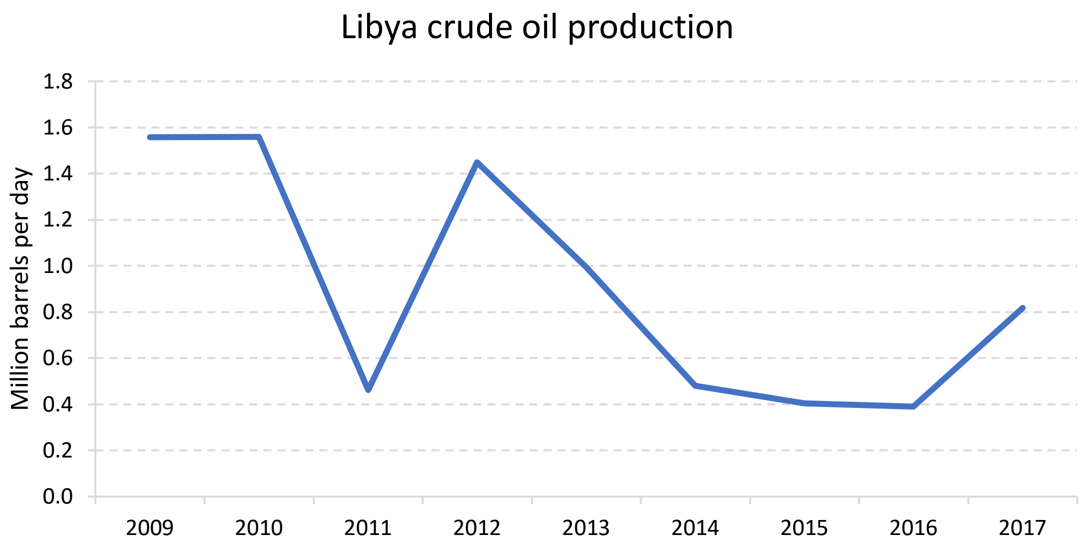

Figure 18. Libya crude oil production. Source: OPEC based on secondary sources.

The civil war in Syria also disrupted its oil production. Even if a minor producer, it is important to mention this conflict as it also affected Iraq. Tensions led to terrorist attacks on Iraqi oil infrastructure.

All these events generated panic in the markets: oil price was expected to surge, but despite alarmism on oil disruptions, prices did not keep rising due to three main reasons. First, the spare capacity of some OPEC members (especially Saudi Arabia, which will be further analysed later) compensated part of the losses, second, the growth of US shale oil kept the market well supplied, and finally, lower demand growth during economic recovery mitigated the impact of the disruptions.

4.1.1.2.2. Long-term effects of the Arab Springs

Leaving aside the short-term effects, which are interesting to know, for the purpose of this thesis it is key to understand the long-term impacts.

The fear of social revolts drove the monarchies of the Gulf to increase the social spending towards areas such as housing, employment creation, unemployment benefits, subsidies or higher wages for government workers. Funding these expenditures means that oil exporters have become even more dependent on oil revenues; now, higher oil price is required to balance the budget. This does not mean that OPEC members will defend prices and prevent them from dropping with aggressive output policies. Indeed, treating the break-even point as a floor is overly simplistic. Moreover, the budget does not need to be balanced every single year, and the low indebtedness and large reserves that important members such as Saudi Arabia have allowed them to have a relieved position. The important point to grasp from higher social spending is that it puts more pressure on the maximization of revenues coming from oil exports. This situation has also ripples in the long-term depletion of the reserves: higher social spending and the fear of the ruling class to lose power in the close future may change the investment and exploitation policy in favour of higher revenues in the short-term at the expense of future generations.

As stated before, part of the social spending goes to subsidies to fuel consumption in oil-producing countries. Despite the effects such measure can have in the short-term, such as the maintenance of social stability, this situation distorts market signals and leads to an inefficient allocation of resources. These subsidies can have perverse effects in the future as they encourage non-efficient consumption: there is no incentive for innovation or for a change towards cleaner energies or less energy-intensive industries. The main result of this policy is the widening of the gap between supply and demand.

In a nutshell, the Arab uprisings have caused deep political and social changes in some countries like Libya and Syria, which also saw their energy sector hurt by the turmoil. As pointed out before, these disruptions in the oil supply chain did not have a visible impact in the oil market, as seemingly unaffected countries, especially Gulf monarchies, were able to compensate losses with its spare capacity. Even if no social turmoil took place in these countries, the fear of contagion has been responsible for changes in social spending policies and consequently in output policies.

4.1.1.3. Main OPEC Players

In this section, we will analyse the three biggest OPEC players. As pointed out earlier, both based on their outputs and their political relations, these are Saudi Arabia, Iran, and Iraq. The study conducted includes a more technical examination of the available reserves, transportation systems and trade partners, and a second part we will dig into its oil policy.

4.1.1.3.1. Saudi Arabia

Why analysing Saudi Arabia as an important player in the oil trade? Saudi Arabia has the second largest oil reserve base in the world, and it is all under the centralized control of national company Saudi Aramco. This means that response to any market incentive will be more effective than the one of any other player with fragmented production. Moreover, Saudi Arabia accounts for a large share of global oil production and crude oil trade. Finally, it is the only country that has an official policy of maintaining spare capacity that can be utilized within a relatively short period of time.

A. Reserves, transportation and trade partners

The bulk of Saudi Arabia's oil reserves are located in the country's east and North Eastern provinces, especially concentrated in nine giant fields: Ghawar, Safaniya, Khurais, Manifa, Shaybah, Qatif, Khursaniyah, Zuluf, and Abqaiq. Oil exploration and production are conducted by national oil company Saudi Aramco, which estimates total proven reserves of 266.6bn bbl (BP, 2017), resulting in a reserve to production ratio of approximately 60 years. As shown in Figure 19, Saudi Arabia has accommodated its production to world demand, so that both variables have always followed the same trend. This ability to adapt production to growth in demand and to temporary shocks is what explains the historically dominant position of the kingdom in the world oil market.

Another key variable to analyse is the variety of crudes in Saudi Arabia. Crudes are classified based on two main variables which are its API gravity and the Sulphur content. Light oils (higher API gravity or lower density) and sweet oils (low Sulphur content) are priced higher as their refining processes are easier. Saudi Arabia presents a broad variety of crudes covering the whole spectrum: from super light and sweet crudes such as Arab Super Light, with 50.1º and 0.09% of Sulphur, to heavy oils such as Saudi Arabia Heavy with 27º of API gravity. On top of this variety that allows the kingdom to serve any refinery, Saudi Arabia has one of the lowest (if not the lowest) lifting costs of the industry. This is mainly due to the shallow position of the crude and the size of its fields. Moreover, political stability and efficient transportation systems reduce other costs.

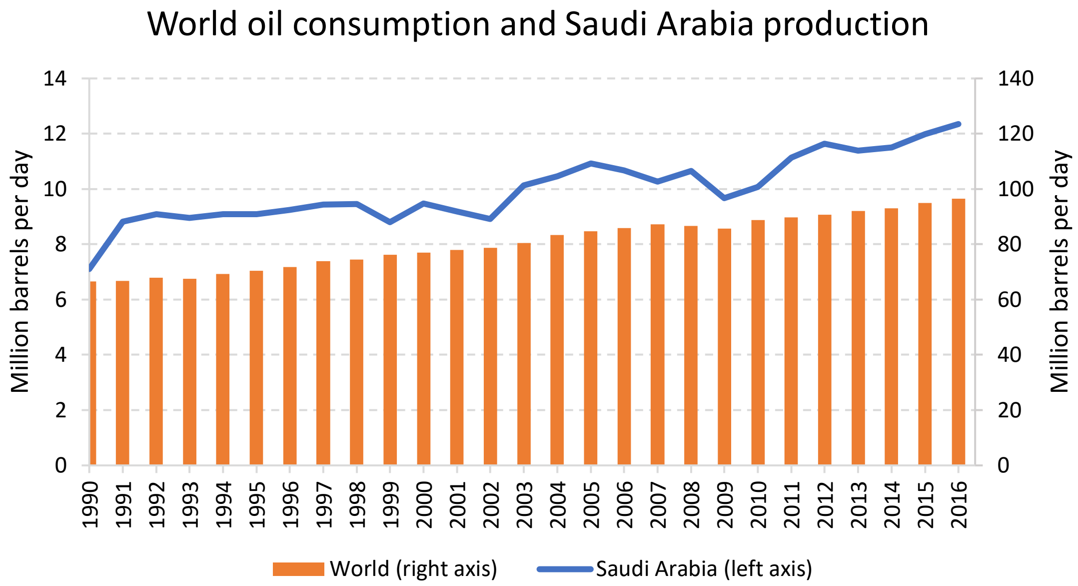

Figure 19. World oil consumption and Saudi Arabia production (thousands of barrels per day). Source: BP.

$	
Gross taxes	0.00
Capital spending	3.50
Production costs	3.00
Transportation and administrative costs	2.49
Total[5]	**8.99**

Table 1 - Cost of producing a barrel of oil in Saudi Arabia. Source: The Wall Street Journal (2016) based on secondary sources.

Next step is to know the systems the kingdom has for midstream operations, that is, how oil is transported from wells to refineries. We will essentially focus on crude oil exports. A very important feature to highlight is the geographic position of the kingdom: near to of the biggest chokepoints. These are the strait of Hormuz, linking the Persian Gulf and the Gulf of Oman and the Arabian Sea, and Bab-el-Mandeb, connecting the Red Sea and the Gulf of Aden. The first one accounted for 18.5 million b/d of crude oil and other liquids during 2016, whereas through the latter, 4.8 million b/d flowed during the same period (U.S. Energy Information Administration, 2017).

These two waterways are not only key in the crude oil market, but for the global maritime transportation in general as they connect the Persian Gulf, the Indian Ocean, and the Mediterranean Sea. To serve them, Saudi Arabia relies heavily on two ports: Ras Tanura for the Persian Gulf, which is the main port of the kingdom, while the King Fahad Industrial Port in Yanbu serves the Red Sea. Last but not least, it is important to highlight that Saudi Aramco operates more than 12,000 miles of pipelines linking production

[5] According to the same source, average production cost of a barrel of oil stands between $20 and $25

plants, refineries, consumption centres and export terminals. Among them, the main pipelines if the Petroline, connecting East and West bypassing the Strait of Hormuz, but lacking enough capacity to substitute the waterway in case it is choked. Figure 20 gathers all the relevant information related to production and transportation systems.

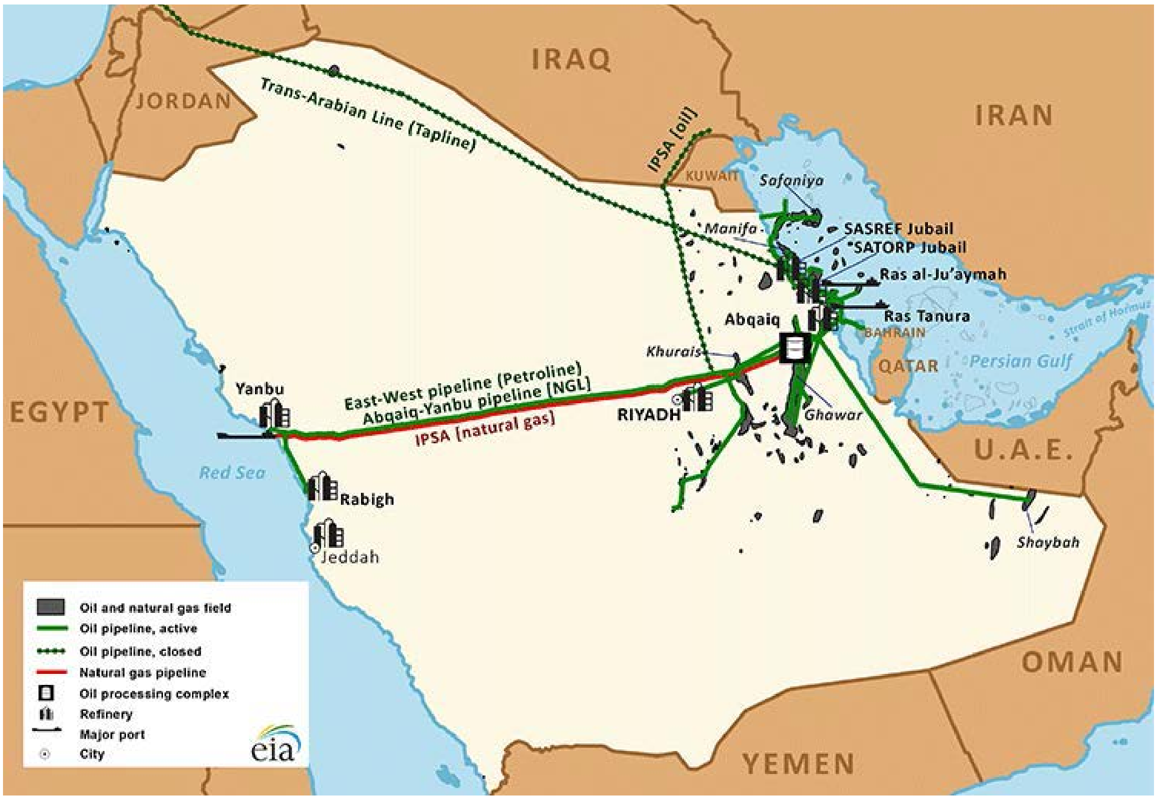

Figure 20. Saudi Arabia oil infrastructure. Source: U.S. Energy Information Administration (2017).

The last thing to analyse is trade partners. A major trend can be identified in the last years. Indeed, a shift towards Asian clients has taken place, as it can be seen in Figure 21. This can be seen as a focus on the major growth market in an environment essentially driven by competition for market share. Indeed, this shift towards Asian customers was the trend followed by almost every crude oil producer after the sanctions imposed to Iran. Every single producer took advantage of the absence of Iranian crude in the markets to gain market share in these regions.

However, this focus on emerging markets can also be interpreted as part of a broader strategy that was notably favoured by the international sanctions, which are nothing but a temporary situation. This is of course mainly justified by the expected growing demand for countries like China and India. In order to define a better strategy that ensures direct access to the final consumer regardless of market prices, Saudi Aramco has started acquiring stakes of refineries and refinery projects in the United States and in Asia. For instance, Saudi Aramco acquired recently a 50% stake in an Indian refinery to ensure it remains a steady customer (ET Bureau, 2018). Under this new scenario, we can say that the kingdom controls the whole supply chain by developing its downstream business in the fastest growing regions of the world, and hence ensures a steady demand for its crude.

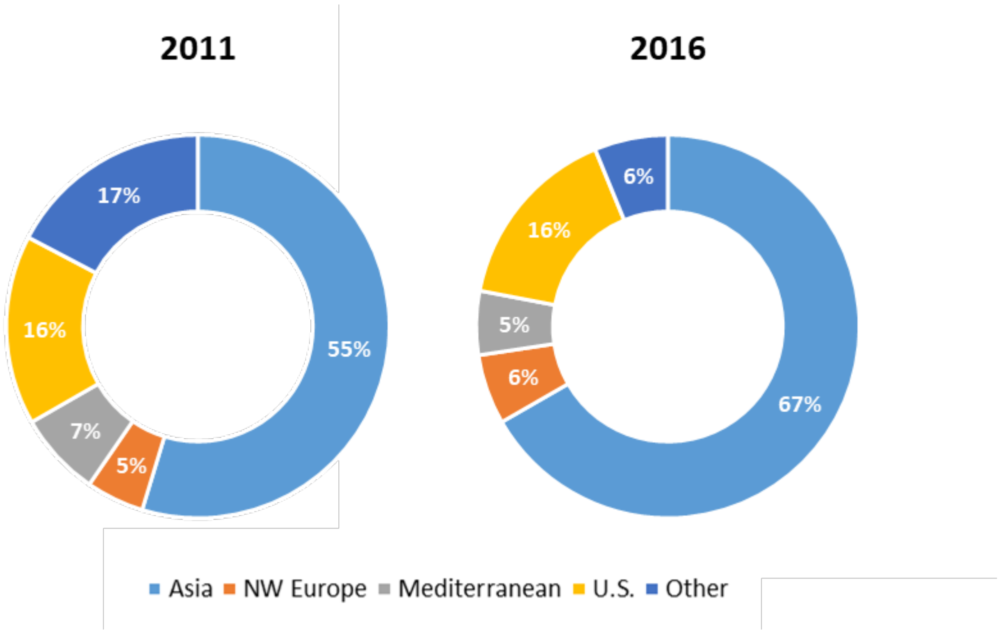

Figure 21. Arabian crude oil exports by region. Source: Saudi Aramco annual reports.

B. Saudi Arabia Oil Policy

Saudi Arabia oil policy is shaped by different factors that will be described next. Under all these constraints and circumstances, the kingdom will necessarily face different trade-offs.

The first factor to take into account is that Arabian economy is not diversified enough and relies heavily on oil revenues. Economic growth is mainly sustained by government spending which is essentially financed by oil revenues. Therefore, the goal of maximizing oil revenues plays an important rule when setting output decisions. Under this circumstance, the kingdom has developed a plan under the name of Saudi Vision 2030 to reduce its dependence on oil and diversify its economy giving a larger role to the private sector. This shift towards non-oil source of revenues has already started as it can be observed in Figure 22. Interpretation of the figures must be done carefully: the sharp decrease in the oil revenues is essentially due to sliding prices as export volumes have increased on a year on year basis. Nevertheless, a steady increase in non-oil revenues can also be observed over the period.

Nevertheless, to achieve diversification, long-term demand for Arabian crude needs to be secured. Despite presenting only two factors, we have already found the main trade-off the kingdom will face in the coming years: securing long-term demand needs to be balanced with revenue maximization in the short-term. This circumstance paves our way to the analysis of other factors also involved in the trade-off.

A reduction in demand caused by higher oil prices, or by substitutes driven by climate change concerns is undoubtedly an incentive to seek diversification. In that sense, recent acquisitions of stakes in refineries around the world are part of a strategy to secure customers in the future and to reinforce its position in key markets such as the U.S., Europe, and Asia and to sustain demand on all crude varieties.

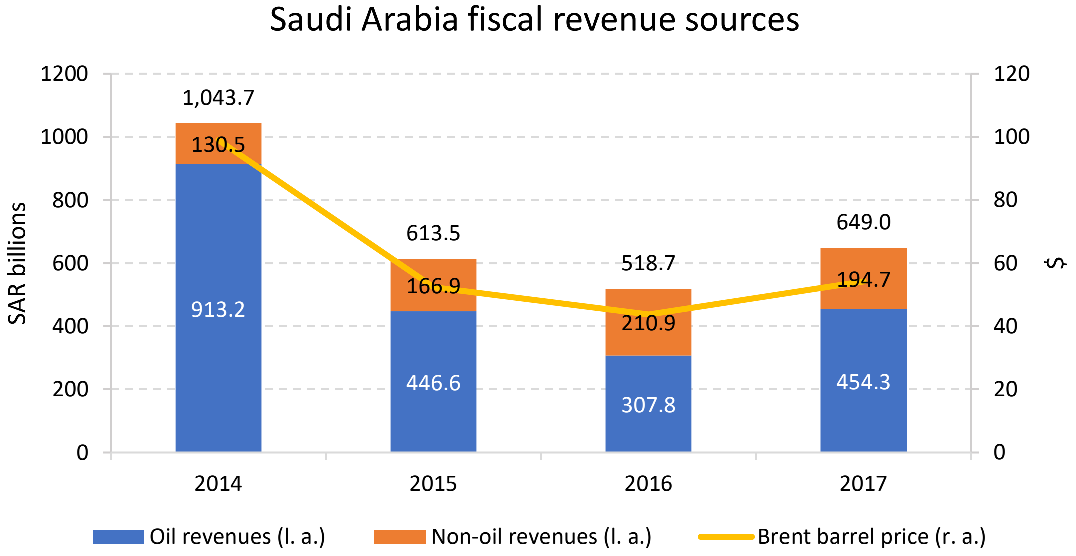

Figure 22. Fiscal revenues sources. Source: International Monetary Fund (2017).

More focused on the short-term, it is important to highlight that Saudi Arabia can influence the price, and therefore the demand, using its spare capacity. This concept is defined by the EIA as the volume of production that can be brought on within 30 days and sustained for at least 90 days. Indeed, Saudi Arabia has an official policy to maintain spare capacity, which is estimated between 1.5 to 2 million barrels per day. This spare capacity can be used to fill shortages when conflicts arise such as the war in Libya in 2011 or to calm price spikes. The impacts of the spare capacity can be observed in Figure 23: a decrease in the production leads to an increase in prices, whereas an increase calms price spikes.

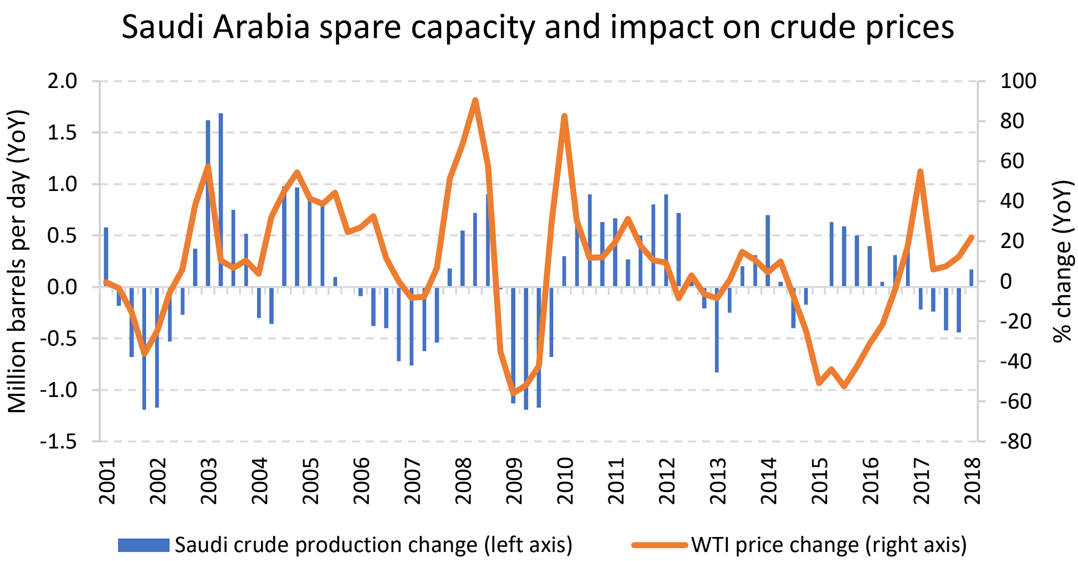

Figure 23. Saudi spare capacity and its impact on crude price. Source: U.S. Energy Information Administration.

In a nutshell: low spare capacity reduces the ability of the kingdom to calm oil markets if any disruption happens, while large spare capacity drags down oil prices and reduces the rate of return on the investment. However, it is important to bear in mind that this spare capacity can only be used to temporary shocks, having little impact on large disruptions of the world oil market. Thus, future investments and output policy are set taking into account spare capacity optimization.

All the previous factors, which can be interpreted as incentives for diversification, are external factors as they are all dependent on global markets. On the other hand, internal circumstances, which mainly support revenue maximization in the short-term, also need to be analysed. Over the last years, internal consumption has shown a breakneck increase as it can be seen in Figure 24: from 607 thousand barrels per day in 1980 to 3906 thousand barrels per day in 2016 (BP, 2017).

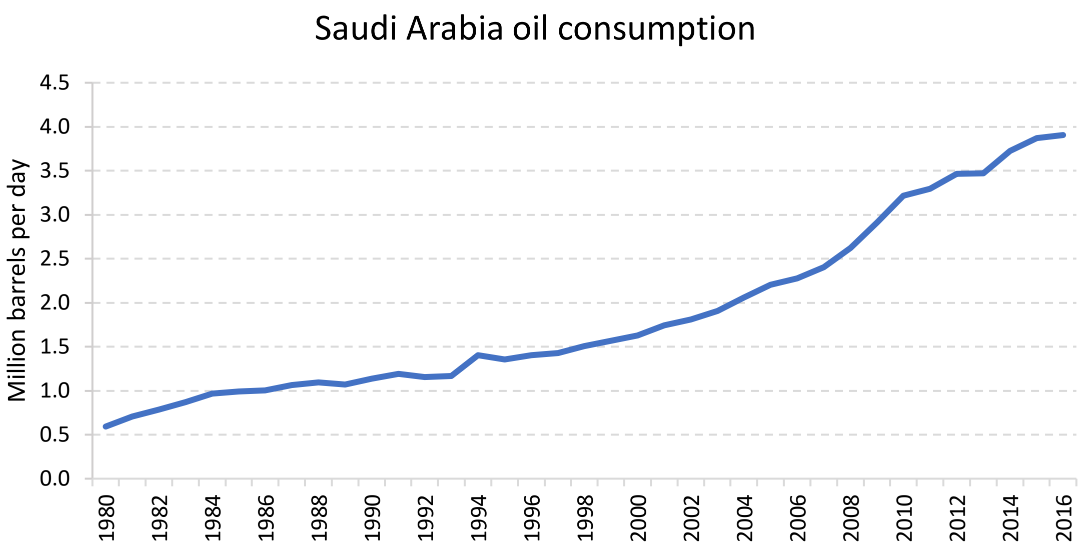

Figure 24. Saudi Arabia oil consumption. Source: BP.

This can be explained by the improvement of living standards in the kingdom and by the consumption of domestic refineries. Another important factor is the subsidies of the government on consumption of downstream products, which have an impact on the output decision (Hochman & Zilberman, 2015), and will definitely be maintained in the short-term to avoid social turmoil, especially after knowing the effects of the Arab Spring. Therefore, to both satisfy subsidized internal demand and external demand, Saudi Arabia has progressively increased its production to current levels above 12 million barrels per day (BP, 2017). Even if the graph showed earlier proving that non-oil revenues were becoming more important, this increase in production can be interpreted as a greater reliance on oil revenues. This trend will continue in the future leaving less room for fluctuations and is a major argument in favour of revenues maximization in the short-term.

Finally, last important circumstance to take into consideration is the political stability of Saudi Arabia and of the region. In an unstable region, maintaining internal stability is important to reach any objective and to ensure global energy security. As pointed out before, even if Arab Springs did not have a direct impact on Saudi Arabian political entities as it did in other countries, the fear of contagion has put social stability as a key goal. This situation has shaped both the output policy and the internal subsidies for downstream products, widening the gap between supply and demand. This situation also generates a trade-off between revenue maximization in the short-term to ensure control of current political elites, or think about future generations and economic diversification in a system less dependent on oil revenues.

All the above goals form a heterogeneous group: there are short-term and long-term objectives, as well as internal and external factors. To reach them, the number of tools for regulators is also limited: adjusting output and signalling to the market in the short-term, and determining the pace of investment in its energy sector in the long-term (Fattouh & Sen, 2015). One important trade-off is between the objective of revenue maximization against that of maintaining market share and production volumes above a certain level. The second and the main trade-off is the determination of the time horizon of current policies: will the kingdom focus on revenue maximization to ensure political and social stability through subsidies or social spending, or would it rather focus on long-term diversification leaving part of oil revenues for future generations? Under these circumstances, the decisions taken by Saudi Arabia will be shaped by external market conditions, cohesion among OPEC members and internal dynamics of the kingdom.

All the factors presented above have been key to determine Saudi Arabia oil policy for the last years, but more recently, US shale oil and new players like Russia are important drivers also shaping output decisions. Indeed, they were key in the big change in policy following the slide in oil prices between 2014 and 2015. Despite expectations of cuts in production to set a floor for oil prices, OPEC's decision was to avoid cutting production. This raised doubts among academics on the theoretical framework to explain this new policy and on the role of Saudi Arabia and OPEC on the oil trade. Has Saudi Arabia stopped being a swing producer or has the OPEC become irrelevant in the new oil order?

In conclusion, all the above shows that, despite permanent evolution over time, Saudi Arabia oil policy is determined by key factors. These same influences will remain over time and are the foundations to anticipate Saudi Arabia oil policy in the future, and thus its role in the new oil order.

4.1.1.3.2. Iran

A. Reserves, transportation and trade partners

Iran has the fourth largest reserve behind Venezuela, Saudi Arabia, and Canada with 158.4 thousand million barrels (BP, 2017). All upstream and downstream projects are controlled by the state-owned National Iranian Company (NIOC), but International Oil Companies can also participate through buyback contracts.

Crude oil production comes from 34 fields, of which 22 are onshore and 12 offshore. The biggest producing field is Ahwaz-Asmari, which has a production capacity of about

750,000 b/d. This field, along with the second and third largest, are located in the Khuzestan province, in the East of the country, North of the Persian Gulf.

When it comes to production, Iran is also in the fourth place with 4.6 million barrels daily, way behind Saudi Arabia, the United States, and Russia that have productions above the 10 million barrels daily.

Regarding the crude varieties, Iranian crude is medium in Sulphur content and an API gravity of around 30º. There are two main type: Iran Heavy and Iran Light, accounting for more than 80% of the whole production. Iranian crude is also very cheap to produce, although a bit more expensive than Arabian oil.

$	
Gross taxes	0.00
Capital spending	4.48
Production costs	1.94
Transportation and administrative costs	2.67
Total	**9.08**

Table 2. Cost of producing a barrel of oil in Iran. Source: The Wall Street Journal (2016) based on secondary sources (The Wall Street Journal, 2016).

Just like Saudi Arabia, Iran relies essentially on maritime transport for crude exports. The terminals located in the Persian Gulf (Kharg, Lavan and Sirri Islands) handle almost all of Iran's crude oil exports. Their total storage capacity is estimated at 38 million barrels (U.S. Energy Information Administration, 2015). Indeed, to serve clients in Asia, all the Iranian crude needs to flow through the Hormuz Strait. To reach European Clients, the Suez canal or the SUMED pipeline are the paths to follow.

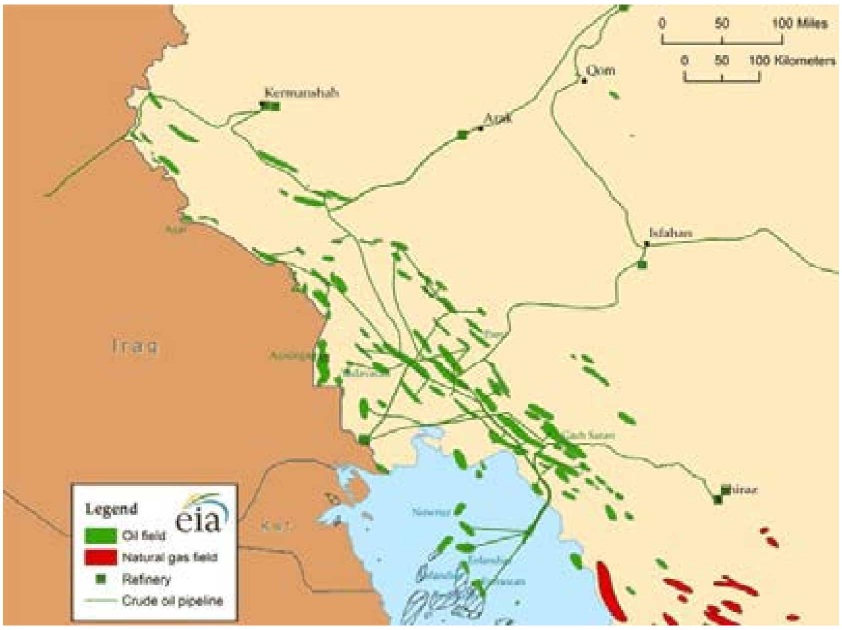

Figure 25. Iran oil infrastructure. Source: U.S. Energy Information Administration (2017).

Regarding the main trade partners of Iran, an analysis like the one for Saudi Arabia cannot be conducted due to the scarcity of information. Nevertheless, despite lacking reliable data, the main partners are China, Europe, South Korea, India, and Japan. Due to the heavy sanctions imposed by the international community, exports were severely affected during the last years. Iran is expected to increase its output to regain market share, and this growth will be essentially captured by China and India.

B. Iran Oil Policy

First, we need to know the way Iranian oil is produced. As pointed out before, all upstream and downstream projects are controlled by a state-owned company. Traditionally, International Oil Companies are allowed to participate in the process through buyback contracts. They invest their capital and their knowledge through Iranian subsidiaries, and once the plant is developed and producing, it reverts back to NIOC. The proceeds from the sale of the product (whether it is crude oil or refined goods) are used to pay back the International Company. The rate of return of these contracts is around 15% with payback periods of seven years (Facts Global Energy, 2014). More recently, the government launched a new Iran Petroleum Contract (IPC) in order to attract foreign investment. Under this new framework, the time period of the contracts is extended, and IOCs will be allowed to manage the projects. That is, their knowledge will not only be limited to the building process, but they will enhance the efficiency by actively participating in the production. As the remuneration scheme is not changed (it is still based on the proceeds of every plant), interests of both parties are perfectly aligned.

After briefly summarizing the rules to extract oil in Iran, we will focus on its oil policy. Current and future Iranian oil management is essentially determined by its international relations, and more particularly by the international sanctions Iran has received during the last years following its nuclear plan. Even if part of these penalties were lifted with the Joint Comprehensive Plan of Action (JCPOA), an agreement between Iran, the United States, the UN and the European Union, the consequences for the Iranian oil exports have been dramatic. Therefore, to analyze its current policy, we will first focus on the effect of the sanctions, to then study the path Iran output policy will take.

Iran holds approximately 158.4bn barrels of reserves, which represent almost 10% of the total world reserves. Despite its historical position as a top producer and exporter, sanctions following its nuclear plan clearly weakened its position in the global markets. The description of the international and US sanctions against the Iranian government is not the subject of this thesis, but the consequences are. On the one hand, focusing on the international investments in Iranian oil fields, penalties impeded international companies to form joint ventures. This lack of investment has supposed a delay in the adoption of Improved Oil Recovery techniques and in the development of new oil fields and refineries. On the other hand, world exports were also hurt under international sanctions. Under US penalties, International Oil Companies could not buy oil from National Iranian Oil Company, and EU, that accounted for 25% of the Iranian exports were reduced. Moreover, Asian customers, even without an explicit ban, reduced imports under US pressure (Munro, 2016). In a nutshell, foreign markets closed and international investment evaporated. In this environment, Iran crude oil production dropped drastically and lost market share benefitting other big players such as Saudi Arabia, Russia, and Iraq which seized the opportunity to supply European and Asian customers.

The abovementioned consequences can be observed in Figure 26, where we see a sharp decrease in Iranian crude oil production following the sanctions and a rapid recovery after they were lifted. However, it would be interesting to compare these figures of productions with those of exports, which are also representative of the impact of the sanctions. Unfortunately, these numbers are not available.

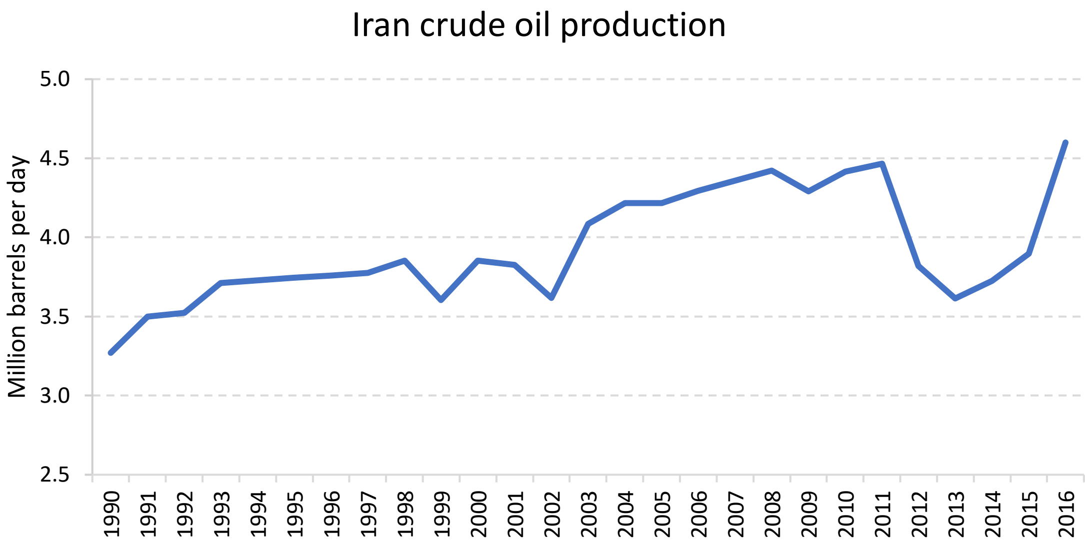

Figure 26. Iran crude oil production. Source: BP.

Following the lift of part of the sanctions under the JCPOA, Iran tried to attract foreign investment to restore oil production to pre-sanction levels. A clear action to achieve this goal was the implementation of the abovementioned Iran Petroleum Contract, which is clearly more attractive to foreign investors than traditional buyback contracts. However, the current market environment is not the same and the new solutions are therefore not that effective. The market is nowadays oversupplied and participants are fighting for market share. In addition, Iran is facing difficulties with the financing of new projects and the shipment of crude oil.

Despite a less hostile international environment, Iran still has difficulties to get foreign funds. This can be explained with two main reasons. First, even under the JCPOA, some US sanctions are still active such as the ban to access the US banking system. Moreover, financial institutions are also subject to potential sanctions. This was the case for BNP Paribas, which paid $8.9bn after violating the sanctions. Second, political uncertainty, both in the US and Iran, is also a key factor taken into account by potential investors. Under the Trump administration, the future of the diplomatic relations is anything but certain. On the other hand, despite the support received by the current government in the 2017 presidential election, lack of transparency and terrorism weaken the attractiveness of Iran. Therefore, Iran's plans to attract funds from International Oil Companies to finance capital-intensive projects and to expand reserves of existing oil fields with new technologies are not working as expected.

In its fight to gain market share, Iran has sold most of its crude to Asian buyers and new euro-denominated contracts have been signed with European clients. However, the transportation to EU clients has also changed and raised geopolitical tensions. Traditionally, crude was sold through Cost, Insurance, Freight terms. CIF terms state that sellers maintain ownership of the product until it reaches destination. Under this contract, Iran arranged the transport of crude through the Suez canal and stored it in the East Suez port terminal so that crude can be delivered through the SUMED pipeline. However, Saudi Arabia has banned ships transporting Iranian crude from entering its waters. Moreover, the kingdom, which owns part of the pipeline along with other Gulf members is apparently blocking Iran's access to SUMED. Under these circumstances, contracts have changed and currently, Iran uses Free on Board arrangements in order to avoid Saudi interference. Under this arrangement, less attractive than the previous one, buyers take ownership of crude oil once it is shipped. Conflicts between Saudi Arabia and Iran are not new in the region and have its roots in history such as the interpretations of Islam. Saudi Arabia can be seen as closer to the United States, whereas Iran, founded in an anti-Western revolution has close ties to Russia. Nowadays, no diplomatic relations exist between the two countries.

Following the lifting of some sanctions, Iran has regained the market in an unprecedented condition. The oversupply driven by new players and technologies obliges Iran to fight to capture market share in the new oil order. However, lack of internal security, as well as its difficult relations with the US and Saudi Arabia that are deterring foreign investments, may make Iran less competitive than other players. Nevertheless, the enormity of its oil reserves ensures growth in production in the coming years and therefore a clear impact on global oil markets.

4.1.1.3.3. Iraq

A. Reserves, transportation and trade partners

Iraq is the second largest OPEC crude oil producer and holds the fifth largest reserves in the world. Its reserves amount to 153 billion barrels. The fields are mainly located in two zones: in the South, near the Persian Gulf, and in the Kurdistan Region of Iraq in the North of the country. The central region is rather poor in resources.

As it can be seen in Figure 27, Iraq has historically shown a steady increase in its crude oil production except during two periods: The Gulf war between 1990 and 1991, and the U.S.-led invasion in 2003. These conflicts caused major disruptions in the Iraqi oil system. As we will see later, these conflicts, as well as the new tensions, are key drivers of the current policy taken.

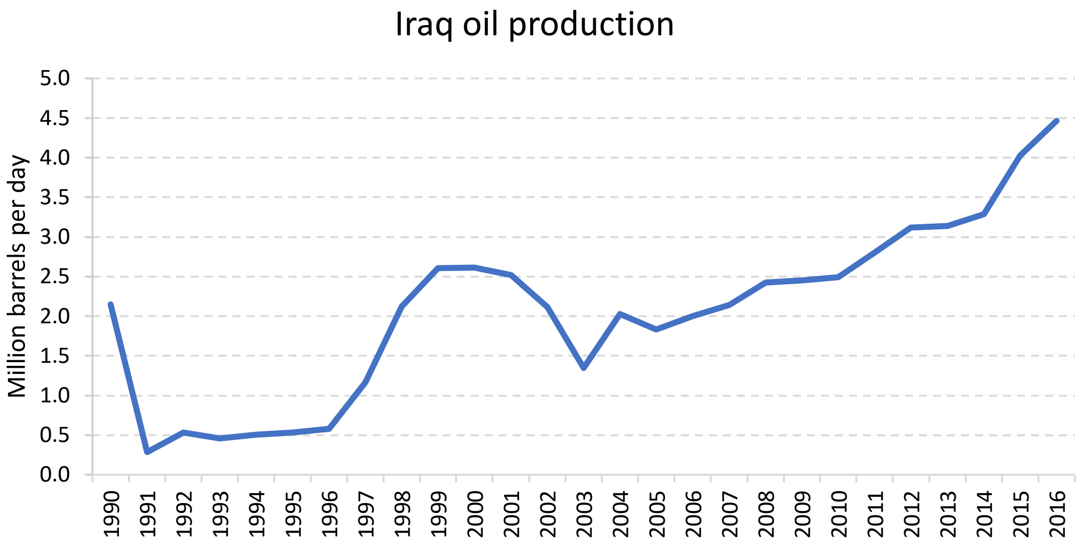

Figure 27. Iraq oil production. Source: BP.

Regarding resource management, as it is the case in all the surrounding countries, it is carried by a state-owned company. However, increasing division in the country between the region of Kurdistan, located in the North, and the central government make the situation more complex. Indeed, as the northern region is rich in the resource, the exploitation of them and the revenue sharing scheme are a source of controversy.

In addition, International Oil Companies are also present in the country, but the contract used depends on the counterparty. If it is the central government, technical service contracts are employed, whereas if it is the Kurdish government, production share agreements, which are more attractive for international companies, are used. Later in this section, the conflicts between Bagdad and the Kurdistan will be analyzed.

Regarding the spectrum of Iraqi crude oil, we can say that as it was the case with previous players, it is large, covering different qualities, although the majority of it can be considered as heavy oil. The two main blends for export are the Basra Light blend, produced in the Southern region, and the Kirkuk blend, extracted from the fields in the North. As it was the case with Arabian and Iranian crude, Iraqi oil is also very cheap to produce thanks to the huge size of its fields and its uncomplicated geology. Nevertheless, security issues imply higher administrative and transportation costs.

$	
Gross taxes	0.91
Capital spending	5.03
Production costs	2.16
Transportation and administrative costs	2.47
Total	**10.57**

Table 3 - Cost of producing a barrel of oil in Iraq. Source: The Wall Street Journal (2016) based on secondary sources.

Concerning transportation systems, there is also a difference between the North and the South of the country. The proximity between the Southern fields and the Persian Gulf explains why 85% of crude oil exports come from offshore terminals (U.S. Energy Information Administration, 2016). This is achieved thanks to the Al Basrah and the Khor al-Amaya oil terminals. It is important to highlight that capacity of these ports should be expanded in the coming years if the growth keeps the same pace.

Northern crude follows an alternative path as it is exported mainly using pipelines to Turkey. Transportation of northern crude is also a source of conflict. Indeed, the Iraqi pipeline stopped operating in 2014 following terrorist attacks, but the Kurdistan built another pipeline which is currently active and connected to the Ceyhan port in Turkey on the one end and to the production plants on the other end. As we will see, this situation gives the Kurdish region bargaining power in any conflict. All this information is summarized in Figure 28.

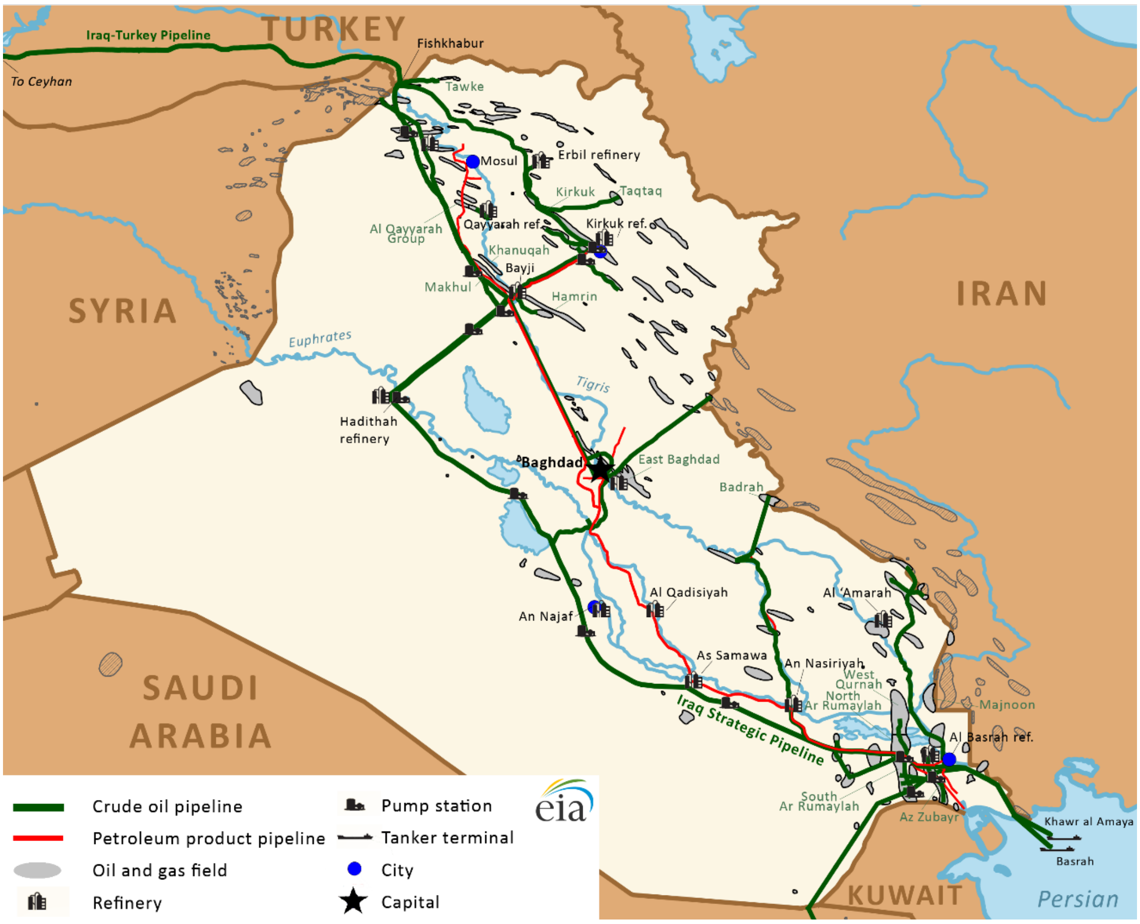

Figure 28. Iraq oil infrastructure. Source: U.S. Energy Information Administration (2017).

Finally, regarding total crude oil exports, they exceeded the 3.3 million barrels per day in 2016 with the distribution shown in Figure 29. As it was the case with Saudi Arabia, we can see that the most important customers are India and China. Indeed, for Iraq, there has also been a shift towards the fastest growing oil consumers taking advantage of the international sanction Iran received.

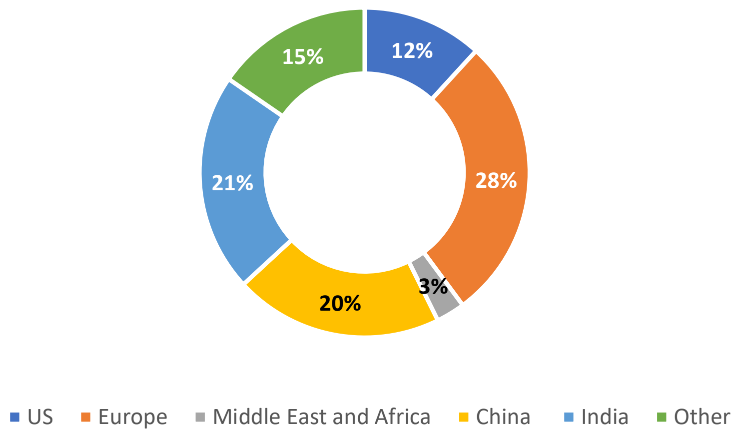

Figure 29. Iraqi crude oil exports by region. Source: BP.

B. Iraq Oil Policy

As it is the case with its neighbours, Iraq's oil policy is shaped by its internal divisions which are responsible for the lack of stability in its political and social environment. These conflicts, in turn, have a deep impact in regional politics. To further understand the current situation, we need to review the events that have recently taken place.

Political instability stems directly from the U.S.-led invasion which resulted in almost ten years of civil war and the overthrow of the Ba'ath regime led by Saddam Hussein in 2003. Two years later, in 2005, a new constitution was drafted and approved. The lack of political centralization, as well as the different interpretations of the law, ignited internal opposition. Indeed, the new legal framework gave legal entity and autonomy to the Kurdistan Region of Iraq (KRI), located in the resource-rich northern region, and it consequently opened a debate on resource-based revenues sharing between federal and regional governments.

Before 2003, little exploration was made in Kurdistan; instead, the federal government followed a common strategy among OPEC members: only state-run companies are in charge of production with no intervention of International Oil Companies, which could only sign technical service contracts with the Ministry of Oil in Baghdad. Nevertheless, after 2005, given the autonomy the Kurdistan Regional Government (KRG) gained, production-sharing agreements were signed with International Oil Companies in order to allow them to explore in the North of the country. This resulted in multiple discoveries that made the region richer. Needless to say that the federal government feared this new equilibrium and sought to exert a tighter control on the revenues flow. Tension escalated before and after the Kurdish referendum for independence held in September 2017, and the main consequence was that part of the Kirkuk field, one of the most important oil fields standing between Iraq and the Kurdistan Region of Iraq, was taken by Iraqi forces supported by Iran in October 2017. Therefore, as no law sets a proper framework for resource management and revenue sharing, the interpretation of the 2005 constitution is at the root of current conflicts.

In a nutshell, geographic dispersion of resources and ethnical differences within the country are the key internal factors shaping Iraq oil output policy as they lead to different interpretations of the constitution, which in turn, pave the way for divergent policies between the two polities. Therefore, enduring an effective, certain and sustainable oil revenue management is the biggest challenge Iraq will face in the coming years. On the one hand, this is the case because Iraq is an oil revenue reliant government that has been severely damaged by the conflicts with ISIS and by the decline in oil prices, reaching a point where external debt is hardly sustainable. On the other hand, efficient revenue management is necessary to smooth internal and external tensions, and this is especially true for the period following the elections that will be held in Iraq and in Kurdistan in 2018.

On the other hand, we cannot forget the implications that internal conflicts have in regional politics, which also shape the output policy. This involves notably Turkey, Iran, Saudi Arabia and Russia.

Iran's ambitions for regional hegemony are present due to the significant influence it seeks to exert in Iraq as the collaboration to take over Kirkuk shows. On top of that, both countries are aligned in their opposition to Kurdish independence. This was of course noticed by Saudi Arabia, the main rival of Iran in the region. Following these events, the kingdom tried to restore ties through different meetings and the reopening of the Arar border, closed since 1990, and the signing of agreements for cooperation in the energy sector (Mostafa, 2017).

The role Turkey plays is more difficult to understand and is closely linked to the Kirkuk-Ceyhan pipeline. It is Iraq's largest crude-export line and it has been a sabotage target since the U.S.-led invasion started in 2003. As pointed out before, the pipeline is severely damaged currently and exports from Kirkuk oilfields have been on hold since the takeover (Rashed, 2017). In this situation, the government is willing to build another pipeline. Nevertheless, these attacks have not isolated the KRI as it built in 2013 another pipeline avoiding war zones and connecting with the Kirkuk-Ceyhan pipeline in the Turkey-Iraq border.

With the current situation depicted, we can try to understand the controversial role Turkey plays. As it is the case with Iran, it also opposes Kurdish independence, and therefore, it would like to weaken its autonomy. In fact, after the referendum, Turkey warned Kurdish population that it can "close the valves" on oil exports (Ant & Ansary, 2017). However, the threat to close the tap seems far, and the incentives to keep the pipeline running are huge, given the interest of Turkey to become a key player in energy distribution and the fact that the KRG is heavily indebted to Turkish companies.

Finally, the role Russia plays is somehow easier to understand. State-owned company Rosneft heavily invested in the KRI and has offered loans for the coming years. Its economic interests in the region are behind the Russian support to the independence referendum and the help it is offering the KRG in the talks with Iraq in order to resume oil exports and reach another revenue sharing agreement.

Iraq is definitely a perfect example of the political complexities surrounding oil. Political instability following the U.S.-led invasion and the approval of a new constitution, as well as the lack of a common interpretation of the new legal framework by the different ethnic groups, sparked internal conflicts over the management of the main resource the country has. But the importance of oil revenues for other players and energy security matters imply that internal conflicts in major producers immediately become of international relevance, and thus, oil output policy is increasingly complex due to the divergent interests that are at stake.

4.1.1.4. Oil production outlook

The previous sections described the main drivers behind the output decisions of the main OPEC members, and they clearly reflected the complexity of such process. To close this part that has focused on OPEC we consider that it is also important to have an overview of the forecasts on oil production given by important institutions. This can be seen as a summary of all the above mentioned or as an introduction to the second part of this work. The results taken are gathered in Figure 30. Please note that only the IEA provides enough granularity whereas the rest only focus on OPEC as a group.

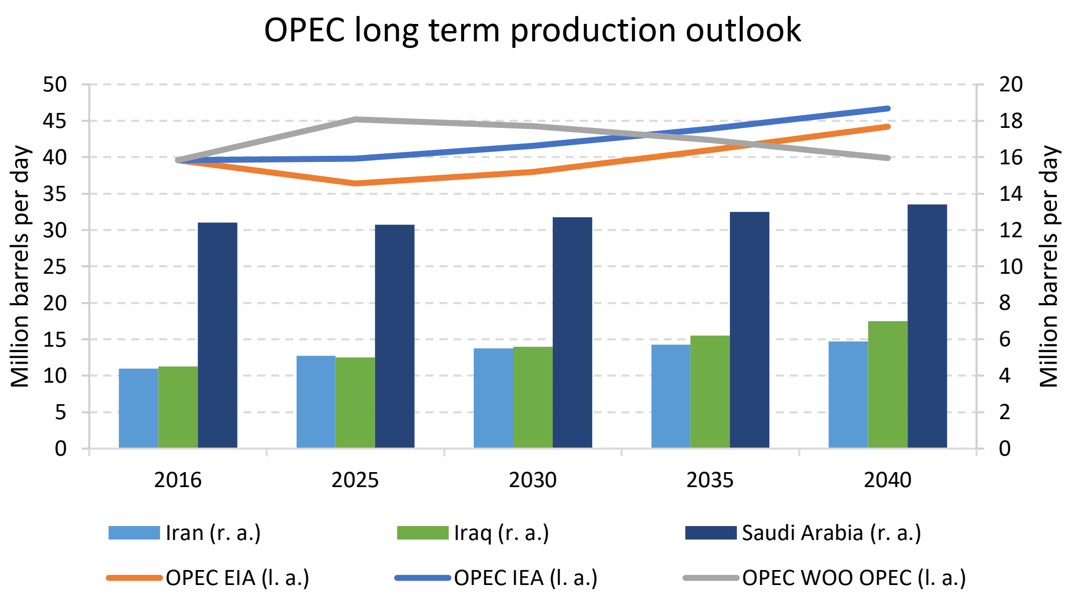

Figure 30. Production forecasts. Source: International Energy Outlook 2017, World Energy Outlook 2017, World Oil Outlook 2040.

The previous chart shows some interesting results. First, regarding individual country productions, we observe that Iraq is expected to drive the growth for the Middle East producers. However, there is some downside risk for the Iraqi output due to the budgetary constraints, the required investment in new infrastructure and security problems which were analysed earlier. On the other hand, Saudi Arabia is expected to remain as the top producer within the organization with a steady growth over the period studied.

The other set of data to be analysed concerns the projection for the OPEC as a whole. In this case, two phases can be studied, the first one ending between 2025 and 2030. During this first period, demand is expected to grow and projections estimate non-OPEC producers will capture most of this growth. This is why both EIA and IEA show a decline in OPEC output. On the other hand, the organization itself assumes it will also capture part of the new demand given the strategies set in place like the investments in Asian refineries, resulting in an increase in the output.

During the second phase, EIA and IEA expect non-OPEC producers to reach a plateau and OPEC should benefit from that by increasing its output even if demand will grow at a slower pace due to the new technologies adopted. On the other hand, the organization is less optimistic, and as it was the case for the first phase, they see the market will move as a whole and that every player will be affected by a progressive reduction in oil consumption, resulting in a steady decrease of the output.

If we confront now the fact that oil consumption is expected to decline at some point in time, due to the development of new technologies and of more sustainable policies, with the budgetary constraints, the revenue maximization trade-off and the entry of new players that the Middle East producers face, a question arises for the short term. Should the OPEC try to flood the market in order to drag prices down and choke its competitors, or is it a better solution to accommodate to the current environment and wait?

4.1.2. United States

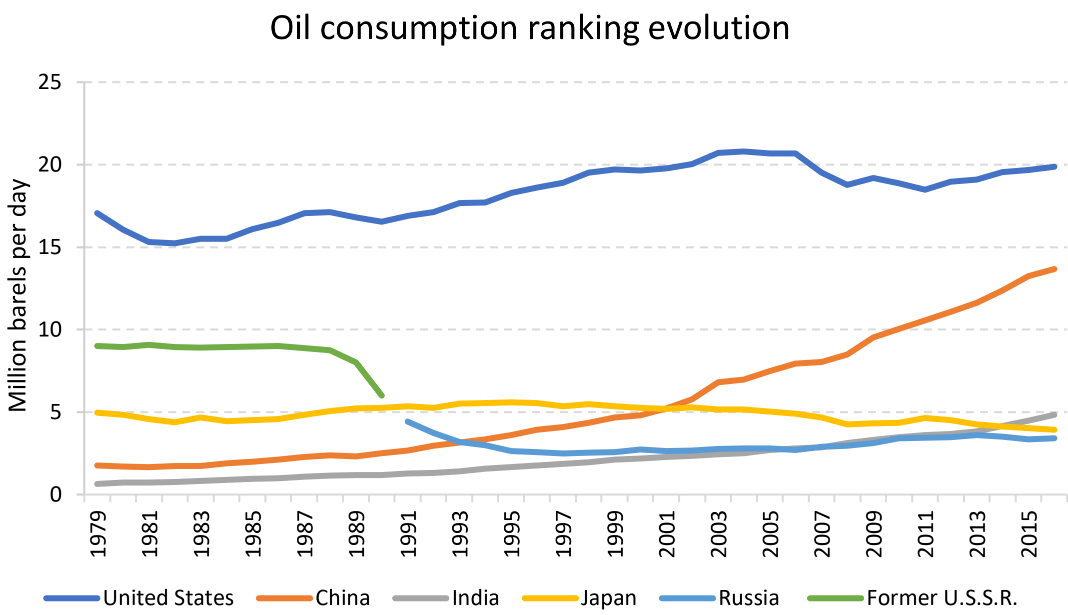

Figure 31. Top 5 oil consuming countries evolution, includes refined petroleum products. Source: U.S. Energy Information Administration.

The U.S. is an undisputable key player in the oil industry. Historically, it has not only been the top petroleum products consuming country (see Figure 31), but also one of the top three oil suppliers worldwide along with Saudi Arabia and Russia (see Figure 32). Its economy relies heavily on oil and they have historically been also the largest oil importing country until 2017, when China surpassed the U.S. in annual gross crude oil imports with 8.4 mb/d compared to U.S.'s 7.9 mb/d, according to the latest available data from the U.S. EIA.

The rapid rise in U.S. unconventional oil output from 2000 onwards (also referred as "the shale oil revolution"), has returned the U.S. to top dog producer and brought millions of barrels per day to the supply pool, shaking up the whole oil market. With global oil demand growth lagging behind, U.S.'s quickly-evolving output can have a significant impact on the global demand-supply balance, ultimately affecting oil prices. The shale oil boom has the potential to become a real game changer, leaving the OPEC supremacy and Saudi Arabia's role of swing supplier behind.

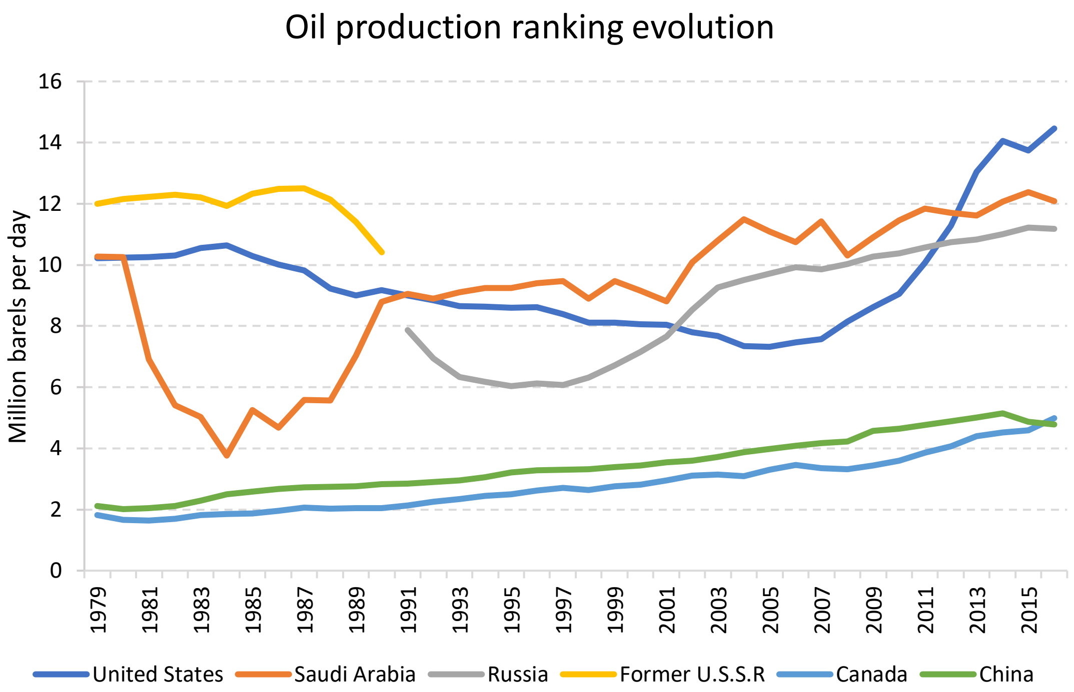

Figure 32. Top 5 oil producing countries worldwide evolution, includes crude oil, lease condensates, NGL and other liquids. Source: U.S. Energy Information Administration.

However, not all that glitters is gold. The U.S. has had to cope with multiple challenges to digest successfully the ever-increasing flow of high-quality light sweet tight oil. Significant constraints in refining and transportation infrastructure led to an oil glut in its oil hub in Cushing, Oklahoma, causing significant discounts to their oil price benchmark, the West Texas Intermediate (WTI), with respect to Brent oil price benchmark from 2011 to mid-2014. Moreover, despite the rapid growth that this new resource is experiencing, the technology required to exploit it is expensive and complex. Consequently, after OPEC's decision to let prices sink in mid-2014, most tight oil producers saw its results enter into deep negative territories (EY, 2017). Many U.S. exploration and production companies became financially distressed and filed for bankruptcy between 2015 and 2016 (Haynes & Boone, 2016). However, the industry resisted the low-oil price environment thanks to significant reductions in well-head breakeven prices and rig productivity improvements, and has bounced-back given the recent oil price recovery following OPEC-non-OPEC agreement to cut production.

In this section, we will first introduce the shale oil revolution and other important concepts. We will then cover U.S.'s tight oil challenges mentioned above, and their current state, so as to better predict U.S.'s ability to sustain its output growth in the medium to long term. Moreover, we will reveal some of the key reasons why, despite market expectations, the U.S. tight oil industry resisted the oil downturn (namely its dynamic economics) so as to better understand the competitiveness of this new resource and its potential to become a real game changer. In addition, we present current estimations of proven and unproven reserves, which should provide some light on for how long and how high can the shale oil revolution go. We will finally expose analysts' views regarding U.S. oil output prospects in the medium to long term.

4.1.2.1. The shale oil revolution

4.1.2.1.1. Oil shale, shale oil and tight oil definitions

First of all, given the recurrent misunderstanding/misuse of these terminologies, and to avoid confusion going forward, we will begin by defining some basic concepts surrounding unconventional oil resources: oil shale, shale oil and tight oil.

Oil shales are organic-rich fine-grained sedimentary rocks containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons called shale oils can be produced (U.S. Energy Information Agency).

Shale oil, also known as kerogen oil or oil-shale oil, is an unconventional oil produced from oil shales by pyrolysis, hydrogenation, or thermal dissolution. These processes convert the organic matter within the rock (kerogen) into synthetic oil and gas. The resulting oil is generally light (low density) and sweet (low sulphur content) that can be used immediately as a fuel or upgraded to meet refinery feedstock specifications by adding hydrogen and removing impurities such as sulphur and nitrogen. The refined products can be used for the same purposes as those derived from crude oil (U.S. Energy Information Agency).

Shale oil is only one subset of a broader category of unconventional oil referred as *tight oil*, and also known as light tight oil (abbreviated LTO), which is characterized for being located in relatively low-porosity and permeability petroleum-bearing formations (shales), and whose extraction is somehow complicated but now possible thanks to technological advances (such as the combined use of horizontal drilling techniques together with hydraulic fracturing) in parallel with increased oil prices that make its exploration and exploitation bankable (U.S. Energy Information Agency).

4.1.2.1.2. Shale oil revolution

At the beginning of 1970s, and as the majority of onshore U.S. hydrocarbon fields matured, the U.S. oil industry had apparently reached its peak-oil supply at 9.7 mb/d (U.S.

Energy Information Agency) (production from conventional reservoirs without fracking) and crude oil output entered into a considerable continuous downward trend which was only temporarily offset by Alaska's crude oil production rise from 1976 up to 1988 (see Figure 33[6]).

Moreover, 1973's OPEC oil embargo (which was OPEC's decision to cut oil exports to the U.S. and other western nations over their support for Israel during the Yom Kippur War) forced oil prices to spike and toughly hit not only the U.S. oil industry, but also its overall economy. The U.S. authorities responded with the enactment of the crude oil export ban in 1975, in an attempt to insulate the U.S. from future foreign oil price shocks.

With U.S. domestic hydrocarbon production on the decline, American oil companies were forced to move towards foreign frontiers and expensive deep offshore production. U.S. shallow water offshore, and later on deep water supply, provided some extra million barrels per day, but were not enough to offset the natural decline rates of the majority of U.S. fields, which were on the mature and decline stages of their life cycle.

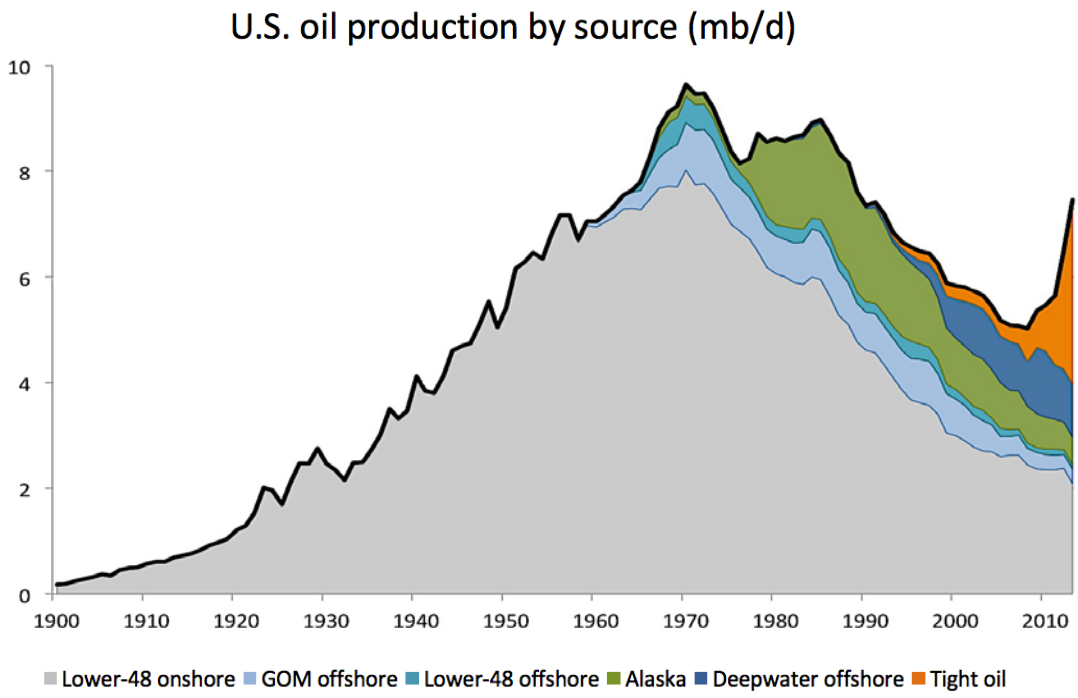

Figure 33. U.S. oil production by source evolution from 1900 to 2013. Source: U.S. Energy Information Administration.

This was until early 2000, when rising natural gas prices and a technology innovation boom in unconventional drilling techniques made the extraction of shale gas and tight oil in vast shale deposits economically feasible. This unexpected surge of tight oil production in the mid-2000 is referred to as the "U.S. shale revolution", which was able to reverse the decades of output decline already by 2008, when U.S. oil production

[6] Note that these Figure 33 exclude natural gas liquids (NGL). Lower-48 onshore includes conventional and enhanced oil recovery crude oils; GOM refers to Gulf of Mexico and includes shallow water offshore; Lower-48 offshore excludes GOM.

reached a minimum of 6.8 mb/d. By that time, the U.S. imported a total of 12.9 mb/d and exported a total of 2.0 mb/d of crude oil and petroleum products. The U.S. was already the third largest oil producing country with a total 8.2% share, but considerably lagging behind Saudi Arabia and Russia who respectively accounted for 12.9% and 12.0% of world's total oil output (BP, 2017).

Crude oil production in the U.S. has increased rapidly ever since (see Figure 34), primarily thanks to the rapid technological development and increased cost efficiency of horizontal drilling and multi-stage hydraulic fracturing techniques being used to access oil and natural gas from shale rock formations. Already in 2014, the U.S. jumped from the third position to lead the world's oil production with 11.8 mb/d or a total 13.3% share (BP, 2017).

In mid-2014, oil prices plummeted due to OPEC's decision to keep pumping oil (despite oil market's oversupply driven by U.S.'s shale oil boom) in an attempt to get rid of high-cost tight oil producers and gain back market share. To the overall industry surprise, tight oil players resisted the downturn well better than expected, with production increasing until 2015 and slightly decreasing in 2016. This unexpected resilience forced OPEC members to reverse their strategy and cut production (OPEC-non-OPEC agreement), which has led to oil price recovery and, consequently, a significant rebound of U.S. tight oil activity in 2017.

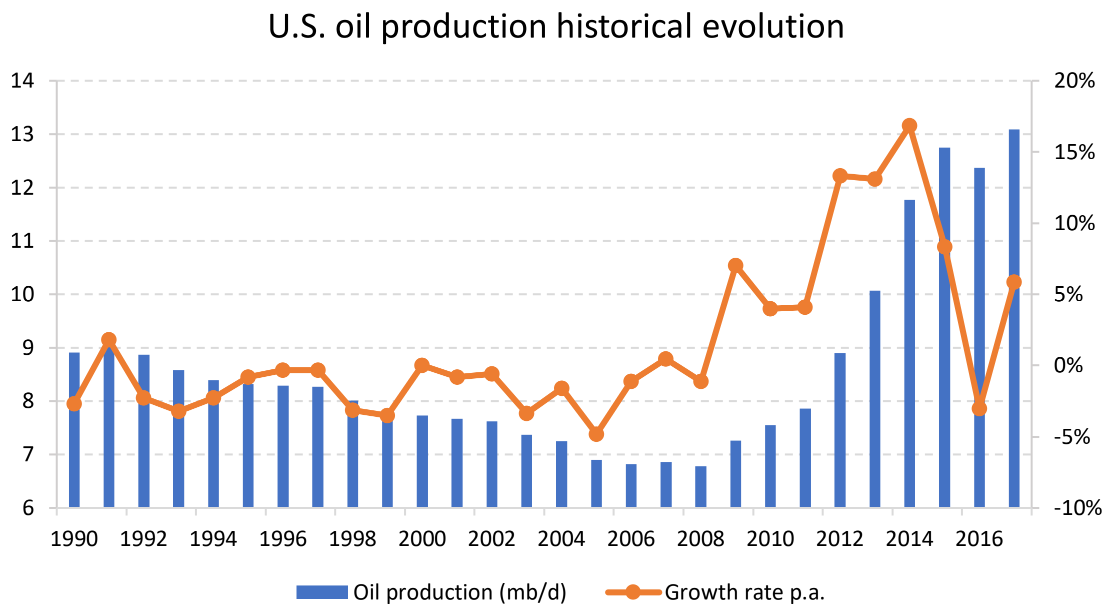

Figure 34. U.S. oil production recent historical evolution, in million barrels per day. Includes crude oils and NGLs. Source: U.S. Energy Information Administration.

As of 2016, the U.S. produced a total 12.4 mb/d, which represents an astonishing 82% net increase and a 7.8% CAGR from 2008 levels. It occupied the first position along with Saudi Arabia (both with a total 13.4% share of world oil output), followed by Russia's 12.2% share. The U.S. imported a total of 10.1 mb/d (22% decrease with respect to 2008) and exported a total of 4.7 mb/d (140% increase with respect to 2008) of crude oil and petroleum products (BP, 2017). Despite the considerable decrease of net import activity, total imports by the U.S. in 2016 represented a significant 15.4% share of total world imports.

There has been a lot of noise regarding the U.S. having reached its well desired "energy independence", however, as we can see in Figure 35, the U.S. still remains an important net importer of crude oil and petroleum products. Notwithstanding, the EIA's 2018 Annual Energy Outlook (AEO) projections set the U.S. as a net exporter of petroleum liquids and products from 2029 to 2045 in its reference case, and a net exporter by 2020 in an event of persistent high oil prices and high shale resource and technology.

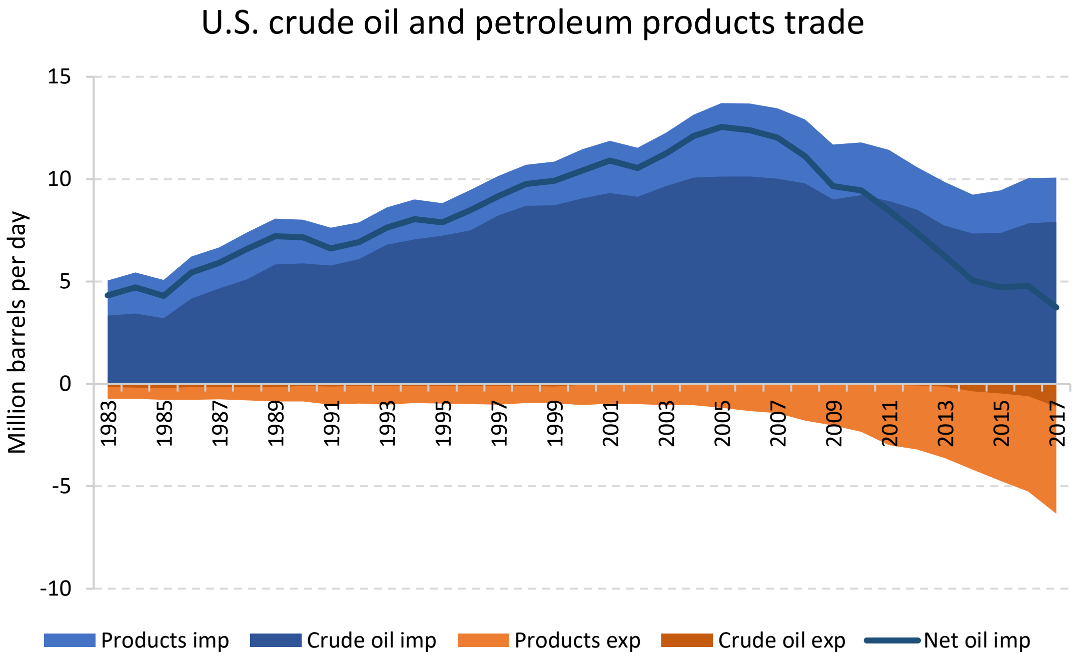

Figure 35. U.S. crude oil and petroleum products trade evolution, in millions of barrels per day. Products imports and exports include finished petroleum products, hydrocarbon gas liquids (HGL) and other liquids. Source: U.S. Energy Information Administration.

4.1.2.1.3. Tight and shale oil plays

U.S. tight oil production is concentrated in a small number of geographic regions (see Figure 37), also known as tight or shale oil plays (despite being "tight" oil play a more accurate denomination). The vast majority of LTO output and growth in the past decade has come from the prominent Permian Basin in Western Texas (which includes, among others, the important Spraberry, Bone Spring and Wolfcamp plays), the Eagle Ford in Southern Texas, and the Bakken formation in Montana and North Dakota (see Figure 36).

The dramatic increase of oil production from a small number of specific geographical locations within the U.S. has been a key challenge for its transportation to the main oil hub in Cushing, Oklahoma, and the main refining areas in the country. As we will see later on in this chapter, there have been significant efforts to expand transportation infrastructure to avoid bottlenecks that erode U.S. ability to fully exploit LTO output potential.

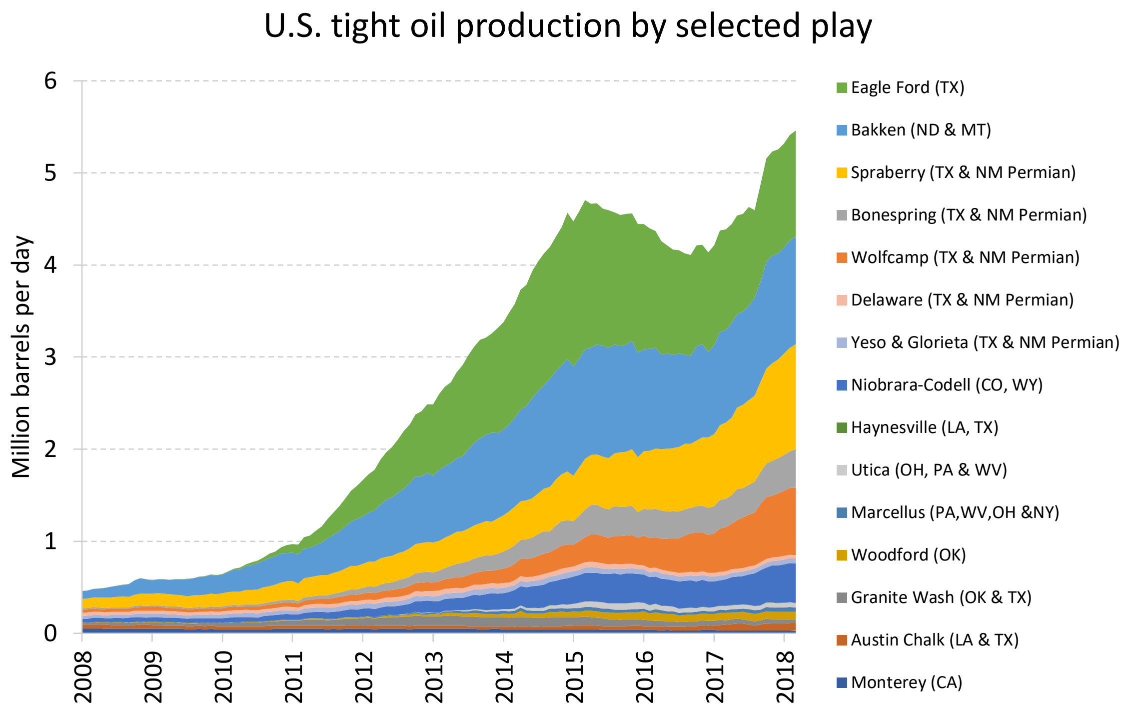

Figure 36. U.S. tight oil production by selected play, in millions of barrels per day. Source: U.S. Energy Information Administration.

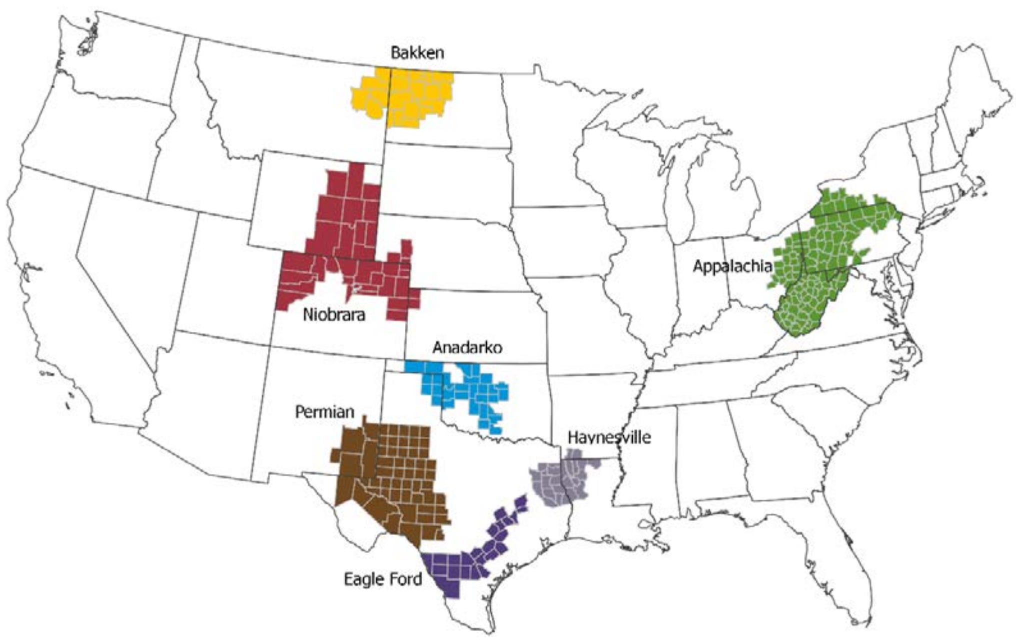

Figure 37. Geographical location of major U.S. tight oil plays and basins, as of 2018. Source: U.S. Energy Information Administration.

Note that data presented in Figure 36 is the latest update published by the U.S. Energy Information Administration and does not include NGLs derived from tight crude oil. This fact is underlined so as to bear in mind that output figures from the selected plays graph represent 5.5 mb/d out of a total reported crude oil production (without NGLs) of c. 10

mb/d as of March 2018. This represents more than half of total U.S. crude oil output coming from shale rock formations.

4.1.2.1.4. Tight oil challenges

The unforeseen shale oil revolution caught the U.S. oil industry off guard. Several challenges arose that are important to understand when trying to predict the future of U.S. LTO production. Beneath we will briefly discuss the effects of differences in quality of conventional and unconventional crude oil, the structure of the U.S. refining industry, the oil export ban and capacity constraints in refining and transportation of LTO which led to the oil glut in Cushing, and the economics behind these revolutionary start-up resource.

A. Oil quality differences, U.S. refining industry and the "Oil Glut in Cushing"

The quality of crude oil can be disassembled into two dimensions: density and sulphur content. The purchase costs of several crude oils depend primarily on these two unique qualities, and other factors such as location and transportation costs.

On the one hand, oil density ranges from light to heavy and is generally measured according to the American Petroleum Institute (API) gravity formula (the inverse of the density of a petroleum liquid relative to water). The higher the API gravity, the lower the density of the petroleum liquid, such that light oils have high API gravities. Lighter oils are of higher quality, and thus more expensive.

On the other hand, the sulphur content defines crude oil as sweet (when it has low levels of sulphur) or sour (referring to high sulphur content). Sulphur is an impurity so that the lower the sulphur content, the higher premium will the crude oil command.

Commonly quoted crude oil benchmarks such as Brent and WTI have low density (API gravity around 35 to 40) and low sulphur content, which means that they represent conventional light sweet crude oils (see Figure 38[7]). LTO generally consists of high-quality light sweet crude (ranging 40 to 45 API), and also ultralight sweet crude (about 47 API) and condensates (as high as 60 API) (Kilian, 2016). This indicates that the crude oil obtained in shale formations corresponds generally to light sweet expensive oil.

[7] Mars refers to an offshore drilling site in the Gulf of Mexico, WTI - West Texas intermediate, LLS - Louisiana Light Sweet, FSU - Former Soviet Union, UAE - United Arab Emirates.

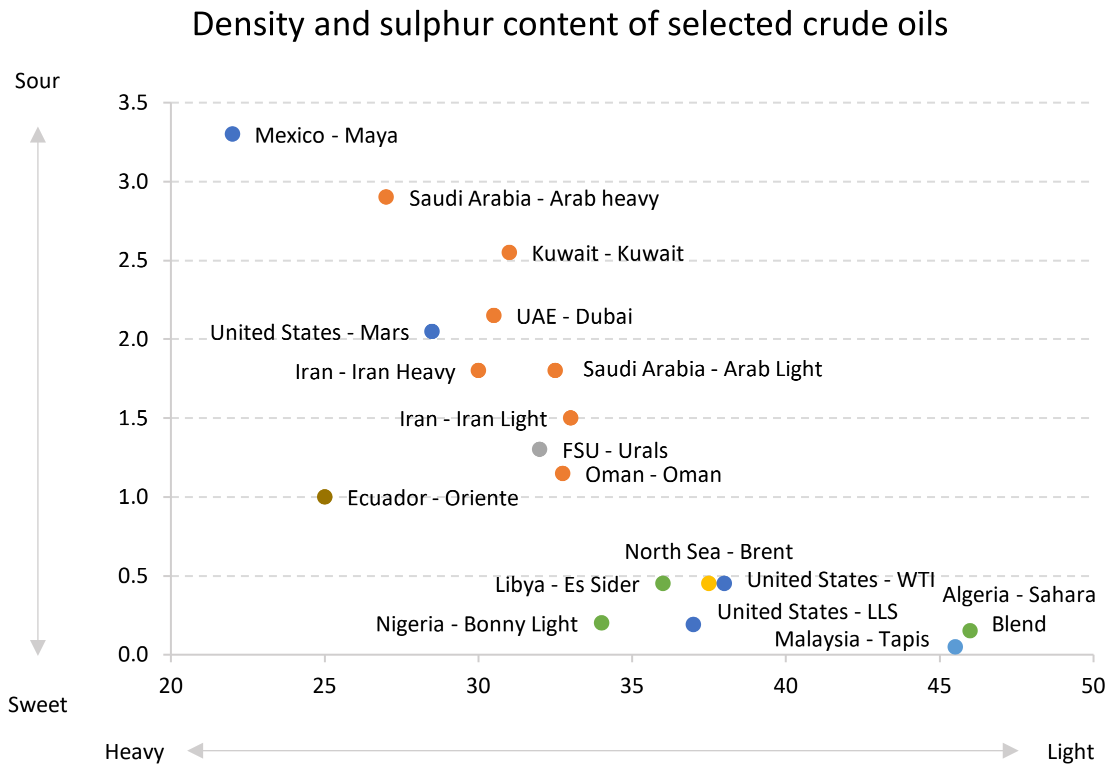

Figure 38. Density and sulphur content of selected crude oils. Source: U.S. Energy Information Administration (2015).

These differences in quality are relevant given that they affect the yield of petroleum products obtained in the refining process. In actual fact, not all refineries are equipped to process any kind of crude oil as feedstock and not every crude oil is appropriate to obtain certain petroleum products. For example, light sweet crudes are well suited for producing gasoline, and heavier sour petroleum liquids can be better refined into diesel and heavy fuel oils. Refining heavier crudes into gasoline would require more advanced technologies, such as large secondary conversion capacity including hydrocrackers, cokers, and desulfurization units. Installation of these additional systems is expensive but can make economic sense considering that heavier and sourer crudes tend to be cheaper than conventional light sweet crude oil (such as Brent or WTI benchmarks). Hence, a refinery's technical configuration determines which kind of crude oil it is best suited to process.

This feature of the refining process has been particularly relevant in the U.S. shale oil revolution, given the structure of U.S. oil refining industry. Around the 2010s, U.S. refineries were mostly concentrated along the Gulf Coast (accounting for over half of total U.S. refining capacity (U.S. Energy Information Administration)), the Midwest region and the East Coast. Signs that light sweet crude was becoming increasingly scarce before the shale oil boom made Texas refiners (which are the ones located right next to main tight oil plays producing light sweet crude) invest heavily in new technology to process heavier crudes from Saudi Arabia, Venezuela and Mexico. Midwest refiners were also set up so as to process heavy sour crude slates. On the contrary, East Coast refiners implemented less secondary conversion capacity, in general processed crude oil with lower sulphur content and lighter density, and relied on imports of high-quality crude oils from Nigeria, Angola and Algeria (U.S. Energy Information Administration, 2012). Hence, refiners that were most suitable to treat this light sweet tight oil were primarily located at the East Coast, far away from the main Permian, Eagle Ford and Bakken tight oil plays (see Figure 39).

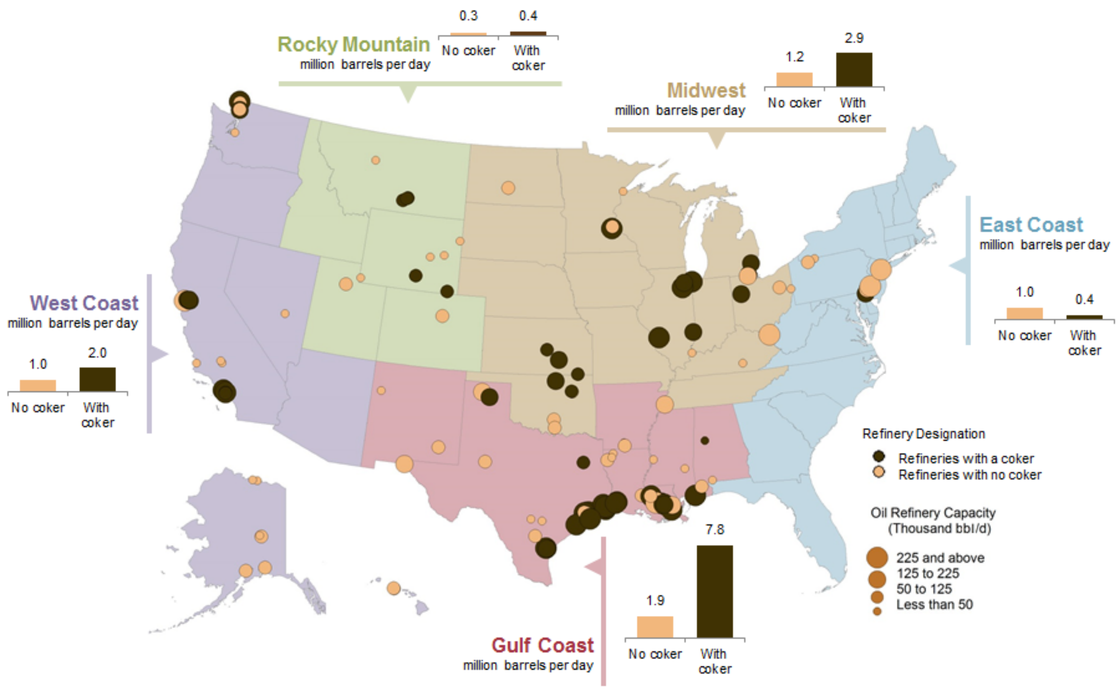

Figure 39. U.S. regional refinery capacity and complexity. Source: U.S. Energy Information Administration (2015).

Once LTO began to be shipped to the U.S. oil market hub in Cushing, existing infrastructure in place allowed imported and refined oil from the east to be shipped to the centre, and not the other way around. There was not enough rail or barge transportation capacity in place to absorb the increasing amounts of high-quality inventories at Cushing. Additionally, selling a relatively expensive tight oil to Gulf Coast refiners was a difficult task at the beginning given their important investments in technology to process cheaper heavy oils and the lack of enough oil pipelines to transport economically LTO from Cushing to Texas. To these facts, one must add the increasing imports of heavy western Canadian crudes extracted from Alberta and Saskatchewan sent directly through pipeline to Cushing, where they also failed to find enough buyers (cheaper heavy crude from Saudi Arabia and Venezuela).

By 2011, the previous events originated the so called "Oil glut in Cushing", which is evidenced by the subsequent fragmentation of the oil market that followed, and lasted until 2014. At the beginning, the excess of light sweet crude supply in Cushing generated a downward pressure on U.S. price of light sweet crude oil (WTI) relative to the Brent benchmark. As reflected in Figure 40, the WTI-Brent price spread went unprecedented given the lack of demand for so much high-quality tight oil in Cushing.

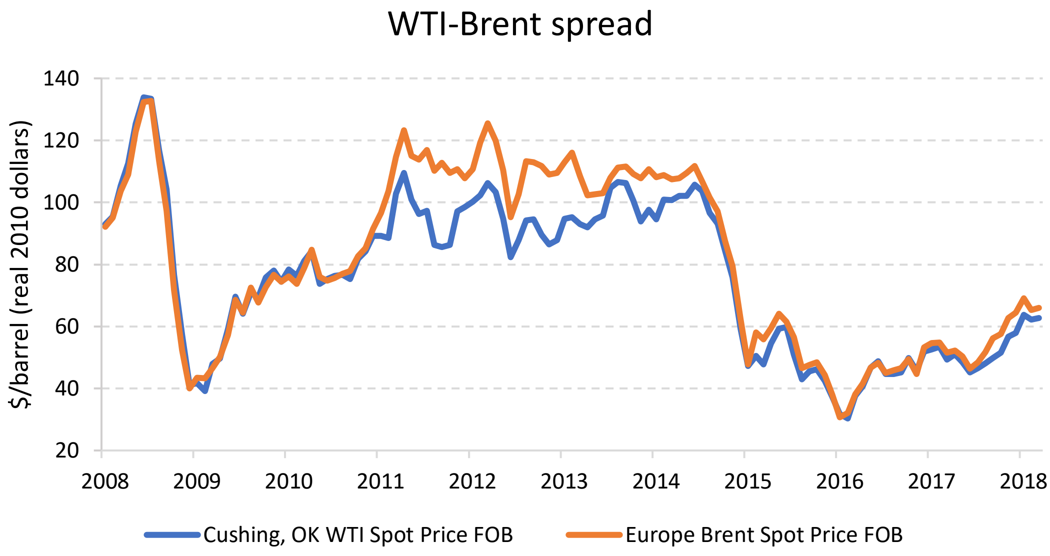

Figure 40. Fragmentation of the oil markets in 2011-2014, WTI-Brent spread historical evolution. Source: U.S. Energy Information Administration.

By the end of 2013, the oil glut in Cushing had softened thanks to:

- Obama's administration progressive export ban reliefs on crude oil (see Figure 35) which somehow remained under effect until the end of 2015, moment when the ban was officially lifted.

- Significant efforts to accommodate refining capacity in the Gulf Coast (most importantly in Texas).

- Exponential investment to expand transportation infrastructure throughout the whole country (such as the expansion and reversal of existing oil pipelines, new pipeline development and relevant increases of the rail and barge transport networks).

The oil glut in Cushing evidences that transport and refining infrastructure capacities evolving in parallel to LTO output growth act as a key milestone and are paramount to ensure efficient exploitation of this new energy resource.

In actual fact, the problem has not been fully resolved yet, as shown by the current $6 per barrel WTI-Brent spread forecast for 2018 published by the U.S. EIA in its November 2017 Short-Term Energy Outlook. Reasons behind the discount on U.S. light sweet oil remain increasing inventories and storage volumes at Cushing due to transportation constraints in moving domestically produced crude oil from Cushing and from the Permian basin in Texas to the Gulf Coast. To a lesser extent, another factor is the transportation cost of tight oil that cannot be economically processed in-house from the U.S. Gulf Coast to Asia (now exportable thanks to the removal of the crude oil export ban in 2015). To compete with Brent, WTI prices must reflect the additional transportation costs that U.S. oil flows incur given their temporary use of smaller and less-economic vessels and complex shipping agreements.

B. National constraints in refining and transportation infrastructure

Despite the incipient refinery nature and location constraints, the U.S. reacted quickly to absorb increasing amounts of crude production by building new refineries next to the main tight oil plays and adjusting Gulf Coast's technology and capacity to process lighter crude slates. The following map illustrates U.S. efforts to locate new refineries next to main shale formations and the increasing pipeline network built around both of them.

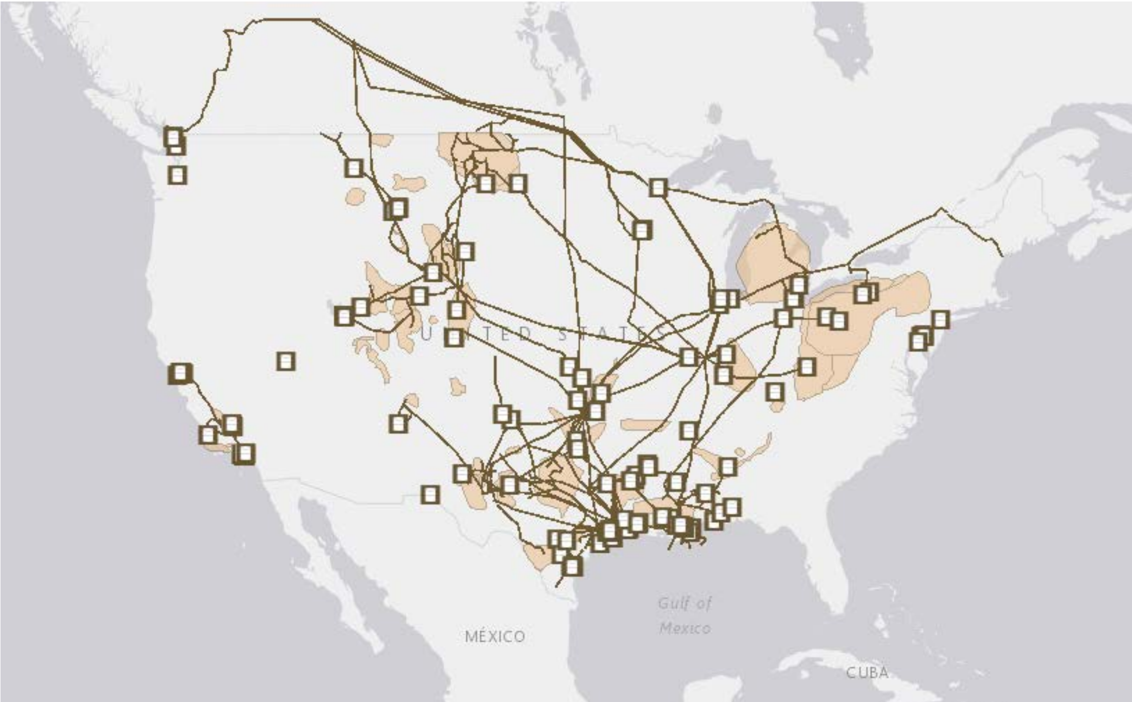

Figure 41. U.S. main tight oil formations, refineries and pipelines, 2018. Source: U.S. Energy Information Administration (Interactive Maps).

During the latest years, the key challenge to handle the ever-increasing LTO production has been the existence of appropriate transportation infrastructure to reach the main refining plants. There are three main oil transporting mechanisms in the U.S.: pipelines, rail transport and barge traffic.

Firstly, there has been considerable investment in expanding, reversing, and converting existing pipelines to increase the flow of crude oil to the refineries along the Gulf Coast. Some of the pipelines that historically sent crude oil from the Gulf Coast to northern U.S. (such as Midwestern areas) have been reversed, including Seaway Pipeline (from Cushing to Freeport Texas) and the Pegasus Pipeline (from Patoka, Illinois to Nederland, Texas). One major construction project has been part of the Keystone XL pipeline which connects U.S. oil hub to the Gulf Coast refiners. However, difficulties concerning terrain, legal permits and necessary long-lasting commitments from producers and financers for pipeline construction, in parallel with uncertainty about the future prospects of LTO and the short life cycles of tight oil plays (strong natural decline rates), impeded the incipient development of additional pipeline network to reach East Coast refiners (Kilian, 2016). Currently, bullish economic sentiment and significant firepower of infrastructure funds are facilitating major pipeline investments to minimise bottlenecks in the medium to long term.

Secondly, the rapidly growing production and the comparatively slow development of new pipeline capacity has led to increasing amount of oil transported by rail, truck or barge. In actual fact, during the shale oil boom several rail terminals were developed in North Dakota to move Bakken's crude oil to the East, West and Gulf Coasts, which led to a total of 70% of North Dakota's tight oil being transported by rail in 2014 (Kilian, 2016). The greater advantage of rail transport compared to pipelines comes from its flexibility: easier regulatory approval process and flexible volume shipment capabilities. Notwithstanding, rail transportation is more expensive that pipeline and its availability is limited to existing rail infrastructure.

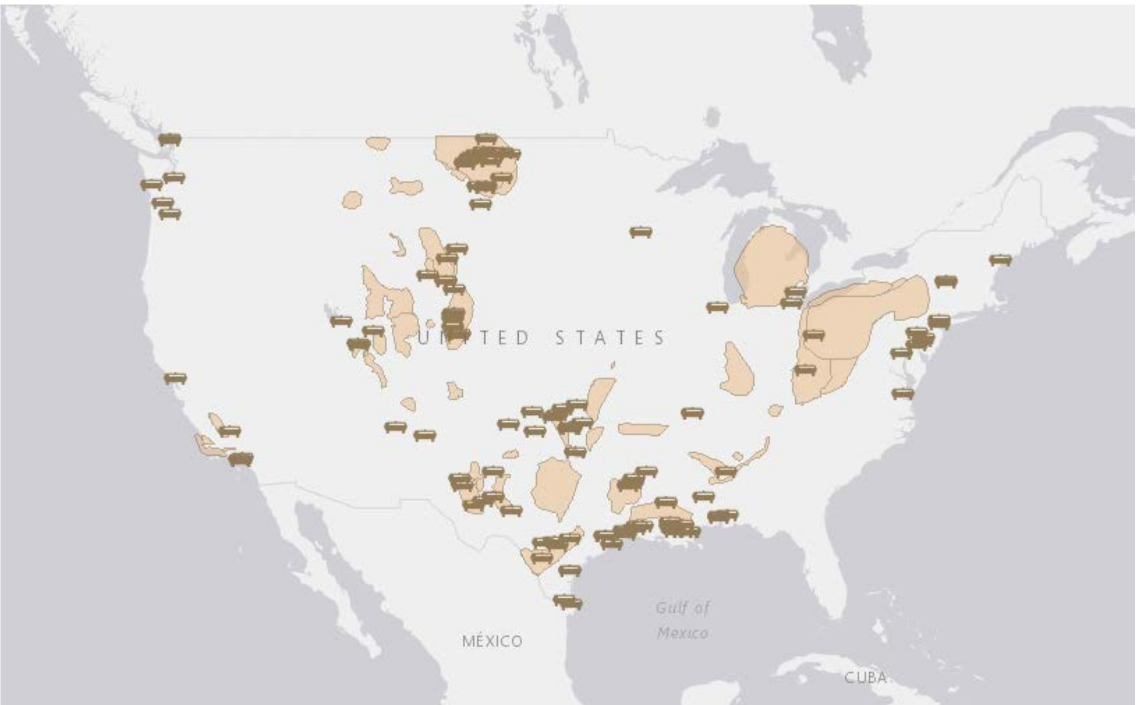

Figure 42. U.S. main tight oil formations and rail terminals, 2018. Source: U.S. Energy Information Administration (Interactive Maps).

Finally, oil barges transport oil on river and coastal waters, and are mainly shipping Eagle Ford's oil from the port at Corpus Christi, Texas, up to the Gulf and East Coasts. To a lesser extent, Bakken supplies have also been barged down the Mississipi River to Gulf Coast refineries (despite not being shown in the graph). Considerable oil ports are also being built to facilitate and make ship transport more flexible (Kilian, 2016).

Figure 43. U.S. main tight oil formations, river ways and oil ports, 2018. Source: U.S. Energy Information Administration (Interactive Maps).

4.1.2.1.5. U.S. as marginal producer and tight oil breakeven point dynamics

From 2011 to mid-2014, U.S. crude oil production increased from c. 7.5 mb/d to c. 11.0 mb/d (BP, 2017), primarily led by LTO production. This dramatic output growth experienced during the U.S. shale oil revolution does not mean that tight oil development economics are as good as those seen in conventional oil fields. Actually, shale oil wells set up requires specialized equipment (such as superior bottom hole assemblies capable of horizontal drilling and fleets of truck-mounted high-pressure high-volume pumps (Kleinberg, Paltsev, Ebinger, Hobbs, & Boersma, 2016)) which makes this technology both more costly and complex to construct. However, Brent crude oil generally traded above $100/bbl by those times, which enabled these start-up technologies to start expanding rapidly.

Following this astonishing trend, the public opinion anointed the U.S. as the number one rival to Saudi Arabia, but only as a marginal (The Economist, 2014). Analysts placed breakeven points of tight oil projects around $60/bbl to $90/bbl (EY, 2014) (Wood Mackenzie, 2014) (Bloomberg, 2014). It was widely believed that given tight oil wells' short life-cycles (production declines as much as 60-70% after the first year) and the significant amount of LTO being produced (c. 4% of global production), this breakeven point threshold acted as shock absorber which would bring stability to oil market prices. Hence, in an event of falling demand (and oil prices), it would be the U.S. production which would fall to adjust the overall supply-demand balance.

During the second half of 2014, LTO growth rates outstripped those of worldwide oil demand. Instead of reducing their quotas, the OPEC (and particularly Saudi Arabia) opened their oil taps further (see Figure 44) in an attempt to stop U.S. tight oil producers' quick advancement, gain market share and retain profits: *"If I reduce, what happens to my market share? The price will go up and the Russians, the Brazilians, U.S. Shale producers will take my share"* – Ali Al Naimi, Saudi Arabia Oil Minister - Abu Dhabi, December 2014. The oil market reacted aggressively to their modest supply increases with Brent crude oil price falling from c. $115/bbl in June 2014 to $48/bbl by January 2015 and to $29/bbl by January 2016, well below LTO breakeven price threshold computed by energy economists.

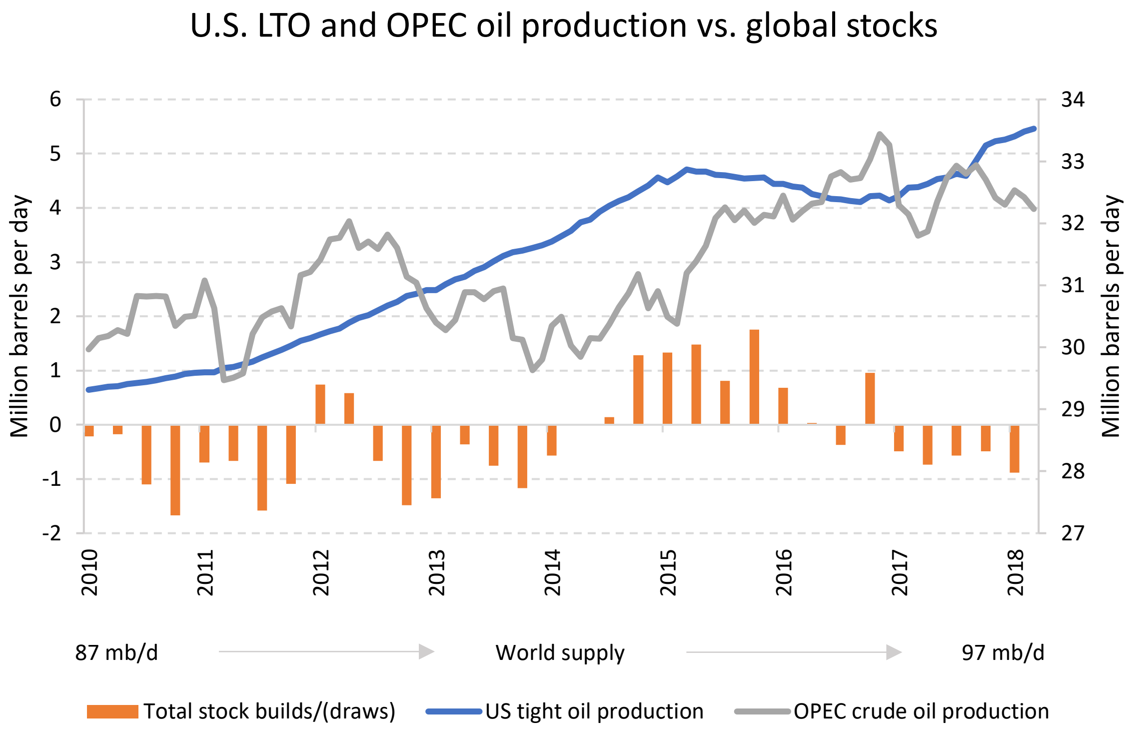

Figure 44. The growth of U.S. light tight oil production and OPEC decision to keep pumping oil upset the global balance between supply and demand, leading to persistent additions of oil stocks after mid 2014, in millions of barrels per day. Source: U.S. Energy Information Administration.

With oil prices nose diving, rig counts from the main shale plays entered into sharp decline (with a lag of two to three months). However, U.S. LTO supply did not decline as soon and as much as expected, and after all, the U.S. did not behave so much as a marginal producer as previously thought. In actual fact, production from the Eagle Ford play peaked with a lag of 9 months, output from the Bakken region kept growing until one year later (when it started to moderately decline), and production at the Permian basin continued to rise despite analysts' and oil experts' beliefs (see Figure 45). As OPEC reported in December 2016, *"the resilience of supply in the lower oil price environment caught the industry by surprise, particularly tight oil in North America"* (OPEC, 2016). Although there is no documented evidence that the OPEC acted on these assessments, we can speculate that this fact might have influenced their decision to swap strategy under their December 2016 OPEC-non-OPEC agreement with Russia to cut supply by 1.2 mb/d.

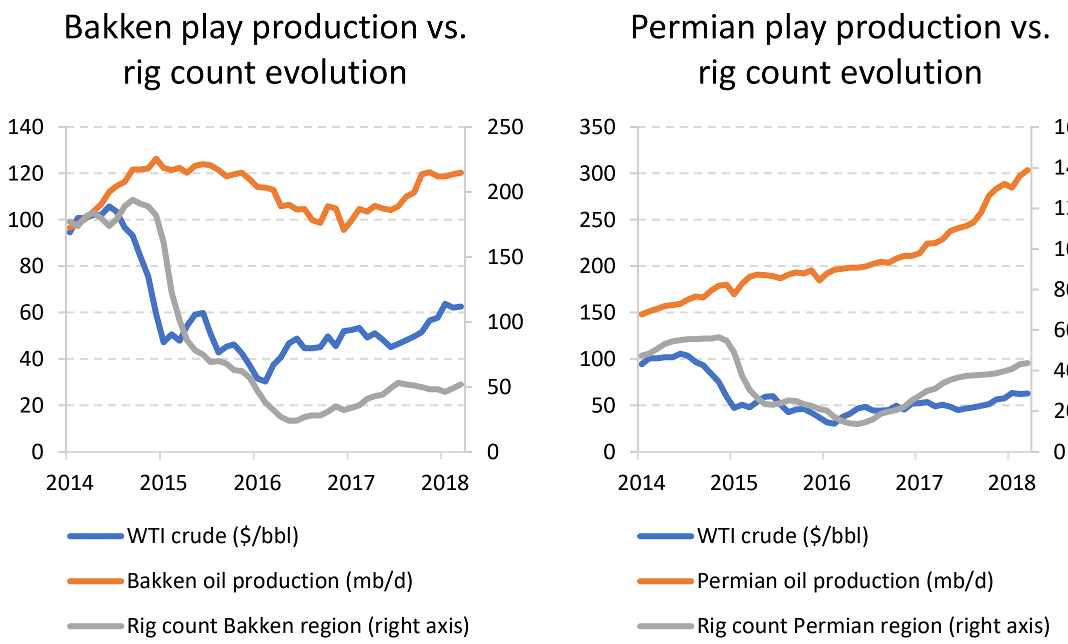

Figure 45. Production and rig count evolution for selected plays during 2014 oil downturn. Source: U.S. Energy Information Administration (Drilling Productivity Report), Bloomberg.

An important reason why the industry was “caught by surprise” is a misunderstanding of tight oil play’s breakeven point dynamics. It is paramount to understand U.S. LTO production dynamics and behaviour under different price scenarios when trying to forecast future output growth from these new resource in the medium to long term, and these dynamics are mostly driven by its economics.

A. Definition, types and factors affecting breakeven points

We need to first introduce the concept and different types of breakeven points given that in many publications they are presented without adequate disclosure of what exactly is meant by breakeven.

We can define breakeven point, also referred as breakeven price (or breakeven cost if looked from the project’s costs point of view), as the required market price for which the net present value of its future cash flows is zero. Defining a particular discount rate is relevant, as derived breakeven points figures might defer considerably. A general market practice is to take 10% as required rate of return.

Moreover, we can define multiple and different breakeven points for any given project. In particular, and concerning U.S. LTO production, there exists several breakeven prices which are relevant depending on which phase of the well’s development and exploitation cycle an investor is in. The following are highlighted (Kleinberg, Paltsev, Ebinger, Hobbs, & Boersma, 2016):

- *Lifting Costs (or Cash Cost)* is the incremental cost of producing one additional barrel of oil from an existing well in an existing field. It is similar to variable costs of production, but also includes general and administrative expenses, which are corporate overheads. Lifting costs is the appropriate breakeven point to use when the producer acknowledges a field is in decline and is functioning as a "cash cow", for which little or no further investment is anticipated in the present phase of the business cycle. In mid-2014, lifting costs for U.S. tight oil produced by horizontal well construction and massive hydraulic fracturing were below $15/bbl.

- *Half Cycle Breakeven Point* is the cost of oil production, including lifting cost, the expense of existing well workovers, and of drilling, completing, and stimulating additional wells in a developed field, with the goal of maintaining level production. The cost of financing these activities is also included. This measure is useful in case of "drilled and uncompleted" wells (DUCs), when an oilfield operator is under contractual obligation to continue drilling but wishes to conserve capital and delay production until market conditions are more favourable. In mid-2014, half cycle breakeven point for U.S. tight oil produced by horizontal well construction and massive hydraulic fracturing were in the range of $50/bbl to $70/bbl.

- *Full Cycle Breakeven Point* encompasses the cost of oil production including all expenses of developing a new field. It is thus the most comprehensive measure of the cost of oil, and is appropriately used when planning a major extension of operations. In mid-2014, full cycle breakeven point for U.S. tight oil produced by horizontal well construction and massive hydraulic fracturing were in the range of $60/bbl to $90/bbl.

It is also relevant to emphasize that the figures presented above are subject to substantial variance, as there are other factors that influence breakeven points. Hence, geological factors (such as wells located in richer zones within a given shale field), geographical factors (such as local availability of the necessary oil field infrastructure, existence of economies of scale and closeness leading to low transportation costs), quality factors (such as lighter and sweeter nature of the tight oil produced commanding premium prices), the pricing hub location (such as hubs located next to final oil purchasers with sufficient available transport capacity), and exchange rate factors (such as a devaluating home currency when costs are mostly domestic -e.g. Russia-) might derive to lower breakeven points than the presented above.

Full cycle			Capital expense	Finding	Exploration
					Leasing
					Reservoir delineation
				Development	Engineering
					Gathering pipelines
					Roads & other infrastructure
					Cost of financing field development
					Decommissioning
	Half cycle				Cost of financing well development
		DUC[8]			Well pad construction
					Well construction
					Drilling, casing, cementing
		F[9]			Completion
		Lifting cost	Operating expense	Production	Lease operating expense
					Repairs & maintenance
					Fuels and electric power
					Labour
					Royalties & taxes
					Transport to market
					Water & wate disposal
					General & administrative

Table 4. Components of various breakeven points. Source: MIT 2016[10]

[8] DUC represents the cost of wells that are drilled, cased, and cemented, but not completed.
[9] F represents the cost of fracturing or refracturing a well.
[10] Kleinberg, Paltsev, Ebinger, Hobbs, & Boersma, *Tight Oil Development Economics: Benchmarks, Breakeven Points, and Inelasticities*, 2016

B. Breakeven point dynamics

As mentioned earlier, the mid-2014 oil price collapse pushed rig counts downwards. Many U.S. exploration and production companies filed for bankruptcy between January 2015 and June 2016 (Haynes & Boone, 2016), which shows that the full cycle breakeven point around \$60-\$90/bbl was broadly accurate. However, breakeven points declined from \$76/bbl in June 2014 (Wood Mackenzie, 2014) to \$37/bbl in August 2016 (Wood Mackenzie, 2016) in several counties of the Permian basin, which made many players from the region survive during these tough oil market conditions (see Figure 46).

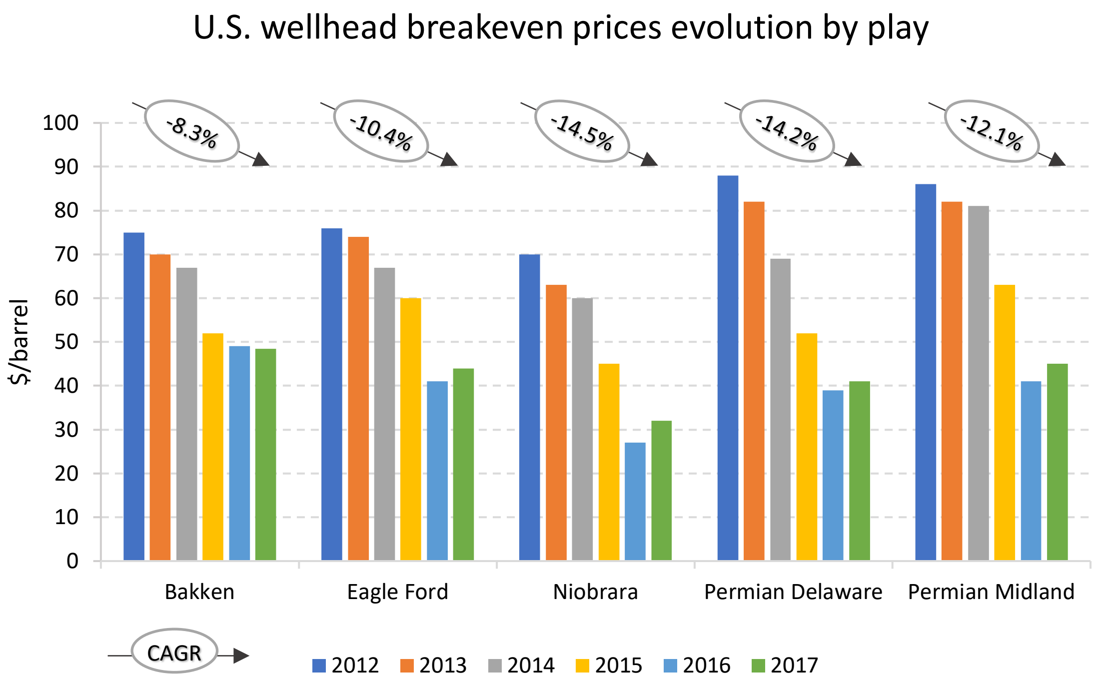

Figure 46. Evolution of full cycle wellhead breakeven prices by selected play. Source: World Oil Outlook 2040.

On the one hand, changes of U.S. tight oil plays' breakeven points come from two main sources (Kleinberg, Paltsev, Ebinger, Hobbs, & Boersma, 2016):

- *Endogenous changes* that reflect continuous improvements in infrastructure and efficiency, which generally lead to decreasing costs over time. Later in the development cycle, breakeven points fall thanks to supply chain and infrastructure debottlenecking, process optimization and increased competition among service providers. Decreasing costs can also happen in parallel to increasing production thanks to rises in rig productivity as expertise in the tight oil sector increases.

- *Exogenous changes* that take place due to changing economic conditions. For oil fields, breakeven points vary as a result of oil price movements. For example, production costs depend on capital, labour, and material inputs which are influenced by oil market conditions (with high oil prices producers are incentivized to grow quickly despite inefficiencies and service providers offer newer and costlier technology to meet producer's objectives, being the opposite also true for a low oil price environment). Moreover, rig productivity can rise sharply once oil prices fall low enough to allow for asset and operational high grading, which correspond to reducing activity to sweet spots and areas with existing infrastructure and the survival of the most modern and efficient rigs, manned by the most experienced and successful drilling crews.

The Permian basin example shows how quickly a price structure might change due to endogenous and exogenous changes. Even if oil-directed rig count fell by more than 75% from November 2014 to April 2016, LTO output kept increasing through 2016 (recall Figure 45). While stable oil prices from 2012 to 2014 doubled rig productivity through endogenous improvements, decreasing oil prices after mid-2014 triggered exogenous improvements, which grew rig productivity by another factor of 2.7 (see Figure 47), while well and production costs declined by 35% and 25%, respectively (Pioneer Natural Resources, 2017).

On the other hand, there is another important factor to bear in mind: the type of breakeven point which is relevant for each stage of the well exploitation changes over time. This tiered nature of breakeven prices is relevant given the considerable difference between each tier.

During the initial years of the U.S. shale oil boom, when oil prices were rising and as producers searched for new fields to exploit, investors and planners were mostly interested in full cycle breakeven points (as they also include, amongst others, exploration, reservoir delineation, engineering and infrastructure setting costs) which stood around $60/bbl to $90/bbl. Afterwards, during the episode of stable oil prices, most producers had already financed the necessary field development expenses (which became sunk costs) and began to focus on in-fill drilling. The half cycle breakeven point, which was in the range of $50/bbl to $70/bbl, was relevant at this stage as it also includes well development and construction costs but excludes field exploration and engineering costs. Finally, when oil prices sunk after mid-2014, players that had their rigs set up and were exploiting their wells focused on the immediate economic bankability of their existing assets, which can be benchmarked with its lifting costs (immediate operating expenses which, by that time, stood around $20/bbl). To these numbers, one must subtract the inherent decrease of the cost ranges due to endogenous and exogenous drivers (recall Figure 47[11]).

[11] Endogenous changes occur during periods of relatively stable oil prices, e.g. 2011 to mid-2014. Exogenous changes are driven by rapid declines in the price of oil with a certain lag, e.g. late-2014 through 2016.

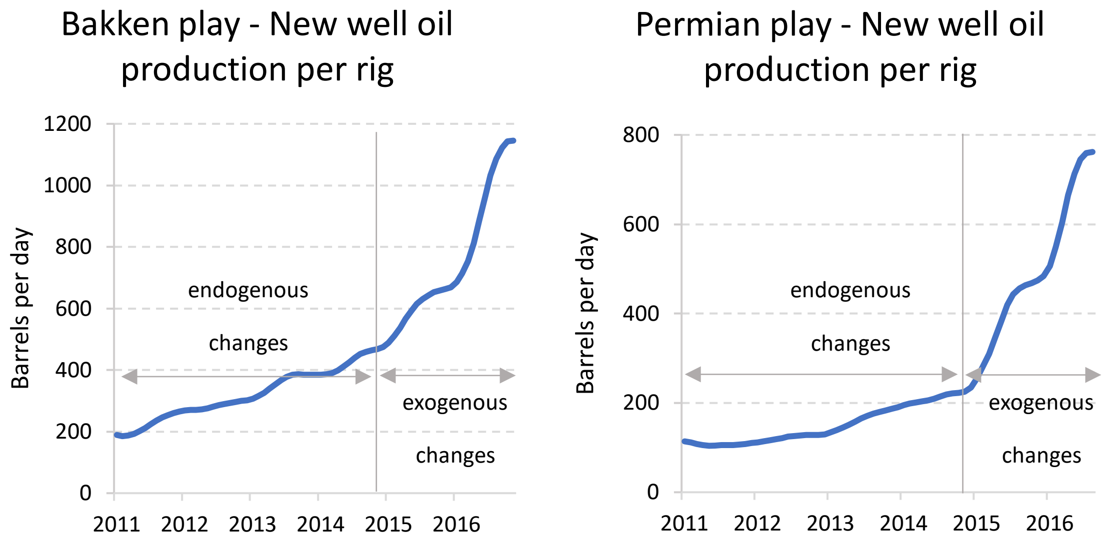

Figure 47. Productivity of drilling rigs directed to Bakken and Permian tight oil. Source: U.S. Energy Information Administration (Drilling Productivity Report).

To sum up, we can state that production of U.S. regions was actually sustained by relatively slow decline of substantial number of legacy tight oil wells, improvements in rig productivity (advanced technology and techniques providing efficiency gains), reduced costs of oil production (upstream drilling, labour and other), and a dynamic redefinition of breakeven points (Kleinberg, Paltsev, Ebinger, Hobbs, & Boersma, 2016).

Hence, when trying to forecast the survival of a relatively high-cost resource under a low price environment, one has to bear in mind the speed with which endogenous and exogenous factors might improve its economics (technological advances are critical and a lot of effort and investment is being put into these new resource), as well as the tiered nature of its relevant costs to producers and investors during its life-cycle. Moreover, significant variability of its breakeven points can be found based on several geological and geographical factors, amongst others. Hence, it is imperative to analyse individually the characteristics that prevail amongst those fields which are the most productive and therefore drive a significant part of the growth brought by that new resource.

4.1.2.1.6. U.S. as swing producer, spare capacity and shale oil as a game changer

Many noise has been made around the U.S. becoming the new swing producer, ousting Saudi Arabia, given its light sweet tight oil's exponential output rise (IHS, 2013) (Krane & Agerton, 2015) (Ezrati, 2015) (The Economist, 2015). We want to challenge this assumption.

We first begin by introducing the concept. Wikipedia defines a swing producer as *"a supplier or a close oligopolistic group of suppliers of any commodity, controlling its global deposits and possessing large spare production capacity. A swing producer is able* *to increase or decrease a commodity supply at minimal additional internal cost, and thus able to influence prices and balance the markets, providing downside protection in the short to medium term"*. As stated in the previous definition, a key feature characterizing a swing supplier is its spare production capacity. Moreover, EIA defines spare capacity as *"the volume of production that can be brought online within 30 days and sustained for at least 90 days. If a supply disruption occurs, oil producers can use spare capacity to moderate increases in world oil prices by boosting production to offset reduced oil supplies"* (U.S. Energy Information Administration, 2018).

In an event of supply disruption, it is pretty clear that Saudi Arabia, in concert with other OPEC members, can coordinate their actions so as to supply considerable more barrels per day that quickly. However, within this game the U.S. is clearly out of play. Currently, the U.S. oil industry is not only facing significant struggles building up sufficient infrastructure to move their LTO production to refineries within the country and abroad, but also their relatively high cost structure would make it unfeasible to increase production in a low oil price environment. In addition, it is also unlikely that hundreds of independent producers (exploiting disparate resources and worrying about their own interests and benefits) can coordinate their actions as OPEC members do.

In actual fact, Americans showed its lack of coordination skills with the oil glut in Cushing (causing Brent-WTI spread to reach unprecedented levels), which led to Saudi Arabia and OPEC facing calls to curb production in response in 2014. Ali al-Naimi called it a "historic decision" for OPEC to rely on market forces rather than controlling prices as a swing producer, which only shows that they were able to balance supply and demand, but were not interested in doing so to gain back market share.

Consequently, we believe that anointing nowadays the U.S. as the new swing supplier is not accurate nor correct. Notwithstanding, significant amounts of U.S. light sweet oil flowing into the market have the potential to impose significant discipline on crude oil pricing. For sure, the most economically recoverable resources and productive wells from the main shale formations in the U.S. proved resilient despite bottomed oil prices. Their proved resilience will prevent future strategies from lower-cost oil-dependent competitors to increase production in an attempt to gain market share, which already shows that U.S. tight oil is changing the rules of the game somehow.

Into the future, further reductions of breakeven points through technological improvements and enhanced transportation network and infrastructure are key pillars to make the U.S. a real threat to Saudi Arabia as swing producer. Moreover, to determine if the U.S. shale is a real game changer, we need to understand how long will this new resource last and how much flow of oil it can bring into the system, a topic that will be covered in the next chapter.

4.1.2.2. Resources and reserves

According to the U.S. EIA, the U.S. held an estimated amount of 35.2bn barrels of crude oil and lease condensate of proved reserves (demonstrated with reasonable certainty and recoverable under existing economic and operating conditions) at 2016 year-end, with almost no increase with respect to 2015 figures. The onshore lower-48 states proven reserves increased by 3% (c. 846m barrels) which offset the 865m barrels decrease in Alaska's and in the Federal Offshore (both Pacific and the Gulf of Mexico) (U.S. Energy Information Administration).

Moreover, proven reserves in the U.S. are pretty concentrated along the Gulf Coast. As seen in Figure 48, Texas held most of the proven reserves and saw the largest volumetric increase from 2015 to 2016. Most reserve additions were in the form of field extensions in the Spraberry Trend Area and Wolfcamp shale play in west Texas (U.S. Energy Information Administration).

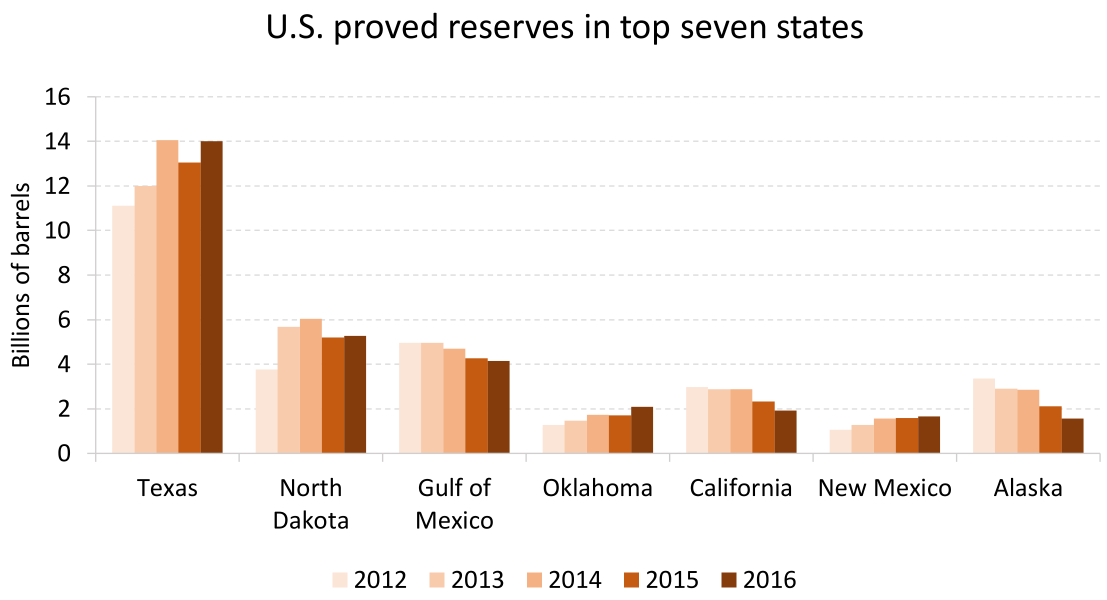

Figure 48. Proved reserves of the top seven U.S. oil reserves states, includes crude oil and lease condensates. Source: U.S. Energy Information Administration.

BP Statistical Review of World Energy 2017 figures for proven oil reserves (including crude oil, gas condensate and natural gas liquids) assigns a total of 48bn barrels to the U.S. (considerably higher than EIA's 35.2bn estimation), accounting for a relatively small 2.8% share of total proven oil reserves. To get a sense of dimension, Venezuela and Saudi Arabia alone hold a 17.6% and 15.6% share of world's proven oil reserves, respectively. Notwithstanding, the U.S. holds the ninth position as for oil proven reserves. Moreover, U.S. reserves to production (R/P) ratio stood around 10.6 for 2016 (BP, 2017).

Moreover, Figure 49 shows the significant increase that the U.S. has seen in its total proven oil reserves since 2008.

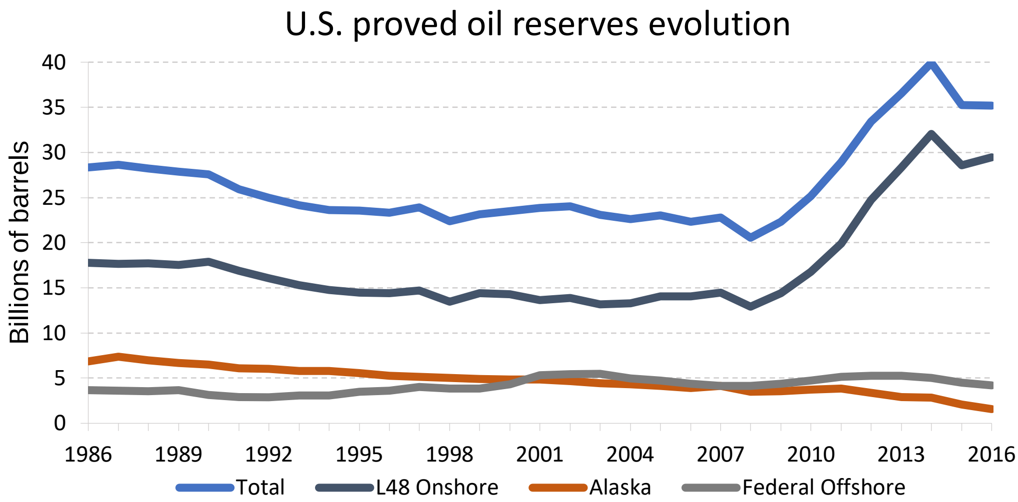

Figure 49. U.S. proved oil reserves evolution, includes crude oil and lease condensates. Source: U.S. Energy Information Administration.

More interestingly, a study carried out by the U.S. EIA in 2013 (and updated afterwards in 2015) about world's technically recoverable shale oil and shale gas resources estimated that the U.S. held an astonishing unproved total of 78.2bn barrels of tight oil, the largest among all assessed basins worldwide (followed by Russia's with 74.6bn barrels). In its latest update in April 2018, the EIA has revised upward these c. 80bn barrels of unproved technically recoverable tight/shale crude oil resource to 103.8bn barrels as of January 2016. With these new figures, total technically recoverable U.S. crude oil resources rises to 285bn barrels (U.S. Energy Information Agency, 2018).

Significant uncertainty remains on U.S. tight oil potential: if we sum altogether the highest and lowest resource estimates for individual plays within the U.S., technically recoverable resources could range from less than 50bn barrels to well above 190bn barrels (International Energy Agency, 2017). With this outlined, it is clear that precise projections on U.S. shale oil revolution scale will unlikely to be seen until the understanding of this resource potential increases. However, resource estimations do nothing but rise, so we should not expect shale oil's plateau to happen in the short term.

4.1.2.4. Oil production outlook

Literature review shows relatively similar views as for U.S. oil liquids supply prospects in the medium term, up to 2025. However, in their respective reference case scenarios, OPEC 2017 World Oil Output's and IEA 2017 World Economic Outlook's long-term views differ significantly with the US EIA 2018 Annual Energy Outlook's projections. While OPEC and IEA analysts believe that a plateau will be reached by 2025 at c. 17 mb/d (with the U.S. becoming the undisputable top dog) and that subsequent years' production would fall at c. 1% per annum (falling to c. 14.5 mb/d by 2040), the US EIA predicts a brighter future for U.S. crude oil output which remains at c. 17 mb/d by 2040 (see Figure 50).

In all cases, it is LTO output the undisputable growth driver in the medium term, accounting for up to 80% of the net increase in production to 2025 (International Energy Agency, 2017). Tight oil production's contribution has also been significantly revised upwards (almost doubling it from 2016 reports) mainly in the back of higher resource estimates, but also factoring in U.S. LTO's proven resilience and ability to quickly bounce back in a higher oil price environment. Notwithstanding, other sources of growth, such as the Gulf of Mexico offshore crude (i.e. ultra-deep water project Mad Dog II) and multiple onshore pockets in the lower-48 states, are also expected to remain buoyant (OPEC, 2017) (U.S. Energy Information Administration, EIA, 2018). In the medium term, oil output growth in the reference case is justified by:

- Higher-than-expected prices and, most relevantly, generalized bullish market sentiment leading to increased upstream activity and investment. A strategic shift has been seen by major companies in favour of investment in shorter cycle projects, which will boost rig count and flourish LTO production.

- Decreased well-head breakeven prices, continued cost reductions, increased recovery rates and efficiency optimisation in the most prolific plays, which are also expected to keep improving through technological innovation.

- Achieved infrastructure debottlenecking in parallel with major ongoing projects to assure that significant oil output growth can be handled.

- Increased light sweet oil refinery capacity. New condensate splitters are also likely to come online in the short-term future. However, increased export activity will be needed to avoid piling up high-quality inventories above acceptable levels. (see Figure 51)

These buoyant projections last until 2025 in OPEC's and IEA's base case scenario. Despite continuous technology and efficiency gains, costs will begin to rise considerably once sweet spots are depleted and second and third-tier acreages begin to be exploited, which will undermine tight oil project's economics.

However, one must bear in mind that this reference case plateau is subject to considerable uncertainty: besides crude oil prices, the quality and amount of reserves assumption is critical when defining for how long and how high LTO production can rise and this figure varies significantly within studies as mentioned before. Moreover, tight oil and unconventional NGL production estimation is difficult considering that large portions of the known shale formations have relatively little or no production history, and extraction techniques and practices continue to evolve rapidly. Hence, they are also susceptible to significant variability.

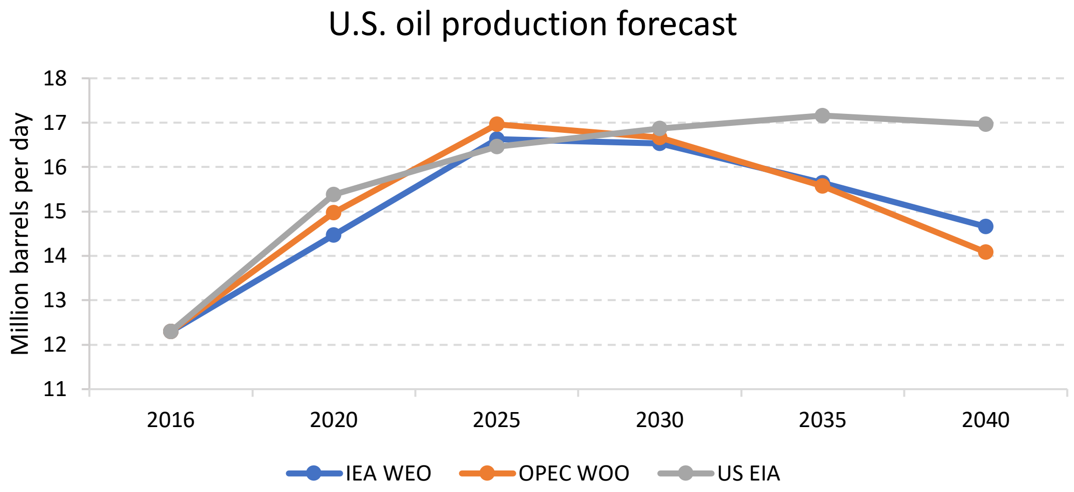

Figure 50. U.S. long-term oil liquids supply outlook, in millions of barrels per day. Source: BP Statistical Review of World Energy 2017, Annual Energy Outlook 2018, World Energy Outlook 2017, World Oil Outlook 2040.

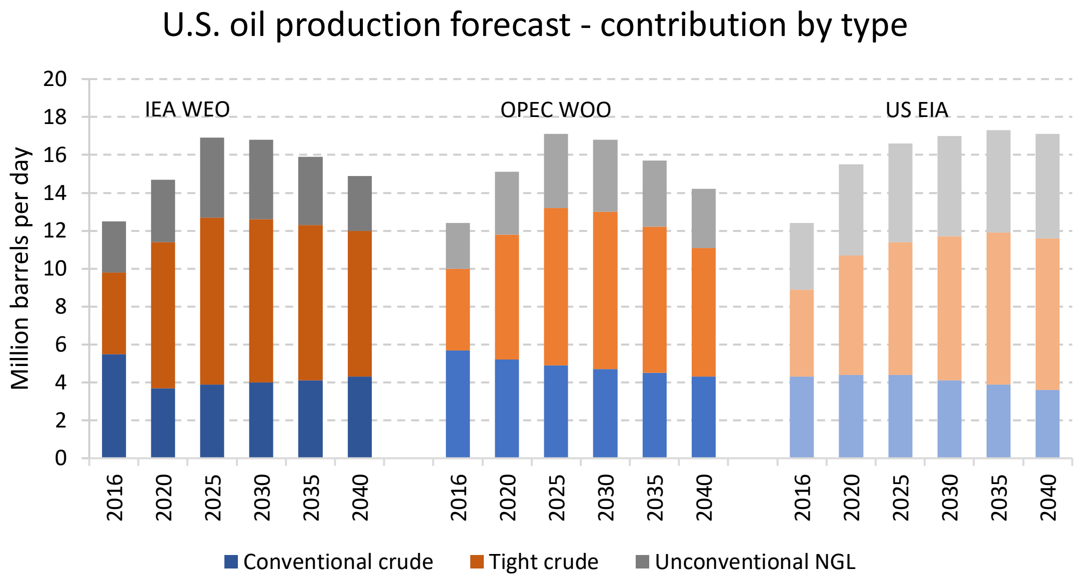

Figure 51. U.S. long-term oil liquids supply outlook, in millions of barrels per day. Source: Annual Energy Outlook 2018, World Energy Outlook 2017, World Oil Outlook 2040.

To conclude, there is high ambiguity on how long will the shale oil boom last (as this is directly linked to tight oil reserves assumptions) and whether if the US's oil supply will decrease sharply thereafter or remain at c. 17 mb/d, at least until 2040. However, there is small chance that the country won't see a significant rise in its output capacity (becoming the undisputable production leader before 2020) in the medium term given the current macroeconomic, geological and technological conditions.

4.1.3. Russia

Russia's crude oil and petroleum products production and export capabilities are of crucial importance both to the domestic economy and to the global energy market.

In 2016, crude oil and refined petroleum accounted for about 26% and 16%, respectively, of Russia's $262bn exports of goods and services (United Nations, 2016) and the oil and gas industry contributed almost 36% of Russia's federal budget revenues (U.S. Energy Information Administration, 2017), and 18% of total Russian GDP (Ministry of Energy of the Russian Federation, 2018). Moreover, companies that operate in the oil industry account for about half of the Russian stock market index, making both the index and the rouble exchange rate highly dependent on oil price evolution (Simola & Solanko, 2017).

Globally, in 2016 Russia was the third largest oil producer after the US and Saudi Arabia with a share of 12% of world oil production and the leading oil exporting country responsible for 13% of total oil exports (BP, 2017). Consequently, changes in its output might lead to a significant impact on the global demand-supply balance, ultimately affecting oil prices.

Additionally, Russia's strategic geographic location nearby key energy-dependent importing countries such as Europe, China or India, along with its extensive network of ports and pipelines in the Atlantic and Pacific basins, make Russian exports reach economically any place around the world. Hence, Russia's global reach acts as a key pillar of the country's position as a global energy superpower, providing the Kremlin with significant geopolitical influence despite deteriorating relationships with many countries in the international community after the 2014 crisis in Ukraine.

This economic dependence on oil has had its drawbacks in the latest years due to the effects of plummeted oil prices since mid-2014, which was a catalyst for more than two years of recession in Russia. The effects of US and EU sanctions and the lack of economic reform also had roles to play and should be analysed when discussing Russian oil production outlook.

Other factors, such as the government tax policy in the energy sector, the effects of a depreciating rouble, the revised upstream expenditure plans and refinery upgrading commitments, the impact of delays in the arctic and tight oil developments, the potential for enhanced oil recovery at existing fields, and the effects of the new alliance with OPEC will be analysed so as to have a clearer view on Russia's potential future oil production behaviour.

4.1.2.3. Historical overview

The history of Russian production over the past quarter of the century can be broken down into three clear periods and provide light on the key areas of interest when predicting the future oil output.

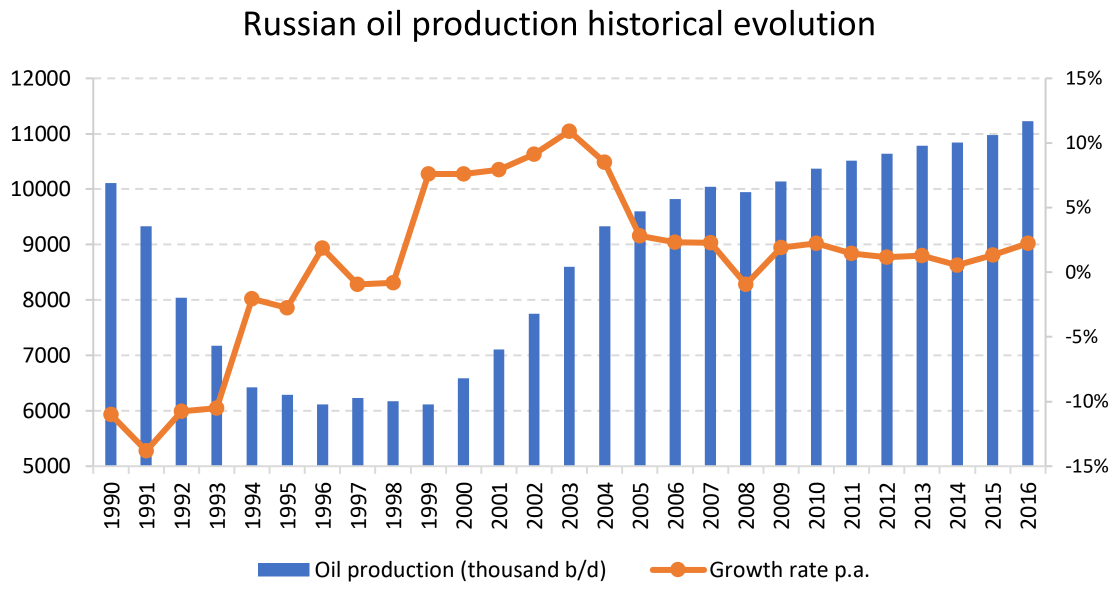

Figure 52. Russian oil production historical evolution. Source: BP Statistical Review of World Energy (2001, 2006 and 2017).

First, from 1990 to 1999, a sharp fall in investment led to a rapid decline in output driven by a collapsing Russian economy, which was unable to invest in Soviet-era fields in West Siberia, new oil field discovery or refinery upgrading. The problem of Russian fields is that natural decline can be as high as 10-15% per annum due to the geology of the fields, and the significant amounts of water as well as oil that are produced (Henderson, Key Determinants for the Future of Russian Oil Production and Exports, 2015). Hence, investment constraints led to significant output shortages.

Second, from 1999 to 2005, rising oil prices and Russia's economic recovery provided some extra revenues that were deployed to enhance the recovery rates at existing fields and to develop new greenfield projects. A buoyant private sector and international oil majors' involvement were key to achieve an average annual increase in production of 7.5% (International Energy Agency, 2014).

Finally, from 2005 to the present, a much slower increase in oil production has been seen, averaging 1.4% per annum (BP, 2017). This slowdown follows a considerable industry consolidation into larger and more bureaucratic entities and the rise in dominance of state-controlled companies, such as Rosneft and GazpromNeft as key players (respectively accounting for about 38% and 11% share of total Russian oil production) (Baev, 2016), which appear to be much less effective at growing production compared to the small Russian private enterprise. Moreover, western sanctions following Russia's annexation of Crimea from Ukraine as well as the dramatic oil price fall in mid-2014 have made it more difficult for Russian oil companies to sustain output growth.

Oil and condensate production in Russia grew by 2.2% in 2016, following an increase of 1.3% in 2015 (BP, 2017). Even if there exists some stagnation driven by the increased difficulty and cost to counter high natural decline rates in the production of traditional fields in Western Siberia, better-than-expected improvements in production efficiency, reservoir productivity (such as the significant growth in horizontal wells) and the introduction of new fields in the Russian Far East, Eastern Siberia and the Arctic region have replaced the production of the traditional fields, but have not been enough yet to maintain the previous growth rates.

4.1.3.2. Oil fiscal policy

The consistent, even if non-linear, growth of production since 2000 suggests that the Russian government does have a fairly successful history of making ad hoc adjustments to the tax regime to encourage the maintenance in crude output. In actual fact, in the last decade, the Russian oil sector evolution has been shaped by a number of key tax reforms affecting the production-based Mineral Resources Extraction Tax (MRET), which has a fixed component per tonne produced and a variable component dependent on the oil price and the rouble-dollar exchange rate, and the exports customs duty on crude oil (CED) and oil products. These two revenue-based fiscal instruments are being used as important strategic levers to balance the attractiveness of upstream and downstream operations and investment.

4.1.3.2.1. Tax breaks, international involvement and US and EU sanctions

From 2008 onwards, as it became clear that many of the older and larger fields in Russia were reaching the limits of their productive capacity, a number of miscellaneous tax benefits and privileges (applied to MRET and CED) were put in place in order to incentivise specific investment projects. Special features related to the production location and process might justify tax relief. To support new production, taxation of fields recently brought on-stream and fields subject to difficult production conditions generally received large tax discounts.

These special tax rates or tax holidays to encourage investment in difficult-to-develop resources and Russia's potentially vast resources, such as Arctic offshore and low-permeability reservoirs (including shale reservoirs), were crucial to attract many international companies, who entered into partnerships with Russian firms to explore Arctic and shale resources. As examples, ExxonMobil, Shell, BP, and Statoil all signed agreements with Russian companies to explore shale resources. Moreover, ExxonMobil, Eni, Statoil, and China National Petroleum Company (CNPC) all partnered with Rosneft in 2012 and 2013 to explore Arctic fields (U.S. Energy Information Administration, 2017).

However, in 2014, in response to Russia's actions with respect to Ukraine, the US and Europe imposed a series of sanctions on Russia which basically restrict Russian major oil, financial and defence companies' access to western capital markets and also prohibited the export to Russia of goods, services and technology in support of deep-water, Arctic offshore, or shale projects. These sanctions have not been withdrawn yet, but actually tightened, as proven with the US's new legislation code published in August 2017, which extended the prohibition on providing technology in support of projects to cover not only projects in Russia, but also projects anywhere in the world in which a person or entity already subject to sanctions owns 33% or more of the project (U.S. Energy Information Administration, 2017).

Following the sanctions, considerable involvement in Arctic offshore and shale projects by Western companies (such as Exxonn, Shell or Total) were suspended, and it is unlikely that these projects will continue in full without western's large-scale investments. However, no major effect on Russian short-term production have followed US and EU sanctions given that these projects were expected to begin producing in 5 to 10 years at the earliest. We must bear in mind, notwithstanding, that sanctions will undermine Russia's ability to offset considerable decline rates in mature production areas in the medium-term when defining oil output forecasts.

4.1.3.2.2. Lower oil prices, rouble devaluation and marginal tax rates

In parallel to western sanctions, oil prices began to fall from over \$100/bbl in the first half of 2014 to less than \$50/bbl by January 2015 and \$30/bbl by January 2016. This massive fall in oil prices would generally degrade profitability and derive into significant cuts in spending at both brownfield management and greenfield development levels. Notwithstanding, and despite high natural decline rates from large traditional fields, Russian oil companies have been able not only to sustain production growth in 2014 and 2015, but also to achieve a 2.2% output growth for 2016 (BP, 2017).

An element that helps explain this phenomenon is the marginal rate and sliding scale of Russia's taxes on the oil industry based on oil prices. This protects oil companies' cash flows considerably more than government revenue from oil price declines. This element, in parallel to the important rouble devaluation that came after Putin switched to a flexible exchange rate regime in November 2014 (which was key as it significantly reduced costs in US dollar terms given that c. 80% of the industry costs are domestic (International Monetary Fund, 2017)), led to low US dollar breakeven prices which justify Russia's production resilience despite sanctions and volatile oil markets over the past three years (see Figure 53 and Figure 54).

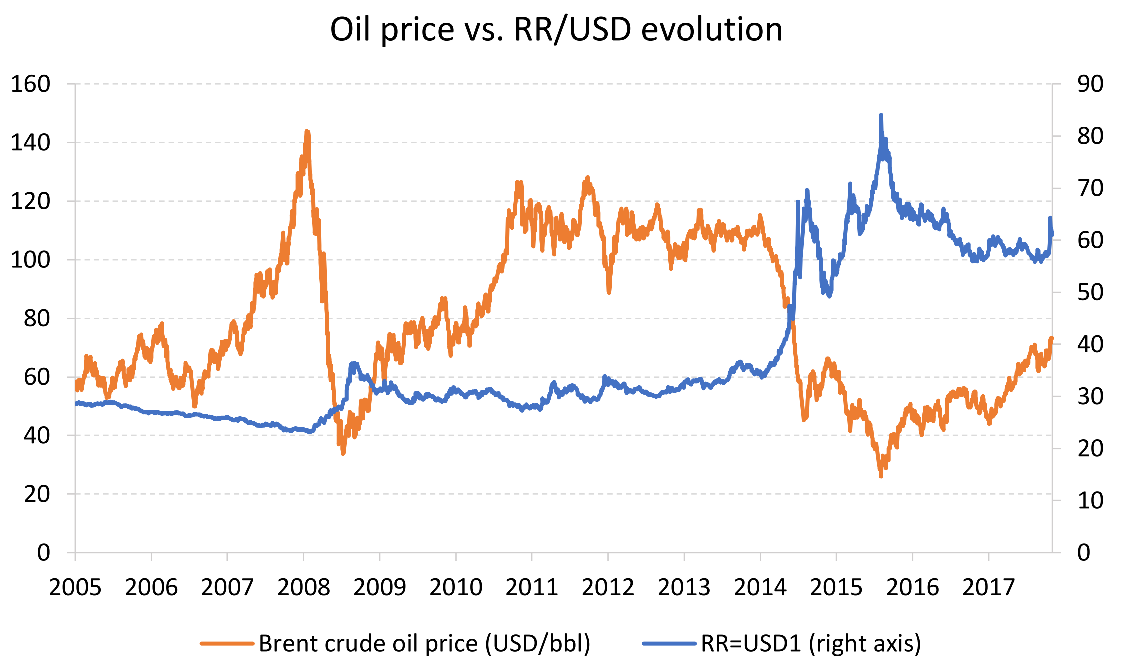

Figure 53. The movement of the oil price and the Russian rouble. Source: Thomson Reuters, The Central Bank of the Russian Federation.

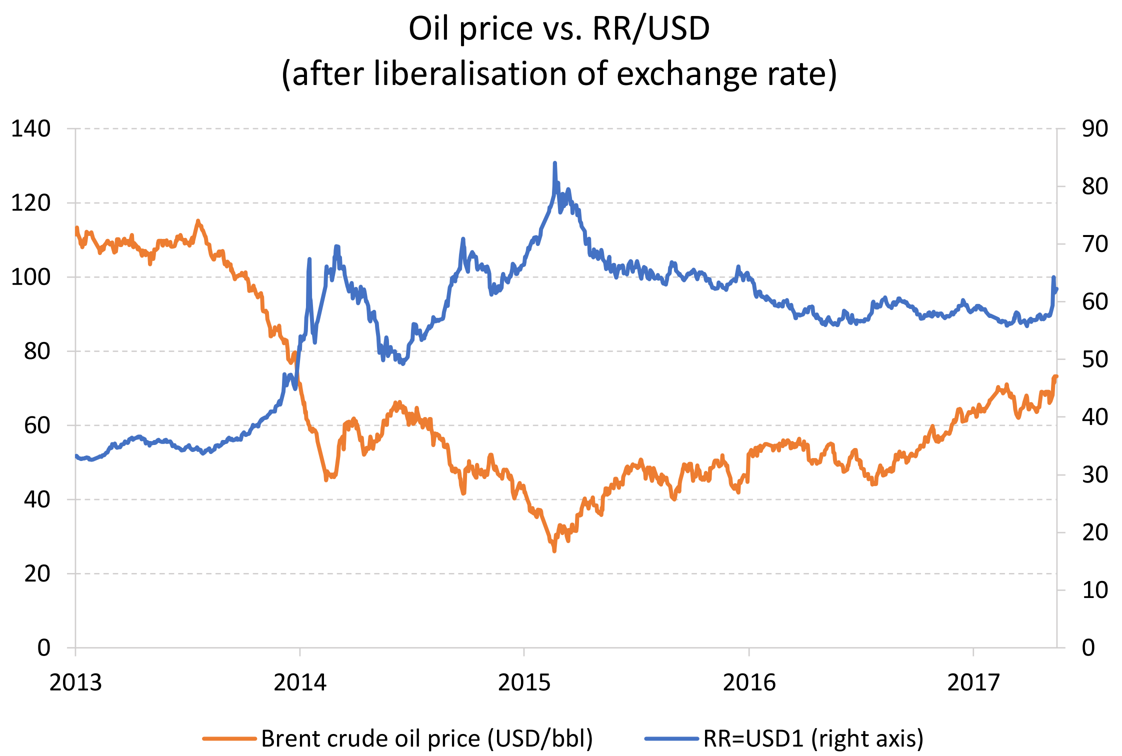

Figure 54. The symmetric movement of the oil price and the Russian rouble after the exchange rate liberalisation in November 2014. Source: Thomson Reuters, The Central Bank of the Russian Federation.

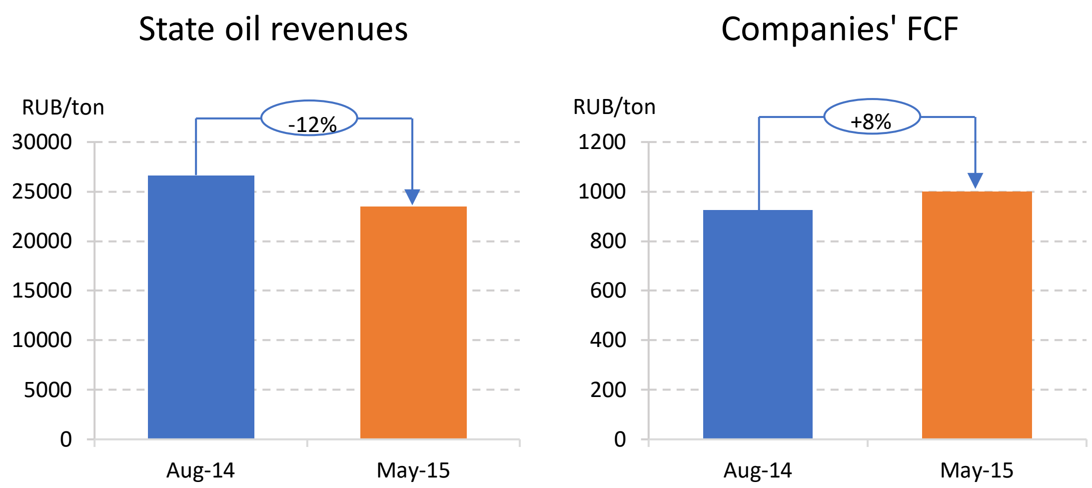

Figure 55. Russian government revenue and companies' FCF impact of 2014 oil price collapse. Source: EY (2015)[12].

The impact of Russian marginal oil taxes on the overall cost base at different oil prices can be seen in Figure 56. From the graph we can conclude that:

- Cash cost without government payments for conventional oil production in Russia stands below \$10/bbl. Russia's cash cost before state tax burden is relatively low compared to other relevant oil producing countries. For example, Rystad Energy research analysts locate Russia's cash costs at c. \$7/bbl, same level as Saudi Arabia. There are a few lower-cash costs countries, such as United Arab Emirates, Iran and other Persian Gulf states (c. \$4/bbl to \$6/bbl). However, cash costs are higher for other relevant players such as Iraq or the U.S., whose cash costs stand at c. \$9/bbl and c. \$12/bbl, respectively (Rystad Energy, 2016).

- Cash flows after government payments and taxes do not decrease proportionally as much as oil prices, which explains Russian oil companies' resilience during the 2014 oil price collapse.

- Russia's production after taxes and at current oil prices (c. \$65/bbl) can breakeven at below \$11/bbl, so that companies are nowadays still incentivized to maintain output growth at existing fields.

Moreover, development costs of new fields average c. \$6/bbl and the breakeven point for investment in new production stands at c. \$20/bbl (Henderson & Grushevenko, 2017). Hence, margins enable Russian oil companies to generate enough cash flow to partly finance these levels of expenditures.

[12] Kondrashov, *Taxation in the Russian oil sector: learning from global fiscal perspectives*, 2015

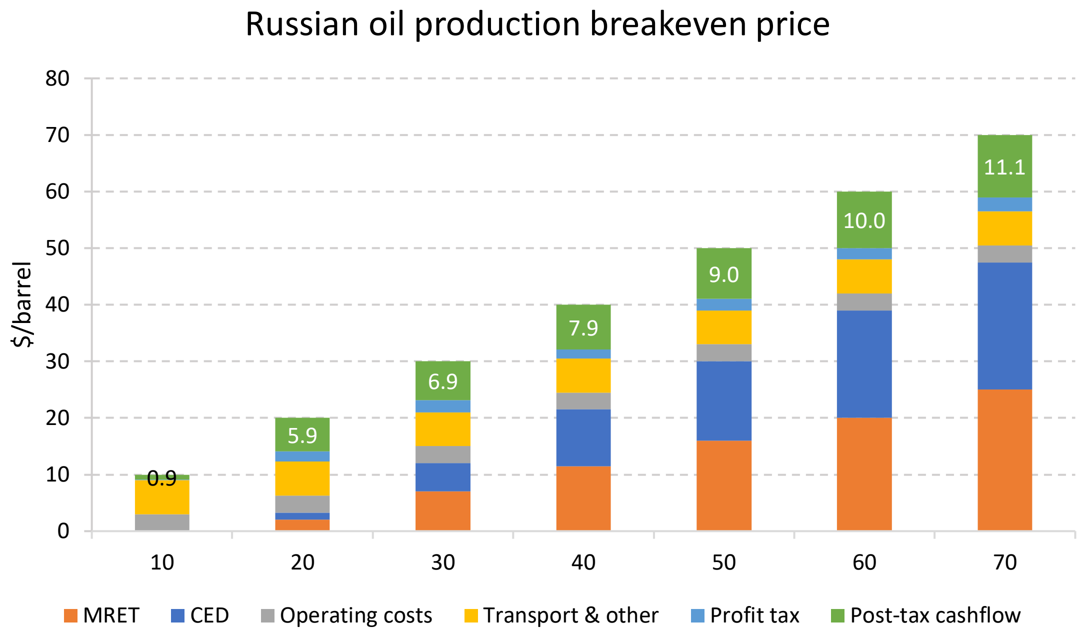

Figure 56. Breakeven price of Russian conventional oil production, in USD/bbl. Source: Oxford Institute for Energy Studies (2017)[13]*.*

Note than this breakeven point analysis has been done for a traditional field. In case of difficult-to-develop reserves, Enhanced Oil Recovery techniques (EOR) and capital intensive projects require subsidies, tax benefits and reliefs in order to achieve investor's minimum acceptable rate of return.

Overall, the decline in value of the rouble and the structure of Russia's taxation system has enabled Russian operators to resist the oil and economic downturn in the later years. Low cash costs seem to suggest that profitability of Russia's conventional oil fields exploitation is guaranteed. However, non-traditional oil sources will still need to be subsidized in order to be bankable. In an event of the Russian rouble stabilizing back to 2013 levels (recall Figure 53), there will be a considerable downgrade of the industry's profitability and ability to invest in new production development, leading to significant output shortages in the medium term. We must be cautious when predicting production outlook given that costs in dollar terms are currently in a very favourable situation.

4.1.3.2.3. The tax manoeuver, OPEC agreement and the profit-based fiscal system

Even if the devaluation of the rouble and the sliding scale nature of Russian oil taxation softened the impact of the decline in oil prices in Russian oil companies, the Russian balance was considerably hit and the government had to intervene by implementing further fiscal reforms (the "tax manoeuver") so as to increase oil export revenues and maintain output growth without damaging state's budget balance in excess.

[13] Henderson & Grushevenko, *Russian Oil Production Outlook to 2020*, 2017

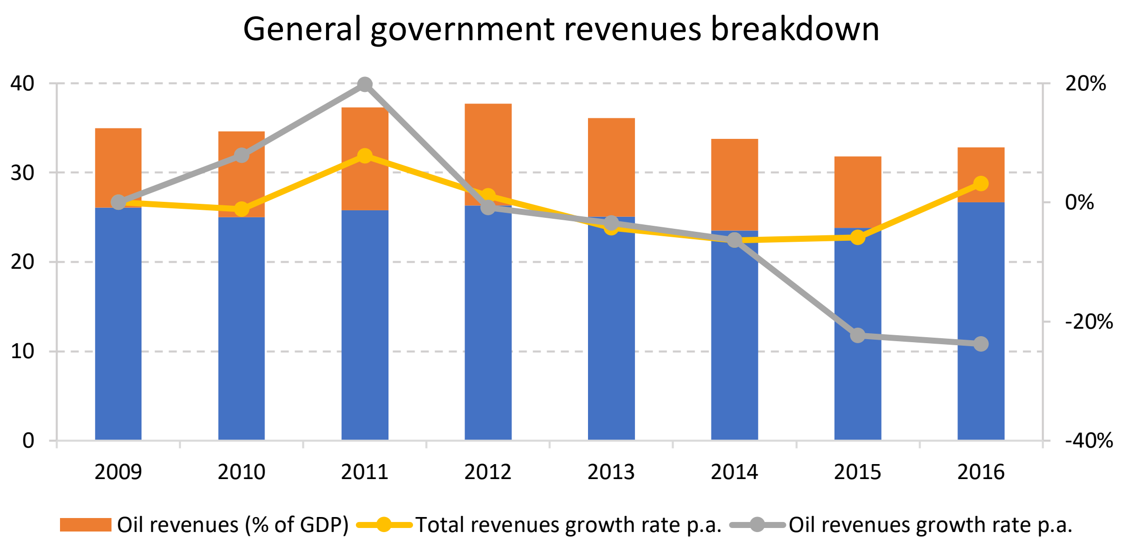

Figure 57. Russian general government budget revenues breakdown, as % of GDP. Source: International Monetary Fund (2014 and 2017) [14].

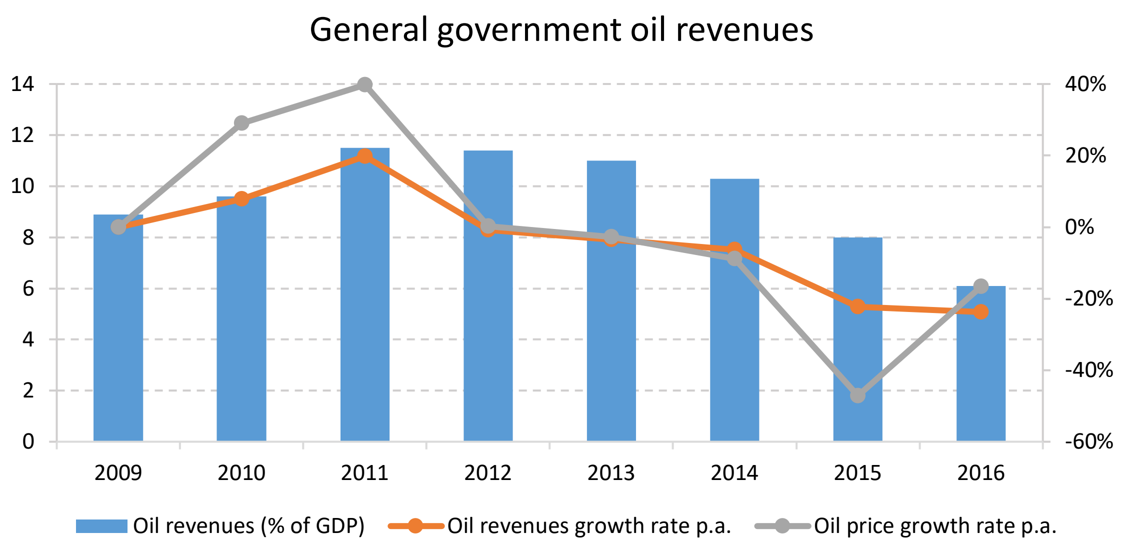

Figure 58. Russian general government oil budget revenues evolution, as % of GDP. Source: International Monetary Fund (2014 and 2017) [15].

Until the first "tax manoeuver" introduced in January 2015, and as the car fleet became more modern, the growing demand for gasoline and diesel in Russia made the government try to encourage oil companies to export low-value fuel oil profitably while keeping gasoline and diesel in the domestic market. Hence, the tax system subsidized oil refiners, maintaining inefficient and too old-fashioned refining production. Due to high

[14] International Monetary Fund, Russian Federation Article IV Consultation, 2014 and 2017
[15] International Monetary Fund, Russian Federation Article IV Consultation, 2014 and 2017

crude oil export duties (CED), it was more profitable for oil producers to sell oil even at a significantly lower price to domestic refiners than to export it.

With the "tax manoeuver", and one year later the "big tax manoeuver", there was a considerable decrease in CED (from 59% to 30% cap rate by 2017) and high-quality oil products ED balanced with a rise in fuel oil ED (from 66% to 100% of the CED by 2017) and a marginal royalty (MRET) tax increase (PwC, 2014). The objective of these reforms were to incentivize export of crude oil, energy efficient growth, stimulate the sector's modernization and undermine the economics of making heavy oil products such as fuel oil, while increasing output and exports of value-added products given its rise in global demand. Moreover, it would harmonise Russian export duties with those existing in other Eurasian Economic Union countries.

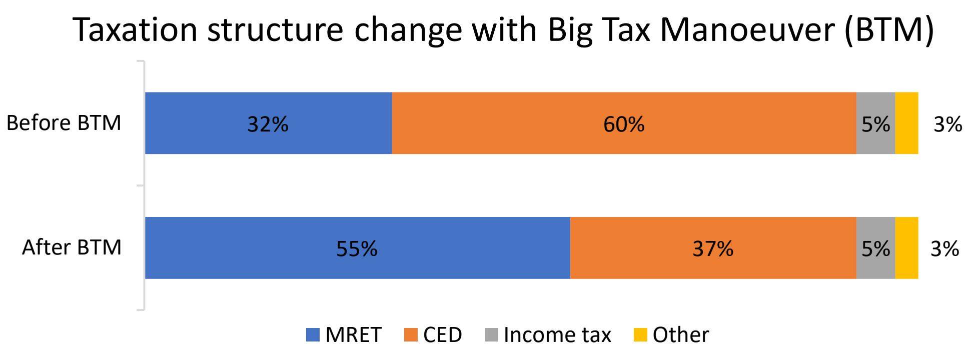

Figure 59. Russian taxation structure before and after the Big Tax Manoeuver in 2017. Sources: EY (2015)[16].

The tax reform provided a marginal short-term boost to upstream profitability, given the increased crude oil exports, but did not address the problem of incentivizing long-term investment and also hit downstream operations. This can be seen in the following graphs, which show how there is an overall decline in capital expenditure, which is logical considering decreased revenue, but spending in upstream activities has increased consistently.

Another way to try to increase oil revenues is to try to increase crude oil price. In late 2016, the OPEC, Russia, and other oil-producing countries agreed to limit production from January 2016 through June 2016 to try to stabilize the oil market. Russia agreed to reduce its production by 300,000 b/d versus its October 2016 production level, implementing these cuts gradually to reach the full cut by the end of April 2017. OPEC and Russia have generally adhered to their agreed production cuts, and in May 2017, OPEC and non-OPEC countries met and agreed to extend production cuts through the end of March 2018 (U.S. Energy Information Administration, 2017).

The latest tax reform is currently being implemented at pilot projects and consists in switching to a profit-based fiscal system by January 2019 (once OPEC agreement ends), in contrast to the current revenue-based MRET and CED, which will spur production and better reflect exploration costs and risks. Even if state budget revenues will first decrease,

[16] Kondrashov, *Taxation in the Russian oil sector: learning from global fiscal perspectives*, 2015

output growth is expected to rebalance the incipient shortage and have a positive effect in government's coffer in the long-run (Deloitte, 2017).

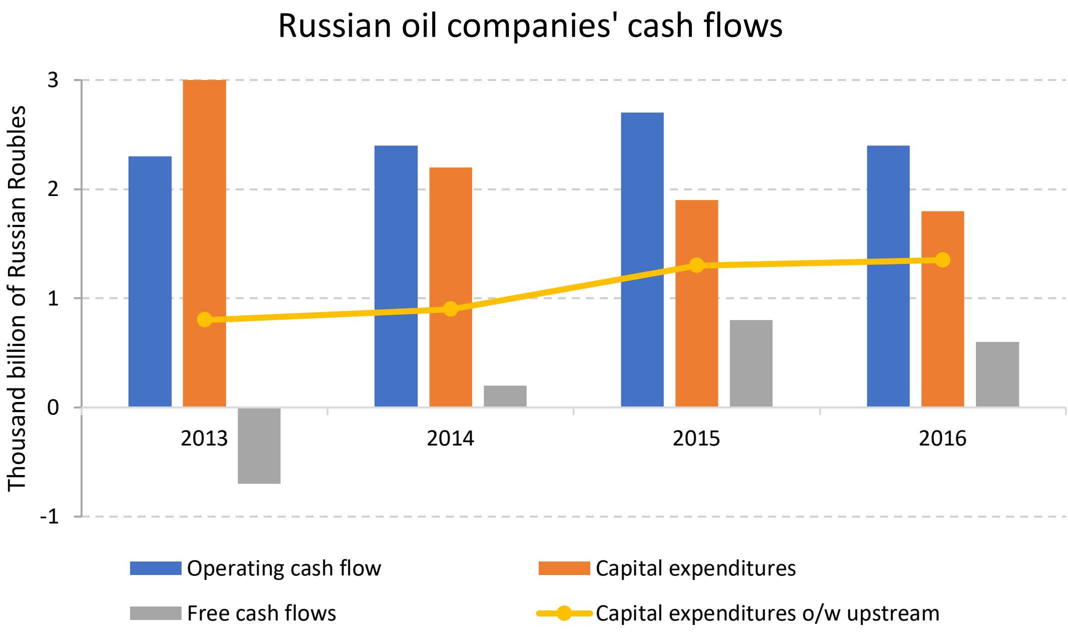

Figure 60. Russian oil companies' cash flows evolution, in Russian Rouble. Source: Oxford Institute for Energy Studies (2017)[17].

In conclusion, even if the short-term outlook of Russian production is to decrease due to the OPEC agreement, other measures are being put in place so as to grant a more efficient fiscal system, the BTM and in particular the profit-based fiscal system, which would incentivise production output growth and enhance oil state revenue collection once the restriction is lift. As for the medium-term production outlook growth potential, the main risks are Russia's refinery industry upgrading so as to ensure competitiveness in the high-quality oil market and, more importantly, how long will it take for the production cut OPEC-non-OPEC agreement to reach its desired price target.

4.1.3.3. Arctic, deep water and tight oil

Russia's total production accounts for 11.2 mb/d or a 12% global share in 2016 (BP, 2017). Most of Russia's oil production originates in West Siberia and the Urals-Volga regions (58% and 23%, respectively, in 2016), with slightly more than 10% of production in 2016 originating in East Siberia and Russia's Far East. However, this share is up from less than 5% of production in 2009 (U.S. Energy Information Administration, 2017).

A regional analysis carried out by the Energy Research Institute of Russian Academy of Sciences (ERI RAS) showed that by 2025, share of production in the Volga-Urals will fall to 60%, while the share from East Siberia and the Far east will slightly increase. Most of

[17] Henderson & Grushevenko, *Russian Oil Production Outlook to 2020*, 2017

the growth, however, will come from greenfield developments, such as Arctic, Deep Water and Tight oil resources.

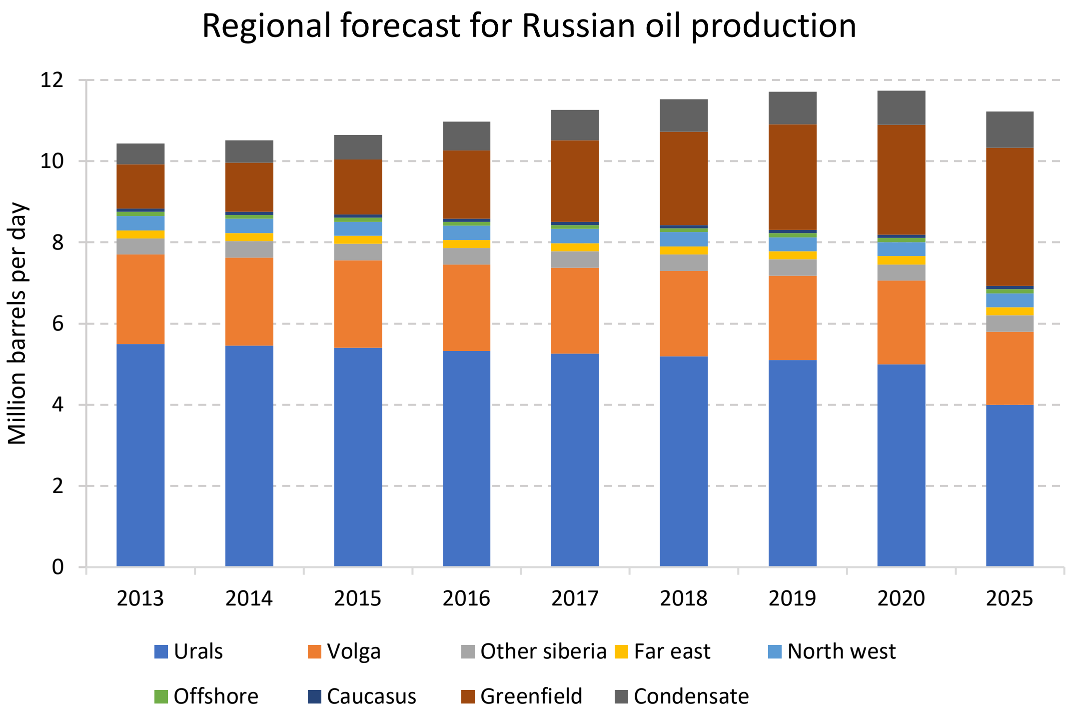

Figure 61. ERI RAS Regional forecast for Russian oil production, in thousands of barrels per day. Source: Oxford Institute for Energy Studies (2017)[18]*.*

In actual fact, there are three regions that can significantly contribute to medium and long-term growth and explain Russia's oil reserve base great potential. Russia's proven oil reserves as of 2016 account for 6.4% share of world reserves, or an equivalent of 266.5 billions of barrels (BP, 2017). However, East Siberia itself has 10bn barrels of proved reserves, while resource estimates indicate as much as 160bn barrels (Henderson, The Strategic Implications of Russia's Eastern Oil Resources, 2011). Simultaneously, growth in oil demand is increasingly coming from non-OECD eastern countries, such as China and India. These facts explain why eastern regions have been a strategic government priority over the last years.

The second region is the Russian continental shelf, or concretely the Arctic, with potentially 50bn barrels of additional oil reserves (as even greater amount of gas). Apart from the delays caused by US and EU sanctions, considerable operational barriers (difficult and expensive drilling) make this region exploitation before 2030 unrealistic. Low oil prices have also made companies shift focus to lower-cost and shorter-term alternatives to keep up oil output levels. Notwithstanding, in an event of higher oil prices and sanctions withdrawals, it is likely that it will provide a considerable boost to Russia's oil production in the long-run (Henderson & Grushevenko, 2017).

[18] Henderson & Grushevenko, *Russian Oil Production Outlook to 2020*, 2017

Finally, the third growth opportunity comes from unconventional oil resources, such as tight and shale oil. A study carried out by the United States Geological Survey (USGS) assessed Russia as having the largest potential resource base with 75bn of technically recoverable barrels (Henderson & Grushevenko, 2017). Again, sanctions have diminished Russia's ability to import essential international drilling expertise, techniques and equipment. Real progress will only be made once sanctions are lifted.

Overall, there is certain confidence in Russia's ability to keep production at c. 11mb/d in the future. If international sanctions end and oil price recovers the increase in financial viability of Arctic, Deep Water and Tight oil developments will certainly lead to significant output growth from these greenfield projects. However, delays mean that growth is expected to come in the longer-term and high natural decline rates from existing oil fields suggest that significant overall output growth in the medium-term is unlikely.

4.1.3.4. International oil trade

Russia represents the largest oil exporting country as of 2016 with a 13% share of worldwide oil exports. Europe has traditionally been Russia's major trading partner accounting for c. 65% of Russia's 274 million tonnes of oil exports in 2016. The reverse is also true, as imports coming from Russia account for 36% of total European oil imports in 2016 (BP, 2017). Russia is also a leading exporter of refined products, specially fuel oil and diesel, which are again mainly sold to European countries. Europe's geographical proximity to traditional west Siberian fields and the extensive pipeline network built between both regions have made Russia too dependent on the revenues associated with exporting oil and petroleum products to countries such as Germany, the Netherlands, Poland and Belarus.

Russia's transportation system is firmly in place to reach key importing regions surrounding the country, specially Europe, and it consists primarily of a vast network of strategically distributed pipelines (completely owned and run by the state-run Transneft) and ports. Oil reaches North-west Europe via tanker from Russia's Baltic ports of Primosk and Ust Luga, Southern Europe through its Black Sea port of Novorossiysk, and Central Europe via Druzhba pipeline.

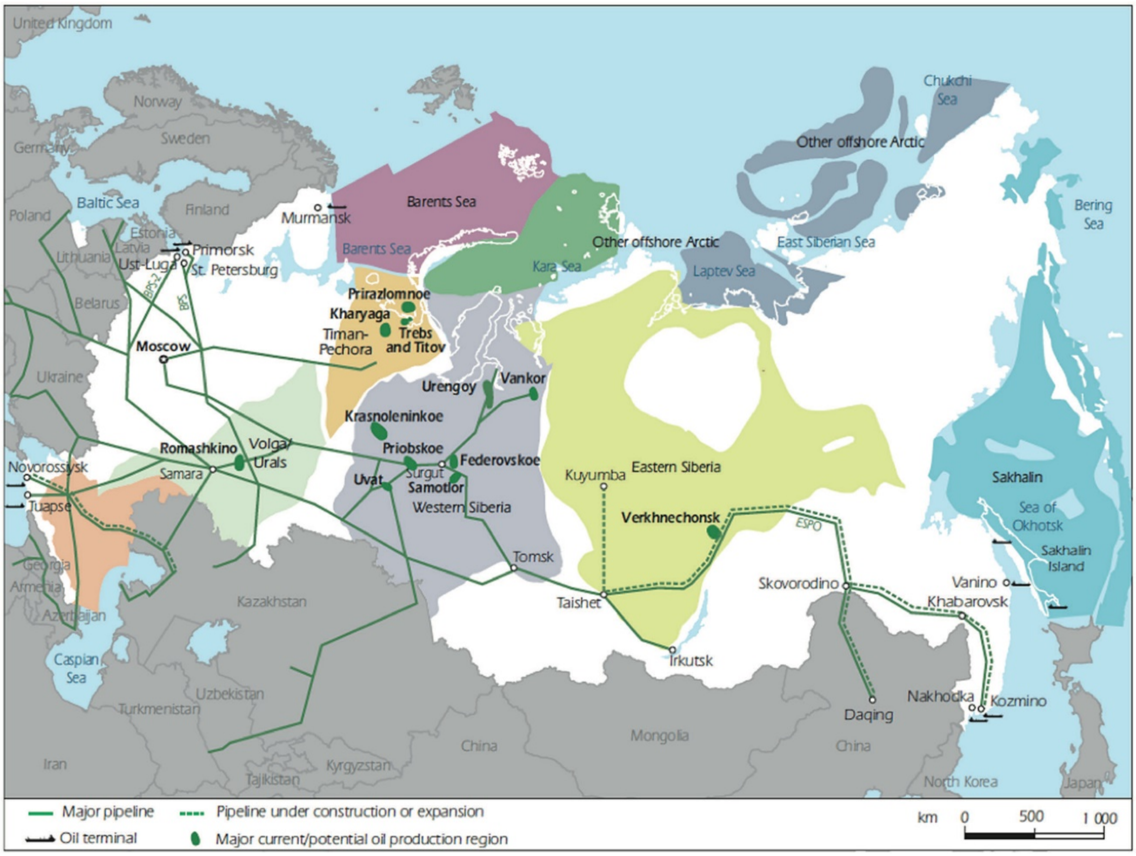

Figure 62. Russia's oil producing basins and export infrastructure. Source: International Energy Agency (2015)[19].

However, in recent years, Russian oil industry is fundamentally changing its focus from Europe towards Asia. The latter seems logical given that, on the one hand, Europe has a mature oil market with a clearly declining consumption trend coming from efficiency gains, inter-fuel substitution and saturation effects (International Energy Agency, 2015). On the other hand, Asia is driving growth in oil demand and shows a rapidly increasing oil dependency. In particular, consumption in China alone is expected to reach 15.5 mb/d by 2035 compared to current 11.5 mb/d levels in 2016 (International Energy Agency, 2017).

Consequently, Russia intends to double the flow of oil to Asia by 2035, as stated in its Energy Strategy, which would increase the region's share in total Russian oil exports from c. 20% to above one-third. Putin is working to aggressively implement this shift in trading strategy by the use of fiscal policy, mainly through tax breaks and incentives which aim to stimulate production from greenfield projects mainly in eastern Siberia and Far East regions, and lower export taxes in key eastern pipelines (such as the Eastern Siberian-Pacific Ocean -ESPO- pipeline) which make piping oil to Asia more profitable than to Europe (Six, 2015).

[19] International Energy Agency, *World Energy Outlook*, 2015

Figure 63. Oil fields in Eastern Russia and ESPO pipeline. Source: Clingendael International Energy Programme (2015)[20].

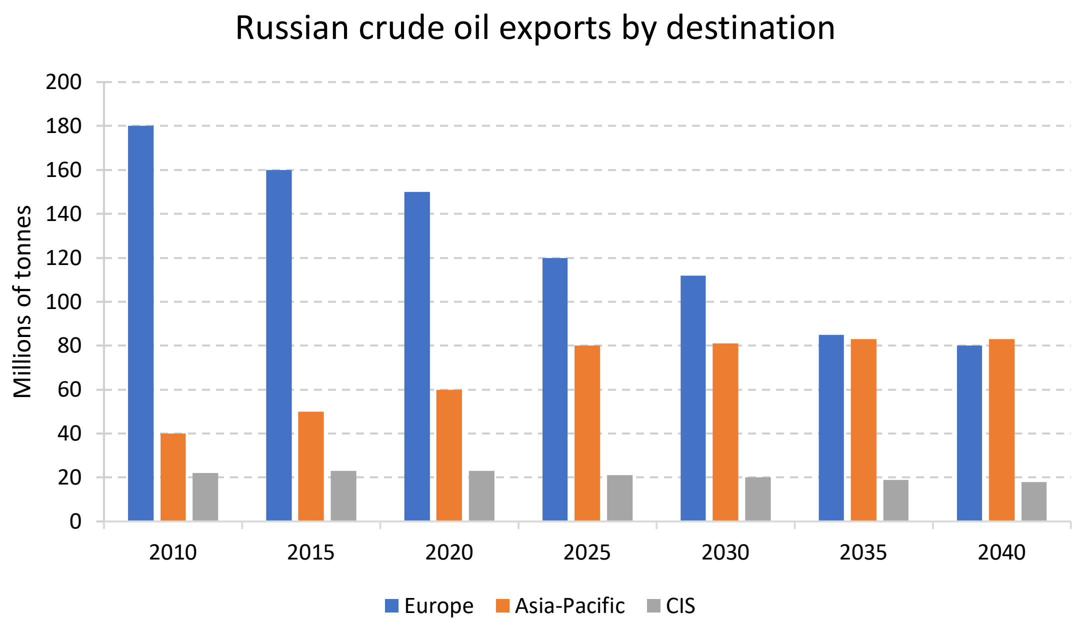

Figure 64. Crude oil exports from Russia by destination, in millions of tonnes. Source: ERI RAS (2015)[21].

[20] Six, *Russia's Oil Export Strategy: Two Markets, Two Faces*, 2015

[21] Energy Research Institute of the Russian Academy of Sciences, *Global and Russian Energy Outlook up to 2040*, 2015

Political tensions between Russia and the west following the Ukraine crisis in 2014 have catalysed political, economic and financial co-operation between Russia and China. Within the oil industry scope, further “loan-for-oil” schemes have been created whereby China generally provides a portion of the funds needed to complete a specific project in exchange for guaranteed long-term oil supply contracts. An important example of these kind of agreements is China’s $25bn loan to Transneft to finance the second phase construction of the ESPO pipeline and the spur pipeline to Daqing in 2009, which should pump 300,000 b/d of Russian crude directly to China every year for 20 years (Henderson & Mitrova, 2016). A second conduit is currently being built to double China’s ESPO crude import capacity to 600,000 b/d.

Intensifying supply commitments to China, in parallel with capital and technological constraints from sanctions, add uncertainty on Russia’s ability to generate sufficient output growth from its greenfield projects in East Siberia and the Far East to honour its supply contracts. For the moment, Russia is having to redirect increasing volumes of its intended western crude oil towards Asia, which is pushing up the price of varieties available for sale to Europe (Henderson & Mitrova, 2016). However, increased liquidity of the international oil market due to the US shale revolution (which has freed up millions of barrels of oil from West Africa and Middle East) enables Europe to easily replace Russian flows with West African, Caspian or Latin American supplies.

Oil contracts with China generate a security of demand for Russia, but might also hamper export diversification efforts in the long run. Hence, Russia will have the solidify its position in Western markets, competing primarily in terms of quality with Saudi Arabia and the UAE. The latter will require further modernisation of its refining industry.

4.1.3.5. Oil production outlook

Literature review shows different views as for Russian oil liquids supply prospects in the long run. While the OPEC 2017 World Oil Output and the US EIA 2017 Annual Energy Outlook studies are confident on Russia’s ability to sustain its c. 11mb/d output, the IEA 2017 World Economic Outlook predicts a significant 2.8% decrease in 2040 from 2016 levels in its reference case scenario.

On the one hand, OPEC and US EIA analysis believe that, despite major frontier areas such as sanctions and prohibitively expensive and difficult to develop Arctic and non-conventional resources, specific new start-ups (such as further ramp-ups at existing important fields and continued investment at other brownfields) are likely to succeed in offsetting natural decline rates at mature fields. Russia’s ample reserve base potential is also considered to be a new source for long-term oil supply (OPEC, 2017) (U.S. Energy Information Administration, 2017). On the other hand, the IEA analysis underlines the high cost and difficulty for Russian operators to increase production efficiency of traditional fields. The move to new frontier projects in east Siberia and the Arctic, together with some tight oil development, is seen as insufficient to offset declines in mature production areas in western Siberia and the Volga-Urals region (International Energy Agency, 2017).

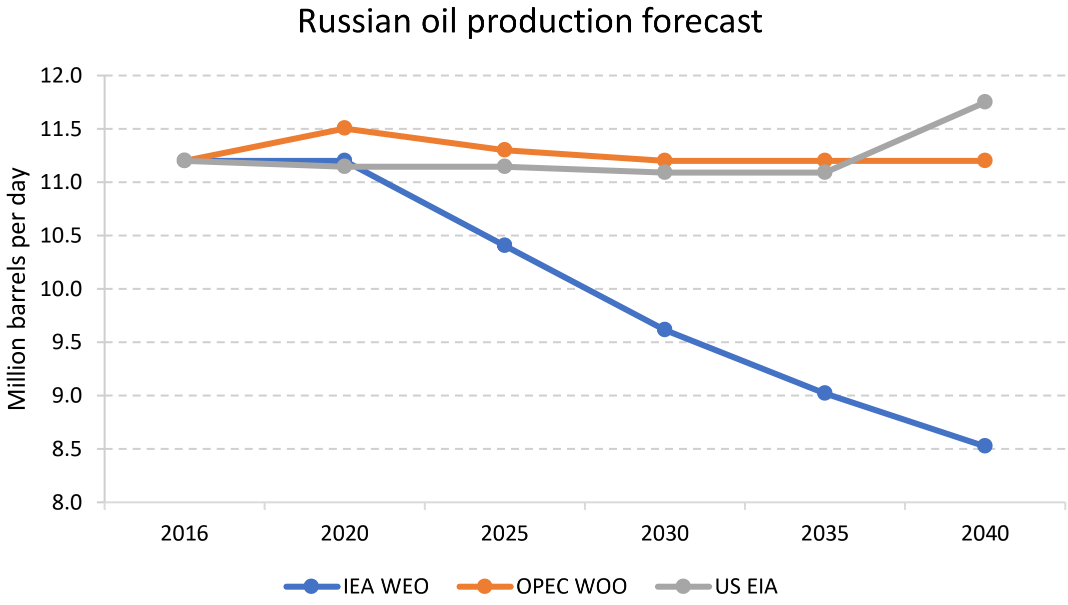

Figure 65. Russian long-term oil liquids supply outlook, in millions of barrels per day. Source: BP Statistical Review of World Energy 2017, World Economic Outlook 2017, World Oil Outlook 2017, International Energy Outlook 2017.

To conclude, there is ambiguity on whether if Russia's oil supply will decrease or remain at 11mb/d. However, there is small chance that the country will see a significant rise in its output capacity given the current macroeconomic, political and geological conditions.

4.2. Demand

Once the production main players have been introduced and their key characteristics analyzed, we will move on to the demand side. First, we will comment the global demand trends and we will identify the main players in it. Then, we will analyze individually those countries or trends that we identified as the most relevant ones in the oil market outlook in order to get a better view of their key characteristics. Finally, their position in the global oil market will be commented and how their outlooks look like towards predicting and understanding better the potential future scenarios in the demand side.

4.2.1. Global oil demand

Since more than 50 years ago, crude oil has been the largest global primary source of energy. Its demand has driven the global oil market and has made the supply adapt to changes, dependent on the countries' oil necessities.

In 2016, the region that has consumed more crude oil has been Asia Pacific with 29.6 million barrels per day (mb/d). However, United States (19.8 mb/d) has been the largest oil consumer as a country followed by China (11.5 mb/d). Figure 66 shows the split of oil demand between the main regions[22] and the countries driving the demand in each case.

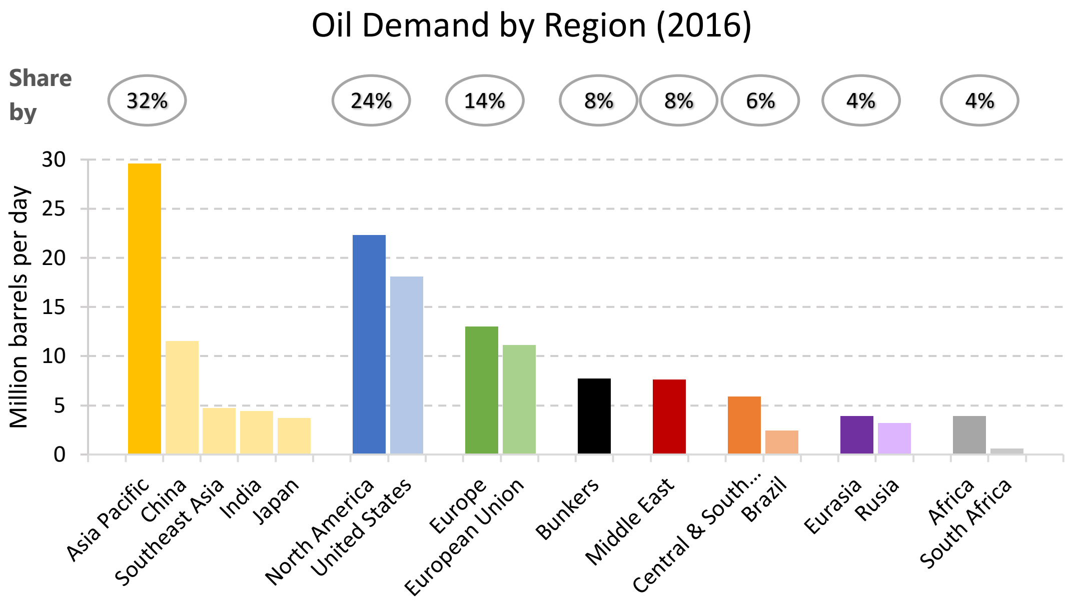

Figure 66. Oil demand by region (2016). Source: WEO 2017, IEA.

But the actual demand comes from very different patterns of oil consumption across OECD and non-OECD countries in the past. OECD countries have historically consumed more oil but since 2014 are being surpassed by the heavy oil demand growth the non-OECD countries are experiencing. In Table 5 it can be seen that the non-OECD countries have increased the demand by 74% whereas the OECD countries have decreased it by 3%.

In mb/d	2000	2005	2010	2012	2013	2014	2015	2016	CAGR 16-40
OECD	48.4	50.4	47.1	46	46.1	45.9	46.4	46.8	-0.21%
Non-OECD	28.7	34.2	41.3	44.2	45.6	47.1	48.6	49.8	3.50%

Table 5. Oil demand in OECD vs Non-OECD countries. Source: Eni, World Oil Review 2017.

Across sectors (Figure 67) there is wide divergence and the demand is driven and balanced by the road transport mainly, which has consumed 40.7 mb/d, both passenger and freight in 2016. In the period between 2000 and 2016, the demand for oil in this sector has grown with an average annual rate of 1.9%, being the sector that has increased the most its demand in the period.

[22] The region "Bunkers" includes international marine and aviation fuels.

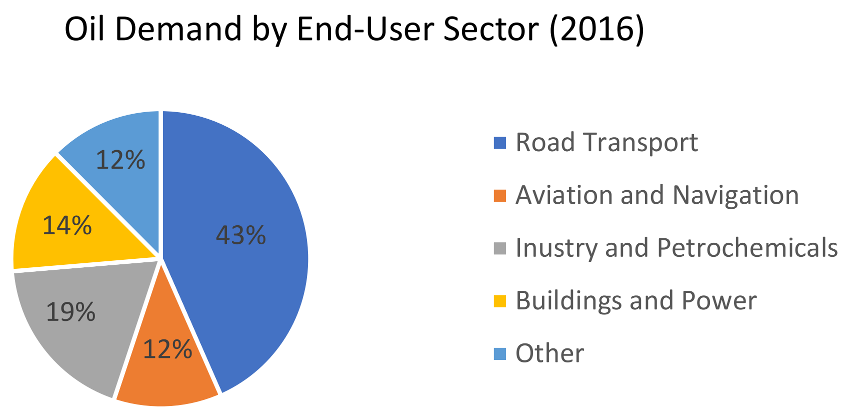

Figure 67. Oil Demand by End-User Sector (2016). Source: WEO 2017, IEA.

But analysing future oil demand, several trends and changes in policies that are being undertaken will shape the demand of oil in the different countries and sectors, what will completely define the global oil markets production necessities.

According to the AEO's reference case (U.S. Energy Information Administration, 2017), the world's petroleum and other liquid fuels consumption is expected to rise 18% between 2015 and 2040, from 95 mb/d to 113 mb/d by 2040. From the WEO's New Policies Scenario (International Energy Agency, 2017), two distinct phases can be identified (Figure 69). Between 2016 and 2025 the average annual growth of the oil demand exceeds 0.8 %, reaching 102 mb/d by 2025, and between 2025 and 2040, the average increase in demand slows down to 0.4 % reaching 109,1 mb/d of oil and liquids demand by 2040 (see Figure 68).

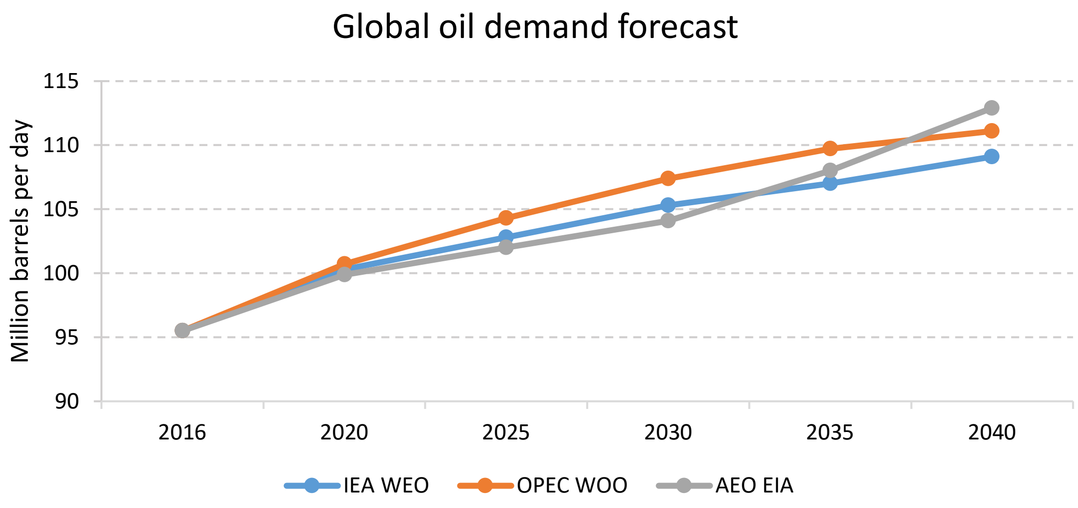

Figure 68. Global long-term oil liquids demand outlook, in millions of barrels per day. Source: IEA WEO 207, OPEC WOO 2017 and EIA AEO 2017.

At this point it is important to define what each scenario/case contemplates when creating its forecasts. In the case of the IEA's New Policies Scenario, in the 2017 WEO report they describe it as follows (International Energy Agency, 2017). *"New Policies aims* *to provide a sense of the direction in which latest policy ambitions could take the energy sector. In addition to incorporating policies and measures that governments around the world have already put in place, it also takes into account the effects of announced policies, as expressed in official targets and plans. (···). Given that "new policies" are by definition not yet fully reflected in legislation or regulation, the prospects and timing for their full realization are based upon our assessment of the relevant political, regulatory, market, infrastructural and financial constraints.".* For the EIA's reference case, the description they provide in the AEO 2017 report is the next one (U.S. Energy Information Administration, 2017). *"The Reference case projection assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central views of leading economic forecasters and demographers. It generally assumes that current laws and regulations affecting the energy sector, including sunset dates for laws that have them, are unchanged throughout the projection period. The potential impacts of proposed legislation, regulations, or standards are not reflected in the Reference case.".*

However, the demand growth, is not homogeneous among countries as historically it has been seen. In non-OECD countries the petroleum and other liquid fuels demand will increase a 39% due to the strong economic growth, the increased access to marketed energy and the fast-growing populations. In contrast, in OECD countries, the petroleum and other liquid fuels consumption is forecasted to decrease by 3% over the same period. The oil demand will decrease in 11 mb/d, driven by the decrease in consumption in the United States and Europe. About 60% of this drop comes from reductions in oil use in passenger cars due to fuel-economy standards that push for oil efficiency and EVs increasing adoption by the mass market.

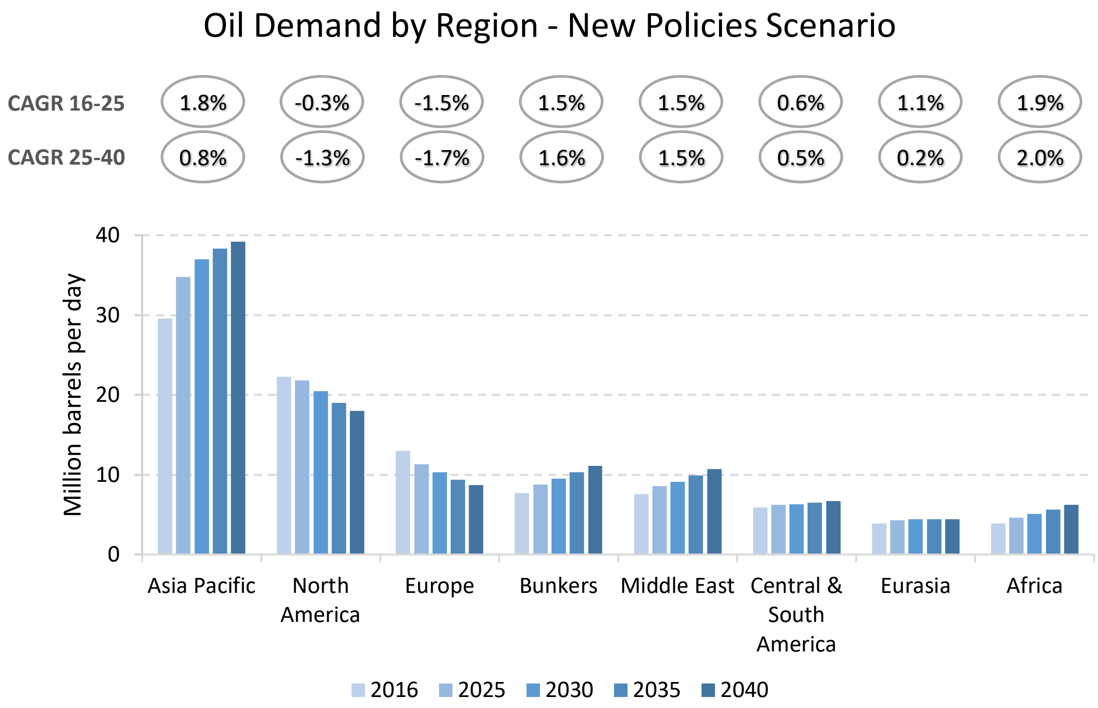

Figure 69. Oil Demand by Region - New Policies Scenario. Source: WEO 2017, IEA.

The outlooks for energy demand are mainly based in the GDP growth together to each economy's structure and population between others. The EIA bases its outlooks in the next GDP forecasts, a 1.7% annual GDP growth in the OECD countries compared to a 3.8% annual GDP growth in non-OECD countries. Between then non-OECD regions, India will be the fastest-growing economy averaging 5.0% annual growth GDP from 2015 to 2040 and China will follow second with a 4.3% annual growth. Nevertheless, this growth for China means an economic slowdown as over the past decade the country's GDP has been growing at a 9.6% annual rate.

As mentioned, GDP growth being an important driver of the energy demand, Asia accounts for more than 80% of the increase in liquid fuel consumption in non-OECD regions in the next years, leaded by China and India. In particular, the two main end-user sectors driving the demand in both countries are the rapid industrial growth and the increased demand for transportation. In detail, China's use of liquid fuels for transportation is projected to increase by 36% from 2015 to 2040 and by 142% for India over the same period. As a result, by 2040 China and India will account for almost a quarter of global oil demand (25% in 2025, up from 17% in 2017). And actually, by the late 2020s, annual oil demand additions in India will surpass those of China according to the IEA.

Thoroughly, world share of oil demand by end-user sector holds almost constant even the total consumption increases, the aviation (+3. mb/d) and navigation sector (+1.4 mb/d) being the ones with the largest average growth per year (see Figure 70). In history, and as verified for 2016, the transportation sector has been the main consumer of oil as all the means (sea, road and sky) used and still use oil to power the engines. In consequence, and since the total demand for travel and freight services increases at a faster rate than the demand in other applications, transportation remains being the largest consumer with a 56% of share by 2040 (54% share in 2015).

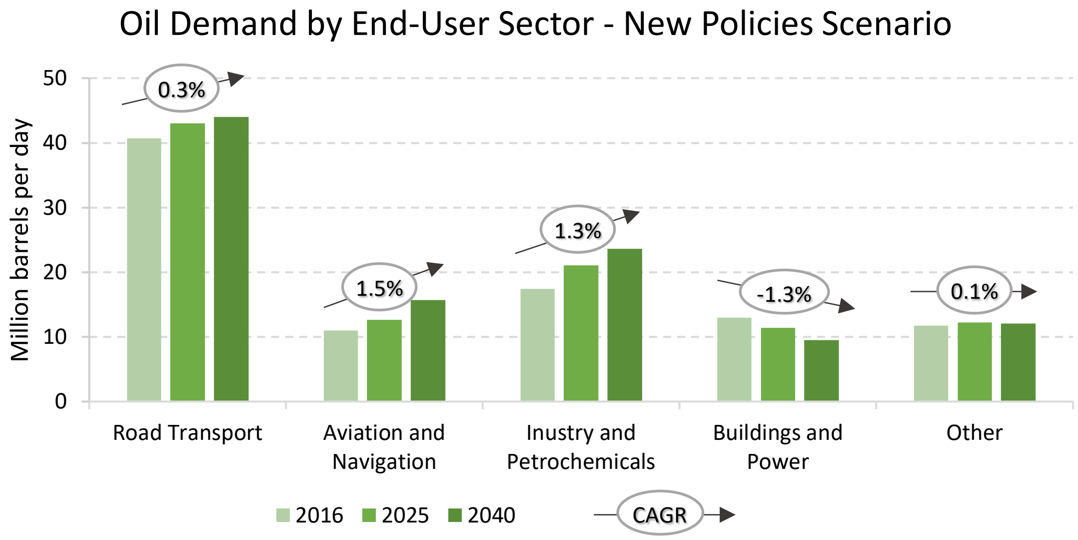

Figure 70. Oil Demand by End-User Sector (New Policies Scenario). Source: WEO 2017, IEA.

Nevertheless, it is of great importance to pay attention to the little average annual growth that the road transport sector shows. Even if oil demand continues to increase, vehicles are becoming more efficient and technological improvements and the introduction of electric vehicles, autonomous driving and car sharing, potentially announce an upcoming mobility revolution. In addition, not only in the transportation sector but globally, in fossil fuel consumption terms, the strong political and social move towards less carbon emissions and the reduction of the carbon footprint will change severely the demand patterns. Due to it, the main driver of the road transport demand growth towards 2040 is not the fuel for passenger cars but for trucks, accounting for an increase of 3.9 mb/d.

To sum up, we consider that further analysing the demand in China, India and the United States together to the passenger transportation revolution trend will enable us to go deeper into those potential upcoming changes in the world oil demand. China, due to its strong oil consumption growth during the last decades and the outlook of potential economic structural changes that will affect the oil demand. India, because its fast industrialization will soon take the country's oil consumption to surpass China's oil demand growth. United States, because until the 2030s it will continue being the country that consumes oil the most, while decreases its oil demand together with other OECD countries, as in 2004 the country reached its oil demand peak. Finally, the passenger vehicle revolution trend, because the market is not yet properly adopting the massive impact that will cause in the global oil demand. So, the objective with these four more detailed analysis is to detect the major characteristics that make them so relevant in the oil price's game theory, and to anticipate the disruptions they might cause on it and the potential effects.

4.2.2. China

China is the world's second largest economy in the world with 1.4 billion citizens and is the largest oil importer, the largest energy-consumer since 2009, the second largest oil consumer behind United States and the 7th largest oil producer. All these together accounting for the scale of its energy sector, provides China a huge weight in the global energy market.

Indicator	2000	2005	2010	2016	Change 00-16
GDP ($2016 billion, PPP)	5,278	8,318	14,023	21,721	312%
Share of world GDP	8%	10%	14%	18%	-
Population (billion)	1.27	1.31	1.34	1.38	9%
GDP per capita ($2016, PPP)	4,158	6,347	10,428	15,685	277%
Total primary energy demand (Mtoe)	1,143	1,794	2,551	3,006	163%
Total primary energy demand/capita (toe)	0.90	1.37	1.90	2.17	141%
Total oil demand (mb/d)	4.7	6.9	9.5	11.5	145%

Table 6. Economic and energy indicators for China. Source: WEO 2017, IEA AND EIA database.

Between 2000 and 2010 China's energy demand has grown in an annual average of more than 8%. However, since 2010 China's energy needs are changing towards a more sustainable growth and its energy demand is only growing at a 3% per year. The main reason behind it is the fact that the economy is moving progressively away from its reliance on heavy industry exports, towards higher value-added manufacturing, services and domestic consumption, what entails a structural shift on the country's economy.

Even if a structural transition is underway, China's energy mix is dominated by the coal, which still governs the industry sector's energy use, sector that consumes around 50% of the country´s primary energy demand (Figure 71). However, coal consumption is expected to suffer the biggest decline in the coming years due to China's change in industrial structure, what might provide good prospects in the short term for oil demand.

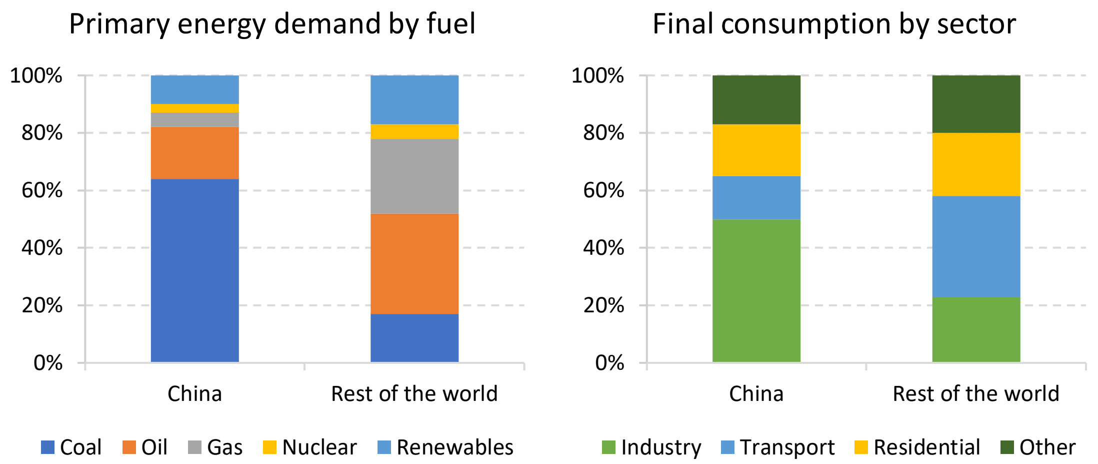

Figure 71. Comparison of China´s primary energy demand by fuel and final consumption by sector with the rest of the world average, 2016. Source: WEO 2016, IEA.

Actually, although the oil demand has not yet reached the end of its period of robust growth, it is also set to slow down due to the "Energy Revolution" that is taking place in the country. The 13th June 2014, the president Xi Jinping said, "China needs a revolution in the way it produces and consumes energy, as demand continues to rise and supply challenges mount" published Reuters (China's president calls for energy revolution, 2014). Since, a strong policy focus on energy efficiency has raised. At the end of the day, China's government's aim is to build a more secure, sustainable, diverse and efficient energy future for the country.

The main reasons to seek this revolution have been:

- Public health and environment. Over the past decades China's fast economic growth has had significant effects on its environment and public health. The total CO2 emissions from 2000 to 2016 have raised a 187%, to 8,973 Mt in 2016. To face this growth, the Chinese government has imposed stringent policies to improve the air and water quality and reduce the greenhouse-gas emissions.
- Energy security. China turned into a net importer of oil in the early 1990s. In 2016 imported the 64.4% of the oil it consumed (7.6 mb/d), and its oil import dependence is expected to rise to 80% (11.3 mb/d) by 2040, mainly driven by the

fall of the domestic production and the increase in demand. Of every ten barrels of internationally traded oil in 2040, almost three barrels will be heading to China. For this reason, China is now seeking to mitigate the risks of such an oil import dependence.

- Energy efficiency. In China most of the growth has been driven by the heavy industry. The government now is looking forward to transform and upgrade the traditional industries into more energy efficient ones by pushing for an optimized use of resources. For most of the heavy industries, energy accounts for a huge part of their costs and energy efficiency is being identified as the biggest lever to boost profits. What at the end of the day will translate into a lower demand of oil from the China's industry side.

4.2.2.1. The 13th Five-Year Plan and the commitment at COP 21

Since 1953 China has published thirteen plans of social and economic initiatives, becoming the county's instrument to set policy directions and provide guidance. The plan published in March 2016 that contemplates 2016-2020 is focused on "promoting a low carbon development path, and building a clean, low carbon, safe and efficient modern energy system". In order to build such an energy system, China plans to accelerate the innovation in technology to increase the share of non-fossil fuels in the primary energy demand of the country, and to promote a clean and efficient use of oil, coal and other fossil fuels.

The action plan introduced by the 13th Five-Year Plan that most affects the oil industry is the one promoting the expansion of the use of natural gas so that by 2020 accounts for 20% of the primary energy use in China. Other significant action plans also promote low-carbon means of transportation and in particular the development and use of new energy vehicles. Finally, it is also encouraged to improve the fuel quality and promote the use of alternative fuels so that by 2050 the share of fossil fuels in China in the primary energy mix drops to 40% (China Chemical Reporter, 2016).

In the summit of COP 21 in Paris in 2015, several policies to address climate change also were committed by China. The country engaged to achieve the CO2 emission peak as early as possible and additionally cut the CO2 emissions per unit of GDP by 60%-65% from 2005's level. One of the main targets to achieve the CO2 goal before 2030 is non-fossil fuels to account for 20% of its primary energy use by then (15% by 2020). But in 2016 only coal consumption accounted for 62% and adding the oil and gas consumption, the 89% of the consumption came from fossil fuels.

These plans identify specific medium-term indicative or binding objectives, and mechanisms to track and monitor the progress. China's aim is to evolve towards a more market-oriented system and the targets have been specifically designed to address this shift.

4.2.2.2. Oil demand

In 2016 oil demand in China reached 11.5 mb/d, 55% of the demand growth between 2000 and 2016 coming from the increase of cars and trucks' oil consumption. Since 2000, the number of cars in China has increased by a factor of more than 25 and the amount of freight by a factor of three. In 2016, 90% of the transport sector oil needs were satisfied with oil, becoming an important cause of China's oil imports.

In the industry sector, the strong industrial output growth supported a fast GDP growth for the country for the last decades. In 2016, demand for oil in the feedstock and the petrochemical industry also grew strongly, but demand for diesel dropped as is used primarily for freight, closely correlated with heavy industrial activity, which has been declining in the last years due to the economy's structural shift.

Looking forward, in the IEA's World Energy Outlook "New Policies Scenario", China's oil demand increases by 35% to 15.5 mb/d in 2040. Between 2016 and 2030 is when the majority of the growth occurs due to still robust economic growth, the continuous growth of cars on the roads and the speedy urbanization. But afterwards, growth slows mainly due to the revolution in the automotive sector and the shift in the industry towards less heavy activity (Table 7).

In mb/d	2000	2016	2020	2025	2030	2035	2040	CAGR 16-40
Oil demand	4.7	11.5	13	14.5	15.4	15.5	15.5	1.3%

Table 7. China oil liquids Demand - New Policies Scenario. Source: WEO 2017, IEA.

However, there are some discrepancies between different outlooks (Figure 72). While OPEC's reference case in the World Oil Outlook of 2017 is quite in line with the IEA's New Policies Scenario of the WEO 2017 until 2030, for the 2030s decade it forecasts the oil demand in China to continue growing at the same path. In contrast, the EIA in the International Energy Outlook of 2017 forecasts a faster demand growth than the IEA, but the same slowdown after 2030, mainly driven by the structural change that the country undertakes.

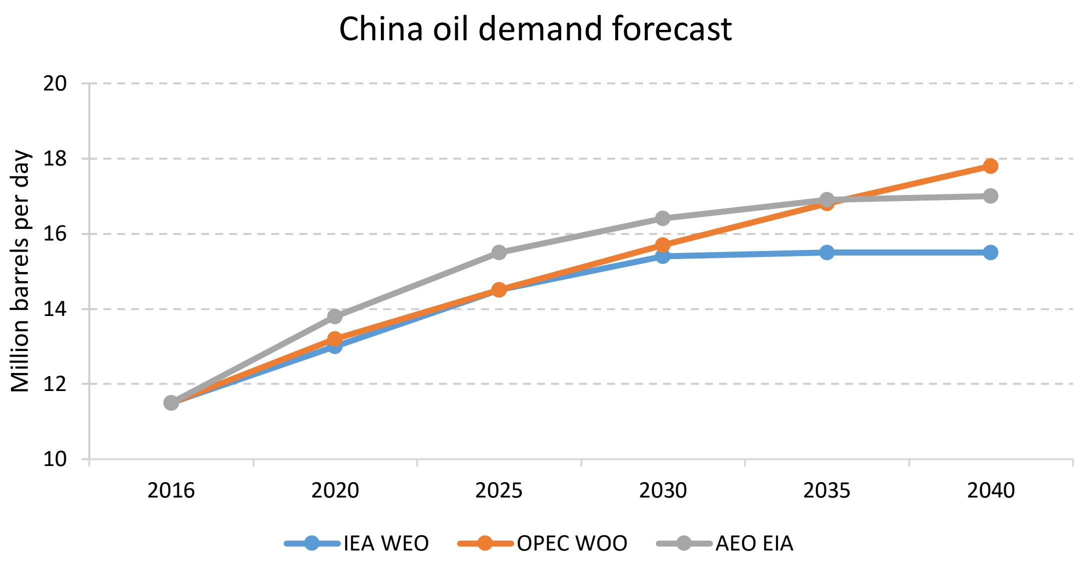

Figure 72. China long-term oil liquids demand outlook, in millions of barrels per day. Source: IEA WEO 207, OPEC WOO 2017 and EIA AEO 2017.

In the transport sector demand in particular, oil shows robust growth towards 2025, see Table 8. In 2016, gasoline-fueled vehicle sales grew by 16% what increased oil demand, but at the same time China is becoming the world's largest market for electric cars, pushing for more environmental friendly transport alternatives. In consequence, in the upcoming years, even if transport continues to push up oil demand growth especially until 2025, the average growth rate will gradually slow down as the growth of total passenger cars slows, cars become more efficient and the number of electric vehicles in the market rise.

	CAGR 16-25	CAGR 25-40	CAGR 16-40
China's Total Primary Oil Demand	**2,3%**	**0,4%**	**1,1%**
China's Total Final Oil Consumption	**2,7%**	**0,6%**	**1,4%**
Industry	-0,2%	-1,3%	-0,9%
Transport	3,5%	0,6%	1,7%
Buildings	0,0%	-2,2%	-1,4%
Other (petrochemical, feedstock, etc.)	3,3%	1,7%	2,3%

Table 8. China's Oil Demand Sector Breakdown- New Policies Scenario. Source: WEO 2017, IEA

4.2.2.3. Oil production

China's oil output has declined a 7% from 2015 to 2016, but at 4.0 mb/d in 2016, it remains the world's 7th largest producer, with a 4.5% of global oil production share. The production is mainly concentrated in Heilongijiang province (Northeast region) and in Shandong province (East region). In addition, 90% of it comes from three major national oil companies (NOCs): China National Petroleum Corporation (CNPC); China Petroleum and Chemical Corporation (Sinopec); and China National Offshore Oil Corporation (CNOOC).

China's domestic oil production grew until 2015 in a continuous way, but as most of the current oilfields production began in 1960, the oil fields are maturing. In consequence, the NOCs are facing challenges with high production decline rates and water cuts, implying high extraction costs. On top of that, due to the low international oil prices during the last years, the NOCs have struggle to break even at $40-50 per barrel. This has had impact in the revenues and the domestic investments by the NOCs have been reduced by 40-60% in the past two years.

As of 2016 China has 114 billion barrels of significant remaining technically recoverable oil resources. Nevertheless, in the IEA's projections, oil production in China is expected to continue falling to 3.1 mb/d by 2040 (Figure 73), as given the oil price in the market is hard to secure investments for projects that would compensate for the decline in production. A broader investor base or the entry of new players such as specialized technology players could be a way to stem the current decline in the output, as China's main challenge does not lie in its volume resources but in the complexity and the high costs of the extraction.

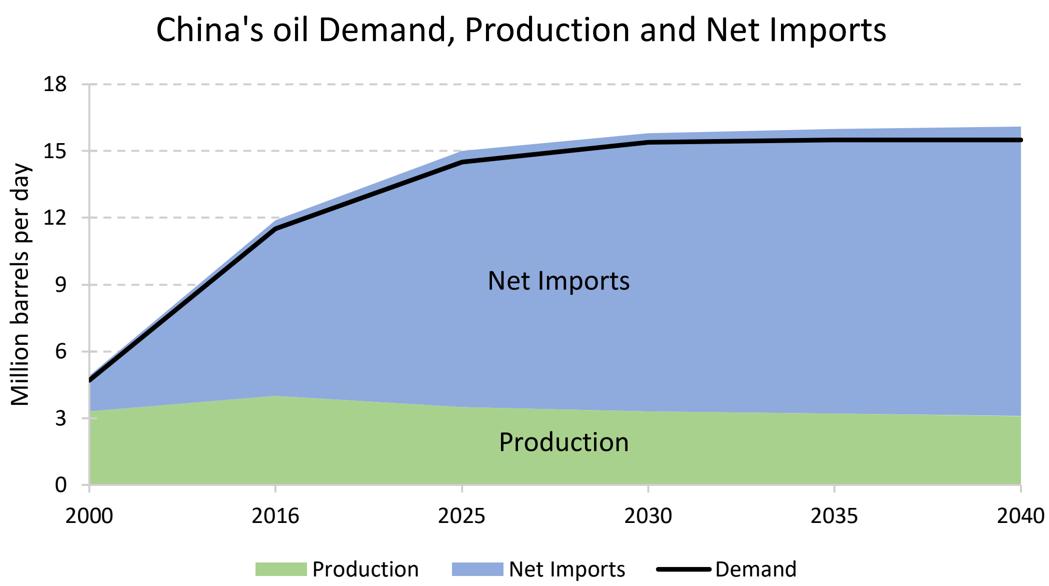

Figure 73. Chinese oil Demand, Production and Net Imports - New Policies Scenario. Source: WEO 2017, IEA.

4.2.2.4. Oil refining

In 2000, China had a 5.4 mb/d refining capacity which implied a 7% of the global refining market. By 2016, China has more than tripled its capacity to 15.6 mb/d increasing its global market share to 16%. In 2016 China became a net exporter of refined products such as gasoline, diesel and kerosene. Its position as an exporter of refined products is now one of the factors driving its crude oil imports and will be analysed below.

By 2040, it is likely that China will become the refining world leader, overtaking the refineries in the United States and reaching a production of 14 mb/d, a 30% increase from the 2016 output. If the total capacity reaches 18.2 mb/d by 2040 as is expected the country´s oil demand and in consequence the import requirements could rise even higher than expected.

4.2.2.5. Oil imports

In 2016, China imported 7.6 mb/d of crude oil, what supposed an increase of 13% compared to the 2015, and a dependence in oil imports of 65% of the county's oil demand.

The main risk that arises for the Chinese economy is that the oil imports rely on a limited number of sources and transportation routes. In 2010, almost 80% of the crude oil was imported from the Middle East and Africa and 80% of the imports were estimated to arrive through the Strait of Malacca (Figure 74).

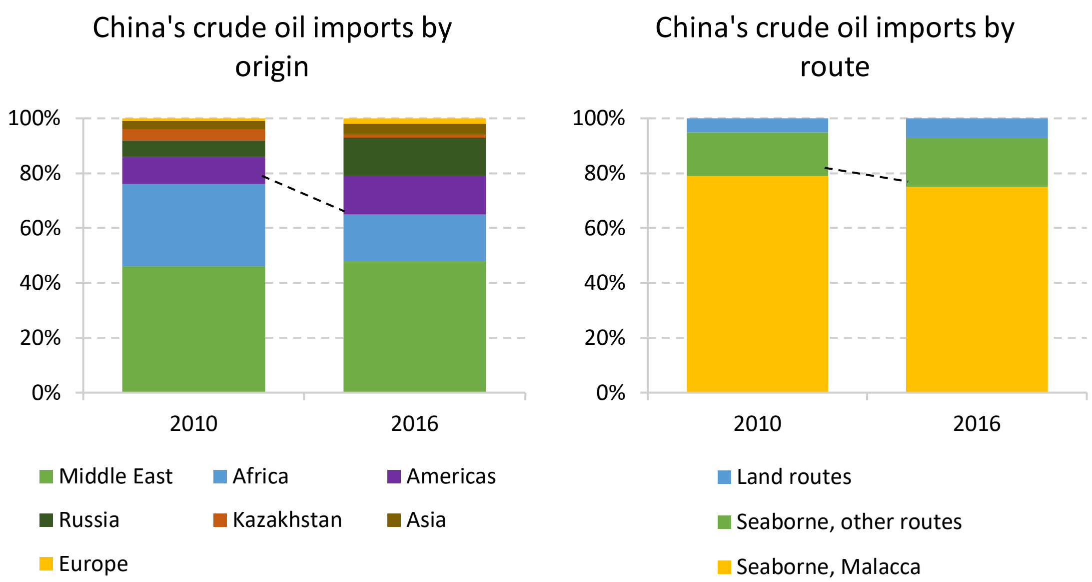

Figure 74. China's crude oil imports by origin and route. Source: WEO 2017, IEA.

By 2040, the prospects indicate that Chinese imports are expected to continue growing up to 11.3 mb/d. This volume will imply 80% of oil import dependence, remaining the worlds' largest oil importer throughout the period and becoming the largest amount ever imported by a single country. For every ten barrels of internationally traded oil in 2040, almost three will be imported by China. But faster than the volume will grow the import bill. From $110 billion in 2016 is expected to increase to $460 billion by 2040 in consequence of not only the volume increase, but mainly the increase in the oil price.

By 2040, reliance on the Middle East and the Strait of Malacca will continue high, but the overall picture becomes a little more diverse as oil imports from Eurasia and North America grow (see Figure 76).

4.2.2.6. The Strait of Malacca

The Strait of Malacca is the chokepoint that threatens the most oil trade between the Middle East and China together with the Strait of Hormuz, which has been commented in the section 4.1.1.3.1.A. The sea route that goes through the Strait of Malacca is one-third shorter than any other sea-based alternatives. In addition, it is the world's second in oil transport by volume only after the Strait of Hormuz.

The Strait of Malacca is located between Indonesia, Malaysia and Singapore and is 885 kilometers long and 2.5 kilometers wide on its narrowest section. The geographic limitations for the transport of the crude through other routes make the strait a strategic chokepoint for both the oil importer East Asian countries and the Middle East´s oil exporters. However, the economies that rely the most on it are the Chinese, as 80% of its oil imports travel through the strait, and the Japanese, with 60% of the total oil imports flowing through this sea route. Due to it, having open access to the strait is necessary for both countries' economic security.

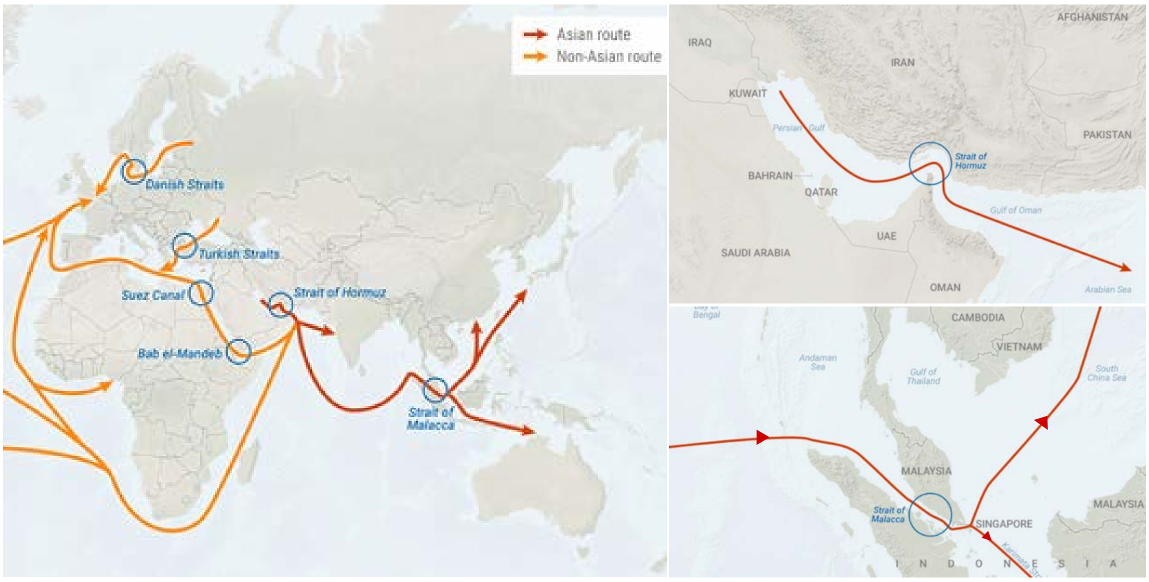

Figure 75. Oil maritime transit routes through maritime chokepoints towards Asia and details of the Straits of Hormuz (right, up) and Malacca (right, down). Source: Mauldin, 2017.

Nevertheless, relations between China and Japan lack of animosity due to their confronted determination in becoming the dominant geopolitical power in the terrain. If the rivalry scenario worsened, it could lead to one of them blocking the access to the strait to the other, but this kind of actions could shunt towards a more severe political conflict, inflicting an economic downturn and setting precedents for other countries to ensure for the control of the strait, what is not in interest of neither of them.

In order to mitigate those risks, both China and Japan have taken actions. China has strengthened its economic and political relations with the countries around the Strait of Malacca and Japan, like the Middle East countries, relies on its alliance with the US to ensure the free access to the transportation of goods by sea.

4.2.2.7. Oil security

Concerned about the import dependence rise and the exposure it implies for the economy, China has already started to mitigate the risk additionally by implementing different measures to diversify the actual supply sources and routes.

The first approach the country has taken in the last years has been to invest in overseas oil producing assets, rising its equity in overseas oil output up to 3mb/d in 2016. Indeed, not only the government but also private companies have followed the path in order to mitigate possible risks. Chinese companies are increasing their presence in all major upstream markets and primarily in resource-rich countries as is beneficial for both sides. They provide them with access to the Chinese growing market and at the same time they improve their energy security situation, building bridges and reducing the import dependence risks. In particular, China's oil strategic partners are Russia and Saudi Arabia, which are now the largest providers of crude oil together to the United States.

In 2017, the Chinese private group CEFC China Energy bought a 14.16% of Russia's state oil giant Rosneft, worth $9.1 billion stake, agreeing to supply CEFC China Energy with 244,000 b/d over the next five years. Russia's existing infrastructure is mainly oriented towards Europe so rising the deliveries towards China will need investments to expand the pipelines capacity to meet the Chinese demand in the long-term. What at the end of the day also diversifies the routes used and specially decreases the reliance on the so dependent Strait of Malacca.

Not only that, but in the past months China's state-owned companies PetroChina and Sinopec have announced their interest in a direct deal to buy the 5% of Saudi Arabian national oil company Saudi Aramco, when it gets listed in 2018/2019. The Saudi economy is also looking for diversification and to pursue it, the Kingdom is about to list 5% of its national oil company, leading to the world's biggest listing.

The second approach has been, taking advantage of the low oil prices and increasing the oil stocks of the country under the "Mid-Long-Term Plan of National Oil Stocks", which will expand further to 2020. The objective is to increase the ability to absorb potential supply disruptions without causing major consequences in the economy. According to China's National Bureau of Statistics, the oil stocks in 2016 rose to 245 million barrels, what is equivalent for more than 30 days of net imports for the country.

The third action has been to develop alternative land-based oil delivery routes to reduce the volumes transiting through the Southeast Asian sea. The main effort has been focused on improving the oil relationships with Russia and Kazakhstan due to their proximity and oil production resources. The Kazakhstan-China pipeline commissioned in 2006 with a 400kb/d capacity and the East Siberian-Pacific Ocean pipeline began to operate at its full capacity, 1mb/d, in 2012. With these main routes together to other additional infrastructure, Russia got to double its import share from 6% to 14% between 2010 and 2016.

In 2017, the Myanmar-China pipeline was commissioned in order to take crude oil from the Middle East or Africa towards China. This new pipeline was designed to reduce the reliance on the Strait of Malacca and allow a faster delivery of the oil with a capacity of 440kb/d.

Towards 2040 (Figure 76), and in order to continue with the diversification on the long term, the most promising options are to continue investing in the pipelines connecting China with Russia and Kazakhstan and to promote seaborne imports from North America, especially from Canada. As these will allow to diversify both, the source and the route of the imported oil.

The East Siberian-Pacific Ocean pipeline has a planned expansion of increasing its capacity to 1.6mb/d and the Kazakhstan-China pipeline will add an extra 360kb/d to its capacity. This extra capacity accounting for almost 1mb/d of possible oil imports coming from Russia and Kazakhstan represents a quarter of China's incremental needs by 2040.

In addition, Canada is well positioned to export oil to China but additional infrastructure needs to be constructed to absorb the increase in the export volume. In case the projected plans are materialized, an additional capacity of 700kb/d could be exported from Canada and United States by 2040.

Concerning future imports from Latin America and Africa, even in recent years the amount of oil imported from these regions has increased, the shrinking production outlook seems unlikely to support China´s necessary increase.

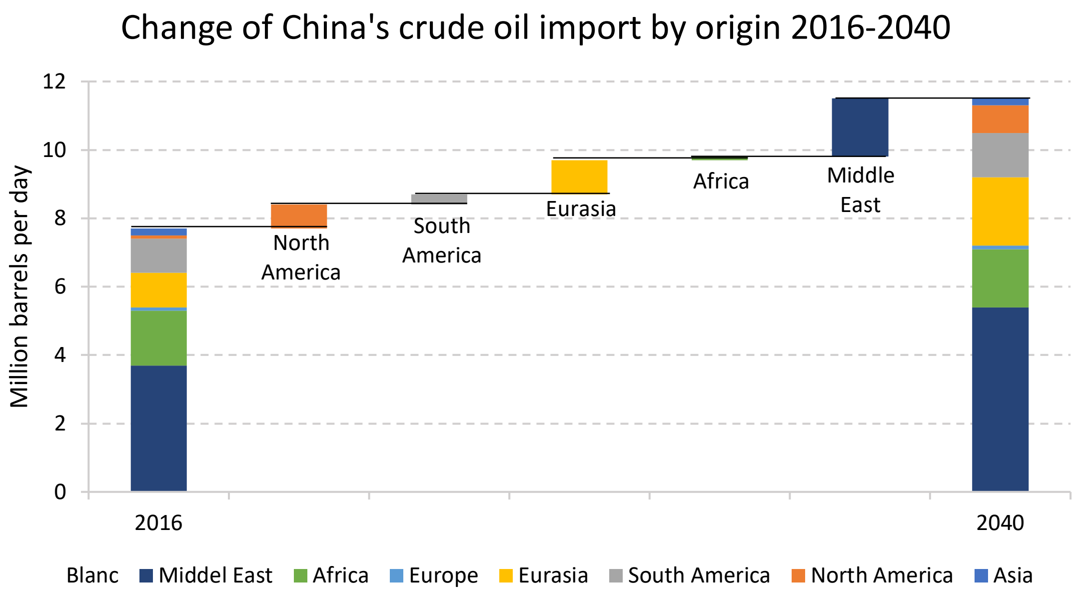

Figure 76. China's crude oil import by origin in the New Policies Scenario. Source: WEO 2017, IEA.

4.2.2.8. China is back in the oil futures market

The 26th March of 2018 China opened a domestic market to trade oil futures contract, allowing Chinese buyers to bolt in crude oil prices using the yuan (Park, 2018). In 1993 China introduced domestic futures too but stopped it only one year later due to volatility. This time, the launch which was proposed in 2012 has been delayed repeatedly due to oil low prices and destabilizing moves in the market. But with the barrel price reaching $70 and China having surpassed the United States in oil imports, they found it the right moment.

Futures trading will allow China to have some control over the pricing, which actually is based in dollars. By using the Chinese currency, this will promote the use of yuan within global trade which is one of China's long-term objective. In addition, the futures market might imply a strengthened oil security for the country as local refineries will be able to lock to the futures contracts fix prices in order to get protected against future import bill increases.

4.1.1.India

India's economy is the world's third largest by GDP in PPP terms behind China and the United States and is the home to 18.5% of the world's population. In terms of primary energy consumption is the world's fourth-largest energy consumer, but it only consumed world's 5.5% in 2016, even it has been responsible form almost 10% of the increase in the global energy since 2000. The mismatch between the world's population share and the world's primary energy consumption share is a strong indicator of the potential further growth of the energy demand in the country. According to the report "The World in 2050" (PWC, 2017), China will continue to be the largest economy in the world, while India could leave the US in a third place. This forecast is based in India reaching a 15% of the world's GDP (PPPs) share by 2050, while China remains on top with a 20% and the US drops to the third position with just a 12% of the share.

Indicator	2000	2005	2010	2016	Change 00-16
GDP ($2011 billion, PPP)	2,627	3,637	5,422	8,068	106%
Share of world GDP	4,2%	4,77%	5,95%	7,2%	-
Population (million)	1144	1231	1311	1327	16%
GDP per capita ($2016, PPP)	2,296	2,955	4,136	6,080	165%
Total primary energy demand (Mtoe)	441	496	537	897	103%
Total primary energy demand/capita (toe)	0.39	0.40	0.41	0.68	75%
Total oil demand (mb/d)	2.3	2.5	3.3	4.4	91%

Table 9. Economic and energy indicators for India. Source: WEO 2017, IEA and World Bank database.

Diving into the primary energy demand of the country by types of fuel, almost three-quarters of the demand are met by fossil fuels (Figure 77). From 2000 on, as households have moved away from the traditional use of solid biomass for cooking, the coal consumption has raised rapidly. In terms of oil consumption, as in the data of Table 9 can be seen, since 2000 to 2016 the crude oil consumption has raised from 2.3 mb/d to 4.4 mb/d implying a 90% of increase, even the total energy mix share has declined by 2%.

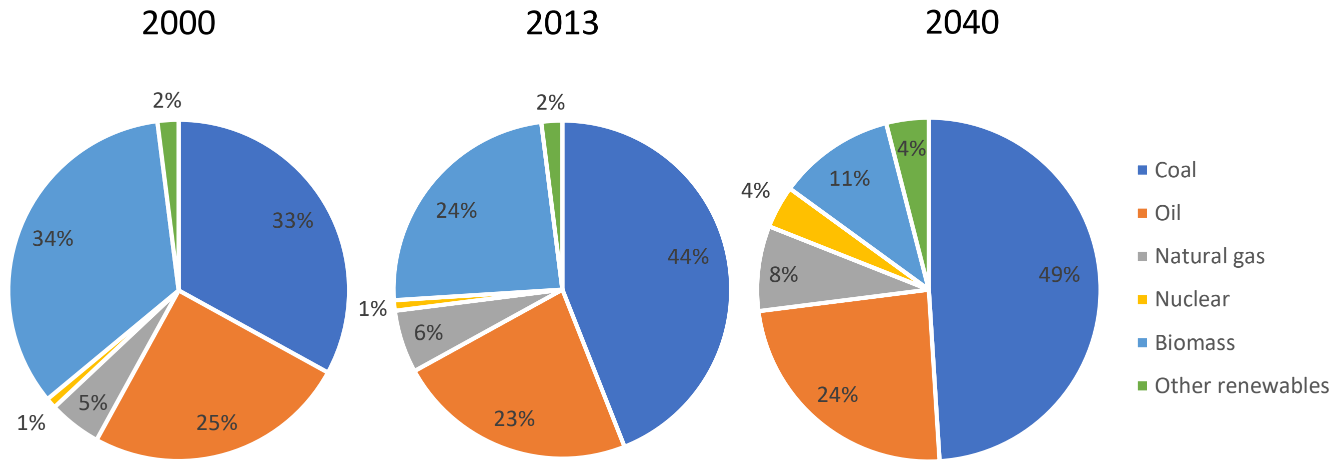

Figure 77. India's primary energy demand by fuel. Source: Indian Energy Outlook, WEO 2015.

Towards 2040, India is expected to have a compound average annual real GDP growth rate of 6.5% and the population is expected to rise to 1,634 million. India being the fastest growing country for the 2016-2040 period, according to the WEO's Indian Special Report (International Energy Agency, 2015), in absolute terms the total primary energy demand will grow from 775 Mtoe to 1908 Mtoe by 2040. In addition, the outlook for the energy mix indicates that India will be more reliant in coal while maintaining the share for the oil consumption.

Nevertheless, Indian government has learned from the Chinese government's failures in terms of emissions causing air pollution resulting from fast industrialization and car adoption and is taking several measures to promote the use of alternative sources of energy. In terms of emission outlook, CO2 emissions in India are forecasted to double by 2040 and the transportation and the industry sector will be the main drivers of it. The "Make in India" initiative is focused in the development of the industrial sector in order to boost the economic growth by increasing the share of manufacturing in the share of GDP, resulting directly in future emissions growth. This together with the rising vehicle ownership level that is expected in India, by 2040 India's annual per capita CO2 emissions are expected to reach 3 tons, which are yet much lower than those of world's biggest economies (less than one-third of those of the United States and Russia). Due to it, India is committed to lower its fossil fuel use to deal with the CO2 emissions as indicates in the National Electricity Plan and in the draft of the National Energy Policy (released in July 2017).

In the transportation area, India accounts with a National Electric Mobility Mission plan towards 2020, which aims to promote the use of electric vehicles by providing subsidies. The target is to reach a sales level of 6-7 million of electric and hybrid vehicles in the Indian roads by 2020. In addition, for heavy vehicles, new fuel efficiency standards will come into force in 2018, with harder standards to be introduced by 2021. These together will push to lower the oil demand in the transportation sector as in the next subchapter is analyzed.

4.2.3.1. Oil demand

In terms of oil, India is the third largest oil consumer, consuming 4.4 mb/d in 2016, what entails a 4.4% world's oil consumption share behind the United States (20.6%) and China (12.3%) (Eni, 2017). Between 2008 and 2016 the demand has grown at an average annual growth rate of 3.2% mainly due to the strong economic growth happening in the country, but at the same time the country has been very reliant on imports as it has 5.7 billion barrels of proven oil reserves, while yearly it consumes more than 1.6 billion b/d.

As 2016, the transportation sector accounted for 40% of the oil demand, and inside the transportation sector, 90% of the demand came from the road transport. But road transport's oil consumption prospects will be shaped in the future by two main drivers. The first one refers to the vehicle ownership levels per capita, as levels are still very low compared to other emerging countries and far below the levels of developed countries. The main reason behind it not only is the income per capita but also the poor road infrastructure of the country, what makes car ownership impractical even in affordable cases according to the World Bank. Nevertheless, according to the WEO's Indian Special Report (International Energy Agency, 2015), the number of cars per household in India will multiply by a factor of five between 2016 and 2040 as the country gets improving its infrastructure and incomes increase. As a result, the transportation sector will account for a major share in the increase in oil demand on account of the rising vehicle ownership level.

The second main driver will be the effort by the Indian Government towards the use of electric vehicles to cut reliance on oil, so that the import bill can be lowered together with reducing environmental issues and air pollution. Even there is not a strict target and at some point the Indian Government even appointed to push for a 100% of electric vehicles sold to the market by 2030, the 7th March 2018, Ajay Kumar Bhalla, the secretary at the Indian Ministry of Power said at the launch of national electric mobility program in New Delhi that "The government is focusing on creating charging infrastructure and policy framework so that by 2030, more than 30 percent of vehicles are electric vehicles" (Bhanvi, 2018). The results from this politics will increase the use of electric vehicles by 2040, resulting in a reduction of the oil demand in the end-use transport sector.

From the WEO's Indian Special Report (International Energy Agency, 2015), the conclusions point out that even the share of oil in the primary energy mix might fall slightly, oil will be used as a fuel input to meet the additional electricity demand of India, so at the end of the day the share will not be so shrank.

Looking forward, in the IEA's World Energy Outlook "New Policies Scenario" (Table 10), India's oil demand increases by 103% to 9.7 mb/d in 2040. With these prospects, China leaves the world's oil consumption growth leadership to India post 2025, as India alone will provide almost half of the 12 mb/d oil demand growth of the developing countries of the Asia Pacific. This contribution worldwide will mean an increase of almost 30% of the growth coming from India, what will offset the long-term decrease in oil demand of the OECD countries.

								CAGR
In mb/d	2000	2016	2020	2025	2030	2035	2040	16-40
Oil demand	2.4	4.4	4.8	6.3	7.5	8.7	9.7	3.31%

Table 10. India's Oil Demand - New Policies Scenario. Source: WEO 2017, IEA.

However, there are some discrepancies between different outlooks (Figure 78). While OPEC's reference case in the World Oil Outlook of 2017 is very much in line with the IEA's New Policies Scenario of the WEO 2017, the EIA in the International Energy Outlook of 2017 forecasts a slower demand growth through 2030. Nevertheless, after 2030 the growth rate gets in line with the one forecasted by the OPEC, while the IEA prospect predicts a little slowdown.

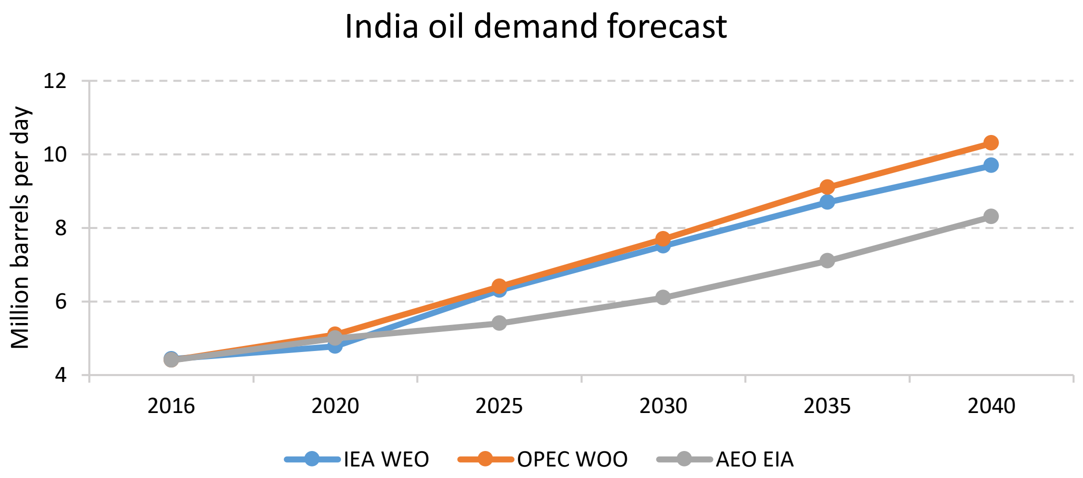

Figure 78. India long-term oil liquids demand outlook, in millions of barrels per day. Source: IEA WEO 207, OPEC WOO 2017 and EIA AEO 2017.

In terms of sector demand mix, the transportation sector will account for 65% of the Indian oil consumption rise according to the WEO's Indian Special Report (International Energy Agency, 2015), demand climbing to 5.3 mb/d in 2040. WEO's Indian Special Report's estimates are based in 260 million of additional new passenger cars circulating in Indian roads, together to 30 million new trucks and 185 million two and three-wheeler vehicles.

In Mtoe	1990	2013	2020	2025	2030	2035	2040	CAGR 13-40
Total Primary Oil Demand	**63**	**176**	**229**	**273**	**329**	**393**	**458**	**3.6%**
Total Final Oil Consumption	**52**	**150**	**202**	**243**	**298**	**360**	**423**	**3.9%**
Industry	10	19	24	29	34	40	45	3.2%
Transport	18	72	104	130	166	210	258	4.8%
Buildings	11	27	31	33	38	43	47	2.1%
Other	13	32	43	51	60	67	73	3.1%

Table 11. India's Oil Demand by End-User Sector - New Policies Scenario. Source: Indian Energy Outlook, WEO 2015.

4.2.3.2. Oil Production

In 2016 the domestic crude oil production reached 850kb/d (BMI Research, Q3 2017), but the oil output has been declining over the past years due to limited resources and relatively high costs concerning new oil projects. India has proven resources of around 5.7 billion barrels which are located in Rajasthan, the western part of the country, and in offshore areas near Gujarat and Maharashtra.

In terms of corporations, upstream production is dominated by two national companies, the Oil and Natural Gas Corporation Limited (ONGC) and Oil India Limited (OIL) controlling 70% of India’s oil output, and the rest of the production comes from joint ventures created under the New Exploration Licensing Policy introduced in 1999.

For the last decade, the Indian government has tried to boost the oil production in the country by opening the country’s upstream sector to non-state and private investors, but as the regulatory environment, the uncertainty around contracts and pricing arrangements, and the still not well explored resource base, the sector has underperformed. The Indian oil production output has been declining for the last five years and for 2017 the output has felt to 836 kb/d. This decrease has made India’s import dependence rise to 83% from 82% the previous year.

The Indian government being conscious of the risks that entails the dependence on overseas energy resources, is aiming to bring down the oil import dependence to 67% by 2022. For that the main drivers are increasing back the local output and increasing the use of biofuels in the transportation sector.

In order to increase back the oil output, since the election of Prime Minister Nerendra Modi’s, steps towards reforms in licensing and fiscal terms have been undertaken and prospects for greenfield projects in the Indian oil upstream sector have improved. Small and marginal fields have been auctioned and budgets of work programs and field development plans have been reviewed. Nevertheless, to increase the local oil production still will take a number of years. The BMI’s researchers forecast in the short term is shown in the Table 12.

In kb/d	2015	2017	2019	2021	2023	2025	CAGR 15-21	CAGR 21-25	CAGR 15-40
Oil production	846.3	836.3	835.1	844.8	901.5	915.9	-0.03%	2.04%	0.79%

Table 12. India's Oil Production - New Policies Scenario. Source: BMI Research.

4.2.3.3. Oil refining

The refining sector is very strong in India with a 4.4 mb/d capacity as 2015. Since 2005 it has almost doubled its refining capacity by adding more than 2 mb/d, giving the country a surplus of refined products. In consequence the domestic consumption has been outpaced and India is now a net exporter of refined products. In addition, between the refineries in India, the world's largest complex can be found, Reliance's Jamnagar, with a capacity over 1.2 mb/d, which is already more than the country's own production.

Refinery output is expected to rise a further 3.4 mb/d by 2040, being third country in the world in refining capacity after China and Middle East. Prospects forecast that high utilization rates will be increasingly focused to feed the domestic market's demand towards 2040.

4.2.3.4. Oil imports and security

In 2014 India met to be the third largest crude oil importer (9.8%) behind United States (17.3%) and China (17.0%) but at the same time being a major exporter of oil products due to the large refining sector the country has. By 2017 India reached 83% oil import dependency, both to reach the country's growing demand and to meet its refinery needs for crude oil. In consequence, the country has become very sensitive to oil prices fluctuations, as they affect directly and heavily to the country's economy and in particular the inflation. In terms of source, the largest import bill is from the Middle East while Latin America and Africa have also a considerable share. In Figure 79 the import shares in 2014 and the expected evolution forecasted by the IEA towards 2040 can be seen.

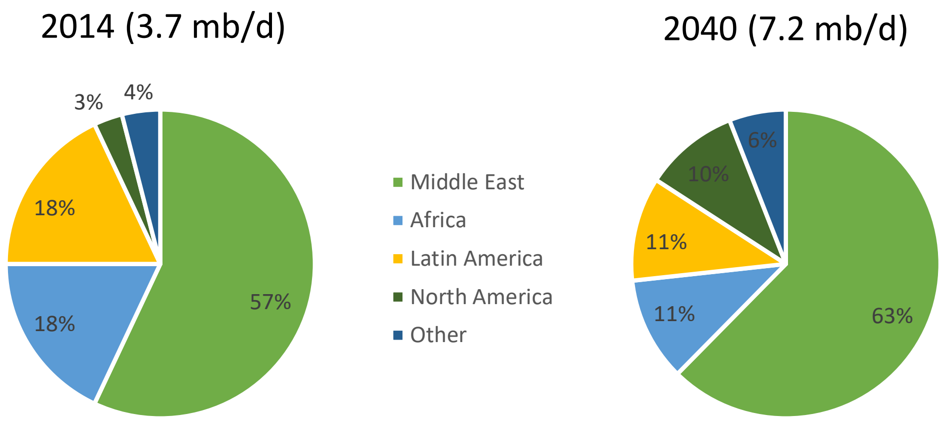

Figure 79. Crude oil imports by origin in India according to the New Policies Scenario. Source: Indian Energy Outlook, WEO 2015

Due to the demand growth and the little local oil production, by 2040 the net crude oil imports are expected to rise to 7.2 mb/d implying an import dependence of more than the 90%, which lies on increasing the reliance in the Middle East. This will make India the world's second larger importer after China, leaving ahead the United States who will reduce its import bill thanks to the domestic shale oil production revolution. In terms of import bill, for India is expected to increase from $110 billion in 2014 (5.3% India's GDP), to $300 billion in 2030 and $480 billion in 2040 (4.6% India's GDP) (International Energy Agency, 2015).

As outlooks predict 90% of oil dependence for India by 2040, security of oil supply has become an important concern for the Indian government. In order to deal with it several actions have been taken over time. Firstly, Indian oil and gas companies have increased their investments abroad to access low risk international supply and have increased their control over the whole import supply chain creating long term contracts and infrastructure-linked deals. Secondly, India is increasing its domestic production to decrease consequently its dependence in imports by implementing investor-friendly initiatives and reforms (McKinsey&Company, 2017). The aim with it is to boost the investments in the oil and gas sector and to increase the exploration and production activities. In addition, thanks to the lately low crude oil prices the Indian government has taken advantage of it and increased its stockpiles in order to be able to absorb oil price shocks.

In terms of pipelines and strait reliance, as for China, part of the India's imports coming from the Middle East also go through the Strait of Hormuz. Nevertheless, is not as reliant as China as it has deep water pipelines and land routes to import oil from the Middle East. In addition, its imports from Africa and America do not rely in any chokepoint so the international oil transport is not so critical for India.

4.2.4. United States

In section 4.1.2 we have analyzed the main characteristics that make United States a key player as a producer. Refer to the 4.1.2 for information related to the position of the United States in the world oil market, the "Shale oil revolution", production outlook and its refinery's capacities and characteristics.

In this section we analyze why United States is also a relevant player in the demand side in the oil market. For that, first we introduce the country's demand and trends in terms of primary energy consumption and its mix, and later on we focus in the actual and future oil demand and its characteristics and effects in the global oil market.

According to the WEO (International Energy Agency, 2017), as 2016 the U.S. is the world's second largest primary energy consumer after China, with a total primary energy demand of 2.154 Mtoe, world's 15,6% share (Table 13). In addition, as an energy consumer on a per capita basis, the U.S. is in the third position behind Iceland and Canada driven by the high incomes of the country.

Indicator	2000	2005	2010	2016	Change 00-16
GDP ($2011 billion, PPP)	12.976	14.706	15.273	17.024	31%
Share of world GDP	20,6%	19,30%	16,75%	15,5%	-
Population (million)	285	296	310	324	13%
GDP per capita ($2011, PPP)	45.495	49.662	49.308	52.908	16%
Total primary energy demand (Mtoe)	2.270	2.263	2.093	2.154	-5%
Total primary energy demand/capita (toe)	7,96	7,64	6,76	6,66	-16%
Total oil demand (mb/d)	19,7	20,8	19,2	19,6	-1%

Table 13.Economic and energy indicators for US. Source: WEO 2017 IEA, Statista, EIA and World Bank database.

Prospects in the medium term for the United States macroeconomic trends show that the real GDP is expected to grow at a compound average annual rate of 2% between 2016 and 2040, as it reaches a population of 378 million by 2040. Nevertheless, primary energy demand in the U.S. is forecasted to decrease a 0.1% to 2,122 Mtoe by 2040 due to a reduction in the energy intensity of the country, what implies a fall of the country's primary energy consumption share to 12,1%. The EIA predicts through 2040 the energy intensity of the U.S. to decrease at an average annual rate of 2%, mainly driven by the decline of the energy consumption in the transportation sector.

In terms of energy mix by end use consumer, the transportation sector accounts for 29% of the energy used and 88% of it are products derived from the petroleum. In the other hand, in terms of source (Figure 80), an evolution has been seen over the last decade, as coal consumption peaked in 2008 and has lost share since then, which has been gained mainly by oil and renewables. Through 2040, in the AEO (U.S. Energy Information Administration, EIA, 2018) is forecasted that the oil consumption will continue increasing its share, while its demand pattern will change from the transport sector to the industry sector, as the demand for oil for petrochemicals feedstock is rising. The main drivers behind the recent consumption drop in the transportation sector are the advanced fuel efficiencies, the effect of low fuel prices subsidies and the increasing focus on emissions. Notwithstanding, Trump's administration is revising the vehicle emissions and fuel efficiency rules put in place by Barack Obama's administration, which could lead to a less pronounced decrease of oil demand in the transport sector in the short term.

Not only that, but in March 2017 an Executive Order was released by the Trump's administration where the use of US energy resources was emphasized towards improving the domestic economic growth and employment of the country. This implies a new direction in the United States energy policy as its leading to reviews of the existing regulations, the Clean Power Plan and has also resulted in the US withdrawing from the Paris Agreement on climate change.

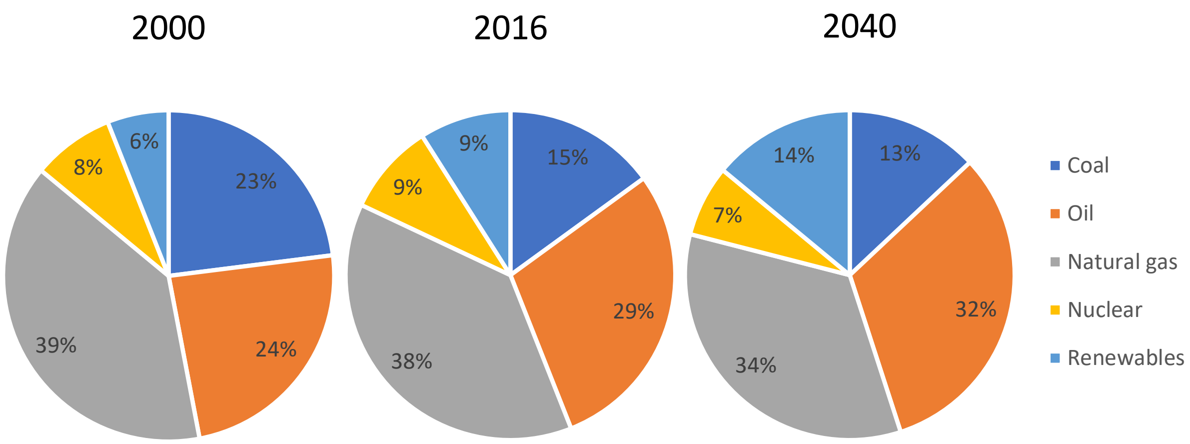

Figure 80. United States' primary energy demand by fuel. Source: EIA.

4.2.4.1. Oil demand

As 2016 United States continues being the world leader in terms of oil consumption, consuming 19.8 mb/d, what makes the U.S. to dominate 20.6% of global oil consumption share. Nevertheless, the U.S. has lost since the 2000 5.3% of its share due to an annual average growth rate of 0.0%, while the world's oil demand has grown at a 1.4% annual average growth rate, mainly driven by the increase of oil consumption in the non-OECD countries. Moreover, the U.S. reached its oil demand peak in 2004, and afterwards the consumption decreased together to the rising oil prices and stagnated (see Table 13).

The main reasons behind the 0.0% annual average growth rate between 2000 and 2016 are related to changes in the transportation sector (see Figure 81). The increase in fuel economy and the decline in the miles travelled have been the huge unpredicted disruptors. Given that the U.S. population has been growing at a 1% average annual growth rate for the last years, it seemed that the miles travelled should have kept growing at least at the same path, but as miles per person dropped, the effect in the U.S. oil consumption has been devastating compared to what the EIA forecasted in its reports at the beginning of the 2000s.

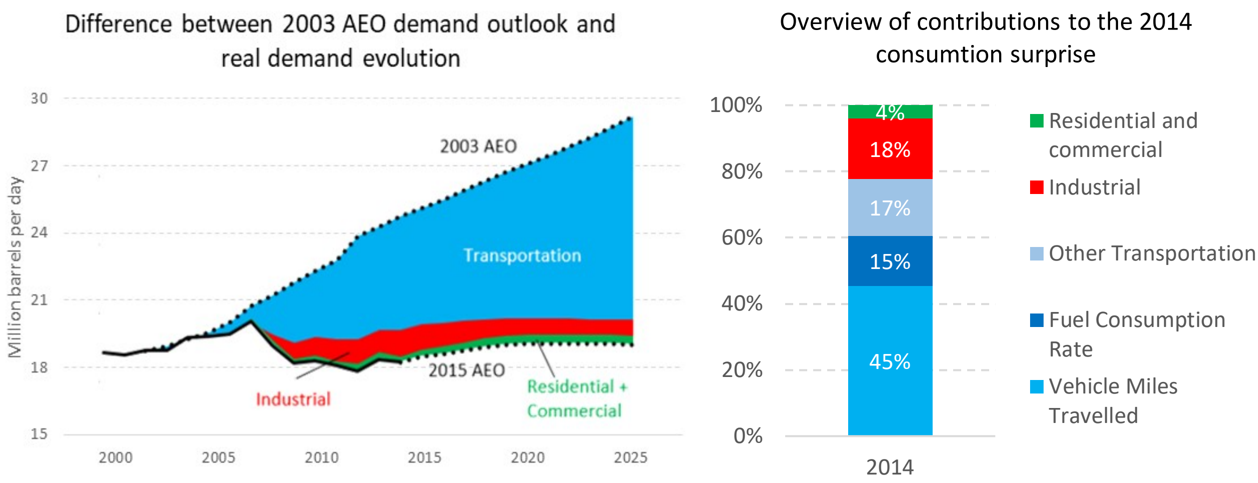

Figure 81. United States unpredicted demand evolution 2003-2014-2025. Source: EIA.

In terms of oil consumption per sector, the transportation sector accounted for the 66% of the consumption share in 2000 and has grown to 71% by 2016, consuming 13.9 mb/d (see Figure 82). Even the share has increased, further fuel efficiencies might play a significant role in the demand of oil products coming from the vehicles in the near future, together with the expected electric and autonomous vehicle revolution. Despite, the sector that has proven an increase that could be sustainable in the future has been the petrochemical one. The cheap domestic shale has opened the door to oil consumption as feedstock which is answering for the rising demand for consumer goods, where a large number of chemicals derived from oil are used for the manufacture of many products.

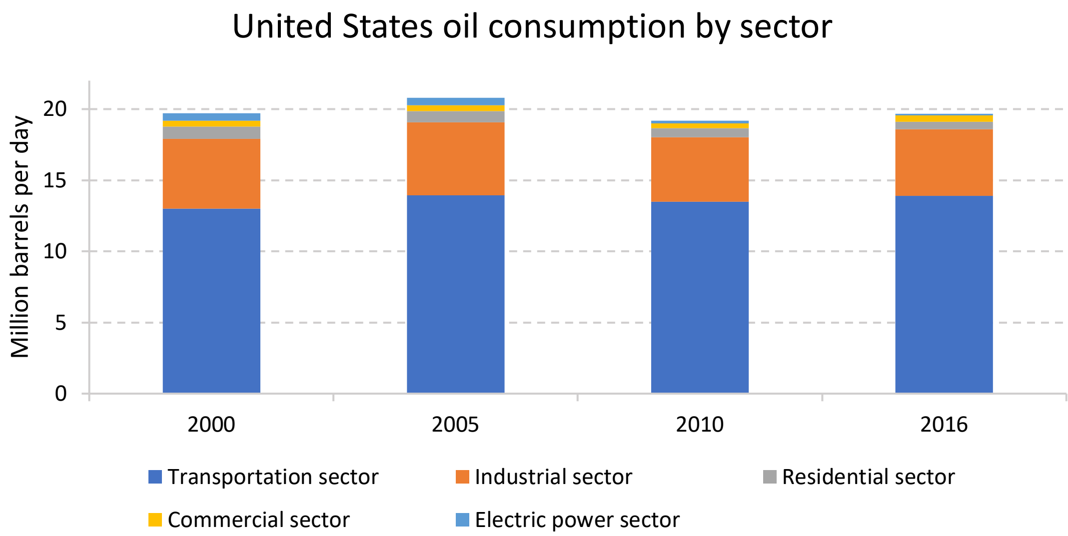

Figure 82. United states oil consumption by sector. Source: Statista.

Looking forward, in the IEA's World Energy Outlook "New Policies Scenario" (Table 14), the U.S. oil demand decreases by 1.2% to 14.6 mb/d in 2040. As mentioned before, the strongest growth will come from the petrochemical sector, which will soften the expected growth fall of the oil consumption from the road transportation. With these prospects, by 2030 China will overtake the U.S. as the largest oil consumer.

							CAGR
In mb/d	2000	2016	2025	2030	2035	2040	16-40
Oil demand	18.9	19.8	18.6	17.3	15.7	14.6	-1,2%

Table 14. United States Oil Demand - New Policies Scenario. Source: WEO 2017, IEA.

However, there are some discrepancies between different outlooks (see Figure 83). While IEA's New Policies Scenario is predicting a disruption coming from the road transportation sector which will not be offset by the increase of oil consumption in the petrochemical sector, the EIA in the International Energy Outlook of 2017 takes a much more positive view, forecasting a slower demand decline through 2030. In addition, after 2030 the growth rate gets almost stagnant around 19 mb/d, which is quite weird as the autonomous and electric vehicle revolution is estimated to be heavily adopted in the United States in those decades which is predicted to imply a huge decline in consumption.

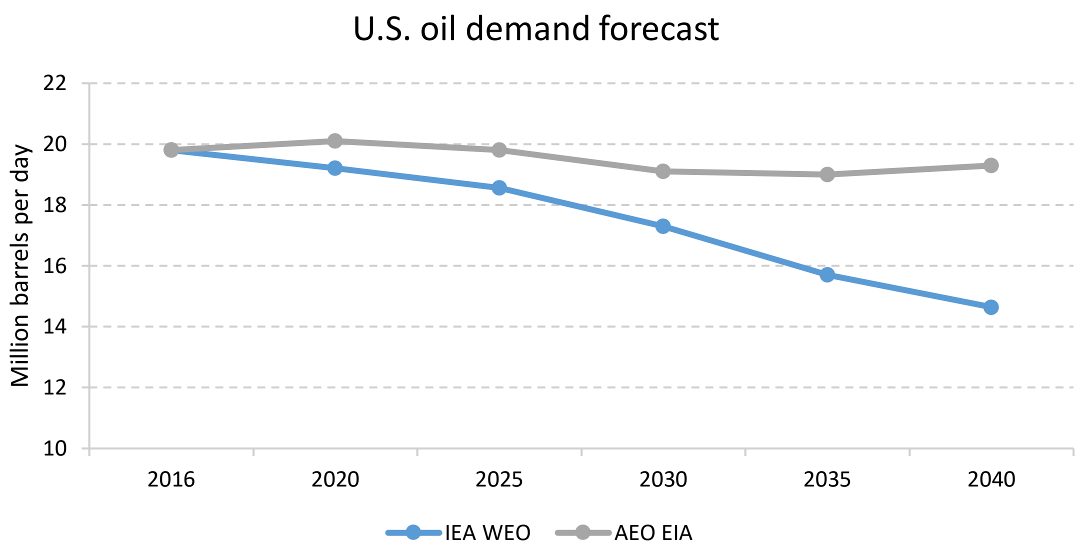

Figure 83. United States long-term oil liquids demand outlook, in millions of barrels per day. Source: IEA WEO 207, and EIA AEO 2017.

4.2.4.2. Oil imports and exports

From 1975 to end of 2015, United States traded under the crude oil export ban, measure the country implemented in response to the oil embargo that the Organization of Arab Petroleum Exporting countries pursued against the United States at the time. Since 1975, only exports towards Canada were exempt from the ban. Notwithstanding, in the beginning of the 2010s, as a result of the shale revolution in the United States, the domestic production grew and led to an increase in the exports to Canada. But at the same time the increasing oversupply in the domestic oil market was contributing to depress the domestic crude oil prices relative to international ones. In response to the fear of a discount in the U.S. crude prices relative to the international ones, the U.S. lifted the ban over crude oil exports in January 2016.

As 2016, the U.S. imported a total of 10.1 mb/d of crude oil and petroleum products, what implied 22% decrease with respect to 2008 due to the rise in domestic tight oil production. In the exports side, as the domestic oversupply of crude resulted in the lift of the ban of crude oil exports, the U.S. exported a total of 4.7 mb/d implying 140% increase compared to 2008 (BP, 2017). Nevertheless, the U.S. net imports still represent a significant 15.4% share of total world's net import activity in 2016, see historical trade evolution in Figure 35. The five largest petroleum import sources and the five largest export destinations are shown in the table below.

Five largest shares of U.S. petroleum trade

Imports		Exports	
Canada	40%	Mexico	17%
Saudi Arabia	9%	Canada	13%
Mexico	7%	China	7%
Venezuela	7%	Brazil	6%
Iraq	6%	Japan	6%

Table 15. United States five largest import and export partners by share in 2017. Source: EIA.

As one of the Trump administration's objective is to achieve the "energy dominance", the strong domestic production together with a flattening oil demand is expected to allow the United States to become a net oil exporter by the late 2020s in a high oil price scenario. In the reference case of the AEO (U.S. Energy Information Administration, EIA, 2018) is indicated that the U.S. might become a net exporter of petroleum liquids and products between 2029 and 2045 depending on the market conditions (see Figure 84). In particular, the country will become a net exporter of light crude and refined products, but still will continue to be a major importer of heavier crudes as the US refineries' configurations needs to be suited.

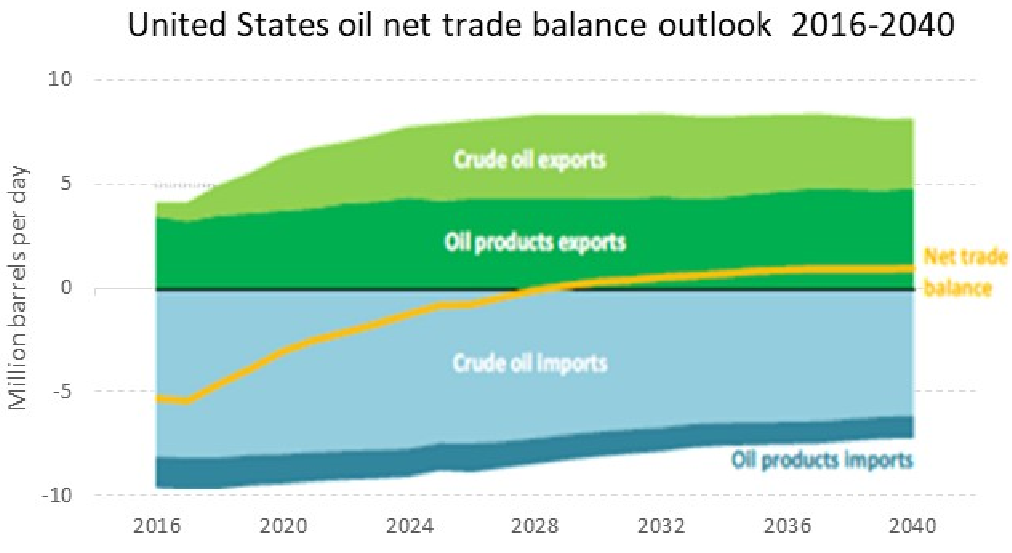

Figure 84. United States net trade balance in the New Policies Scenario. Source: WEO 2017, IEA.

In detail, the oil trade outlook of the United States is mainly shaped by the U.S. refineries limitation to process the domestic light crude. In consequence, part of the domestic tight oil will continue being exported, reaching around 4 mb/d by 2030, and falling to 3.4 mb/d by 2040 as tight oil production starts to squeeze. By 2040, over 6 mb/d of heavier crude will be imported from Canada, the Middle East and Latin America to match the demand of the U.S. refineries. In addition, unless there is a continuous discount of domestic oil prices compared to the international ones, is unlikely that major investments will be taken towards adapting the U.S. refineries to process domestic light crude oil.

In terms of oil security, until de 2010s, the United States focused on decreasing the country's dependence in oil imports. Thanks to the shale oil revolution this issue has been addressed and actually, the U.S. produces more crude oil than it imports. This has made the oil security of the country to change in some extent. But the Hurricane Harvey left visible the domestic oil production is also subject to risks and that not just by reducing the imports the vulnerability to supply shocks gets reduced. Actually, the Harvey Hurricane caused damages and heavy disruptions in the refining, production and pipeline facilities around Texas. As mentioned in the section 4.1.2. U.S. needs to improve its domestic oil transportation infrastructure and the oil refining capacity while keeping relations with its main heavy crude oil import partners and decreasing the potential import risks, in order to control the whole supply-chain of the oil consumed by the country.

4.2.5. Transportation Sector Disruption

The transportation sector accounts for 43% of the global oil demand consuming 40.7 mb/d as 2016 by passenger and freight transport, and it is forecasted to decrease to 42%, consuming 44 mb/d by 2040 at the time the global car fleet doubles from 0.9 billion in 2015 to more than 2 billion in 2040. The IEA estimates that the peak of the demand of oil in the road transport will be in the late 2020s as the use of oil for the trucks will continue to grow, while for passenger vehicles the peak will be in the early 2020s due to efficiencies in internal combustion engines, the adoption of electric vehicles and the disruption towards the passenger road transport as a service.

These new trends together are driving the emergence of the future mobility, which center lies on moving cheaper, faster, safer, cleaner, and in ways that are more convenient to the consumers, pushing the overall cost in the sector down. Nevertheless, due to the fast technological changes, there is uncertainty around the timing of the shift and the impact new trends might have in the long term in the oil demand.

4.2.5.1. Efficiencies and regulations

In the period to 2025, fuel efficiencies in the internal combustion engine cars, together to the regulations around diminishing pollution might improve both the safety and the efficiency of the journeys. In detail, according to the IEA, the stringent efficiency standards pushing for fuel efficiencies might lead to a reduction in the oil demand of 14mb/d from passenger vehicles[23] by 2040. In addition, as 2016, fuel efficiency policies covered 80% of the global passenger vehicles sales, while just 50% of the truck sales were adhered to this kind of policies, which leads to a pace of future improvement. For example, is forecasted by the IEA that trucks will be able to use 40% less of fuel by 2040 than today. The figure below shows the forecasted increase in gasoline fuel efficiency vehicles, decreasing the consumed litres per kilometer from around 6 in 2016 to near 2l/km by 2040

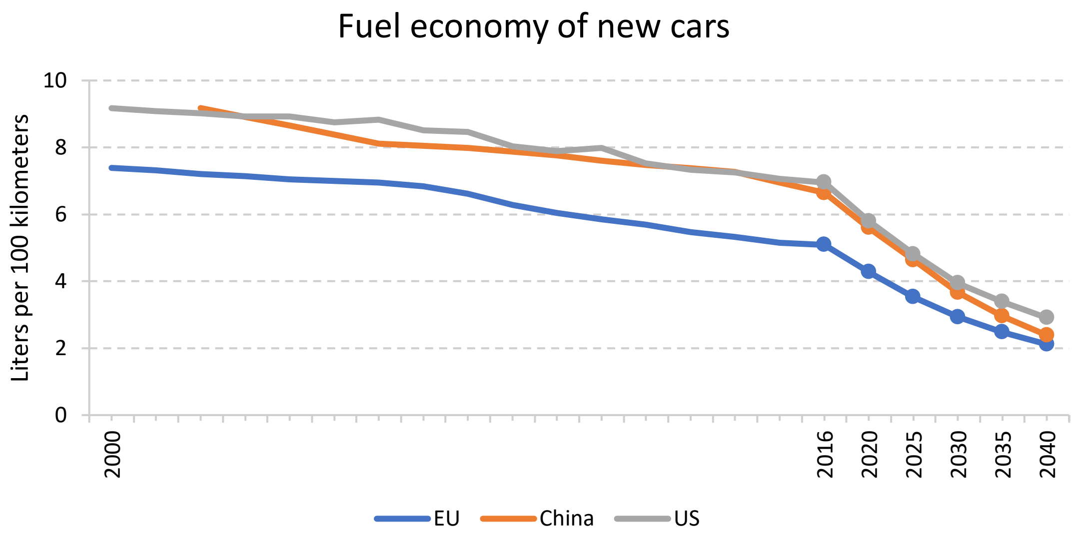

Figure 85. Fuel economy evolution (gasoline fuel) and forecast for Europe, China and United States. Source: BP energy outlook 2018.

4.2.5.2. Electric vehicles (EVs)

In 2016 more than 760,000 electric cars were introduced to the world's roads, rising the amount of EVs to 2 million. In the past years, China and India have positioned themselves as market leaders, China having sold almost half of the global electric cars worldwide. Nevertheless, towards future adoption of electric cars by the mass-market, the growth will be driven by three main elements that determine the cost and the attractiveness of the vehicle for the consumers.

- **The cost of electric vehicles compared to the conventional ones**. In an electric vehicle the main cost driver is the battery, but since 2010 they have been coming down at an annual rate of 7% and is forecasted to continue reducing at 6% rate until 2025 due to the fast increase in market share and the consequent economies of scale. Nevertheless, capital costs for an EV as 2025 are expected to remain still higher than those corresponding to conventional vehicles. But conventional internal combustion engine (ICE) cars are expected to become more expensive in

[23] Includes passenger cars, two/three wheelers and buses.

the future, as air polluting standards and more demanding fuel-economies will arise. In consequence and as daily running costs for EVs are lower, payback periods for consumers will be attractive. However, this will vary across countries because consumer’s car preferences are wide. In United States for example, the payback periods will be higher compared to Europe, India or Japan because as consumers prefer large vehicles, larger batteries are required, increasing the costs.

- **The incentives and the supportive policies**. The EVs sales are directly related to the subsidies that the governments might provide to close the gap between electric and conventional vehicles. Particularly in cities such as Copenhagen, London, New York City or San Francisco, policies that promote the use of electric vehicles are being implemented to deal will the air pollution and push for the electrification of the cars and the public transport. But also policies to decrease the use of conventional internal combustion engine cars are implemented to deter people from using old cars and promote the sale of more fuel-efficient vehicles and EVs.

- **The recharging infrastructure.** There are two main challenges linked to the EVs charging infrastructure. The first one is about the recharging system itself. It needs to ensure that provides enough energy in a proper time period to a great number of vehicles (power supply standpoint). Refilling a conventional ICE car with oil takes less than 10 minutes in a petrol station compared to a 4-8 hours charge that a battery needs to reach the same level of autonomy. The second challenge is about the density of the recharging infrastructure itself (distribution standpoint), which needs to be prepared to provide the needed energy at the needed place. The main problem is the circularity behind it, as a proper recharging infrastructure provides more autonomy to electric vehicles, but the number of electric vehicles in the road still is not enough to push for such investments.

Nevertheless, the low oil prices provide an advantage to the conventional fuel cars as it makes the economic barrier harder to overcome for the mass-market. All together, the first adopters of electric cars will be those with high usage rates, likely in countries where oil prices are high due to taxes. From 2020 to 2025 the EVs fleet is forecasted to grow 50% annually and by 2025 there will be around 50 million of EVs on the road. By 2025 is expected that electric cars start to be attractive for the mass-market and other segments too (see Figure 86[24]). For example in Europe, the payback for an electric car with a drive range of 200-300km will be of four years due to low running costs. By 2030 in India and Japan the payback period also will become attractive to the mass-market and a little later in China. According to the IEA, the amount of electric cars on the roads by 2025 will displace 0.7 mb/d of the global oil demand.

[24] ICE vehicles make reference to hybrid vehicles that do not plug into the power grid.

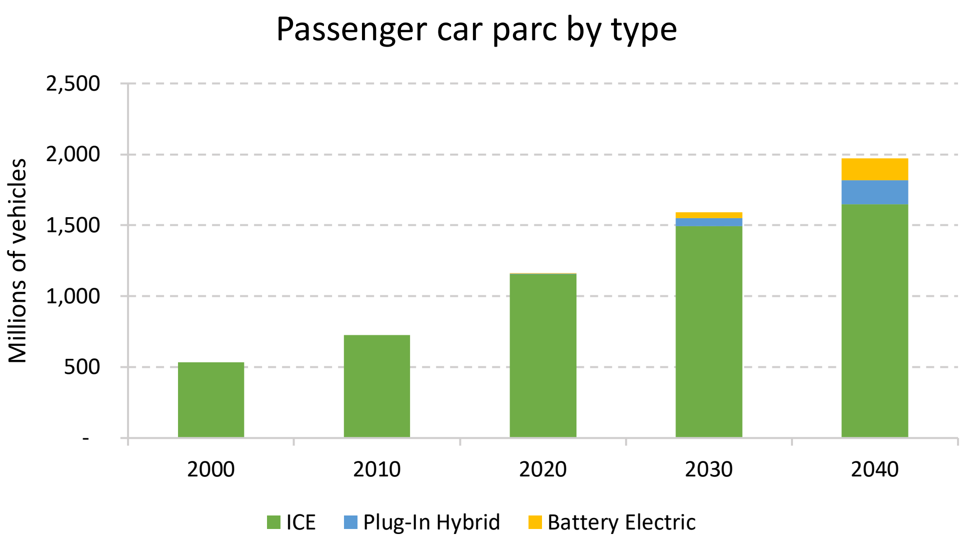

Figure 86. Passenger car parc by type. Source: BP Energy Outlook 2018.

By 2040, the World Energy Outlook's New Policies Scenario (International Energy Agency, 2017) forecasts that 280 million electric cars (40% of the global car stocks) will circulate worldwide, what will lead to 2.5 mb/d of potential oil consumption displaced. In the case there is a stronger policy implementation, investments in the EVs infrastructure will increase and the costs of EVs will get reduced, leaving place for the electric vehicles fleet to expand to around 900 million, leading to further oil consumption displacement, what could possible change the long term equilibrium of oil prices.

At the end of the day, all the assumptions and forecasts will depend in the real speed of the mobility revolution, as electric cars are only a part of it. Electric cars, together to autonomous driving, car sharing and ride pooling will shape the future oil demand for the passenger road transport.

Going further in those trends, autonomous vehicles are estimated to reduce the energy demand in a 25% both in the EVs and in the ICE cars. In the case of the car sharing, the initiative alone does not directly affect the oil demand, but in case the shared car is an electric vehicle or an autonomous (AVs) one, the effect over the oil demand gets amplified as more conventional cars get displaced. Finally, the ride pooling directly decreases the number of kilometres driven by a conventional car as it rises the number of occupants per vehicle reducing the number of conventional vehicles in the roads.

4.2.5.3. Transport-as-a-service (TaaS)

All the technologies together, a future trend is being created which still is not very visible in the market. The real passenger transportation revolution implies the passenger vehicles moving to an on-demand autonomous electric vehicle service model, which will be owned by fleets and not by individuals. The disruption will have heavy implications in all the value chain of the transportation sector, affecting directly to the oil demand and its prices. What is uncertain about it is when will be fully adopted by the consumers as both technology improvements and regulatory approvals are needed.

The Taas disruption, predicted by James Arbib and Tony Seba (Arbib & Seba, 2017) in the report "The Disruption of Transportation and the Collapse of the Internal-Combustion and Oil Industries" is forecasted to provide 95% of the passenger travelled kilometres within 10 years after the broad regulatory approval of the autonomous vehicles. From their research, they estimate widespread regulatory approval for AVs to happen by 2020, and already by 2030 they estimate just 40% of ICE vehicles left in the United States fleet, which will only provide the 5% of the passenger travelled miles, the other 95% being covered by the TaaS platforms.

Pre-TaaS platform providers as Uber and Lyft are an example of the highly competitive market that might rise after the approval of the autonomous vehicles, as they will transition fast their fleets from human driven intern combustion engine cars towards autonomous electric vehicles following the "winners-take-all" dynamics, what will imply large upfront investments. From the consumers stand point, the cost saving offered by TaaS will be the main driver to adopt it, as it will offer four to ten times lower costs per kilometer than buying a new car, and two to four times lower costs than operating an existing ICE vehicle. On the other hand, the main deterrents not to adopt it will be the passion for driving, the fear towards new technology or habits, and the waiting times and costs related to it in suburban and rural areas.

James Arbib's and Tony Seba's analysis forecast's a very fast and extensive disruption after the autonomous vehicles get approved. Their research points out that the global oil demand 10 years after the widespread approval of AVs falls by 30% and remarks that the implications and disruptions the TaaS might cause have not been fully recognized by the market yet. But the transition might not be that fast due to regulatory, legal, ethical and behavioral barriers. What is the most visible of this upcoming mobility revolution is that electrification of cars has enabled autonomous driving, and the implementation and approval of autonomous driving will accelerate the adoption of electric vehicles, leading to the strongest oil demand displacement the oil market might see in not a very long term.

5. Future outlook expectations for the oil market

In this section, we will compile the demand and supply forecasts presented throughout this project. We will also expose the main strengths and weaknesses, as well as opportunities and threats, of each essential player in the new oil order so as to build a solid foundation for the application of game theory throughout section six.

5.1. OPEC

Strengths

- The group's coalition and quota system make them behave as a cartel, leading to significant power over oil price management. Historical review suggests that they accommodate production to retain a c. 40% share of world oil output.
- The countries involved control conventional oil fields having the lowest full-cycle breakeven points (average onshore production at c. $27/bbl), which means flexibility to produce under whichever oil market condition.
- Members control over 72% of global proven oil reserves, causing not only lower necessity to efficiently manage available oil resources (in favour of satisfying interim government budget calls) but also the power to assimilate supply gaps once other regions reach output peaks.
- Middle East countries in particular display an opportune geographical setting adjacent to major net oil importing players such as Europe, China and India, with a strong maritime and pipeline transportation infrastructure in place.

Weaknesses

- Players involved are primarily oil-dependent states whose oil industry is governed by NOCs. Their objectives are predominantly linked to maximise their respective states' welfare and geopolitical powers: goals which are much more obscure and complex compared to IOC's shareholder-value maximization targets. This creates certain difficulty when awarding supply targets to their members.
- OPEC is a non-perfectly colluding cartel: non-compliance of production quotas is common practice given member's tendency to overproduce. This tit-for-tat strategy generates overall less profits in the long term and damages OPEC's price management capabilities.
- Social and political instability following the Arab Spring have brought a considerable increase in government social spending plans, which in turn kindled states' oil dependency. Budget financing needs pose certain inelasticity towards OPEC's future decisions concerning oil price management practices. This situation is even worsened due to the trade-offs faced with the existing diversification plans.

Opportunities

- The organisation should take advantage of its convenient geographical position to secure long term demand from pivotal Asian neighbours such as India, at present the fastest-growing oil consumer, and China.
- OPEC members should also develop strong and modern refining infrastructure to supply increasing high-value added petroleum products to Europe.
- Maintain alliances with other salient producers (such as Russia with their OPEC-non-OPEC agreement to cut production) in order to seal an effective influence over oil price dynamics and shelter against the downward pressure that disruptive additional oil flows generate.

Threats

- Ballooning social and political turmoil. Certain output shocks emanating from various OPEC members, such as Libya and Syria, have already hit the market. Risk of terrorist attacks to fundamental oil infrastructure can severely damage the prevailing oil flow to the international community.
- Religious clashes and political confrontation between key players, such as the historical duel between Riyadh and Teheran, pose the risk of fragmentation of the organisation and prioritisation of own interests before OPEC's.
- Trump's withdrawal from the JCPOA and U.S.'s re-activation of sanctions on Iran will hurt its output growth outlook in the medium-term. Current oversupply and increased international liquidity in oil markets triggers, despite increased oil prices, a market share loss threat.

5.2. U.S.

Strengths

- Shale oil revolution has unlocked vast high-quality resources. LTO production has soared from 2010 onwards, generating over 5 mb/d of additional oil supplies as of 2018 and rising the U.S. to top dog already in 2013. LTO output surge is expected to continue up to 2025, when the U.S. supply would peak at c. 17 mb/d.
- Despite LTO production being the indisputable growth driver, other sources of growth such as the Gulf of Mexico offshore crude and multiple onshore pockets in the lower-48 states are also expected to remain buoyant.
- Significant market liquidity with large flow of funds and capital injections to sustain greenfield investments create confidence on the country's ability to secure future additional sources of supply and extend their existing refining and transportation infrastructure network.

- Decreasing dependence on oil thanks to increased light sweet oil from shale plays and Venezuela and Mexico.

Weaknesses

- Shale oil wells' set up requires specialized equipment which makes this technology both more costly and complex to construct (full-cycle breakeven prices stand around $65/bbl, well above OPEC's low-cost supplies). U.S.'s increasing reliance on expensive unconventional resources reduces its flexibility and poses a challenge towards its ability to survive under a low oil price environment (despite the recent resilience shown).
- Transportation and refining infrastructure constraints to handle ever-increasing flows of high-quality liquids into U.S.'s oil industry requires additional capital-intensive infrastructure projects (such as pipelines) to avoid excessive inventory build-ups in Cushing.
- Geographical insulation compared to key competitors and higher transportation costs lead to high WTI-Brent spread and difficulty to compete with Middle East players.
- Fragmentation of the oil industry into thousands of independent IOCs, without incentives to maintain spare capacity in place, make a coordinated action to manage oil market prices unrealistic.

Opportunities

- Further exogenous well-head breakeven prices improvement thanks to continuous cost reductions, increased recovery rates and oil rig productivity optimisation (both in the most prolific plays as well as in less exploited areas) through technological innovation.
- Increasing shale oil reserve estimates attract investors and allow for higher production. This increments U.S.'s opportunity to capture market share in the medium-term taking advantage of Persian Gulf's political instability

Threats

- The same beneficial large endogenous decreases in well-head breakeven prices after 2014's oil price drop will be reversed in a higher oil price environment (costs seem to follow oil price). Shale oil play's profitability will materially deteriorate if exogenous improvements don't keep up.
- Worsening international relations with key trading partners due to Trumps' protectionist campaign (specially China following Trump's and Xi Jinping's trade tariffs tussle) originate concerns over US ability to secure long term foreign oil demand with Asian partners
- Lower-than-expected shale oil reserves deriving into sooner-than-later new peak-oil supply.

5.3. Russia

Strengths

- Russian government tendency to make successful ad hoc adjustments to the tax regime to encourage the maintenance in crude output. On the one hand, the marginal rate and sliding scale of Russia's taxes protects oil companies' cash flows, at the expense of state's revenues, under a low oil price environment. On the other hand, current measures such as tax breaks and the Big Tax Manoeuvre have been put in place to incentivise investment in difficult-to-develop resources, upgrade refineries and prioritise increasingly-demanded value-added petroleum products exports.
- The aforementioned fiscal policy should help unlock Russia's potentially vast resources (apart from its 267bn barrels of proved reserves), which include three primary growth dimensions: large basins in the Russian Far East and Eastern Siberia (160bn barrels of unproven oil reserves), the Artic offshore (50bn barrels of additional oil reserves) and low permeability reservoirs including shale plays (75bn barrels of technically recoverable reserves).
- Strategic geographic location nearby key energy-dependent importing countries such as Europe, China or India, along with its extensive network of ports and pipelines in the Atlantic and Pacific basins, make Russian exports reach economically almost any place around the world.

Weaknesses

- Traditional large oil fields in Western Siberia's natural decline rates can be as high as 10-15% per annum due to the geology of the fields. Significant investment is needed to implement enhanced-oil recovery (EOR) techniques at existing fields or new oil field discovery to avoid abrupt output shortages (as seen from 1990 to 1999).
- Deteriorating relationships with many countries in the international community after the 2014 crisis in Ukraine led to the imposition of US and EU sanctions. These sanctions restrict Russia's access to western capital markets, services and technology in support for deep-water, Artic offshore, or shale resources, and drove a suspension of considerable international involvement in Russian projects, with the subsequent delay of such new sources of supply. Sanctions seem far from being lifted in the near-term given recent U.S. tightening's and pose a significant challenge to Russia's output growth capabilities.
- Industry consolidation into larger and more bureaucratic entities and the rise in dominance of state-controlled companies have proven to be much less effective at growing production.

Opportunities

- Maintain and secure long-term demand from key neighbours such as China and its longstanding trading partner, Europe, profiting from their geographical proximity and newly built pipeline infrastructure (ESPO pipeline).
- Upgrade its currently inefficient and too-old fashioned refining production to increase supply of high-value added petroleum products to Europe.
- Maintain coalitions with other key producing players (such as OPEC with their OPEC-non-OPEC agreement to cut production) so as to secure a higher oil price environment to restore state's budget.

Threats

- No major effects on Russian short-term production have followed US and EU sanctions given that the projects affected were expected to begin producing in 5 to 10 years from 2014. However, as time passes and current fields become depleted, production shortages could arise in the near term if investments falls short to counteract high natural decline rates.
- With cheaper conventional oil fields at the declining stage of their life-cycle, output growth needs to come from costly resources, pushing up average full-cycle breakeven prices (currently at c. $50/bbl), therefore with the potential to erode the industry's profitability and competitiveness. Currently, government subsidies and tax reliefs are necessary to achieve investor's minimal acceptable rates of return in EORs and capital-intensive projects.
- Fall in oil prices drove Russian Rouble's impressive devaluation, leading to reduced costs in US dollar terms given that c. 80% of the industry costs are domestic (which helped Russia resist the 2014 oil price downturn). In a higher oil price environment, the reverse will likely hold true, taking breakeven points to higher levels in dollar terms and eroding field's exploitation bankability.
- Russia's high dependence on Europe imports (accounting for c. 65% of current oil exports) creates the necessity to diversify away from this mature oil market player with a clearly declining consumption trend.

5.4. China

Strengths

- The country is the world's second largest oil consumer behind the U.S., and the seventh largest oil producer accounting for a 4.5% share of global oil output.
- China has equity invested overseas, ensuring more than 3mb/d of output driven by its oil security diversification strategy.
- The country's geographical location together with its oil demand volume enables them to build strong and longstanding oil relationships with prominent oil-producing states such as Saudi Arabia, Russia or Kazakhstan.

- Economic structural shifts have triggered a relevant slowdown in China's energy consumption trend, which is not anymore growing at an annual average growth rate of 8%, but 3%. This factor reduces its oil dependency on the one hand, which is positive for the state's oil security; but might also hamper its purchasing power as an oil-consuming country in the long-run.

Weaknesses

- The country's oil security is highly reliant on Middle East's oil imports and the Strait of Malacca seaborne, which are both linked to social and political instabilities.
- China's traditional oil fields started operating in the 1960s and are currently at the mature stage of their respective life-cycles. Many fields are characterized by high production decline rates and increasingly high extraction costs.
- Major oil companies in China are NOCs, which pose the same issues as the aforementioned for OPEC and Russia.
- The country has been suffering public health and environmental issues stemming from its strong fossil fuel consumption. These concerns are morphing into political action plans that affect oil subsidies and promote the use of alternative fuels.

Opportunities

- Similar to the traditional shifts in the type of fossil fuel consumed by developed countries as greenhouse effects awareness grew, China is moving away from coal in favour of oil as its prominent energy source.
- The transportation sector, especially the growth in passenger vehicle fleet, will drive the oil demand growth in the country. The 1.37m population appears highly attractive for this sector, which is set to potentially spike in the upcoming years.
- By 2040, China is forecasted to reach a refinery capacity of 14mb/d becoming the world's top dog refiner. This event will come hand-in-hand with a rise in both crude oil imports and petroleum products exports.
- China should secure and strengthen existing strategic alliances with the international community within oil markets to avoid supply shortages given their recent nosediving upstream investments. Long-term supply contacts, such as the one with Russia through the ESPO pipeline, and new oil flows from their Eastern North American partner, such as U.S. LTO and Canadian oil sands, can be key to diversify risk away from Middle Eastern imports through Malacca's strait.

Threats

- In the past years, domestic upstream investments have been reduced by c. 40%-60% given the low oil price environment. This lack of capital expenditures and greenfield project development, in parallel to a declining domestic oil production, will undermine its future output growth potential and enhance its subordination to foreign oil flows, increasing China's imports reliance to 80% by 2040.

- The country's economy is moving away from the heavy industry towards service, light manufacturing and satisfying domestic consumption necessities. This structural break will likely entail a considerable oil demand drop in the long run.
- There is a chance of China becoming the leader in the electric vehicles market. Fast adoption scenarios of battery-driven cars would derail most oil consumption growth forecasts.
- As we saw earlier for the U.S., worsening international relations with key trading partners (such as the American and Chinese presidents' current trading disputes) might hamper China's ability to diversify away from Saudi Arabia.

5.5. India

Strengths

- Third largest oil consumer in the world.
- Very strong refining sector, India being a net exporter of refined products.
- Strategic geographical location close to the Middle East and Africa, what felicitates the oil flows between the regions.
- India's upstream sector has been opened to non-state and private investors.

Weaknesses

- The domestic oil output has declined over the past five years due to the limited resources of the country and the reduction of investments in new oil projects due to the high costs associated.
- 83% oil import dependency.

Opportunities

- India will surpass U.S. as the second largest economy by 2050, being the fastest growing country in terms of total primary energy demand.
- 30% of the world's oil demand growth by 2040 is forecasted to come from India.
- The "Make in India" initiative focuses on the industrial what will boost the oil consumption of the country.
- The refinery output is expected to grow toc. 8 mb/d by 2040 to become the country with the third highest refining capacity behind China and the Middle East.

Threats

- Promotion of the “National Electric Mobility Mission” plan has a target of reaching 6-7 million EV’s in Indian roads by 2020 what entails a risk for the future oil reliance in the transportation sector.
- The outlook predicts a growth to 90% oil import dependence for India by 2040.

6. Game theory

6.1. Game theory and the global energy market

Game theory is a tool to help us understand the situations, the decision-making process and the outcomes in which decision-makers interact. It is widely used to shed light on economic, political and even biological phenomena. The field of application is so broad that it includes firms competing for a particular business, bidders competing in an auction or animals fighting over prey (Osborne, 2003).

The main tools of game theory are the models used to describe a particular situation. The results, but also the underlying inputs we consider drive the game, allow us to improve our understanding. However, it is important to highlight that the power and the usefulness of models essentially rely on its simplicity, leaving aside irrelevant details. Last but not least, models are not an absolute criterion but a way to understand and to gain interesting insights on specific decisions.

After this brief introduction, it is needless to say that the world energy market, and in particular world oil market, is one the most prolific fields for game theory application. This is indeed underpinned by three main reasons. First, the presence of several decision makers that were presented in the first half of this thesis, each one with diverging interests, perfectly suits the fundamentals of game theory. Secondly, the complexity of the market and of the drivers behind it make game theory the best tool to improve our understanding by simplifying reality and testing the models against oil prices. The final reason is the key role that oil plays nowadays in society. Given the heavy reliance of both developed and emerging countries, and of importing and exporting countries on oil, energy security reasons and budgetary constraints generate a need for a deeper understanding of the oil industry dynamics. This understanding includes, of course, the incentives of every player and the consequence of their decisions and interactions, which is essentially the very definition of game theory.

Before describing the goals and the methods employed in this thesis, it is interesting to quickly introduce the main topics in literature. Of course, this is a very brief overview that only aims at adding some color. Essentially, the main topics related to world oil market and game theory are the following:

- Structure of the oil market in order to develop general equilibrium models to analyze the market. Interest for market modeling began when academics realized the impact of key players' decisions right after the 1973 oil crisis, which resulted in the quadrupling of the oil price. Most of the models developed at the time were inter-temporal optimizations. That is models that seek to determine the optimal path of a variable in time in order to maximize a function depending on this variable. In the case of oil, the variable can be the supply of a player, and the function to maximize can, for instance, be the profit of an oil exporting country. Later in time, optimization models lost market share in favor of simulations that included economic variables. Recently, the popularity of optimization models has decreased driven by its inability to forecast oil prices and by the complexity to understand the role of OPEC in the market. Indeed, the main differences amid the optimization models were the assumptions on the market structure.

- Structure of OPEC and its behavior. Given that clearly reflecting the market structure is one of the main weaknesses of the optimization models, academics sought to understand the nature of OPEC as an organization. As pointed out earlier when describing OPEC, academia is still trying to understand if it is closer to a collusive cartel or if it is rather a heterogeneous group with different goals justifying different decisions. If a consensus had to be reached it would be that the model that best fits reality is the one of a dominant supplier, either Saudi Arabia on its own or OPEC, facing a competitive fringe that includes other significant producers. Of course, these models are far from being completely reliable as they are built upon different assumptions. The most important assumption was also introduced earlier and it is directly linked to the goals of OPEC: is revenue or profit maximization truly what drives its decisions? Given the complexity of their decision-making process and the speculation around it, this assumption is far from being reasonable.
- Last main topic in literature is the public intervention in the oil market to ensure social welfare. This is far from the main topic of this thesis, that seeks to analyze the interaction between all the players involved, but it gives us a sense of the diversity of variables that drive oil price and therefore of the complexity of the oil industry dynamics.

6.2. First models employed: inter-temporal optimizations

On the first part of this second half focused on the application of game theory to world oil market, we will analyze the first models employed. This will be done first from a theoretical point of view, and then, we will review some numerical examples.

The examples that we will study from a theoretical point of view are models that seek to determine the structure of the oil markets and are known as inter-temporal optimizations. As mentioned before, they allow us to determine the optimal path of a variable in order to maximize another one.

Before going deeper into this topic, we need to present the main assumptions we will take in order to use the simplest framework. These are:

- Perfect foresight. This necessarily implies that all markets have the same information, which essentially includes:
    - The demand curve for oil
    - Oil stocks available for every player
- Players are competitive and they seek to maximize their profits

- Stationary demand for oil. Even if most of the models include changes in the demand curve over time, we introduce this simplification in order to have an easier approach
- Technological developments are not considered. This implies that production costs remain constant over time
- Oil will be considered a non-renewable resource. This means that reserves are necessarily depleted over time. Moreover, we consider that all the reserves extracted are immediately sold in the market so that no storage is possible
- Last but not least, it is key to mention that we assume that the crude oil market is seen as an oligopoly and not as a competitive market

Needless to say that most of the above assumptions are debatable. Nevertheless, given the extent and the goals of this thesis, they seem reasonable and sufficient as they allow us to describe the models used, the reasoning behind and their main weaknesses.

6.2.1. Cournot game

The first half of this work introduced and described the main players in the oil industry and the complexity of their interactions. Focusing on the producer's side, it is easy to see there is a particular structure in place: the OPEC, as a cartel, has more power and more reserves than any other producer, and then, there is a competitive fringe gathering other producers that avoid the formation of a monopoly.

Under this simplified scenario, the oil market can be seen as an oligopoly in a Cournot game. The main feature of this game is that every player considers as given the sales path of the rest, which means that the decisions a player takes do not affect the strategy of the rest. In this case, every player, that is, the OPEC and the rest seek to maximize the present value of its profits. Indeed, it is important to note that given that oil reserves are assumed to be depleted over time, the participants need to define a sales path in order to maximize their profits. Moreover, it is also important to highlight that OPEC is assumed to act as a perfect colluding cartel, meaning it can be seen as a single player.

Next question to answer is where does the power of the cartel come from? As pointed out, in a Cournot game, the decisions of the cartel do not impact the decisions the others take: sales path are taken as given. So, the main advantage of the cartel, in this case, is that it has more reserves, and in the case of a reasonable scenario where marginal costs increase, this means that the cartel can achieve the same output at a lower cost. Under all these constraints, whenever no player can increase its profits by adopting a different strategy is known as a Nash-Cournot equilibrium. Next, we will prove that such equilibrium exists based on the paper published by Salant in 1976, and analyze its properties and its implications for the world oil market.

To further simplify our approach, in this case, we will consider no extraction costs and a stationary linear demand curve for oil. The full demand Q is fulfilled with the supply coming from the cartel Q_C and from the fringe competitors Q_F.

$$P(Q) = a - b * Q = a - b * (Q_C + Q_F)$$

P being the price of crude oil in the market

It is now easy to see that in order to maximize its revenues, every player should focus on its marginal revenues: is it better to sell one more unit today or sell it tomorrow? In this case, the marginal revenue for the cartel would be the price it would get by selling Q_C minus the reduction in price due to laa rger supply. Both things can be obtained with the demand curve.

$$MR(Q_C) = P(Q_C + Q_F) - b * Q_C = a - b * (2Q_C + Q_F) \quad [1]$$

What should be compared is then the current marginal revenue and the discounted marginal revenues of selling it in the future, and in order to maximize its revenues, the present value of marginal revenues should be the same over time. Indeed, if this was not the case, a participant would prefer to sell earlier or later. Another important takeaway from the previous reasoning is that crude oil price needs to increase following the discount rate. This is known as the Hotelling rule. Last but not least, another constraint to bear in mind is the reserves available R_C the cartel has, which will be completely depleted over time.

Now, we need to focus on the optimization problem of the competitive fringe. Under our assumptions, they take the sales path as given and they also know the demand curve and the reserves available. As it was the case with the cartel, the competitive fringe also seeks to maximize the present value of its revenues, and they also face the constraint of their available reserves R_F. As no costs are considered, the profits for this group are the product of units sold by the unitary price, hence, as long as the price rises at the discount rate, all profits would have the same present value. Indeed, if the price did not follow the discount rate path, competitive fringe members could decide to sell more units later (if the price increases more than the discount rate) or to sell earlier (discount rate increases more than oil price) in order to improve its present value.

The two previous situations are enough to define an equilibrium. As long as the competitive fringe stays in the game, oil prices will rise following the discount rate, whereas, as long as the cartel still has reserves, its marginal revenues will have the same growth rate. The game will finish only when both players have fully depleted their stocks.

The problem now is to determine the timing of the exploitation. Who finishes first its reserves: the cartel or the competitive fringe? This can be proved mathematically but we will use a qualitative approach.

The most intuitive approach is that the cartel will be the last player to finish its reserves as it has more. We will consider that this is not the case and that the cartel will complete its sales faster than its competitors. According to the conclusions we reached earlier, this implies that once the cartel leaves the market, prices will keep increasing at the discount rate because the competitive fringe is still selling its stock. However, if we compare the marginal revenues of the cartel we see that during the first phase (both players are in the market) they are by construction lower than the price, while in the second phase (the competitive fringe is alone in the market) they are equal to the price (Equation 1). This implies that the marginal revenues will increase at a pace higher than the discount rate, which means that the cartel has an opportunity to improve the present value of its profits. Therefore, we can conclude that in the equilibrium defined, the competitive fringe must sell all of its stock before the cartel. The table below gathers the reasoning.

	First phase	Second phase	Reasoning
Players	Cartel and competitive fringe	Competitive fringe	We assume that the cartel sells its reserves first
Price	Grows at discount rate	Grows at discount rate	Competitive fringe remains in the market
Cartel marginal revenue	Is smaller than the price	Is equal to the price	Definition of marginal revenue in Equation 1 → implies marginal revenue must grow faster than the discount rate

Table 16 – Reasoning to find equilibrium in a Cournot game. Source: own elaboration

This reasoning helps us to complete the equilibrium adding that the competitive fringe will necessarily leave the market before the cartel. Therefore, according to this model, two phases in the oil market can be defined:

- A first phase, that can be described as a duopoly, where both players coexist and where the price of crude oil increases with the pace of the discount rate. This situation lasts until the competitive fringe runs out of reserves.
- A second phase that is a pure monopoly for the cartel. In this case, the marginal revenues grow with discount rates, which implies that the price has a smaller growth.

As pointed out by Salant, differentiating these two periods allows us to backsolve the equilibrium numerically. To do so, we need to call P^* the price at which the competitive fringe leaves the market. As proved earlier, during the first phase, the price is going to rise at the pace of the interest rate. This implies that the price of crude oil n periods before P^* is reached is:

$$P(n) = P^* * e^{-r*n}$$

Where r is an assumption we take on the continuous discount rate.

Similarly, we can compute the marginal revenue for every period. Employing Equation 1 would allow us to obtain the marginal revenue for the period when P^* is attained, and as it also grows following the interest rate we can get it for every period. In this case, it is important to bear in mind that, unlike prices, marginal revenue grows at the same rate during the first and the second period.

$$MR(n) = MR(P^*) * e^{-r*n}$$

Substituting in the definitions of the variables we used earlier, we obtain:

$$P^* * e^{-r*n} \; = \; a - b * (Q_C(n) + \; Q_F(n)) \qquad [2]$$

$$MR(P^*) * e^{-r*n} = \; a - b * (2Q_C(n) + Q_F(n)) \qquad [3]$$

Finally, we need to consider other constraints imposed by the assumptions taken and translate them into equations. As we mentioned earlier, leaving reserves in the ground is never optimal, so both players need to deplete them completely: the competitive fringe at the end of the first phase, and the cartel once the choke price is attained. In this case, the choke price is represented by y-intercept of the demand curve that we named a. Given that we will solve this numerically, in order to simplify it, we will discretize time instead of considering it continuous. This leads us to:

$$\sum_0^N Q_C(n) = Reserves\ of\ the\ competitive\ fringe$$

$$\sum_0^N Q_F(n) + Sales\ in\ the\ second\ phase = Reserves\ of\ the\ cartel$$

Now, we can solve this problem numerically using the next steps:

1. Set an assumption on P^*
2. Equations 2 and 3, along with the fact that the demand curve is linear, allow us to compute the production supplied by the competitive fringe:
   $$Q_F(n) = \frac{a}{b} * (1 - \; e^{-r*n})$$
   And the quantity supplied by the cartel can be obtained using the total demand of the market
3. Backsolving until the reserves of the competitive fringe are exhausted lead us to obtain the duration of the first phase N
4. As we know the path marginal revenues follow, and in the second phase the cartel is alone in the market, we can obtain the production level of the cartel, which equalizes the demand
5. Finally, as it was the case with the first phase, we need to take into account the exhaustibility of the cartel. Under all the previous constraints, the duration of the second phase is obtained by tweaking P^*

To show an application of this method and the results we will employ:

- A demand curve employed in 1982 as the demand curve for crude oil in 1975 (Salant S. , 1982). As we did with the proofs, we will assume demand curve is stationary. The equation is:
  $$P = 56.3347 - 1.2859 * Q$$
  Where P is the price of the barrel in dollars, and Q is the total demand in billions of barrels per year.
- The total proven reserves back in 1975 as reported by BP in their annual statistical review, but as the last data is the one for 1980, we took this one. Total reserves

amounted to 425.4 billion barrels for the OPEC and to 258 billion for the rest of the world, which is assumed to represent the competitive fringe

- A 6% discount rate is taken as it is broadly in line with what is taken in papers of that time

These assumptions must be taken as if we were in 1975, and with the method described earlier to obtain a numerical solution, we obtain the price path and the cartel's marginal revenue path shown in Figure 87.

We can clearly see the yearly growth at 6% of the marginal revenues of the cartel, and the two phases for the price. The first one, when both players are in the market with a yearly growth of 6%, and the second one where the OPEC acts as a monopolist. It is interesting to note that in this second phase, price grows at a slower pace. This result confirms why the competitive fringe decides to deplete completely its reserves: otherwise, it would not maximize the present value of its revenues.

In this model, the competitive fringe would be pushed out of the market when the barrel of crude oil would reach a price around $34, and this price would have been attained in 16 years, that is between 1990 and 1991. After this, the cartel would remain in the market as a monopolist until they run out of reserves. Under these assumptions, this would have happened in 42 years, that is between 2017 and 2018.

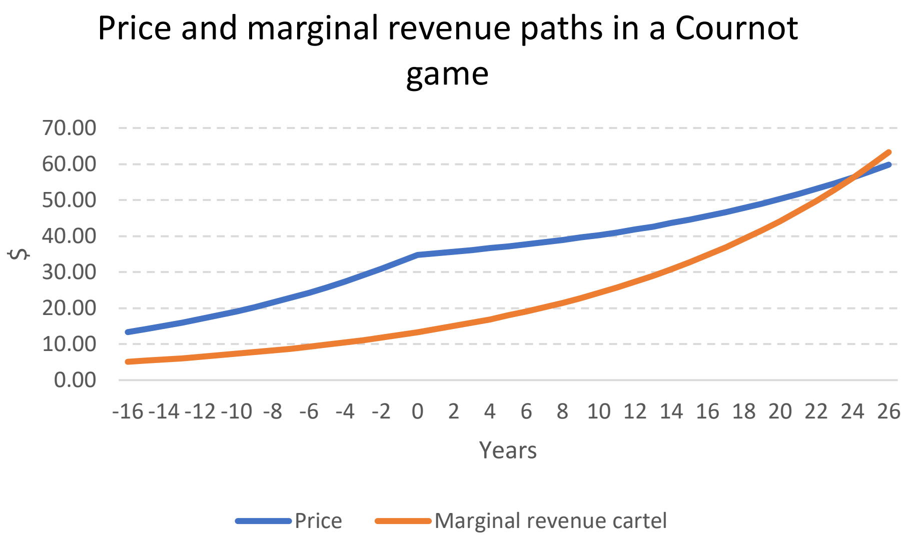

Figure 87. Price and marginal revenue paths in the Cournot game. Source: own elaboration

Needless to say that the results of this simplified model have not met reality. Even if the weaknesses of this model will be developed later, we would like to make a comment now on the consequences of the no costs assumption.

In order to simplify our approach, we have only solved the maximization problem of the revenues. If we consider increasing marginal costs, which seems the most reasonable assumption as the last reserves available will be more difficult to extract, the cartel gains even more power over the competitive fringe. The power of the cartel will not only stem from the fact that it has more reserves but also because it will be able to extract the same volume at a lower cost by pooling its reserves.

This observation raises another question. Given the power a cartel seems to have in reality, it seems reasonable to assume it can exert some influence on its competitors. This seems to adapt the reason behind OPEC which is nothing but managing oil prices.

6.2.2.Stackelberg game

Under a Stackelberg game, the dominant firm could use its power, stemming from the reserves and cost advantages it has and use it against the competitive fringe it faces. This differs notably from a Cournot game, where the sales path of the fringe is taken as given by the dominant firm. However, in a Stackelberg scheme, the leader anticipates the reaction of its competitors and includes it in its maximization problem, and that is how the leader exerts its power. In a nutshell: the leader is a price-maker as it takes into account the reaction of the competitors when setting the prices policy, while the other player, the competitive fringe, becomes a price-taker because it adapts its own maximization problem to the price path set by the leader.

Knowing what a Stackelberg game, the question now is to know whether this framework can be applied to the world oil market. Several reasons underpin such assertion:

- The OPEC as a cartel can play the role of a Stackelberg leader. Indeed, as the main goal of the organization states, they seek the management of oil prices, which is an elegant way to say they use their power and influence to satisfy their interests
- The competitive fringe can represent the rest of oil producers. This simplification has been the situation in the oil market since the inception of OPEC until the financial crisis
- Another key feature of the Stackelberg game is that the leader signals its price path. As we are under the same set of assumptions as before, it is important to highlight that setting the price path is equivalent to setting a production path as the demand curve is supposed to be known by every player. In that sense, the periodic quota announcements made by OPEC can be seen as the mean of signaling: the organization sets the expected production for the coming months, and the competitors adapt themselves to the expected residual demand
- A Stackelberg framework assumes the leader knows the reaction of the rest in order to maximize its benefits. This can somehow be justified by the deep knowledge OPEC has of an industry which is not particularly fragmented
- Last but not least, even if it seems a small detail, game theory assumes instantaneous reactions by the players forming the market. This was not worth to mention in a Cournot game because it has a single stage, but it is especially important in a Stackelberg game where several steps exist: the leader sets its price path, the second player sets its own plan and so on. A market with instantaneous reactions is just a mathematical representation, but given the liquidity of the oil

market, we can say that the instantaneous reaction assumption seems quite reasonable

Instead of defining possible equilibrium paths as we did in the Cournot game earlier, we will focus on describing them after presenting the problem. To do so, we will take the same assumptions as before except that in this case, we will consider increasing marginal costs.

To the notation already exposed, we add $S(t)$ representing the remaining reserves at time t, S^0 representing the initial reserves and $C(t)$ which are the extraction costs, and they are assumed to be convex as we mentioned before.

The previous reasoning we employed to describe the equilibrium still applies in this case. Indeed, the only important change is that we are considering costs and it implies that we will maximize profits and not revenues. This does not affect the reasoning, and the resulting equilibrium is the same as before: a first phase where there is a duopoly in place, followed by a second phase when the competitive fringe fully depletes its reserves and the cartel can act as a monopolist. T_1 and T_2 denote respectively the duration of the first and of the second phase.

As the production path that the leader will follow $Q_C(t)$ is announced, the competitive fringe will seek to set a path $Q_F(n)$ maximizing its discounted profits. This problem is given by the following equation:

$$max \int_0^{T_1} \left[P\big(Q_C(t) + Q_F(t)\big) * Q_F(t) - C_F(t)\right] * e^{-r*t} dt$$

Of course, taken into account the equilibrium we described, the competitive fringe has to comply with the exhaustibility condition:

$$\int_0^{T_1} Q_F(t) dt = S_F^0$$

Now we can apply the Hotelling rule. In this case, we are using profits instead of revenues, but the underlying problem is the same: is it worth to produce more now or wait for the next period? This is captured by the derivative of the profit with respect to the quantity produced. This discounted value of these derivatives should be constant.

$$\lambda = \frac{\partial}{\partial Q}\left[P\big(Q(t)\big) * Q(t) - C(t)\right] * e^{-r*t}$$

Applying the chain rule taking into account that t does not depend on Q, we have:

$$\lambda\,(t) = P\big(Q(t)\big) - \frac{\partial}{\partial t}(C(t))$$

Please note that in the previous equation we are using $\lambda\,(t)$ and not λ, that is, we are using the current value and not the present value, which should be constant. With this we can rephrase the equilibrium condition:

$$\frac{\partial}{\partial t}\lambda - \frac{\partial^2}{\partial t^2}\big(C(t)\big) = r * \lambda$$

This equation considers that the decision of producing today or later should also take into account the convexity of the costs, that is, increasing marginal costs.

Next, we need to address the maximization problem faced by the cartel. The two equations describing this problem are the same as before: a maximization of the discounted profits and the exhaustibility of the reserves. However, in this occasion, the time span to be considered is larger as we take into account the second period where the cartel acts as a monopolist.

$$\begin{cases} max \int_0^{T_2} \left[P\left(Q_C(t) + Q_F(t)\right) * Q_C(t) - C_C(t)\right] * e^{-r*t} dt \\ \int_0^{T_2} Q_C(t)\, dt = S_C^0 \end{cases}$$

With all the previous tools, we should be able to predict the price path of oil as long as we know the quota productions for OPEC and the cost function. Instead of backtesting this model with situations in the past in order to define possible equilibrium paths for the price, we will focus on a simple example and discuss the implications of this models. This decision is underpinned by two main factors: first, we lack the knowledge and the tools to solve these problems, and on the other hand, the results of such model can be checked in many papers like Huppmann (2014).

The example we are going to use will allow us to compare the results of a Cournot model with the ones of Stackelberg. We will assume that in the latter the whole production path is defined since the beginning. On top of that, as mentioned before, we will assume a convex cost function. Results are shown in Figure 88, and the main insights we can obtain from this example are developed below.

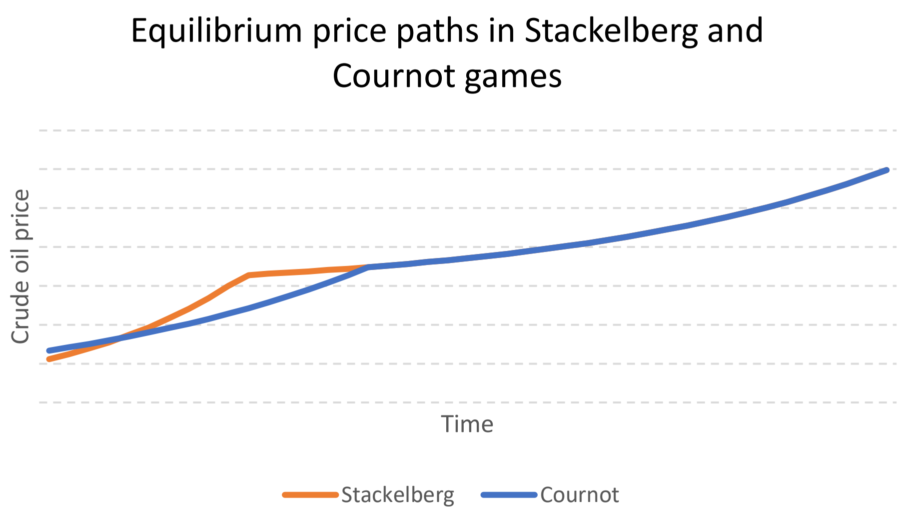

Figure 88. Equilibrium price paths in Stackelberg and Cournot games. Source: own elaboration

From these results, we can derive two main conclusions, one regarding the duration of the process, and the other one concerning the price paths followed.

First, regarding the length of the problem, we see that the total duration is the same. That is, that the total reserves are depleted at the same time. This is mainly due to the constraint imposed by the exhaustibility equation. Then, we observe that the main effect of the framework set by Stackelberg is the split between the two phases. Indeed, we see that the duopoly phase is shorter. This can be explained in an intuitive way. The main reason behind is that, as a monopolist, the cartel earns larger profits. So, all the constraints considered, the leader will set a production path that makes the depletion of the competitive fringe's reserves faster and then benefits from a longer second phase where the cartel will be alone in the market.

Concerning the price paths, there are also interesting takeaways. First, we observe that during the monopoly, the price paths are superimposed. This was something we could expect given that the total duration and the choke price are the same and that the condition describing its behavior is also the same. It is more interesting to focus on the first period. We observe that the initial price is lower for the Stackelberg game. This is essentially due by the fact that the fringe depletes its reserves faster while the cartel extracts them at a slower pace as it has to supply the whole market in a second phase that it is longer. With all the constraints abovementioned, it is easy to see why the price needs to grow faster during the duopoly phase.

6.2.3. Numerical simulations

After understanding the theoretical fundamentals of game theory applied to exhaustible resources like it is the case with oil, we will focus now on some numerical examples. To do so we will take the results gathered by the Energy Modelling Forum in 1982.

After the abrupt changes in crude oil price in seventies models became popular, and by developing and analyzing the results of various models, this report has mainly two goals. First, improve the understanding of the models by comparing their different assumptions and results. Second, to gain a deeper knowledge of current market by analyzing the results and testing them to previous situations in order to forecast the future. However, the problem is not to know the exact price of crude oil at a specific point in time, but to know how fast is going to change in the coming years. Hence, the projections must be used as likely bounds of the future movements in oil prices.

For us, analyzing the results is also interesting. We will be able to compare the results of different models to what really happened afterward. This will allow us to analyze their main weaknesses and to introduce models that are currently used to analyze the market.

At the time the report was written, intertemporal optimizations were already losing popularity and most of the models tested are recursive simulations. The main difference between them is that in simulation models decisions taken by the different players depend on past and current events, whereas in intertemporal optimizations, what we saw earlier, some degree of foreseeability (at least one player has perfect foreseeability) as it is necessary to run the model.

Before going into the results, it is interesting to highlight some features of the model even if they were developed almost forty years ago. Every model considers import policies of developed countries and the impact oil price has on social welfare when computing demand for crude oil. Moreover, another important characteristic of the models is the importance it gives to oil substitutes, and the effects on the oil market of unconventional sources, known as backstop technologies. In any case, it is impressive to observe that they predicted oil prices to rise above backstop costs, making alternative sources profitable and resulting in an oversupplied market.

All the different sets of the model and the resulting different projections confirm again the high complexity of oil market. This complexity is driven by the uncertain network of centralized and decentralized decision-making processes and by the factors behind, which are even harder to predict (Energy Modeling Forum, 1982). Indeed, decisions impacting prices are made by OPEC members, by speculators in trading rooms, by legislators drafting import policies and subsidies programs, by international oil companies and even by the final consumers. Of course, this implies that unforeseeable events like political events can drastically change the market.

After adjusting the results for inflation, the seven projections and the evolution of the real price of the Brent barrel are shown in Figure 89. Comparing the projections with what really happened afterward can give us some interesting insights.

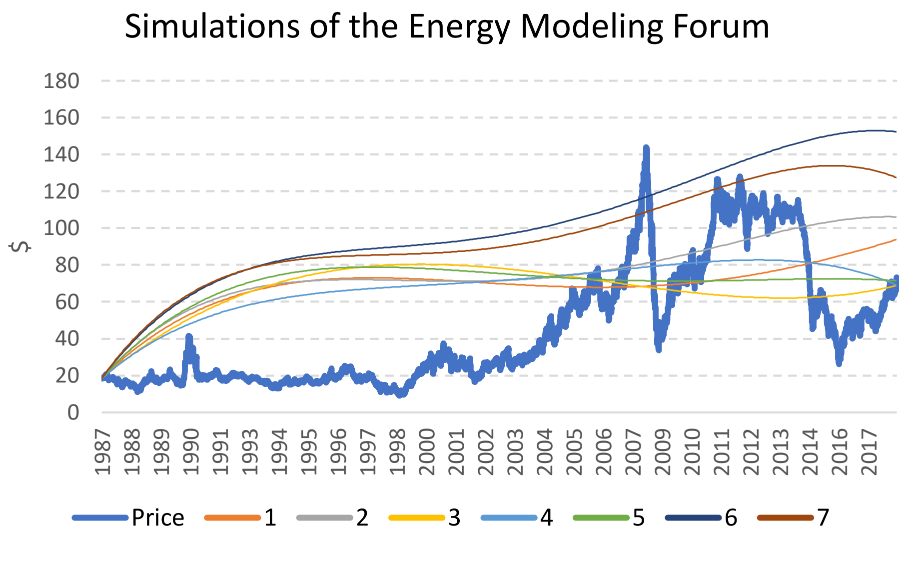

Figure 89. Simulations gathered in the Energy Modeling Forum. Source: own elaboration based on Energy Modeling Forum, 1982

First, we observe that every projection has somehow predicted the general trend of oil prices. The goal of setting likely bounds was achieved in the second half of the time interval, corresponding to the first years of the twenty-first century, but not in the first half. As a first approach, we observe an increase over time of crude oil prices, but the way this increase is achieved do not match what really happened. In the models, a sharp growth takes place at the end of the eighties, followed by a plateau or even a slight decrease. Then, another rise in prices was expected starting around the year 2000, to finish with a decrease that corresponds to the development of backstop technologies.

If we focus on the first half, several reasons can explain why the projections are way above real prices. First, as we mentioned before, geopolitical and other unforeseeable events that are out of reach of the model, severely impacted oil price. These events include drastic changes in OPEC quotas, a slow recovery from 1981-1982 recession or special conflicts like the Gulf war. This resulted in two main consequences: an oversupply in the market and a slower economic growth than expected, which implies smaller demand for crude oil. This justifies why crude oil prices remained steady until 1995 with some spikes. The models included a much more optimistic economic recovery that would drive up crude oil prices.

In the second half of the nineties, stagnation in Asian crude oil demand due to the Asian crisis in 1997, an increase in the Iraqi output amid other unforeseeable events like two consecutive warm winters, continued to put some pressure on crude oil price that even lost the $20 level.

Finally, at the beginning of the twenty-first century, the models projected an increase in demand driven by developing countries, that actually took place, but the pace of this growth was not captured. This spike in prices can be justified by the role speculation played during those years (Kaufmann & B., 2009), by the low elasticity of oil demand or by insufficient capacity expansion. Later on, other events in the domain of the unforeseeable drove prices down, but the models were able to project a decline in the price driven by the development of alternative technologies like it was the case with shale oil.

This brief analysis of previous models paves our way to study their main weaknesses.

6.2.4. Weaknesses of these models

Besides developing models to describe the price path of crude oil, academia has also focused on analyzing them to find which market structure fits the best oil market. Even if it seems to be a consensus around the fact that a Cournot oligopoly with Saudi Arabia as a Stackelberg leader facing a competitive fringe is the model that best describes the crude oil market, this framework can only be applied to the period before the financial crisis in 2008. What are the main weaknesses of these models?

Concerning the role OPEC plays in the markets, some remarks need to be made. First, every model takes the organization as a collusive cartel that acts as a block. However, as we saw in the first half of this work, this is far from being what really happens. Cheating on quota allocation is widespread and is usually accepted by Saudi Arabia, but it is a practice that might hurt the profits of the organization in the long-term. Moreover, in most of the models, the power that OPEC can exert on the market is derived from its reserves and the advantages it brings to its cost structure. This is translated into the models as if they were pooling the reserves. However, as it can be imagined this is not realistic at all, and the models fail to capture other variables like the differences in crude quality and in production costs among members. Finally, another important point needs to be addressed. To derive the price and production paths, in every model it is assumed that the players seek profit maximization. This hypothesis seems perfectly realistic, but as we saw, the reality behind crude oil markets is way more complex and other factors have a significant influence on price. This is especially important for the big players within OPEC. Indeed, as we studied earlier, a variety of factors are behind the output decisions, including diversification plans or subsidies on refined products. In fact, OPEC members should not be taken as private companies, but as more complex player with political interests. Last but not least, this reasoning leads us to another factor to take into account: the current market situation of oversupply implies that players fight for market share and not for revenue maximization.

The new market equilibrium appeared with the development of backstop technologies and the irruption of new important players, particularly the U.S. and Russia. In the previous paragraph, we addressed the issue concerning the Stackelberg leader, but this new paradigm concerns the competitive fringe. The change in market fundamentals and the shift towards market share strategies clearly show that the competitive fringe has ceased to exist. These changes show us the power and the impact new players have on the rest of the market. Hence, neither a Cournot framework nor a Stackelberg model seems to fully adapt to the current situation. OPEC is no longer the most relevant player. Therefore, the hierarchy with several Stackelberg leaders is not as clear as every player can exert some influence on the rest.

Leaving aside the market structure consideration, the models also show consistency issues. Indeed, they assume that the paths computed will not have any deviation. But in reality, whether by mistakes or any other circumstances bring deviations to the projected paths, and consequentially, the rest of the players must react and adapt themselves to the new situation. In a nutshell, despite the complexity of the models, in the equilibriums, no agent knows how its rivals would respond to any deviation since no deviation is possible.

Another important problems of the models analyzed is the application of the Hotelling rule. Despite its importance in a theoretical framework, it has been proved by academia that real crude oil prices do not comply with it (Hart & Spiro). Among the reasons behind this conclusion we can mention the technological process, especially of alternative sources, the sharp increase in marginal costs due to the depletion effects, and of course, uncertainty.

Despite the inclusion of random shocks in the models, the impact of specific events such as nationalizations seem hard to quantify. However, random events do not need to be as important as nationalizations to disrupt the market. Indeed, unpredictable situations such as lags in supply or in demand, or changes in transportations costs, which are not taken into account in most of the models, can be the reason behind an abrupt change in crude oil prices.

Finally, regarding the demand for crude oil, we would like to comment some remarks. If we took into account alternative sources for oil supply, we should also consider their impact on the demand side. Given the development of perfect and imperfect substitutes, and the importance they have on new policies, a holistic approach can be applied and derive crude oil demand from total energy demand. This method is completely different from the traditional use of a specific demand curve for crude oil, as it implies that crude oil demand will not depend exclusively on price, but also on factors such as the subsidies existing for other sources. This has direct implication on demand elasticity. Indeed, having alternatives that are more attractive makes consumers less dependent on oil, which translates in an increase of demand elasticity.

In conclusion, we can say that due to the large scale of these models, some simplifications are necessary in order to define an equilibrium. However, some of these adaptations of reality to the model may be overly simplistic or directly wrong due to the complexity of the crude oil market and the constant changes it is exposed to. This also shows us that a way to avoid these mistakes is to periodically adapt the models to the new constraints imposed by the market. In any case, we should bear in mind that the role of the models is not to give an exact price for a specific point in time, but to offer a general vision on the trend and the bounds that prices are expected to follow in the future.

6.3. Recent equilibrium models

To go deeper into the game theory applied to world oil market, we will analyze how recent equilibrium models have developed over time. In the eighties, as OPEC gained notoriety, optimization and game theory equilibrium models were developed and applied as it has been studied in the previous section. But as discussed in the models' failures, they were not able to fully capture the market structure and follow the price path due to being over simplistic and because the oil stopped being priced as an exhaustible resource what derived in the equilibrium models getting old fashioned.

Concerning the exhaustibility of the crude oil reserves, the theory indicates that if supplying a finite resource, the price needs to increase following the discount rate in order to avoid the inter-temporal arbitrage, what is defined as the Hotelling rule. But the crude oil price has failed to follow this price path as new technological process improvements and a sharp increase in marginal costs (due to the depletion effects) have appeared together to the increasing market uncertainty. In consequence, the Hotelling rule does not have further long-term relevance in today's crude oil market and can be removed from the models' conditions.

Coming back to the modelling recent history, in the beginning of the XXI century, and due to advances in the computational power and the development of robust algorithms, the Nash-Cournot equilibrium models gained strength again and started to be widely used in the energy market adopting the removal of the Hotelling rule condition. Over the last decade, in the crude oil market five main recent numerical partial equilibrium models which face the equilibrium model from different standpoints (Huppmann D. , Endogenous shifts in OPEC market power - A Stackelberg oligopoly with fringe, 2013) have been published, and we will further analyze in detail two of them later on.

About the other three recent models, just a basic description will be provided to have a broader picture of where the equilibrium models are evolving in the present crude oil market environment. The first one, by Aune et al. (2010), focuses on the requirement of profitability measures to be fulfilled so that investments are undertaken by OPEC. With this main criteria, the dynamic model is based in the strategic decisions taken by OPEC both about production and investments to model the crude oil price (Aune, Mohn, Osmundsen, & Rosendahl, 2010). The second model by Huppmann and Holz (2012) shows that the oligopoly case that best describes the crude oil market is the non-cooperative Nash-Cournot oligopoly by OPEC suppliers, with Saudi Arabia as a Stackelberg leader and the rest of the suppliers acting as a competitive fringe. The spatial model computes prices, quantities and trade flows of the crude oil, including for the first-time arbitrages related to the liquid spot markets (Huppmann & Holz, 2012). Finally, the model by Almoguera et al. (2011) focuses on OPEC's market power in the period between 1974 and 2004. The approach only obtains average results over the period, but evidences that OPEC is a non-cooperative oligopoly with the resto of suppliers acting as a competitive fringe. Due to lack of time we will not further analyze these three models, but we will focus in the other two, which we have considered to be the most relevant ones given the actual oil market's scenario.

Going back to the past model's failure analyzed earlier, the models that we will further analyze are those that have been adapted or designed to address some of the weaknesses observed. In a first section, we will capture those changes that have been introduced in a Stackelberg game, based in a two-stage oligopoly model with a Stackelberg leader facing a competitive fringe. In the second section, we will focus in a model that instead of explaining the crude oil price, explains the dominant strategy to follow by OPEC, the profit maximization or the market share defense, given a set of market conditions based on an algebraic framework. The model captures the recent irruption of new suppliers such as U.S. and Russia and provides a value to the crude oil price as a consequence of the strategy adopted by OPEC.

6.3.1. A Stackelberg oligopoly with fringe

In July 2013 Daniel Huppmann published a paper called "Endogenous shifts in OPEC market power – A Stackelberg oligopoly with fringe", proposing a two-stage oligopoly model for the crude oil market. In the first half of this section we have already introduced this game, but now we will discuss it further with some characteristics that the model explained earlier did not capture at the time.

As in the section 4 has been deeply developed, the increase in supply by the U.S. and Russia, the decrease in global crude demand growth, and the rising competitiveness of alternative and renewable technologies have pushed a shift in the market. This has lead OPEC or Arabia Saudi not to be considered as the only leaders in the Stackelberg game anymore as other suppliers are also able to anticipate the reaction of the competitive fringe. Not only that, but several experts have agreed on crude oil becoming non-exhaustible due to the numerous discoveries of new oil resources and the use of renewable technologies, what is completely in line with the removal of the Hotelling rule condition.

Continuing over the Stackelberg game that has been presented earlier, the next modifications and new feature introductions describe the model developed by Huppmann:

- As in the Stackelberg model already presented, a bathtub model is used where all the suppliers' crude is unified to satisfy one unified aggregated demand function which is driven by a unique global crude oil price.
- The Stackelberg model of the eighties failed to capture the differences both between OPEC members and between those suppliers of the competitive fringe. This new model enables to work with a set of suppliers S that will form an oligopoly and will be the leaders of the Stackelberg game, and a set of fringe suppliers f.

$$i, j \in \{S \cup f\}$$

- The market is not always in equilibrium and does have cases of imperfect competition or market power. In order to capture possible deviations, a parameter (r_i) is introduced called conjectural variables (CV), which was first proposed by Bowley (1924) and Frisch (1933). The parameter is designed to capture the expectation of a supplier after regarding variations in the output of other players. This allows the model to study several market power situations as would be known how the agents would react to deviations of other agents from the equilibrium. The requirement that is needed for this parameter to be plausible is that the conjectures value need to be consistent/rational in equilibrium.

$$r_i = \sum_{j \neq i} r_{ij}$$

  The aggregated reaction of the rivals can be separated into the sum of individual responses of each rival j, r_{ij}.

  Please note that the introduction of conjectural variations to economic models is a subject under discussion as it is found inconsistent to compute an equilibrium based on an arbitrarily chosen exogenous parameter which is not based on any economic theory.

- In the Stackelberg model introduced earlier, the cost function is just defined as a convex (quadratic) cost function, were increasing marginal costs are considered. But such a simple cost function does not capture the real characteristics behind the production costs of extractive industries. Extractive industries are defined to have quite flat marginal production costs in their practicable range and then, when getting near the capacity limit the costs increase drastically. In 1995 Golombek et al. proposed a production cost function with a logarithmic term depending on the capacity utilization which best explains the marginal production costs of the oil fields and which has been adopted by Huppmann in the model.

$$c_i\,(q_i) = (\alpha_i + \gamma_i)q_i + \beta_i q_i^2 + \gamma_i(\overline{q_i} - q_i)\ln(1 - \frac{q_i}{\overline{q_i}})$$

In the equation above, q_i is the quantity supplied by the supplier *i*. α_i, β_i and γ_i are the cost function parameters, which are strictly positive for each supplier *i*. $\overline{q_i}$ is the maximum production capacity for supplier *i*.

It is important to remark that due to the specific nature of the extractive industries, the Stackelberg leaders will gain market power as the fringe's spare capacity goes down, as in a short-term profit maximization scenario would not have sense to continue extracting crude oil due to production costs drastic rise.

- The demand curve employed by Huppmann has the same structure as the one used in the eighties. The inverse demand function is linear with negative slope and the quantities and qualities from different suppliers are perfect substitutes between them.

  $$p(Q) = a - b * Q$$

  Where *a* and *b* are strictly positive parameters and *Q* is the total quantity of crude oil supplied globally.

Once we have introduced the model's main characteristics we will focus in the Stackelberg problem. Even if it has already been described that not all players might seek the same strategy, in this case the utility function for each member has the same structure. It is assumed that all the players want to maximize their profits in the short term. The profit maximization for each supplier is given by the following equation:

$$\max_{q_i \in R_+} p(Q)q_i - c_i(q_i)$$

Needless to say, the equation is the same as in the eighties model but is applied for each player individually rather than to each group of players (leader, competitive fringe).

Due to the complexity of the model, the mathematical proof of it stays out of the scope of the thesis and can be reviewed in the paper of Huppmann (2012) where all the equations, lemma's and theorems are gathered.

Following we will analyze the results that Huppmann published in the "Endogenous shifts in OPEC market power – A Stackelberg oligopoly with fringe" paper to understand better the advantages and limitations of the model. Huppmann developed an application to the crude oil data (2003-2012) based in four oligopoly cases or competition setups. In the case it analyzes a Stackelberg game it assumes the leader to be OPEC and the fringe the rest of non-OPEC suppliers. The four oligopoly cases are:

- The perfect competition setup (Competition). The suppliers decide simultaneously as price takers (one stage game).
- The Nash-Cournot oligopoly (Nash-Cournot). The suppliers decide simultaneously and with equal market power (one stage game).
- The Stackelberg oligopoly with fringe[25] competition (Myopic Cournot). OPEC decides in a first stage and in a second stage the rest of suppliers decide simultaneously and with equal market power as in a Cournot game (two stage game).
- The Stackelberg oligopoly with fringe[25] competition and consistent conjectures, which include the anticipation of the reaction of the fringe by the Stackelberg leaders in case of deviation from the equilibrium by any player (Oligopoly). OPEC decides in a first stage also knowing the other suppliers' actions to deviations, and in a second stage the rest of suppliers decide simultaneously and with equal market power as in a Cournot game (two stage game).

As it can be seen in Figure 90, the perfect competition fixes the floor for the price equilibrium as all the suppliers act as simultaneous price takers and mark a lower benchmark of marginal costs. On the other hand, the Nash-Cournot equilibrium leads to prices that exceed significantly the real values.

Note that the competition setup that better follows the reference crude oil price is the Stackelberg oligopoly with Cournot competition, were OPEC members are supposed to have consistent conjectures regarding the actions of the fringe in case of deviation from the equilibrium.

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[25] In this article, Huppmann used the word *fringe* just to make reference to the second stage competitors. But it does not mean they act in a fringe competition way. In fact, in the article the second stage suppliers compete in a Cournot game way in both Stackelberg scenarios.

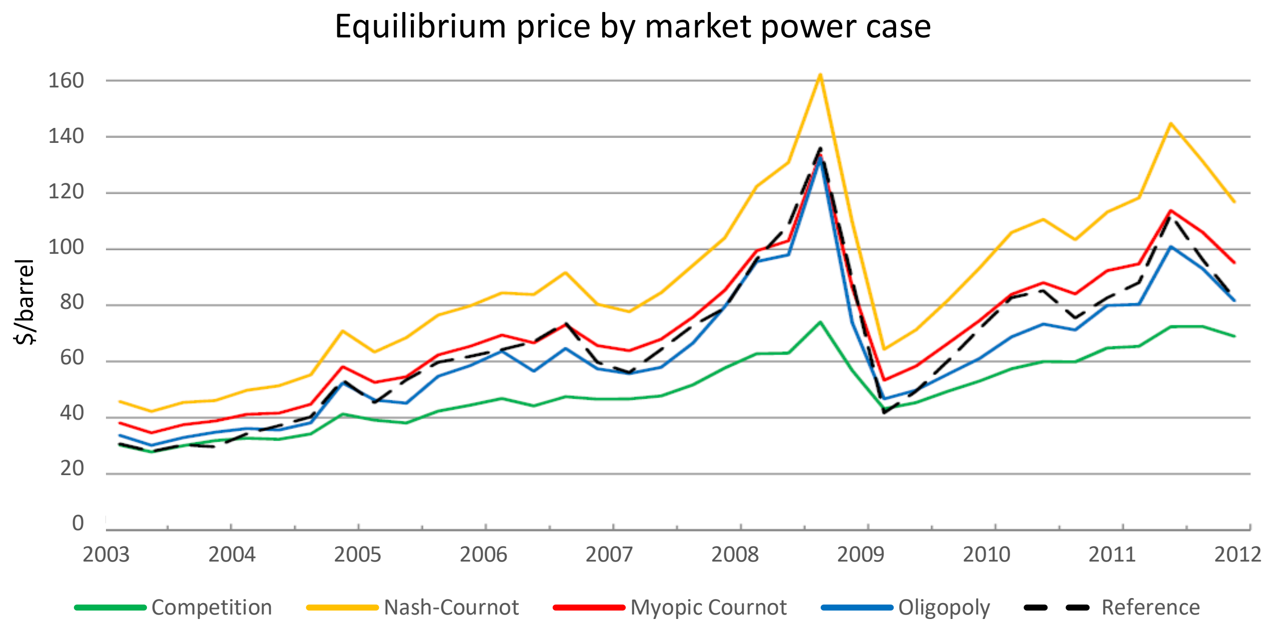


Figure 90. Equilibrium price by market power case in USD/bbl. Reference: D. Huppmann, 2012.

It is important to remark that even in the crude oil market application it has been considered that OPEC acts as a bloc, the model itself enables the possibility to capture the characteristics of each cartel member considering it as an individual, what would be more realistic as OPEC's perfect cartel behaviour is questionable. Nevertheless, not only the optimization would become much more complex, but also as there is no formal compensation mechanism inside the OPEC, would be very hard to define consistent conjectures between each cartel member.

So, the main conclusion by Huppmann through the analysis in its paper (Huppmann D. , Endogenous shifts in OPEC market power - A Stackelberg oligopoly with fringe, 2013) is that the model that captures the consistent conjectural variations and the crude oil market structure as a two stage Stackelberg game with the rest of suppliers following a Cournot game is the one that better follows the real price path between 2003 and 2012.

6.3.2. The short-term profit maximization

Going further with equilibrium models, in 2017, and based in the model of Daniel Huppmann that we have just analyze, Danwud Ansari published a paper called "OPEC, Saudi Arabia, and the shale revolution: Insights from equilibrium modelling and oil politics" in the Energy Policy journal (Ansari, 2017). The objective of Ansari's publication was to prove that even perfect competition did not explain the fall in prices.

The rationale behind OPEC's strategy that started in the late 2014 has been addressed from different views over the last years. Ansari, with its analysis wanted to study if any of the competition setups provided an explanation to it or backed up any of the most common explanation categories:

- OPEC raised its production quotas to defend its market share and long-term profits.
- OPEC was forced to lose its role as the swing producer and had no other alternative that to accept the low prices.
- OPEC wanted to test the resilience of the shale oil.

For that, Ansari included some variations to Huppmann's 2013 model in order to reshape it to the 2014 scenario which was driven mainly by the shale oil revolution, the rising competitiveness of alternative and renewable technologies, the decreasing demand and the geopolitical circumstances.

As for model modifications, Ansari left aside the conjectural variation parameter but included a quality parameter that relaxed the strong assumption of homogeneous crude oil made by the bathtub framework application. As discussed in the model's failures, the differences in crude quality were not being captured in previous models and as quality leads to relevant differences in terms of refineries and also in the price they yield, it is an important characteristic to consider. To face the issue, Ansari included a quality adjustment parameter in each producer-specific cost function. This way the producers profit margin was adjusted not via revenues as the bathtub framework did not permit it but via costs by multiplying them. The quality adjustment parameter then penalized (favours) suppliers with lower (higher) quality crude incurring them higher (lower) costs.

The complete model with the notations and the algebraic relationships can be found in the Appendix A1 of the "OPEC, Saudi Arabia, and the shale revolution: Insights from equilibrium modelling and oil politics" paper (Ansari, 2017).

As Huppmann, Ansari analyzed different competition setups:

- Perfect competition (PC).
- Cournot (Cournot).
- Stackelberg game, Saudi Arabia leader, rest of suppliers Cournot game (KSA-CO).
- Stackelberg game, Saudi Arabia leader, rest of suppliers Fringe[26] game (KSA-FR).
- Stackelberg game, unified OPEC leader, rest of suppliers Cournot game (UNI-CO).

[26] Fringe game makes reference to the rest of the suppliers (the followers) behaving competitively between them and suppling the residual demand.

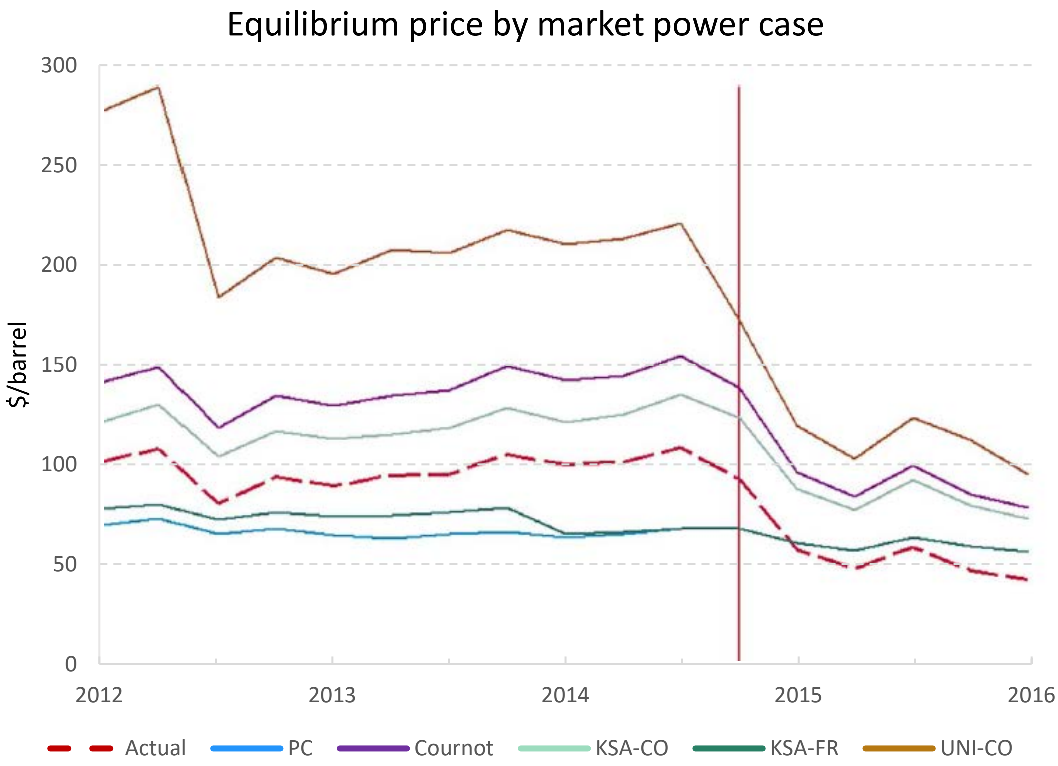


Figure 91. Equilibrium price by market power case in USD/bbl. Reference: D. Ansari, 2017.

As in Figure 91 can be seen, until late 2014 the model, especially the Stackelberg game with Saudi Arabia as leader and the rest of suppliers acting within a Cournot game follows the real price path. Afterwards, even the perfect competition setup can not explain the fall in prices as it goes below the lower benchmark of the marginal costs for some suppliers. This means that the price drop can not be a result of static competition under full information.

In addition, in Figure 91 can be identified that the competition setup that would leave better off OPEC is the case in which they act as a unified entity and they maximize their joint profit. Obviously, this is not a realistic scenario as it has been evidenced over the last years that OPEC does not collude as a perfect cartel. The widespread cheating of the quotas by smaller OPEC members driven by each country's individual profit has derived in global OPEC's profits damage. In consequence, some OPEC members such as Arabia Saudi are not willing to do large sacrifices for the better of the rest of the organization members.

But this is not an obstacle just within the OPEC. As the US shale oil and the Russian production capacities have grown, any production cut coming from the OPEC or from Arabia Saudi would be responded with a production increase by the rest of the suppliers, what leaves the supplier undertaking the production cut worse off. Not only that, but high prices would lead to an increase in financing new shale oil projects, what would mean enlarging the production capacity of the US even more. So, the production cutting strategy for Arabia Saudi and for OPEC in the new oil order scenario is not incentive compatible anymore.

This is why the strategy adopted by OPEC in the late 2014 appears as an inflection point. The market flooding strategy they adopted enabled them to defend their market share and to secure long-term profits while testing the response of the shale oil in a low-price environment. Not only that, but it also helped to mitigate the fears about the oil peak translating into an oil demand peak, as it slowed down the adoption of renewables and substituting technologies.

But defending the market share does not come free of charge. Low oil prices hit the fiscal state of oil dependent economies, which are mainly OPEC members and could not be sustained much longer as they started to face fiscal hardship. In consequence, in 2016 Arabia Saudi started to negotiate a deal with Russia and Iran to coordinate a production cut that would leave them better off. The lack of coordination led the deal to move forward in December 2016. This enabled a price recovery, which demonstrated that OPEC still has a dominant position in the crude oil market and that Arabia Saudi continues being the swing producer. Never the less, the introduction of the shale oil and the increase of the Russian production capacity has led to a price corridor in which OPEC has a lower and upper bond out of which OPEC does not have incentives prices to move as it can affect to its stability. So is in OPEC's best interest to look for stability around a moderate price level in order to ensure both its short-term and long-term profits.

Going back to the model, Ansari demonstrated that the short-term profit maximization, even it explains the price path until 2014 quite precisely, fails to explain the low prices of late 2014 and 2015, which fall out of the usual competition setup. In this context and facing a changed crude oil market structure, Behar and Ritz (2017) published a paper where they developed a model that predicts the strategic decision that OPEC might be interested to take, defending the market share by flooding crude oil to the market or maximizing short-term profit by coordinating production cuts, depending on the markets characteristics (Behar & Ritz, 2017). The model of Behar and Ritz will be analyzed in the section below.

6.4. OPEC's strategies: Profit maximization versus market share

As in the models' failures section has been analyzed, not all players might seek the same strategy, or not all the market scenarios might fit for a short-term profit maximization strategy. As we have previously seen, in late 2014 OPEC moved towards a squeezing strategy where they drove up production to drive down prices. In order to further study the fundamental market factors that are behind a strategy shift by OPEC, the equilibrium model by A. Behar and R. A. Ritz (2016) provides a rational.

The model, an algebraic framework with numerical computations, just focuses on predicting the strategic decision of OPEC between defending market share and maximizing short-term profit depending on market fundamentals. So, for the rest of the section we will describe how the model is built and we will run it in some future scenarios we have built after merging all the information of the main players we have gathered in the section 4 which is resumed in section 5.

6.4.1. The Equilibrium model of A. Behar and R. A. Ritz (2017)

The simple economic model that presented A. Behar and R. A. Ritz (2017) models a framework where OPEC has a degree of market power and competes against a set of non-OPEC producers who act as price-takers. So, at the end of the day OPEC is the dominant player and chooses the prices of the market (or equally the production level).

If we continue with the set of failures that over the years different models have fixed, in this case we have two of them faced. The first one, as we have already explained, is the fact that two possible strategies are contemplated for OPEC rather than just the short-term profit maximization one. The second one makes reference to the fact that no model has captured the reality behind OPEC's behaviour and the evidence that it does not form a perfectly efficient cartel. This has led OPEC to lose pricing power in the actual crude oil market and to capture this, a parameter $\lambda \in (0, 1]$ has been introduced. $\lambda = 1$ refers to a fully- efficient cartel and as the value of λ decreases, it corresponds to a weaker pricing power for OPEC.

Here below we will introduce the model in a schematic way. For further information on it please refer to A. Behar and R. A. Ritz's "OPEC vs US shale: Analyzing the shift to a market-share strategy" paper.

Main parameters

Parameter	Definition	Units
P	Price	\$/barrel
D(P)	Demand	mbd
β	Demand slope (β>0)	
α	Demand intercept (α>0)	\$/barrel
Ki	OPEC production capacity	mbd
Ci	OPEC marginal cost of production	\$/barrel
λ	OPEC pricing power 0<λ<1	-
S_i^*	OPEC supply accommodate	mbd
S_i^{**}	OPEC supply squeeze	mbd
Kj	US shale production capacity	mbd
Cj	US shale marginal cost of production	\$/barrel
Kl	Non-OPEC, non-shale suppliers production capacity	mbd
Cl	Non-OPEC, non-shale suppliers marginal cost of production	\$/barrel
Kn	Non-OPEC suppliers production capacity	mbd
Cn	Non-OPEC suppliers marginal cost of production	\$/barrel

Table 17. Main parameters of the A. Behar and R. A. Ritz (2017) model.

Simplifying assumptions

- The model does not incorporate dynamics or intertemporal changes.
- The model does not capture uncertainty nor the role of asymmetric information.

- Non-OPEC suppliers' production is modelled as binary, considering they produce up to their capacity (K_n) if the price is above their marginal cost ($P - C_n > 0$), and zero otherwise.

Strategies that can be adopted by OPEC

- "Accommodate" is the strategy that maximizes profits by increasing the crude oil prices through coordinated production cuts.
- "Squeeze" is the strategy that focuses on maintaining or gaining market share. OPEC does it by lowering the crude oil price through flooding the market with additional crude until the price reaches the marginal cost of the supplier that has the highest one, leaving it out of the market. In the present analysis, the US shale has the highest marginal cost, so it would be left out of the competition and would produce zero in case of a squeeze scenario.

The demand curve

The global demand curve takes a linear form, which is a common assumption in the literature as we have seen in previous models.

$$D(P) = \frac{(\alpha - P)}{\beta}$$

Assumptions on parameters values

- The US shale needs to be viable under the "Accommodate" strategy. Which means that also the rest of suppliers and OPEC are viable as their costs are smaller than those of US shale.

A1. $$\left(C_j - C_i\right) < \lambda \left[\left(\alpha - C_j\right) - \beta\left(K_j + K_l\right)\right]$$

- In case of a "squeeze" strategy, OPEC needs to have enough spare capacity to carry it out. That means that non-shale suppliers need to have the capacity to supply the required global demand.

A2. $$\left(\alpha - C_j\right) \leq \beta(K_i + K_l)$$

Combining A1 and A2 the minimum OPEC production capacity is obtained where $C_j > C_i$.

$$K_i > K_j + \frac{\left(C_j - C_i\right)}{\lambda\beta}$$

Strategy 1: Accommodate

As the oil price is considered to be higher than US shale oil production costs ($P - C_j > 0$), the US shale produces up to its capacity K_j, as the rest of the non-OPEC and non-shale players do. This means that OPEC will produce the residual demand that is left and will choose the price that maximizes its profit.

$$Residual\ demand = \left\{D(P) - K_j - K_l\right\}$$

$$\max_P \Pi_i(P) \equiv \{D(P) - K_j - K_l\}(P - C_i) = \frac{1}{\beta}\{(\alpha - P) - \beta(K_j + K_l)\}(P - C_i)$$

The pricing power of OPEC is introduced in the first-order condition so that accounts for the inframarginal units of production corresponding to the marginal unit on which OPEC gains a margin of $(P - C_i)$. Solving, the optimal price for OPEC is P* and its profits under this strategy:

$$P^* = \frac{C_i + \lambda[\alpha - \beta(K_j + K_l)]}{(1 + \lambda)}$$

$$\Pi_i^* = S_i^*(P^* - C_i) = \frac{\lambda}{\beta}\left(\frac{(\alpha - C_i) - \beta(K_j + K_l)}{(1 + \lambda)}\right)^2$$

Strategy 2: Squeeze

In this case the optimal price is given by the value of the marginal cost of the supplier with the highest marginal cost, which is the US shale. So, by definition $P^{**} = C_j$.

$$S_i^{**} = \{D(P^{**}) - K_l\}$$

$$\Pi_i^{**} = S_i^{**}(P^{**} - C_i) = \frac{1}{\beta}[(\alpha - C_j) - \beta K_l](C_j - C_i)$$

Switch of strategy

It is needless to say that OPEC will choose the strategy that maximizes its profits, so being the difference between the two strategies $\Delta\Pi_i \equiv (\Pi_i^{**} - \Pi_i^*)$, when $\Delta\Pi_i > 0$ will choose to squeeze and when $\Delta\Pi_i < 0$ will choose to accommodate.

6.4.2. Relevant market factors and strategy switch drivers

If we study the formulas for each strategy's profit, we can deduce that the value of some of the parameters can lead one strategy to be more profitable than the other. If we focus in the parameters that make the squeeze strategy more preferable we can find the following conditions:

- When the US shale oil capacity production is higher ($\uparrow K_j$), under the accommodate strategy the price of the crude oil would decreased. So, for OPEC would be more attractive to leave out of the market a US shale with great capacity rather than a US shale with insignificant capacity, because it would have access to a larger market share.
- In case global demand gets reduced ($\downarrow \alpha$), both volume and price are affected as both decrease. In an accommodate strategy it happens straight forward, but in a squeeze strategy, the price is fixed to the higher cost producer's marginal cost so

just the volume decreases. That's why at the end of the day if the global demand decreases considerably, OPEC would choose a squeeze strategy.

- In the same way as when the US shale oil capacity production is higher, in case the production capacity of other non-OPEC, non-shale players increases ($\uparrow K_l$), OPEC will lead to a squeeze strategy. The reasoning behind it is the same as when the global oil demand decreases, an increase in other's capacity decrease both volume and price for OPEC so is more profitable to switch to a squeeze strategy where the price is fixed.
- The OPEC pricing power which is a result of its internal cohesion is a strategy driver too. If the internal cohesion is low ($\downarrow \lambda$), is harder for OPEC to conduct a production cut which needs high coordination, so the switch towards a squeeze strategy is more feasible.
- Last but not least, the higher the US shale oil marginal costs ($\uparrow C_j$), the more attractive is for OPEC to change to a squeeze strategy as the reduction in price needed would be smaller.

In addition to all these parameter conditions, there is one critical value for the production capacity of the US shale ($\overline{K_J}$), for which scenarios with $K_j > \overline{K_J}$ determine that the optimal strategy for OPEC is the squeezing one. The critical value for $\overline{K_J}$ is derived from the equation $\Pi_i^{**} > \Pi_i^{*}$, and depends mainly on demand and cost conditions. The expression that defines it is the next one:

$$K_j > \left[\frac{1}{\beta}\left((\alpha - C_i) - (1+\lambda)\sqrt{\frac{1}{\lambda}\left[\left(\alpha - C_j\right) - \beta K_l\right]\left(C_j - C_i\right)}\right) - K_l\right] \equiv \overline{K_J}$$

Therefore, is straight forward to see that the model reveals that best responses for certain market conditions for OPEC can generate discontinuous jumps in crude oil prices and supply. As OPEC's strategy is shifted when some parameter's thresholds are crossed, both prices and production volumes change. The Figure 92 and Figure 93 show the impact of the US shale capacity and of the global demand respectively, in both OPEC's profits and its optimal supply volume's evolution are shown.

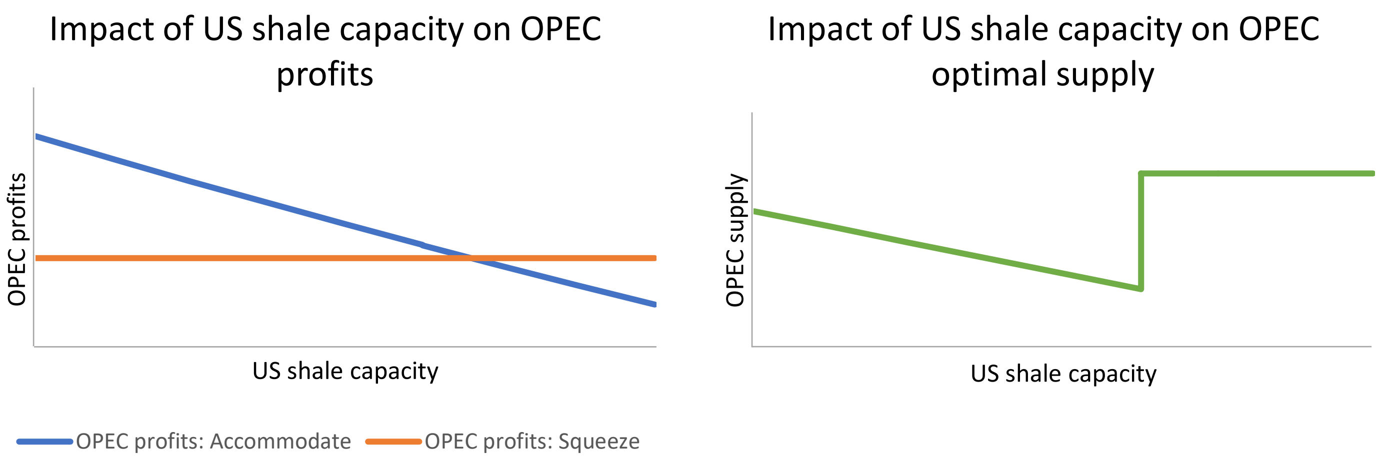


Figure 92. Impact of US shale oil production capacity on OPEC profits. Source: A. Behar, R. Ritz (2017).

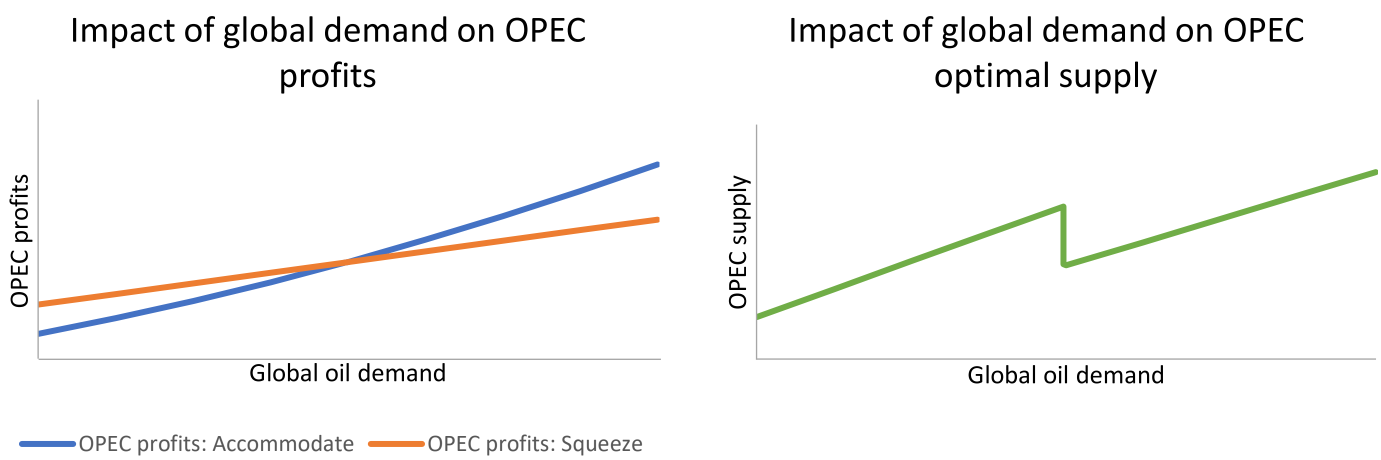


Figure 93. Impact of global oil demand on OPEC profits. Source: A. Behar, R. Ritz (2017).

6.4.3. Application of the model to the oil market outlook scenarios

Throughout the thesis, we have studied in detail the main players of the oil market and understood their main strengths and weaknesses to face the future oil market development. In addition, we have reviewed the different models that have been used during history to explain the oil price path. And in particular, we have focused in the model of A. Behar and R. A. Ritz (2017) as we have considered that is the one that best captures the actual oil market structure.

Our final goal once we have collected all this information is to join it and make a unified analysis out of it. With this purpose, we have created a total of seven outlook scenarios, one for every 5 years to 2050, based on the different information we have analyzed in section 4. Those scenarios will be the ones we will test in the model of A. Behar and R. A. Ritz (2017) and comment the results. In detail, we will comment on how future oil strategies seem to evolve, who will be the winners and the losers, and how oil will further develop.

6.4.3.1. Source of values and outlook scenarios

The input data to create the outlook scenarios has been obtained from the U.S. Energy Information Administration (EIA) and completed in some cases with data from the International Energy Agency (IEA). Other data, such as future shale oil and conventional OPEC oil breakeven prices, has been estimated for different oil price scenarios due to the lack of available projections. The next list provides a guide through the different values and its sources for the three oil price cases studied: the reference case, the high oil price case and the low oil price case. Find the numerical values for the scenarios attached in the Appendix A.

- The crude oil price (P) is based on the historical and forecasted data of the EIA's Brent barrel price ($/barrel).

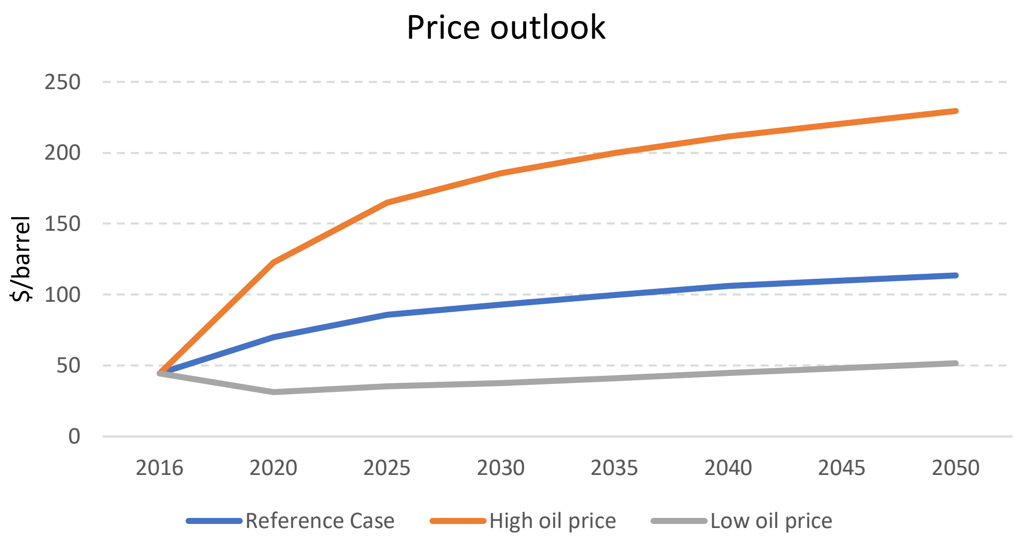


Figure 94. Price outlook to 2050. Source: EIA.

If we analyze the price path in more detail, see Figure 94, the high oil price scenario differs by more than 100% with the reference case and by more than 150% with the low oil price case. This is due to the EIA considering "*the impact of higher world demand for petroleum products, lower Organization of the Petroleum Exporting Countries (OPEC), upstream investment, and higher non-OPEC exploration and development costs*". Meanwhile, the low oil price case assumes the opposite.

- The demand has been considered to be the total estimated crude oil consumption in the world, in millions of barrels per day (EIA).

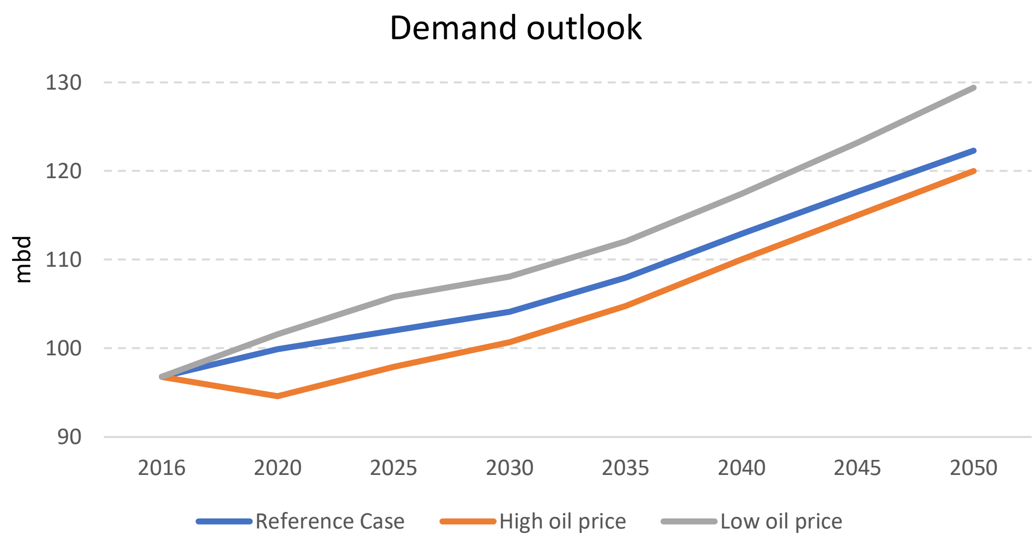


Figure 95. Demand outlook to 2050. Source: EIA.

As it can be seen in Figure 95, the consumption estimate is very positive and with no slowdown in contrast with the conclusions that we reached in the demand section 4.2. If we go back to the Figure 68, we can see that the EIA is the only source which is not expecting a crude oil demand slow down. Despite not being completely in line with the average outlook, we will use this data as it is consistent in source with the rest of data that we are using. Not only that, but this set enables us to capture all the required information in a coherent way, given the scarcity of reliable and disaggregated data for the crude oil market.

- The parameter β, which indicates the demand's slope, has been chosen to be 8. This value ensures the elasticity on the demand that the literature supports (demand elasticity of around -0,15 when crude oil price is at 100$/barrel and -0,07 when crude oil price is around 50$/barrel). The parameter α has been endogenously solved using the demand equation and the values of P, D and β.

- Non-OPEC and non-shale player's production capacity (Kl) is assumed to be equal to their estimated production. As mentioned earlier, for IOCs it is not cost-effective to build up spare capacity so they produce near or at full capacity. It is important to remark that this production capacity does not distinguish between crude oil and NGLs (EIA).

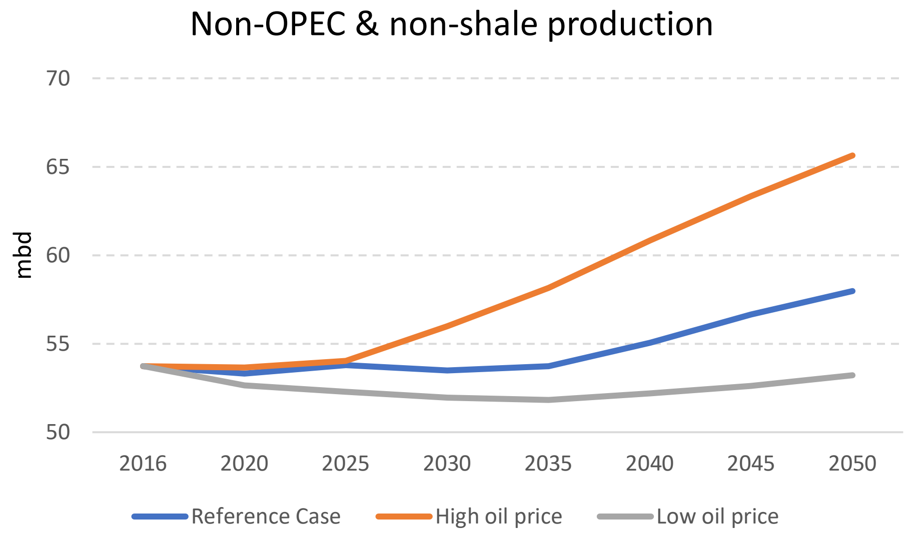


Figure 96. Non-OPEC and non-shale supplier's production to 2050. Source: EIA.

As we will see later for US shale production, non-OPEC and non-shale player's production fields are mainly owned and exploited by IOCs, which varies significantly with oil prices. For instance, as IOCs only invest when projects are estimated to be profitable, investments are more likely to get ahead when oil prices are high.

Also, the fact that conventional oil extraction investments are long term projects can be noticed in the high oil price case, as it takes until 2025 for the output to rise. This is also a result of the low oil price period after 2014, when conventional oil suppliers sustained production but reduced the investment needed to grow the future capacity.

- For OPEC, the capacity (Ki) is just crude output capacity so we have added the NGLs output capacity to make it coherent with the rest of the data set (EIA and IEA). In addition, capacity forecasts were only available until 2022, so to have projections up to 2050 we have computed the average production to capacity ratio (production taken one year ahead from capacity to include the inherent lagged influence of available capacity to next years' output) between 2017 to 2022, which was 91,8%, and we have used it to infer the capacity from the forecasts of OPEC's production up to 2050.

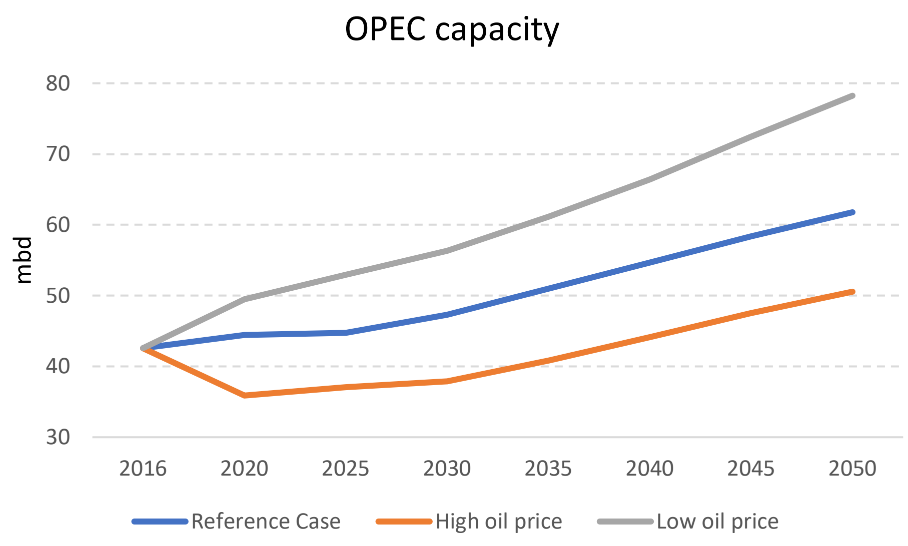


Figure 97. OPEC production capacity to 2050. Sources: EIA, IEA and personal elaboration.

It is interesting to remark that OPEC is the only supplier that has a higher capacity in the case of the low oil price case. Even if it can seem counterintuitive, it is totally reasonable. Indeed, low oil price, implies higher demand (Figure 95) but also pushes shale producers with higher breakeven points (Figure 98) out of the market. Consequently, OPEC needs to satisfy more demand on its own, which justifies why OPEC capacity is higher in the low oil price case.

- For US shale oil, the capacity (Kj) has also been assumed to be the estimated output (EIA) as for the non-OPEC, non-shale player's capacity.

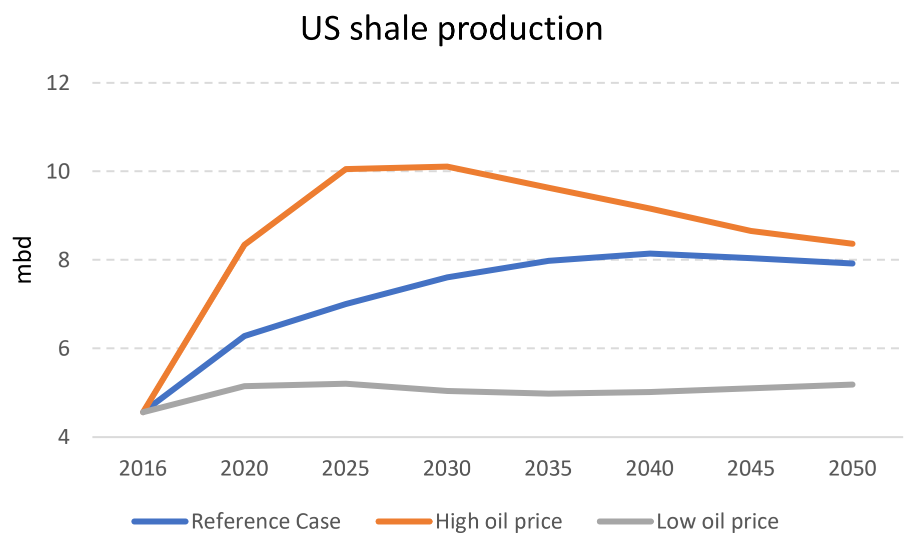


Figure 98. US shale production to 2050. Source: EIA.

In contrast to the conventional oil, shale oil is more dependent on investments as the rigs life-cycle is short, so in order to sustain or grow the output, investments need to be sustained or increased in a continuous way. This makes investments to be directly related to the oil prices and explains why US shale is considered to be one of the most flexible oil producing resources. In the case of low oil prices, very few investments will be carried forward and as it can be seen in Figure 98, the production will stagnate very quickly. Instead, if prices rise as expected in the high oil price case, vast amounts of money will be invested in new rigs and shale output will increase drastically as the response of shale is fast compared to the conventional oil. Nevertheless, the amount of recoverable shale is such, that in the high oil price case by 2028 the peak will be reached and then extraction costs will ramp up as it can be seen in Figure 98.

- In terms of OPEC's pricing power (λ), it has been solved endogenously to match the market price with the accommodate strategy's price equation. OPEC literature implies that a common value for the parameter of OPEC's pricing power is λ<0,5, which is in all cases except from the high oil price scenario, which we will comment later on.

  In some cases, the endogenously solved lambda was not big enough to comply with the A1 and A2 assumptions, so the required minimum value of lambda has been taken as lambda so that the assumptions could be valid.

- OPEC's marginal cost refers to its cash costs (EIA). OPEC's marginal costs into the future have been slightly modified to reflect exogenous changes in cash costs stemming from the different oil price scenarios.

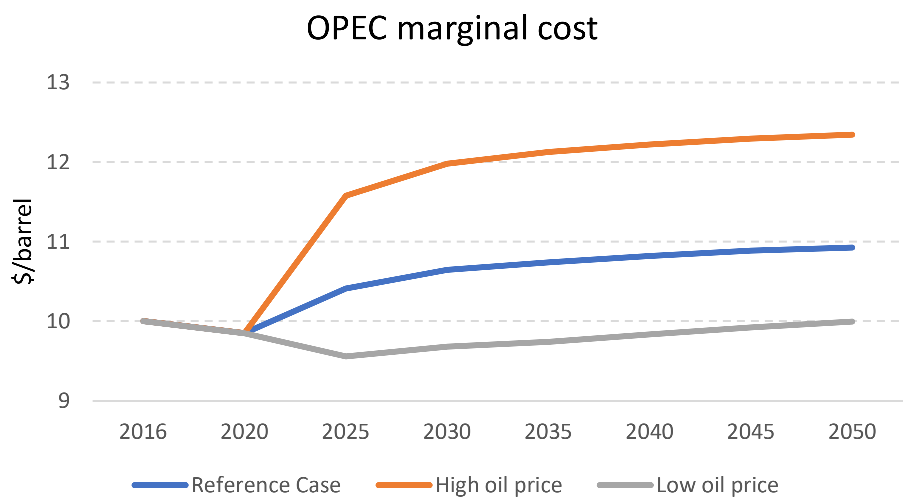


Figure 99. OPEC marginal cost to 2050. Source: EIA.

- The US shale oil marginal cost instead refers to the full-cycle cost and includes the upfront investments due to its short life-cycle compared to conventional oil extraction (EIA). It is important to remark that the US shale oil is not the player with the highest production cost. Nevertheless, is the player that produces the biggest volume at the highest cost so a simplification of the rest of the marginal high cost producers is done, as it is estimated that the production levels they have are not significant.

US shale oil full-cycle breakeven costs have been fully estimated. Given the crucial paper that this variable plays into the model, special care has been given so as to fully reflect the effect that different oil price scenarios have in breakeven costs evolution.

The starting point is EIA's data on full-cycle wellhead breakeven costs per US play from 2012 to 2017. Total production in each play for each year has been used so as to obtain a weighted average full-cycle breakeven costs for US shale from every year from 2012 to 2017.

This set of figures have been used to compute the yearly evolution of breakeven shale oil prices (output variable being breakeven costs yearly growth rate), which have then been linearly trended taking as explanatory variable the year-on-year WTI price change. This simple model created to predict shale oil costs evolution captures both the endogenous (technology improvement) and exogenous (price evolution effects) changes suffered by wellhead shale oil full-cycle breakeven costs. In actual fact, the R-square obtained is pretty impressive: 94% when applying the model to the available data from 2012 to 2017. Note that the model incorporates a half year lag in this trend, as WTI price's growth rate used as input variable considers year end figures, while available breakeven costs data are year averages. To illustrate how the model works, WTI year end price growth rate from 2012 to 2013 is used as input variable to derive 2013 to 2014 average breakeven costs growth rate (not end of year due to limitation from available data).

This model is useful when endogenous changes, such as decreased costs thanks to technological improvements and increased productivity, are constant. To reflect the effects of the natural S curve of endogenous changes and peak oil supply, the intercept from our linear model has been modified accordingly in each of the reference, high oil price and low oil price cases. The results obtained are reasonable

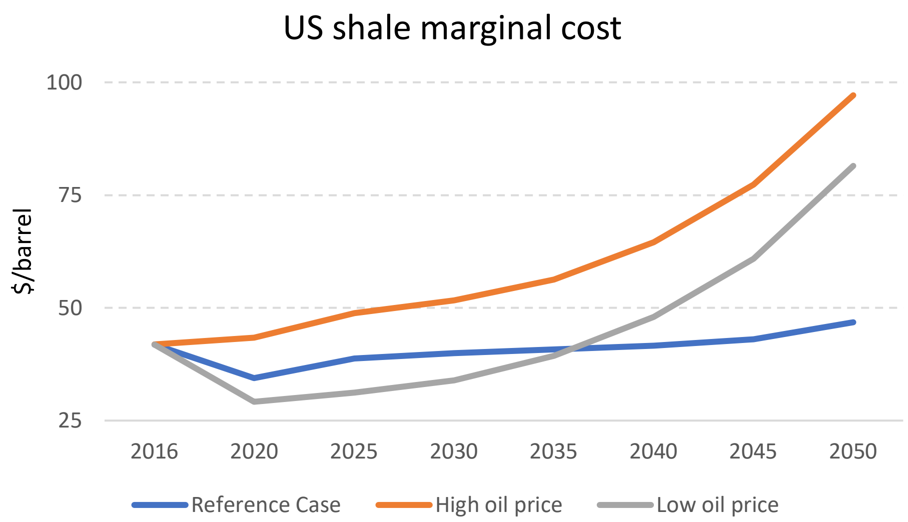


Figure 100. US shale full-cycle cost to 2050. Source: EIA.

6.4.3.2. Model's output, winners and losers

Taking 2016 as a starting point, we will analyse the three oil price cases independently as each case shows a similar pattern through the case outlook as we will see. Find the complete results' tables and additional figures in Appendix B.

Reference case

From late 2014 OPEC decided to switch to a squeeze regime in order to protect their market share from the rising US shale capacity, the weak global demand and the OPEC coordination problems together to other market factors.

In 2016 the model results reveal that the squeeze strategy was almost at its end, as the profit provided was only around $50 million per day above the accommodate strategy's profit. After two years, for some of the OPEC members the squeeze strategy was being hardly sustainable and even Saudi Arabia noticed an increase of its deficit account while its economic growth stagnated. Due to it, Saudi Arabia started to negotiate with Russia a cut in their oil production level that would benefit both parts.

In December 2016 the deal was reached, what prompted a regime switch towards accommodate. Thanks to the deal, by 2020 prices are estimated to recover what leads a US shale capacity grow and a reduction of its marginal costs, while non-OPEC and non-shale players' capacity will not grow so fast. The deal will also require a higher level of coordination between OPEC members what means an increase of lambda to values near 0,20. All the market factors together, the model predicts to be more profitable for OPEC to sustain the accommodate strategy as they can still control the prices thanks to the deal with Russia, while obtaining larger profits.

To 2050 the outlook does not show any critical year with market factors prompting a regime switch, in fact, the more we approach to 2050, the more profitable is for OPEC to stay within the accommodate regime. It is true that by 2050 non-OPEC capacities and the US shale marginal cost grow, but OPEC's capacity surpasses that of the non-OPEC non-shale suppliers while demand increases, so there is no point for OPEC for a regime switch.

In this oil price case, OPEC is able to control the prices with the help of Russia, as the internal cohesion of the OPEC is not strong enough to face the sustained capacity grow of the non-OPEC players. In addition, they are able to control prices not rising excessively, fact that would facilitate the US shale output expansion, or a faster development of other alternative fuels.

High oil price case

In the high oil price case, the average annual growth rate of the price from 2016 to 2050 is estimated to be 4,9%. But not all that glitters is gold and as a consequence of a vast increase in the price, the demand growth will be lagged.

In addition, as the model's output reveals, such a high price needs to be supported by greater OPEC coordination. The endogenously solved value for lambda appears to be above the 0,5 addressed by the literature. Nevertheless, to sustain the high oil price coordination is essential, because if countries individually started to focus on its profit to take advantage of the high oil price (which has been common practice between OPEC members), they would start to flood oil to the market and prices would drop.

All the market factors together, the model suggests that the most profitable regime for OPEC is the accommodate one. If we take a look to the market share, is true that the value for OPEC falls to around 35% compared to around 60% market share in the squeeze regime. But having more market share does not provide OPEC with more profit. In this case, out of the three oil price cases, OPEC supplies the least crude to the market and gains the highest profit. This means that even non-OPEC players production rises to maximums, it is not profitable to decrease prices in more than $100 per barrel to gain more market share by leaving them out of the market, that would be too expensive.

It is interesting to remark that US shale costs at the end of the period increase drastically to $97,1 per barrel, what seems that should prompt a regime switch. But on the other hand, its production capacity is not estimated to grow enough while prices continue to be on maximums. Due to it OPEC still is much more profitable in an accommodate regime than reducing the price by $130 per barrel and gaining just 8,4 mbd of output.

In this high oil price case we believe that OPEC would be the clear winner as would force an early tight oil peak in 2028, what would enable them to increase their market power back afterwards. In addition, also non-OPEC non-shale players would be able to ensure a future long-term capacity increase thanks to the investments that could be undertaken due to the high oil price. Nevertheless, it is important to remark that such high prices would also deter the use of oil and push for a faster replacement of crude by other cheaper and cleaner alternative fuels, so will be important to keep an eye on these moves and its consequences. In particular, the electric vehicles adoption will be faster as the payback period for the mass-market will be more attractive than the one for a conventional vehicle, what will displace more oil from the roads than what is really estimated.

Low oil price case

The low oil price case is the one that changes more from one regime to the other. The main reason behind it is that prices stay very low and near the US shale marginal cost. This means that for some market factors, it is very likely that by decreasing the price in a couple of dollars per barrel OPEC could leave out of the market the US shale suppliers. So in that case, the reduction of profits due to the price decrease could be compensated by the market share that OPEC would gain from the US shale.

In 2020, mainly driven by the low oil prices and a fall in the OPEC power market, the most profitable strategy keeps being the market share one. To 2030 the prices increase slowly and as the difference between them and the US shale marginal cost increases, is slightly more profitable the accommodate strategy, also because the non-OPEC capacities stay flat. From 2035 onwards, prices continue rising, but US shale costs rise above them, what places US shale players out of the market. Given that situation, for OPEC the most interesting move is to rise prices to the value of the US shale's marginal cost, the limit, so to switch to a squeeze regime.

Given the low oil price case, the US shale together with the high cost producers would be the ones that would lose more, as in the late 2014 price drop happened. For the rest of suppliers would not be easy to survive a long period neither, but at least would not place them outside the market. The other side of it would be that the introduction or switch to alternative fuels would be delayed what will enable the oil demand peak to be delayed too.

6.4.3.3. Model's weaknesses

After having played with the A. Behar and R. A. Ritz (2017) model and analyzed the output's obtained, we have collected a series of issues that we believe could be improved towards having a more accurate result. Nevertheless, we are also aware that introducing them would make in some case the model too complex what at some point could not be interesting.

The first weakness and the one we consider more relevant is the sensitivity of the model to the value of OPEC's pricing power parameter (λ). A change of 0,01 in the value of lambda changes the value of the critical capacity of the US shale $\overline{K}_j$ by between 2,5 and 3 mbd, what is a large amount considering the volumes the US shale oil is able to produce. This means that if the appropriate value of lambda is not obtained, the output could provide an unreal change of regime, so results will not capture the reality. So, the problem then moves to the search of the real value of lambda, which is even more abstract given the opacity of the OPEC.

If we look at the situation in the low oil price case after 2035, prices fall below those of the US shale marginal cost. What means that they go below the optimal squeeze scenario, which has no sense from the OPEC's profit maximization viewpoint. But actually, US shale players are not one with a single and unified marginal cost, but they are numerous little suppliers within a range of different marginal cost values. This affects two issues around the assumption of the binary output by the US shale depending on the oil price. The first one is that it has not sense to leave out of the market all the US shale supply when the price matches the average marginal cost, as still several players will be able to operate, so an oversimplification is being undertaken. The second issue refers to the fact that actually, and due to the nature of the US shale suppliers, it has sense to drop prices below Cj, as this enables to leave more US shale players out of the market.

Finally, in addition to the US shale players, there are several shale players that have not been considered as their marginal costs are higher than the one of the US shale and their production levels low. Low oil prices may have deterred them to invest in extraction projects, but in case prices rise they should be considered as their supply capacity will grow. So, if they undertake appropriate investments, their output capacity would grow and their marginal cost decrease, what at the end of the day could alter the results obtained.

6.5. Future models

How could current models de adapted to better explain future strategies and oil price development?

During the section 6 we have analyzed the application of the game theory to the crude oil market. We have seen old models and examined how some of their failures were amended in the new ones. And finally, we have run some outlook scenarios to see what future strategies will OPEC follow in the future.

Now, if we take a look to how the oil market will evolve and to the equilibrium models studied until the moment, we can see that some of the initially identified failures still have not been capture and that others that will be interesting to take into account in the future have emerged. So, how should models evolve in the near future?

The first thing that models need to capture more appropriately is the reality behind OPEC's behavior. It has been demonstrated that OPEC does not have any more the ability to act as a completely collusive cartel as it used to have, but nevertheless its actions as an organization are very relevant and have direct consequences in the oil market. Due to it, a proper identification of their internal cohesion and price setting ability is relevant towards a proper modelling.

The next issue is to deal with the numerous suppliers in the market and its different interests and characteristics. This makes very complex to model all the behaviors and leaves the Cournot nor the Stackelberg frameworks just available in case considerable assumptions are taken. So, a big challenge in the oil market equilibrium modelling will be to create a framework that captures the plurality of players and its characteristics.

In addition, as we have seen in the model of Ansari (2017), deviations and predictions of rivals' responses could be captured by the conjectural variations. Nevertheless, the solution by Ansari it is not consistent nor based on any economic theory, what makes its results questionable. So, this avenue of research is still open and is considered to be an important gateway to the proper equilibrium modelling.

Finally, the demand side also appears to be a challenge. The estimates do not seem to capture the realities that are arising around the substitutes and the passenger vehicle revolution. So as mentioned earlier, the unpredictable situations such as lags in supply or in demand, nationalizations, or changes in transportations costs are still not taken into account in most of the models and in contrast, they could be the source of abrupt changes in the crude oil price and in the oil market structure itself.

7. Conclusions

Retaking the study "The Three Epochs of Oil", published in 2010 by the National Bureau of Economic Research, we can say that we are currently living a fourth epoch that begun a few years ago. Indeed, the current situation is brand new and cannot be compared to anything that has been seen before. This can be applied to both the supply side and the demand side.

OPEC is still being the most prominent and powerful figure on the supply side mainly supported by the reserves it has and its quota system that historically has allowed to control the flow of oil to the global market. However, this cooperation between oil producing countries is also its main weakness. Budgetary pressures, oil revenues dependency, the trade-offs existing between short-term and long-term goals, amid uncountable factors, vary for every member. This implies that consensus will never exist within the organization, therefore incentivizing cheating. This situation is further complicated by internal geopolitical conflicts and by the new competition it is facing. The ripples of the U.S. shale revolution are far from being over and U.S. shale production is still growing, but it is a less reliable source of crude oil for global markets. Indeed, this new source is mainly characterized by small projects with high breakeven prices lacking the appropriate transportation and refining infrastructure. This implies, first, that the production will heavily depend on global financial conditions and on crude oil prices, and secondly that its fragmentation and lack of coordination will prevent U.S. shale from becoming a true market force. The final player to be taken into consideration is Russia that is undertaking ambitious reforms and reaching agreements with OPEC to unleash its full potential.

As it has been the case in the last decades, the demand side is essentially driven by the growth of Asian countries, especially of India and China. In order to ensure a steady supply, both countries have made several investments and reforms becoming big players in the refining sector. Nonetheless, particularly in China the expected GDP growth will not necessarily translate into demand for crude oil growing at the same pace, justified by the shift from heavy industry towards services. The diminution of oil demand also reaches a global scale due to a stronger environmental consciousness present in new policies to fight oil dependency. This is empowering the progressive adoption of new technologies such as the electric vehicle, and experts point out that by 2030 transport could transform into a service based on autonomous electric vehicles, what will further disrupt the oil demand.

With this current situation, two main strategies have been defined for OPEC: squeeze or accommodate. With the first one, the organization would use its market power by flooding global markets to drag prices down and push shale producers out of the market to gain market share. The latter is self-explanatory: a profit maximization strategy by increasing prices through coordinated production cuts. The tools of game theory were then applied to predict the evolution of crude oil prices on three different scenarios. Results show that in the coming years, with current market conditions, closer to the high oil price case, OPEC would prefer to accommodate. These computations also showed us the main weaknesses of the models. Indeed, while building the model and gathering all the relevant data, the flaws, with no solution, that every model has were faced. First, the arbitrariness that needs to be introduced when choosing values for relevant variables that are not directly measured or predicted in a reliable way. Secondly, the difficulty to find a theoretical framework that faithfully represents reality. Finally, the trade-off between complexity or granularity, allegedly making the model closer to reality and the required simplicity so that the model is still useful. Moreover, some factors are completely unpredictable or even unknown, and therefore cannot be captured by a model, which is nothing but a tool to gain deeper knowledge and assess the importance of the main drivers while bringing some certainty for the short-term. In that sense, the value of this thesis and its main outcome are not the projections made, but its ability to depict the complexity of the global oil market and the most important forces behind it.

Appendix

A. Outlook scenarios for three oil price cases

Reference Case

	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)	44,5	70,0	85,7	92,8	99,9	106,1	110,0	113,6
D (mbd)	96,8	99,9	102,0	104,1	108,0	112,9	117,7	122,3
Ki (mbd)	42,6	44,4	44,8	47,3	51,0	54,7	58,4	61,8
Ci ($/barrel)	10,0	9,9	10,4	10,6	10,7	10,8	10,9	10,9
Kj (mbd)	4,6	6,3	7,0	7,6	8,0	8,1	8,0	7,9
Cj ($/barrel)	41,9	34,4	38,8	39,9	40,7	41,6	43,0	46,8
Kl (mbd)	53,7	53,3	53,8	53,5	53,7	55,1	56,7	57,9

High oil price

	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)		122,6	164,8	185,5	199,7	211,6	220,4	229,5
D (mbd)		94,6	97,9	100,7	104,8	110,0	115,0	120,0
Ki (mbd)		35,9	37,0	37,9	40,9	44,1	47,5	50,6
Ci ($/barrel)		9,9	11,6	12,0	12,1	12,2	12,3	12,3
Kj (mbd)		8,3	10,1	10,1	9,6	9,2	8,7	8,4
Cj ($/barrel)		43,4	48,8	51,6	56,3	64,5	77,3	97,1
Kl (mbd)		53,7	54,0	56,0	58,2	60,8	63,3	65,6

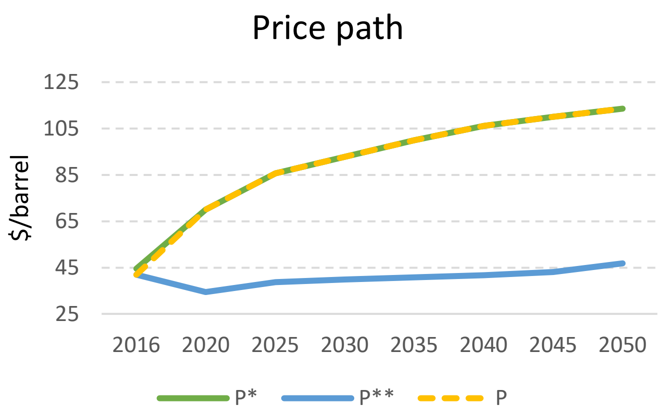
Low oil price

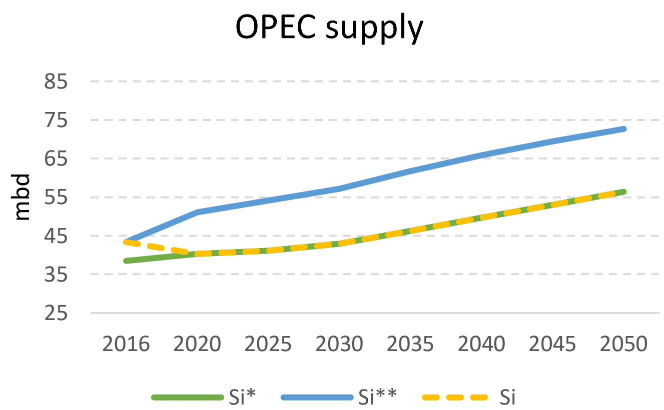
	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)		31,3	35,3	37,6	41,1	44,9	48,0	51,6
D (mbd)		101,6	105,8	108,1	112,1	117,4	123,2	129,4
Ki (mbd)		49,5	53,0	56,3	61,1	66,5	72,5	78,2
Ci ($/barrel)		9,9	9,6	9,7	9,7	9,8	9,9	10,0
Kj (mbd)		5,1	5,2	5,0	5,0	5,0	5,1	5,2
Cj ($/barrel)		29,2	31,2	34,0	39,4	48,1	60,9	81,5
Kl (mbd)		52,7	52,3	52,0	51,8	52,2	52,6	53,2

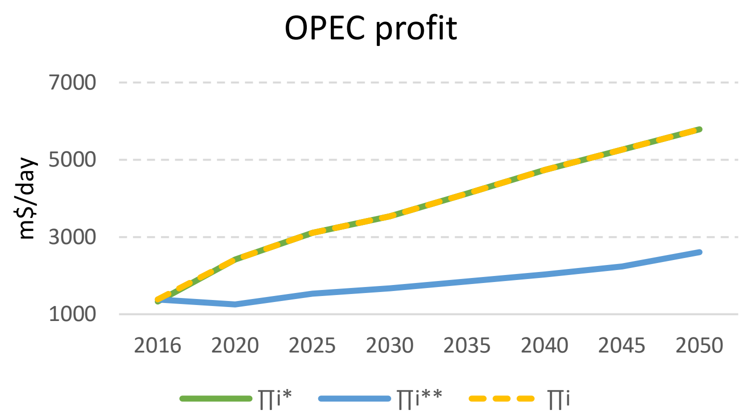
B. Model’s output by oil price case

Reference Case

	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)	44,5	70,0	85,7	92,8	99,9	106,1	110,0	113,6
D (mbd)	96,8	99,9	102,0	104,1	108,0	112,9	117,7	122,3
Ki (mbd)	42,6	44,4	44,8	47,3	51,0	54,7	58,4	61,8
Ci ($/barrel)	10,0	9,9	10,4	10,6	10,7	10,8	10,9	10,9
Kj (mbd)	4,6	6,3	7,0	7,6	8,0	8,1	8,0	7,9
Cj ($/barrel)	41,9	34,4	38,8	39,9	40,7	41,6	43,0	46,8
Kl (mbd)	53,7	53,3	53,8	53,5	53,7	55,1	56,7	57,9
Strategy	Squeeze	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.
λ	0,11	0,19	0,23	0,24	0,24	0,24	0,23	0,23
$\overline{K_J}$	3,7	19,7	22,0	24,2	27,0	29,4	30,8	30,7
Accommodate								
P*	44,5	70,0	85,7	92,8	99,9	106,1	110,0	113,6
Si*	38,5	40,3	41,2	43,0	46,3	49,7	53,0	56,4
∏i*	1328,7	2422,5	3101,6	3533,5	4126,7	4734,5	5255,3	5788,5
Market share	40%	40%	40%	41%	43%	44%	45%	46%
Squeeze								
P**	41,9	34,4	38,8	39,9	40,7	41,6	43,0	46,8
Si**	43,4	51,0	54,1	57,2	61,7	65,9	69,4	72,7
∏i**	1383,8	1253,7	1534,2	1675,6	1850,5	2026,7	2230,6	2606,9
Market share	45%	51%	53%	55%	57%	58%	59%	59%

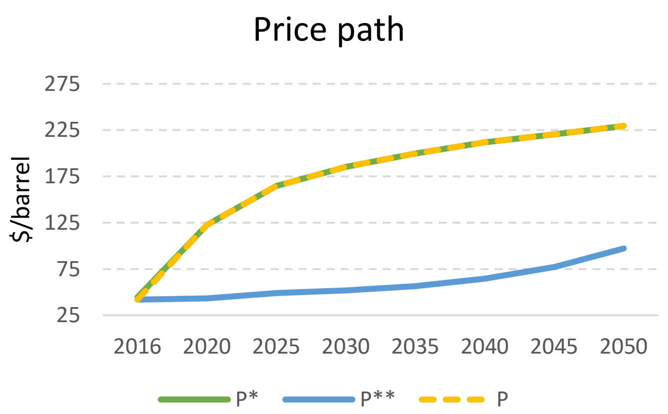


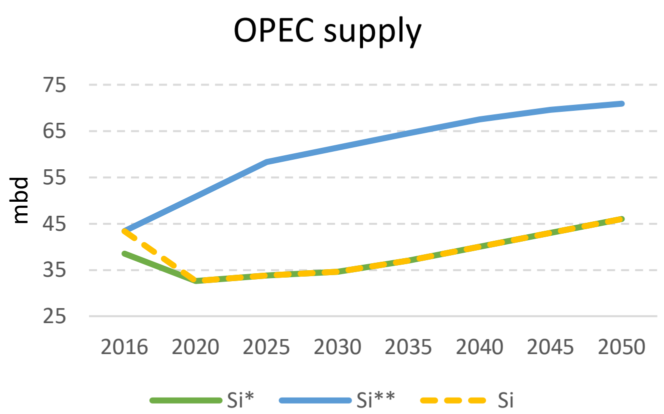


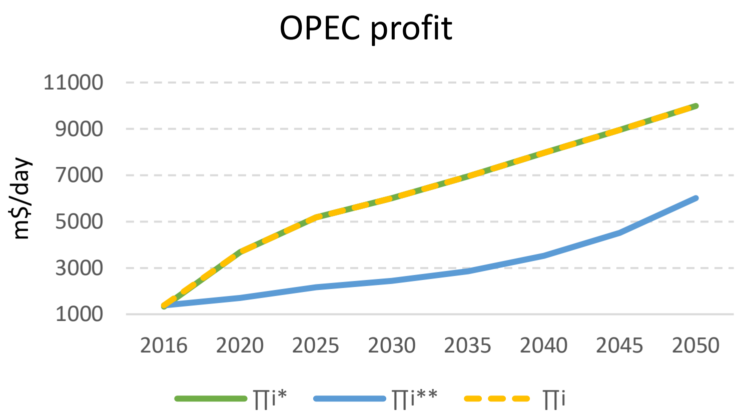


High oil price

	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)	44,5	122,6	164,8	185,5	199,7	211,6	220,4	229,5
D (mbd)	96,8	94,6	97,9	100,7	104,8	110,0	115,0	120,0
Ki (mbd)	42,6	35,9	37,0	37,9	40,9	44,1	47,5	50,6
Ci ($/barrel)	10,0	9,9	11,6	12,0	12,1	12,2	12,3	12,3
Kj (mbd)	4,6	8,3	10,1	10,1	9,6	9,2	8,7	8,4
Cj ($/barrel)	41,9	43,4	48,8	51,6	56,3	64,5	77,3	97,1
Kl (mbd)	53,7	53,7	54,0	56,0	58,2	60,8	63,3	65,6
Strategy	Squeeze	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.	Accomm.
λ	0,11	0,43	0,57	0,63	0,63	0,62	0,60	0,59
$\overline{K_j}$	3,7	23,2	28,7	30,6	31,3	30,9	28,6	24,8
Accommodate								
P*	44,5	122,6	164,8	185,5	199,7	211,6	220,4	229,5
Si*	38,5	32,6	33,8	34,6	37,0	40,0	43,0	46,0
∏i*	1328,7	3677,2	5180,5	6005,0	6941,6	7974,5	8947,7	9989,1
Market share	40%	34%	35%	34%	35%	36%	37%	38%
Squeeze								
P**	41,9	43,4	48,8	51,6	56,3	64,5	77,3	97,1
Si**	43,4	50,8	58,4	61,4	64,6	67,5	69,5	70,9
∏i**	1383,8	1707,8	2171,2	2435,7	2851,0	3530,8	4521,7	6011,9
Market share	45%	54%	60%	61%	62%	61%	60%	59%

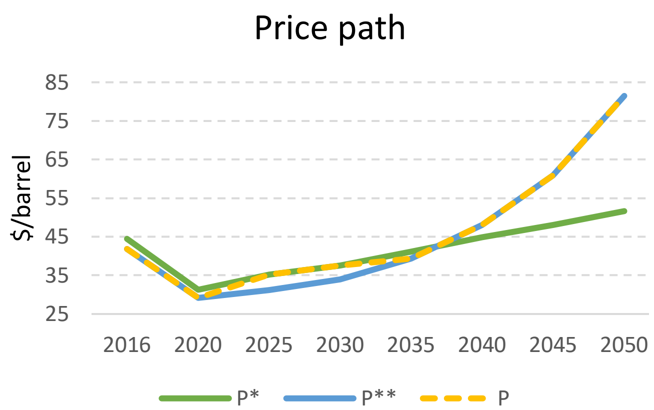


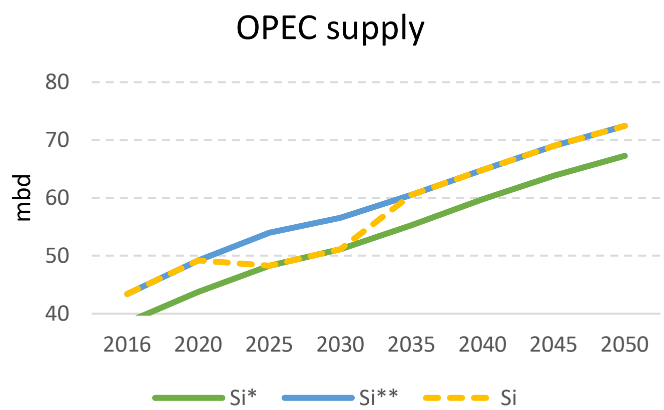


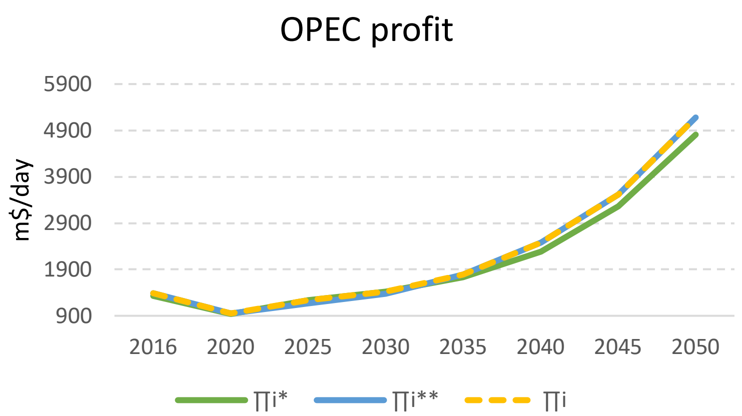


Low oil price

	2016	2020	2025	2030	2035	2040	2045	2050
P ($/barrel)	44,5	31,3	35,3	37,6	41,1	44,9	48,0	51,6
D (mbd)	96,8	101,6	105,8	108,1	112,1	117,4	123,2	129,4
Ki (mbd)	42,6	49,5	53,0	56,3	61,1	66,5	72,5	78,2
Ci ($/barrel)	10,0	9,9	9,6	9,7	9,7	9,8	9,9	10,0
Kj (mbd)	4,6	5,1	5,2	5,0	5,0	5,0	5,1	5,2
Cj ($/barrel)	41,9	29,2	31,2	34,0	39,4	48,1	60,9	81,5
Kl (mbd)	53,7	52,7	52,3	52,0	51,8	52,2	52,6	53,2
Strategy	Squeeze	Squeeze	Accomm.	Accomm.	Squeeze	Squeeze	Squeeze	Squeeze
λ	0,11	0,06	0,07	0,07	0,07	0,08	0,10	0,13
$\bar{K}_J$	3,7	4,8	6,8	6,0	4,0	2,4	2,4	2,3
Accommodate								
P*	44,5	31,3	35,3	37,6	41,1	48,1	61,0	81,5
Si*	38,5	43,8	48,3	51,1	55,3	59,8	63,9	67,3
∏i*	1328,7	938,6	1242,0	1425,6	1735,4	2285,6	3263,7	4808,5
Market share	40%	43%	46%	47%	49%	51%	52%	52%
Squeeze								
P**	41,9	29,2	31,2	34,0	39,4	48,1	60,9	81,5
Si**	43,4	49,2	54,0	56,6	60,5	64,8	69,0	72,5
∏i**	1383,8	950,8	1167,8	1374,9	1794,3	2477,4	3515,6	5179,0
Market share	45%	48%	51%	52%	54%	55%	56%	56%







Bibliography

Simola, H., & Solanko, L. (2017). *Overview of Russia's oil and gas sector.* Bank of Finland, BOFIT - Institute for Economies in Transition. BOFIT Policy Brief.

Almoguera, Douglas, & Herrera. (2011). *Testing for the cartel in OPEC: Non-cooperative collusion or just non-cooperative?* Oxford Review of Economic Policy.

Ansari, D. (2017). *OPEC, Saudi Arabia, and the shale revolution: Insights from the equilibrium modelling and oil politics.* Berlin: Energy Policy.

Ant, O., & Ansary, K. A. (2017, September 25). *Turkey Warns Iraq Kurds It Can "Close the Valves" on Oil Exports*. Retrieved from Bloomberg: https://www.bloomberg.com/news/articles/2017-09-25/turkey-warns-iraq-kurds-it-can-close-the-valves-on-oil-exports

Arbib, J., & Seba, T. (2017). *The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries.* RtehinkX.

Aune, Mohn, Osmundsen, & Rosendahl. (2010). *Financial market pressure, tacit collusion and oil price formation.* Energy Economics.

Baev, P. (2016, November). Russia and Central and Eastern Europe: Between Confrontation and Collusion. *Russie.Nei.Visions, 97.*

Behar, A., & Ritz, R. (2017). *OPEC vs US shale: Analyzing the shift to a market-share strategy.* Energy Economics. ELSEVIER.

Bhanvi, A. (2018, March 8). *Bloomberg Quint*. Retrieved from India Says Never Targeted 100% Electric Mobility By 2030, Scales Down Aim: https://www.bloombergquint.com/business/2018/03/08/india-says-never-targeted-100-electric-mobility-by-2030-scales-down-aim

Bloomberg. (2014, October 17). Retrieved from Break-Even Points for U.S. Shale Oil: https://www.bloomberg.com/news/2014-10-17/oil-is-cheap-but-not-so-cheap-that-americans-won-t-profit-from-it.html

BMI Research. (Q3 2017). *India Oil & Gas Report.* BMI Research.

BP. (2017). *BP Statistical Review of World Energy June 2017.*

BP. (2017). *China's energy market in 2016. BP Statistical Review.*

BP. (2017). *Statistical Review of World Energy.*

China Chemical Reporter. (2016). China's 13th Five-Year Plan to Focus on Oil and Gas Reforms. *China Chemical Reporter*.

China's president calls for energy revolution. (2014, June 13). Retrieved from Reuters: https://uk.reuters.com/article/china-energy/chinas-president-calls-for-energy-revolution-idUKL4N0OU2ZB20140613

Deloitte. (2017). *Doing business in Russia 2017.* Tax & Legal.

Dvir, E., & Rogoff, K. S. (2010). *The Three Epochs of Oil.* National Bureau of Economic Research.

Energy Modeling Forum. (1982). *World Oil: EMF 6 Summary Report.*

Energy Research Institute of the Russian Academy of Sciences. (2015). *Global and Russian Energy Outlook up to 2040.*

Eni. (2017). *World Oil Review.*

ET Bureau. (2018, April 12). *The Economic Times*. Retrieved from Saudi Aramco picks up 50% stake in Maharashtra refinery: https://economictimes.indiatimes.com/industry/energy/oil-gas/india-ready-to-give-saudi-aramco-50-per-cent-stake-in-planned-mega-refinery-source/articleshow/63709097.cms

EY. (2014). *US upstream: costs, prices and the unconventional treadmill.* EYGM Limited.

EY. (2017). *U.S. oil and gas reserves study.*

Ezrati, M. (2015, August 12). *The National Interest*. Retrieved from America: Oil's New Swing Producer: http://nationalinterest.org/feature/america-oils-new-swing-producer-13556

Facts Global Energy. (2014). *Iran's Oil and Gas Annual Report 2014.*

Fattouh, B., & Sen, A. (2015). *Saudi Arabia Oil Policy: More than Meets the Eye?* Oxford Institute for Energy Studies.

Ghodussi, H., Nili, M., & Rastad, M. (2017). On quota violations of OPEC members. *Energy Economics*, 410-422.

Gilbert, R. J. (1978). Dominant Firm Pricing Policy in a Market for an Exhaustible Resource. *The Bell Journal of Economics*, 385-395.

Grosse-Ophoff, A., Husler, S., Heineke, K., & Moller, T. (2017, April). *Mckinsey & Company.* Retrieved from Automotive & Assembly: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-shared-mobility-will-change-the-automotive-industry

Hart, R., & Spiro, D. (n.d.). The elephant in Hotelling's room. *Energy Policy*, 7834-7838.

Haynes & Boone. (2016). *Oil Patch Bankruptcy Monitor.*

Henderson, J. (2011). *The Strategic Implications of Russia's Eastern Oil Resources.* University of Oxford, Oxford Institute for Energy Studies.

Henderson, J. (2015). *Key Determinants for the Future of Russian Oil Production and Exports.* University of Oxford, Oxford Institute for Energy Studies.

Henderson, J., & Grushevenko, E. (2017). *Russian Oil Production Outlook to 2020.* University of Oxford, Oxford Institute for Energy Studies.

Henderson, J., & Mitrova, T. (2016). *Energy Relations between Russia and China: Playing Chess with the Dragon.* University of Oxford, Oxford Institute for Energy Studies.

Hochman, G., & Zilberman, D. (2015). The political economy of OPEC. *Energy Economics*, 203-216.

Huntington, H. (2018, April). Measuring Oil Supply Disruptions: A Historical Perspective. *Energy Policy, 115*, 1-644.

Huppmann, & Holz. (2012). *Crude oil market power - Ashift in recent years?* The Energy Jurnal.

Huppmann, D. (2013). *Endogenous shifts in OPEC market power - A Stackelberg oligopoly with fringe.* Berlin, Germany: German Institut of Economic Research (DIW Berlin).

Huppmann, D. (2014). Endogeneous shifts in OPEC market power - A Stackelberg oligopoly with fringe. *IAEE International Conference.* New York.

IHS. (2013). *Tight oil brings the swing era back to the United States.*

International Energy Agency. (2014). *World Energy Outlook.*

International Energy Agency. (2015). *India Energy Outlook (World Energy Outlook Special Report).*

International Energy Agency. (2015). *World Energy Outlook.*

International Energy Agency. (2017). *World Energy Outlook.*

International Energy Agency, I. (2017). *World Energy Outlook 2017 (WEO 2017).*

International Monetary Fund. (2014). *Russian Federation Article IV Consultation.*

International Monetary Fund. (2017). *Russian Federation Article IV Consultation.*

International Monetary Fund. (2017). *Saudi Arabia 2017 Article IV.*

Kaufmann, R., & B., U. (2009). Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and future prices. *Energy Economics*, 550-558.

Kilian, L. (2016). The Impact of the Shale Oil Revolution on U.S. Oil and Gasoline Prices. *Review of Environmental Economics and Policy, 10*(2), 185–205.

Kleinberg, R., Paltsev, S., Ebinger, C., Hobbs, D., & Boersma, T. (2016). *Tight Oil Development Economics: Benchmarks, Breakeven Points, and Inelasticities.* MIT Center for Energy and Environmental Policy Research.

Kondrashov, A. (2015). *Taxation in the Russian oil sector: learning from global fiscal perspectives.* EY.

Krane, J., & Agerton, M. (2015). *OPEC imposes 'swing producer' role upon U.S. shale: Evidence and implications.* International Association for Energy Economics.

Mauldin, J. (2017, April 17). *2 Choke Points That Threaten Oil Trade Between The Persian Gulf And East Asia.* Retrieved from Forbes: https://www.forbes.com/sites/johnmauldin/2017/04/17/2-choke-points-that-threaten-oil-trade-between-persian-gulf-and-east-asia/2/#69983dd2055f

McKinsey&Company. (2017). *Building a new energy security architecture.*

Ministry of Energy of the Russian Federation. (2018). Retrieved from Statistics: https://minenergo.gov.ru/en/activity/statistic

Mostafa, M. (2017, December 5). *Iraq, Saudi Arabia sign 18 energy memorandums in Basra*. Retrieved from Iraqi News: https://www.iraqinews.com/business-iraqi-dinar/iraq-saudi-arabia-sign-18-energy-agreements/

Munro, D. (2016). *Past Imperfect, Future tense: Iran's Oil Industry Post-Sanctions.* Arab Gulf States Institute.

Okullo, S. J., & Reynès, F. (2016). Imperfect cartelization in OPEC. *Energy Economics*, 333-344.

OPEC. (2016). *World Oil Outlook 2040.*

OPEC. (2017). *World Oil Outlook 2040.*

Osborne, M. J. (2003). *An Introduction to Game Theory.* Oxford University Press.

Park, S. (2018, March 8). *How China Is About to Shake Up the Oil Futures Market.* Retrieved from Bloomberg Markets: https://www.bloomberg.com/news/articles/2018-03-08/how-china-is-about-to-shake-up-the-oil-futures-market-quicktake

Pioneer Natural Resources. (2017). *EIA Energy Conference.*

PwC. (2014). *On tax manoeuvre and other issues.*

PWC. (2017). *The World in 2050.*

Rashed, A. (2017, December 24). *Iraq invites bids to build new Kirkuk export pipeline*. Retrieved from Reuters: https://www.reuters.com/article/us-iraq-oil-pipeline/iraq-invites-bids-to-build-new-kirkuk-export-pipeline-idUSKBN1EI0BL

Rystad Energy. (2016, April 15). *True Economics*. Retrieved from Of Breakeven Price of Oil: Russia v ROW: http://trueeconomics.blogspot.com.es/2016/04/15416-of-breakeven-price-of-oil-russia.html

Salant, S. (1982). Imperfect competition in the international oil market: a computerized Nash-Cournot model. *Operations Research*, 252-280.

Salant, S. W. (1976). Exhaustible Resources and Industrial Structure: A Nash-Cournot Approach to the World Oil Market. *Journal of Political Economy*, 1079-1094.

Schmalensee, R. (1987). Competitive advantage and collusive optima. *International Journal of Industrial Organization*, 351-367.

Six, S. (2015). *Russia's Oil Export Strategy: Two Markets, Two Faces.* Clingendael International Energy Programme.

The Economist. (2014, December 6). Retrieved from Sheikhs v Shale: https://www.economist.com/news/leaders/21635472-economics-oil-have-changed-some-businesses-will-go-bust-market-will-be

The Economist. (2015, May 16). Retrieved from After OPEC: https://www.economist.com/news/business/21651267-american-shale-firms-are-now-oil-markets-swing-producers-after-opec

The Wall Street Journal. (2016, April 15). *The Wall Street Journal*. Retrieved from Barrel Breakdown: http://graphics.wsj.com/oil-barrel-breakdown/

Till, H. (2015). *When Has OPEC Spare Capacity Mattered for Oil Prices?* EDHEC Business School, EDHEC-Risk Institute. Premia Research LLC.

U.S. Energy Information Administration. (2012, September 26). Retrieved from Attributes of crude oil at U.S. refineries vary by region: https://www.eia.gov/todayinenergy/detail.php?id=8130

U.S. Energy Information Administration. (2015). *Country Analysis Brief: Iran.*

U.S. Energy Information Administration. (2016). *Country Analysis Brief: Iraq.*

U.S. Energy Information Administration. (2017). *Country Analysis Brief: Russia.*

U.S. Energy Information Administration. (2017). *Country Analysis Brief: Saudi Arabi.*

U.S. Energy Information Administration. (2017). *International Energy Outlook.*

U.S. Energy Information Administration. (2018, May 8). Retrieved from What drives crude oil prices: Supply OPEC: https://www.eia.gov/finance/markets/crudeoil/supply-opec.php

U.S. Energy Information Administration, E. (2017). *International Energy Outlook 2017 (IEO2017).*

U.S. Energy Information Administration, EIA. (2018). *Annual Energy Outlook 2018 (AEO2018).*

U.S. Energy Information Agency. (2018). *Oil and Gas Supply Module.*

United Nations. (2016). International Trade Statistics Yearbook . *1*(E.17.XVII.2 H).

Wood Mackenzie. (2014). *Oil prices: North American oil plays - breakeven analysis.*

Wood Mackenzie. (2014). *Wolfcamp Key Play Report.*

Wood Mackenzie. (2016). *Midland Wolfcamp Key Play Report.*