Literature Review on Oil Market Modeling and OPEC's Behavior

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Introduction

This literature review is divided into two parts (1) oil market modeling and (2) OPEC's behavior within the oil market. In the first part, we look at various oil market simulation and optimization models conducted to date with more emphasis on the optimization ones as we attempt building an oil market model of a similar nature. The second part of the review covers the literature on the efforts conducted to date on modeling, testing and analyzing OPEC's behavior within the oil market as such a market behavior is pivotal to the proposed model's mathematical formulation and solution.

1. Oil Market Simulation and Optimization Modeling

The interest in oil market modeling grew rapidly right after the Arab embargo and the quadrupling of the oil price in 1973. Stephen Powel (1990) mentions that by the late seventies there were more than thirty publicly available oil market models. Since then the oil market modeling efforts have slowed down significantly. In this part of the review, we briefly present the more popular oil market models that were mentioned in surveys and studies conducted to date and then elaborate more on the optimization models as they are more related to our proposed model.

The survey by Fischer et al (1975) is one of the early surveys conducted on oil market modeling. In their survey, they listed and criticized seven world oil models including Blitzer-Meeraus-Stoutjestdijk, Kalymon-I & II, Bohi-Russel, US-Federal Energy Administration, Kennedy, Levy and Nordhaus models. The models of Kalymon-I & II (1975), Bohi-Russel (1975) and Nordhaus (1973) were the only optimization models in their review. All these optimization models are discussed in greater details later in this part of the review. In a similar effort, Nazli Choukri (1979) compared the structures of twelve world oil market models. Four of these models were static simulation, four were dynamic simulation and four were optimization models including Kalymon I & II (1975), Nordhaus (1973), Bohi-Russell (1975) and Hnyilicza and Pindyck (1976).

In 1990, Stephen Powel noted that most existing oil market models are either inter-temporal optimization or behavioral simulation and listed three models as inter-temporal optimization models including ETA-MACRO (Manne, 1981), Salant (1981) known as Salant-ICF, and Marshalla and Nesbitt (1981) known as DFI-CEC. Eight years later, Baldwin and Prosser (1998) conducted a similar survey and followed the same classification as that of Powel (1990) and believed that most of the oil market models belong to either recursive simulation models or inter-temporal optimization models.

A more comprehensive and critical survey was conducted by Cremer and Salehi-Asfahani (1991) where they surveyed fifteen years worth of economic literature on oil market modeling. In the survey, they divided modeling efforts into informal (with no or minimal mathematical symbolism), simulation and theoretical models. They further subdivided the informal models into two basic types according to behavior emphasis: monopolistic (cartel or dominant firm) and competitive modeling (backward bending supply curve, property rights or supply shocks). Simulation models were further subdivided into three groups including reduced form, optimization and energy balance models. Under the simulation models and without classifying they included Kennedy (1974), Nordhaus (1973), Blitzer-Meeraus-Stautjesdijk (1975), Kalymon (1975), Ben-Shahar (1976), Cremer and Weitzman (1976), Hnyilicza and Pindyck (1976), Gately-Kyle-Fischer (1977), Pindyck (1978), Ezzati (1978), Houthakker and Kennedy (1978), Daly-Griffen-Steel (1982), MacAvoy (1982), and Salant (1982). At the end of their survey, they covered econometric studies conducted on the oil market with hypotheses related to market structure and functioning.

The survey was later updated by Salehi-Asfahani (1995) to include new studies on resource exhaustibility in an attempt to explain two issues: price staying above cost and new informal models (cartel, dominant firm and competitive). He also included some new empirical studies of alternative theories of the oil market. In the update, he noted that economists were still divided on the importance of the exhaustibility concept and on explaining high oil prices staying above costs.

In 1981, the Economic Modeling Forum (EMF) which is a group of energy experts, analysts, and policy makers conducted a study named EMF-6 on oil market modeling. In the study, they used ten oil market models to evaluate twelve scenarios on the future evolution of the oil market. The models list included Gately-Kyle-Fischer (New York University), IEES/OMS (U. S. Department of Energy), IPE (Massachusetts Institute of Technology), Salant-ICF (U.S. Federal Trade Commission/ICF Inc.), ETA-MACRO (Stanford University), WOIL (U. S. Department of Energy), Kennedy and Nehring (University of Texas/RAND corporation), OILTANK (Christian Michelson Institute), Opeconomics (British Petroleum Corp.), and OILMAR (Energy and Power Subcommittee, House of representative). [1,2] Out of these ten models studied, only three models including ETA-MACRO, Kennedy and Nehring, and Salant-ICF were optimization models.

The study was later updated in 1991 by the EMF to compare international oil supplies and demands alternatives and discuss how they affect the world's dependence on the oil imported from the Middle East. The study used eleven economic models of the world oil market (EMF-11) to simulate twelve scenarios including nine different predetermined price paths and three market clearing price scenarios. The models list included EIA/OMS (Energy Information Agency), IPE (Massachusetts Institute of Technology), ETA-MACRO (Stanford University), WOMS (Power Gen., UK), CERI (Canadian Energy Research Institute), HOMS (Oak Ridge National Lab.), FRB-Dallas (Federal Reserve Bank of Dallas), DFI-CEC (Decision Focus Inc.), BP America (British Petroleum), Gately (New York University) and Penn-BU (Boston University). Out of these eleven proprietary models, the ETA-MACRO and DFI-CEC were the only optimization models while the rest were simulation models. [3] The study found that dependence on the oil from the Middle East will grow in the future and can not be halted or reversed. It also found that oil demand would grow proportional to economic growth assuming prices do not change and that at the price of $19 OPEC members will be expected to increase their production capacities.

In 1992, Margaret Walls surveyed the literature on empirical oil and gas supply modeling and divided the supply modeling into three major groups including geological-engineering, econometric, and hybrid models. She further divided the geological-engineering models into play analysis (simulation) and discovery (process) models. Also, she suggested that the hybrid models containing features from econometric and discovery process models are the best path for future research.

[1] IEES/OMS stands for International Energy Evaluation System-Oil Market Simulation.
[2] IPE stands for International Petroleum Exchange.
[3] ETA-MACRO is also known also as Global-2100

Although the above mentioned surveys were relatively comprehensive, they missed a few oil market models that we believe are important. Again, in this part of the review we attempt to briefly present the more popular oil market models that some of which are optimization models and then elaborate on these optimization ones as they are more related to our proposed model. In the following few paragraphs, more oil market models will be presented and their objectives and findings will be investigated.

In 1974, Michael Kennedy developed a regional multi-commodity optimization model of the world oil market. The model was a static model and had four sectors including crude production, transportation, refining and consumption. It also had seven trading regions and assumed a monopolist behavior for OPEC. The model studied the consequences of OPEC's behavior through simulating the effects of export taxes. The model results showed that the high prices in 1973 are not likely to remain as large producers will have problems allocating reduced production.

Alsmiller and Horwedel (1985) developed a dynamic World Oil Market (WOM) model for the period 1980-2040 to be a part of the framework of another model, the Generalized Equilibrium Modeling System (GEMS) which is available from Decision Focus Incorporated. The GEMS system is basically a group of process sub-modules that are connected together and their equations are solved simultaneously to determine prices and quantities as functions of time. In the WOM, results were presented for two cases, when OPEC is treated as a Stackelberg cartel and when OPEC is treated as a competitive producer. Model results showed that full cooperation among OPEC member can cause a 25% increase in the oil price for 1990-2010.

In 1986, Lorentsen and Roland developed a traditional simultaneous econometric model for the world oil market for the Norwegian Ministry for Oil and Energy. Their model was used to trace crude oil price throughout the year 2000. Several scenarios were developed for different economic growth and conservation rates and for different alternative energy prices. A year later, Geroski, Ulph, and Ulph (1987) developed an empirical model for the world oil market where the pricing conduct is allowed to respond to several factors and can vary over time. Changes and variation in players' behavior appears to be playing an important role in price movements and tit-for-tat strategy (discipline and reward) was found consistent with the data.

To analyze oil market conditions and oil prices, Amano (1987) developed a small-scale econometric model for the oil market. The model simulation results anticipated wide price fluctuation if OPEC's core members (Saudi, Kuwait, UAE, Qatar, Libya) attempt to defend the cartel's market share. A year later, Baldwin and Prosser (1988) developed a recursive simulation model for the World Oil Market (WOM) and various strategies for OPEC were tested assuming that OPEC can set either the price or the output. Both oil consumers and non-OPEC producers were assumed to be price takers where consumers maximize their benefits and non-OPEC countries maximize their profits. OPEC on the other hand is assumed to set either price or quantity. Results showed that supply and demand could balance for a range of prices and OPEC output depending on what strategy OPEC adopts.

Another econometric model for the oil market was developed by Robert Kaufmann (1994) to integrate the effects of economics, geological, political and environmental changes into the LINK model.[4] The model by Kaufmann forecasted oil prices based on market condition and OPEC behavioral changes. In fact, the model results showed that OPEC can influence medium and long run prices through the rate they add capacities.

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[4] The "Project LINK is an econometric model of the world economy. It consists of macroeconomic models for 78 nations whose economic activity is connected by an international trade matrix." (Kaufmann, 1994, pp. 165)

In 2004, Dermot Gately developed a simulation model for the oil market in the form of an Excel spreadsheet to see whether OPEC's members would more than double their production capacity in two decades as the Department of Energy (DOE) expected. The model simulated OPEC's payoffs for two scenarios, a fast growth at which OPEC meets the DOE expectations, and a slower (the normal) capacity growth. The model results showed that it would be unlikely for OPEC to expand their capacity as there would not be so much difference in the payoff for OPEC between the two scenarios.

A year later, Dees et al. (2005) described a structural econometric model for the world oil market that can be used to forecast supply, demand and prices. It simulates two behaviors for OPEC, competitive and cooperative. In the model, oil prices are calculated using a "price rule" which takes into account both OPEC's behaviors and market conditions. The model concluded that OPEC's quota and capacity utilization effect oil prices significantly.

Also, Noureddine Krichene (2005) estimated a simultaneous equation model (SEM) for the world oil and natural gas markets for both short and long runs. The model was constructed to study the influence of the United States Nominal Effective Exchange Rate (NEER) and the US interest rate on the crude oil price and to estimate short and long run price and income elasticities. Results showed that demand for both crude oil and natural gas is price inelastic in the short run. It also showed a significant reduction in long run supply price elasticity, suggesting change from competitive to market power. Also, results showed that falling interest rate and depreciating NEER could result in a surge in the oil price.

As part of the DOE's National Energy Modeling System (NEMS) model, the International Energy Model (IEM) is a recursive model of world petroleum supply and demand by region. The IEM model calculates the average price of the imported crude and the international trade patterns of crude oil and refined products. It also consists of three components; World Oil Market (WOM), Petroleum Product Supply (PPS), and Oxygenates Supply (OS) models. The WOM is a new version of the Oil Market simulation model (OMS) developed in earlier years by the EIA and uses a recursive simulation approach. On the other hand, the PMM is a linear programming (LP) model that chooses the mix of the refining operations to meet the US domestic demand at the lowest cost (DOE, 2003).

Other known oil market models include the Oil Market Simulation Model (OMS) that is used by the Energy Information Administration (EIA) to forecast future world oil prices and OPEC oil production (Grillot, 1983) and OPEC's World Energy Model (OWEM) which is an econometric model developed by OPEC in the 1980's for medium to long-term oil and energy trends projections (OPEC Secretariat, 1994).

Out of the forty oil market models summarized above, only thirteen are found to be optimization models. For the rest of this part of the literature review, we will focus on these optimization models as they are of a similar nature to the model we propose. The list includes Kalymon I & II (1975), Cremer and Weitzman (1976), Hnyilicza and Pindyck (1978), Ben-Shahar (1976), Ezzati (1976), Bohi and Russel (1975), Nordhaus (1973), ETA-MACRO (Manne, 1981), Kennedy and Nehring, Salant-ICF (Salant, 1981), and DFI-CEC (Marshalla and Nesbitt, 1981), Deam (1974), and Kennedy (1974).

Seven of these optimization models were compared and contrasted for the price behavior of OPEC by Shawkat Hammoudeh (1979). They include models of Kalymon I & II, Cremer-Weitzman, Hnyilicza and Pindyck, Ben-Shahar, Ezzati and Bohi and Russel. Despite the fact that these models differ in the way they group suppliers, they all consider OPEC as either a residual supplier behaving like a monolith, a duopoly or a non-cohesive cartel.

As Hammoudeh shows, both Kalymon-I & II dynamic models determine optimal price trajectories that maximize the sum of producer's surplus (from sales to domestic and foreign consumers) and consumer's surplus (for domestic consumers) for a certain supplier or group of suppliers. The difference between the two models is that Kalymon-I model treats OPEC as a whole as a residual supplier (monolith) while Kalymon-II model has three ways for grouping the residual suppliers: 1) Saudi Arabia alone, 2) Saudi, Kuwait, Abu Dhabi and Neutral zone and 3) Saudi and Iran.

In fact, we find Kalymon-II to be the only oil market optimization model treats Saudi Arabia individually as a separate supplier and therefore maximizes the Saudi social welfare which is defined as the sum of producer's surplus (net revenues from oil sales to domestic and foreign consumers) and consumers' surplus (obtained by domestic buyers) is maximized. Despite the fact that Kalymon-II is the closest model to our proposed one, we find that our proposed model to be different than that of Kalymon-II in many ways. Such differences between our proposed model and Kalymon-II are covered in greater details, in our model paper, after describing our model.

Cremer-Weitzman model is a little different than that of Kalymon. It assumes that the Persian Gulf and North Africa producers act as a monolith while the rest of the world acts competitively. In addition, the model maximizes discounted profits for Persian Gulf and North Africa. The fourth model in the study is the Hnyilicza and Pindyck model which computes the optimal sum of discounted profits for OPEC under two cases. In the first one, OPEC acts like a unified cartel, while in the second OPEC acts as a two-part cartel: spenders (with high discount rate) and savers (with low discount rate).

In a similar approach, the Ben-Shahar model assumes OPEC is the residual producer (monolith) satisfying the difference between the world's demand and the non-OPEC supply and has three supplying groups including OPEC and non-OPEC, non-oil energy. The model solves for the optimal price path for OPEC for the years 1976 to 1990. The model maximizes the present value of the oil revenues in addition to the present value of reserves at the end of the mentioned time period.

The sixth model, the Ezzati model, employs the interactive cartel approach in which each country in OPEC optimizes to derive its production requirements and the sum of the requirements meets the residual demand. The optimization in the model determines various members' production requirements in order to maximize the present value of future consumptions. In the model, suppliers are divided into three groups: UAE-Qatar-Ecuador-Gabon, rest of OPEC and the non-OPEC. The model of Bohi and Russel is the last model in the study. The model has two objectives: to examine the stability of OPEC as a cartel and to determine the optimal price path for OPEC. Also, the supply side in the model is divided into two groups: USA and other producers whereby each member optimizes individually.

Also, as mentioned earlier, Choukri (1979) compared the model structures of twelve world oil market models out of which four were optimization models. The optimization models included Kalymon I & II (1975), Bohi and Russell (1975), Nordhaus (1973) and Hnyilicza and Pindyck (1978). Again, the Kalymon model selects the price trajectory that maximizes the total discounted benefits of oil production and export for OPEC while the model of Bohi and Russell uses optimizing techniques for dual objectives: to forecast the actual price for OPEC in the future and to evaluate the stability of OPEC without assuming their collusion. The Nordhaus dynamic model focuses on the whole energy market and minimizes discounted costs to meet the demand and assumes competitive supplier operating in a competitive market. The fourth model, the Hnyilicza and Pindyck model which treats OPEC as a duopoly and divides it into two groups: spenders and savers then solves for the optimal bargaining solution for the two-part cartel.

Also, three more optimization models including Mann's ETA-MACRO, Kennedy and Nehring, Salant-ICF were mentioned previously in the Economic Modeling Forum (EMF-6) study which was conducted in 1981. In short, the ETA-MACRO model maximizes the discounted utility of consumption for consumers. The Kennedy and Nehring model takes OPEC's production as exogenous and maximizes the discounted profits for non-OPEC while the Salant-ICF maximizes the discounted profits for both OPEC and Non-OPEC. The study was later updated in 1991 and used eleven economic models (EMF-11) out of which only 2 models were optimization models including the ETA-MACRO (Global 2100) and DFI-CEC models. As we mentioned, the ETA-MACRO model maximizes the discounted utility of consumption for non-OPEC while the DFI-CEC model (proprietary model from decision Focus Inc.) divides OPEC's supply into core and non-core (price takers) and maximizes both the discounted profits for all OPEC producers and for non-OPEC.

Another global oil market optimization model is that of R. I. Deam (1974) mentioned in the survey conducted by Hoffman and Wood (1976). In fact, the model is the Queen Mary College's optimization model but was published by Deam in 1974. The model defines the world patterns of crude oil and gas production and supply, refining, product demand and international oil and gas movements in a linear programming (LP) terms. The model has 25 regions, 52 types of crude including Arabian light and Arabian heavy, 22 refining centers, 6 types of tankers, 11 refining processes, and eight refining products. The model minimizes costs and solves for the optimal allocation and routing of crude oil and products between different centers. Also, the model solves for the required refining activities, tankers and production to meet projected demands for a certain year.[5] Although, this model is global in nature and looks at the same activities we address in our model, we find our proposed model to be much different than that of Deam in many ways. Such differences between our proposed model and that of Deam are covered in greater details after describing our model

Furthermore, Kennedy's (1974) World Oil Model (WOM) is another global oil market optimization model. The model is a multi-commodity, multi-region single period economic equilibrium model with four sub-models (crude production, transportation, refining, and consumption), four refined products and seven regions. The international market equilibrium was computed via solving a quadratic programming problem for maximum gross net economic benefit. Once solved, the model determined products consumptions, crude production, equilibrium prices, refining outputs, and crude flow trades.

As can be seen from the number of oil market optimization models built in the last few decades, the number has decreased significantly. Morrison (1987) believes that these models have decreased in popularity for three reasons. Firstly, they could not anticipate the 1979-80's price fall and that is why only one of the EMF-6 (1982) models is an optimization model (Salant-ICF model). Secondly, the complex decision-making process within OPEC is described by a simple revenue maximizing objective. Thirdly, they are built on a perfect foresight assumption. Morrison also suggests that simulation models were not good either as seven out of ten in EMF-6 (1982) depend entirely on a price rule, which states that price increases as OPEC exceeds its utilization target.

To summarize this part of the review, we presented more than forty oil market models out of which thirteen are optimization models. None of these optimization models answers our research question of maximizing Saudi Arabia's economic profits from producing various crude types. Therefore, we believe that attempting to optimize Arabia's production levels for different crude types, that is maximizing its economic profits subject to market constraints will be a genuine contribution to the literature of economics and eventually will have an impact the way a major oil supplier such as Saudi Arabia operates within the oil market. This concludes the first part of the literature review which addresses the issue of oil market modeling. Now, we move to the second part of the review covering the literature on OPEC's behavior within the oil market.

[5] The model is static and solves year by year from 1972 to 1977.

2. OPEC Behavior within the Oil Market

Since the crude oil price quadrupled in 1973-1974, numerous theoretical and empirical studies were undertaken by economic theorists to examine oil market structure and analyze the behavior of the OPEC. In this part of the literature review, we briefly cover studies and approaches conducted on modeling, testing and analyzing OPEC behavior in the last three decades as we believe that understating such a behavior is pivotal to any attempt to model the oil market for simulation and optimization purposes.

In fact, the economics literature on OPEC behavior has been surveyed and criticized in many studies. Dermot Gatley (1984) conducted one of the early such surveys and grouped OPEC behavior modeling approaches into either a dominant theoretical approach based on the wealth maximizing model or a simulation approach based on the target capacity utilization model. [6] Both of these models are discussed in greater detail later in this paper. In 1991, Cremer and Salehi-Isfahani conducted a more comprehensive survey covering the economic literature on oil market models for the years 1975-1990. In their survey, they divided OPEC models into two basic types: monopolistic models including carteland dominant firm models and competitive models including backward bending supply curve, property rights, and supply shocks models. [7, 8, 9, 10] Later the survey was updated by Salehi-Isfahani in 1995 to include some new informal models.

In 1998, Mabro surveyed and criticized the literature on OPEC behavior for the period 1960-1998 and grouped it into six categories including: history, previous literature surveys, economic modeling, political economy, policy proposals, and trade journals reporting. More surveys but rather shorter ones are included as part of the literature reviews in studies conducted by Moran (1982), Griffin (1985), Dahl and Yucel (1991), Al-Yousef (1998), Alhajji and Huettner (2000 a, b and c), Ramcharran (2001 and 2002), Smith (2005) and Kaufmann et al (2006).

Despite the large number of studies attempting to model OPEC behavior in the last three decades, the literature review we present in this paper reveals that the empirical literature as a whole remains inconclusive regarding OPEC behavior and that experts still have different views and opinions about what model represents the oil market structure and fits OPEC behavior. This backs up observations made by Gately (1984), Griffin and Teece (1982), Griffin (1985), Bockem (2004), and Smith (2005) where Gatley noted "it remains an open question how best to design a model of the behavior of OPEC". Twenty years later, Bockem still noted, "there exists neither an accepted theoretical model, nor an econometric model of this market. Moreover, there is a surprising dispute between economic theorists and energy economists whether OPEC can be regarded as a cartel or not." Similarly, Smith concluded that contributions "remain largely inconclusive regarding the behavior and impact of OPEC, despite the best efforts of those authors."

On an extreme note, Griffin and Teece believed that "OPEC behavior is not well understood, either by politicians, professional analysts, or the OPEC members themselves." Griffin tried explaining such a problem noting that "the standard practice to date has been to reach onto the shelf of economics models, to select one, to validate its choice by pointing to selected events not inconsistent with the model's

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[6] As Gately (1984) explains, the target capacity utilization model assumes that OPEC gropes towards a price path by implicitly following a target capacity utilization rule of thumb. For example, a target capacity utilization of 85% for OPEC means that the more OPEC capacity utilization is below 85%, the more they will produce and the lower the price will be and vice versa.

[7] The cartel model treats OPEC as a monolithic wealth-maximizing monopolist restricting production to control price.

[8] Supply curve is upward sloping at low prices but at higher prices, the supply curve bends backwards (becomes downward sloping) as the producers seeks a certain level of revenues.

[9] The property rights model suggests that price changes in early 1970s were due to the change in oil reserves ownerships from International Oil Companies (IOC's) to host countries. The model assumes that the IOC's had higher discount rates than host countries

[10] Supply interruptions as a result of conflicts and wars (referred to as political models in this paper)

predictions, and to proceed with some normative exercise." In fact, we believe that the study by Griffin (1985) is what triggered most of the recent empirical research on OPEC behavior. This study was later followed by a series of contributions by Geroski, Ulph and Ulph (1987), Jones (1990), Dahl and Yucel (1991), Polasky (1992), Gulen (1996), Alhajji and Huettner (2000), Spilimbergo (2001), Ramcharran (2002), and Smith (2005) all of which will be discussed in various sections of this review.

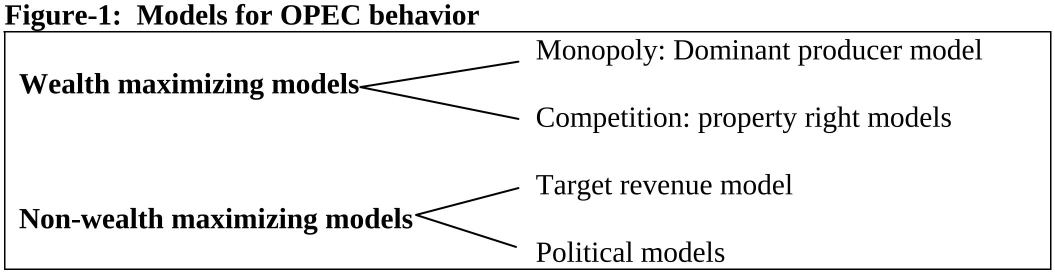
Even though the literature as a whole remains inconclusive about OPEC behavior, our review reveals that the literature on OPEC behavior can be divided into two main streams. The first one concludes that the oil market has some power and that OPEC, or part of it (OPEC core or Saudi Arabia), can be described by cartel behavior, dominant firm behavior, or target behavior. This stream assumes that OPEC members' objective is to maximize their profits by controlling production, individually or collusively, and thereby influencing market price. [11] We find that this stream constitutes most of the literature on OPEC behavior. The second stream considers the market to be more competitive and attempt to explain the price fluctuations through factors other than the collusion among OPEC members. A summary of our literature review on OPEC behavior within the oil market is included in the appendix.

The first part of this review covers the first stream literature which recognizes OPEC, OPEC core, or Saudi Arabia as a source of market power. We divide this part into three sections covering cartel behavior, dominant firm behavior, and target behavior models. The second part of the review covers the second stream considering the oil market to be more competitive and referring the price changes to reasons other than market power. This stream includes political, and property rights models.

A. MARKET POWER MODELS

Several studies and models tried to explain OPEC behavior in the oil market and concluded that there is some market power but did not suggest a specific model for OPEC behavior within the oil market. As an example, Griffin and Teece (1982) divided models to two categories: wealth maximizing models and non-wealth maximizing models. They further divided the wealth maximizing models into: monopoly models (dominant producer models) and competition models (property rights models) and divided the non-wealth maximizing models into: target revenue models and political models (Figure –1). [12] In their conclusion, they recognized the presence of economic rent and power over price and implicitly rejected property rights model but did not suggest any specific model for OPEC behavior believing that "OPEC behavior still elicits considerable puzzlement."

Figure-1: Models for OPEC behavior



Source: Griffin and Teece (1982)

Similarly, Geroski, Ulph and Ulph (1987) did not suggest any specific model for OPEC behavior either. In their study, they developed an empirical model in which the pricing conduct varies over time responding to endogenous and exogenous factors. They applied the model to the oil market and specified different

[11] The OPEC core includes the major producers within OPEC (Saudi Arabia, Kuwait, UAE, and Qatar). See Tourk (1977), Daly (1982), Alhajji and Huettner (2000) and Hansen and Lindholt (2004).
[12] Some countries desire a certain level of oil revenues and cut production if such a level is exceeded.

objective functions (weighted members' profit) for various OPEC members. Results rejected the "constant behavior" hypothesis showing that OPEC members play a tit-for-tat strategy, which is a combination of cooperative and competitive behaviors.

In 1991, Dahl and Yucel tested several hypotheses including: dynamic optimization, target revenue, cartel, competitive, and swing producers to model OPEC behavior. They assumed that in competitive dynamic optimization, user costs (price minus marginal cost) are equal in different periods while in the dynamic monopoly optimization the monopolist would equate the marginal revenue minus the marginal cost in different periods. Under the target revenue model, they examined both a strict and variant target revenue models where production was assumed a function of investment required by producers. For the swing producer hypotheses, the swing producers were expected to have larger proportionate changes in their productions than the total OPEC production. Results rejected both variants of the target revenue model and found no evidence of dynamic optimization or competitiveness for either the whole market or for the fringe. Also, they found no evidence suggesting strict cartel behavior or swing production. As a whole, the study suggested that loose coordination or duopoly is the closest description to OPEC behavior.

Besides hypothesis testing, other concepts including scarcity and resource exhaustibility were also used to demonstrate the existence market power in the oil market. In 1992, Polasky extended an oligopolistic model that was originally developed by Loury (1986) to predict production patterns for several exhaustible resource producers. [13] The model predictions were tested using oil industry data and found that empirical results were consistent with the "oil"ligopoly theory stating that producers with large reserves always had lower production costs and extracted smaller share of their reserves compared to producers with smaller reserves. Interestingly, results showed that OPEC producers do not appear to restrain production compared to non-OPEC and that the pattern of extraction in the oil market is inconsistent with either patterns predicted by competitive theory or dominant firm-competitive fringe theory.

A few more new concepts were used to test the existence of market power in the oil market. In an econometric model, Danielsen and Kim (1988) investigated the oil market power using "reserve sacrifice" ratio, "capacity sacrifice" ratio, and production variability concepts. [14, 15] The objective was to see if oil market behavior could be characterized as cooperative or competitive market. The sacrifice concept implies that "a country that is producing at relatively slow rate is sacrificing relatively more than other cartel members in their joint effort to maintain greater than competitive prices." The model used double logarithmic functional forms for reserve and capacity sacrifice ratios and annual cross-sectional data (1973-1985) for all OPEC countries except Qatar. Although results showed that the cooperation among OPEC countries is significant, Danielsen and Kim did not suggest any model to fit OPEC behavior.

In 2005, Smith briefly surveyed and criticized the literature on OPEC behavior and applied an econometric production-based approach to examine alternative hypothesis regarding the world oil market. He conducted two analyses: price analysis (assuming that market price greater than marginal cost indicates market power) and production decision analysis (testing responses to exogenous shocks for evidence of interdependence among firms). In the former case, the null hypothesis of perfect competition (price equals marginal cost) was tested against the alternative of a perfect cartel. In the latter case, the study tested four null hypotheses relating to OPEC and Saudi Arabia competitiveness. The model results showed that there is a significant cooperative effort among OPEC countries to restrict output and raise prices and that "OPEC is much more than a non-cooperative oligopoly, but less than a frictionless cartel". Statistical evidence was mixed on the role of Saudi and other core producers within OPEC including Saudi, Kuwait, and UAE.

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[13] International. Economic Review, 1986, Vol (27), pp. 285-301.
[14] Same definition as the reserves sacrifice but from the capacity prospective.
[15] The country utilizing a relatively smaller ratio of its reserves is thought to be sacrificing to maintain cartel price.

The latest empirical attempt to explain OPEC behavior was conducted by Kaufmann et al (2004 and 2006). They estimated a modified version of Griffin's (1985) econometric model to identify the economic and organizational variables influencing production decisions of the nations of OPEC. On one hand, the model results showed that quotas are significant determinant of OPEC production implying that OPEC can change prices and therefore has a market power. On the other hand, results showed that real prices effect production and this effect depends on OPEC capacity implying that OPEC acts competitively. Kaufmann et al concluded, "recognizing that OPEC does not fit neatly into a single behavioral model is not an intellectual retreat".

So far, none of the studies covered in this review have actually recognized a specific model for OPEC behavior within the oil market. In the next three sections, the review will cover studies explicitly specifying a power model for OPEC behavior and that will include cartel behavior, dominant firm behavior, and target behavior models.

A.1. Cartel Behavior Models

A more explicit description of OPEC behavior is the market-sharing cartel. The cartel behavior assumes that OPEC, as a whole or grouped into two or three-parts, functions as a monolithic wealth-maximizing monopolist. In fact, several studies and modeling efforts analyzed OPEC behavior and concluded that OPEC countries constrain their coordinated production to raise the price and therefore maximize their profits while non-OPEC producers act as competitive producers. Other studies used the assumption that OPEC behaves as a cartel to see this assumption effect on the oil market. In this section, we will review the former group of studies that concluded that OPEC is a "cartel".

One-Part Cartel Models

As mentioned earlier, it is Griffin (1985) that triggered most of the recent empirical research on OPEC behavior. In fact, Griffin was the first to systematically test OPEC market behavior across the existing competing hypothesis including cartel, competitive, target revenues, and property right models. For the cartel model, he specified a log-log function for individual OPEC members' production as a function of oil price, and other members' production. The intuition was that any correlation between individual members' production and the overall OPEC production indicates market-sharing behavior. We believe that even in competitive markets, the firms outputs may move parallel as they respond to market shocks and cost fluctuations that affect the whole market.

For the competitive case, a log-log function was specified for individual members' production as a function of price only. Any positive correlation indicates a positively sloped supply schedule. For the target revenue model, an investment parameter was added to the competitive case. For a specific investment need, any price increase implies an output decrease indicating target revenue behavior. Finally, to investigate the property rights model, members' production was regressed against the percentage of the government-controlled production in a log-log relation. Results showed that the partial market sharing cartel model could not be rejected for OPEC members and that the partial market sharing dominates the competitive market model. On the other hand, the competitive model could not be rejected for eleven non-OPEC members. An extension by Jones (1990) used the same formulation but covering period 1983-1988. Similar to Griffin's conclusion, Jones concluded that most OPEC members continued to behave like a "partial market sharing" while non-OPEC behaved more competitively.

Another attempt on testing OPEC behavior was conducted by Loderer in 1985 to see if the price changes for years 1974-1983 were caused by OPEC collusion. The tested null hypothesis was that OPEC is unable to affect the market price while the alternative was the otherwise. The investigation found no evidence that decisions reached in OPEC meeting had any effect on the oil market price between1974 and1980. Loderer noted that for the period 1974-1980, OPEC was nothing more than a “trade association” but the evidence on collusion was found in years between 1980 to1983.

An update to Griffin’s (1985) study was carried Youhanna (1994) adding lagged oil reserves and using quarterly data for 1983-1989. The study failed to alter Griffin’s conclusion that a partial market sharing cartel model dominates all other models (competitive, property right, and target revenues) in explaining OPEC behavior. In 1995, Al-Sultan formulated none possible profit maximizing behaviors models for OPEC out of which only two were estimated: a competitive model and a Nash-Cournot non-cooperative model. He found out that the Nash-Cournot non-cooperative model (OPEC as a Nash-Cournot with non-Opec as a fringe) can potentially explain the oil market better than the competitive.

Although most studies analyzing OPEC behavior used hypothesis testing, some studies used other concepts such as scarcity and cointegration analysis and causality testing to demonstrate the existence market power in the oil market. Adelman (1982, 1986, 1990 and 1993) attempted to study the relation between scarcity and oil market power. He argued that the stability of oil development costs indicates that oil is not getting scarce and that the existence of monopoly power, which is “OPEC”, slowed down resource depletion.[16] He suggested that higher costs producers (non-OPEC) sell all they can while low cost producers (OPEC) restrict supplies to increase pieces. He demonstrated that “the price increases since 1970 have nothing to do with scarcity, and must therefore be due to market power” and that OPEC members “have formed a loosely cooperating oligopoly- or a cartel.”

In 1996, Gulen used cointegration analysis and causality testing to determine whether OPEC is a cartel with members coordinating their output and cutting production to increase the oil prices. In fact, the study repeated the first test conducted by Dahl and Yucel (1991) but with a longer time period (1965-1993). The idea tested was that if OPEC was an effective cartel, there would be a long-term relationship between its members’ productions and the cartel’s total production. When this idea was tested using cointegration analysis, only three members (none of which was a major producer) were founded to be moving together with the cartels’ production. Still, results still showed evidence of output coordination and suggested that OPEC acted like a cartel in the 1980’s (1982-1993) to maintain prices. We believe that the same criticism that was mentioned for Griffin’s model, that even in competitive markets the firms outputs may move parallel, applies here too.

Using a relatively new technique, Bockem (2004) derived a market description for the oil market using the ideas of New Empirical Industrial Organization (NEIO). In the NEIO literature, both demand and supply functions are jointly estimated without assuming any special case for the market model. These joint estimates are used to derive a “market power parameter” indicating a competitive market when such a market power parameter value is zero.[17] He concluded that the crude oil market is best described as a price leader model where OPEC appears to be the leader and all non-OPEC countries are regarded as price takers.

Few other studies simply assumed that OPEC is a cartel. These include Salant (1976), Cremer and Weitzman (1976), Pindyck (1979), Newbery (1981), Morrison (1987), Greene (1991), Griffin (1992), Berg et al (1996), Dahl and Celta (2000), and Byzalov (2002).

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[16] As oil reserves would have been depleted under competition

[17] This market power parameter or indicator is “the degree of inclusion of the slope of the demand function in a generalized supply relation.” See Bockem (2004).

Two-Part and Three-Part Cartels Models

A smaller group of literature analyzed OPEC market behavior and concluded that OPEC behaves as a two-part or three-part cartel coordinating and restraining production to alter prices and therefore achieve maximum profits. An early effort by Hnyilicza and Pindyck (1976) examined pricing policies for OPEC assuming that the cartel is composed of two blocks: spenders and savers. They described spenders as countries with large cash needs and savers as countries with small need for cash. Their results showed that the optimal path depends on whether the output shares are fixed or subject to change. If output shares are fixed then the optimal price path is the optimal monopoly price path, but if not, then the optimal paths depend on the relative bargaining power of savers and spenders. Using a similar approach and classification, Aperjis (1982) reached the same conclusion as Hnyilicza and Pindyck.

In 1977, Tourk divided OPEC into two blocs, one with large reserves and small population (Saudi, UAE, Kuwait and Qatar) and the other one with large population but small reserves (the rest of OPEC). He assumed different discount rates for both blocs whereby the former bloc with limited absorption capacity has a lower discount rate than the latter bloc. The main objective for blocs is to maximize the net present value of their future profits. He concludes that his model "seems to explain the ability of OPEC to control supplies."

For the three-part cartel model, studies by Eckbo (1976), Houthakker (1979), Noreenge (1978), and Griffin and Steele (1986) concluded that OPEC behavior could be explained by a three-part cartel including core members, price maximizing members and quantity maximizing members.[18] In addition, a dynamic simulation model by Daly et al. (1982) used the assumption that OPEC behaves like a three-part cartel to estimate non-communist world oil demand, non-OPEC supply, and OPEC supply. For OPEC supply, they divided OPEC into: a cartel core including Saudi Arabia, Kuwait, UAE, Qatar, and Libya; price maximizers including Iran, Algeria, and Venezuela; and output maximizers including the rest of OPEC-13 and then compared OPEC cartel behavior pre and post Iranian revolution.[19] They concluded that a price above $32 is not sustainable and will encourage conservation and induce synthetic fuels.[20] They also suggested that long run prices are more likely to be between $15 and $32.

A.2. Dominant Firm Behavior Models

Saudi Arabia as a Dominant Firm Models

A large portion of the literature on OPEC behavior used the dominant firm behavior to explain the role that OPEC plays in the oil market. Several empirical models and studies suggested that OPEC ultimate monopoly power is indeed invested in the largest producer with most of the access capacity, Saudi Arabia, while other OPEC and non-OPEC producers act more like a competitive fringe. Others suggested that OPEC power is more likely to be concentrated in what is identified as OPEC core including Saudi Arabia, Kuwait, UAE, and Qatar while the remaining OPEC and non-OPEC producers act more like a fringe.

Mabro (1975) noting "OPEC is Saudi Arabia" and Erickson (1980) are some of the early studies concluding that Saudi Arabia is a dominant producer within OPEC and that remaining OPEC and non-OPEC members are a competitive fringe. Similarly, Plaut (1981) notes "OPEC does not follow the cartel

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[18] Cartel core: Saudi Arabia, Kuwait, Qatar, UAE and Libya. Price Maximizers: Iran, Algeria,and Venezuela. Output Maximizers: Iraq, Nigeria, and Indonesia. Griffin and Steele (1986) Gately (1984).

[19] Now OPEC has 12 members after Ecuador left on 1992, Gabon left on 1995 and Angola joined in 2007.

[20] The world oil price increased from $15 to 432 during Iranian revolution in 1978-79.

pattern of restricting supply and allocating output. It behaves more like an oligopoly with Saudi Arabia as a price leader and largest producer". Even Adelman (1982, 1986, 1990 and 1993), who is more of the opinion that OPEC is best described as a "cartel", noted in 1995 that "Saudis have acted as what they are: the leading firm in the world oil market."[21] In addition, Griffin and Teece (1982) described Saudi Arabia as the swing producer or the "balance wheel" absorbing fluctuations to maintain a monopoly price. They believed that Saudi chooses the price path that maximizes its wealth taking the fringe reaction into account.

In 1994, Griffin and Nielson found evidence that after the price collapse in 1985-1986, Saudi Arabia played a significant role in disciplining and rewarding the cartel members through its tit-for-tat strategy. Testing the Saudi role was also conducted by Al-Yousef (1998) where she tested two economics models for the Saudi behavior in the oil market for the period 1976-1996. The first model was a swing producer model covering the period 1975-1986 while the second one was a market sharing model covering 1987-1996. The objective function for Saudi in the first model was to minimize the difference between the oil spot price and OPEC official price while the objective function for the second model was to maximize Saudi revenues. Indeed, the modeling results were positive showing that Saudi Arabia acted as a swing producer (adjusting output in order to stabilize prices) in the period 1976-1986 and as a market-sharing producer (concerned more about its share and revenues) for the period 1978-1996.

In an attempt to test OPEC behavior, Alhajji and Huettner (2000a) investigated the existence of certain economic literature characteristics in six different commodity cartels including OPEC. These characteristics included quota system, monitoring system, punishment mechanism, cartel authority, side payments, large market share, and additional differences. They found that none of these "economic literature characteristics" fit OPEC and concluded that neither statistical tests nor economic theory supported modeling OPEC as a cartel or as a competitive model and that OPEC is mainly Saudi Arabia, the dominant producer, and some other sub-groups.

In another effort, Alhajji and Huettner (2000b) used a simultaneous systems model to investigate the existence of a dominant producer in the oil market from 1973 to 1994.[22] Their study covered three possible market behaviors including: dominant firm, Cournot, and competitive behavior. The model results rejected all three models and showed that neither OPEC nor the OPEC core (Saudi Arabia, Kuwait, UAE, Qatar) fits the dominant firm model but Saudi Arabia when taken alone acts as a dominant producer.

At the end of the study, Alhajji and Huettner gave seven reasons why Saudi would fit this dominant firm model which includes: 1) most non-OPEC produce at their capacity at all times, 2) none of OPEC producers (except Saudi) reduces production unless forced to do so, 3) only Saudi Arabia has history of mothballing production capacity, 4) only Saudi production is negatively correlated with the rest of OPEC, 5) the model has the highest R-square value even when corrected for autocorrelation, 6) OPEC decided in 1983, when the quota was assigned, that Saudi will be the swing producer, and 7) Saudi is the only OPEC country that operate in the elastic part of the demand curve. The seventh reason is criticized by Smith (2005) noting that "it is quite easy to envision market conditions under which a perfectly competitive industry comes to equilibrium at a point on the upper half of the demand curve (i.e., where the demand is elastic)."

A year later, Spilimbergo (2001) reached the same results when he investigated the dynamic competitive and collusive behavior among OPEC members between 1983 and 1991. When the hypothesis of a cartel sharing agreements was tested against the alternative "competitive" behavior hypothesis, it was rejected at a very high confidence level except for Saudi Arabia. Here, it is worth mentioning that Smith (2005)

[21] In his book "The genie out of the Bottle", page 81. See references.
[22] Most of the literature use single equations.

believed that Spilimbergo's results should be inconclusive as results are not strong enough to distinguish between the null and its alternative.

The last study we include in the dominant firm literature is a computable general equilibrium (CGE) study by De Santis (2003). He constructed a CGE for Saudi Arabia to study the effect of oil supply and demand shocks on oil price and outputs under two scenarios: production quota and dominant firm model. The model results supported De Santis prior believes that short run price fluctuations are due to OPEC quota agreements while in the long run Saudi Arabia acts like a dominant firm. The model results also indicated that Saudi Arabia does not have incentives to intervene when the market is in equilibrium, has the incentive in negative demand shocks, and has the disincentive in positive demand shocks. In addition, results showed that to bring prices down, the Organization for Economic Cooperation and Development (OECD) should not apply taxes bur rather should apply policies that can increase price elasticity of demand.

A Core Group as a Dominant Firm Model

The second part of the dominant firm behavior literature suggests that OPEC core members including Saudi Arabia, Kuwait, UAE, and Qatar is where OPEC power is concentrated while the remaining OPEC and non-OPEC producers act as a competitive fringe. Such literature includes studies by Singer (1983), Dahl and Yucel (1990), Mabro (1991), and Hansen and Lindholt (2004).

The study by Singer (1983) concluded that a quasi-monopoly model, which is a dominant firm model, is the best model to fit the oil price between 1974 and 1978. In his study, Singer believed that Saudi Arabia and smaller Arab producers dominate the residual demand and get to determine the worlds' oil price through adjusting their production levels. Similarly, Dahl and Yucel recognized the power of OPEC core members and concluded that "OPEC, rather than being a weak cartel, consists of a non-competitive core of swing producers" including Kuwait, Nigeria, Saudi Arabia, and Venezuela.[23]

In addition, Mabro argued "the core producers can set either a supply plan or more straightforwardly a price." however, "there exist some political constraints on OPEC-core producers when setting the oil price." Here, it is worth mentioning again that in 1975 Mabro was more of the opinion that, "OPEC is Saudi Arabia."[24]

In a more recent effort to test OPEC core behavior, Hansen and Lindholt applied a dynamic econometric model on the world market for the period 1973-2001 to test whether the behavior of OPEC as a whole or a sub-group of OPEC would fit the behavior of a dominant producer. The model results showed that producers outside OPEC are best described as competitive producers (price takers), while OPEC members are not. Results also showed that OPEC as a whole cannot be looked at as a dominant producer and that neither Saudi Arabia nor OPEC core (Saudi, Kuwait, Qatar, UAE) can be looked as a dominant producer before 1994. However, the dominant producer behavior fits the OPEC core very well between 1994 and 2001.

We believe that treating Saudi Arabia as a dominant firm and others oil producers as a competitive fringe is the most compelling modeling approach given the excess production capacity and the large reserves Saudi possesses. Therefore, this market behavior describing the Saudi role is the one we chose for our proposed model.

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[23] The study has been mentioned with more details earlier in this review.
[24] That was mentioned in the section discussing Saudi Arabia as a dominant firm.

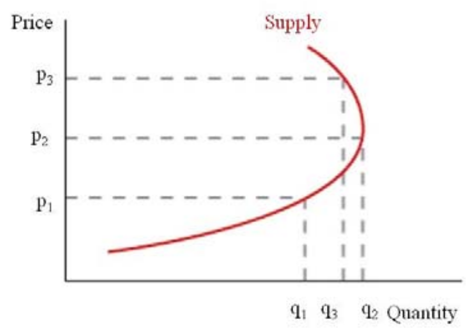
A.3. Target Behavior Models

The third part of the literature that recognizes OPEC market power covers the target behavior modeling. It includes target revenue models, target capacity models, and target price models. The target revenue models assume that OPEC members seek certain revenue levels to meet individual governments internal budgetary obligations. The target capacity models believe that OPEC production oscillates around a certain capacity utilization level and that OPEC members adjust their production levels accordingly. The third type of target behavior modeling, the target price models, assumes that OPEC adjusts production to maintain the oil price at a certain level or within a certain price band.

Target Revenue Models

The target revenues models are the most prominent among the target behavior models. The literature on the target revenue models either assumes or concludes that each country within OPEC faces a backward-bending supply curve meaning that cut backs occur if oil prices rise above a specific level so countries satisfy certain, or "fixed" to be exact, target revenues for their internal investment use (Figure-02). In the figure, any increase in the price above P_2 would result in a cutback in production, as the producer desires a fixed level of revenues.

Figure-02: Backward-bending supply curve



In 1982, Adelman argued that OPEC countries cutback production to raise prices and get more money for their oil and that they have less pressure to cheat as higher oil prices make them better financially. Despite the fact that he noted, "a loosely cooperating oligopoly-or cartel" behavior for OPEC, he concluded that the "backward-bending supply curve" could explain OPEC behavior in the short run.

Similarly, but more explicitly, Teece (1982) described OPEC behavior as a target revenue model. He indicated that it is "inappropriate" to model OPEC as a wealth maximizing classical cartel and that some important OPEC members set their oil production with reference to certain "budgetary requirements and internal and external political constraints." He suggested that members of OPEC shut-in production capacity if their export receipts and foreign earnings meet certain expenditure requirements and increase production if otherwise and this relationship between the price and output is best described by a backward-bending supply curve.

A modification to Griffin's (1985) target revenue model, described earlier, was conducted by Salehi-Isfahani (1987) where he replaced the current oil price in Griffin's model by the long-term price, assumed individual OPEC member's production as a function of price and investment needs and re-estimated the model. The conclusion supported the target revenue model for OPEC.

In 2000, Alhajji and Huettner briefly reviewed the literature describing OPEC behavior as a target revenue model and used four econometric models (1 static and 3 dynamic) to examine the target revenue model for individual OPEC members that don't coordinate production with Saudi Arabia. In the static model, individual production was assumed to be a function of oil price and individual country's investment needs. For the dynamic models, the first one assumed production as a function of price, investment needs and lagged production. The second assumed that current production depends on lagged prices, lagged investment needs and lagged production while the third assumed current production to be a function of lagged prices and lagged investment needs.

The model results showed that investments and budgetary needs do not affect oil production in free-market economies, but do in centrally planned, isolated and oil dependant economies. Only the African OPEC countries were found to be fitting the backward-bending supply curve.[25] The strict proportional version of the target revenue model fits only one country (Libya), the non-proportional version fits Libya and Nigeria, while the weak version fits Libya, Nigeria. Mexico, Egypt, USSR, China, and Malaysia.[26]

Another modification to Griffin's (1985) target revenue model, described earlier, was conducted by Ramcharran (2001) to test the target revenue theory for OPEC and to estimate supply elasticities for OPEC and non-OPEC countries using 1973-2000 data. Similar to Alhajji and Huettner (2000), results were more supportive of the "partial" version of the revenue target model more than of the "strict" version model. A year later, Ramcharran (2002) repeated the same exercise using 1973-1997 data. Again, the results partially supported the target revenue hypothesis, rejected the competitive hypothesis for all OPEC countries and supported the competitive hypothesis for non-OPEC.

Target Capacity Models

The target capacity utilization assumption implies that OPEC sets and attempts to maintain a certain capacity utilization target. If this limit or target is exceeded then oil price will increase as OPEC reduces the production to match their predetermine capacity utilization level. For example, a target capacity utilization of 80% implies that if OPEC capacity utilization rate exceeds 80%, then higher demand will stimulate OPEC price increases. The higher price will then reduce demand and eventually reduces OPEC capacity utilization, and vice versa.

In an attempt to see whether the target capacity utilization rule satisfies OPEC economic objectives, Suranovic (1993) used the United States Energy Information Administration's Oil Market Simulation model called OMS92. The OMS92 model is an annual model projecting the global oil market conditions to the year 2010. The model has seven regions including USA, Canada, Japan, Europe, formerly Centrally Planned Economies (CPEs), OPEC, and others.

In the OMS92, the demand by OPEC, CPEs, and the US government for strategic petroleum reserves are considered exogenous while the demand for the remaining five regions is determined using geometric Koyck-lag demand function estimated using reduced form equations with coefficients derived from large-scale EIA and non-EIA macroeconomic models. Similarly, the supply from the CPEs is considered exogenous while supply from other regions is determined using geometric Koyck-lag supply function estimated using reduced form equations with coefficients derived from large-scale macroeconomic models. The model results showed that "the target capacity utilization rule comes closest to optimum either when there are no lags" in supply and demand "or when OPEC optimizes subject to a minimum revenues constraint". In fact, this study by Suranovic is the only study we found on testing the target capacity

[25] Algeria, Libya, and Nigeria
[26] A unit increase in investment needs results in a unit increase in production.

model for OPEC. We believe that the reason is that this model is not quite popular in modeling OPEC behavior.

Target Price Models

A few more studies either assume or conclude that OPEC targets a certain price level or a price band and then defends it through production adjustments. The three studies reviewed in this part of the literature involved Shawkat Hammoudeh either as a stand alone or as a joint author.

In 1995, Hammoudeh and Medan incorporated market expectations and inventories shocks and expectations in examining OPEC oil pricing mechanism and behavior. They applied the literature on target zone and speculative attack to investigate oil price dynamics in two models: two-sided target zone model and asymmetric tolerance zone model.[27,28] Their modeling results showed that OPEC credibility to intervene is directly related to oil price sensitivity to changes in both the output and price expectations.

Later on, Hammoudeh (1997) conducted a similar study and discussed the price solutions for single and multi-target zone models. He concluded that under normal conditions, market participants form expectations that cause price fluctuation in anticipation of OPEC interventions while under other circumstances OPEC shifts the target zone when it fails to hold the line with previous targets. Furthermore, Tang and Hammoudeh (2002) tested the same model and investigated the oil price behavior for the period 1988-1999.[29] They found that OPEC tried to maintain a weak target zone regime for the oil price, that the oil price is affected by both OPEC behavior and the market's expectation of OPEC behavior, and they also suggested that OPEC became more explicit in adopting a target price zone model.

B. OTHER MODELS

The second part of this literature review on OPEC behavior covers the second and the smaller stream suggesting that the oil market to be more competitive and referring the price changes to reasons other than market power. This stream includes political and property rights models.

B.1. Political Models

Although empirical studies by Griffen (1985), Jones (1990), Dahl and Yucel (1991), and Gulen (1996) rejected the hypothesis that OPEC behavior is consistent with that of a competitive firm, several studies including Ezzati (1976, 1978), Moran (1981), MacAvoy (1982), and Verleger (1987) suggested that the oil market is competitive and that significant oil price changes are due to factors not related to market power.

Early studies by Ezzati (1976) concluded that the price increases were due to political factors and that the price was sustained at high levels due to OPEC limited absorptive capacity. In 1981, Moran tried explaining the behavior using a political model. He critically reviewed past attempts to model OPEC behaviors models based on maximizing revenues and suggested that a political decision rule was the driver of the Saudi energy policy. He claimed that the data between 1973 and 1980 suggested that not a single economic model is consistent with the Saudi behavior except for that of the political decision rule. He argued that the Saudi behavior can be better explained by "an operational code of advancing Saudi political priorities while minimizing hostile external and internal pressures upon the kingdom" rather than any other model.

[27] OPEC establishes a band for the market price (with an upper and lower limits) around the target price.
[28] OPEC places a tolerance zone below the target price.
[29] OPEC had a target price $21 in 1986.

Similarly, MacAvoy (1982) suggested that the oil price can be explained by a model focusing on supply and demand, “market fundamentals”, rather than cartel behavior and that the price increases in 1973-74 and 1979-80 were due to shortages and cut backs that were mainly due to political conditions and accidents (e.g. Arab embargo and Iraq-Iran revolution and war) rather than any “cartel collective supply control”. Also, Verleger (1987) followed the same path and explained the oil market behavior using a competitive model rather than a market power one.

B.2. Property Right Models

Another part of the literature suggesting the oil market to be more competitive tries to explain the market power using property rights models. These models conclude that the producing governments have much lower discount rates than international oil companies and that the lower the discount rate, the lower the preferred production. This implies that producing governments value future productions more than the international oil companies and therefore decide to produce reserves in future rather than now.

Similar to Mead (1979) and Odel and Rosing (1983), Johany (1979 and 1980) argued that the price hike in 1974 was mainly a result of property rights changes where individual oil producers, rather than international oil companies, started determining their oil production rates at different market prices. He argued that countries have lower discount rate than companies because they have longer production horizon while companies have limited concessionaries time. The idea is that different discount rates, depending on property right, lead to different production rates and hence different prices.

To summarize, this part of the review reveals that despite the large number of studies attempting to model OPEC behavior (Table-1), the empirical literature as a whole remains inconclusive regarding OPEC behavior and that experts still have different views and opinions about what model represents the oil market structure and fits OPEC behavior. In general, the literature on OPEC behavior can be divided into two main streams. The first and the more popular one concludes that the oil market has some sort of market power and that OPEC or part of it, OPEC-core or Saudi Arabia, can be described by cartel behavior, dominant firm behavior, or target behavior. This stream assumes that OPEC members seek to maximize their profits by controlling production, individually or collusively, and thereby influencing market price. We believe that treating Saudi as a dominant firm and others as competitive fringe is the most compelling model. The second stream considers the market to be more competitive and attempt to explain the price fluctuations through factors other than the collusion among OPEC members.

Table-1: A summary of the literature review on OPEC behavior

			Model/Study	Finding
Market Power Models Other Market Power models	A-Cartel Behavior	Indicating Collusive Behavior (Some Market Power Exists)	Griffin and Teece (1982)	Recognized the presence of economic rent and power over price
			Geroski, Ulph and Ulph (1987)	Rejected the “constant behavior” hypothesis
			Dahl and Yucel (1991)	OPEC behavior can be described as a loose coordination or duopoly.
			Polasky (1992)	Pattern of extraction in the oil market is inconsistent with either patterns predicted by competitive theory or dominant firm-competitive fringe theory.
			Danielsen and Kim (1998)	Cooperation among OPEC countries is significant.
			Smith (2005)	OPEC is much more than a non-cooperative oligopoly, but less than a frictionless cartel
		A1-One Cartel Models	Griffin (1985)	Partial market sharing cartel model could not be rejected for OPEC
			Jones (1990)	Most OPEC members continued to behave like a “partial market sharing” while non-OPEC behaved more competitively.
			Loderer (1985)	Found evidence that OPEC members colluded in years 1980-1983.
			Youhanna (1994)	Partial market sharing cartel model dominates all other models
			Al-Sultan (1995)	Nash-Cournot non-cooperative model (OPEC as a Nash-Cournot versus a fringe) can potentially explains the oil market more than the competitive.
			Gulen (1996)	Evidence of output coordination and suggested that OPEC acted like a cartel in the 1980’s (1982-1993)
			Molchanov (2003)	OPEC behavior is consistent with cartel theory
			Bockem (2004)	Crude oil market is best describes as a price leader model where OPEC appears to be the leader and all non-OPEC are regarded as price takers.
		A2-Two and Three-Part Cartels	Tourk (1977)	Divided OPEC into two blocs as they may have different discount rates
			Hnyilicza and Pindyck (1976)	The “cartel”, OPEC, is composed of two blocks: spenders and savers.
			Aperjis (1982)	Concluded that OPEC behavior could be explained by a two-part cartel including spenders and savers
			Eckbo (1976), Houthakker (1979), Noreenge (1978), and Griffin and Steele (1986)	Three-part cartel including core members, price maximizing members and quantity maximizing members.
	B-Dominant Firm	B1-Saudi Arabia as Dominant Firm	Mabro (1975), Erickson (1980)	Saudi Arabia is a dominant producer
			Plaut (1981)	OPEC behaves more like an oligopoly with Saudi Arabia as a price leader and largest producer.
			Singer (1983)	Saudi Arabia and smaller Arab producers produce the residual demand and determine the worlds’ oil price
			Adelman (1986, 1990, 1993 and 1995)	Identified OPEC as the market power and price increases have nothing to do with scarcity. Saudis have acted as what they are: the leading firm in the world oil market
			Griffin and Nielson (1994)	Saudi Arabia played a significant role in disciplining and rewarding the cartel members through its tit-for-tat strategy.
			Al-Yousef (1998)	Saudi Arabia acted as a swing producer in the period 1976-1986 and like a market sharing producer for the period 1978-1995.
			Alhajji and Huettner (2000)	OPEC is mainly Saudi Arabia, the dominant producer, and some other sub-groups and Saudi alone acts like a dominant producer.
			Spilimbergo (2001)	Reached the same results

			De Santis (2003)	Short run price fluctuations are due to OPEC quota agreements while in the long run Saudi Arabia acts like a dominant firm.
		B2- Core Group as a Dominant Firm	Delay et al (1982)	Grouped OPEC into three groups: Cartel Core (Saudi/Kuwait/UAE/Qatar/Libya), Price Maximizers (Iran, Algeria, Venezuela), and Output Maximizers (rest of OPEC-13)
			Dahl and Yucel (1990)	OPEC, rather than being a weak cartel, consists of a non-competitive core of swing producers
			Mabro (1991)	The core producers can set either a supply plan or more straightforwardly a price
			Hansen and Lindholt (2004)	Dominant producer behavior fits core-OPEC very well after 1994.
	C-Target Behavior Models	C1-Target Revenue Models	Adelman (1982)	Backward bending supply curve could explain OPEC behavior in the short run.
			Teece (1982)	OPEC will shut-in or increase production capacity to meet certain export receipts and foreign earnings
			Salehi-Isfahani (1987)	Conclusion supported the target revenue model
			Tussing (1989)	OPEC can control the world oil market via restricting supplies to increase prices and achieve certain revenues.
			Alhajji and Huettner (2000)	African OPEC countries (Algeria, Libya, and Nigeria) were found to be fitting the backward-bending supply curve.
			Ramcharran (2001 and 2002)	Not supportive of the hypothesis of a strict version of the revenue target model (but partially supporting)
		C2-Target Capacity Models	Suranovic (1993)	"The TCU rule comes closest to optimum either when there are no lags" in supply and demand "or when OPEC optimizes subject to a minimum revenues constraint".
		C3-Target Price Models	Hammoudeh and Medan (1995)	OPEC credibility to intervene is directly related to oil price sensitivity to the change in the output and expectations.
			Hammoudeh (1997)	Market participants form expectations about OPEC actions and that cause price fluctuation while under other circumstances; OPEC shifts the target zone when it can't hold in line with previous targets.
			Tang and Hammoudeh (2002)	OPEC becomes more explicit in adopting a target price zone model.
Other Models	Political Models		MacAvoy (1982)	Oil price increase in 1973-74 and 1979-80 were due to shortages and cut backs that were due to political conditions and accidents
			Vergeler (1987)	Followed the same path and explained the oil market behavior using a competitive model
			Moran (1981)	Saudi behavior can be better explained by "an operational code of advancing Saudi political priorities while minimizing hostile external and internal pressures upon the kingdom
			Ezzati (1976 and 1978)	Price increase was due to political factors and sustained because OPEC members have limited absorptive capacity.
	Property Right Models		Johany (1979 and 1980)	Argued that the price hike in 1974 was a result of property rights changes (national oil companies have lower effective discount rate than oil companies)
			Mead (1979) and Odel and Rosing (1983)	Believed that the price increased in 1973 was mainly due to the property rights changes.

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