THE DOMINANT ROLE OF SAUDI ARABIA IN THE OIL MARKET FROM 1997-2010

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Abstract

With the world's largest crude oil production capacity, Saudi Arabia can increase its oil production during both demand surges and supply shocks. Oil is important to the Saudi Arabian economy. Hence, to preserve the importance of oil in the global energy mix, Saudi Arabia attempted to moderate the price of oil and thereby continue the growth of demand**.** Because OPEC's spare capacity declined and non-OPEC supply experienced low growth throughout the nineties, Saudi Arabia now has more control of the oil market. This paper attempts to analyze the role of Saudi Arabia in the oil market by considering the swing producer model for the period from 1997-2010. Using the bounds testing approach to co-integration within the Autoregressive Distributed Lag (ARDL) framework allows us to utilize a mixture of variables that are integrated to different degrees. The resulting analysis shows that Saudi Arabia acted as a swing producer in the global oil market from January 1997 to December 2010.

Key words: Saudi Arabia, Swing producer. Oil market. ARDL. Co-integration. Price of oil. Oil supply. Oil Policy. OPEC. Producer model.

1.Introduction:

Since global oil prices experienced a four-fold increase in 1973, analyzing the international oil market has been a major concern for economists. In the following decades, economic analysts have sought to understand the major players and model both their behavior and other related issues. The Organization of Petroleum Exporting Countries (OPEC) has also played a significant role on the oil market. Saudi Arabia, the largest supplier in OPEC, has the highest share of global oil exports and the highest share of OPEC's oil production (29 percent of OPEC in 2009), as the country produces an average of 12 percent of the world's total oil production. In addition, Saudi Arabia has the world's highest total of proven oil reserves at 262.5 billion barrels, which amounts to approximately one-fifth of the world's proven oil reserves. The country's current reserve to production ratio is 75 years. With an average production rate of 9.8 MB/d in 2009, it also has the highest share of global oil production after Russia. Saudi Arabia maintains the world's largest crude oil production capacity, which was estimated to be over 12 million bbl/d at the end of 2010. Over 2 million bbl/d of capacity was added in 2009 with the addition of the oil fields in Khurais and Shaybah. Unlike other producers, whose exports are limited to a specific region, Saudi Arabia is the world's largest (net) oil exporter and has exported 14 percent of its crude oil to the United States, 4 percent to Europe and 57 percent to Asia in 2009. Saudi Arabia exported an estimated 7.5 million bbl/d of petroleum liquids in 2010. The country has two primary oil export terminals: the Ras Tanura in the east (75 percent) and the Yanbu terminal in the Red Sea (25 percent) with a capacity of 4.5 million bb/d. Saudi Arabia produces and exports five crude qualities ranging from the 45^0 API Arab Super Light (ASL) to the 23.7^0 API Arab Heavy (AH). The light crudes constitute the majority of its production and exports (80 percent).

With the largest crude oil production capacity, Saudi Arabia can increase its production during demand surges and supply shocks. Since the mid-nineties, "This capacity cushion throughout the nineties and beyond kept markets well balanced and ensured Saudi Arabia's role as the supplier of last resort."ALmoneef[1]

Oil is important to the economy of Saudi Arabia. In 2009, oil comprised 85 percent of the government's revenue, and the oil sector's share of the GDP was 29 percent. Because oil plays a vital role in the Saudi Arabian economy,[2] oil pricing and production decisions are determined at the highest levels of the government in Saudi Arabia. Oil revenues and oil-related activities, such as the production and refining of petrochemicals, heavily finance the Saudi Arabian government's expenditures. Hence, to preserve the importance of oil in the global energy mix, Saudi Arabia has tried to moderate the price of oil and thereby continue the growth of demand, as has been shown in the literature.

2.Literature Review:

Given the size of Saudi Arabia's proven reserves and its large share of global oil production and exports, several studies have discussed the importance of Saudi Arabia. In the early seventies, Mabro (1975) indicated, "OPEC is Saudi Arabia."[3] Doran (1977) has recognized that the members of OPEC adopted certain pricing strategies for different political reasons. For the members with large petroleum reserves, the long-term strategy is to slowly increase oil prices to minimize the probability that new energy sources will be developed and that new discoveries will occur as well as to decrease the possibility of substitution.[4] Because Saudi Arabia is the largest member of OPEC, the country's actions are more explained by political factors than by the results of an optimized economic model. Saudi Arabia has exercised price leadership within the cartel to stabilize or moderate oil prices and thereby achieve its political objectives Moran (1982). [5] Saudi Arabia has also been described as a swing producer or the balance wheel that absorbs fluctuations in the supply and demand to maintain the monopoly price. Griffin and Teece (1982) have stated that the monopoly price and the stability of OPEC depends more on whether Saudi Arabia's share of the cartel's oil production satisfies its objective than on the cartel's cohesion. According to this model, Saudi Arabia will choose the price path that maximizes its wealth over time while considering the reactions of the fringe members.[6] OPEC's behavior resembles a loosely cooperative oligopolistic cartel or a residual firm monopolist that allows everyone else to maximize their own profits by choosing their own production levels while raising its own prices by restricting output. OPEC chooses its own production to maintain the cartel price, and Saudi Arabia acts as the swing producer Adelman (1982).[7,8] In the 1970s and 1980s, Saudi Arabia's oil policy was designed to optimize the long-term value of its oil reserves and to attain its political goals Quandt (1982).[9] Several studies on OPEC have treated Saudi Arabia as a separate entity and have highlighted its importance as a cartel member. Askari (1991) [10] suggested that, in addition to profits, historically broad political goals and economic factors have also motivated Saudi Arabia's oil policy. The political concerns of these studies concentrate on Saudi Arabia's role in the world. Dahl and Yucel (1991) tested the swing producer model by analyzing the coordinated output among the OPEC members and OPEC's total production. Using quarterly data for Saudi Arabia from 1971-1987, these researchers rejected the notion that the OPEC members coordinate their output and concluded that Saudi Arabia's production has no relationship with the production of other countries[11]. Griffin and Neilson (1994) utilized econometric testing to analyze the swing producer model and focused on the strategies that OPEC used to generate cartel profits from 1983-1990. The results supported the hypothesis that OPEC had adopted a swing producer strategy from 1983-1985. However, when Saudi Arabia's profit fell below the level of the Cournot profits in the summer of 1985, it abandoned the role of swing producer. As a result, the prices were driven to the Cournot level. Saudi Arabia appears to have adopted a tit-for-tat strategy designed to punish excessive cheating by other OPEC's members.[12] Stevens,(1991,1995).[13,14] has considered Saudi Arabia to be the price setter in OPEC and the objective of the country's pricing policy to be crucial to understanding OPEC's behavior. Stevens (1995) also showed that Saudi Arabia pursues moderately low prices because it aims to keep a higher value on its huge reserves and because of the influence of the USA on its oil policy. A more recent study[15] investigated the concerns about the presence of dominant producers in the global oil market for the period from 1973-1994 and whether OPEC, the non-OPEC countries or Saudi Arabia fit the model of Cournot competition. All of the models were rejected, with the exclusion of the dominant model for Saudi Arabia Alhajji and Huettner (2000). The swing producer model showed that Saudi Arabia had adopted the model when the quota system was formally adopted in 1982 to achieve cooperative reductions and expand the OPEC supply such that the supply could match the fluctuations in market demand Libecap (2001).[16] Khole (2002) tested OPEC behavior from 1998-2001[17] and concluded that, during these three years, OPEC revived itself, improved its discipline and acted more professionally and cooperated more with other countries in its efforts to manage the global oil market. Other method of analysis De Santis, and Roberto (2003) [18] included a CGE model for Saudi Arabia that was used to numerically quantify the impact of crude oil demand and supply shocks on prices, output, profits and welfare. The results showed that Saudi Arabia has an incentive to cut production to sustain higher prices. After testing the behavior of OPEC in the oil market, Smith (2005) [19] concluded that, researchers could no longer ignore the importance of Saudi Arabia's role as a large oil producer. Previous scholars also tested other models such as capacity utilization,[20,21] and found that OPEC's production decisions may have significantly affect the real crude price.

The statistical evidence in the literature shows mixed results on the question of whether Saudi Arabia and other core producers have played a special role within the cartel.
In the seventies, OPEC set the price of Arabian Light as a reference point, and the OPEC members set the price of their oil accordingly while they sold as much oil as they wanted. Saudi Arabia was able to maintain its role as the residual supplier and acted as the swing producer by adjusting its output to stabilize the price of oil. However, in the eighties, the expansion of the non-OPEC supply and other factors influencing the global oil market led Saudi Arabia to adopt the role of market sharing producer. Alyousef (1998) tested the two models,[22] the swing producer for the period from 1976-1985, and the market sharing producer model for the period from 1987-1996. It was concluded the applicability of the two models to such periods.

This paper extends the analysis of the role of Saudi Arabia in the global oil markets and covers the period from 1997-2010. From 1997-2010, the global oil market experienced a structural change. Since the early 1990s, spare OPEC capacity had witnessed considerable decline. This decline could primarily be attributed to accelerating global demand combined with low growth in the non-OPEC oil supply, particularly from 1990-2010. Thus, these years were a complete reversal of the trend in the 1980s.

Saudi Arabia played an important role from 1974-1985. However, in 1985, Saudi Arabia abandoned its swing producer role. Since 1987, Saudi Arabia has maintained its share of the oil market. However, with the decline in prices in 1998, the decline in OPEC's spare capacity and the low growth of the non-OPEC supply, Saudi Arabia gained more power in the oil market. This paper attempts to analyze the role of Saudi Arabia in the oil market by considering its role as a swing producer model from 1997-2010.

3.OPEC decisions on production 1997-2010

In December 1997, OPEC increased its quota by 2.5 MB/d (10 percent) to 27.5 MB/d effective January 1, 1998. In 1998, Asian Pacific oil consumption declined for the first time since 1982. The combination of low consumption and high OPEC production caused a sharp decline in oil prices. In response, OPEC cut its quotas by 1.25 MB/d in April and another 1.335 MB/d in July. The price continued to fall through December 1998. The prices began to recover in early 1999, and OPEC reduced its production by another 1.719 MB/d in April. Between early 1998 and the middle of 1999, OPEC production dropped by approximately 3 MB/d, and the price rose above $25 per barrel. With growing economy in the US and the world in general, the price continued to rise throughout the year 2000. Between April and October, 2000, OPEC increased its quota three times for a total of 3.2 MB/d. OPEC increased its quota again by 500,000 MB/d on November 1, 2000. In 2001, a weakened US economy and increases in non-OPEC production imposed downward pressure on the oil prices. In response, OPEC performed several reductions and cut 3.5 MB/d by September 1, 2001. However, the spot prices continued to decline. Because of the political climate after September 11, OPEC delayed additional cuts until January 2002. It then reduced its quota by 1.5 MB/d and was joined by several non-OPEC producers, including Russia. The prices increased to $25, and OPEC increased its quotas by 2.8 MB/d in January and February of 2003. On March 19, 2003, the US commenced military action in Iraq. Because of its improving economy, the US demand for oil continued to increase, and Asian demand for crude oil grew at a rapid pace.

Figure 1 about here

Several factors affected the price of oil in 2003. The loss of production capacity in Iraq, the cuts in Venezuela production because of domestic problems, and the increased OPEC production to meet growing international demand all led to a decline in excess oil production capacity below 2 MB/d. Starting in 2004, oil demand from developing countries, especially China, increased sharply, and the advanced economies proved to be more resilient against rising oil prices than previously believed.

From April to June 2004, OPEC (excluding Iraq) announced an agreement to reduce actual production by 1 MB/d by January 1 because the price of the OPEC basket was in the $30/B range. For much of 2004 and 2005, the spare capacity to produce oil was under 1 MB/d. One million barrels per day is not enough spare capacity to cover an interruption in supply for most OPEC producers. Other major factors contributing to the increasing level of prices included a weak dollar as well as the continued rapid growth of the Asian economies and their levels of petroleum consumption.

Figure 2 about here

In 2006, the crude oil prices declined from approximately $76 per barrel in August toward $55/barrel in October. Therefore, OPEC cut its production levels by approximately 1500,000 b/d in November 2006 and by approximately 500,000 b/d in February 2007. When the prices were $80/barrel in October 2007, OPEC decided to increase its production levels by 1,500,000 b/d on November, 1 2007.

In July 2008, the oil prices peaked at over $145/barrel for the WTI oil. However, the prices eventually declined, and the strong growth in demand for oil in China, the Middle East and Asia has not been enough to offset the huge decline in oil demand in the OECD countries. In September, OPEC agreed to cut its production by 4.2 MB/d after oil prices declined dramatically to below $40 per barrel.

In 2009 and 2010, OPEC left its production target unchanged. The prices reached an average of $63/barrel in 2009 and increased in 2010 to reach an average of $80/barrel.

4.The Swing Producer Model

Price control is defined as setting an effective transaction price and preventing market forces from changing it. However, high prices will induce competitors to enter the market. Thus, a dominant supplier has a choice. It can achieve short-run profits by raising its price at the expense of losing its dominance in the future or it can charge a moderate price that supports its market share and generates highly competitive profits over time. If the supplier engages in the latter strategy, then it will try to lead the market by signaling the price it strives to maintain.

Saudi Arabia can adjust its production to changes in world oil demand, the non-OPEC production and other OPEC members' production levels. The fringe members will adjust their market share according to their marginal costs, which include the user cost, whereas Saudi Arabia's market share will fall if the demand for OPEC decreases and will rise if the demand increases. If Saudi Arabia is the residual supplier, then we can calculate the following equation:

$$Q^{SA} = Q^{W} - (Q^{NO} + Q^{OO})$$

where Q^{W} is the global demand for oil, Q^{NO} is the non-OPEC supply and Q^{OO} is the production by the other OPEC members. In the swing producer model, Saudi Arabia can be considered the price maker in the oil market, whereas the other members of OPEC and the non-OPEC suppliers represent the fringe competitors. As the residual supplier, Saudi Arabia is the Stackelberg leader that maximizes its profit by choosing an optimal production path while considering the reactions of the fringe producers to its policies, whereas the fringe producers must take the prices as they are given.

Because Saudi Arabia has a high reserve/output ratio, its aims to maintain a stable oil price to keep oil competitive over the long term, maintain the initiative in OPEC’s pricing objectives and assert its power in the market.

To achieve these objectives, Saudi Arabia increases output to keep spot prices low and reduces output to maintain stable oil prices. This model appears to fit the country’s behavior at various moments in the history of the oil market. In April 1999, Saudi Arabia lowered its production in accordance with Venezuela and Mexico to increase the price of oil. On other occasions, Saudi Arabia varied its production to achieve its price objectives and to compensate for the supply shortfalls resulting from the Iraq invasion. In 2009, because the financial crisis caused a decline in global demand for oil, Saudi Arabia decreased its production.

Therefore, from 1997-2010, Saudi Arabia was a member of a cartel that exercised its power by assigning a price and producing the quantity necessary to maintain that price to satisfy its objective of keeping oil prices at a stable level.

Accordingly, the country can also be described as a price leader that sets the price of oil, which others must take as given. We can calculate the price leadership model as follows: Saudi Arabia Q^{SA} (i.e., production by Saudi Arabia) is a price leader with the other OPEC members Q^{OO} (i.e., OPEC production) and the non-OPEC suppliers constituting the competitive fringe Q^{NO} (i.e., production by non-OPEC producers). The oil market comprises Saudi Arabia, the price-setting leader, and the competitive fringe, which is composed of the other OPEC members and the non-OPEC producers. To test for the Swing Producer Model, we used the relation between Saudi Arabia's production and the production of the other OPEC members to maintain the price level. When the difference between the target price (P^T) and the market price (P^M) increased, Saudi Arabia would increase or decrease its production to lower the gap between the two oil prices in either direction. More specifically, when the production of the other producers increased, Saudi Arabia's production would decrease, and vice versa. However, the main reason that Saudi Arabia changed its production levels was to influence the price of oil. Saudi Arabia increased its production to stabilize the price of oil at times when a shortage resulted in an increase in oil prices. Then it would increase its output to offset the shortage of the oil supply. This scenario occurred during the US invasion of Iraq in 2003. However, when the price of oil was pressured to decline to a level that would affect the Saudi economy, Saudi Arabia tried to maintain higher oil prices by decreasing its output level. This scenario occurred in 2009. Therefore, the difference between the spot oil prices P^M and the target OPEC oil prices P^T should be included in the equation for the period from 1997-2010. For that period, Saudi Arabia was concerned about price stability.

During those years, Saudi Arabia followed the price of the OPEC basket. It manipulated its production by minimizing the difference between the target price P^T and the market price PM. However, it was not concerned about the absolute value but rather the proportionate difference. Thus, the objective function is

$\left(\frac{P^T}{P^M}\right)=1$, where the difference between both prices is equal to zero.

If the demand for OPEC oil was high, then $\left(\frac{P^T}{P^M}\right)<1$, and Saudi Arabia would increase its output.

If the demand for OPEC oil was low, then $\left(\frac{P^T}{P^M}\right)>1$, and Saudi Arabia would decrease its output.

This function is constrained by the following factors:

1) One constraint is Saudi Arabia's production capacity, which is calculated as 2.2 MMBD ≤ production capacity ≤ 12.0 MMBD. In 2009, Saudi oil production was 9,759.69 Thousand Barrels Per Day, which constitutes 11.56 percent of the world's total oil production.[23].

2) In 2009, the total OPEC oil supply[24] was 33.872 Thousand Barrels Per Day, which constitutes 40.13 percent of the 84,388.90 Thousand Barrels Per Day produced by the global oil market. In 2009, Saudi Arabia worked as a swing producer.

3) In 2008, the world's total petroleum consumption was approximately 171.80 Quadrillion Btu, which was equivalent to approximately 35 percent of the world's total energy consumption, 492.59 Quadrillion Btu[25].

Using the notation $P^{TM} = \left(\frac{P^T}{P^M}\right)$, we arrive at the following function:

$$Q^{SA} = f(P^{TM})$$

However, Saudi Arabia is a member of OPEC, so its production is also a proportion of the total OPEC production.

$$Q^{SA} = f(Q^{OPEC})$$
$$Q^{OPEC} = (Q^{OO} + Q^{SA})$$

Thus, by substituting for the values of the oil production from Saudi Arabia and OPEC and by combining these values with the equation, we arrive at the following equation:

$$Q^{SA} = f(Q^{OO}, P^{TM}).$$

Using these models, we may reasonably assume that Q^{SA} is a function of the price level and other factors, such as the size of the reserve and the extraction cost. However, according to other oil market theories, Saudi Arabia's production output was also influenced by various factors, such as the level of its financial needs, speculation and the dollar exchange rate. In the absence of reliable data regarding the extraction costs and the size of the reserves, one is forced to disregard their effects. Therefore, we can state that Saudi output is a function of the production from other countries and of the ratio of target to spot oil prices.

$$Q^{SA} = f(Q^{OO}, P^{RM})$$

5.Data

The variables in this study include Saudi Arabia's monthly crude oil production Q^{SA}, the other OPEC members' production Q^{OO}, the target price for OPEC P^T, and the market oil price P^M. The period of the study witnessed changes in the global oil market in that the demand for oil increased from July 2003 to August 2008. A dummy variable is used to represent this period. Dummy variables are designed to account for the impacts of exogenous variables (e.g., increased speculation) that affect the global oil market. The source of the data is the OPEC secretariat.

Production: Using different production series can be problematic if the production reporting methods differ from one source to another. In recent years, the OPEC secretariat and the ministerial meetings primarily relied on production data from six sources (i.e., Petroleum Argus, Reuters, Petroleum Intelligence Weekly (PIW), Platt's Oilgram Price Report, International Energy Agency (IEA), Middle East Economic Survey (MEES), and Petrostrategies) and took a simple average of these sources' estimations of the OPEC members' actual production levels. We will rely on the data provided by the OPEC secretariat for the period analyzed by our study.

The Market price: The OPEC Reference Basket[26] (ORB) price will be used.

The Target Price**:** Since 1987, OPEC has set a reference price (i.e., the OPEC Reference Basket) that serves as a guideline for determining the ceiling of OPEC production. This reference price is determined by OPEC. In 1987, the price was $18 per barrel. In the 1990s, OPEC set a minimum reference price of $21/B.

In June 2000, the OPEC members established a mechanism to adjust the supply of oil by 500,000 B/d if the 20-day average price of oil moved outside of the $22 to $28 price band. Hence, the price of the OPEC basket will be used for the market price and for the target price. From 1999-June 2003, the midpoint for the price band of $22 to $28 per barrel was $25/barrel. The price band eroded in subsequent years as oil prices continued to rise to more than $50/barrel.

From April to June 2004, OPEC (excluding Iraq) announced an agreement to reduce its actual production levels by 1 MB/d by January 1. Because the price of the OPEC basket was in the range of $30/B, this decision signaled that OPEC's implicit price target was above $30, as the price increased to above the $30 per barrel production ceiling.

Table 1: The OPEC Basket price from August 2004 to February 2005

Month	OPEC basket Price $/B	Saudi Oil production Quota	OPEC production Ceiling
Feb-04	28.49	7963	23230
Mar-04	30.77	7963	23230
Apr-04	31.69	7638	22282
May-04	34.65	7638	22282
Jun-04	33.58	7638	22282
Jul-04	34.7	8288	24178
Aug-04	38.22	8450	24653

Source: OPEC secretariat

In 2006, crude prices declined from approximately $76 per barrel in August toward $55/barrel in October. In response, OPEC cut its production by approximately 1500,000 b/d in November 2006 and again in February 2007 by approximately 500,000 b/d such that the target price for that period was above $70/barrel. When the price was $ 80/barrel in October 2007, OPEC increased its production level by 1,500,000 b/d, which was effective as of 1 November 2007.

Table 2: The OPEC Basket price from August 2004 to February 2005

Month	OPEC basket Price $/B	Saudi Oil production Quota	OPEC production Ceiling
Jul-06	74.13	9099	26549
Aug-06	75.42	9099	26549
Sep-06	63.32	9099	26549
Oct-06	54.87	9099	26549
Nov-06	56.93	8719	26300
Dec-06	62.55	8719	26300
Dec-06	62.55	8719	26300
Jan-07	55.39	8719	26300
Feb-07	58.44	8561	25800
Mar-07	62.83	8561	25800
Apr-07	68.74	8561	25800
May-07	68.12	8561	25800
Jun-07	68.41	8561	25800
Jul-07	76.88	8561	25800
Aug-07	73.67	8561	25800
Sep-07	76.98	8561	25800
Oct-07	84.96	8561	25800
Nov-07	93.64		27253
Dec-07	94.53		27253

Source: OPEC secretariat

From April 2003 to February 2005, the price of oil was $35/barrel, and OPEC used the OPEC basket as the target price. From March 2005 to November 2006, OPEC used $50/barrel as the target price. From December 2006 to December 2007, OPEC used $75/barrel as the target price. From 2008 to 2010, OPEC used the price of $75/barrel, as announced by King Abdullah[27] in November 2008.

In December 2009, OPEC gave the strongest indication yet that it intends to keep oil prices at the $70-$80/barrel range to support the economic recovery.

Figure 3 about here

6.Method of analysis

The Swing Producer equation that will be estimated in this study is calculated as follows:

$$\ln Q_t^{SA} = \beta_0 + \beta_1 \ln Q_t^{OO} + \beta_2 \ln P^{TM} + u_t \qquad (1)$$

This equation is estimated using a natural logarithm of the variables. Hence, each coefficient is estimated as an elasticity. To describe the Saudi Arabian production policy from

January 1997 to December 2010, we test the swing producer model by imposing the following restrictions. If the swing producer role β2≠0, then the difference between the target price and the market price influences Saudi Arabia's output decision. If the ratio P^{TM} between P^{T} and P^{M} decreases ($P^{T} < P^{M}$), then Saudi Arabia will increase its production to lower the ratio. If the ratio P^{TM} increases ($P^{T} > P^{M}$), then Saudi Arabia will decrease its production to increase P^{M} $\beta \neq 0$ for the model. That is, Saudi Arabia must have a relationship with the other OPEC members' production levels if we are to show Saudi Arabia acts as the swing producer within the OPEC cartel.

To examine the long-run relationship between Saudi Arabia's production levels and those of its determinants (Oil price and the other OPEC members production), we employ the autoregressive distributed lag (ARDL).[28,29], and we test the null hypothesis of no cointegration against the existence of a long-run relationship. Unlike other cointegration techniques (e.g., Johansen's procedure) that require certain pre-testing for the unit roots and the underlying variables to be integrated into an order of one, the ARDL model provides an alternative test for examining a long-run relationship regardless of whether the underlying variables are I(0), I(1) or fractionally integrated.

The test consists of two stages. In the first stage, if the theory predicts there is a long-run relationship among the variables y, x and z; assuming no prior information about the direction of the long-run relationship among variables; the following three unrestricted error correction (EC) regressions are estimated, where each variable is considered in turn as a dependent variable:

$$\Delta y_t = \alpha_{0y} + \sum_{t=1}^{n} b_{ty} \Delta y_{t-j} + \sum_{i=1}^{n} c_{iy} \Delta x_{t-j} + \sum_{i=1}^{n} d_{iy} \Delta z_{t-j} + \gamma_{1,y} y_{t-j} + \gamma_{2,y} x_{t-j} + \gamma_{3,y} z_{t-j} + \nu_{1t} \quad (2a)$$

$$\Delta x_t = \alpha_{0x} + \sum_{t=1}^{n} b_{tx} \Delta y_{t-j} + \sum_{i=1}^{n} c_{ix} \Delta x_{t-j} + \sum_{i=1}^{n} d_{ix} \Delta z_{t-j} + \gamma_{1,x} y_{t-j} + \gamma_{2,x} x_{t-j} + \gamma_{3,x} z_{t-j} + \nu_{2t} \quad (2b)$$

$$\Delta z_t = \alpha_{0z} + \sum_{t=1}^{n} b_{tz} \Delta y_{t-j} + \sum_{i=1}^{n} c_{iz} \Delta x_{t-j} + \sum_{i=1}^{n} d_{iz} \Delta z_{t-j} + \gamma_{1,z} y_{t-j} + \gamma_{2,z} x_{t-j} + \gamma_{3,z} z_{t-j} + \nu_{3it} \quad (2c)$$

The F tests are used for testing the existence of long-run relationships. When such relationships are found to exist, the F tests dictate which variable should be normalized. The null hypothesis for testing the 'nonexistence' of the first 'long-run relationship' is as follows:

$$H_0 : \gamma_{1y} = \gamma_{2y} = \gamma_{3y} = 0 \qquad \textit{the test} \quad F_y(y/x,z). \quad \textit{for} \quad (2a)$$

$$H_0 : \gamma_{1x} = \gamma_{2x} = \gamma_{3x} = 0 \qquad \textit{the test} \quad F_x(x/y,z). \quad \textit{for} \quad (2b)$$

$$H_0 : \gamma_{1z} = \gamma_{2z} = \gamma_{3z} = 0 \qquad \textit{the test} \quad F_z(z/y,x). \quad \textit{for} \quad (2c)$$

The *F* test has a non-standard distribution, which depends upon; (a) whether variables included in the ARDL model are I(0) or 1(1), (b) the number of regressors and (c) whether the ARDL model contains an intercept and or a trend. Two sets of critical values are reported in Pesaran and Pesaran (2010) (see also Pesaran et al., 2001) [30]. The two sets of critical values provide critical value bounds for all classification of the regressors into purely ~ (l), purely I(O) or mutually cointegrated. One has to compare the F-statistic computed in the second step with the upper and lower 90%, 95% or 99% critical value bounds (FU and FL). As a result, three cases can emerge. If F > FU $\gamma_1 = \gamma_2 = \gamma_3 = 0$ is rejected and hence it is concluded there is a long-term relationship between y and the vector of x's. However, if F < FL, then $\gamma_1 = \gamma_2 = \gamma_3 = 0$ cannot be rejected and it is concluded that a long-run relationship does not exist. Finally, if FL < F < FU, the inference is regarded as inconclusive and the order of integration of the underlying variables has to be investigated more deeply.

Once a long-run relationship has been established, in the second stage, a further two-step procedure to estimate the model is carried out. First, the orders of the lags in the ARDL model are selected using appropriate lag selection criteria such as the Schwartz Bayesian Criteria (SBC). Secondly, the selected model is estimated by the ordinary least squares technique [cite]. Equation (1) shown above is estimated using the following ARDL (*m*, *n*, *p*) model:

$$Q_t^{SA} = \beta_0 + \sum_{p=1}^{m} \beta_1 Q_{t-1}^{SA} + \sum_{p=0}^{n} \beta_2 Q_{t-m}^{OO} + \sum_{p-0}^{p} \beta_2 p_{it-p} + u_t \qquad (3)$$

In the presence of cointegration, short-run elasticities can also be derived by constructing an error correction model of the following form.

$$\Delta l Q_t^{SA} = \alpha_0 + \sum_{i=1}^{k=4} \alpha_1 \Delta l Q_{t-1}^{SA} + \sum_{i=0}^{k=4} \alpha_2 \Delta l Q_{t-1}^{OO} + \sum_{i=0}^{k=k} \alpha_3 \Delta l p_{t-1}^{TM} + \lambda_1 \ln Q_{t-1}^{SA} + \lambda_2 \ln Q_{t-1}^{OO} + \lambda_3 \ln p_{t-1}^{TM} + e \qquad (4)$$

Where ECM_{it-1} is the error correction term defined as:

$$ECM_{it} = Q_t^{SA} - \beta_0 - \sum_{p=1}^{m} \beta_1 Q_{t-p}^{SA} - \sum_{p=0}^{n} \beta_2 Q_{t-p}^{OO} - \sum_{p-0}^{p} \beta_2 p_{it-p} + \qquad (5)$$

Here Δ is the first difference operator; αs are the coefficients relating to the short-run dynamics of the model's convergence to equilibrium, and λ measures the speed of adjustment.

Results

We estimate Equation (1) for the Saudi production levels with monthly data over the period from 1997-2010. To test the null hypothesis of no cointegration, we must decide the order of lags on the first-differenced variables. The Augmented Dickey-Fuller Test (ADF) is used to determine the degree of integration of the series. For comparison purposes, we repeat the test for unit root using the Philip-Perron test.

Table 3: Unit root test results

	Intercept only				**Intercept & trend**			
Variable	**Level**		**First difference**		**Level**		**First difference**	
	ADF	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**
CV	2.8788	-3.4369	2.8788	-3.4369	-3.4371	3.4369	-3.4371	3.4369
$LQ^{SA}(1)$	-2.7353	2.3321	7.67799	7.6106	2.9027	2.4328	-7.6540	-7.5860
$LQ^{OO}(1)$	-1.8789	1.84963	12.3753	12.3753	2.2394	12.3432	-2.2743	-12.343
$LP(1)$	-2.7388	-3.7362	-11.5123	-	-3.2084	-3.7362	-11.4845	-

The lag number are shown in the brackets, C.V are the critical value at, 5 percent level of significance. Table 1 shows the results of both the augmented Dickey-Fuller (ADF) test and PP test for the level and the difference series on constant only and constant and trend. The number of lags included in the estimation to eliminate the possibility of autocorrelation of residuals. The lag number is determined according to the minimum value of (AIC). The results indicate that the null hypothesis of non-stationarity (of unit root) at level cannot be rejected for log of Q^{SA} and log of Q^{OO} variables at 5 percent level of significant, which casts doubts on the validity of the (OLS) results. However for log of the ratio of target to spot oil prices we cannot accept the null hypothesis of non-stationarity by PP test, o we conclude that the variable is stationary, I(0) To determine the degree of integration, the non stationary variables were tested in their first difference. The ADF and PP tests reject the null hypothesis of a unit root at 5 percent level of significant. The results are shown in table (3). It appears that the two variables are integrated of order one.

In the first step of estimating equation (3), equations (2*a*) to (2*c*) are estimated to examine the long-run relationship. For the maximum order of lags in the ARDL we choose one and use the SBC to select the appropriate lags. The estimation is conducted for the period 1997.1-2010.12. The calculated F-statistics is reported in Table 4

Table 4. F-statistics for the co-integration relationship

		Critical value bounds of the F-statistics with intercept and no trend ($k = 1$)			
	F-value	95 percent Lower Bound	95 percent Upper Bound	90 percent Lower Bound	90 percent Upper Bound
$lQ_t^{SA} / lQ_t^{OO}, lP$	6.3332	3.9219	4.8619	3.2399	4.1251
$lQ_t^{OO} / lQ_t^{SA}, lP$	4,3716				
$lP / lQ_t^{OO} / lQ_t^{SA}$	4,9427				

Source: Critical value[31] bounds are from Microfit 5 Pesaran and Pesaran, 2010

Table 4 reports the results of the calculated F-statistics when each variable is considered as a dependent variable (normalized) in the ARDL-OLS regressions. The calculated F-statistics $lQ_t^{SA} / lQ_t^{OO}, lP$=6.3332 is higher than the upper bound critical value 4.8619 at the 5 percent level. Thus, the null hypotheses of no co integration is rejected at 5 percent level. Calculated F statistics for $lQ_t^{OO} / lQ_t^{SA}, lP$=4,3716 is also lower than the upper-bound critical value 4.8619 at the 5 percent level. However, higher than 4.1251 at the level 10%. Thus, the null hypotheses of no co-integration is accepted at the level 5 percent but is rejected at 10 percent. For price as the dependent variable, the calculated F is $lP / lQ_t^{OO} / lQ_t^{SA}$ =4, 9427 is also lower than the upper-bound critical value 4.8619 at the 5 percent level. However, higher than 4.1251 at the level 10%. Thus, the null hypotheses of no co-integration is accepted at the level 5 percent but is rejected at 10 percent. Thus, at the level 5 percent the results are implying long-run cointegration relationships amongst the variables when the regressions are normalized on lQ^{SA} variables (Table 4). Which indicate that the theory of Saudi Arabia as a swing producer is stronger than this of other members of OPEC, and we establish the long-run cointegration relationship.

Once we established that a long-run cointegration relationship existed, equation (1) was estimated using the ARDL (1, 1, 0) specification. The results obtained by normalizing on Saudi production in the long-run, are reported in equation (6).

Estimated Long Run Coefficients using the ARDL Approach ARDL(1,1,0) selected based on Schwarz Bayesian Criterion

$$\ln Q_t^{SA} = \beta_0 + \beta_1 \ln Q_t^{OO} + \beta_2 \ln P^{TM} + u_t$$

$$\ln Q_t^{SA} = 12.44 - 0.34 \ln Q_t^{OO} - 0.46 \ln P^{TM} + u_t \qquad (6)$$

$$t-value\ 2.490.013] \ -0.68[0.495] \ -2.51[0.013]$$

If a swing producer role β3≠ 0, then the difference between the Saudi price and the market price influences Saudi Arabia's output decision. If the ratio P^{TM} between P^T and P^M decreases ($P^T < P^M$), then Saudi Arabia will increase its production to lower the P^M . If the ratio P^{TM} increases ($P^T > P^M$), then Saudi Arabia will decrease its production to increase the P^M . If $\beta_2 < 0$ in the model, then Saudi Arabia has a negative relationship with the production of the other OPEC members. In this case, Saudi Arabia acts as the swing producer in the OPEC cartel.

In the second stage, we retain the lagged levels of the variables and estimate equation (2) with an appropriate lag selection criterion, such as the adjusted R^2 , AIC, and SBC. The long-run coefficient estimates are reported in Table 2. As expected, the coefficient of the other OPEC members is negative and that the coefficient of the difference between the target price and the market price is also negative.

Table 4 presents the estimates of the error correction representation selected by the adjusted R2, AIC, and SBC. We used the long-run coefficients reported in Table 2 to generate the error correction terms. The adjusted R2 are coefficients of determination for the models, which suggests that these error correction models fit the data reasonably well. In addition, the computed F-statistics clearly reject the null hypothesis that all regressors have zero coefficients for all cases. Importantly, the error correction coefficients carry the expected negative sign and are highly significant. This finding helps reinforce the co-integration results provided by the F-test.

Table 5: Error correction representation using the ARDL Approach ARDL(1,1,0) selected based on Schwarz Bayesian Criterion

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	Dependent variable is $\Delta \ln Q_t^{SA}$	
	Coefficient	t-value
Intercept	0.00015	0.49.[.894]
$\Delta \ln Q_{t-1}^{SA}$	0.422	6.158[000]
$\Delta \ln Q_{t-1}^{OO}$	-0.090	-1.647[.101]
Δlp_t^{TM}	-0.04	-3.279[.001]
ECM_{t-1}	-0.04	-3.805[.000]
		$\overline{R}^2 = .30$
		$F_{4,161} = 19.42[000]$
		$Durbin's\ h-statistic = -327[.743]$
		$LM = \chi_1^2 = 19.59[0.075]$
		$RESET = \chi_1^2 = 3.42[0.065]$

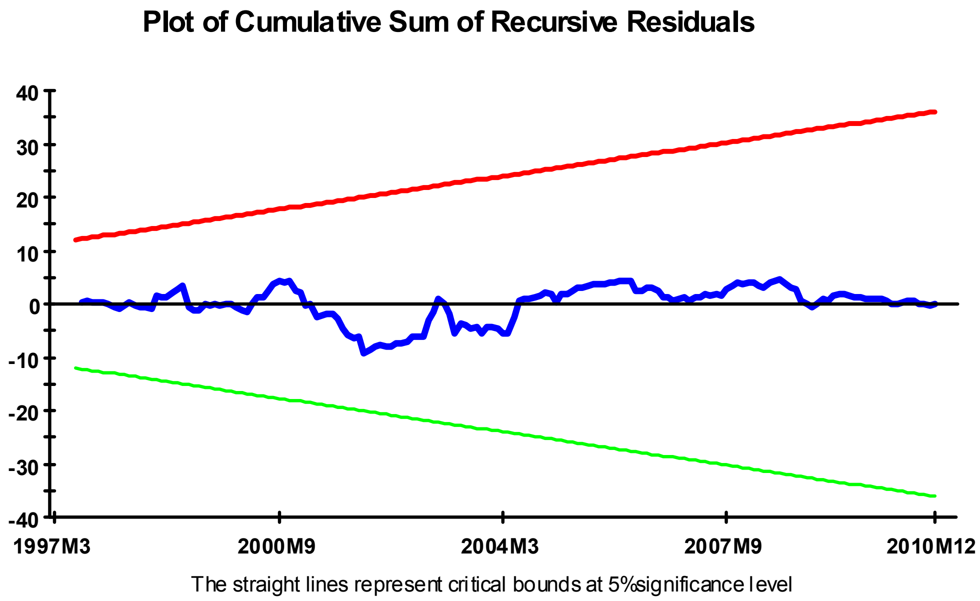
Using the long-run coefficient estimates from equation 3, we form the error-correction term *ECM*. After replacing the lagged level variables with *ECMt-1,* we recalculate the model at the same optimum lags used on the cointegration test. Table 4 shows that the significantly negative coefficient obtained for the lagged error-correction term supports an adjustment toward equilibrium. The speed of the adjustment itself, which is 3 percent, indicates a low rate of convergence toward equilibrium. The larger the error correction coefficient, the faster the economy returns to its equilibrium once the economy is shocked. In addition, the table reports the results of the three other diagnostic tests. The Lagrange Multiplier (LM) test statistic for the presence of autocorrelation suggests that the null hypothesis of no autocorrelation is acceptable.

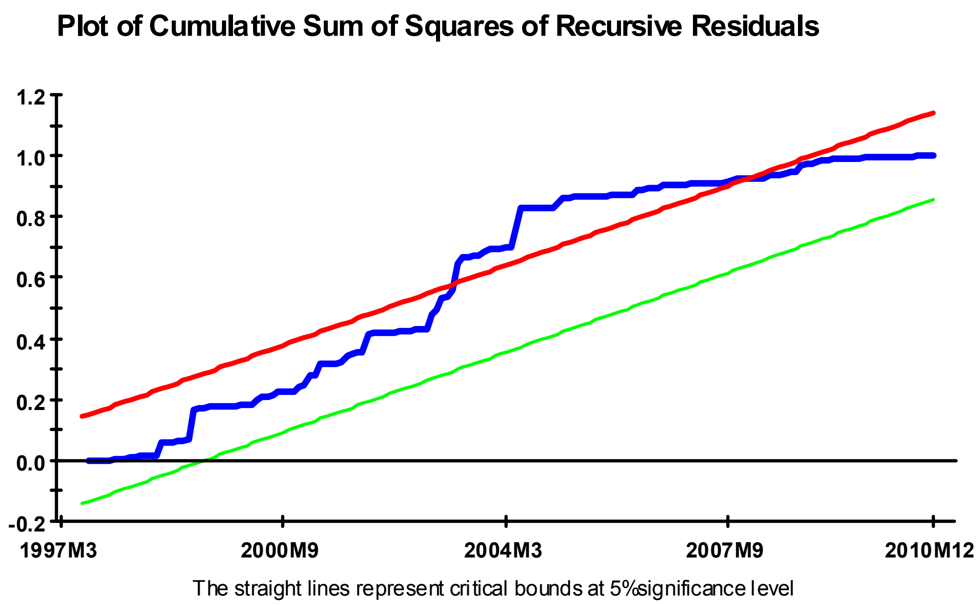
Table 6: Elasticities of Production of Others and Price.

	Production of other members	Price
Long-run Elasticity	-0.34	-0.46
Short-run Elasticity	-0.09	-0.04

Finally, we examine the stability of the long-run coefficients together with the short-run dynamics. In doing so, we follow Pesaran and Pesaran (2010)[32] and apply the CUSUM and the CUSUMSQ tests, both of which were proposed by Brown, Durbin, and Evans (1975)[33]. We apply these tests to the residuals of the model in Table 3. Specifically, the CUSUM test utilizes the cumulative sum of the recursive residuals based on the first set of *n* observations. It is updated recursively and plotted against the break points. If the plot of the resulting CUSUM statistics stays within the critical bounds of the 5 percent significance level, which is represented by a pair of straight lines drawn at the 5 percent significance level (the equations are given by Brown, Durbin, and Evans (1975)), then the null hypothesis that all of the coefficients in the error correction model are stable cannot be rejected. If either of the lines is crossed, then the null hypothesis of coefficient constancy can be rejected at the 5 percent significance level. A similar procedure is used to carry out the CUSUMSQ test, which is based on the squared recursive residuals. Figure 2 shows a graphical representation of the CUSUM and CUSUMSQ plots, which are applied to the error correction model selected by the adjusted R2 criterion. For the CUSUM plot, the statistics do not cross the critical bounds. Thus, the plot indicates no evidence of any significant structural instability. The CUSUM test detects systematic changes in the regression coefficients, while the CUSUM Square test is particularly useful in capturing sudden departures from the constancy of regression coefficients So, for the CUSUMSQ plot, the statistics cross the line for the period from 2003-2008 which suggests significant changes from 2003-2008.

Figure 3. Plots of the CUSUM and CUSUMSQ Statistics for Coefficient Stability





8.Concluding Remarks

We examined the role played by Saudi Arabia in the oil market with monthly data over the period from January 1997 to December 2010. By applying a relatively new cointegration technique, we were able to identify a long-run relationship among Saudi

Arabia's oil production, the other OPEC members' oil production and the difference between the target price for OPEC and the market price. In doing so, we were able to test Saudi Arabia's role as a swing producer. We obtained the expected signs for the suggestion that Saudi Arabia change its production in response to the difference between the target and the market prices to stabilize the price of oil. In addition, we can state that Saudi Arabia inhabits the role of a swing producer because the kingdom changed its production levels to maintain stable oil prices.

Endnotes:

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[23] U.S. Energy Information Administration. www.eia.doe.gov.

[24] Crude oil, NGPL, and other liquids.

[25] U.S. Energy Information Administration. www.eia.doe.gov

[26] The OPEC Reference Basket (ORB) price was introduced on January 1, 1987. Until June 15, 2005, it was the arithmetic average of seven selected crudes: Saharan Blend (Algeria), Minas (Indonesia), Bonny Light (Nigeria), Arab Light (Saudi Arabia), Dubai (United Arab Emirates), Tia Juana Light (Venezuela) and Isthmus (Mexico). Mexico is not a member of OPEC. As of June 16, 2005, the ORB is calculated as a production-weighted average of the OPEC basket of crudes, which include the following: Saharan Blend (Algeria), Girassol (Angola — as of January 2007), Oriente (Ecuador — as of October 19, 2007), Iran Heavy (IR Iran), Basrah Light (Iraq), Kuwait Export (Kuwait), Ess Sider (SP Libyan AJ), Bonny Light (Nigeria), Qatar Marine (Qatar), Arab Light (Saudi Arabia), Murban (United Arab Emirates) and Merey (Venezuela).

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