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THE PROMINENT ROLE OF SAUDIA ARABIA IN THE OIL MARKET FROM 1997 TO 2011

*Nourah AlYousef**

Introduction

Since global oil prices experienced a fourfold increase in 1973-1974, 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 the Petroleum Exporting Countries (OPEC) also has played a significant role in the oil market. Saudi Arabia, the largest supplier in OPEC, has the highest share of global oil exports and the highest share of the organization's oil production (29 percent of OPEC in 2009), as the country produces an average of 12 percent of the world's total oil output. In addition, Saudi Arabia has the world's greatest proven oil reserves at 262.5 billion barrels—which amounts to approximately one-fifth of the global proven oil reserves. The country's current reserve-to-production ratio is 75 years. With an average production rate of 9.8 million barrels per day (b/d) in 2009, it also has the highest share of global oil production after Russia. Saudi Arabia

*Nourah AlYousef, Associate Professor of Economics at King Saud University (Riyadh, Saudi Arabia), earned a B.A. in business administration and an M.B.A. from the University of Bellarmine (Kentucky), a master's degree in economics from King Saud University, and a Ph.D. in economics from Surrey University (United Kingdom). She conducted postdoctoral research at the Oxford Energy Institute. The author's professional positions have included Vice Chair of the Economics Department and as an Advisor to the Saudi Arabian Ministry of Petroleum and Mineral Resources, to the Gulf Cooperation Secretariat, and to the "Majuls Alshura" (Saudi Arabian Parliament). Dr. AlYousef's areas of research concentration are in the fields of energy economics and econometric applications. This article is an extension of the author's presentation at the 30th USAEE/IAEE North American Conference, Washington, D.C., October 2011.

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maintains the world's largest crude oil production capacity, which was estimated to be over 12 million b/d at the end of 2010. Over 2 million b/d of capacity was added in 2009 with the oil fields in Khurais and Shaybah. Unlike other producers, whose exports are often limited to a specific region, Saudi Arabia is the world's largest (net) oil exporter; in 2009 it exported 14 percent of its crude to the United States, 4 percent to Europe, and 57 percent to Asia. Saudi Arabia exported an estimated 7.5 million b/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 b/d. Saudi Arabia produces and exports five crude qualities ranging from the 45° API Arab super light (ASL) to the 23.7° API Arab heavy (AH). The light crudes constitute the majority of its output and exports (80 percent).

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

Clearly, oil is a vital economic driver of the Saudi economy. In 2009, oil comprised 85 percent of the government's revenue with the oil sector's share of the gross domestic product (GDP) accounting for 29 percent. Because oil plays such a crucial role in the Saudi economy, oil pricing and production decisions are determined at the highest levels of the government.[2] Oil revenues and oil-related activities—such as the production and refining of petrochemicals—heavily finance the Saudi 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.

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 its dominance; for example, in the early 1970s, R. Mabro asserted, "OPEC is Saudi Arabia."[3] C. Doran recognized that the members of OPEC adopted certain pricing strategies for different political reasons.[4] For the members with large petroleum reserves, Doran suggested that the long-term strategy is to slowly increase oil prices to minimize the probability that major new energy sources will be developed as well as to decrease the possibility of fuel substitution. Because Saudi Arabia is the largest producer in 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 organization to stabilize or moderate oil prices and thereby achieve its political objectives, according to the work of T. Moran.[5] Moreover, the country has been described as a swing producer or the balance

wheel that absorbs fluctuations in supply and demand to maintain the monopoly price. J. Griffin and M. Teece have stated that the monopoly price and the stability of OPEC depends more on whether Saudi Arabia's share of the organization's oil production satisfies its objective than on OPEC's cohesion.[6] 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. 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. According to the works of M. Adelman, OPEC chooses its own production to maintain the cartel price, and Saudi Arabia acts as the swing producer.[7] Another contemporaneous argument put forth by W. Quandt suggested that in the 1970s and 1980s, Saudi oil policy was designed to optimize the long-term value of its oil reserves and to attain its political goals.[8]

Several studies on OPEC have treated Saudi Arabia as a separate entity and have highlighted its significance as a member. H. Askari asserted that, in addition to profits, historically broad political goals and economic factors also have motivated Saudi oil policy.[9] The political concerns of these studies concentrate on Saudi Arabia's role in the world. C. Dahl and M. Yücel tested the swing producer model by analyzing the coordinated output among the OPEC members and the organization's total production.[10] Using quarterly data for Saudi Arabia from 1971 to 1987, these researchers rejected the notion that the OPEC members coordinate their output and concluded that Saudi production has no relationship with that of other countries. J. Griffin and W. Neilson utilized econometric testing to analyze the swing producer model and focused on the strategies that OPEC used to generate profits from 1983 to 1990.[11] The results supported the hypothesis that OPEC had adopted a swing producer strategy from 1983 to 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 members.

P. Stevens' research 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 the organization's behavior.[12] He further demonstrated 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 United States on its oil policy.

A more recent study by A. Alhajji and D. Huettner investigated the concerns about the presence of dominant producers in the global oil market for the period from 1973 to 1994 and whether OPEC, the non-OPEC exporters, or Saudi Arabia fit the model of Cournot competition.[13] In this work, all of the models were rejected, with the exclusion of the dominant model for Saudi Arabia.

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, according to G. Libecap and J. Smith.[14] W. Kohl tested OPEC behavior from 1998 to 2001 and concluded that, during these three years, OPEC revived itself, improved its discipline, acted more professionally, and cooperated more with other countries in its efforts to manage the global oil market.[15] Another method of analysis by R. DeSantis included a computable general equilibrium (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.[16] 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, J. Smith concluded that researchers could no longer ignore the importance of Saudi Arabia's role as a large oil producer.[17] Previous scholars also tested other models, such as capacity utilization, and found that OPEC's output decisions may significantly have affected the real crude price.[18]

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 OPEC. In the 1970s, the organization set the price of Arabian Light as a reference point, and its members set the price of their oil accordingly while they sold as much oil as they wanted. Saudi Arabia was able to maintain its position as the residual supplier and acted as the swing producer by adjusting its output to stabilize the oil price. However, in the 1980s 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. N. Al-Yousef tested the two models: the swing producer for the period from 1976 to 1985 and the market-sharing producer model for the period from 1987 to 1996.[19] The work concluded the applicability of the two models to these periods.

This paper extends the analysis of the role of Saudi Arabia in the world oil markets and covers from 1997 to 2011, a period when the global market experienced a structural change. Since the early 1990s, spare OPEC capacity had witnessed a considerable decline. This decline primarily could be attributed to accelerating global demand combined with low growth in the non-OPEC supply, particularly from 1990 through 2010. Thus, these years were a complete reversal of the trend in the 1980s.

Saudi Arabia assumed an essential position in the oil markets from 1974 to 1985. However, in 1985 Saudi Arabia abandoned its swing producer mantle. Since 1987, Saudi Arabia has maintained its share of the market. However, with the decline in prices in 1998, the decline in OPEC's spare capacity, and the low growth of non-OPEC supply, Saudi Arabia gained greater power in the oil markets. 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 to 2011.

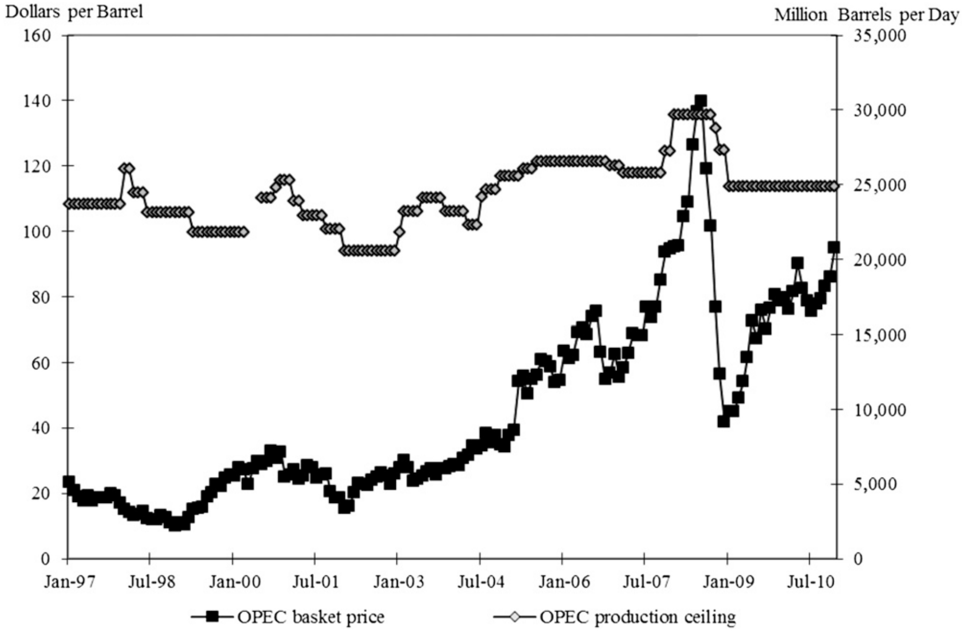
OPEC Decisions on Production, 1997-2011

In December 1997, OPEC increased its quota by 2.5 million b/d (10 percent) to 27.5 million b/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 drop in oil prices. In response, OPEC cut its quotas by 1.25 million b/d in April and another 1.335 million b/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 million b/d in April. Between early 1998 and the middle of 1999, OPEC output dropped by approximately 3 million b/d, and the price rose above $25 per barrel. With a growing economy in the United States 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 million b/d. OPEC increased its quota again by 500,000 million b/d on November 1, 2000. In 2001, a weakened U.S. economy and increases in non-OPEC production imposed downward pressure on oil prices. In response, OPEC performed several reductions and cut 3.5 million b/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 million b/d and was joined by several non-OPEC producers, including Russia. The prices increased to $25, and OPEC increased its quotas by 2.8 million b/d in January and February of 2003. On March 19, 2003, the United States commenced military action in Iraq. Because of its improving economy, the U.S. demand for oil continued to increase and Asian demand for crude oil grew at a rapid pace. Figure 1 provides a snapshot of OPEC production ceilings and basket oil prices.

Several factors affected the price of oil in 2003. The loss of production capacity in Iraq, the cuts in Venezuelan output because of domestic problems, and the increased OPEC production to meet growing international demand all led to a decline in excess production capacity below 2 million b/d. Starting in 2004, oil demand from developing countries, especially China, increased sharply and the developed 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 output by 1 million b/d by January 1 because the price of the OPEC basket was in the $30-per-barrel range. For much of 2004 and 2005, the spare capacity was under 1 million b/d; that level is insufficient 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 1
ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC): PRICE OF OPEC BASKET AND PRODUCTION CEILING, JANUARY 1997 TO NOVEMBER 2011
(OPEC basket priced in U.S. dollars per barrel on left axis; oil production ceiling in million barrels per day on right axis)



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

In July 2008, oil prices peaked at over $145 a barrel for West Texas intermediate (WTI) oil. However, the prices eventually declined, a trend that could not be offset by the strong growth in demand for oil in China, the Middle East, and Asia in light of the huge drop in OECD oil demand. In September, OPEC agreed to cut its production by 4.2 million b/d after oil prices declined dramatically to below $40 per barrel.

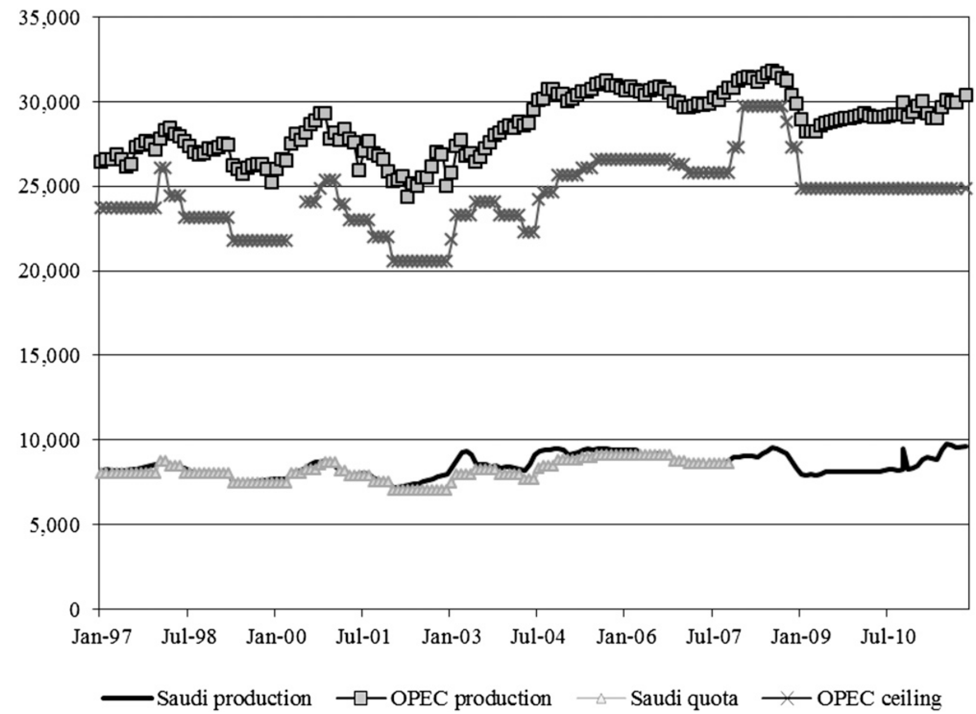
In 2009 and 2010, OPEC left its production target unchanged. The prices reached an average of $63 a barrel in 2009 and increased in 2010 to reach an average of $80. On December 14, 2011, the 160th OPEC Conference decided to maintain the current production level of 30 million b/d, including production from Libya now and in the future. Moreover, at that conference the members agreed that

they would take steps, if necessary, including voluntary downward adjustments of output, to ensure market balance and reasonable price levels; the WTI price reached an average of $94 per barrel in 2011. Figure 2 provides a historical overview of production levels and quotas for OPEC, Saudi Arabia, and the other country members during the time period of this study.

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

Figure 2
ACTUAL PRODUCTION FOR SAUDI ARABIA AND OTHER MEMBERS OF THE ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC) AND SAUDI QUOTA AND TOTAL QUOTAS FOR OTHER OPEC MEMBERS, JANUARY 1997 TO NOVEMBER 2011
(in million barrels per day)



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, non-OPEC output, 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 profits 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, it aims to maintain a stable oil price to keep oil competitive over the long term, to preserve its initiative in OPEC's pricing objectives, and to 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 output 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 through 2011, Saudi Arabia was a member of an organization—OPEC—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 also can 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 the "swing producer model," we used

the relation between Saudi Arabia's output 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 output of the other producers increased, that of Saudi Arabia 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 liftings 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 U.S. invasion of Iraq in 2003. However, when the price of oil was pressured to decline to a level that would affect the Saudi economy, the country 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 1997-2011. 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 P^M. However, it was not concerned about the absolute value but rather the proportionate difference. Thus, the objective function is

$$(P^T/P^M) = 1,$$

where the difference between both prices is equal to zero.

If the demand for OPEC oil was high, then $(P^T/P^M) < 1$, and Saudi Arabia would increase its output.

If the demand for OPEC oil was low, then $(P^T/P^M) > 1$, and Saudi Arabia would decrease its production.

This function is constrained by the following factors. (a) One constraint is Saudi Arabia's spare production capacity, which is calculated at 2.2 million barrels b/d out of a production capacity of approximately 12.0 million b/d. In 2009, Saudi oil production was 9,759,690 b/d, which constituted 11.56 percent of the world's total oil output.[20] (b) In 2009, the total OPEC oil supply was 33,872,000 b/d—which constituted 40.13 percent of the 84,388,900 b/d produced by the global oil market.[21] In 2009, Saudi Arabia operated as a swing producer. (c) In 2008, the world's total petroleum consumption was approximately 171.80 quadrillion British thermal units (Btu's), which was equivalent to about 35 percent of the world's total energy consumption of 492.59 quadrillion Btu's.[22]

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

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

However, Saudi Arabia is a member of OPEC, so its production also is 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 reserves and the extraction cost. However, according to other oil market theories, Saudi Arabia's output also was 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:

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

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 output data from six sources (i.e., *Petroleum Argus*, *Petroleum Intelligence Weekly* [PIW], Platt's *Oilgram Price Report*, the 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 shall rely on the data provided by the OPEC secretariat for the period analyzed by our study.

The market price: The OPEC Reference Basket (ORB) price will be used.[23]

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 per barrel.

In June 2000, the OPEC members established a mechanism to adjust the supply of oil by 500,000 barrels per day 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 through June 2003, the midpoint for the price band of $22 to $28 per barrel was $25 a barrel. The price band eroded in subsequent years as oil prices continued to rise to more than $50 per barrel.

From April to June 2004, OPEC (excluding Iraq) announced an agreement to reduce its actual production levels by 1 million b/d by January 1. Table 1 provides an overview of production quotas and prices over this period. Because the price of the OPEC basket was in the range of $30 per barrel, this decision signaled that OPEC's implicit price target was above $30 as the price increased to above the $30-per-barrel production ceiling.

In 2006, crude prices declined from approximately $76 per barrel in August toward $55 in October. In response, OPEC cut its production by approximately 1.5 million b/d in November 2006 and again in February 2007 by around 500,000 b/d such that the target price for that period was above $70 per barrel. When the price was $80 per barrel in October 2007, the organization increased its production level by 1.5 million b/d, which was effective as of November 1, 2007. Table 2 outlines the price and production quotas during this time span.

From April 2003 to February 2005, the price of oil was $35 a barrel; OPEC used its basket as the target price. From March 2005 to November 2006, the organization took

Table 1

THE BASKET PRİCE OF THE ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC), SAUDI OIL PRODUCTION, AND OPEC OIL PRODUCTION, FEBRUARY 2004 TO AUGUST 2004

Month	OPEC Basket Price (U.S. dollars per barrel)	Saudi Production Quota (thousands of barrels per day)	OPEC Production Ceiling (thousands of barrels per day)
Feb. 2004	28.49	7,963	23,230
Mar. 2004	30.77	7,963	23,230
Apr. 2004	31.69	7,638	22,282
May 2004	34.65	7,638	22,282
June 2004	33.58	7,638	22,282
July 2004	34.70	8,288	24,178
Aug. 2004	38.22	8,450	24,653

Source: Organization of the Petroleum Exporting Countries (OPEC), Secretariat.

Table 2
THE BASKET PRİCE OF THE ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC), SAUDI OIL PRODUCTION, AND OPEC OIL PRODUCTION, JULY 2006 TO DECEMBER 2007

Month	OPEC Basket Price (U.S. dollars per barrel)	Saudi Production Quota (thousands of barrels per day)	OPEC Production Ceiling (thousands of barrels per day)
July 2006	74.13	9,099	26,549
Aug. 2006	75.42	9,099	26,549
Sept. 2006	63.32	9,099	26,549
Oct. 2006	54.87	9,099	26,549
Nov. 2006	56.93	8,719	26,300
Dec. 2006	62.55	8,719	26,300
Jan. 2007	55.39	8,719	26,300
Feb. 2007	58.44	8,561	25,800
Mar. 2007	62.83	8,561	25,800
Apr. 2007	68.74	8,561	25,800
May 2007	68.12	8,561	25,800
June 2007	68.41	8,561	25,800
July 2007	76.88	8,561	25,800
Aug. 2007	73.67	8,561	25,800
Sept. 2007	76.98	8,561	25,800
Oct. 2007	84.96	8,561	25,800
Nov. 2007	93.64		27,253
Dec. 2007	94.53		27,253

Source: Organization of the Petroleum Exporting Countries (OPEC), Secretariat.

$50 a barrel as the target price. From December 2006 to December 2007, the target price was $75 a barrel. From 2008 to 2011, OPEC used the price of $75 a barrel, as announced by Saudi King Abdullah in November 2008.[24] In December 2009, the organization gave the strongest indication yet that it intended to keep oil prices in the $70- to $80-per-barrel range to support the global economic recovery. Figure 3 provides an overview of Saudi oil production and OPEC basket prices for the period of our study.

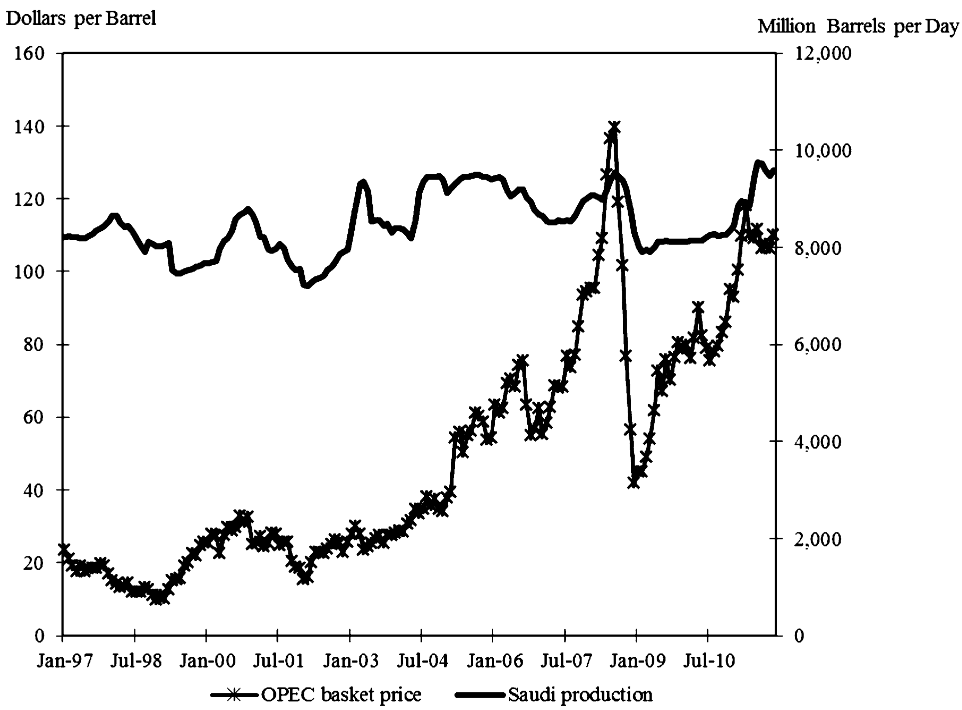
Method of Analysis

The swing producer equation that will be estimated in this study is calculated as follows:

$$ln Q_t^{SA} = \beta_0 + \beta_1 \, ln Q_t^{OO} + \beta_2 \, ln P^{TM} + u_t. \tag{1}$$

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

Figure 3
SAUDI ARABIA CRUDE OIL PRODUCTION AND BASKET PRICES OF THE ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC), JANUARY 1997 TO NOVEMBER 2011
(OPEC basket priced in U.S. dollars per barrel on left axis; Saudi Arabia crude oil production in million barrels per day on right axis)



policy from January 1997 to December 2011, we test the swing producer model by imposing the following restrictions. If the swing producer role $\beta_2 \neq 0$, 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 production will increase to lower the ratio. If the ratio P^{TM} increases ($P^T > P^M$), then Saudi output will drop 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 that Saudi Arabia acts as the swing producer within the organization.

To examine the long-run relationship between Saudi production levels and those of its determinants (oil price and the output of other OPEC members), we employ the autoregressive distributed lag (ARDL), and we test the null hypothesis of no cointegration against the existence of a long-run relationship.[25] 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, 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:

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

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

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

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:

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

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

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

The F-test has a non-standard distribution, which depends upon, first, whether variables included in the ARDL model are I(0) or I(1), second, the number of regressors, and, third, whether the ARDL model contains an intercept and or a trend. Two sets of critical values are reported in H. Pesaran and B. Pesaran.[26] 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-percent, 95-percent, or 99-percent 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 Schwarz Bayesian criteria (SBC). Second, the selected model is estimated by the ordinary least squares technique. Equation (1) shown above is estimated using the following ARDL (*m*, *n*, *p*) model:

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

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

$$\begin{aligned} \Delta ln\, Q_t^{SA} = \alpha_0 + \sum_{i=1}^{k=4} \alpha_1 \, \Delta ln\, Q_{t-1}^{SA} + \sum_{i=0}^{k=4} \alpha_2 \, \Delta ln\, Q_{t-1}^{OO} + \sum_{i=0}^{k=k} \alpha_3 \, \Delta ln\, P_{t-1}^{TM} \\ + \lambda_1 \, ln Q_{t-1}^{SA} + \lambda_2 ln\, Q_{t-1}^{OO} + \lambda_3 \, ln p_{t-1}^{TM} + e \end{aligned} \tag{4}$$

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

$$\begin{aligned} ECM_{it} = Q_t^{SA} - \beta_0 - \sum_{p=1}^{m} \beta_1 \, Q_{t-p}^{SA} - \sum_{p=0}^{n} \beta_2 \, Q_{t-p}^{OO} \\ - \sum_{p=0}^{p} \beta_2 \, p_{it-p} \end{aligned} \tag{5}$$

Here Δ is the first difference operator, α's 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 1997-2011. To test the null hypothesis of no cointegration, we must decide the order of lags on the first-differenced variables. The augmented Dickey-Fuller (ADF) test 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 (PP) test.

The lag numbers are shown in the brackets and CV represents the critical values at a 5-percent level of significance. Table 3 shows the results of both the ADF and PP tests for the level and the difference series on constant only and constant and trend. The number of lags included in the estimation is to eliminate the possibility of autocorrelation of residuals. The lag number is determined according to the minimum value of the Akaike information criterion (AIC). The

Table 3
UNIT ROOT TEST RESULTS[a]

Variable	Intercept Only				Intercept and Trend			
	Level		First Difference		Level		First Difference	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP
CV	–2.8776	–2.8776	–2.8778	–2.8777	–3.4352	–3.4352	–3.4355	–3.4354
$LQ^{SA}(1)$	–2.5130	–2.1218	–8.0709		–2.9929	–2.5438	–8.0657	–7.9825
$LQ^{OO}(1)$	–2.3382	–2.3127	–11.9951	–14.3507	–2.9323	–2.6501	–11.9755	–14.3250
LP(1)	–2.5494	–3.0590	–11.9316	–11.9244	–3.2643	–3.8067	–11.4845	–11.9029

[a]ADF = adjusted Dickey Fuller test; PP = Philip-Perron test; CV = critical values at the 5-percent level of significance.

results indicate that the null hypothesis of non-stationarity (of unit root) at level cannot be rejected for the log of Q^{SA} and log of Q^{OO} variables at a 5-percent level of significance, which casts doubts on the validity of the OLS results. However, for the log of the ratio of the target to spot oil prices, we cannot accept the null hypothesis of non-stationarity by the PP test; thus, 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 a 5-percent level of significance. The results are presented in table 3. It appears that the two variables are integrated of order one.

In the first step of estimating equation (3), equations (2a) to (2c) are estimated to examine the long-run relationship. For the maximum order of lags in the ARDL, we choose one and use the Schwarz Bayesian criterion to select the appropriate lags. The estimation is conducted for the period from January 1997 through December 2011. The calculated F-statistics are reported in table 4.

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 $lQ_t^{SA}/lQ_t^{OO}, lP = 7.3331$ is higher than the upper-bound critical value 4.8619 at the 5-percent level. Thus, the null hypotheses of no cointegration is rejected at the 5-percent level. The calculated F-statistics for $lQ_t^{OO}/lQ_t^{SA}, lP = 4.2976$ also is lower than the upper-bound critical value 4.8619 at the 5-percent level. However, it is higher than 4.1221 at the 10-percent level. Thus, the null hypotheses of no cointegration is accepted at the 5-percent level but is rejected at the 10-percent level.

Table 4
F-STATISTICS FOR THE COINTEGRATION RELATIONSHIP

	F-Value	**Critical Value Bounds of the F-Statistics with Intercept and No Trend (k = 1)**			
		95-Percent Lower Bound	**95-Percent Upper Bound**	**90-Percent Lower Bound**	**90-Percent Upper Bound**
$lQ_t^{SA}/lQ_t^{OO}, lP$	7.3331	3.8403	4.9036	3.1936	4.1221
$lQ_t^{OO}/lQ_t^{SA}, lP$	4.2976				
$lP/lQ_t^{OO}/lQ_t^{SA}$	4.5007				

Source: Critical value bounds are from H. Pesaran and B. Pesaran, *Microfit 5.0: Interactive Econometric Analysis* (Oxford: Oxford University Press, 2010).

For price as the dependent variable, the calculated F-statistic $lP/lQ_t^{OO}/lQ_t^{SA} =$ 4.5007 also is lower than the upper-bound critical value 4.9036 at the 5-percent level. However, it is higher than 4.1221 at the 10-percent level. Thus, the null hypotheses of no cointegration is accepted at the 5-percent level but is rejected at the 10-percent level. Thus, at the 5-percent level the results are implying long-run cointegration relationships among the variables when the regressions are normalized on lQ^{SA} variables (table 4). This indicates that the theory of Saudi Arabia as a swing producer is stronger than that 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 Saudi production in the long run, are reported in equation (6). The estimated long-run coefficients using the ARDL approach ARDL(1,1,0) selected based on Schwarz Bayesian criterion can be written as:

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

$$ln Q_t^{SA} = 11.55 - 0.25 ln Q_t^{OO} - 0.46 ln P^{TM} + u_t. \quad (6)$$

$$t\text{-}value\ 4.25[0.007] - 0.58[0.557] - 2.92[0.004]$$

If a swing producer role $\beta_3 \neq 0$, 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 output 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 organization.

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 equation (6). As expected, the coefficient of the other OPEC members is negative and the coefficient of the difference between the target price and the market price also is negative.

Table 5 presents the estimates of the error-correction representation selected by the adjusted R^2, AIC, and SBC. We used the long-run coefficients reported in equation (6) to generate the error-correction terms. The adjusted R^2 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 cointegration results provided by the F-test.

Using the long-run coefficient estimates from equation (3), we form the error-correction term *ECM*. After replacing the lagged level variables with ECM_{t-1}, we recalculate the model at the same optimum lags used on the cointegration test. Table 5 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 includes the long- and short-run elasticities.

Table 5

ERROR-CORRECTION REPRESENTATION USING THE AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) APPROACH ARDL(1,0,1) SELECTED BASED ON SCHWARZ BAYESIAN CRITERION

	Dependent Variable is $\Delta ln\, Q_t^{SA}$	
	Coefficient	**T-Value**
$\Delta ln\, Q_{t-1}^{SA}$	0.42	5.53[000]
Δlp_{t-1}^{TM}	–0.01	–0.98[0.327]
Δlp_{t-2}^{TM}	–0.03	–2.84[0.005]
ΔlQ_{t-1}^{OO}	–0.04	–0.65[0.510]
ΔlQ_{t-2}^{OO}	–0.11	–1.52[0.130]
ECM_{t-1}	–0.03	–2.42[0.016]
		$\overline{R^2} = 0.29$
		$F_{5,170} = 15.44[000]$
		$LM = \chi_1^2 = 16.58[0.166]$
		$RESET = \chi_1^2 = 0.78[0.374]$

Table 6
ELASTICITIES OF PRODUCTION OF NON-SAUDI MEMBERS OF THE ORGANIZATON OF THE PETROLEUM EXPORTING COUNTRIES AND PRICE

	Production of Other Members	**Price**
Long-run elasticity	–0.42	–0.46
Short-run elasticity	–0.11	–0.04

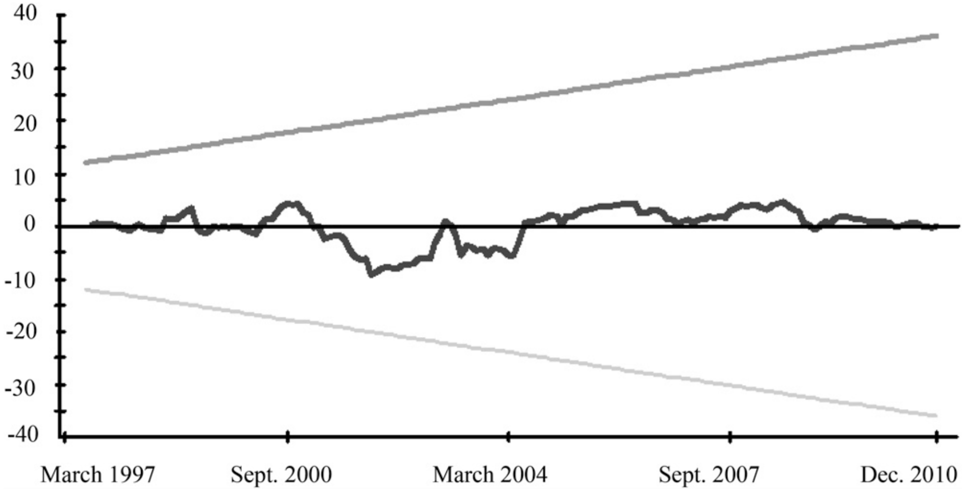
Finally, we examine the stability of the long-run coefficients together with the short-run dynamics. In doing so, we follow H. Pesaran and B. Pesaran and apply the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of the squares of the recursive residuals (CUSUMSQ) tests, both of which were proposed by R. Brown, J. Durbin, and M. Evans.[27] 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 R. Brown, J. Durbin, and M. Evans), 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 4 shows a graphical representation of the CUSUM plot, while figure 5 depicts the CUSUMSQ plot, which is applied to the error-correction model selected by the adjusted-R^2 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 CUSUMSQ 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 to 2008, which suggests significant changes during this time period.

Concluding Remarks

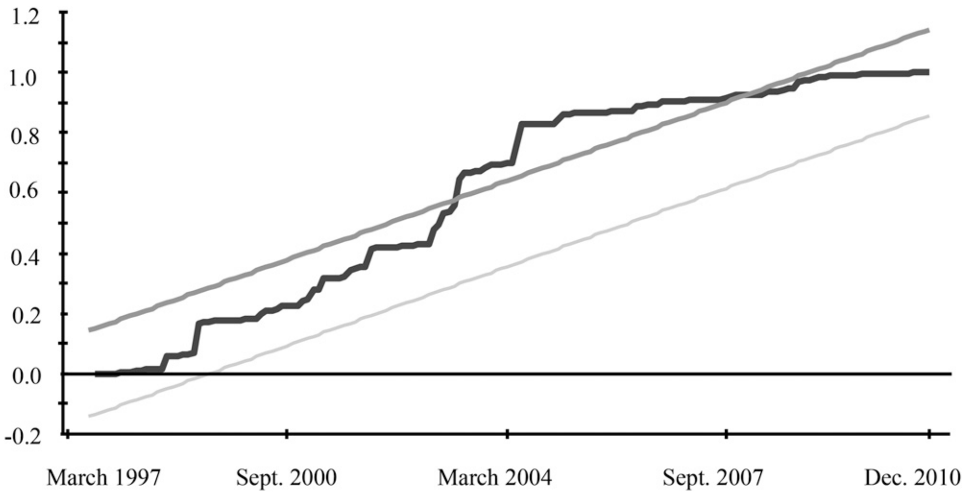
We examined the role played by Saudi Arabia in the oil market with monthly data over the period from January 1997 to December 2011. By applying a relatively new cointegration technique, we were able to identify a long-run relationship among Saudi oil production, the other OPEC members' output, and the 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 that

Figure 4
PLOT OF CUMULATIVE SUM OF RECURSIVE RESIDUALS FOR COEFFICIENT STABILITY
(straight lines represent critical bounds at the 5-percent significance level)



support the suggestion that Saudi Arabia changed 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 fills the role of a swing producer because it changed its output levels to maintain stable oil prices.

Figure 5
PLOT OF CUMULATIVE SUM OF SQUARES OF RECURSIVE RESIDUALS FOR COEFFICIENT STABILITY
(straight lines represent critical bounds at the 5-percent significance level)



NOTES

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[21]Crude oil, natural gas plant liquids (NGPLs), and other liquids.

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[23]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 that includes 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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