

**Modelling Saudi Arabia Behaviour  
in the World Oil Market 1976-1996**

By

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ABSTRACT

The importance of Saudi Arabia as a large producer of oil can be ignored. In the seventies, OPEC determined the price of Arabian Light as a reference and the members of OPEC set the price of their oil, selling as much as they wanted, while Saudi Arabia was able to maintain its role as the residual supplier and acted as the swing producer adjusting its output to stabilize the price of oil. However, the expansion of non-OPEC supply and other factors influencing the world oil market in the eighties led Saudi Arabia to adopt the role of market sharing producer. Two models are tested using Cointegration analysis (Johansen procedures) and appropriate time series of oil price and product data are used.

## **1.Introduction**

The importance of Saudi Arabia as a large producer of oil can not be ignored. Adelman (1982) Mabro (1975, 1991) Stevens (1982, 1991) have drawn attention to its role. In my discussion with Stevens (1996), he stated his views that Saudi Arabia was acting as a swing producer for the period 1975-1986, when it changed its output in order to influence the price of oil. Mabro applied the dominant producer theory to the oil market with Saudi Arabia acting as the Stackelberg price leader. In the seventies, OPEC determined the price of Arabian Light as a reference and the members of OPEC set the price of their oil, selling as much as they wanted, while Saudi Arabia was able to maintain its role as the residual supplier because of its lower absorptive capacity. However, the expansion of non-OPEC supply in the eighties caused the demand for OPEC oil to decline, and when the demand became less than the aggregate volume, which could be, produced excess capacity increased, causing difficulties in maintaining prices. In 1982 the organisation started allocating output under a quota system.

Cremer and Salehi-Isfahni (1991) in their review of world oil market models analysed the role of Saudi Arabia as the dominant firm. Saudi Arabia has significant market power in the short run but in the long run, the influence of its production is small because the world demand and supply of the fringe are more elastic. The elasticity of demand facing Saudi Arabia should be very small to bring about a significant effect. This depends on its share of the market and the elasticity of world demand and the supply of the competitive fringe (world - Saudi Arabia). Saudi's share of the world oil market ranged from a high of 17.5 % in 1981 to a low of 6 % in 1985 and its share of OPEC from a high of 44.2% in 1980 to a low of 20.9% in 1985.

A review of Saudi Arabia's oil policy in different periods indicates that, as a major player of OPEC between 1973 and 1978 Saudi Arabia supported the organisation, but, nonetheless did not want the price of oil to rise high enough to cause any damage to the world oil market. During the period 1978-1981 Saudi Arabia increased its output to the maximum sustainable capacity, to prevent any price increase as a result of economic and political factors and to avoid further shocks to the world oil market. It was in its own interest in the long run to keep prices stable. From 1982-

1985 Saudi Arabia continued to act as a Swing producer to maintain OPEC price levels, producing below its capacity for four years. By 1985, after a long and costly period of production cutbacks, resulting in the need for short-term revenue, Saudi Arabia abandoned the swing producer position and requested other producers (OPEC or non-OPEC) to co-operate with it.

However, following the price collapse in 1986, the oil market has changed from what it was during the time of administered prices (1973-1985) to the time of market-related prices (1987- present). This is the result of many major structural changes in the world oil market. We can summarise such changes as follows: first, oil's share in the world energy mix declined from 55% in 1974 to 41% in 1995.<sup>1</sup> The relationship between economic growth and oil/ energy use weakened and in 1982-1985 the relation was even negative on the demand side, as a result of either efficiency gains or energy consumption regulation. Today, the industrialised world uses 40% less oil to generate the same unit of real GNP that they produced two decades ago.<sup>2</sup>

On the supply side major changes were underway as well. While OPEC's production constituted more than 54 % of the world oil supply in 1973, it decreased to 30 % in 1986 and recovered to 41 % in 1994. The share of the world's oil production supplied by Saudi Arabia, the largest producer of oil, reached a high of more than 17% in 1981 to decline to 6% in 1986 and accounted for an average of 13.5 % in 1996. Production from new areas such as Alaska, the North Sea and new formations in Latin America and Africa increased the non-OPEC supply dramatically from 25 MMBD in January 1974 to 35.9 MMBD in January 1995.<sup>3</sup>

Financial development, worldwide telecommunications and technological advancement since the early eighties have overtaken the oil market. Today, the paper oils market, whether forward, futures, options or derivatives, along with its speculative, aspects, influences the oil market as much as oil companies or OPEC conferences.

Saudi Arabia as an oil producer has been facing the challenge of responding to world oil market realities. It has done this since 1987 by making oil prices market oriented, using formula prices with a factor

adjustable to the prices of other leading oil indicators. It is trying to follow a market share model where the objective of its policy is to maintain a market share. Thus since 1987 Saudi Arabia has acted as a large producer who is concerned with output. According to Lambertini (1996) the demand function can affect firms' ability to collude. The cartel stability can continue only if they act as quantity setters rather than price setters. According to Lambertini (1996), "As the number of firms tends to infinity, Cournot behaviour is preferable to Bertrand behaviour in order to stabilise collusion".

We can say that during the first period Saudi Arabia followed a swing producer strategy, adjusting output so as to stabilise price. After 1986, it abandoned the role of swing producer and adopted instead a role of market sharing producer.

This study is divided into 4 section. Following this introduction, section 2, discussions of the swing producer and market-sharing model is provided. In Section 3, Oil Data are discussed. In Section 4, descriptive and testing of the properties of the data are also provided. A major part of this section is devoted to discussion of Cointegration analysis and results of diagnostics tests are reported. Section 5 provides the result of testing the Swing producer, estimating the Swing producer and market sharing models. In Section 5, the study is concluded with summary of findings.

## **2.The Models of the Study:**

The above discussion points out clearly that Saudi Arabia followed swing producer during the period 1975-1985. Also, it shows that the role of market sharing is adopted for the period 1986-1996.

### **2.1 The Swing Producer Model (1975-1986)**

Saudi Arabia can adjust its production to changes in world oil demand, non-OPEC production and other OPEC members' production. The fringe members would adjust their market share according to their marginal costs; including the user cost while Saudi Arabia's market share would fall when the demand for OPEC decreased and would rise when the demand increased. Assuming that Saudi Arabia is the residual supplier:

$$Q_t^{SA} = Q_t^W - (Q_t^{NO} + Q_t^{OO}) \quad 1$$

Where  $Q^W$  is world demand,  $Q^{NO}$  is the non-OPEC supply and  $Q^{OO}$  is other members of production. Saudi Arabia can be considered in the swing producer model as the price maker in the oil market, and other members of OPEC and non-OPEC suppliers, the competitive fringe. Being the residual supplier, Saudi Arabia is the Stackelberg leader that maximises its profit by choosing an optimal production path, taking into consideration the reaction of the fringe to its policies, where as the competitive fringe takes prices as given.

**Saudi Arabian objectives of a stable oil price are:**

To keep oil competitive over the long term since Saudi Arabia has a high reserve/output ratio.

To keep its share in the market as a low cost producer.

To maintain the initiative in OPEC pricing decisions and asserts its power in the market.

**Saudi Arabian policies to achieve these objectives are :**

Resisting attempts by other producers to raise the price as witnessed in, 1975,1977,1979 and beyond.

Selling at official set prices and using volume control to ascertain such periods.

Increasing output to keep spot prices lower (1977 and 1979-1981) and reducing it to maintain stable oil prices (1975, 1982-1985).

Maintaining its market share at reasonable levels despite an increase in non-OPEC production (1994-1997).

This model seems to fit the behaviour of Saudi Arabia at various times in the history of the oil market. During 1975-1982 it varied its production to achieve its price objectives and to fill the gap of supply shortfalls resulting from the Iranian revolution and the Iran-Iraq war. Between 1982 and 1985 Saudi Arabia officially undertook the swing producer role when it agreed with the OPEC quota system to vary its production in order to balance the market. Although that role was only one episode and Saudi Arabia did not take a quota, it continued swinging its production in 1975, 1978, 1979 and 1981. In the 1987-1997 period, Saudi Arabia abandoned the Swing producer role and insisted on protecting its market share (AbdelAziz Al-Saud 1997). Some believe, like the former

Saudi Minister of Petroleum, that it is still performing the swing producer role<sup>5</sup>..

Therefore, Saudi Arabia can be described during the period 1975-1986 as a member of a cartel that exercised its power by assigning a price and producing the quantity necessary to maintain that price so as to satisfy its objective of keeping the oil price at a stable level. Accordingly it can also be described as a price leader who sets the price which others take as given. The price leadership model is solved as follows: Saudi Arabia  $Q^{SA}$  (production of Saudi Arabia) is a price leader with other OPEC members  $Q^{OPEC}$  (OPEC production) and the non-OPEC supplier constituting the competitive fringe  $Q^{No}$  (Production of non-OPEC producer). The oil market is assumed to be composed of Saudi Arabia as a price-setting leader and a competitive fringe, which is, composed of the other members of OPEC and non-OPEC producers.

In this study, to test for the Swing producer Model the relation between Saudi production and the production of other OPEC members was used to maintain the price level. When the difference between the official price ( $P^{SA}$ ) and the market price ( $P^M$ ) increased Saudi Arabia would increase or decrease its production to lower the gap between the official oil price in either direction. Therefore, if the production of others increased Saudi Arabia's production would decrease and the converse was usually true.

However, the main objective for swinging its production was to influence the OPEC official price of oil which was used by Saudi Arabia to sell its oil while other members of OPEC were more influenced by spot oil prices. Saudi Arabia increased its production to stabilise the price of oil at times when there was a shortage resulting in an increase in price. It would increase its output to offset the influence of the shortage

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<sup>5</sup> During an interview in Decembe1996 with ex-Petroleum Minister, Zaki Yamani, he stated that he believed Saudi Arabia to be a swing producer by definition and not only did it exercise the swing role in the 1982-1985 period but even prior to that, and continues until today. The 1975 downward production swing and the 1979-1981 and 1990-1991 periods of upward production swing are examples. And today, he said, Saudi Arabia swings its production by keeping it constant while others in OPEC increase theirs. Saudi Arabia objects to any increase in oil price, explained Yamani, because "Oil prices should not be raised in a way which would reduce demand for oil and as a consequence weaken the OPEC position." This agrees with the idea that Saudi Arabia was trying to keep the oil prices stable.

of oil supply, as happened during the Iranian revolution and the Iran/Iraq war. However when there was pressure on the price of oil to decline to a level that would affect the Saudi economy, Saudi Arabia tried to keep higher oil prices by decreasing its output level. Such was the case in the early eighties. Therefore, the difference between spot oil prices  $P^M$  and the official OPEC oil prices  $P^{SA}$ , should be included in the equation for the period 1975-1985. For that period Saudi Arabia was concerned about price stability. Since OPEC used a price setting strategy, and Saudi Arabia followed that price (the price of the marker Arabian Light API 34<sup>0</sup>). Saudi Arabia did not just defend that price, it manipulated its production in order to minimise the difference between the official price  $P^{SA}$  and the market price  $P^M$ . However, it was not concerned about the absolute value, it was concerned about the proportionate difference.

For the period 1975-1986, the objective function of Saudi Arabia in the world oil market was to minimise the difference between the spot price  $P^M$  and the official price of OPEC or Saudi Arabia  $P^{SA}$ . Thus, the objective function is

$$\left( \frac{P_t^{SA}}{P_t^M} \right) = 1 \quad \text{keeping the difference between both prices equal to zero}$$

If the demand were high for OPEC oil  $\left( \frac{P_t^{SA}}{P_t^M} \right) < 1$  Saudi Arabia would increase its output.

If demand were low for OPEC oil  $\left( \frac{P_t^{SA}}{P_t^M} \right) > 1$  Saudi Arabia would decrease its output.

This function is under several constraints

1- The production capacity of Saudi Arabia which is:

$$2.2 \text{ MMBD} \leq \text{production capacity} \leq 10.5 \text{ MMBD}$$

2- The OPEC supply should constitute at least 40% of the market for Saudi Arabia to work as swing producer.

Oil share from consumption should be at least 50% of total world energy.

Using the notation  $P_t^{SM} = \left( \frac{P_t^{SA}}{P_t^M} \right)$  the function will be

$$Q_t^{SA} = f_1(P_t^{SM}) \quad 2$$

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

$$Q_t^{SA} = f_2(Q_t^{OPEC})$$
$$Q_t^{OPEC} = (Q_t^{OO} + Q_t^{SA})$$

Thus, by substituting the values of Saudi and OPEC production and combining with equation 5.2, we can arrive at the following equation

$$Q_t^{SA} = f(Q_t^{OO}, P_t^{SM}) \quad 3$$

It is reasonable to assume that  $Q^{SA}$  is a function of the price level as well as other factors (using the above models) 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 factors such as the level of its financial needs. In the absence of reliable data on the extraction cost and reserves, one is forced to disregard their effects. Therefore, we can say that Saudi output is a function of production of other countries and of the ratio of official and spot oil prices.

## **2.2 .Market-Sharing Model (1987-1996)**

Since 1987 and in the absence of a binding agreement to restrict output, Saudi Arabia and other members of OPEC have been involved in a repeated game between quantity-setting producers, with Saudi Arabia acting as a Stackelberg leader and others as followers. Saudi Arabia wants to operate at the point on the other producers' reaction curve where it has the output that yields the largest possible profits. In 1982, OPEC adopted output rationing, but did not abandon price fixing. However by 1987, Saudi Arabia had led the other members of OPEC to determine output without specifying a fixed price<sup>6</sup>. This confirm that Saudi Arabia act as Stackelberg leader. The model is actually a two-stage model in which Saudi Arabia gets to move first, before other producers can

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<sup>6</sup> According to Minister Hisham Nazer (1997) within OPEC Saudi Arabia assigns a quantity of production and other members of OPEC take it as given.

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choose their own optimal level of output. Given Saudi Arabia's output, the rest of the OPEC producers want to maximise their profit,  $[P(Q^{SA} + Q^{OPEC}) Q^{OPEC} - \text{Cost}]$ . According to the Stackelberg leadership model, Saudi Arabia wants to determine its level of output in anticipation of the response of the other members.

The objective function of Saudi Arabia the period 1987-1996, with price no longer set up by OPEC, and given the factors discussed above is to determine the output level that maximises its revenue. Therefore, the equation for testing for the period 1987-1996 is as follows:

$$Q_t^{SA} = j(Q_t^{OO}, P_t^M) \quad 4$$

Griffin (1985), Dahl and Yucel (1991), Al-Turki (1994), ), Al-Yousef. Dahl and Yucel (1991), Griffin and Neilson (1994), and Gulen (1996) tested this model. However, this study will tested the model for a different period 1986-1996 using monthly data while all others used a quarterly data. Also this study tested the properties of the time series thoroughly and used the most recent econometric procedures such as Johansen procedures. While for others, use of classical econometric procedures such as OLS (see Griffin 1985), Dynamic models such Koyc (See Al-Turki 1994) and test for Cointegration while determining the long run-relationship such as),), Dahl and Yucel (1991), Griffin and Neilson (1994), and Gulen (1996).

#### **Variable and data of the study**

The variables of the study are Saudi's monthly crude oil production  $Q^{SA}$ , other OPEC members' production  $Q^{OO}$ , the Saudi selling price  $P^{SA}$ , and the market oil price  $P^M$ . The period of the study witnessed changes in the world oil market in terms of oil supply interruptions as well as structural changes, which have affected the production profiles. The oil market can be divided into different sub-periods with dummy variables used to indicate sub-periods along the. We divide the data into two periods:

$D_t=1$  for 1978.11 - 1982.02, 1990.8 -1991.2

$D_t=0$ , for 1976.3 - 1978.10, 1982.03 - 1990.7, 1991.3 - 1995.8.

The dummy variables are designed to account for the impact of unexpected political events on the oil market. The Iranian revolution occurred in October of 1978 and led to oil supply interruption was followed by a substantial increase in spot oil prices. Also, the start of the Iraq/Iran War in October 1980 caused a sharp increase in oil spot prices. By March 1982, the influence of such events was diminished. In August 1990,

Kuwait was invaded by Iraq leading to the Gulf war in January 1991 which continued until the end of February 1991.

**Oil Prices Data**

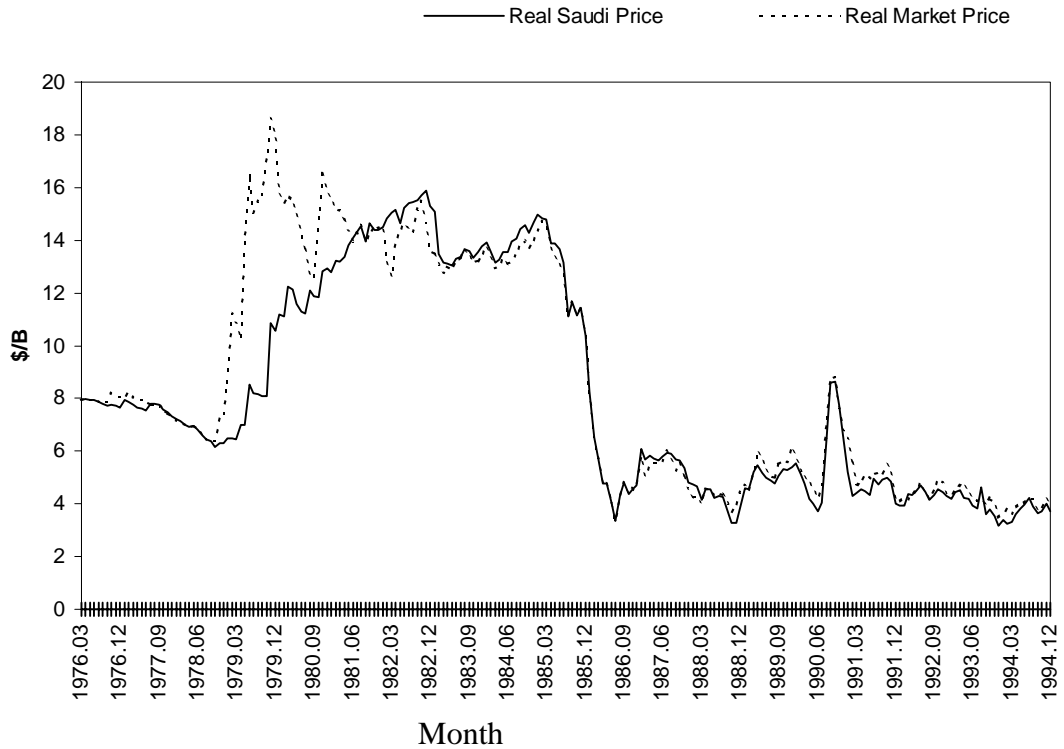
The first time series is the Saudi selling price. There are two important issues to be considered in the selection of crude oil price series. First, crude oil is classified into various types and qualities on the basis of its specific gravity. Consequently, there are as many prices as there are types of crude. Associated with this is the fact that there are different price series according to quantity, location and length of contract for each type of crude oil. Saudi Arabia used the OPEC reference price for its crude during the period from 1974 to July 1985 and we will be using the OPEC official price of the Marker (Arabian Light 34<sup>0</sup>) as the Saudi price P<sup>SA</sup>, throughout the period, while for market price, we will use the Arabian Light spot prices, which started to be reported in March 1976, the data when we start.

For the period of August 1985 to December 1986, Saudi Arabia used the netback price. The netback price of Arabian Light will be obtained from The international Crude Oil and Product Prices.<sup>4</sup> For the period January 1987 to July 1987 Saudi Arabia reverted to the official selling price, so we will be using the official selling price of Arabian Light. Starting from August 1987, when the price is pegged to Brent (Europe), WTI (North America) and Dubai/Oman for the Far East. The simple average price of Arabian Light 34<sup>0</sup> derived from these formulas will be used from Platt's assessment. The source of the price data is the OPEC Secretariat.

**Table: 1 Crude Oil Prices Data for the Swing Producer Model**

Period	Saudi Arabia Selling Oil Price (P <sup>SA</sup> )	Market Oil Price (P <sup>M</sup> )
Jan. 1974.- Jul. 1985	Official Price of OPEC Arabian Light API 34 <sup>0</sup>	Spot Price Arabian Light API 34 <sup>0</sup>
Aug.1985-Dec 1986.	Crude oil netback values Basis NW Europe/ARA port of Shipment	Crude oil netback values Basis NW Europe/ARA port of Shipment
January 1987- July 1987.	Official selling price of Arabian Light	Official selling price of Arabian Light
August 1987- December 1996.	Arabian Light price derived from formulas will be used from Platt's assessment.	

**Figure 1: Saudi Selling and Market Oil Price (1976.3-1994.12)**

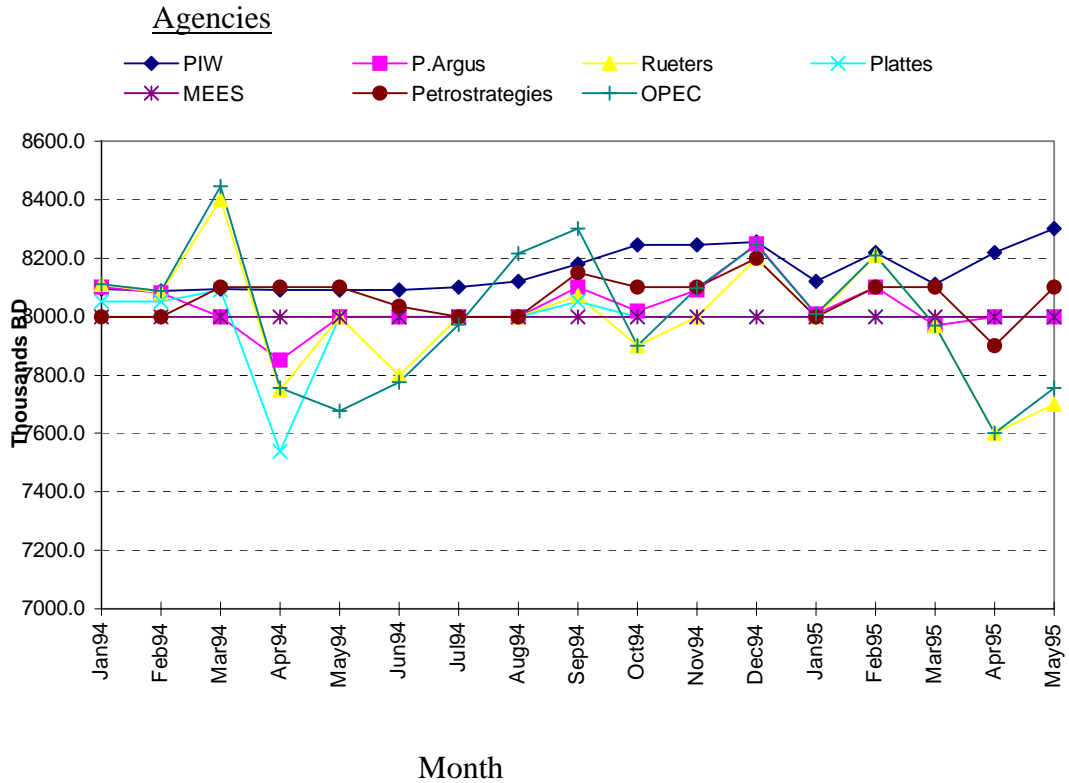


The figure above provided the movement of oil prices used by the study. It shows that the oil prices were high during the period 1979:3 – 1985:12 . The prices used by the study as follow; for the period 1974-1985, the Arabian Light spot price was the market price used (see table 1). For the period August 1985 to June 1987 Saudi Arabia was using netback pricing, so there was no difference between the selling price and the market price.

**Table 2: Crude Oil Production Data.**

Period	Production Data
Jan. 1974 - Feb. 1982	Direct Communication.
March 1982-Dec. 1996	Average of the six agencies that report oil production data

**Figure 2:** Saudi Arabia's Crude Oil Production as Reported by OPEC and the Six

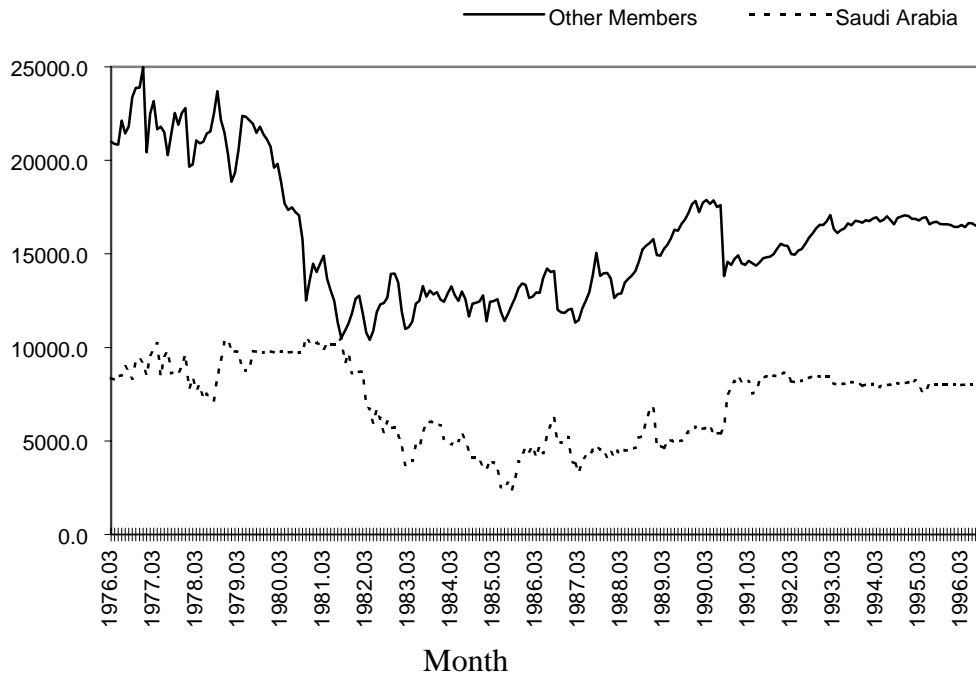


#### 4.2 Production Data

For production there is the problem of using different production series when the reporting of production differs from one source to another (see Figure 2). Thus, for the period 1975-March 1982, with OPEC members reporting to OPEC on the production with no concern over quotas, direct communication to OPEC can be relied on. In the period from March 1982, the use of quotas led to different methods of reporting by OPEC members. This was as because some countries were exceeding their quotas by manipulating the production/ domestic consumption system to report lower numbers. In recent years the OPEC secretariat and the ministerial meetings relied more on production data from six sources (Petroleum Argus, Reuters, Petroleum Intelligence Weekly (PIW), Platt's Oilgram Price Report, International energy Agency (IEA), Middle East Economic Survey (MEES), Petrostrategies,

taking a simple average of the estimation of those sources of OPEC members actual production. We will rely on this data for that period.

**Figure 3:** Saudi Arabia and Other Members of OPEC's Monthly Oil Production (Thousands Barrel per Day).



## 5 The Properties of the Time Series

The three time series to be considered here are; the log of the monthly crude oil production for Saudi Arabia  $Q^{SA}$ , log of the production for other members of OPEC  $Q^{OO}$ , and log of the market price  $P^M$ ; observed from 1976-1997.

### 5.1 Descriptive data:

Tables 3 and 4 show descriptive statistics of Saudi oil production, production of other members of OPEC and market oil prices, Table 3, covers the period from 1976.3 to 1986.12 and Table 4 covers the period 1987.1 to 1997.5.

**Table 3: Descriptive Statistics for the Variables of the Study for the Period 1976:3 to 1986:12**

	Mean	SD	Minimum	Maximum
Saudi production	7259.30	2421.5	2340.0	10533.3
Other members	16147.0	4435.1	10408.7	24978.3
Nominal Saudi Selling Price	22.73	08.76	08.99	34.00
Nominal Market Price	24.44	09.53	08.99	41.31
Difference	-01.71	04.86	-20.00	-5.53

**Table 4: Descriptive Statistics for the Variables of the Study for the period 1987:to 1997.5**

	Mean	SD	Minimum	Maximum
Saudi production	7032.3	1626.0	3277.50	8664.2
Other members of OPEC	15943.93	1648.36	11327.50	19014.50
Price	17.36	3.63	11.92	34.56

The study covers the period from 1976-1996. During the 1976-1986, all data fluctuate at high rate, from high of \$34/B of 1979 to low prices of 1986 \$8/B (see Figure 1). Between 1987-1996, prices were fluctuating around a mean \$ 17.36/B. Saudi oil production mean was above 7 MBBD for both periods. While production of others was higher for the first period.

**5.2 Test for Seasonality:**

To obtain a first and tentative impression of the amount of seasonal variation, Franses (1996) suggested the use of the approach advocated in Miron (1994). The method amounts to the regression of the first order difference variables on the 12 seasonal dummies

$$\Delta_1 y_t = \delta_1 D_{1t} + \delta_2 D_{2t} + \delta_3 D_{3t} + \dots + \delta_{12} D_{12t} + u_t \quad 5$$

where  $u_t$  is some error process. By using  $R^2$  for the regression and the estimate of the coefficient  $\delta_i$ , assuming the filter  $\Delta_1$  is sufficient to remove the stochastic trend from the time series, and that the seasonal dummies are sufficient to describe seasonality. These assumptions may be debatable (see e.g., Hylleberg et al 1990), therefore I follow the suggestion of Franses (1996,b) concerning the use of a tentative model framework that can give some indication of the amount of seasonal

variation in a monthly time series. Franses used  $R^2$  and divided the sample to sub-samples and compared the estimates of the coefficients  $\delta_{..}$ .

**Table 5: Estimation Results from the Regression**

$\Delta y_t = \delta_1 D_{1,s} + \delta_2 D_{2,s} + \delta_3 D_{3,s} + \delta_4 D_{4,s} + \delta_5 D_{5,s} + \delta_6 D_{6,s} + \delta_7 D_{7,s} + \delta_8 D_{8,s} + \delta_9 D_{9,s} + \delta_{10} D_{10,s} + \delta_{11} D_{11,s} + \delta_{12} D_{12,s}$  where  $D_{t,s}$  ( $s = 1, 2, 3, \dots, 12$ ) are Seasonal Dummies.

	Sample	$R^2$	$\delta_1$	$\delta_2$	$\delta_3$	$\delta_4$	$\delta_5$	$\delta_6$	$\delta_7$	$\delta_8$	$\delta_9$	$\delta_{10}$	$\delta_{11}$	$\delta_{12}$
lnQ <sup>SA</sup>	76-97	0.13	-.07	.01	-.04	.01	.03	.03	.03	.01	.01	.04	.01	.01
	76-86	0.16	-.06	.01	-.04	.00	.05	.04	.03	.03	.00	.05	.01	-.00
	87-97	0.18	-.06	.00	-.02	.01	.00	.01	.01	.02	.03	.02	.01	.02
lnQ <sup>O</sup>	76-97	0.11	-.05	.01	.00	.00	.01	.01	.00	.00	.01	.01	.01	.00
	76-86	0.19	-.07	.01	.00	.01	.01	.01	.01	.00	.02	.01	.01	.00
	87-97	0.06	-.02	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00
lnP <sup>M</sup>	76-97	0.06	-.01	.01	-.03	.01	-.02	-.00	.03	.01	.02	.01	.02	-.02
	76-86	0.08	-.02	.01	-.02	.00	.02	.00	-.02	.01	.00	.02	.02	-.02
	87-97	0.07	.00	.00	-.03	.00	.01	.00	.02	.02	.02	.01	.02	-.04

The estimated  $R^2$  value tentatively indicates the amount of variation in time series accounted for by seasonality (see Table 5). For the three time series,  $R^2$  ranges from 6% to about 19%, which indicates that the seasonality effect is too small. Further tentative observations from the results for the coefficients  $\delta_i$ , show that  $\delta_i$  seems constant over time. So we conclude that the time series does not have any deterministic seasonality.

The rejection of the presence of deterministic seasonal effect does not mean there is no presence of non-stationary stochastic seasonality due to seasonal unit roots. It is the ‘non-stationary’ due to seasonal unit roots that raises the most troubling statistical issues. So we first proceed with a test for the presence of seasonal unit root. In order to test hypotheses about various unit roots, one estimates equation 8.1 with additional lags of  $y_{12}$  lags to whiten the errors.

$$\Delta_{12} y_t = \sum_{i=1}^{12} \alpha_i D_i + \sum_{i=1}^{12} \beta_i y_{i,t-1} + \sum_{i=1}^k \varphi_i \Delta_{12} y_{t-1} + \varepsilon_t \quad 6$$

The equation is estimated by OLS. For a 5% significant level, the critical value for monthly data, provided in Beaulieu and Miron (1993).

For a time series with 240 observations, the critical values are for  $\pi_1$ , is equal to -2.76,  $\pi_2$  is equal to -2.76, and for odd coefficients is equal to -3.25 and even coefficients is equal to -1.85. The hypothesis tested is  $\phi=0$ , ( $\phi$  consists of the coefficients  $\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7, \pi_8, \pi_9, \pi_{10}, \pi_{11}$  and,  $\pi_{12}$ ). (see Table, 6)

**Table 6: Results of Tests for Seasonal Unit Roots in Monthly Time Series (1976.3-1997.5) for the log of the Variables  $Q^{SA} Q^{OO} P^M$**

Variables	$\pi_1$	$\pi_2$	$\pi_3$	$\pi_4$	$\pi_5$	$\pi_6$	$\pi_7$	$\pi_8$	$\pi_9$	$\pi_{10}$	$\pi_{11}$	$\pi_{12}$
$\ln Q^{SA}$	5.3	5.6	1.0	.24	3.1	1.9	.14	2.6	5.2	.25	3.6	1.8
$\ln Q^{OO}$	4.7	5.0	1.7	1.6	3.4	0.7	7.4	9.4	2.8	5.9	2.2	7.4
$\ln P^M$	0.7	4.2	2.9	.46	.01	4.7	1.5	8.9	1.3	9.3	2.7	4.0

With F-statistic for the three time series  $F(23,226)= 109.37$  for  $Q^{SA}$ ,  $F((23,202)= 85.59$  for  $Q^{OO}$  and  $F(23,198) = 189.77$  for  $P^M$ . Since the null is two dimensional, the F-statistics for the joint null for the coefficient for  $(\pi_5, \pi_6)$   $(\pi_7, \pi_8)$   $(\pi_9, \pi_{10})$  and  $(\pi_{11}, \pi_{12})$  are computed and reported in Table 7 which provide strong evidence against seasonal unit roots. The 5% critical value for the F-test (with intercept, seasonal dummies and no trends) is 6.25.

**Table 7 : Results of Tests for Seasonal Unit Roots in Monthly Time Series (1976.3-1997.5) for the log of the Variables  $Q^{SA} Q^{OO} P^M$  Using the F- statistic for the Joint Null for the Coefficients.**

Variable	F for $\pi_5, \pi_6$	F for $\pi_7, \pi_8$	F for $\pi_9, \pi_{10}$	F for $\pi_{11}, \pi_{12}$
$\ln Q^{SA}$	7.61	33.80	13.8	9.01
$\ln Q^{OO}$	6.04	78.40	18.54	30.85
$\ln P^M$	9.41	46.26	48.85	8.80

Table 6 and 7 present the results, applying HEGY (1990) test procedures, for the Saudi crude oil production, production of other members of OPEC and the market price of oil. The definition of each series is given in appendix 1. The estimation equations include a constant, seasonal dummies and lags of the dependent variable. We allow for seasonal dummies in all tests, because the loss of power that results from inclusion when unnecessary is significant compared to the bias that results from their omission when necessary (Franses 1996a). The value of the

coefficients and the F-test statistic are reported in Tables 6 and 7. Lag length is determined using a test for serial correlation of residuals which is reported in Table 8

**Table 8: Test for Serial Correlation of Residuals.**

Variables	LR $\chi^2(1)$ [p-value]	F statistic [p-value]
$\ln Q^{SA}$	.0.6263 [.429]	$F_{1,225} = 0.565$ [.453]
$\ln Q^{OO}$	0.617 [.432]	$F_{1,197} = .549$ [.459]
$\ln P^M$	1.004 [.316]	$F_{1,197} = .895$ [.345]

We generally reject seasonal unit roots at the 5% level at all seasonal frequencies using the t-test Table (6) and compare its value with critical value reported by Beaulieu and Miron (1993). We reject the null hypothesis of zero for most of the coefficients  $\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7, \pi_8, \pi_9, \pi_{10}, \pi_{11}$ , and  $\pi_{12}$  and we reject the joint null for the coefficients  $(\pi_5, \pi_6), (\pi_7, \pi_8), (\pi_9, \pi_{10})$  and  $(\pi_{11}, \pi_{12})$ . The data on Saudi production rejects unit roots less often than those for other members of OPEC, where for  $Q^{SA}$ , they fail to reject zero coefficients for  $\pi_3, \pi_4, \pi_6, \pi_7$ . While for  $Q^{OO}$  we fail to reject for only one coefficient  $\pi_6$ . For  $P^M$  we fail to reject zero coefficients for  $\pi_1, \pi_4, \pi_5, \pi_7, \pi_9$ . However, they were all rejected by the joint hypothesis test.

To summarise, for most series we reject unit roots (seasonality unit roots), and there is no series for which we fail to reject unit roots for at least eight of the frequencies. The strongest evidence for seasonal units is in Saudi production, and price, but even in this case we reject more often than not at the 5% level. Generally we reject the hypothesis of unit roots for the three time series and we proceed accepting the hypothesis of no seasonality effect.

### Tests for Stationarity and Unit Root

In this section, the time series properties of data used in the study will be examined. The Augmented Dickey-Fuller (ADF) tests and Phillips-Perron Test (PP) will be applied to the time series employed in the study:  $Q^{SA}, Q^{OO}, P^{SM}$  and  $P^M$ . Unit root tests with trend and without time trend using equation (7.8) and (7.9) from chapter 7 are applied. All test equations include a constant. The Akaike information criterion, Schwarz Bayesian criterion, and Hannan-Quinn criterion are used to determine the

log order for the ADF test to guarantee white noise for the disturbance of the equations.

**Table 9: Tests for Stationarity for the Time Series for the Period 1976:3-1986:12**

Variable (lag order)	Without Trend		Variable (lag order)	With Trend	
95% critical values	-2.87 PP(1)	-2.87 ADF		-3.45 PP	-3.45 ADF
$\ln Q^{SA}(1)$	-1.32	-1.40	$\ln Q^{SA}(2)$	-2.39	-2.36
$\ln O^{OO}(1)$	-1.31	-1.77	$\ln O^{OO}(1)$	-1.31	-2.29
$\ln P^{SA}(1)$	-0.23	-0.45	$\ln P^{SA}(1)$	-0.41	0.15
$\ln P^M(1)$	-0.49	-0.89	$\ln P^M(1)$	-0.23	-0.65
$\ln(P^{SM})(0)$	-1.85	-1.92	$\ln(P^{SM})(0)$	-2.07	-2.24

**Table 10: Test for Stationarity for the Time Series for the Period 1987:1-1995.8**

Variable (lag order)	Without Trend		Variable (lag order)	With Trend	
95% critical values	-2.87 PP	-2.87 ADF		-3.43 PP	-3.45 ADF
$\ln Q^{SA}(3)$	-2.16	-1.10	$\ln Q^{SA}(3)$	-2.03	-2.48
$\ln O^{OO}(0)$	-2.87	-2.54	$\ln O^{OO}(0)$	-2.09	-2.63
$\ln P^M(2)$	-2.99	-3.08	$\ln P^M(1)$	-3.11	-5.16

### The Dickey Fuller Test

The test statistic suggested by Dickey Fuller (1979) is used to test the null hypothesis of the presence of unit root (non-stationarity) for all the relevant variables. The results of the ADF tests are reported in Tables 9 and 10 along with their 95% critical values which are taken from Fuller (1976). It follows that the null hypothesis of a unit root, for Saudi Arabia's production and for the level of oil production of others, cannot be rejected for both periods. It also can not be rejected for the Saudi Price, market price and the difference of prices for the first period. However for the crude oil price  $P^M$  (1987-1995.8) the price time series is stationary and we reject the null hypothesis of unit root. Almost all test statistics were higher than the critical value, where the critical value is -2.87 without a time trend and -3.43 with a time trend. Therefore, it is concluded that all time series

included in the study are non-stationary in levels except the price of oil variable for the period (1987-1995.8).

## 2. Phillips-Perron Test

When time series contain one or more time breaks, and a break consists of one or more changes in the level and or in the slope of the trend function, Phillips-Perron suggested that it might influence the test of stationarity. By taking this into account the PP test is used in testing for the presence of unit roots in levels of all variables included in the study and the results are reported in Tables 11 and 12. It follows that the null hypothesis of a unit root cannot be rejected for the level of production for Saudi Arabia, the production of other countries, and the real price at the 5% significant level, which confirms the ADF results of the test.

**Table 11 Test for the Degree of Integration 1976:3-1986.12:**

Variable (lag order)	Without Trend		Variable (lag order)	With Trend	
95% critical values	-2.89	-2.89		-3.43	-3.43
	PP	ADF		PP	ADF
$\Delta \ln Q^{SA}(0)$	-11.69	-11.00	$\Delta \ln Q^{SA}(0)$	-	-10.96
$\Delta \ln O^{OO}(0)$	-10.60	-9.20	$\Delta \ln O^{OO}(1)$	-	-9.17
$\Delta \ln P^{SA}(1)$	-9.30	-6.24	$\Delta \ln P^{SA}(1)$	-9.64	-6.52
$\Delta \ln P^M(1)$	-8.40	-7.71	$\Delta \ln P^M(1)$	-8.66	-8.07
$\Delta \ln(P^{SM})(2)$	-11.35	-4.65	$\Delta \ln(P^{SM})(2)$	11.35	-4.70

**Table 12: Test for the Degree of Integration 1987:1-1995.8**

Variable (lag order)	Without Trend		Variable (lag order)	With Trend	
95% critical values	-2.89	-2.89		-3.43	-3.43
	PP	ADF		PP(1)	ADF(1)
$\Delta \ln Q^{SA}(2)$	-10.68	-06.92	$\Delta \ln Q^{SA}(2)$	-	-6.88
$\Delta \ln O^{OO}(0)$	-12.14	-10.76	$\Delta \ln O^{OO}(0)$	-	-10.77
$\Delta \ln P^M(1)$	-08.07	-07.36	$\Delta \ln P^M(1)$	-	-7.35
				08.06	

### 5.3.3 Test for Degree of Integration

Variables to be included in the VAR model, should all be integrated of the same order. Since the degree of integration is the number of times the variable is differentiated to induce stationarity, the ADF and PP tests are used, to test for stationarity of the first difference:

$$\Delta^2 X_t = \delta_0 + \delta_1 T + \delta_2 \Delta X_t + \sum_{i=1}^p \gamma_i \Delta^2 X_{t-i} + \varepsilon_t \quad 7$$

Where  $\Delta^2 X_{t-1} = \Delta X_t - \Delta X_{t-1}$

Both ADF and PP tests are used for comparing the computed statistics given in Table 11 and 12. The critical values used are from Dickey and Fuller (1981) and Fuller (1976). The tests firmly reject the null hypothesis of a unit root in the first difference of the time series.

Therefore, it is concluded that the time series included in the two periods are integrated of order one Saudi oil production  $\ln Q^{SA} \sim I(1)$ , production of others  $\ln Q^{OO} \sim I(1)$ , and the ratio of prices  $\ln(P^{SM}) \sim I(1)$ . The crude oil price series for the period 1987-1995.8 is integrated of order 0,  $P^M \sim I(0)$  and is stationary in level. So we can proceed to do the Cointegration tests.

### The Multivariate Cointegration Model

Having specified the variables included in the model, the next step is to explain how the equation should be estimated and tested. The focus of attention is on a single equation, but we can not ignore the concept of exogeneity. In a VAR system all variables are treated as endogenous, which leads to the use of the p-dimensional vector auto-regressive model with Gaussian errors

$$X_t = \Gamma_1 X_{t-1} + \dots + \Gamma_k X_{t-k} + \delta D_t + \varepsilon_t \quad 8$$

The variables included in the model are Saudi oil production, production of other members of OPEC and price difference, all expressed in logarithm [ $\ln Q^{SA}$ ,  $\ln Q^{OO}$ ,  $\ln(P^{SM})$ ]. To get the real crude oil prices, the Saudi selling price and the market price are divided by the indices of exchange rate and inflation based January 1972 (source DSD/Statistics Section). The form of (8) will be better understood if we express it as a

three equation model, with Maximum lag of  $p=2$  periods. The equations take the form

$$\ln Q_t^{SA} = \gamma_{11} \ln Q_{t-1}^{SA} + \gamma_{12} \ln Q_{t-1}^{OO} + \gamma_{13} \ln(P_t^{SM})_{t-1} + \delta_{11} \ln Q_{t-2}^{SA} + \delta_{12} \ln Q_{t-2}^{OO} + \delta_{13} \ln(P_t^{SM})_{t-2} + \varepsilon_{1t}$$

$$\ln Q_t^{OO} = \gamma_{21} \ln Q_{t-1}^{SA} + \gamma_{22} \ln Q_{t-1}^{OO} + \gamma_{23} \ln(P_t^{SM})_{t-1} + \delta_{21} \ln Q_{t-2}^{SA} + \delta_{22} \ln Q_{t-2}^{OO} + \delta_{23} \ln(P_t^{SM})_{t-2} + \varepsilon_{2t}$$

$$\ln(P_t^{SM}) = \gamma_{31} \ln Q_{t-1}^{SA} + \gamma_{32} \ln Q_{t-1}^{OO} + \gamma_{33} \ln(P_t^{SM})_{t-1} + \delta_{31} \ln Q_{t-2}^{SA} + \delta_{32} \ln Q_{t-2}^{OO} + \delta_{33} \ln(P_t^{SM})_{t-2} + \varepsilon_{3t}$$

In equation (9) the vectors  $\mathbf{X}$  and  $\boldsymbol{\varepsilon}$  are given by

$$\mathbf{X} = \begin{pmatrix} \ln Q_t^{SA} \\ \ln Q_t^{OO} \\ \ln(P_t^{SM}) \end{pmatrix}, \text{ and } \boldsymbol{\varepsilon}_{it} = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix} \quad 9$$

We notice in (8) each variable in the VAR model depends on all other variables, with exactly the same lags structure applied to each variable; in all equations no current values for any variables appear on the right-hand side of any equation. In fact a VAR can be regarded as the reduced form of a structural model in which no variables are exogenous.

Since the model has more than two variables, it may feature as part of several equilibrium relationships governing the joint evolution of the variables. It is possible for up to  $(n-1)$  linearly independent cointegrating vectors to exist. We can assume that there is only one cointegrating vector. In fact when there are more it leads to inefficiency in the sense that we can only obtain a linear combination of these vectors when estimating a single equation model. However, the drawback of estimating only one equation extends beyond its ability to validly estimate the long-run relationships between the variables, even if there is only one Cointegration relationship, estimating a single equation is potentially inefficient. It is useful to extend the single equation to a multivariate framework by defining a vector  $\mathbf{X} = [\ln Q^{SA}, \ln Q^{OO}, \ln(P^{SM})]$  and allowing all three variables to be potentially endogenous.

For testing the cointegrating relations the Johansen estimation method based on the error correction representation of the vector auto-regressive

(VAR) model is used, as suggested by Johansen (1988,1989), and Johansen and Juselius (1990,1992). The model is reformulated in the error-correction form,

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_k \Delta X_{t-i} + \Pi X_{t-k} + \mu + \delta_1 T + \gamma_1 D_t + \varepsilon_t \quad 10$$

Where  $X$  represents the vector of  $\ln Q^{SA}, \ln Q^{OO}, \ln P^{SM}$ , and  $\Delta X_t$  represent the vector of first differences of the three variables  $\Delta \ln Q^{SA}, \Delta \ln Q^{OO}, \Delta \ln P^{SM}$ . If  $\Pi$  is less than a full rank it can be written as  $\Pi = \alpha \beta'$  where  $\beta'$  represents the coefficients of the cointegrating vector which describes the long-run relationship that links together the three variables, and  $\alpha$  represents the adjustment to the deviation from the long run path which is interpreted as the error correction mechanism.

The hypothesis of Cointegration is formulated as a reduced rank of the matrix  $\Pi$ -matrix

$$H_A(r): \Pi = \alpha \beta'$$

This hypothesis implies that  $\Delta X_t$  is stationary,  $X$  is not stationary, but  $\beta' X$  is stationary (see Johansen 1991). The error correction formulation includes both difference and levels in the same model allowing us to investigate both short-run and long run effects in the data.

**Rank Determination:** That is the number of cointegrating relations. There are two statistics for testing the hypothesis that the cointegrating rank is at most ( $r < k$ ), using the likelihood test for Trace Statistic. The likelihood ratio statistic for the null hypothesis of at most  $r$  cointegrating vectors,

$$-2 \ln(Q) = -T \sum_{j=i+1}^n (1 - \hat{\lambda}_j) \quad 11$$

and the Maximal -eigenvalue of  $\lambda$  - max Statistic as follow

$$-2 \ln(Q) = -T(1 - \hat{\lambda}_{i+1}) \quad 12$$

The null hypothesis in the LR tests is that  $\lambda_{r+1} = \lambda_{r+2} = \dots = \lambda_p = 0$ . The LR ( $N-r$ ) do not follow  $\chi^2$  distribution. Johansen 1989 applies some results of Brownian motion theory and gives the critical values for the distribution of LR( $N-r$ ). The third test is the eigenvalue of the Companion

matrix. By investigating the roots of the companion matrix, where we get the roots describing the dynamic properties of the process. To test the null hypothesis that there are at most  $r$  cointegrating vectors:

$$H_0: \lambda_i = 0 \quad i= 1, 2$$

where we use the test for  $\lambda_1 = \lambda_2 = \lambda_3 = 0$  when the hypothesis is accepted one has the number of unit-roots and thereby the number of cointegrating vectors.

Testing for unique Cointegration vectors: Restriction on  $\beta$  -vector: Following the determination of the number of cointegrating vectors and establishment of the existence of a long-run relationship between the variables, it is necessary to impose restrictions motivated by the economic theory to obtain unique vectors lying within the space, then test whether the columns  $\beta$  are identified. This identification is achieved by placing linear restrictions on the parameters of the cointegrating vector,  $\beta$  coefficient, by Johansen (1992, 1996). This can be tested by using the likelihood ratio (LR) test

$$LR = T \sum_{i=1}^r \ln \frac{(1 - \lambda_i^*)}{(1 - \lambda_i)} \quad 13$$

where  $\lambda_i^*$  are the eigenvalues produced by the restricted vector, and  $\lambda_i$  are the corresponding eigenvalues for the unrestricted estimate. The L statistics follow an asymptotic chi-square distribution with degrees of freedom equal to  $r(n-s)$  where  $n$  is the number of variables and  $s$  is the number of restrictions and  $r$  is the number of vectors.

### **7. Testing The Swing Producer Model For The Period 1976-1986**

The following equation would represent the cointegrating vector, which describes the long-run relationship linking together the three variables.

$$\ln Q^{SA} = \beta_2 \ln Q_t^{OO} + \beta_3 \ln P_t^{SM} + \varepsilon_t \quad 14$$

To describe the Saudi Arabian production policy for the period 1976: 3 to 1986:12, we test the swing producer model by imposing the following restrictions:

For a swing producer role  $\beta_3 \neq 0$ , which means the difference between the Saudi price and the market price has an influence on the Saudi output decision. When the ratio  $P^{SM}$  between  $P^{SA}$  and  $P^M$  decrease ( $P^{SA} < P^M$ ) Saudi Arabia would increase its production to lower  $P^M$ . When the ratio  $P^{SM}$  increases ( $P^{SA} > P^M$ ) Saudi Arabia would decrease its production to increase  $P^M$ .  $\beta_2 \neq 0$  for the model. that is Saudi Arabia has a relationship with the production of other members of OPEC, to prove that we have a cartel behaviour with Saudi Arabia acting as the swing producer.

### **7.1 Specification of the cointegrating VAR Model:**

To choose the optimal lag length we tested down from the general 12 lags system. The Schwarz Bayesian criterion (SBC) and the Akaike information criterion is (AIC) suggesting a different order of VAR. We can choose 2 as the order of the VAR (see appendix 2).

We use the Log-Likelihood ratio statistic for testing zero restrictions of the coefficients of a subset of deterministic/ exogenous variables; for the intercept LR test of restriction  $\chi^2= 5.7365$  [0.125], for the deterministic trend  $\chi^2= 0.962$  [0.810], and for the dummy representing the structural change  $\chi^2=15.11$ [.002]. Therefore, the model for the period 1976-1986 has no intercept, no trend, but has a dummy variable.

The results of the Johansen-Juselius Cointegration tests are presented in Table 13. The trace test, the trace statistic and the eigenvalue (maximum) test indicates also the existence of one relationship, suggesting that there exist one co-integrating relationship.

$$\ln Q_t^{SA} = \beta_2 \ln Q_t^{OO} + \beta_3 \ln(P_t^{SM}) + \varepsilon_t$$

We use the LR test of deletion of deterministic variables in the VAR, is used to test for the presence of intercept  $\mu$ , the result is the LR test of restrictions  $\chi^2(3)= 3.9281$  [.269]. Thus we reject the zero coefficients of the variables, which indicates no presence of intercept.

**Table 13. Cointegration with no Intercepts or Trends in the VAR. Cointegration LR test based on Maximal Eigenvalue and LR Test based on Trace of the Stochastic Matrix. Period 1976:3-1986:12, lags=2**

Eigenvalue	L=Max	Trace	H <sub>0</sub> =r	H <sub>A</sub> =P-r	Critical Value	
					90% 90%Trace	L-Max
.24656	36.22	49.05	0	1	19.02	28.78
.088795	11.60	12.83	1	2	13.98	15.75
.00959	1.22	1.22	2	3	6.50	6.50
.0000						

Table 13 shows Johansen likelihood ratio statistics for determining the number of cointegrating vectors  $r$ , using the maximal eigenvalue test ( $\lambda$ -max test) and the trace test, starting with the null hypothesis of zero cointegrating vector  $r=0$ , followed by tests for  $r \leq 1$ , and  $r \leq 2$ . The  $\lambda$ -max test shows that the hypothesis of zero cointegrating vectors is rejected at the 90 % and 95 % critical value (The source of critical values is Pesaran & Pesaran (Microfit.4, 1997) see also Pesaran, et al (1997)). The results of the trace test confirm the conclusion that there is one cointegrating relationship with respect to the three variables. While the model selection criteria (Table 14) only SBC select one relationship.

**Table 14 Cointegration with no Intercepts and no Trends in the VAR. Choice of the Number of Cointegrating Relations using Model Selection Criteria.**

Rank	Maximised LL	AIC	SBC	HQC
r=0	152.55	140.55	116.16	128.86
r=1	170.66	152.66	122.14	139.08
r=2	176.47	154.47	120.67	140.14
r=3	177.08	153.08	118.88	139.17

Since we accept the existence of the relationship amongst the three variables, we proceed to the next step of the Johansen procedures, which is the estimation of the normalised cointegrating vector.

$$\ln Q_t^{SA} = \beta_2 \ln Q_t^{OO} + \beta_3 \ln(P_t^{SM}) + \varepsilon_t$$

$$\ln Q_t^{SA} = -1.44 \ln Q_t^{OO} - 0.87 \ln(P_t^{SM}) + \varepsilon_t \quad 15$$

The equation 8.11 shows the results from the Johansen ML estimation for the estimates of  $[1, \beta_2, \beta_3]$  which were obtained by normalising the corresponding elements by the coefficient  $\beta_1$  of  $Q^{SA}$  for the cointegrating vector.  $\beta_3$  close to 1 which means that any change in the

ratio of the two prices would be met by 0.87 change in production of Saudi Arabia (elasticity of supply is less than one). We test for  $\beta_3=0$ , the  $\chi^2(1)=23.477[.000]$ . Have we reject the null hypothesis of no relationship between the ratio of prices and the production of Saudi Arabia, we test for  $\beta_2=0$ , the  $\chi^2(1)=32.92[.000]$ . We can reject the null hypothesis of no relationship between the production of others and the production of Saudi Arabia

It is concluded that there is a relationship between  $Q^{SA}$  and  $Q^{OO}$  and  $(P^{SA}/P^M)$  and we say that the swing producer model is applicable to Saudi Arabia for the period (1976-1986), that the production of Saudi Arabia has a relation with the difference in price and with the supply of others. These results indicate that Saudi Arabia was trying to keep the price of oil stable and close to the official price either by increasing production when the market price was high in order to lower prices, or by decreasing production when the market price was low.

The estimated coefficients of errors for  $\ln Q^{SA}$ ,  $\alpha_1=0.009$ ,  $\alpha_2=.001$ ,  $\alpha_3=.001$ , which represents the adjustment to the deviation from the long-run path. The values are too small, suggesting that it would take a long time for the equation to return to its equilibrium once it had been shocked.

## **8. Test The Market-Sharing Model For The Period 1987- 1996**

For the second period 1987:1 to 1995.8 we test for the existence of the relationship between the production of Saudi Arabia and the production of the others and the price of oil using the following equation.

$$\ln Q^{SA} = -\gamma_2 \ln Q_t^{OO} + \gamma_3 \ln P_t^M + \varepsilon_t \quad 16$$

where  $P^M$  is the price of Arabian Light 34<sup>0</sup> API for the period 1987.1-1995.8.

$\gamma_2$  differs according to the type of market share we are investigating; Partial market share means that  $0 < \gamma_2 < 1$  and negative, and  $\gamma_3 \neq 0$ . Constant market share  $\gamma_2 = -1$  and negative, and  $\gamma_3 = 0$ . With  $P^M \sim I(0)$ , we will be testing for the constant market share

### **8.1 Specification of the cointegrating VAR Model:**

To choose the optimal lag length we tested down from the general 12 lags system. The Schwarz Bayesian criterion (SBC) suggests a VAR of order 1, the Akaike information criterion is (AIC) of order 2. We can choose 1 as the order of the VAR (see appendix 2).

We use the Log-Likelihood ratio statistic for testing zero restrictions of the coefficients of a subset of deterministic/ exogenous variables; for the intercept LR test of restriction  $\chi^2= 8.93$  [0.012], for the deterministic trend  $\chi^2= 9.85$  [0.007], and for the dummy representing the structural change  $\chi^2=24.54$ [.000]. Therefore, the model for the period 1987:1-1995:8 cannot reject the presence of intercept, time trend and a dummy variable.

Table 15 shows the Johansen likelihood ratio statistics for determining the number of cointegrating vectors  $r$ , using the maximal eigenvalue test ( $\lambda$ -max test) and the trace test, Table 16 shows the number of cointegration relations using model selection criteria (AIC, SBC and HQC). With the three variables  $Q^{SA}$  and  $Q^{OO}$ . However, with  $P^M \sim I(0)$  as a stationary variable the cointegrating vector includes the Saudi production and other members production. Both the maximum eigenvalue and the trace static suggest  $r=1$ . The hypothesis that  $r=0$  is rejected against  $r=1$ , but the hypothesis that  $r=1$  cannot be rejected against  $r=2$ .

**Table 15 Cointegration with Unrestricted Intercept and Unrestricted Trend in the VAR. Cointegration LR test based on Maximal Eigenvalue and LR test based on Trace of the Stochastic Matrix. Period 1987:1-1995:8 lags=1**

Eigenvalue	L=Max	Trace	$H_0=r$	$H_A=P-r$	Critical value	
					90% L-Max	90%Trace
0.12771	17.72	25.60	0	1	16.28	21.23
0.03942	7.88	7.88	1	2	9.75	9.75

**Table 16 Cointegration with Unrestricted intercept and Unrestricted Tend in the VAR. Choice of the Number of Cointegrating Relations using Model Selection Criteria**

Rank	Maximised LL	AIC	SBC	HQC
$r=0$	349.03	341.03	330.45	336.75
$r=1$	357.89	346.89	332.35	341.00
$r=2$	361.83	349.83	333.97	343.41

Since we accept the existence of the relationship amongst the two variables, with the price, we proceed to the next step of the Johansen procedures which is the estimation of the normalised cointegrating vector.

$$\begin{aligned} \ln Q_t^{SA} &= \mu_1 + \gamma_2 \ln Q_t^{OO} + \varepsilon_t \\ \ln Q_t^{SA} &= -.726 \ln Q_t^{OO} + \varepsilon_t \end{aligned} \quad 17$$

The equation shows the results from the Johansen ML estimation for the estimates of  $[\gamma_2]$  which were obtained by normalising the corresponding elements by the coefficient  $\gamma_1$  of  $Q^{SA}$  for the cointegrating vector. For the production of other members the sign is negative which means that an increase in supply of others means a decrease in the Saudi production.

To explain the model we test for hypothesis  $\gamma_2 = 1$  belongs to the space spanned by the cointegrating vector  $[-1, 1]$ . This means that any change in the production of others would be met by a change in Saudi production with elasticity one  $\chi^2(1) = .144[0.704]$  which indicates that with stationary market prices, the elasticity of Saudi supply in respect to the production of others is one.

The estimated coefficients of errors for  $\ln Q^{SA}$ ,  $\alpha_1 = 0.004$ ,  $\alpha_2 = 0.0009$ . Which represent the adjustment to the deviation from the long-run path. The values are too small suggesting that it would take a long time for the equation to return to its equilibrium once it has been shocked.

## **9. Conclusion**

By dividing the sample into two periods 1976-1986 and 1987-1995, we can test both models for the swing producer role for the first period and for the market-sharing role for the second period. We can say that the swing producer is applicable to Saudi Arabia where the Kingdom changed its production in order to keep stable oil prices. So it increased its production when demand was high for OPEC oil (e.g. 1978.8-1981.8) and decreased its production when the demand was low (1983.3-1985.8). For the second period (1987-1995) where prices of oil became market related with the number of producers in the world oil market increased, Saudi

Arabia acted as a market-sharing producer who was concerned with maintaining its share in the oil market.

## **Notes**

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<sup>1</sup> OECD Economic Outlook and Energy Policies Program of IEA Countries.

<sup>2</sup> OECD Economic Outlook and Energy Policies Program of IEA Countries.

<sup>3</sup> Source: OPEC secretariat.

<sup>4</sup> International Crude Oil and Product Prices, July 1996. Prepared by F. R. Parra Associates in co-operation with Middle East Economic Survey.

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**APPENDIX (1)**

**1 Definition of the Polynomial used in Seasonality Testing**

For seasonal integration in monthly data, The auxiliary regression is augmented by lagged values of the dependent By defining the Polynomial :

$$Y_{1t} = (1+L+L^2+L^3+L^4+L^5+L^6+L^7+L^8+L^9+L^{10}+L^{11})X_t,$$

$$Y_{2t} = (1-L+L^2-L^3+L^4-L^5-L^7+L^8+L^9-L^{10}-L^{11})X_t,$$

$$Y_{3t} = -(L-L^3+L^5-L^7+L^9-L^{11})X_t,$$

$$Y_{4t} = -(1-L^2+L^4-L^6+L^8-L^{10})X_t,$$

$$Y_{5t} = 1/2(1+L-2L^2+L^3+L^4-2L^5+L^6+L^7-2L^8+L^9+L^{10}-2L^{11})X_t,$$

$$Y_{6t} = \frac{\sqrt{3}}{2} (1-L+L^3-L^4+L^6-L^7+L^9-L^{10}+L^{11})X_t,$$

$$Y_{7t} = 1/2 (1-L-2L^2-L^3+L^4+2L^5+L^6-L^7-2L^8-L^9+L^{10}+2L^{11})X_t,$$

$$Y_{8t} = \frac{\sqrt{3}}{2} (1+L-L^3-L^4+L^6+L^7-L^9-L^{10}+L^{11})X_t,$$

$$Y_{9t} = 1/2 (\sqrt{3}-L+L^3-\sqrt{3}L^4+2L^5-\sqrt{3}L^6+L^7-L^9+\sqrt{3}L^{10}-2L^{11})X_t,$$

$$Y_{10t} = 1/2(1-\sqrt{3}L+2L^2-\sqrt{3}L^3+L^4-L^6+\sqrt{3}L^7-2L^8+\sqrt{3}L^9-L^{10})X_t,$$

$$Y_{11t} = 1/2(\sqrt{3}+L-L^3-\sqrt{3}L^4-2L^5-\sqrt{3}L^6-L^7+L^9+\sqrt{3}L^{10}+2L^{11})X_t,$$

$$Y_{12t} = -1/2(1+\sqrt{3}L+2L^2+\sqrt{3}L^3+L^4-L^6-\sqrt{3}L^7-2L^8-\sqrt{3}L^9-L^{10})X_t,$$

$$Y_{13t} = (1-L^{12})X_t,$$

**APPENDIX (2)**

**Selecting the Order of the VAR Model**

1- Based on 118 observations from 1976.3 to 1986.12 Order of VAR = 12

List of variables include in the unrestricted VAR:  $\ln Q^{SA}$ ,  $\ln Q^{OO}$ ,  $\ln(P^{SA}/P^M)$  . with intercept.

Order	LL	AIC	SBC	Adjusted LR test
12	231.92	120.92	-32.84	
11	225.10	123.10	-18.20	$\chi^2(9)= 9.36$ [.404]
10	220.44	127.44	- 1.39	$\chi^2(18)= 15.76$ [.609]
9	216.08	132.08	15.71	$\chi^2(27)= 21.75$ [750]
8	207.37	132.37	28.47	$\chi^2(36)= 33.71$ [.578]
7	199.11	133.11	41.67	$\chi^2(45)= 45.05$ [.470]
6	191.81	134.81	55.84	$\chi^2(54)= 55.07$ [.434]
5	184.54	136.54	70.04	$\chi^2(63)= 65.05$ [.405]
4	175.01	136.01	81.98	$\chi^2(72)= 78.12$ [.290]
3	170.03	140.03	98.47	$\chi^2(81)= 84.96$ [.360]
2	160.76	139.76	110.67	$\chi^2(90)= 97.69$ [.272]
1	152.04	140.04	123.41	$\chi^2(99)= 109.67$ [.218]
0	-548.19	-551.19	-555.34	$\chi^2(108)=1071.00$ [.000]

2- Based on 104 observations from 1987:1 to 1986:12. Order of VAR = 12

List of variables include in the unrestricted VAR:  $\ln Q^{SA}$ ,  $\ln Q^{OO}$ , and  $\ln P^M$ ) as a stationary variable, with intercept.

Order	LL	AIC	SBC	Adjusted LR test
12	425.04	373.04	304.29	
11	422.11	374.11	310.64	$\chi^2(4)= 4.40 [.354]$
10	410.84	366.84	308.67	$\chi^2(8)= 21.30[.006]$
9	407.14	367.14	314.25	$\chi^2(12)= 26.85 [008]$
8	404.41	368.41	320.81	$\chi^2(16)= 30.95 [.014]$
7	395.68	363.68	321.37	$\chi^2(20)= 44.05 [.001]$
6	375.17	347.17	310.15	$\chi^2(24)= 74.80 [.000]$
5	370.15	346.15	314.41	$\chi^2(28)= 82.34[.000]$
4	366.49	346.49	320.05	$\chi^2(32)= 78.83[.000]$
3	358.69	342.69	321.54	$\chi^2(36)= 99.52[.000]$
2	358.06	346.06	330.20	$\chi^2(40)= 100.47[.000]$
1	352.92	344.92	334.34	$\chi^2(44)= 108.19[.000]$
0	-125.97	-129.97	<b>-135.26</b>	$\chi^2(48)= 826.53[.000]$