SEEDS
Surrey Energy Economics
Discussion paper Series

SURREY
ENERGY
ECONOMICS
CENTRE

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

Nourah AbdullRahman Al-Yousef

June 1998

SEEDS 93
ISBN 1852372125

Department of Economics
University of Surrey

SEEC consists of members of the Department of Economics who work on energy and environmental economics. SEEC's aims include the promotion of research and teaching in the broad area of energy economics and policy. SEEC was founded in 1983. Its creation was intended to consolidate the research on energy economics which developed at the University of Surrey after the appointment of Colin Robinson to the Chair of Economics in 1968. Colin and the colleagues he attracted to the University built up Surrey's reputation, initially with pioneering work on North Sea oil and gas, and subsequently in all the other major areas of energy economics.

- Recent research covers the following areas: Electricity, gas and coal privatisation in the UK; privatisation in the Middle East; the structure of UK energy demand; North Sea oil and gas economics and policy: international oil markets; electricity economics; the transport of energy; environmental policy in the UK; energy and environmental policy in the Third World; global environmental issues.

- SEEC research output includes **SEEDS** - **S**urrey **E**nergy **E**conomic **D**iscussion paper **S**eries (recent titles may be found on the backcover), as well as a range of other academic papers, books and monographs including ***SEEC Occasional Papers*** and SEEDS Technical Papers.

- Each year SEEC organises a range of energy conferences and workshops on energy themes. Specialist workshops include the meetings of the the joint SEEC/BIEE **Energy Modelling Group**, convened by David Hawdon and Paul Appleby (BP).

- Members of SEEC provide major inputs into the postgraduate energy courses run by the Economics Department - in particular, the M.Sc. courses on Energy Economics and Energy Policy, and the Diploma in the Economics of Energy and Development for Graduates.

Enquiries:
***Director of SEEC and Editor of SEEDS*:**
David Hawdon *email: d.hawdon@surrey.ac.uk*
Secretary:
Isobel Hildyard *email: i.hildyard@surrey.ac.uk*

SEEC, Economics Dept, School of Human Sciences, University of Surrey, Guildford GU2 5XH, UK.
Telephone: +44 (0)1483 259379 Fax: +44 (0)1483 259548

University of Surrey
Surrey Energy Economics Discussion paper Series
SEEDS 93

Modelling Saudi Arabia Behaviour in the World Oil Market 1976-96

Nourah AbdullRahman Al-Yousef
University of Surrey

ISBN: 1852372125
June 1998

British Library Cataloguing-in-Publication Data.
A Catalogue record for this book is available from the British Library

ASTRACT

The importance of Saudi Arabia as a large producer of oil can not be ignored. In the Seventies, OPEC determined the price of Abrabian 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 stabilise 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 tests (Johansen procedures) and appropriate time series of oil price and product data are used. Each time series is tested for stationarity and seasonality.

1 INTRODUCTION

The importance of Saudi Arabia as a large producer of oil can not be ignored and Adelman (1982) Mabro (1975, 1991) Stevens (1982)(1992) have drawn attention to its role. Stevens (1996), has stated his view 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-Isfahani (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.[1] 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.[2]

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.[3]

Financial development, world wide telecommunications and technological advancement since the early Eighties have overtaken the oil market. Today, the paper oil 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.

2 THE SWING PRODUCER MODEL (1975-1986)

As we have shown, 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 with increasing demand. Assuming that Saudi Arabia is the residual supplier:

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

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, the competitive fringe takes prices as given.

Under the swing producer model, Saudi Arabian objectives include a stable oil price in order:

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

2. To keep its share in the market as a low cost producer.
3. To maintain the initiative in OPEC pricing decisions and assert its power in the market.

Saudi Arabian policies to achieve these objectives are :

1. Resisting attempts by other producers to raise the price, 1975, 1977, 1979 and beyond.
2. Selling at official set prices and using volume control to ascertain such periods.
3. Increasing output to keep spot prices lower (1977 and 1979-1981) and reducing it to maintain stable oil prices (1975, 1982-1985).
4. 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. During my interview in December 1996 with ex-Petroleum Minister, Zaki Yamani, he told me that he believed Saudi Arabia to be a swing producer by definition. He said that 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.

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} is a price leader with other OPEC members Q^{OPEC} and the non-OPEC supplier constituting the competitive fringe Q^{No}. 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 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} (Saudi selling prices), 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 34^0). 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 (the price of the Marker API 34^0) P^{SA}. Thus, the objective function

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

This function is under several constraints

1- The production capacity of (C) Saudi Arabia which was 2.2 MMBD $\leq$ C $\leq$ 10.5 MMBD

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

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

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

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

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

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

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 2, we can arrive at the following equation

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

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.

3 MARKET-SHARING MODEL (1987-1996)

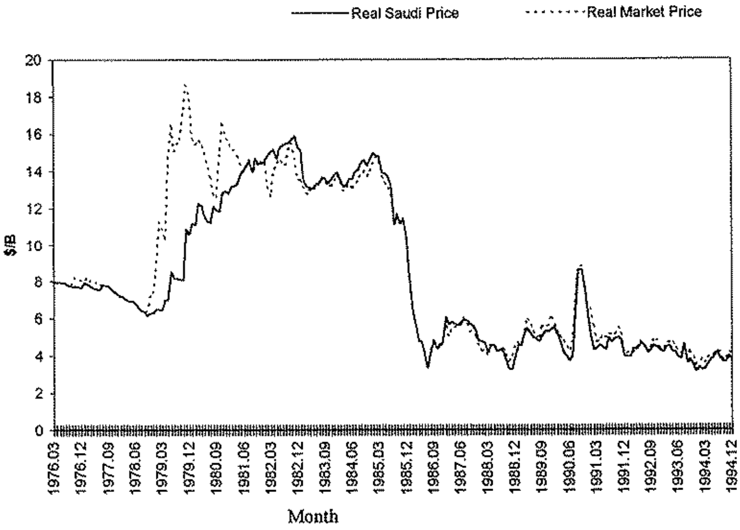
Since 1987 and in the absence of a binding agreement to restrict output, Saudi Arabia and other members of OPEC have been involved in a repeated game between quantity-setting producers, with Saudi Arabia acting as a Stackelberg leader and others as followers. Saudi Arabia wants to operate at the point 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. According to Minister Hisham Nazer (1997) within OPEC Saudi Arabia assigns a quantity of production and other members of OPEC take it as given. This suggests that Saudi Arabia acts as Stackelberg leader. The model is actually a two-stage model in which Saudi Arabia gets to move first, before other producers can choose their own optimal level of output. Given Saudi Arabia's output, the rest of the OPEC producers want to maximise their profit, [Price(Q^{SA} + Q^{OPEC}) Q^{OPEC} - 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:

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

This model was tested by Griffin (1985), Dahl and Yucel (1991), Al-Turki (1994), Al-Yousef (1994), Griffin and Neilson (1994), and Gulen (1996).

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



4 OIL PRICES DATA

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. The first time series is the Saudi selling price. Saudi Arabia used the OPEC reference price for its crude during the period from 1974 to July 1985 and I will use the OPEC official price of the Marker (Arabian Light 34^0) as the Saudi price P^{SA}, throughout the period, while for market price, I will use the Arabian Light spot prices, which started to be reported in March 1976.

For the period August 1985 to December 1986, Saudi Arabia used the netback price (see Table 1). The netback price of Arabian Light will be obtained from. The international Crude Oil and Product Prices.[4] 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, the prices are pegged to Brent (Europe), WTI (North America) and Dubai/Oman for the Far East. The simple average price of Arabian Light 34^0 derived from these formulas will be used from Platts assessment. The source of the price data is the OPEC Secretariat.

Table 1: Crude Oil Prices Data For the Swing Producer Model

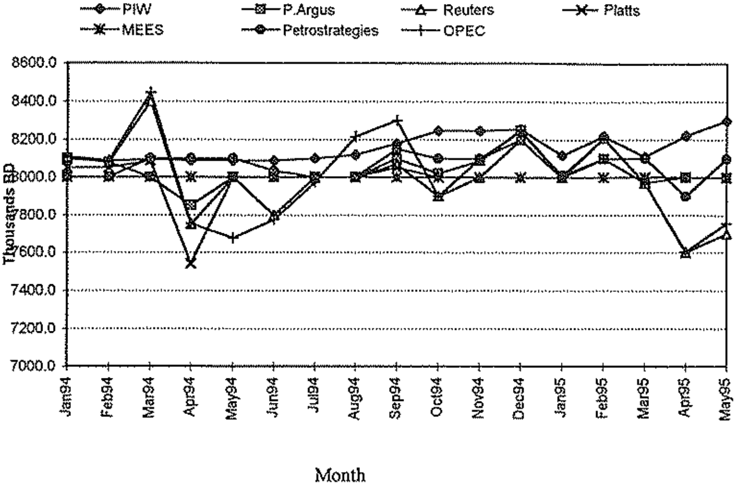
Period	Saudi Arabia Selling Oil Price (P^{SA})	Market Oil Price (P^{M})
Jan. 1974 - Jul. 1985	Official Price of OPEC Arabian Light API 34°	Spot Price Arabian Light API 34°
	Crude oil netback values Basis NW Europe/ARA port of Shipment	Crude oil netback values Basis NW Europe/ARA port of Shipment

For the period 1974-1985, the Arabian Light spot price was the market price used (see Table 2). 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

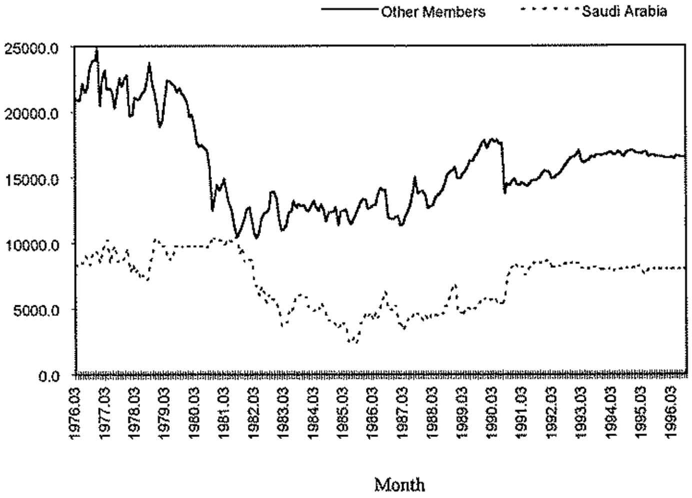
Figure 2: Saudi Arabia's Crude Oil Production as Reported by OPEC and the Six Agencies



5 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 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 (PIW, Petroleum Argus Reuters, Platt's Oilgram Price Report, IEA, CGES), taking a simple average of the estimation of those sources of OPEC members actual production (Figure 3). 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).



6 VARIABLES OF THE STUDY

The variables of the study are Saudi Arabia'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 lines discussed in chapter 4. 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 upset of unexpected political events on the oil market. The Iranian revolution occurred in October of 1978. The Iranian 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.

7 DESCRIPTIVE STATISTICS

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 1987.1 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

8 TESTING 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 1974-1997.

Table 5: Estimation Results from the Regression

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

	Sample	R^2	δ_1	δ_2	δ_3	δ_4	δ_5	δ_6	δ_7	δ_8	δ_9	δ_{10}	δ_{11}	δ_{12}
$\ln Q^{SA}$	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
$\ln Q^{OO}$	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
$\ln P^{M}$	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

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

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

where u_i is some error process. By using R^2 for the regression and the estimate of the coefficient δ_I, assuming the filter Δ_I 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 1993), 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 δ.

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 δ_i, show that δ_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.

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

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 π_1, -2.76, for π_2 -2.76, for odd coefficients -3.25 and for even coefficients -1.85. The hypothesis tested is $\varphi=0$, (φ consists of the coefficients π_1, π_2 , π_3 , π_4 , π_5 , $\pi_{,6}$, π_7,π_8 , π_9, π_{10}, π_{11} and, π_{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	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8	π_9	π_{10}	π_{11}	π_{12}
$\ln Q^{SA}$	-5.3	-5.6	-1.0	-.24	-3.1	1.99	.14	-2.6	-5.2	-.25	3.6	1.8
$\ln Q^{OO}$	4.7	-5.0	-1.7	1.69	3.4	0.70	-7.4	-9.4	-2.83	5.9	2.2	-7.4
$\ln P^M$	0.7	4.26	2.97	-.46	.01	4.72	1.59	-8.9	-1.35	9.33	2.7	-4.0

F-statistic for the three time series are as follows: 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 (π_5, π_6) (π_7, π_8) (π_9, π_{10}) and (π_{11}, π_{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.

Variables	F for $\pi_5 \pi_{,6}$	F for $\pi_7, \pi_{8,}$	F for π_9, π_{10}	F for π_{11}, π_{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 π_1, π_2 ,π_3,π_4,π_5,$\pi_{,6}$,π_7, π_8, π_9, $\pi_{10,}$ π_{11}, and π_{12} and we reject the joint null for the coefficients ($\pi_5\pi_{,6}$) (π_7, π_8),(π_9, π_{10}) and (π_{11}, π_{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 $\pi_{3,}$ $\pi_{4,}$ π_6, $\pi_{7,.}$ While for Q^{OO} we fail to reject for only one coefficient π_6 . For P^M we fail to reject zero coefficients for $\pi_{1,}$ $\pi_{4,}$ π_5 π_7. π_9. However, they were all rejected by the joint hypothesis test.

To summarise, for most series we reject 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.

9 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 the following equation.

$$\Delta y_t = \delta_0 + \delta_1 T + \delta_2 y_{t-1} + \sum_{i=1}^{P} \gamma_i \Delta y_{t-i} + u_t$$

All test equations include a constant. The Akaike information Criterion, Schwarz Baysian 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	-2.87PP(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

9.1 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 price of oil (1987-1995.8)

9.2 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 PP	-2.89 ADF		-3.43 PP	-3.43 ADF
$\Delta \ln Q^{SA}(0)$	-11.69	-11.00	$\Delta \ln Q^{SA}(0)$	-11.69	-10.96
$\Delta \ln O^{OO}(0)$	-10.60	-9.20	$\Delta \ln O^{OO}(1)$	-10.60	-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 PP	-2.89 ADF		-3.43 PP(1)	-3.43 ADF(1)
$\Delta \ln Q^{SA}(2)$	-10.68	-06.92	$\Delta \ln Q^{SA}(2)$	-10.78	-6.88
$\Delta \ln O^{OO}(0)$	-12.14	-10.76	$\Delta \ln O^{OO}(0)$	-12.20	-10.77
$\Delta \ln P^{M}(1)$	-08.07	-07.36	$\Delta \ln P^{M}(1)$	-08.06	-7.35

9.3 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:

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

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}~I(1), production of others lnQ^{OO}~I(1), and the ratio of prices ln(P^{SM})~I(1). The crude oil price series for the period 1987-1995.8 is integrated of order 0, P^{M} ~I (0) and is stationary in level. So we can proceed to do the cointegration tests.

10 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 Gausian errors

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

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 takes the form

$$\ln Q^{SA} = \gamma_{11} \ln Q^{SA}_{t-1} + \gamma_{12} \ln Q^{OO}_{t-1} + \gamma_{13} \ln\left(P^{SM}_t\right)_{t-1} + \delta_{11} \ln Q^{SA}_{t-2} + \delta_{12} \ln Q^{OO}_{t-2} + \delta_{13} \ln\left(P^{SM}_t\right)_{t-2} + \varepsilon_{1t}$$

$$\ln Q^{OO} = \gamma_{21} \ln Q^{SA}_{t-1} + \gamma_{22} \ln Q^{OO}_{t-1} + \gamma_{23} \ln\left(P^{SM}_t\right)_{t-1} + \delta_{21} \ln Q^{SA}_{t-2} + \delta_{22} \ln Q^{OO}_{t-2} + \delta_{23} \ln\left(P^{SM}_t\right)_{t-2} + \varepsilon_{1t}$$

$$\ln\left(P^{SM}_t\right) = \gamma_{31} \ln Q^{SA}_{t-1} + \gamma_{32} \ln Q^{OO}_{t-1} + \gamma_{33} \ln\left(P^{SM}_t\right)_{t-1} + \delta_{31} \ln Q^{SA}_{t-2} + \delta_{32} \ln Q^{OO}_{t-2} + \delta_{33} \ln\left(P^{SM}_t\right)_{t-2} + \varepsilon_{1t}$$

In equation (9) the vectors X and ε are given by

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

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 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) to estimate the equilibrium relationship between the relevant variables. The model is reformulated in the error-correction form,

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

Where X represents the vector of $\ln Q^{SA}, \ln Q^{OO}$ $\ln P^{SM}$, and ΔX_t represent the vector of first differences of the three variables $\Delta \ln Q^{SA}$ $\Delta \ln Q^{OO}$, $\Delta \ln P^{SM}$. If Π 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 α 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 Π-matrix

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

This hypothesis implies that ΔX_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,

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

and the Maximal -eigenvalue of λ - max Statistic as follow

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

The null hypothesis in the LR tests is that $\lambda_{r+1} = \lambda_{r+21} = \lambda_p = 0$ The LR (N-r) do not follow χ^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:

$$H_0{:}\lambda_i = 0 \qquad i = 1, 2$$

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 β -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 β are identified. This identification is achieved by placing linear restrictions on the parameters of the cointegrating vector, β coefficient , by Johansen (1992, 1994) and 1995). This can be tested by using the likelihood ratio (LR) test

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

where λ_i* are the eigenvalues produced by the restricted vector, and λ_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.

11 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.

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

To describe the Saudi Arabian production policy for the period 1976: 3 to 1986:12, we tested 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.

<u>*Specification of the cointegrating VAR Model*:</u> To choose the optimal lag length we tested down from the general 12 lags system. The Schwarz Baysian 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 χ^2= 5.7365 [0.125], for the deterministic trend χ^2= 0.962 [0.810], and for the dummy representing the structural change χ^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 8.11. The trace test, the trace statistic and the eigenvalue (maximum) test indicates also the existence of one relationship, suggesting that there exist one cointegrating relationship.

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

We use the LR test of deletion of deterministic variables in the VAR, is used to test for the presence of intercept μ, 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_0=r	H_A=P-r	Critical Value	
					90% L-Max	90%Trace
.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 (λ-max test) and the trace test, starting with the null hypothesis of zero cointegrating vector r=0, followed by tests for r≤1, and r≤2. The λ-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.

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

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

The equation 15 shows the results from the Johansen ML estimation for the estimates of [1, β_2, β_3] which were obtained by normalising the corresponding elements by the coefficient β_1 of Q^{SA} for the cointegrating vector. β_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 χ^2 (1)= 23.477[.000]. 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 χ^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) it is concluded 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.

12 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.

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

where P^M is the price of Arabian Light 34^0 API for the period 1987.1-1995.8 . γ_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

<u>*Specification of the cointegrating VAR Model:*</u> To choose the optimal lag length we tested down from the general 12 lags system. The Schwarz Baysian 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 χ^2= 8.93 [0.012], for the deterministic trend χ^2= 9.85 [0.007], and for the dummy representing the structural change χ^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 (λ-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} ~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 is stationary we proceed to the next step of the Johansen procedures which is the estimation of the normalised cointegrating vector.

$$\ln Q_t^{SA} = \mu_1 + \gamma_2 \ln Q_t^{OO} + \varepsilon_t$$

$$\ln Q_t^{SA} = -.726 \ln Q_t^{OO} + \varepsilon_t \qquad 17$$

The equation shows the results from the Johansen ML estimation for the estimates of [γ_2,] which were obtained by normalising the corresponding elements by the coefficient γ_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 χ^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}, α_1=0.004, α_2=.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.

13 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 model 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.

ENDNOTES

[1] OECD Economic Outlook and Energy Policies Program of IEA Countries.

[2] OECD Economic Outlook and Energy Policies Program of IEA Countries.

[3] Source: OPEC Secretariat.

[4] International Crude Oil and Product Prices. July 1996. Prepared by F. R. Parra Associates in co-operation with Middle East Economic Survey.

REFERENCES

Al-Turki, S. (1994), 'Autocorrelation in Static Economic Models and their Dynamic Respecifications: an Application to OPEC Behaviour', Journal of King Saud University, Administrative Sciences

Al-Yousef, N. (1994), 'Modelling OPEC Behaviour: an Econometric Analysis', Unpublished Masters Thesis, King Saud University. Riyadh, Saudi Arabia.

Akaike, H. (1973), 'Information Theory and an Extension of the Maximum Likelihood Principle', in B.N, Petrov, F. Caski (eds), 2nd ed. International Symposium Information Theory, Budapest: Academic Kiado, 267-281. Aramco Report (several issues).

Articles of Incorporation of the Saudi Arabian Oil Company' Approved by Royal Decree, No. M/8 4 Rabi II 1409 (13 November 1988).

Askari, H. (1990), Saudi Arabia's Economy: Oil and the Reach for Economic Development, JAI Press, Greenwich, CT.

Askari, H. (1991), Saudi Arabia's Oil Policy: Its Motivations and Impact, In Wilfride Kohl After the Oil Collapse. OPEC the United States and the World Oil Market, John Hopkins University Press.

The Basic Law of Government, The Kingdom of Saudi Arabia.

Banerjee, A. Dolado, J. Galbraith, J. and D. Hendry, D. (1993). Cointegration, Error-Correction, and the Econometric Analysis of Non-Stationary Data, Oxford University Press.

Beaulieu, J. and Miron, J. (1993) 'Seasonal Unit Roots in Aggregate U.S. Data', Journal of Econometrics. 55: pp. 305-328.

Bergendahl, G. (1984) The Management of OPEC's Financial Surpluses, Oxford Institute for Energy Studies.

Box, G. and Jenkins, G. (1970), Time Series Analysis Forecasting and Control, 3ed. Prentice Hall, Englewood Cliffs, New Jersey.

Box, G. Jenkins, G. and Reinsel, G. (1994), Time Series Analysis Forecasting and Control, 3ed. Prentice Hall, Englewood Cliffs, New Jersey.

BP, A Statistical Review of World Energy. (Various issues).

Business Week 22/11/76.

Campbell, J. and Perron, P. (1991), 'Pitfalls and Opportunities : What Macroeconomics Should Know about Unit Roots' Macroeconomics Annual NBER, pp.141-201.

Canova, F. and Hansen, E. (1995) 'Are Seasonal Patterns Constant Over Time? A Test for Seasonal Stability' Journal of Business and Economics Statistics, 13: pp. 237-252.

Cremer, J. and Salehi-Isfahani, D. (1980), 'Competitive Pricing in the Oil Market: How Important is OPEC?', Working Paper, University of Pennsylvania, Phil.

Cremer, J. and Salehi-Isfahani, D. (1991),Models of the Oil Market, UK: Hardwood Academic Publishers.

Cremer, J. and Weitzman, M. (1976), 'OPEC and the Monopoly Price of World Oil', European Economic Review, 8: pp.155-64.

Cuthberston, K. Hall and Taylor, M. (1992), Applied Econometric Techniques, Philip Allan, London.

Cutler, H., Davis, S. Rhodd, J. and Schwarm. W. (1997), 'The Demand for M1 in a Large Macroeconomics System: Evidence from Cointegration Analysis', Journal of Macroeconomics. 19(1): pp. 53-78.

Dahl, C. and Yucel, M. (1991), 'Testing Alternative Hypotheses of Oil Producer Behaviour', Energy Journal; 12(4): pp.117-38.

Dasgupta, P. and Heal, G. (1979), The Economic Theory of Exhaustible Resources, Cambridge University Press.

Davidson, A. Hendry, D, Srb, F, and Yoo, B. (1978) (DHSY) 'Econometric Modelling of the Aggregate Time Series Relationship between Consumers' Expenditure and Income in the. U.K', Economic Journal, 88: pp. 661-92.

Davidson, R. and MacKinnon, J. (1993), Estimation and Inference in Econometrics, Oxford : Oxford University Press.

Dickey, D. and Fuller, W. (1979), 'Distribution of the Estimators for Autoregressive Time Series with Unit Root', Journal of the American Statistical Association, 74: pp. 457-431.

Dickey, D. and Fuller, W.(1981), Likelihood Ratio Test Statistics for Autoregressive Time Series with a Unit Root', Econometrica, 49: pp. 1057-1072.

Dickey, D. Hasza, D. and Fuller, W. (1984), 'Testing for Unit Roots in Seasonal Time Series', Journal of American Statistical Association: 79: pp. 355-367.

Dolado, J., Jenkinson, T. and Sosvilla-Rivero, S. (1990), 'Cointegration and Unit Roots', Journal of Economic Surveys, 4: pp. 249-273.

Doran, C. (1977), Myth, Oil, and Politics: Introduction to the Political Economy of Petroleum, New York: The Free Press.

Economist. Feb.8/ 1975, p 69.

Energy & Oil Statistics (1993), OPEC Secretariat Research Division DSD/ Statistics Section.

Engle, R. (1982), 'A General Approach to Lagrange Multiplier Model Diagnostics', Journal of Econometrics, 20: pp. 83-107.

Engle, R. and Granger, C. (1987), 'Cointegration and Error Correction Representation, Estimation and Testing', Econometrica 55: PP. 251-276.

Engle, R. and Granger, C. (1991) Long-Run Economic Relationships: Reading in Cointegration, Oxford : Oxford University Press.

Engle, R. Granger, C. and Hallman (1989), ' Merging Short-and Long-Run Forecasts: an Application of Seasonal Cointegration to Monthly Electricity Sales Forecasting' Journal of Econometrics, 40: pp.45-62.

Engle, R. Granger, C. Hylleberg, S. and Lee, H. (1993) 'Seasonal Cointegration: the Japanese Consumption Function', Journal of Econometrics, 55: pp. 275-298.

Engle, R and Yoo, B. (1987), 'Forecasting and Testing in Co-integrated Systems', Journal of Econometrics, 35: pp. 143-159.

Estrin, S. Laider, D. (1995), Introduction to Microeconomics, Harvester, Wheatsheaf, London.

Evans, J. (1987), OPEC, Its Member States and the World Energy Market, England: Longman Group.

Ezzati, A. (1976), 'Future OPEC Price and Production Strategies as Affected by its Capacity to Absorb Oil Revenues', European Economic Review, 8: pp.107-38.

Ezzati, A. (1978), World Energy Markets and OPEC Stability, Cambridge, Mass: Lexington Books.

Fisher, A. (1981), Resource and Environmental Economics,: Cambridge Surveys of Economic Literature, Cambridge University Press.

Franses, P. (1996a), Periodicity and Stochastic Trends in Economic Time Series, Oxford: Oxford University Press.

Franses, P. (1996b), 'Recent Advances in Modelling Seasonality', Journal of Economic Surveys, 10(3): pp. 299-345.

Franses, P. (1997), ' Critical Values for Unit Root Tests in Seasonal Time Series', Journal of Applied Statistics, Vol. 24, No. 1, 1997, pp. 25-47.

Fuller, W. (1996), Introduction to Statistical Time Series, 2nd ed. Wiley & Sons New York.

Gately, D. (1983), 'OPEC: Retrospective and Prospects 1973-1990', European Economic Review 21: pp.313-31.

Gately, D. (1984), 'A Ten-Year Retrospective: OPEC and the World Oil Market', Journal of Economic Literature, 22: pp.1100-1114.

Gately, D. (1995), 'Strategies for OPEC's Pricing and Output Decisions', The Energy Journal, 16(3).

Geroski, P. Ulph, A. and Ulph, D. (1987), 'Model of the Crude Oil Market in which Market Conduct Varies', Economic Journal, 97: pp. 77-86.

Gilbert, C. (1986), Professor Hendry's Economic Methodology', Oxford Bulletin of Economics and Statistics, 48: pp. 283-307.

Gilbert, R. (1978), 'Dominant Firm Pricing in a Market for an Exhaustible Resource', The Bell Journal of Economics, 9: pp.385-395.

Golub, D. (1985), When Oil and Politics Mix Saudi Oil Policy, 1973-1985, Centre For Middle Eastern Studies. Harvard University.

Godfry, L. (1988), Misspecification Tests in Econometrics. The Lagrange Multiplier Principle and other Approaches, Cambridge : Cambridge University Press.

Gonzalo, J. (1994), 'Five Alternative Methods of Estimating Long - Run Equilibrium Relationships'. Journal of Econometrics, 60: PP. 203-233.

Granger, C. (1969) 'Investigating Casual Relationship By Econometric Models and Cross Spectral Methods', Econometrica, 37:pp. 424-438.

Granger, C. (1986), 'Development in the study of cointegrated economic variables', Oxford Bulletin of Economics and Statistics, 48: PP. 213-228.

Granger, C. and Newbold, P. (1974), 'Spurious Regression in Econometrics', Journal of Econometrics, 2: PP. 111-120.

Granger, C. and Newbold, P. (1986), Forecasting Economic Time Series, 2nd ed. Academic Press, Inc. Orlando, Florida.

Griffin, J. and Steel, H. (1980), Energy Economics and Policy, New York: Academic Press.

Griffin, J. (1985), 'OPEC Behaviour: A Test of Alternative Hypotheses', American Economic Review, 75: pp.954-963.

Griffin, J. and Jones (1986), 'Falling Oil prices where is the Floor?', The Energy Journal, 7(4): PP.

Griffin, J. and Teece, M. (1982), OPEC Behaviour and World Oil Prices, London: George Allen and Unwin.

Griffin, J. and Neilson (1994), 'The 1985-86 Oil Price Collapse and Afterwards', Economic Inquiry. 32(4): pp. 543-561.

Gulen, G. (1996), 'Is OPEC a Cartel ? Evidence from Cointegration and Causality Tests', The Energy Journal 17(2): pp. 43-57.

Hall, S. and. Henry, S. (1988), 'Dynamic Modelling and Cointegration', Chapter 2 in Macroeconomics Modelling. North Holland.

Hannan, E. and Quinn, B. (1979), 'The Determination of the Order of an Autoregression', Journal of the Royal Statistical Society, B(41): pp. 190-195.

Hargreaves, C. (1994), 'A Review of Methods of Estimating Cointegrating Relationships', in Nonstationary Time Series Analysis and Cointegration, edited by C. Hargreaves Oxford University Press.

Harris, R. (1992), 'Testing for Unit Roots using the Augmented Dickey-Fuller test: Some Issues relating to the size power and the lag structure of the test', Economic Letters, 38: pp. 381-386.

Harris, R. (1995), Cointegration Analysis in Econometric Modelling, New York, Prentice Hall.

Hartshorn, J. (1993), Oil Trade Politics and Prospects, Cambridge: Cambridge University Press.

Hausman, J. (1978), 'Specification Tests in Econometrics', Econometrica, 46:pp.125-127.

Harvey, A. (1990), The Econometric Analysis of Time Series, 2nd ed. Philip Allian. London.

Hatanaka, M. (1996), Time- Series-Based Econometrics Unit Roots and Cointegration, Oxford : Oxford University Press.

Haza, D. and Fuller, W.(1982), 'Testing for Nonstationary Parameter Specification in Seasonal Time Series Models', Annals of Statistics, 10:pp.1209-1216.

Hendry, D,. (1986), 'Econometric Modelling with Cointegrated Variables: an Overview', Oxford Bulletin of Economics and Statistics, 48: pp. 201-212.

Hendry, D. (1995), Dynamic Econometrics, Oxford: Oxford University Press.

Hendry, D. and Mizon, G. (1978), 'Serial Correlation as a Convenient Simplification, not a Nuisance: a Comment on a study of the demand for money by the Bank of England', Economic Journal, September. 88: pp.549-563.

Hendry, D. and Richard, J.(1983), 'The Econometric Analysis of Economic Time Series' International Statistical Review, 51: pp. 111-163.

Hendry, D. Pagan, A. and Sargan, J. (1984), 'Dynamic Specification', in Griliches, Z. and Intriligator, M. D. (eds.) Handbook of Econometrics, Amsterdam: North Holland.

Hnyilicza, E. and Pindyck, R. (1976), 'Pricing Policies for a Two-part Exhaustible Resources Cartel', European Economic Review, 8: PP.139-154.

Holden, D. and Perman, R. (1994), 'Unit Roots and Cointegration for the Economist', in Cointegration for the Applied Economist, edit by B. Bhaskara Rao. Macmillan.

Horsnell, P. and Mabro, R. (1993), Oil Markets and Prices The Brent Markets and the Formation of World Oil Prices, Oxford: Oxford University Press.

Hotelling, H. (1931), 'The Economics of Exhaustible Resources', The Journal of Political Economy, 39: pp.137-175.

Hylleberg, S. (1995). 'Tests for Seasonal Unit Roots: General to Specific or Specific to General?', Journal of Econometrics. 69: pp.5-26.

Hylleberg, S. Engel, R,. Granger, C. and Yoo, B. (HEGY).(1990), 'Seasonal Integration and Cointegration', Journal of Econometrics, 44: pp. 215-38

International Crude Oil and Product Prices. (July 1996). Prepared by F. R. Parra Association in co-operation with Middle East Economic Survey. MEES publications.

Jaidah, A. (1988), 'Producers' Policies: Past and Future', in The 1986 Oil Price Crisis Economic Effects and Policy Responses, R. Mabro, (ed.) Oxford Institute for Energy Studies.

Johansen, S. (1988), 'Statistical Analysis of Cointegration Vectors', Journal of Economics Dynamics and Control, 12: pp. 231-54.

Johansen, S. (1991), Statistical Analysis of Cointegration Vectors', in Engle, R. and Granger, C. (1991), Long-Run Economic Relationships: Readings in Cointegration, Oxford University Press.

Johansen, S. and Juselius, K. (1992), 'Testing structural hypothesis in a multivariate Cointegration analysis of the PPP and the UIP for UK', Journal of Econometrics. 53: pp. 211-44.

Johansen, S. (1996), Likelihood-Based Inference in Cointegrated Vector Auto-Regressive Models, Oxford University Press.

Johany, A. (1978), 'OPEC not a Cartel. The Property Rights Explanation of the Rise in Crude Oil Prices', Unpublished Doctoral Dissertation, U.C. Santa Barbara.

Johany, A. (1980), The Myth of the OPEC Cartel The Role of Saudi Arabia, New York: John Wiley and sons.

Johany, A, Berne, M. Mixon, J. (1986), The Saudi Arabian Economy, Baltimore: The John Hopkins University Press.

Kelly, J. (1980), The Gulf and the West, New York: Basic Books.

Khan, J. and Ogaki, M. (1992), 'A Consistent Test for the Null of Stationarity Against the Alternative of Unit Root', Economic Letter. 39(1): pp. 7-11.

Kohl, W. (1991), After the Oil Price Collapse OPEC, the United, States and the World Oil Market, John Hopkins University Press

Lambertini, L. (1996), 'Cartel Stability and the Curvature of Market Demand', Bulletin of Economic Research, 48(4): pp. 329-335.

Lin, A. and Swanson, P. (1997), 'The U.S. Dollar in Global Money Markets: A Multivariate Cointegration Analysis', The Quarterly Review of Economics and Finance, 37(1): pp. 139-159.

Linderoth, H. (1992), 'Target Revenue Theory and Saudi Arabia Oil Policy', Energy Policy, Nov., pp. 1078-1088.

Lutkepohl, H. (1993), Introduction to Multiple Time Series Analysis, 2nd ed. Springer-Verlag.

Mabro, R.(ed) (1986), The 1986 Oil Price Crisis: Economic Effects and Policy Responses, Oxford: Oxford Institute for Energy Studies.

Mabro, R. (1975), 'Can OPEC hold the line', in OPEC and the World Oil Market: The Genesis of the 1986 Price Crisis, R. Mabro.(ed) Oxford Institute for Energy Studies.

Mabro, R. (1984), On Oil Price Concept, Working Paper, Oxford Institute for Energy.

Mabro, R. (1987), Netback Pricing and the Oil Price Collapse of 1986, Oxford. Institute for Energy Studies.

Mabro, R. (1988), Presentation at the Oxford Energy Seminar. 15/9/1988.

Mabro, R. (1989), OPEC's Production Policies: How do they work? Why don't they work?, Oxford Institute for Energy Studies.

Mabro, R. (1991), 'OPEC and the Price of Oil', The Energy Journal,, 13: pp. 1-17.

MacAvoy, P. (1982), Crude Oil Prices as Determined by OPEC and Market Fundamentals, Cambridge, Mass: Ballinger.

MacKinnon, J. (1991), 'Critical Values for Cointegration Tests', in Engle, R. and Granger, C. (1991), Long-Run Economic Relationships: Readings in Cointegration, Oxford University Press.

MacKinnon, J. (1996), Numerical Distribution Functions For Unit Root and Cointegration Tests, Journal of Applied Econometrics, 11: pp. 601-618.

Maddala, and Kim, (1996), 'Structural Change and Unit Roots', Journal of Statistical Planning and Inference, 49: pp. 73-103.

Masih, R. and Masih, A. (1996), 'Macroeconomics Activity Dynamics and Granger Causality: New Evidence From Small Developing Economy Based on a Vector Error-Correction Modelling Analysis', Economic Modelling, 13: pp. 407-426.

Middle East Economic Survey (MEES) Several Issues.

Mills, T. (1990), Time Series Techniques for Economists, Cambridge: Cambridge University Press.

Miron, J. (1994), 'The Economics of Seasonal Cycles', in Sims, C. (1994), Advances in Econometrics Sixth World Congress, Cambridge: Cambridge University Press.

Morimune, K. and Mantini, (1995) 'Estimating the Rank of Co-integration after Estimating the Order of a Vector Auto-regression', Japanese Economic Review

Nelson, C. and Plosser, C. (1982), 'Trends and Random Walks in Macroeconomics time series', Monetary Economic, 10: pp. 139-162.

OECD Economic Outlook and Energy Policies of IEA Countries 1984 and 1987 Review.

Oil and Energy Trends, Oxford: BlackWell Energy Research.

Oil and Gas Journal, various years, weekly, annual supplement World Wide Oil, last issue of year.

OPEC Annual Statistical Bulletin, Vienna: The Secretariat of OPEC, Various Issues.

OPEC Official Resolutions and Press Releases 1960-1996. (1996), Vienna: The Secretariat of OPEC.

Osborn, D. (1990) 'A Survey of Seasonality in UK Macroeconomics Variables', International Journal of Forecasting, 6:pp. 327-336.

Osborn, D., Chui, J. Smith, P and Birchenhall, C. (1988) 'Seasonality and the Order of Integration for Consumption', Oxford Bulletin of Economics and Statistics 50: pp. 361-377.

Osterwald-Lenum, M. (1992), 'A Note with Quintiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics', Oxford Bulletin of Economics and Statistics, 54(3): pp. 461-472

Pegan, A. and Wickens, (1989), 'A Survey of Some Recent Econometric Methods', Economic Journal 99: pp. 962-1025.

Perman, R. (1991), 'Cointegration: An Introduction to the Literature', Journal of Economic Studies, 18: pp. 3-30.

Perron, P. (1994), 'Trends, Unit Root and Structural Change in Macroeconomics Time Series'. in Cointegration for the Applied Economist, Bhaskara Rao, B. London.Macmillan.

Perron, P. (1989), 'The Great Crash, the Oil Price Shock and the Unit Root Hypothesis', Econometrica, 57: pp. 1361-1401.

Perron, P. and Vogelsang (1992), 'Testing for Unit Root in a Time Series with a Changing Mean Correction and Extension', Journal of Business and Statistics. 10:pp. 467-470.

Pesaran, M. (1997), 'The Role of Economic Theory in Modelling the Long run', Economic Journal, 107: PP. 178-191.

Pesaran, M. Shin, and Smith, R. (1997), 'Structural Analysis of Vector Auto-regressive Models with Exogenous I(1) Variables,, DAE, Working Paper. Amalgamated Series, No. 9706, University of Cambridge.

Petroleum Intelligence Weekly (PIW) 6/ 4/11979.

Phillips, P. and Perron, P. (1988), 'Testing for a Unit Root in Time Series Regression' Biometrica, 75: pp. 335-346.

Phillips, P. (1987), 'Time Series Regression with a Unit Root', Econometrica, 55: pp. 277-301.

Said, S. and Dickey, D. (1984), 'Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order', Biometrika, 71: pp. 599-607.

Sargan, J. and Bhargave, A. (1983) 'Testing Residual from least squares Regression for Being Generated by Gaussian Random Walk,', Econometrica, 51:pp. 153-174.

Sargan, J. (1964), 'Wages and Prices in the United Kingdom: a study of econometric Methodology', In P. E. Hart and J. Whittaker (eds.) Econometric Analysis for Natural Economic Planning, London: ButterWorths.

Saudi Arabian Monetary Agency (SAMA). Annual Report, different issues.

Schwarz, G. (1989), 'Tests for Unit Roots: A Monte Carlo Investigation', Journal of Business and Economic Statistics, 7: pp.147-159.

Stock, J. (1987), 'Asymptotic Properties of Least-Squares Estimators of Cointegrating Vectors', Econometrics: 55: pp. 1035-1056.

Stock, J. and Watson, M. (1988), 'Testing for Common Trends', Journal of American Statistical Association, 83(404): pp. 1097-107.

APPENDIX (1)

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}, lnQ^{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	χ^2(9)= 9.36 [.404]
10	220.44	127.44	- 1.39	χ^2(18)= 15.76 [.609]
9	216.08	132.08	15.71	χ^2(27)= 21.75 [750]
8	207.37	132.37	28.47	χ^2(36)= 33.71 [.578]
7	199.11	133.11	41.67	χ^2(45)= 45.05 [.470]
6	191.81	134.81	55.84	χ^2(54)= 55.07 [.434]
5	184.54	136.54	70.04	χ^2(63)= 65.05 [.405]
4	175.01	136.01	81.98	χ^2(72)= 78.12 [.290]
3	170.03	140.03	98.47	χ^2(81)= 84.96.[.360]
2	160.76	139.76	110.67	χ^2(90)= 97.69 [.272]
1	152.04	140.04	123.41	χ^2(99)= 109.67[.218]
0	-548.19	-551.19	-555.34	χ^2(108)=1071.00[.000]

2- Based on 104 observations from 1987m1 to 198612 Order of VAR = 12

List of variables include in the unrestricted VAR: ln Q^{SA}, lnQ^{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	χ^2(4)= 4.40 [.354]
10	410.84	366.84	308.67	χ^2(8)= 21.30[.006]
9	407.14	367.14	314.25	χ^2(12)= 26.85 [008]
8	404.41	368.41	320.81	χ^2(16)= 30.95 [.014]
7	395.68	363.68	321.37	χ^2(20)= 44.05 [.001]
6	375.17	347.17	310.15	χ^2(24)= 74.80 [.000]
5	370.15	346.15	314.41	χ^2(28)= 82.34.[.000]
4	366.49	346.49	320.05	χ^2(32)= 78.83[.000]
3	358.69	342.69	321.54	χ^2(36)= 99.52[.000]
2	358.06	346.06	330.20	χ^2(40)= 100.47[.000]
1	352.92	344.92	334.34	χ^2(44)= 108.19[.000]
0	-125.97	-129.97	-135.26	χ^2(48)= 826.53[.000]

LIST OF SURREY ENERGY ECONOMICS DISCUSSION PAPER SERIES (SEEDS) 69-93
SEEC OCCASIONAL PAPER and SEEDS TECHNICAL PAPER

SEEDS Number

93 Modelling Saudi Arabia Behaviour in the World Oil Market 1976-1996
Nourah AbdullRahman Al-Yousef ISBN 1852372125 June 1998

92 The Socio Economic Impact of Renewable Energy Technologies
Hayley Myles ISBN 1852372087 March 1998

91 Pressure Groups and Political Forces in Britain's Privatisation Programme
Colin Robinson ISBN 1852372079 February 1998
(final paper subs 96/97)

90 Environmental Information and the Demand for Super Unleaded Petrol in the United Kingdom
Roger Fouquet SBN 1852371951 June 1997

89 Petrol Price Asymmetries Revisited
Barry Reilly and Robert Witt ISBN 1852371919 August 1996

88 **Withdrawn 11/97**
Performance of Power Sectors in Developing Countries - A Study of Efficiency and World Bank Policy using Data Envelopment Analysis
David Hawdon ISBN 1852371900 August 1996

87 UK Energy Policy: Findings from Two Surveys
Peter J G Pearson and Roger Fouquet ISBN 1852371897 August 1996

SEEDS TECHNICAL PAPER
No.1 Using LAMBDA for DEA
David Hawdon and Ian M McQueen ISBN 1852371811 April 1996

86 An Analysis of UK Energy Demand Using Multivariate Cointegration
Lester C Hunt and Robert Witt ISBN 1852371803 December 1995

85 Freeing the Nuclear Industry
Colin Robinson ISBN 185237179X March 1996

84 The Efficiency of the National Electricity Board in Malaysia - An Intercountry Comparison
Jamaluddin bin Mohd Yunos and David Hawdon ISBN 185237165X January 1996

83 Privatisation: Saving the British Coal Industry?
Colin Robinson ISBN 1852371633 November 1995

82 Electricity Privatisation in England and Wales: Progress and Problems
Colin Robinson ISBN 1852371528 August 1995

SEEC OCCASIONAL PAPER
No.2 The S.E.E.C. United Kingdom Energy Demand Forecast (1995-2000) Update
Roger Fouquet, David Hawdon, Peter J G Pearson, Colin Robinson and Paul Stevens ISBN 185237151X July 1995

SEEDS Number			
81	The Nuclear Review David Hawdon (Ed): Elroy Dimson, Robin Jeffrey, Martin O'Neill, M.P., Colin Robinson and Mike Staunton	ISBN 1852371501	April 1995
80	Regulation as a Means of Introducing Competition Colin Robinson	ISBN 185237148X	February 1995
79	Privatising Nuclear Power: evidence for the review of future prospects for nuclear power Colin Robinson	ISBN 1852371455	November 1994
78	Energy, Externalities and Environmental Quality: Will Development Cure the Ills it Creates? Peter J G Pearson	ISBN 1852371447	October 1994
77	The Demand for Car Fuel Efficiency: An Hedonic Price Approach Robert Witt	ISBN 1852371439	October 1994
76	Economics and the Environment - the Shadow Price of Greenhouse Gases and Aerosols David Maddison	ISBN 1852371412	July 1994
75	End Use Elasticities Joseph G Hirschberg	ISBN 1852371404	June 1994
74	A Model of Relative Price Elasticities from the Second Moments of Demand Joseph G Hirschberg	ISBN 1852371390	June 1994
73	Liberalisation of the Energy Market: A Favourable Supply-side Shock for the UK Economy? Colin Robinson	ISBN 1852371382	June 1994
72	Recent Studies of the Demand for Energy in the UK D Hawdon (Ed): Joyce Dargay, Roger Fouquet, Andrew Henley, Keith Miller and John Peirson	ISBN 1852371331	November 1993
71	An Econometric Study of the Demand for Gasoline in the Gulf Cooperation Council Countries M Nagy Eltony and Mohammad Almahmeed	ISBN 1852371315	October 1993

SEEC OCCASIONAL PAPER

No.1	*The S.E.E.C. United Kingdom Energy Demand Forecast (1993-2000)* *Roger Fouquet, David Hawdon, Peter J G Pearson, Colin Robinson and Paul Stevens*	*ISBN 185237134X*	*16 December 1993*

70	International Bargaining and the EC Large Combustion Plant Directive Roger Fouquet	ISBN 1852371129	July 1993
69	Fuels for Electricity Supply after the UK Coal Review Peter J G Pearson (Ed): Anthony Baker, Nigel Evans, PMS Jones and Colin Robinson	ISBN 1852371099	May 1993

Details of SEEDS 1-68, prices and *annual Subscription Scheme* on request.