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The market power of OPEC 1973-2001

Abstract:
We apply a multi-equation dynamic econometric model on monthly data to test if the behaviour of OPEC as a whole or different sub-groups of the cartel is consistent with the characteristics of dominant producers on the world crude oil market in the period 1973-2001. Our results indicate that the producers outside OPEC can be described as competitive producers, taking the oil price as given and maximising profits. The OPEC members do not fit the behaviour of price-taking producers. Our findings of low residual demand price elasticities for OPEC underpin the potential market power of the producer group, and are in line with the results in some recent energy studies. On the other hand, our findings indicate that neither OPEC nor different sub-groups of the cartel can be characterised as a dominant producer in the period 1973-1994. However, we find that the characteristics of a dominant producer to some extent fit OPEC-Core as from 1994. Thus, although OPEC clearly has affected the market price, the producer group has not behaved as a pure profit-maximising dominant producer.

Keywords: Oil market, OPEC, Market power, Equilibrium Correction Mechanism model

JEL classification: C32, L13, L71, Q30

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1. Introduction

Crude oil plays a crucial role in the world economy, accounting for around 40 per cent of the primary energy consumption. For the market participants it is of vital importance to understand how this market functions. For OPEC it is crucial to understand how world demand and Non-OPEC supply reacts to oil price changes, as this is significant in determining their potential market power. It is important for producers outside the organisation and for the oil importing countries to understand to what extent OPEC has exercised its market power, as this may give some indications on the future movements in the oil price.

In this paper we carry out an econometric analysis to study if OPEC as a whole or different sub-groups of the cartel have exercised any market power on the world crude oil market. We apply an Equilibrium Correction Mechanism (ECM) model to estimate price elasticities of the total demand, and supply from a competitive group of producers. A positive price response from the competitive group of producers is consistent with competitive behaviour. We use the results from the estimation to calculate the residual demand price elasticity facing the dominant producer. We employ this residual demand price elasticity and the production cost of the suggested dominant producer to show the optimal price behaviour.

Our study use more advanced econometric methods to study the market structure of the world crude oil market than the vast majority of the numerous *econometric* studies that have been published since the oil price ascended in 1973. Surveying theses studies we take notice of the largely inconclusive nature of the findings. While some of them find bits of evidence that is consistent with a largely competitive market, others find weak proof of various forms of collusive behaviour among the OPEC members.

Griffin (1985), Al-Turki (1994) and Gülen (1996) test whether the output level of individual OPEC members tends to move in tandem, and find partially effective output coordination. Although parallel movement is not inconsistent with the cartel hypothesis as Griffin (1985) emphasises, it is not inconsistent with competitive behaviour either. As pointed out by Smith (2002), the output levels of perfectly competitive producers should be expected to move together in response to demand and cost fluctuations.

Dahl and Yücel (1991) point out that low-cost producers in a profit-maximising cartel are expected to produce more than high-cost producers. Hence, marginal cost should enter negatively into the production equation for cartel members. This is supported by their data. However, again as pointed out by Smith (2002), low-cost producers dominating high-cost producers would also be expected to hold for perfectly competitive producers. Again, evidence is consistent with very different market structures.

The strict version of the target revenue theory in Griffin (1985) states that producers vary production inversely with price to maintain a constant level of revenue in accordance with exogenous investment needs. If these investment needs influence the production decision to a lesser degree, we have a "partial" variant of the target revenue theory. Griffin (1985), Dahl and Yücel (1991) and Alhajji and Huettner (2000a) find it easy to reject the strict version of this theory, but they also find the partial (and more reasonable) version difficult to reject.

Griffin (1985), Jones (1990) and Ramcharran (2002) study single-equation models, where the competitive hypothesis implies a positive relationship between a country's output and price. They reject the competitive hypothesis only for some OPEC countries. Their treating of the oil price as exogenous to test for market power can cause biased and inconsistent estimators. In addition, as they exclude costs from the econometric model, it is difficult to believe in their rejection of the competitive hypothesis. Competitive behaviour implies that, if a producer's costs are held constant, the price and output should move together.

As in Alhajji and Huettner (2000b) we apply a multi-equation dynamic econometric model to test if OPEC as a whole or different sub-groups of the cartel have exercised any market power on the world crude oil market. The vast majority of earlier studies have relied on single-equation (and often static) models to test for cartel behaviour. This causes autocorrelation in the residuals and biased estimates. With our multi-equation dynamic model we are able to estimate simultaneously the supply and demand side.

To our knowledge, we are the first to apply an ECM model in our econometric specification to measure the market power of OPEC. Since the data are found to be non-stationary and we assume that the variables are cointegrated, we apply the ECM model to estimate the long-term global demand elasticities and supply elasticities of the competitive producers. From these elasticities we study more formally whether OPEC as a whole or different sub-groups of the cartel have exercised any market power. Another significant contribution of our study is that it utilises data on a monthly level and for a longer period than other studies. Furthermore, a distinction is made between the producer and the consumer price of oil. We also use supply cost estimates allowing for uncertainty about their magnitude.

In Section 2 we derive the theoretical model. A description of the development of central variables and other data is given in Section 3. In Section 4 we outline the econometric model and in Section 5 we discuss the results. Section 6 concludes the paper.

2. Theoretical models

As Prokop (1999) we assume the supply side of the oil market to be characterised by a dominant producer, comprised of some or all of the OPEC-countries imposing a selling price on a competitive group of followers, which are price-takers. Given the residual demand schedule, the dominant producer has to determine the price/output combination that maximizes total profits for the single producer or for the producer group[1]. In this study we disregard the internal cohesiveness of the producer groups and focus on market power in three cases:

Table 1. The different producer groups in the three cases in our estimation

Dominant producer	Non-dominant producer/competitive producer
1) OPEC	Non-OPEC (the so-called competitive fringe)
2) OPEC-Core (Saudi-Arabia, Kuwait, Qatar and UAE)	Non-OPEC-Core (Non-OPEC + other OPEC-countries than OPEC-Core)
3) Saudi-Arabia	Non-Saudi-Arabia (Non-OPEC + other OPEC-countries than Saudi-Arabia)

We follow the dominant producer model outlined in Alhajji and Huettner (2000b), but we distinguish between the producer price (P_p) and the consumer price (P_c) of oil, where the consumer price is a tax-term (T) (which also includes cost of transportation, distribution and refining) multiplied with the producer price. We do not focus on the dynamics and skip the time-notation in the following, but this will be elaborated on when we derive the econometric model. The world demand (D_w) is a function of the consumer price, GDP (G), US oil price control dummy variable (r) and other variables (X) that will be explained later.

(1) $$D_w = D\left(\overset{-}{P_c}, \overset{+}{G}, \overset{+}{r}, X \right)$$

[1] This is actually a static version of a Stackelberg leader focusing on each period and not on the resource depletion theory of Hotelling. With large reserves in most OPEC-countries and a long remaining production period, it seems reasonable to put aside the problem of optimising pricing decisions over the lifetime of the resource. To take resource depletion into consideration is of greater importance for the price-taking followers, as only 22 % of the world's proved reserves exist in Non-OPEC countries (BP, 2002).

We suppose a negative price derivative and a positive GDP derivative in Eq. (1). We assume a positive derivative for the dummy variable during the US price regulation from January 1973 to January 1981. US demand, which represents a large part of world demand, is expected to have increased, because of lower consumer prices generated by the price control[2].

The oil supply from the non-dominant producers (S_{nd}) is a function of the producer price (P_p), average supply costs (C_{nd}), the US price control dummy variable (r) and other variables (Z).

$$(2) \qquad S_{nd} = S\left(\overset{+}{P_p}, \overset{-}{C_{nd}}, \overset{-}{r}, Z\right)$$

We expect a positive producer price derivative. In addition, the derivative of the average supply costs should be negative. We do not employ marginal costs, as they will be equal to the oil price if the producers have competitive behaviour. In addition, the marginal costs do not reflect the underlying variation in costs caused by changes in technology and changes in capital costs. We try to isolate the true price effect by introducing the average costs in Eq. (2). A negative derivative is expected for the US price control dummy variable, because price regulation should suppress the profitability of US oil production.

If the equilibrium condition is satisfied, the residual demand for the dominant producer (D_d) is

$$(3) \qquad D_d = S_d = D_w - S_{nd}$$

Since we focus on the size of the demand faced by the producers, we add changes in inventories to consumption. The dynamic econometric specification of Eq. (1), (2) and (3) is described in Section 4.

The non-dominant producers maximize profits (π_{nd}), taking the oil price as given:

$$(4) \qquad \max \pi_{nd} = P_p \cdot S_{nd} - C_{nd}$$

The first order condition for the non-dominant producer equals price and marginal supply costs (MC_{nd}):

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[2] Through the price control both wellhead prices and refining and marketing profit margins were controlled. We have separated the effect of the US price control from the estimated world consumer price.

(5) $$P_p = C'_{nd} = MC_{nd}$$

To study the behaviour of the dominant producer, we introduce the inverse demand function $D_w^{-1} = P_c(D_w) = P_c(S_{nd} + S_d)$. Knowing that $P_c(\cdot) = T \cdot P_p(\cdot)$, the dominant producer maximises profits by setting the oil producer price, taking into consideration that the price is a function of total supply:

(6) $$\max \pi_d = P_p(S_d + S_{nd}) \cdot S_d - C_d$$

The first order condition equals marginal revenue and marginal costs:

(7) $$P_p + P'_p \cdot (\frac{\partial S_{nd}}{\partial S_d} + 1) \cdot S_d = C'_d = MC_d$$

Because $P_c = T \cdot P_p$, the price elasticity of world demand is $\beta = El_{p_c} D_w = El_{p_p} D_w$. The price elasticity of the non-dominant supply is $\alpha = El_{p_p} S_{nd}$. Following Alhajji and Huettner (2000b) we divide through Eq. (7) with P_p, rearrange and get:

(8) $$P_p = \frac{MC_d}{1 + \frac{1}{E_d}}$$

where $E_d = \frac{D_w}{S_d} \cdot \beta - \frac{S_{nd}}{S_d} \cdot \alpha$ is the elasticity of the residual demand facing the dominant producer. This expression is crucial in determining the market power of the dominant producer. A necessary condition for a profit-maximising dominant producer is that $E_d < -1$, but still the equilibrium condition in Eq. (8) has to be satisfied. Further, the derivatives of both the global demand in Eq. (1) and the supply of the non-dominant producers in Eq. (2) should have the correct signs and be statistically significant. Letting $M_d = \frac{S_d}{D_w}$ be the market share of the dominant producer, we rewrite Eq. (8) as:

(9) $$\frac{P_p}{MC_d} = \frac{1}{1+\frac{1}{\left[\frac{1}{M_d}\cdot\beta-\left(\frac{1-M_d}{M_d}\right)\cdot\alpha\right]}}$$

This relation shows the dominant producer's mark-up of price over its marginal costs. If $E_d < -1$, we see that the lower the residual elasticity is in absolute value, the larger the mark-up. That is, the mark-up of price over costs increases with the market share. Furthermore, the lower the demand price elasticity in absolute value and the lower the supply price elasticity of the competitive producers, the higher is the optimal price for the dominant producer. Vice versa, the more global demand and supply of the non-dominant producers reacts to a price increase, the less market power can the dominant producer exercise.

When we derive the econometric model in Section 4, we take into consideration that supply and demand take time to adjust to price changes. Short-run elasticities are generally smaller than the long-run elasticities and a complete adjustment requires many years (Greene, 1991). On the demand side this is due to the tremendous inertia of the capital stock of energy using equipment. On the supply side long lags are involved in exploration and development, so that bringing on a new oil field takes up to several years. Hence, the dominant producer will clearly have more market-power in the short run. If the dominant producer chooses a price close to the short-run mark-up (defined by the constant short-run elasticities), next month the demand and the non-dominant supply response would be greater. This implies that the producer group would have to lower prices or surrender market share, or both, to maximise its profits in each following month. If the dominant producer chooses a price on its long-run residual demand-curve according to its market-share that month, the price and the market-share (and profit) could be sustained indefinitely. As will be clear when we see the results of the estimation, we will focus on the long-run elasticities when we test for market power.

3. Description of central variables and other data

Before we turn to the analysis we describe the development of some central variables as the oil price, and the costs and production for the various producer groups. This will shed some light on the context of our analysis. Except for the OPEC production costs, these variables are important input into the econometric model. The size of the OPEC production cost is important in determining the optimal price for the dominant producer.

We apply monthly data between 1973 and 2001. Monthly data on production and consumption are from EIA (2002) and data on oil prices are from OPEC (2001). We use the official spot price of Saudi light crude, and emphasise that the different crude qualities tend to move in accordance with each other. Because oil is traded in dollars, prices are deflated by the US consumer price index from OECD (2001) with 1996 as the base year. We construct a yearly world average tax-term with data from Okogu (1995), Austvik (1996) and IEA (2002). We smoothen these yearly estimates over each twelve-month period to get monthly consumer prices.

Figure 1 shows that the oil market went through a series of oil price shocks from 1973 to 1986. The real oil price increased from $9 to a level of around $30 per barrel during 1974-79, before it increased further to an all-time-high of $57 in 1981. From then on the oil price declined to $11 in 1986. Between 1987 and 1998 the price has been fluctuating between $15 and $21 per barrel in most months, except throughout the Gulf-war in 1990/91, when the price increased to $39. During the recession in South-East Asia in 1998/99 the oil price reached $11 per barrel, the lowest level since 1973. From then on the prices increased, fluctuating between $20 and $25 per barrel in most months.

Figure 1. Real producer price (1996 $)

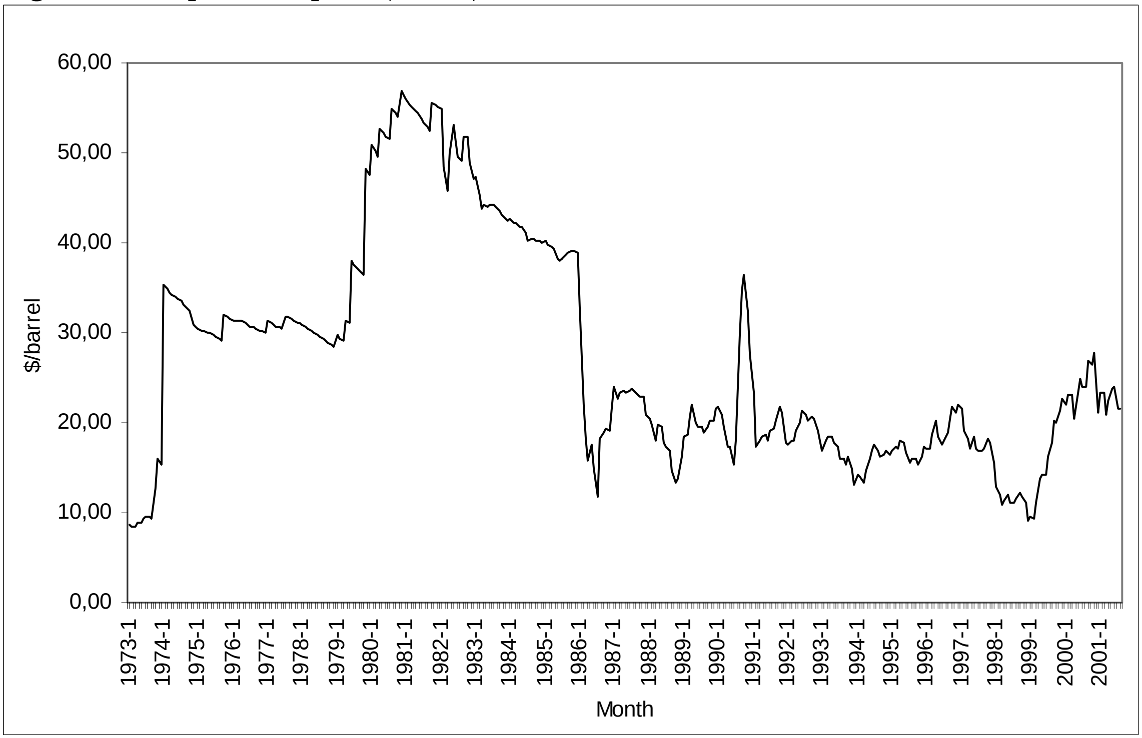
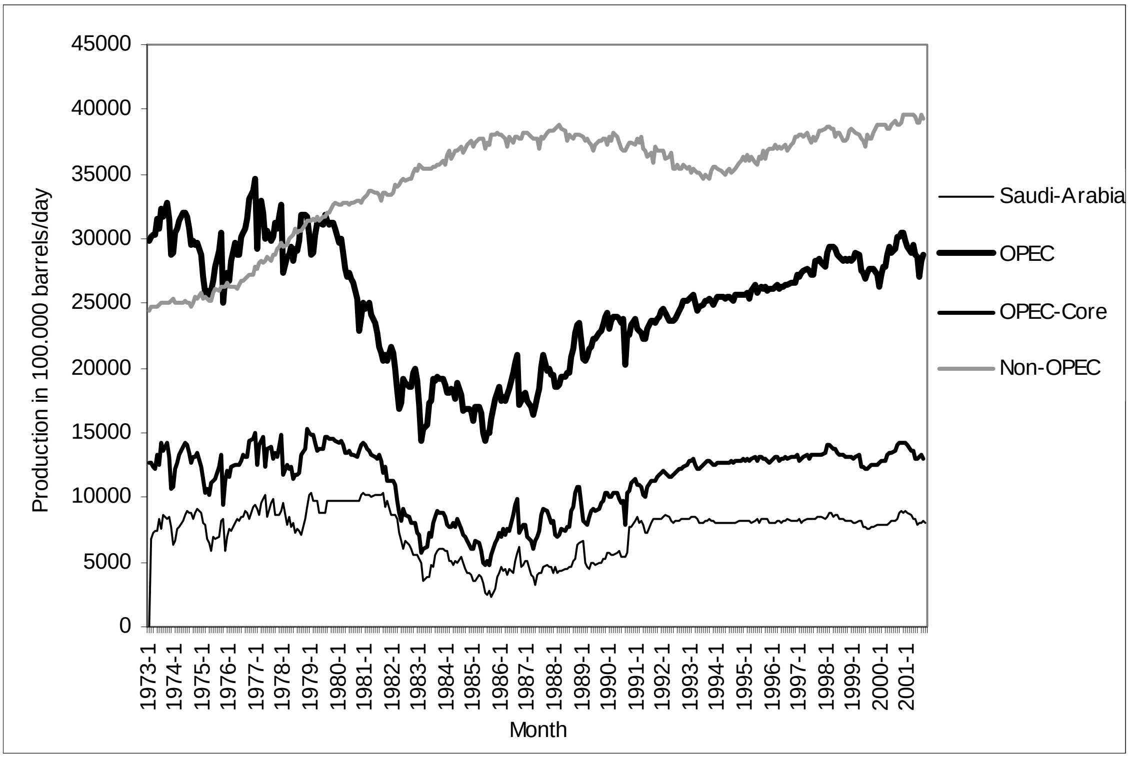


Figure 2 shows very different development in the production of OPEC and Non-OPEC, above all from 1973 to 1986. From an OPEC market share that was generally above 50% until 1979/80, it declined to around 30% in 1986. OPEC sharply curtailed oil production in this period in an effort to preserve the real price gains in 1973/74 and 1979. This was in response to a profound adjustment in oil demand according to Krichene (2002). The adjustment was mainly in the form of energy-saving and substitution between different energy carriers. Extremely high energy taxation (making our world consumer price of oil between 130% and 260% of the producer price) together with high oil prices, were factors inducing significant adjustment in demand. Although OPEC recovered production as from 1986, the cartel did not reach a production level comparable with the pre-1980 level until 1998/99. Between 1993 and 2001 the market share fluctuated around 40%.

Figure 2. Production in Non-OPEC, OPEC, OPEC-Core and Saudi-Arabia



Meanwhile, stimulated by high oil-prices, Non-OPEC increased production at an average rate of 2.2% per year during 1973-1987. The temporary decline in production from 1989 to 1994 was mainly due to the dissolvement of the Soviet Union. In the estimation of Non-OPEC production we single out the supply from market economies, entailing that the net export from the former Soviet Union/Russia and China is treated as exogenous[3].

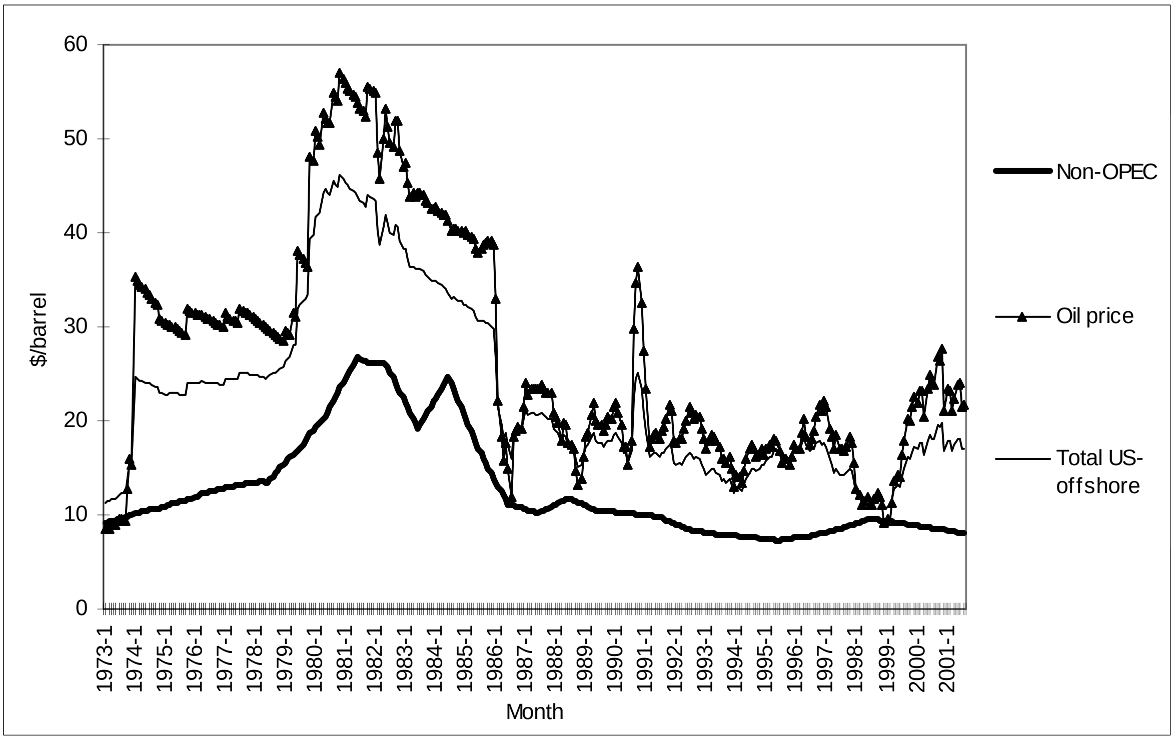
The overall production profile of OPEC-Core and Saudi-Arabia follows that of OPEC as a whole, but it seems that other OPEC countries outside the core started to reduce production already in 1980,

[3] As from 1992 we do not have data for the former Soviet Union republics except for Russia.

although some of this production decline was due to the outbreak of the ten year long war between Iran and Iraq[4].

Figure 3 shows the average supply costs of Non-OPEC and the costs of US offshore. The finding, development and extraction cost of the Non-OPEC group are based on the worldwide average supply costs of US-based oil-companies less taxes (se appendix A). In the estimation of the supply of the non-dominant producer in Eq. (2), we employ these average Non-OPEC supply costs. We also show data for the US-offshore supply costs from EIA (2004a) and these are three-years weighted average costs for all offshore-fields, where we have added petroleum taxes[5].

Figure 3. Real oil price and real supply costs of Non-OPEC and US-offshore (1996$)



We see that the costs are higher in the period 1979-1986 than in the previous years[6], which was a period of steadily increasing Non-OPEC production (Figure 2). The average production level was 29 % higher in 1979-1986 than in 1973-1979, which probably lead to increases in average costs. Crude oil prices were high and many analysts expected the price to rise even higher. This induced the oil

[4]We disregard production from Ecuador and Gabon in the estimates of OPEC production, as they withdrew from the organisation in 1992 and 1994, respectively.

[5] We add $\tau_G \cdot p + \tau_N \cdot (p - C)$ to the supply costs, where τ_G =gross tax of 16.67%, τ_N = net tax of 30%, p =oil price and C =costs per barrel. These tax rates don't seem to overstate the general fiscal take in the US over the years (Mommer, 2001).

[6] The estimated costs prior to 1979 are more uncertain.

companies to develop fields in more difficult and more costly areas. There may also have been few incentives for the oil companies to control costs. As from 1987 the costs are more or less stable. The fall in the average supply costs from the start of the 1980s to the middle of the 1980s can be attributed largely to the introduction and application of innovative geophysical and drilling technologies. The lower oil prices probably also induced more cost-consciousness on the part of the oil companies. We see that the higher offshore cost estimates follow relatively close to the oil price, and this gives some support of the profit-maximising condition in Eq. (5)[7].

Figure 4 shows the development in the minimum and maximum yearly estimated supply costs of OPEC, OPEC-Core and Saudi-Arabia. The various data sources from which we constructed these low and high estimates are listed in Appendix A. Eq. (8) shows that these costs are crucial in determining the optimal price for the dominant producer, as a certain relative increase in the costs leads to the same relative increase in the optimal price for a given elasticity of the residual demand for the dominant producer. Supply costs are the finding, development and production costs[8]. Differences in costs are above all due to geological and operating differences between countries. We do not include taxes, since in the OPEC-countries the respective governments are the owners of the resource, and as a consequence they are paying this component of "costs" to themselves[9]. We apply the average supply costs and not the marginal costs due to lack of data. However, the main oil fields in production in many OPEC countries are quite homogenous, and as a consequence the difference between the average supply costs and marginal costs are often small. In addition, there are many undeveloped fields with the same supply costs as the producing fields.

Surveying the supply costs of different countries, we find that the UAE has the highest supply costs in OPEC-Core, and Indonesia has the highest cost in OPEC as a whole. We see that the costs of Saudi-Arabia are generally the lowest and that OPEC as a whole has the highest cost. The costs were generally lower up to around 1986 than in the following years. The increase in supply costs as from 1986/87 is parallel with the increase in production for all producer groups. This may be due to the fact that increased production on existing fields raises the average costs and also because of increased production in more costly areas.

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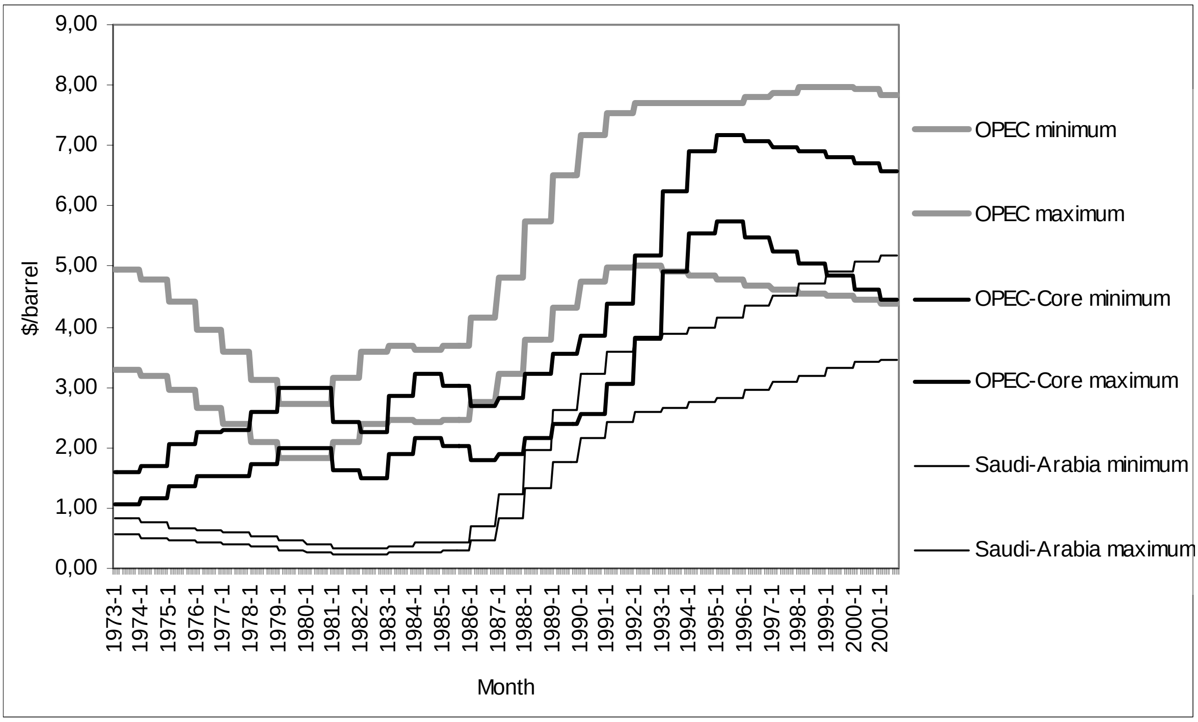
[7] To show this connection more precisely, we should have data for the more marginal high-cost offshore fields and data for the WTI crude price.

[8] The total supply costs should be the user costs, which is the price of replacing the oil stock and includes a scarcity (or resource) rent. We have no data on resource rents, but Adelman (1993) estimates the user cost for the Persian Gulf area to be close to zero.

[9] Alhajji and Huettner (2000b) add a royalty tax of 16.67 % to the oil price. In addition, they simply let the extraction costs start from $0.5 per barrel in 1973 and increase with 3% per year thereafter. They add military costs for each country, although these do not vary with production and should be treated as fixed costs.

Figure 4 pinpoints one central feature of the oil market: The OPEC-countries have supply costs which are generally much lower than the oil prices, even in low-price years. Why has OPEC not expanded output much more? The reason is presumably that output is restrained to increase or maintain prices and, hence, we study more formally to what extent the oil price is a mark-up over marginal (or average) costs for the three different OPEC producer groups in Section 5.2. The assumption that some or all OPEC-members have curtailed their production periodically is supported by the fact that the organisation has had regularly meetings to discuss the oil price. In addition, since 1982 a formal quota system was introduced with production allocations to each member.

Figure 4. Real supply costs of OPEC, OPEC-Core and Saudi-Arabia (1996$)



The GDP data are for the OECD-countries (IMF, 2001). We use this in the demand function as a proxy for the world GDP, since OECD represents 61% of the world crude oil demand (EIA, 2004b). We apply a price index for the US from OECD (2001) to deflate the prices and the costs.

4. Econometric model

Most of the econometric models developed in the literature are single equation static models that generally suffer from first order autocorrelation in the residuals. Lagged adjustment in demand and supply of oil is needed to distinguish between short- and long-run effects. We apply a model similar to the one in Alhajji and Huettner (2000b). However, their dynamic specification is the adaptive expectations approach and this gives a moving average process for the error term, i.e. their error term follows an MA (1) process. It seems that Alhajji and Huettner have not accounted for this in their econometric modelling. We apply an ECM model, because unit root tests show that it is reasonable to assume that the variables are integrated of order 1. We assume one cointegrated relationship between the variables on the demand side, and another cointegrated relationship on the non-dominant supply side of the model.[10] From the theoretical specification of global demand and supply of the non-dominant producers in Eq. (1) and (2), assuming constant elasticities[11], we derive the econometric specification.

To explain the econometric specification, we give the background for Eq. (10). To simplify, we let the desired level of demand in period *t* only be explained by price with a simple lag-structur: $d_t^{*} = \delta^1 + \delta^2 p_t + \delta^3 p_{t-1} + \eta_t$, where η_t is the error term. The desired level is not directly observable, and we assume partial adjustment in demand where $d_t - d_{t-1} = (1-\gamma)(d_t^{*} - d_{t-1})$, where $(1-\gamma)$ is the adjustment factor. Inserting the desired level in this equation, we get: $d_t = (1-\gamma)\delta^1 + (1-\gamma)\delta^2 p_t + (1-\gamma)\delta^3 p_{t-1} + \gamma d_{t-1} + (1-\gamma)\eta_t$, or $d_t = \beta^1 + \beta^2 p_t + \beta^3 p_{t-1} + \gamma d_{t-1} + \varepsilon_t$. The long run effect of a price change is $\dfrac{\beta^2 + \beta^3}{(1-\gamma)}$. We can rewrite this to an ECM model:

$\Delta d_t = \beta^1 + \beta^2 \Delta p_t + (\beta^2 + \beta^3) p_{t-1} + (\gamma - 1) d_{t-1} + \varepsilon_t$, with the same long run solution. We do not know the lag structure and, hence, start with a general specification:

Demand side:

$$\Delta d_{w,t} = \beta_0^k + \sum_{i=0}^{a} \beta_i^D \Delta d_{w,t-i} + \sum_{i=0}^{b} \beta_i^P \Delta p_{c,t-i} + \sum_{i=0}^{d} \beta_i^A \Delta g_{t-i} + \beta^D d_{w,t-1} + \beta^P p_{c,t-1} + \beta^A g_{t-1} + \overline{\beta}\overline{U}_t + \varepsilon_t \quad (10)$$

Supply non-dominant producers:

$$\Delta s_{nd,t} = \alpha_0^k + \sum_{i=0}^{e} \alpha_i^s \Delta s_{nd,t-i} + \sum_{i=0}^{f} \alpha_i^P \Delta p_{p,t-i} + \sum_{i=0}^{h} \alpha_i^c \Delta c_{nd,t-i} + \alpha^s s_{nd,t-1} + \alpha^P p_{p,t-1} + \alpha^c c_{nd,t-1} + \overline{\alpha}\overline{U}_t + \mu_t \quad (11)$$

[10] The assumption of cointegration could not be rejected for the demand side, using the critical values from Banerjee et al. (1998). Because of breaks caused by the level dummies and use of instrument variables, these values are not exact. However, we apply the value from Table 1A in Banerjee et al. (1998), where T=100 and k=5. The critical value 4.92 for the t-value of the estimated β^D is equivalent to a 1 % significance level.

[11] We also allowed the price elasticities to vary with the oil price, but this did not have a significant effect on our results. In addition, the econometric study by Hogan (1992) rejects linear demand models for crude oil in the OECD-countries in favour of constant elasticity formulations.

Equilibrium condition:

(12) $D_{w,t} = S_{nd,t} + S_{d,t}$

The variables in small letters are logarithms and, hence, the parameters belonging to demand, price, economic activity, supply and costs are all elasticities. β_0^k and α_0^k are the intercepts, and $\bar{\beta}$ and $\bar{\alpha}$ are vectors of parameters belonging to the dummy variables. The notation follows from the theoretical model in Section 2, except that Δ means that we use the first difference of the variables. $\overline{U_t}$ is a column vector of dummy variables, which includes the price regulation dummy and other dummy variables, the latter being the X and Z variables in Eq. (1) and (2) in Section 2. These other variables are seasonal dummies and dummies for exogenous shocks[12]. Furthermore, there is a dummy for 1992, taking into account a shift in the dataset, due to lack of data for other former Soviet Union republics than Russia. In the model $P_{c,t}$, $P_{p,t}$, $D_{w,t}$, $S_{nd,t}$, $C_{nd,t}$ are treated as endogenous variables[13], and we apply two-stage least-square estimation to get consistent estimates. Hsiao (1997) shows that this gives consistent estimates also under a cointegrated relationship between the variables, and when an ECM model is applied. Even if we get estimates both for the short and the long run, our main focus is the long-run elasticities. For example, the long run effect of a price change on demand is $\beta = -\dfrac{\beta^P}{\beta^D}$, where β^P contains the price effect of all lags and β^D is the adjustment factor.

We employ spot prices in our estimation, even if futures prices might be as important when producers decide on the production level. Pindyck (2001) finds a strong relationship between spot and futures prices. In addition, he finds that owing to a risk premium the expected futures price usually will exceed the actual future price.

To find a parsimonious model we are using a general to specific modelling strategy. We omit the lagged variables that are insignificant from the general econometric specification. The lagged variables that are omitted from the model are used as instruments. In determining the number of lags in the model we emphasise that the residuals should be well-behaved. The error terms in the model should not be autocorrelated, since this will give inconsistent results. That no heteroscedasticity prevail is important for the efficiency of the estimates. The instruments should be correlated with the

[12] The oil market is known as a market with many exogenous shocks, leading to large swings in oil price and production (see e.g. EIA, 2000). We apply dummy variables for these exogenous shocks in specific months, reported as e.g. 1992-1 as shown in Appendix B. In addition we have included seasonal dummies for months. We apply those dummies that were significant in the final estimation.

[13] We let $C_{nd,t}$ be endogenous. Although this is not explicitly stated in our framework, it could be in an enhanced model.

endogenous variables, and not with the error term in order to correct for the simultaneity bias. The diagnostic tests for these assumptions are reported in Appendix B. The econometric model is estimated for the period 1974:6 (due to the lagged variables) to 2001:8, and re-estimated for the period 1974:6 to 1994:1 in order to check the stability of the model.

5. Results

5.1. Estimation of global demand and supply of the non-dominant producers

Table 2 shows the long-run estimation results of total demand and supply of the non-dominant producers in Eq. (10) and (11), respectively. We have divided the estimation period in various periods to check if the coefficients are stable over time. To compare with Alhajji and Huettner (2000b), we show the results for the period 1974-1994 too[14]. To check the stability of the parameters over time, we have in addition carried out a recursive estimation of the demand price elasticity and the income elasticity (se Figure B at the end of Appendix B) [15]. We see from Table 2 that the model generates very low long-run demand price elasticities. This elasticity is lower in absolute value than reported by Alhajji and Huettner (-0.12) using quarterly data for the period 1974-1994, but is actually close to Krichene (2002), who applied yearly data and found a demand price elasticity of -0.005 from 1973 to 1999. The models are different and this may explain the differences in the results. Krichene (2002) also apply an ECM model, and this implies another lag-structure than in the partial adjustment model employed by Alhajji and Huettner (2000b).

Our long-run income elasticities are stable over time and in the range of the estimates in Alhajji and Huettner. The absolute value of the demand price elasticity is much higher at the start of the 1980s than in the 1990s, and as from 1990 it is more or less stable (see Figure B in Appendix B). This is in line with Krichene (2002) who found higher long-run demand price elasticities prior to 1973 than in the following years. In addition, Haas et al. (1998) find that the price elasticity of crude oil have

[14] In appendix B we list the short-run results for the complete estimation. The supply and demand price elasticities have the correct signs when the model is estimated using the entire sample, but none of them are significant. In Table B1 the short-run demand price elasticity (in the line for $\Delta p_{c,t}$) is estimated to -0.01, but it is not stable over time as it is positive for the sub-period 1974:6 to 1994:1. In Table B2 the short-run supply price elasticity for Non-OPEC is estimated to 0.15 (in the line for $\Delta \ p_t^p$). The supply price elasticities in Table B3 for Non-OPEC-Core and in Table B4 for Non-Saudi-Arabia are 0.25 and 0,21, respectively. The income elasticity in Table B1 (in the line for Δg_t) is 0.22 and it is significant and stable over time (both the sign and the absolute value). The price-dummy of US price control is positive and significant for demand and negative for supply as expected. The signs of the cost coefficients are positive, but not significant.

[15] In the recursive estimation we apply the value of the dummy variables from the estimation-period 1974-2001 to calculate a demand function corrected for exogenous shocks. The recursive estimation is then based on the corrected demand. There is a bias in these estimates because the dummy variables could not be used as instruments in the estimation. However, the deviation in the estimates is insignificant.

become less elastic for OECD-countries, which constitute the major oil consuming countries. This may indicate that demand has gone through a structural change. The large price-increases in 1973/74 and 1979/80 probably compressed long-run demand to a level that was highly inelastic to price changes. There may have been energy-saving and various forms of substitution among petroleum products, and among crude oil and other energy carriers, to such an extent that further structural changes became difficult. A large proportion of oil is used for transport purposes with few substitution possibilities. Oil for stationary purposes is also rather inflexible. Although fuel competition is tougher in the power sector, fuel oil plays a minor role in this sector compared to coal and gas.

Table 2. Long run demand and supply elasticities in the dominant producer model

	Our monthly estimates 1974-2001	Our monthly estimates 1974-1994	Alhajji and Huettner's quarterly estimates 1974-1994
Demand			
Price elasticity	-0.01	-0.01	-0.12
Income elasticity	0.61	0.59	0.49 - 0.78
Supply Non-OPEC			
Price elasticity	0.38	0.64	1.00
Supply Non-OPEC-Core			
Price elasticity	0.44	-0.18	-0.12
Supply Non-Saudi-Arabia			
Price elasticity	0.32	-0.17	-0.19

The supply price elasticities are positive for Non-OPEC production over the whole sample from 1974 to 2001 and also over the period 1974-1994. In addition to having the correct sign, the supply price elasticity is relatively stable over time[16]. We conclude that our results at least give some indication that the fringe producers outside OPEC can be described as competitive producers and take the oil price as given. Looking at Figure 3 also give some support for claiming that the profit maximizing condition in Eq. (5) is satisfied.

Our long-run estimates of the supply price elasticities for Non-OPEC are in the lower range of the results in Ramcharran (2002), who estimated supply functions for nine Non-OPEC countries, finding elasticities between -0.1 and 2.4. However, it is in the range of the Non-OPEC supply elasticities (0.15-0.58) applied in Gately (2004).

[16]Again, to check the stability of the parameters over time, we have also carried out a recursive estimation of the supply price elasticities. Recursive estimation indicated the omitted dummy variable used as instruments caused a deviation in the estimates. Hence, the results are not reported, but they seem to support our conclusion.

We see that the price elasticities of Non-OPEC-Core and Non-Saudi-Arabia are positive over the whole sample, but that they actually are negative from 1974 to 1994. This indicates that the group of producers in Non-OPEC-Core and Non-Saudi-Arabia (taken together) do not fit the behaviour of competitive producers in this period. Alhajji and Huettner confirm our negative price supply elasticities for Non-OPEC-Core and Non-Saudi-Arabia from 1974 to 1994. They conclude that Saudi-Arabia can be considered as a dominant producer in the period 1974 to 1994, but from our point of view the dominant producer model cannot be applied when the other producers fail to have price-taking behaviour.

To fill in the picture, we also tested the competitive hypothesis for OPEC as a whole. The result shows that the price elasticity is -0.40 in the long run, which is contrary to price-taking behaviour. The estimation results are presented in Table B5 in Appendix B.

In Table 2 (and in other tables) we have not reported t-values for the long-run elasticities since it is not evident that the usual t-distribution can be applied for the estimators of these deduced parameters in our model settings.

5.2. Estimation of market power

All in all, our findings of low non-dominant supply and demand price elasticities entail that residual demand only responds slightly to price increases. This underpins the potential market power of OPEC. Furthermore, owing to e.g. a supply-side shock, prices have to react strongly in order to restore market balances. Hence, our result stresses the oil price volatility in response to shocks in the oil market.

We calculate E_d in Eq. (8), applying the estimated long-run global demand price elasticities and supply price elasticities of the non-dominant producers. This gives us the residual elasticity of demand for OPEC, OPEC-Core and Saudi-Arabia as shown in Figure 5.

We see from the figure that OPEC has not been operating on the elastic segment of its residual demand curve between 1973 and 2001. The marginal revenue on the left-hand side in Eq. (7) is actually negative. If OPEC had reduced production further, the marginal revenue could turn positive and reach a level equal to marginal costs, which is the first-order profit-maximising condition. Hence, OPEC does not fulfil the condition for being a profit-maximising dominant producer. Looking at the oil price in Figure 1 and the supply costs of OPEC (as discussed above), we conclude that OPEC clearly has affected the market price, but the producer group has not behaved as a pure profit-maximising dominant producer. There may be various reasons why OPEC can be characterised as a restrained or weak cartel. First of all, OPEC may simply be uncertain about the true elasticities. Our study indicates that the demand price elasticities have declined since the first oil-price shock in 1973. Earlier studies in the 1970s and 1980s generally found higher global demand and Non-OPEC supply price elasticities, entailing that OPEC might have been afraid of loosing a large market share if they were to curtail production even more. Moreover, they might suspect an uncertain limit-price to exist. Reaching such a price level could lead to irreversible shifts away from oil in some markets that are not regained when the price increase is reversed, possibly undermining the market share of OPEC in the long run. Thirdly, OPEC has seldom meetings and is not able to fine-tune the market[17]. OPEC may also fear the consequences if they were to introduce a more stringent cartel. This could lead to increasing difficulty in reaching consensus on output revisions or ultimately that a member withdraws from the organisation. Such transaction costs could easily outweight the benefits from e.g. output reductions among the member countries.

Figure 5. Residual elasticity of the demand for OPEC, OPEC-Core and Saudi-Arabia

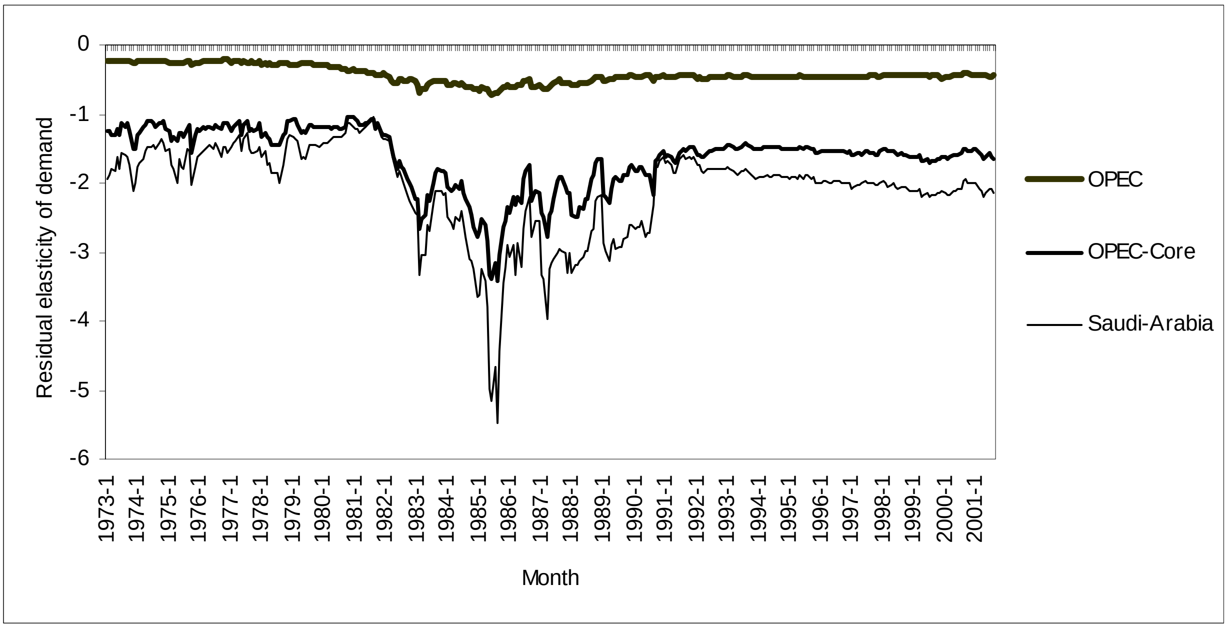
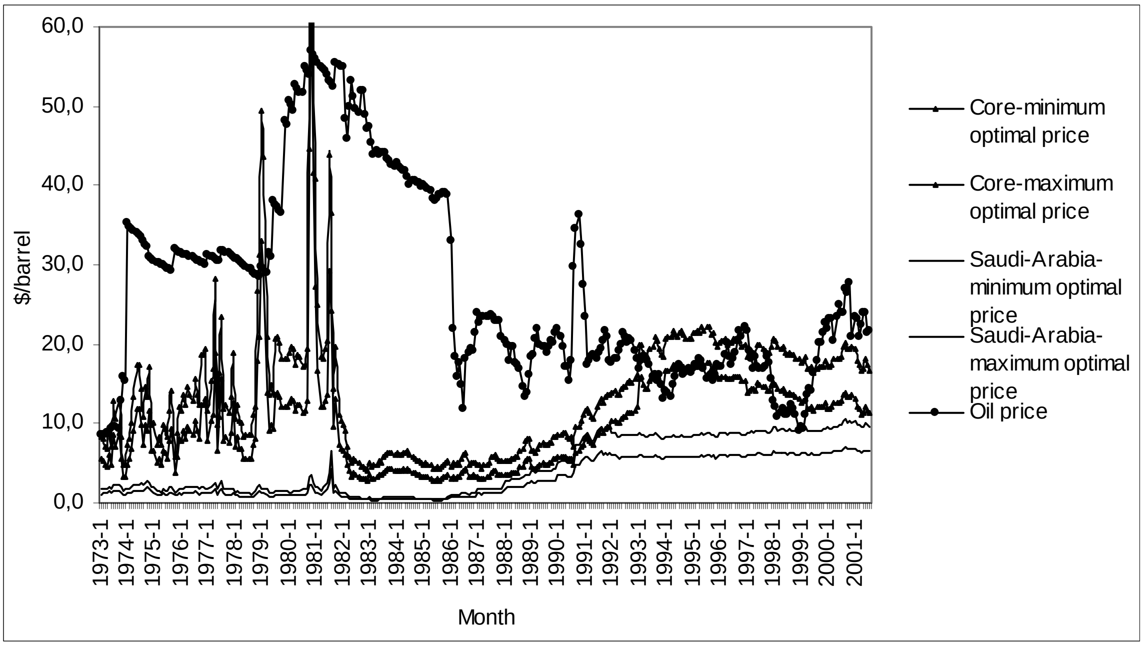


Figure 5 further shows that OPEC-Core and Saudi-Arabia behaviour is consistent with the necessary condition that they have to operate on the elastic segment of their respective residual demand curves. The elasticity is generally lower in absolute value for OPEC-Core, indicating a higher mark-up of price over costs. Inserting the minimum and maximum supply costs of Saudi-Arabia and OPEC-Core in Eq. (9), we get their minimum and maximum optimal price as shown in Figure 6.

[17] Since 1982, when OPEC formally adopted a system of individual quotas to each member, revisions have occurred less than twice per year, on average (although the interval is highly variable, see Smith, 2002).

The results in Table 2 showed that the producers constituting the Non-OPEC-Core and Non-Saudi-Arabia could not be treated as competitive in the period from 1974 to 1994. As our supply price elasticities for these producer groups are positive when estimating using the whole sample, however, we have some indications that the dominant producer model can be applied for Saudi-Arabia and OPEC-Core as from 1994. Figure 6 shows that the optimal price for Saudi-Arabia clearly is below the observed oil price. Consequently, if Saudi-Arabia wanted to behave as a dominant producer after 1994, it should have increased production and let the oil price decline to its optimal level. For OPEC-Core the observed oil price varies somewhat around the minimum and maximum optimal price as from 1994. Thus, the characteristics of a dominant producer fit OPEC-Core somewhat in this period. However, uncertain cost estimates, and uncertainty in the estimated elasticities that is not reflected in Figure 6, entail that it is difficult to draw strong conclusions from the dominant producer model without more precise estimates.

Figure 6. Minimum and maximum optimal real oil price for two dominant producers (1996$)



Note: The optimal oil price for OPEC-Core increased to more than $60 per barrel in the last two months of 1980.

A weakness of the dominant producer approach is that all producers within the dominant group are treated symmetrically, which makes it impossible to explain the strategic behaviour in the cartel. As presented in Salant (1982), we have therefore also made some preliminary tests of a framework that allows for the specification of several Cournot players, as well as competitive producers. When different groups of OPEC act as Cournot-players, they maximise their profits taking the production level from each other as given, but knowing the response of the price-taking competitive group of producers. The countries within each Cournot-group are treated symmetrically with respect to strategic behaviour. Our preliminary estimations which is not reported, show that the three Cournot groups that lead to the best fit with the data as from 1990, are quite heterogeneous and not in line with our a priori beliefs. To elaborate more on the Cournot model might be the subject of further research.

Conclusion

We use a multi-equation dynamic econometric model to test if the behaviour of OPEC as a whole or different sub-groups of the cartel is consistent with the behaviour of dominant producers on the world crude oil market. The vast majority of earlier studies have relied on single-equation (often static) models to test for cartel behaviour. This causes autocorrelation in the residuals and biased estimates. Contrary to single-equation models a multi-equation dynamic model will take into account the behaviour of both the demand and supply side. To our knowledge only a couple of studies have used such an approach. As opposed to those studies, we apply an Equilibrium Correction Mechanism model and distinguish between the producer and consumer price of oil. Using new monthly data from 1973 to 2001, the short- and long-run elasticities of world demand and supply of price-taking producers are estimated. We find it reasonable to assume that the key variables are non-stationary, and assume that the variables are cointegrated. The estimation reveals very low demand price elasticities and somewhat low supply price elasticities of Non-OPEC. The elasticities have correct signs and are stable over time. All in all, economic growth influences oil demand more than the price level. Our results are in line with elasticity estimates in some recent energy studies. This underpins the potential market power of OPEC and also oil price volatility in response to shocks.

The estimation results indicate that the group of producers outside OPEC can be described as competitive producers, maximising profits and taking the oil price as given. In addition, the OPEC members cannot be considered as price-takers. We test for the existence of a dominant producer as a static Stackelberg-leader, choosing the oil price to maximise profits and knowing the response of the demand and the competitive non-dominant group of producers. Our findings indicate that OPEC as a whole cannot be characterized as a dominant producer. OPEC does not operate on the elastic part of its long-run demand curve, which a profit-maximising dominant producer should do. Saudi-Arabia and OPEC-Core do not fit the description of a dominant producer prior to 1994, simply because the producers constituting Non-OPEC-Core and Non-Saudi-Arabia do not have competitive behaviour as Non-OPEC. However, we conclude that the characteristics of a dominant producer fit OPEC-Core to some extent after 1994. Uncertainty about the supply costs as well as uncertainty in our estimated elasticities makes it difficult to conclude from the dominant producer model without more precise estimates.

OPEC has clearly affected the market price, but the producer group has not behaved as a pure profit-maximising dominant producer. There may be various reasons why OPEC can be characterised as a restrained cartel. One reason that our study highlights is that OPEC may simply be uncertain about the true elasticities. Earlier studies generally found higher demand and Non-OPEC supply price elasticities, entailing that the estimated residual demand facing OPEC would decline more if it raised the oil price.

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Appendix A

Sources for the Non-OPEC cost figures are EIA (2002). These costs are estimated from the worldwide total production costs from US-based oil-companies in the world[18], divided by production. This is used as an index for the production costs for the period 1979 to 2001. We set the supply costs for Non-OPEC to 10 dollar per barrel in June 1999 (CERA, 2000), and the index is used to adjust this cost over time. Prior to 1979 Non-OPEC costs are extrapolated to fit the oil price in 1973. We smooth these yearly estimates over each twelve-month period to get monthly supply costs.

We apply the higher and lower supply costs of the OPEC-countries estimated in Adelman and Shahi (1989) for the period 1973-1985. In addition, we employ the estimates of supply costs from Adelman (1986), Dahl and Yücel (1991), Stauffer (1993, 1994), IEA (1995), EIA (1996), IEA (2001) and IEA (2003). The costs are adjusted, if necessary, to include finding, development and production costs. If a high and a low cost estimate do not exist, we let the maximum supply cost to be 50 per cent higher than the minimum cost. We apply interpolation for years with missing cost data. The final costs are adjusted to be three-year weighted averages of the supply costs. We apply the yearly cost data for each month in the specific year.[19]

[18] Although this data also contains some companies' production in OPEC, the vast majority of their activities are situated in Non-OPEC countries.

[19] A detailed description of how the costs are estimated is available from the authors upon request.

Appendix B

Table B1. Estimates of demand

	1974-2001		1974-1994	
Slope coefficients related to indicated variables	Estimate	t-value	Estimate	t-value
Intercept	1.70	6..29	1.74	5.24
$\Delta p_{c,t}$	-0.01	-0.29	0.01	0.27
$\Delta p_{c,t-1}$	-0.04	-2.65	-0.04	-1.93
Δg_{t}	0.22	1.73	0.18	0.91
Δg_{t-1}	0.29	2.27	0.45	2.32
Δg_{t-2}	0.28	2.11	0.22	1.12
$p_{c,t-1}$	-0.002	-0.42	-0.003	-0.39
g_{t-1}	0.13	5.56	0.12	4.17
$d_{w,t-1}$	-0.21	-6.50	-0.21	-5.43
Price dummy	0.04	6.09	0.04	4.77
Dummy 1977-1	-0.10	-5.49	-0.10	-4.75
Dummy 1978-1	-0.10	-5.77	-0.11	-4.99
Dummy 1980-10	-0.07	-3.56	-0.06	-2.96
Dummy 1985-6	-0.05	-2.85	-0.05	-2.54
Dummy 1990-8	-0.06	-2.62	-0.70	-2.61
Dummy 1990-9	0.06	2.92	0.05	2.33
Dummy 1992-1	0.06	3.10	0.06	2.79
Dummy 1987-7	0.04	2.42	0.04	2.08
Seasonal for March	0.01	2.25	0.01	1.93
Dummy for Russia	0.02	4.68	0.02	3.48
Long-run p	-0.01		-0.01	
Long-run g	0.61		0.59	

Diagnostic tests:		
Specification test:[a]	Chi^2(19)= 17.233 [0.5741]	Chi^2(19)= 15.208 [0.7093]
Testing beta = 0:[b]	Chi^2(19)= 214.16 [0.0000]	Chi^2(19)= 158.63 [0.0000]
AR 1-7 test: [c]	F(7,299) = 1.0250 [0.4135]	F(7,209) = 0.94106 [0.4758]
ARCH 1-7 test:[d]	F(7,292) = 0.72148 [0.6539]	F(7,202) = 0.24162 [0.9744]
Normality test:[e]	Chi^2(2) = 127.51 [0.0000]	Chi^2(2) = 66.566 [0.0000]
Heteroscedasticity test:[f]	F(27,278)= 1.8519 [0.0077]	F(27,188)= 1.1665 [0.2709]

---

a Under the null-hypothesis the instrumental variables are not valid, as discussed by Sargan (1964).

b This is the test-statistics for the null-hypothesis that all the slope coefficients are zero.

c Lagrange-multiplier test for up to order 7 residual autocorrelation, distributed as χ 2 in large samples. Under the null hypothesis there is no autocorrelation.

d This is test statistics for absence of ARCH(1-7), as outlined by Engle (1982).

e This is the test for normally distributed error terms as launched by Doornik and Hansen (1994). It is χ 2 distributed with two degrees of freedom.

f This test is based on White (1980). The null hypothesis is that unconditional homoscedasticity prevail.

Identifying Instruments: $\Delta p_{p,t-1}, \Delta p_{p,t-2}, \Delta p_{p,t-3}, \Delta p_{p,t-4}, \Delta p_{p,t-5}, \Delta p_{p,t-6}, \Delta p_{p,t-7}, \Delta p_{p,t-8}, \Delta p_{p,t-9}, p_{p,t-1}$

$\Delta c_{nd,t-1}, \Delta c_{nd,t-2}, \Delta c_{nd,t-3}, \Delta c_{nd,t-4}, \Delta c_{nd,t-5}, \Delta c_{nd,t-6}, \Delta c_{nd,t-7}, \Delta c_{nd,t-8}, \Delta c_{nd,t-9}, c_{nd,t-1}$

Table B2. Estimates of Supply: Non-OPEC

	1974-2001		1974-1994	
Slope coefficients related to indicated variables	Estimate	t-value	Estimate	t-value
Intercept	0.10	0.85	0.06	0.42
$\Delta p_{p,t}$	0.15	0.32	0.05	0.83
$\Delta c_{nd,t}$	0.21	0.85	0.04	0.16
$\Delta s_{nd,t-1}$	-0.27	-5.83	-0.27	-5.05
$p_{p,t-1}$	0.004	0.87	0.01	0.46
$c_{nd,t-1}$	0.0004	0.08	0.001	0.05
$s_{nd,t-1}$	-0.01	-1.01	-0.01	-0.57
Price dummy	-0.01	-0.77	-0.001	-2.33
Dummy 1992-1	0.14	12.2	0.15	11.00
Seasonal for January	0.01	2.93	-0.10	-5.77
Seasonal for February	0.01	4.42	-0.07	-3.56
Seasonal for March	0.01	3.38	-0.05	-2.85
Seasonal for November	0.01	2.49	-0.06	-2.62
Dummy for Russia	0.003	1.00	0.003	0.71
Long-run c	0.4		0.1	
Long-run p	0.38		0.64	

Diagnostic tests:		
Specification test:	Chi^2(9) = 15.250 [0.0843]	Chi^2(9) = 7.1492 [0.6216]
Testing beta = 0:	Chi^2(13)= 234.52 [0.0000]	Chi^2(13)= 179.59 [0.0000]
AR 1-7 test:	F(7,305) = 1.3572 [0.2231]	F(7,215) = 1.9813 [0.0589]
ARCH 1-7 test:	F(7,298) = 1.8806 [0.0724]	F(7,208) = 1.3755 [0.2171]
Normality test:	Chi^2(2) = 1.0251 [0.5990]	Chi^2(2) = 0.23129 [0.8908]
Heteroscedasticity test:	F(19,292)= 1.8910 [0.0145]	F(19,202)= 1.4100 [0.1248]

Identifying Instruments: $\Delta g_t, \Delta g_{t-1}, \Delta g_{t-2}, \Delta g_{t-3}, \Delta g_{t-4}, \Delta g_{t-5}, \Delta g_{t-6}, \Delta g_{t-7}, \Delta g_{t-8}, \Delta g_{t-9}, g_{t-1}$

Table B3. Estimates of supply: Non-OPEC-Core

	1974-2001		1974-1994	
Slope coefficients related to indicated variables	Estimate	t-value	Estimate	t-value
Intercept	0.39	1.22	0.97	2.57
$\Delta p_{p,t}$	0.25	1.82	0.002	0.01
$\Delta P_{p,t-1}$	-0.06	-1.76	0.002	0.06
$\Delta p_{nd,t}$	2.14	1.13	1.37	1.21
Δc_{t-1}	-2.05	-1.23	-1.29	-1.29
$p_{p,t-1}$	0.02	1.13	-0.02	-0.68
$c_{nd,t-1}$	-0.02	-1.16	0.01	0.40
$s_{nd,t-1}$	-0.04	-1.27	-0.09	-2.61
Price dummy	-0.10	-1.46	-0.003	-0.44
Dummy 1977-1	-0.10	-3.53	-0.08	-3.91
Dummy 1978-1	-0.06	-2.42	-0.07	-3.30
Dummy 1979-4	-0.04	-1.40	0.05	2.32
Dummy 1980-10	-0.08	-3.20	-0.09	-4.24
Dummy 1990-8	-0.15	-2.25	-0.04	-0.63
Dummy 1992-1	0.08	3.21	0.09	4.32
Seasonal for June	0.01	1.54	0.001	0.14
Dummy for Russia	0.0004	0.06	0.005	0.67
Long-run c	-0.50		0.11	
Long-run p	0.44		-0.18	

Diagnostic tests:		
Specification test:	Chi^2(5) = 7.7557 [0.1702]	Chi^2(5) = 13.515 [0.0190]
Testing beta = 0:	Chi^2(16)= 63.056 [0.0000]	Chi^2(16)= 100.95 [0.0000]
AR 1-7 test:	F(7,302) = 0.57219 [0.7784]	F(7,212) = 1.0970 [0.3662]
ARCH 1-7 test:	F(7,295) = 0.43805 [0.8779]	F(7,205) = 1.3861 [0.2127]
Normality test:	Chi^2(2) = 42.917 [0.0000]	Chi^2(2) = 6.6407 [0.0361]
Heteroscedasticity test:	F(23,285)= 5.8089 [0.0000]	F(23,195)= 1.6353 [0.0394]

Identifying Instruments: Δg_t, Δg_{t-1}, Δg_{t-2}, Δg_{t-3}, Δg_{t-4}, Δg_{t-5}, g_{t-1}

Table B4. Estimates of supply: Non-Saudi-Arabia

	1974-2001		1974-1994	
Slope coefficients related to indicated variables	Estimate	t-value	Estimate	t-value
Intercept	0.46	1.51	1.02	2.67
$\Delta p_{p,t}$	0.21	1.76	-0.01	-0.04
$\Delta p_{p,t-1}$	-0.05	-1.76	0.002	0.05
$\Delta c_{nd,t}$	1.81	0.99	0.97	0.86
$\Delta c_{nd,t-1}$	-1.77	-1.08	-0.95	-0.94
$p_{p,t-1}$	0.01	1.08	-0.02	-0.71
$c_{nd,t-1}$	-0.02	-1.36	0.01	0.025
$s_{nd,t-1}$	-0.04	-1.54	-0.10	-2.69
Price dummy	-0.01	-1.03	0.002	0.28
Dummy 1977-1	-0.13	-5.15	-0.12	-5.44
Dummy 1978-1	-0.09	-3.51	-0.09	-4.33
Dummy 1979-4	0.04	1.68	0.05	2.47
Dummy 1980-10	-0.08	-3.03	-0.08	-3.75
Dummy 1990-8	-0.18	-3.02	-0.08	-1.31
Dummy 1992-1	0.08	3.04	0.08	3.83
Dummy for Russia	0.002	0.25	0.01	0.76
Long-run c	-0.50		0.10	
Long-run p	0.32		-0.17	

Diagnostic tests:		
Specification test:	Chi^2(6) = 11.557 [0.0726]	Chi^2(6) = 17.936 [0.0064
Testing beta = 0:	Chi^2(15)= 96.901 [0.0000]	Chi^2(15)= 136.72 [0.0000]
AR 1-7 test:	F(7,303) = 0.63267 [0.7288]	F(7,213) = 1.1641 [0.3247]
ARCH 1-7 test:	F(7,296) = 0.79450 [0.5924]	F(7,206) = 1.1349 [0.3425]
Normality test:	Chi^2(2) = 33.454 [0.0000]	Chi^2(2) = 17.684 [0.0001]
Heteroscedasticity test:	F(22,287)= 5.1935 [0.0000]	F(22,197)= 1.5791 [0.0542]

Identifying Instruments: $\Delta g_t, \Delta g_{t-1}, \Delta g_{t-2}, \Delta g_{t-3}, \Delta g_{t-4}, \Delta g_{t-5}, \Delta g_{t-6}, g_{t-1}$

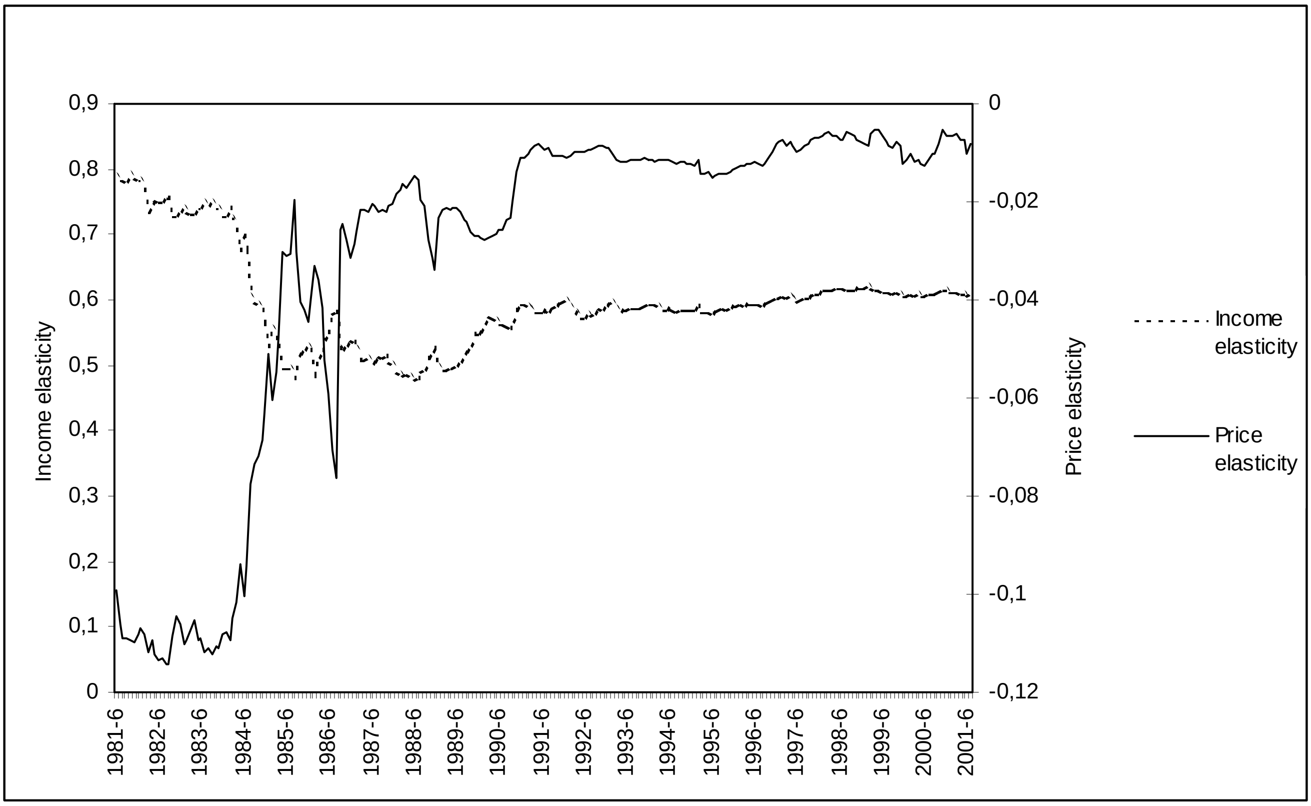
Table B5. Estimates of OPEC as a competitive producer

	1974-2001		1974-1994	
Slope coefficients related to indicated variables	Estimate	t-value	Estimate	t-value
Intercept	0.60	3.03	1.14	3.45
$\Delta p_{p,t}$	-0.02	-0.12	-0.32	-1.21
$p_{p,t-1}$	-0.02	-1.74	-0.04	-2.41
$s_{nd,t-1}$	-0.05	-3.08	-0.10	-3.37
Price dummy	0.02	1.50	0.05	2.71
Long-run p	-0.40		-0.40	

Diagnostic tests:		
Specification test:	Chi^2(10)= 15.811 [0.1052]	Chi^2(10)= 6.0784 [0.8086]
Testing beta = 0:	Chi^2(4) = 12.168 [0.0161]	Chi^2(4) = 12.663 [0.0130]
AR 1-7 test:	F(7,321) = 1.3873 [0.2098]	F(7,231) = 1.2431 [0.2800]
ARCH 1-7 test:	F(7,314) = 0.94691 [0.4704]	F(7,224) = 1.2228 [0.2911]
Normality test:	Chi^2(2) = 84.758 [0.0000]	Chi^2(2) = 129.85 [0.0000]
Heteroscedasticity test:	F(7,320) = 3.0823 [0.0037]	F(7,230) = 29.804 [0.0000]

Identifying Instruments: $\Delta g_t, \Delta g_{t-1}, \Delta g_{t-2}, \Delta g_{t-3}, \Delta g_{t-4}, \Delta g_{t-5}, \Delta g_{t-6}, \Delta g_{t-7}, \Delta g_{t-8}, \Delta g_{t-9}, g_{t-1}$

Figure B. Demand price and income elasticity over time



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