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THE OIL MARKET AS AN OLIGOPOLY

BY

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Abstract

This paper treats the oil market as an oligopoly with a competitive fringe. The oligopoly is assumed to consist of Egypt, Oman, Mexico, Malaysia and Norway plus all OPEC members. The remaining oil producing countries are included in a fringe which by assumption takes the oil price development as exogenously given. Outcomes with varying degrees of collusion within the oligopoly are specified. Intermediate cases are also studied, such as complete or partial cooperation within OPEC, but no cooperation between OPEC and any other countries in the oligopoly. The model is implemented in the PC-based MODLER software, and empirical results from the simulations on the different model versions are presented.

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1 Introduction

The future price development for oil will depend on to what extent the OPEC members are able to coordinate their production decisions, and to what extent OPEC succeeds in cooperating with other major oil producers. Many countries both inside and outside OPEC will suffer through large reductions in incomes by a fall in the oil price as a result of breakdown of OPEC. This obviously forms the background for the fact that some countries outside the organization have found it beneficial to negotiate with OPEC in order to support OPEC's control over the market. For each agent in the market this kind of agreement must be weighted against the benefits of being a "free rider" in the market. The question of benefits from cooperation with OPEC from the point of view of Mexico and Norway is discussed in Berger, Bjerkholt and Olsen (1987). This analysis used a simple partial equilibrium model (WOM) for the international oil market as its point of departure, and the issue of cooperation was then approached by different assumptions of exogenous oil supplies from different regions. Thus, no formal behavioural relations on the supply side of the oil market were underlying these simulations. Even though it may be questioned whether a formal cartel model is suited for fitting the obviously complex relations in the international crude oil market, we still believe that a more formal analysis is useful as a supplement of understanding present and future development in the market.

This paper treats the oil market as an oligopoly with a competitive fringe. Consistent with the reasoning in Berger et al. (op. cit) we assume that Egypt, Oman, Mexico, Malaysia and Norway are the oil producers outside OPEC which are most likely to cooperate with OPEC. The oligopoly is thus assumed to consist of these countries plus all OPEC members. The remaining oil producing countries are included in a fringe which by assumption takes the oil price development as exogenously given. We consider outcomes with varying degrees of collusion within the oligopoly. One extreme case is characterized by a complete breakdown of cooperation within the oligopoly. In this case we assume that the Cournot solution is the market outcome. The opposite extreme is the situation where all countries in the oligopoly coordinate their production decisions so that the total profit of the oligopoly is maximized. We also consider intermediate cases, such as complete or partial cooperation within OPEC, but no cooperation between OPEC and any other countries in the oligopoly.

The net demand for crude oil which the oligopoly is facing is roughly consistent with demand and supply relations in the WOM model. The procedure for calibrating net oil demand in the present framework will be outlined below.

The rest of the paper is organized as follows. In the following section limitations of the theoretical framework will be briefly discussed. Section 3 and 4

describe our assumptions about total demand for oil and the supply of oil from the competitive fringe. Section 5 briefly surveys the cost functions of the oligopoly members. In section 6 we present the specific theoretical models that are implemented and tested empirically, comprising both the pure Cournot solution and cases with varying degrees of collusion between oligopoly members. Empirical results from simulations on the different model versions are given in section 7. Finally, some concluding comments are given in section 8.

2 Restricting the theoretical framework

Throughout this paper we have ignored the fact that oil is a depletable resource. There are two reasons for doing this. The first reason is that we want the model to be as simple and easy to use as possible. It is well known from the literature (see e.g. Newbery (1981)) on exhaustible resources that it is quite difficult to derive numerical solutions to several of the possible solution concepts in oligopoly models of exhaustible resources. Our model framework is intended to be a tool for planners in Norwegian government agencies, oil companies etc. For this purpose the structure of the model must be reasonably simple, and its mechanisms must be well understood by the users.

A second reason for ignoring the fact that oil is depletable is that all Hotelling types of models force us to specify the appropriate interest rate for each country. It is not obvious that the countries use interest rates from international financial markets in their considerations about how much oil they should extract at different points of time. Moreover, international interest rates may depend on OPEC behaviour. This makes the intertemporal decision problems of OPEC-countries even more complex than they are with exogenous interest rate (see e.g. Hoel (1981)). By simply ignoring the depletion issue, from a strictly formal point of view we obtain results corresponding to producers having an infinite interest rate. Since high interest rates tend to increase extraction and reduce prices under all market structures, the fact that we ignore the exhaustibility of oil implies that we tend to overestimate production and underestimate price in our model.

We shall also disregard intertemporal aspects of demand and supply functions. In reality, price changes only gradually affect demand and fringe supply. This means that price changes will only gradually affect the residual demand facing the oligopoly. Our model uses long run demand and supply functions, i.e. we restrict ourselves to long run equilibria. This also means that we assume that participants in the oligopoly only consider long run consequences of alternative production levels. If oligopoly members have a positive interest rate, rational behaviour implies that both short and long run effects will be considered

when agents choose their optimal production strategy (see e.g. Hnyilicza and Pindyck (1976)). By completely ignoring short run considerations, we thus tend to overestimate production and underestimate price in our model, since short run elasticities are smaller than long run elasticities (in absolute value). Our predicted prices may thus be biased downwards due both to our ignoring of the fact that oil is depletable and because we only consider long run elasticities in our description of the behaviour of the oligopoly members.

However, a couple of other features of the model specification tend to overestimate prices, especially in the long run. Firstly, in the model simulations capacities of oligopoly members are kept constant, pushing up marginal costs as demand and production grow. Secondly, in the calculations we have disregarded from the influences of increased substitutability in the oil market, represented in its purest form of the presence of a back-stop technology. Altogether, one may say that our model introduces a negative bias on prices in the short to medium run, but tend to overestimate prices in the long run.

In the present version of our model, capacity limits of all oligopoly members are exogenous. For a long run analysis this is clearly unsatisfactory. In a later version of our model we plan to endogenize production capacities. The simplest way of doing this is to use long run cost functions, which include the cost of capacity expansion. An alternative procedure is to model the oligopoly market as a two stage game. In the first stage, the capacity of each country is determined as a Nash equilibrium of a non-cooperative game. The second stage of the game may be modeled in a similar way as will be described in the following, i.e. with exogenous capacity. The capacity chosen in the first stage will affect the outcome in the second stage and consequently the payoff to each player. The relationship between capacities and payoffs will depend on the degree of collusion in the second stage of the game. One way of modeling the capacity decisions in the first stage is to assume that the players have subjective probability distributions over the different market structures which may arise in the second stage of the game.

However, as mentioned above, so far we treat production capacities as exogenous in the model, and we now proceed to explain this framework.

3 The demand for oil

Total world oil demand (outside the East Bloc and China) in the oligopoly model is specified as

$$D = D(P, Z_d) \quad (1)$$

P is the oil price in (real) dollars. Z_d is a vector of exogenous factors, in-

cluding income levels in different countries, real exchange rates, and prices of other energy sources. As mentioned in the introduction, (1) is derived from the WOM model. More specifically, D is the sum of the oil demand of three regions in WOM, namely USA, the rest of OECD, and the LDC's. In each region i ($i = USA, OECD, LDC$) oil demand is given by

$$D_i = A_i X_i^{\beta_i} P_i^{\epsilon_i} Q_i^{\mu_i} \quad (2)$$

where X_i is GNP, P_i is the real price of oil products (in local currency), Q_i is an index representing the real price of alternative energy, and A_i is an exogenous variable expressing the effects of all other exogenous factors, including a possible time trend. The oil price in local currency is

$$P_i = (\gamma_i r_i P + (1 - \gamma_i) C_i) T_i \quad (3)$$

where r_i is the real exchange rate ($r_{USA} = 1$), C_i is the cost (in local currency) of transportation, refining, distribution and storage of oil products, and T_i represents the tax wedge due to indirect taxes on oil products.

Notice that there are no time lags in our demand function (2), as opposed to the WOM model where there is a Koyck lag structure on price responses. This means that the demand elasticities β_i , ϵ_i and μ_i in (2) must be interpreted as long run elasticities. We have used the following elasticities in our analysis:

	USA	OECD	LDC
GNP elasticity (β_i)	0.70	0.80	1.00
Oil price elasticity (ϵ_i)	-0.93	-0.91	-0.37
Price elasticity of alternative energy (μ_i)	0.20	0.37	0.40

Since the variables A_i , X_i , Q_i , r_i , C_i , T_i , γ_i are exogenous in our analysis, we may summarize (2) and (3) and derive $D = \sum_i D_i$, yielding (1).

4 Oil supply from countries outside the oligopoly

Total world supply from the countries outside the oligopoly (including net exports from the East Bloc) is specified as

$$S = S(P, Z_s) \quad (4)$$

In our specification, the only exogenous factor in the supply function (i.e. in Z , in (4)) is a time trend. The time trend is included to represent a gradually declining supply, for a constant oil price, due to depletion.

More specifically, (4) can be thought of as derived from a supply function

$$S(t) = S(P(t), R(t)) \quad (5)$$

where $R(t)$ is cumulative extraction. (In order to avoid any misunderstanding, we include the time dependency of the variables in this part of our analysis.) We assume that $\partial S/\partial P > 0$ and $\partial S/\partial R < 0$.

The development of $R(\tau)$ is given by

$$\dot{R}(\tau) = S(P(\tau), R(\tau)) \quad (6)$$

If the time path of $P(\tau)$ for $\tau \in [0, t]$ was known, $R(t)$ would follow from the differential equation (6) and the initial value $R_0 (= R(0))$, with $t = 0$ being the base year) of cumulative extraction.

Our model is designed to give a description of the oil market at some future date, e.g. year 2000 or 2010. The model is not intended to give a full intertemporal description of possible oil price developments. In order to motivate (4) we may thus just as well assume a certain structure of the oil price development from the base year 0 to our prediction year, in which case $P(\tau)$ follows from P_0 , $P(t)$ and t . An example of this is an oil price path with a constant growth rate, yielding $P(\tau) = P_0(P(t)/P_0)^{\tau/t}$. But if $P(\tau)$ is completely determined by P_0 , $P(t)$ and τ , so is $R(t) - R_0$ (cf. the discussion above). We may therefore write

$$R(t) = \Phi(P(t), P_0, t, R_0) \quad (7)$$

Inserting (7) into (5) gives

$$S = S(P, \Phi(P, P_0, t, R_0))$$

or

$$S = S(P, t) \quad (8)$$

where we have omitted P_0 and R_0 , since they are fixed throughout our analysis.

The resulting supply function (8) is identical to (5), except that the general vector of exogenous factors in (5) is substituted by the specific time trend in (8).

Our numerical model is based on the following specification of (8)

$$S = B \cdot P^\sigma e^{-\alpha t} \quad (9)$$

where B is a constant term. This supply equation is calibrated in the following way: In the WOM model a submodel is specified for the group of producers outside OPEC. In this submodel oil production from these countries are related to various concepts of oil reserves, and exploration and extraction of these reserves are depending on the (expected) oil price. For given assumptions of the oil price and other independent variables this submodel is simulated a number of years ahead (until 2000), yielding non- OPEC supply for varying combinations of explanatory variables. The resulting set of "synthetic" data are then used for estimating the simpler supply behaviour in the oligopoly model represented by (9). Given that we "believe" in the supply structure in the WOM model, this may seem as a reasonable procedure.

The supply elasticity σ is by this procedure estimated to 0.117 , and the time trend parameter obtained is -0.008.

5 Demand and cost functions of the oligopoly

The participants of the oligopoly are all of the OPEC countries plus Egypt, Oman, Mexico, Malaysia and Norway. The remaining oil producing countries are included in a competitive fringe.

The residual demand facing the oligopoly is

$$E = \bar{E}(P, Z) = D(P, Z_d) - S(P, Z_s) \quad (10)$$

Z represents all exogenous factors influencing net demand. At some stages of our analysis it is convenient to invert the demand function $E(P, Z)$, giving

$$P = P(E, Z) \quad (11)$$

Each member of the oligopoly has a cost function

$$C_i = C_i(X_i) \quad (12)$$

where C_i are total costs and X_i is production.

In our main analysis we assume that the capacity (K_i) of each member of the oligopoly is exogenous. The cost functions are then specified as

$$C_i = c_i X_i + g_i [X_i + (K_i - X_i) \ln \frac{K_i - X_i}{K_i}] \quad (13)$$

where $c_i > 0$ and $g_i > 0$.

Marginal costs are

$$C'_{iX} = c_i - g_i \ln \frac{K_i - X_i}{K_i} \quad (14)$$

Marginal costs thus lie above c_i for all $X_i > 0$, and go to infinity as production (X_i) approaches the capacity limit (K_i). The smaller the positive parameter g_i is, the closer to an "inverse L" is the marginal cost function.

6 Different behavioural models for the oligopoly

6.1 The oil market as a Cournot oligopoly

With no collusion between the oligopoly members, we assume that the outcome is given by the Cournot solution, i.e.

$$P + X_i \frac{\partial P}{\partial E} = C'_{is} \quad (15)$$

and

$$\sum_i X_i = E \quad (16)$$

Equations (11), (15) and (16) are $n + 2$ equations determining production (X_i) of each of the n oligopoly members and the oil price (P), as well as total oligopoly production ($E = \sum_i X_i$).

6.2 Collusion in the oil oligopoly

Assume that a group I of the oligopoly members collude, while the remaining members (group J) act as Cournot oligopolists. If the colluding group acts as a profit maximizing cartel with side payments, it chooses production levels so that

$$P + \left(\sum_{i \in I} X_i \right) \frac{\partial P}{\partial E} \leq C'_{is}, \quad i \in I \quad (17)$$

where (17) and $X_i \geq 0$ hold with complementary slackness. (17) consists of n_I equations. For the $n_J = n - n_I$ non-colluding oligopoly members our previous equations (15) remain valid. Equations (11) and (16) are valid also for the present case, so that we again have $n + 2$ equations determining X_i , E and P .

A crucial question is how many and which members who choose to collude. This problem is not approached in a formal manner in the present paper. A possible procedure would be to set up a two stage game. The first stage is about whether or not to collude, the second stage describes the actual market solution.

d'Aspremont et al. (1983) point out that a stable cartel will exist, i.e. there exists a Nash equilibrium in the first stage of the game where some members choose to collude. As long as all members are equal, it is arbitrary which members collude, but in the case of OPEC this should be determined by invoking economic and cultural conditions.

If the parameter c_i in the cost functions differs between countries, we may get zero production from some of the oligopoly countries. The side payments which would be necessary for the zero production countries to accept such an outcome would be substantial. This may not seem particularly realistic. We shall therefore also study a collusive behaviour where no side payments are allowed.

6.3 Proportionate adjustment of production levels

Without side payments, the most satisfactory solution would be to start by characterizing the efficient outcomes for the oligopoly, i.e. outcomes on the profit possibility frontier. In addition, we would have to make some additional assumptions in order to pick out one particular efficient outcome. One appealing way of doing this is suggested by Osborne (1976). Under relatively weak conditions he shows that maximization of joint profits can be supported as a Nash equilibrium by a quota rule. The cartel must assign a quota to each member, and if one or more members deviate from this quota, the other members must retaliate to preserve their market share. Hence, this solution combines two attractive features, joint profit maximization and simple strategies in a Nash equilibrium.

There are, however, two problems with this approach. First, all countries must have non-zero production in the maximum point. As mentioned above, with realistic cost functions this will not be the case. Secondly, the strategies will in general not be creditable, i.e. the solution will not be a perfect equilibrium.

We shall instead use a simpler approach. Our starting point is the Cournot solution derived in section 6.1. Denote the production levels under this solution by X_i^* for the colluding members (i.e. $i \in I$). We now assume that the collusion solution is characterized by all colluding members reducing their production proportionately from the non-cooperative production levels X_i^* . The production of each colluding member is thus kX_i^* ($i \in I$), where $0 < k < 1$. The non-cooperating oligopoly members act as Cournot oligopolists like before, so that (15) remains valid for these $n - n_I$ oligopoly members. Together with (11), (16) and $X_i = kX_i^*$ for $i \in I$ we therefore have $n + 2$ equations determining X_i , E and P for any given value of k .

One way of determining k is to assume that this parameter is chosen so that the profit of the colluding members is maximized. In other words, k is chosen so that

$$\Pi_I = P(k(\sum_{i \in I} X_i^* + \sum_{i \in J} X_i)) - \sum_{i \in I} C_i(kX_i^*) \quad (18)$$

is maximized for the equilibrium production levels of the non-cooperating members (i.e. for $X_i, i \in J$). This gives the equation

$$P + (k \sum_{i \in I} X_i^*) \frac{\partial P}{\partial E} = \frac{\sum_i X_i^* C'_{is}}{\sum_i X_i^*} \quad (19)$$

An alternative procedure for determining k would be to start by deriving the value k_i of k which maximizes each of the colluding members' profits. k_i is in other words determined so that

$$P(k_i(\sum_{i \in I} X_i^*) + \sum_{i \in J} X_i) - C_i(k_i X_i^*)$$

is maximized for the equilibrium production levels of the non-cooperating members (i.e. for $X_i, i \in J$). This gives the equations

$$P + (k_i \sum_{i \in I} X_i^*) \frac{\partial P}{\partial E} = C'_{is}, \quad i \in I \quad (20)$$

Once all k_i 's are calculated from these relations and (11), (15) (for $i \in J$), and (16), k can be chosen as e.g. the median value of k_i . We shall, however, in the following stick to the first way of deriving k , i.e. by maximizing the colluding oligopoly members' total profits.

The principle difference between our two collusive models is thus that in the case with side payments ((17) prevails), total profits of the colluding members are maximized without any kind of restriction on distribution of production between countries, while in the latter regime ((18), (19) prevail) total output is distributed among members according to quotas (kX_i^*) consistent with the solution in the pure Cournot case.

7 Empirical results

We have implemented the model in the PC-based MODLER software. Exogenous variables on the demand side are taken from a reference simulation on the WOM model. On the supply side we distinguish between 13 OPEC-members and Norway, Mexico, Egypt, Oman and Malaysia. The 5 non-OPEC countries will be referred to as NOPEC. Together the 18 oligopolists have a production capacity of more than 31 mbd which is 67 percent of oil consumed (actual) in the non-communist world in 1986.

The theoretical framework described in sections 3-6 give rise to a large number of different models, distinguished particularly by which countries are grouped together in the two collusive cases. In the calculations to be presented in this paper, we have constructed and simulated 4 different MODLER versions:

1. All 18 countries act as oligopolists
2. OPEC act as a cartel with side payments, NOPEC-countries as oligopolists
3. OPEC acts as a cartel with proportionate reduction of production, NOPEC-countries act as oligopolists.
4. All 18 countries act together in a cartel with proportionate reductions in production.

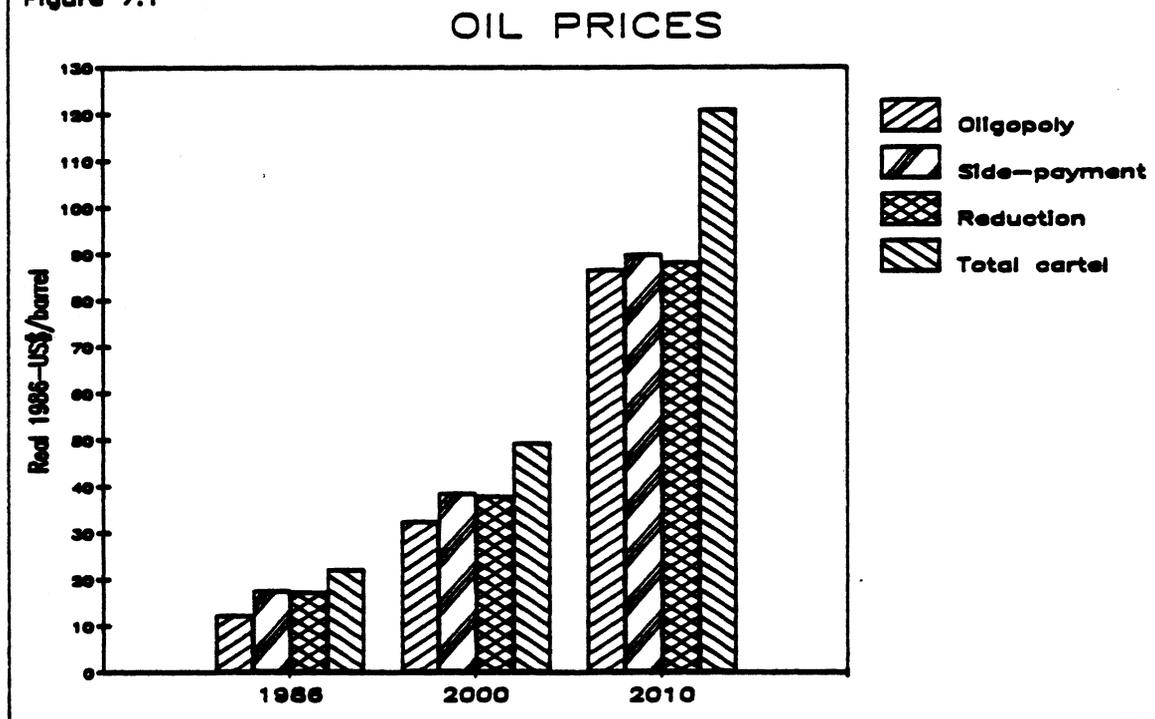
For each of the 18 oil producing countries in the oligopoly we have assessed the central parameters, i.e g_i , c_i and the capacity measure K_i , in the marginal cost function. In the present model version we have assumed values for the constant terms in the marginal cost function (i.e. the c_i - parameters) ranging from 0.5 US\$/barrel (Saudi Arabia) to 5 US\$/barrel (Ecuador). Our estimates for the g_i -parameters have magnitudes that imply moderately inverse-L-shaped marginal cost functions. The countries may be grouped according to three different estimates for the g_i -parameters. The values chosen imply that marginal costs increase by 1, 1.5 and 2.5 US\$/barrel respectively above the constant term at 50 percent capacity utilization. At 90 percent capacity utilization the increase is 2.5, 5 and 8 US\$/barrel. This means that the marginal cost functions is more long run than short run. The capacity variables are fixed close to our estimates of today's production capacities for the various countries and kept constant throughout the simulation period. This means that the assessed capacities are not our best guess estimates of future capacities, rather they constitute a convenient way to demonstrate differences between various forms of market behaviour according to our model.

The models are simulated for the years 1986, 2000 and 2010.

7.1 Oligopoly

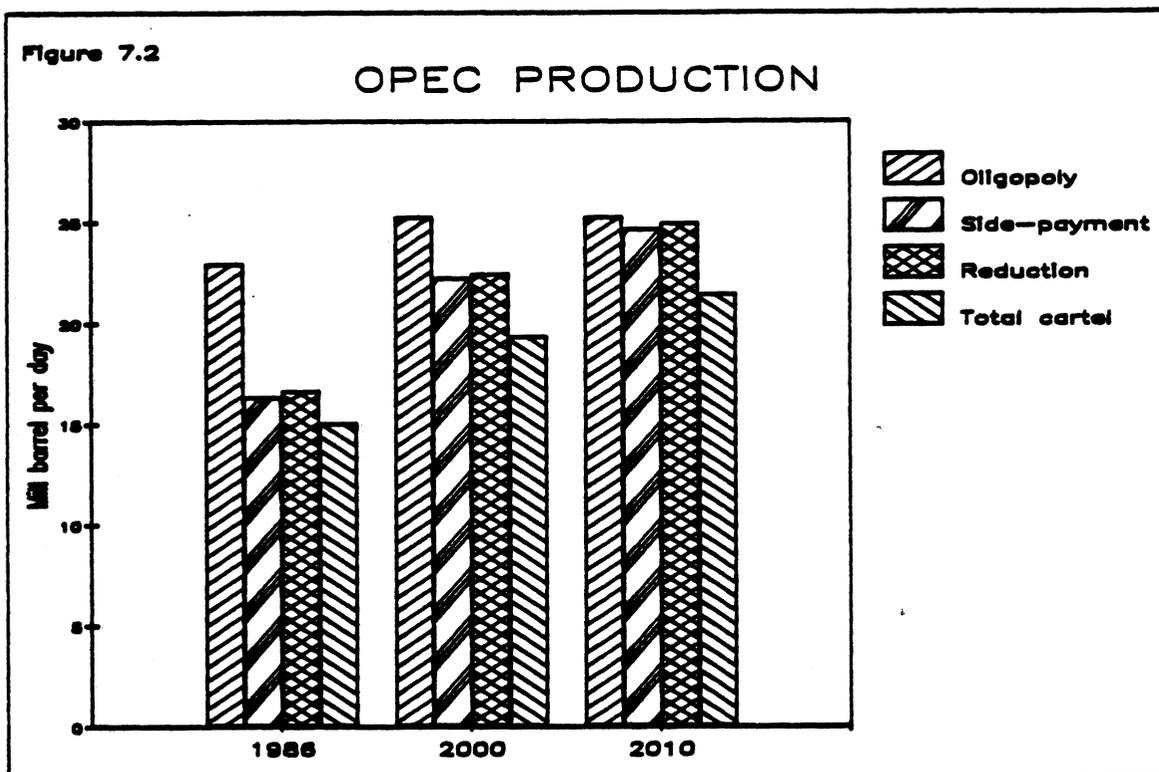
In this model version, mainly because there are quite many oligopoly agents operating in the market, the outcome is probably not very far from a competitive equilibrium. Most countries have marginal costs above 95 percent of the oil price, and only Saudi Arabia has less than 90 percent. The difference between price and marginal cost differs from Saudi Arabia where marginal cost is 68 percent of the oil price to Ecuador with more than 99. Even in the base year every

Figure 7.1



country's production is quite high; the average capacity utilization is close to 90 percent. But there are large differences between the countries; low costs and low maximum capacity tend to increase capacity utilization. An example of such a country is Qatar, where low costs and a capacity of only 0.4 mbd leads to a capacity utilization of 99 percent. High cost countries like Ecuador, Norway and Gabon have capacity utilization rates less than 70 percent, and "large" countries with "high" costs like Venezuela, Nigeria and Indonesia produce just below 80 percent of maximum capacity. The oil price determined by the model for the base year is 12.60 US\$/barrel. As a result of the large total production, the oil price calculated by this model is lower than what really materialized in 1986.

Towards 2000 and 2010 the assumed increase in incomes (GDP) underlying the projections imply strong increases in demand. This pushes the capacity utilization rates close to 100 percent in all countries, even high cost countries produce more than 97 percent. This puts strong pressure on oil prices, which rise from 32.70 US\$/barrel in 2000 to 86.90 US\$/barrel in 2010. Here it should be emphasized that in the presented calculations we have neither taken into account effects from competition from other energy sources nor changes in price- and income responses that probably will occur (especially in developing countries) if income and prices rise. The price paths for the various model simulations are shown in figure 7.1, while the accompanying developments in production from today's OPEC countries are given in figure 7.2.



7.2 OPEC cartel with side payments

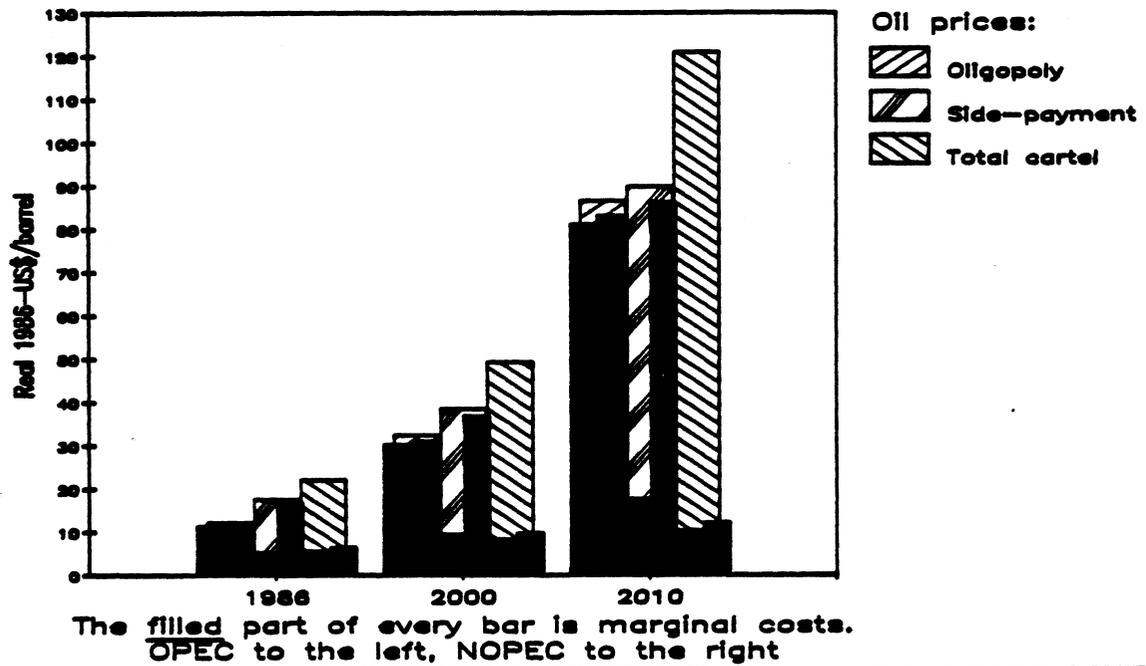
In this simulation we let the 13 OPEC oligopolists act together in a cartel with side payments according to the model outlined in section 6.2. NOPEC countries continue to act as Cournot oligopolists. The most important difference from the pure Cournot case is that OPEC reduces production in the base year and consequently the oil price increases (cf. figure 7.1). OPEC countries produce 65 percent of their capacity in 1986. According to this theoretical model, they allocate production as to minimize costs, i.e. so that all countries have equal marginal cost. The effect on the marginal cost is dramatic compared to the oligopoly simulation; the common marginal cost for OPEC countries only constitutes 31 percent of the oil price. This is illustrated in figure 7.3.

The low marginal cost means that countries with low costs produce relatively large quantities while high cost producers restrict their production. Ecuador has a c_i (constant term in the marginal cost function) that is only marginally smaller than the resulting marginal cost in the base year implying a very small production (cf. relation (6.3)). This country has a capacity utilization of only 7.6 percent in 1986, while Saudi Arabia, having the lowest production cost, produces at 87 percent of maximum capacity in 1986. The NOPEC countries which act as Cournot oligopolists increase their production compared to the pure oligopoly case, and together they have 90 percent capacity utilization in 1986.

In 2000 and 2010 the marginal cost of OPEC is still below the oil price (25

Figure 7.3

OIL PRICES AND MARGINAL COSTS



and 20 percent of price respectively). However, both price and marginal costs increase, implying that production increases correspondingly. Because of the inverse-L shape of the marginal cost functions for these countries, capacities will be high even at moderate levels of marginal costs. The capacity utilization in 2000 is 87 percent while it is 98 percent in 2010.

All the NOPEC countries produce close to their capacities in 2000 and 2010. Oman, with low cost oil fields, produce at full capacity already in the base year. All countries within NOPEC are close to 100 percent of capacity in 2000 and reach 100 percent in 2010. For these countries the marginal costs are close to the oil price, with the exception of Mexico where marginal costs constitute 90 percent of the price.

The oil price is more than 40 percent higher in the base year in this simulation than in the pure oligopoly case. In 2000 the difference has decreased to 18.5 percent and in 2010 the total supply is more or less identical to the oligopoly case which also means that the oil price is about the same.

7.3 OPEC cartel with proportionate reduction of supplies

As described in section 6.3, the other collusive model which we analyze is a hypothetical case where all the OPEC oligopolists reduce their production by the same percent relatively to the market equilibrium in the pure Cournot solution. An important implication of this regime is that marginal costs for OPEC mem-

bers no longer are equalized, so that the allocation of total production within the cartel is not carried out in the most efficient way. The reduction in production compared to the pure oligopoly case is 27 percent in the base year, which is very close to the reduced output in the cartel model with side payments. This furthermore implies that both the oil price and the total supply from OPEC are almost identical in the two collusive models. The important difference is the distribution of production within OPEC.

For non-OPEC producers the intuitively reasonable lesson of this outcome is that what really matters from their point of view is that OPEC act together in their struggle for stabilizing and possibly raising the oil price. How such coordinate efforts are obtained within OPEC is not that important.

7.4 A cartel model including all 18 oil producers

As mentioned above, during the last years coordinate efforts have been undertaken and some tacit agreements have been obtained even between OPEC and some non-OPEC oil producers. Even though these contacts obviously are difficult to describe in any formal manner, the existence of such agreements should create some interest for the present model version.

When the 5 NOPEC countries are included in the cartel, its market power increases considerably. This is exploited by the cartel; total output from the 18 countries is reduced by 1/3 compared to the oligopoly case in the base year, and by 18 percent from the OPEC-cartel solution. The price is 22.40 US\$/barrel in the base year, an increase of 78 percent compared to the oligopoly case (figure 7.1).

In the two OPEC-cartel simulations we saw above that the monopoly power of the cartel almost vanishes towards 2010, reflected in the observation that the oil price is insignificantly above the value in the pure Cournot case. In the present simulation, however, output is reduced in 2010 by 15 percent, while the oil price in the same year is increased from the Cournot solution by 40 percent (figure 7.1).

8 Concluding remarks

The purpose of this paper is to present a framework for analyzing various kinds of strategic behaviour and collusive behaviour in the crude oil market. The analysis is preliminary, and in particular the empirical simulations should be regarded mainly as demonstrations of the framework and differences between the various strategic models. In these calculations we have e.g. not taken proper account to the presence of "back-stop" prices and the possibility that income- and price

elasticities in LDC countries will change as a results of income growth. Both these factors will, when implemented, tend to create more realistic levels for the oil price than in the numerical examples presented in this paper. As mentioned above, we intend to extend the model by relations describing producers decisions with respect to capacity levels.

As supplements to existing simulation models which are being used for projecting the evolution in the crude oil market (among which we may mention the WOM model), we believe that such a framework may show to be very useful as a tool for analyzing market developments. This because the models explicitly build on the fact that strategic behaviour is highly present in the oil market. Used with care and supplemented with more detailed knowledge to the oil market, we thus regard it as a step towards a better understanding of events in this market.

9 References

- Berger, K., O. Bjerkholt and Ø. Olsen (1987): What are the options for non-OPEC producing countries. Discussion Paper No. 26, Central Bureau of Statistics, Oslo.
- Newbery, D. (1981): Oil prices, cartels and the problem of dynamic inconsistency. *Economic Journal*, 91, pp. 617- 646.
- Hoel, M. (1981): Resource extraction by a monopolist with influence over the rate of return on non-resource assets. *International Economic Review*, 22, pp. 147-157.
- Hnylicza, E. and R. Pindyck (1976): Pricing policies for a two-part exhaustible resource cartel: The case of OPEC. *European Economic Review*, 8, pp. 139-154.
- d'Aspremont, C., A. Jacquemin, J.J. Gabszewicz and J. Weymark (1983): On the stability of collusive price leadership. *Canadian Journal of Economics*, 1, pp. 17-25.
- Osborne, D.K. (1976): Cartel problems. *American Economic Review*, 66, pp. 835-844.

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