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Empirical Analysis of OPEC Pricing Behavior Under Wealth Maximization and Rule of Thumb Models

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This paper presents, empirically tests and contrasts two models of OPEC oil price determination over the period 1974-1985. First, we test a structural model that assumes that in order to maximize wealth OPEC adjusts prices and production within each period, as a result of change in underlying demand and cost conditions. Subsequently, we present and test a rule of thumb model to explain OPEC's short run pricing behavior. A central consideration in such models relates to the determination of OPEC's target capacity utilization. Herein two formulations are proposed. First, OPEC is assumed to have an exogenously determined long run target for capacity. Second, it is assumed that OPEC sets the long run price of oil based on a revenue objective.

The models were tested with quarterly data using ordinary least squares corrected for serial autocorrelation by means of the Cochrane-Orcutt technique. The rule of thumb model turns out to be comparable in terms of its explanatory power to a structural model of OPEC's pricing behavior. The results lend support to the notion that OPEC apparently

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sets prices and output within a longer term framework while using a rule of thum by mechanism to react to short term fluctuations in demand. Furthermore, the results reported in this paper are more consistent with a target for capacity utilization, while being strongly inconsistent with a target for revenues objective.

I. Introduction

In recent years developments in international oil markets have been both tumultuous and unpredictable.

The first half of the 1980s has seen the combined effects on oil demand of the recession that plagued the world economy in the early 1980s and the continuing trend toward greater efficiency in energy use and the substitution of other energy sources for oil.

These developments were accompanied by a steady increase in oil peoduction among non-OPEC producers and the reversal in the buildup of inventories by petroleum users. This has resulted in a sharp reduction in OPEC oil production and exports. Between 1979 and 1985 OPEC has experienced about a 50 percent reduction in its volume of crude oil exports.

In March of 1983 OPEC reacted to the precipitous fall in its export earnings and mounting balance of payment difficulties for many of its members, by agreeing on export quotas and an overall production ceiling of 17.5 million barrels per day.[1] At the same time, Saudi Arabia assumed the role of the "swing producer" agreeing to supply the residual amounts of oil that will meet world demand for OPEC oil. Concurrently, OPEC also lowered the price of its "marker" or benchmark crude, from $34 to $29 per barrel.

In the years from 1983 to 1985, oil prices appeared relatively stable, though in the fall of 1984 OPEC had to revise members' production quotas to correspond to a lower production ceiling of 16 million bb/d.

However, the aforementioned market stability was more apparent than real, as Saudi Arabia, in its role as the residual supplier, continued to absorb virtually all the production cutbacks necessitated by the continuing decline in the demand for OPEC oil.

1. OPEC's current account balance swung from about a $100 billion surplus in 1980 to a $21 billion deficit in 1983 and a deficit of about $30 billion in 1986. IMF, *World Economic Outlook*, Washington, DC, April 1987, Table A33, p. 153.

By the summer of 1985 Saudi oil production fell to less than 25 percent of the country's normal productive capacity, and at that point the Saudis were no longer willing to absorb any further production cuts to maintain the viability of the cartel and sustain its price structure. In a major reversal of policy, Saudi Arabia decided to terminate its role as a residual producer and to increase its oil production and export share through aggressive pricing of its crude, based on the spot market prices of refined petroleum products (known as net back pricing).

Largely as a result of the Saudi Arabia's abandonment of its role as swing producer, OPEC production in an already sluggish oil market increased by nearly 3 million b/d between the second and the fourth quarters of 1985. By early 1986 the short-term imbalance between the supply and demand for petroleum led to a broad based collapse of both refined products and crude oil prices.[2] The sudden, precipitous drop of oil prices that took place in 1986 was caused by the virtual abandonment of production quotas by major OPEC producers and also by a change in the method of crude oil pricing.

Until a few years ago, the bulk of crude oil was traded through the conduit of long-term contracts at fixed official prices, or whthin vertically integrated oil companies. In recent years though, the growing importance of the spot market and the emergence of a viable futures market has enhanced competition in the world oil market and has resulted in prices that are much more responsive to short-term market developments.

An important factor in the transformation of the oil pricing system from one based on official selling prices to one where prices are largely determined by market forces, has been the willingness of several oil exporting countries to effectively abandon the offical pricing structure and to provide varying discounts on posted prices. With the change to market-related pricing of oil, spot and future prices now fluctuate widely in response to change in underlying supply and demand conditions and also in market expectations ("news") of an effective production restraint agreement being implemented by OPEC.

This paper presents and empirically tests several models of oil price determination up to the time that oil prices collapsed and OPEC abandoned the strategy of influencing

2. Spot market prices for a number of representative crude oils dropped from a range of about $27-$31 a barrel in November 1985 to the $10-$13 a barrel range in April 1986. After a short-lived recovery, prices fell even lower, to the $8-$10 a barrel range. During this recent interval oil prices were also very volatile, being driven as they were by speculative and temporary factors. IMF, *World Economic Outlook*., April 1987, pp. 97-99.

market prices through a concerted exercise of market power. It is instructive to analyze OPEC's earlier pricing behavior for at least two reasons. First, it now appears that OPEC may yet be able to agree on a reasonably credible output restraint and thus attempt to return to a strategy of controlling prices. Second, the analysis of OPEC's pricing behavior up to 1985 may shed light on factors that led to the break down of OPEC's earlier strategy.

In this paper we compare a structural model of OPEC pricing behavior with rule of thumb models. The structural model was developed in Lowinger, Wihlborg and Willman, LWW (1985b). This model assumes that OPEC adjusts prices and oil production based on change in the underlying demand and supply conditions. The model presupposes that OPEC attempts to maximize its wealth intertemporally, subject to world demand for its oil. Non-OPEC supply is introduced into the model explicitly.

The empirical results of the structural model tested in LWW (1985b) indicate that OPEC did not adjust prices in responses to increases in non-OPEC output the way the model predicts, though OPEC did adjust price in response to change in interest rates and exchange rates in accordance with the model. The structural model is based on two strong assumptions; first, that oil producers are well informed about demand factors within each quarter and second, that OPEC is able to adjust prices to achieve its objectives within that time period. Alternatively, we present a rule of thumb pricing model for OPEC's short run behavior. In such models (see Gately 1979, 1983 and 1984) OPEC is assumed to follow a simple pricing rule that related the quarterly rate of change in oil prices to OPEC's target capacity utilization which is thought to be determined by long term considerations. If OPEC is guided by rule of thumb pricing, it will increase oil prices when the market is "tight" or "tightening" and lower prices when the oil market is "weak" or "weakening". According to Gately such a rule captures the behavior of an "imperfectly disciplined cartel in the face of uncertainty about the true nature of the market", (Gately, 1983, p.330).

An important consideration in rule of thumb models relates to the determination of OPEC's target capacity utilization. Empirical tests of the model are based on two assumptions. First, OPEC is assumed to have a long run target for capacity utilization. Second, it is assumed that OPEC sets the long run price for oil based on a revenue objective. In section II we review the structural model of OPEC behavior developed and tasted in LWW (1985a and 1985b) and Gately's (1983) rule of thumb model. Thereafter, in section III we specify alternative rule of thumb models under explicit assumptions about the longer run target for OPEC. Section IV presents and discusses

our empirical results. Section V states our conclusions and recommendations for future research.

II. Structural and Rule of Thumb Pricing Models

In Lowinger, Wihlborg and Willman, LWW (1985a and 1985b) we developed and tested a structural model for OPEC pricing and output decisions. In LWW (1985a) the purpose was to analyze empirically the relationship between the price of oil and interest rates in world financial markets, while in LWW (1985b) the aim was to study the impact of non-OPEC oil production on OPEC's pricing decisions. In both papers, OPEC was assumed to maximaze wealth subject to a demand function for OPEC oil in a two-period model and subject to a real interest rate determined in world financial markets. Thus, OPEC could borrow against future revenues, or invest current revenues in world financial markets in order to finance future comsumption. In these models the price function takes the following form :

$$p_t = a_0 + \overset{(+/-)}{a_1} r_t + \overset{(-)}{a_2} q_{no,t} + a_3 (q_{t-1} / \overset{(+)}{GDP}_{t-1}) + \overset{(+)}{a_4} GDP_t + \overset{(-)}{a_5} E_t + \overset{+}{a_6} D + e_1 \quad (1)$$

where : p_t=the real dollar price of crude oil (a weighted average of spot and official prices).

r_t=real rate of interest in world financial markets.

$q_{no,t}$=non-OPEC output of crude oil.

q_t=world production of crude oil.

GDP_t=OECD's real gross domestic product.

E_t=the real effective exchange rate between the U.S. dollar and the rest of the world.

D=dummy variable equal to 1 from the second quarter of 1979 and equal to zero before this period.

In LWW (1985a) a cost varible was added to the model, though, without apparent success. In LWW (1985b) non-OPEC output was incloded as an endogenous variable, but the model performed better when it was considered exogenous. The interest rate may affect the price positively or negatively (see LWW, 1985a). In LWW (1985a) the interest rate variable was endogenous to OPEC's decision while in LWW (1985b), it was exogenous. Since the result were not affected much by the latter assumption, we

adopt it in this paper as well. Non-OPEC output (q_{no}) is expected to have a negative impact on price. The q_{t-1}/GDP_{t-1} variable is supposed to capture an apparent rigidity in the substitution between oil and capital and/or labor after a price change. This variable, as well as the GDP of OECD countries are expected to affect oil prices positively.

An increase in E_t reflects a real appreciation of the U.S. dollar. Such a change would increase the real price of oil outside the U.S. given a constant real dollar price of oil. Thus, the demand for oil would fall with a resulting decrease in the real dollar price of oil. The dummy variable that we introduced when the regressions were run for the entire 1974-85 period, was discussed extensively in LWW (1985b). It attempts to capture a structural shift coinciding with, but not necessarily casued by, the Iranian revolution in 1979 and the subsequent Iran/Iraq war. When the regressions were run for sub-periods 1974-1979. 1 and 1979. 2-1985 the dummy variable was not included.

The explanatory value of the srtuctural equation (1) will be compared to rule of thumb models formulated to test OPEC's pricing behavior. It has been argued (see Gately 1983) that OPEC sets oil prices based on a certain behavioral rule of thumb. Specifically, OPEC is thought to increase prices when capacity utilization is above a certain "target" level and rising; and to lower prices when capacity utilization is below the target level and falling. In other cases though, this rule provides little guidance, for example, when capacity utilization is above a certain level and falling, or below a certain level and rising. Gately's (1983) rule of thumb model, though, holds prices fixed.

In the role of thumb model proposed by Gately (1983), the target capacity utilization around which prices are supposed to adjust slowly to a price consistent with the target, is not really specified. In this paper, we develop and test two alternative specifications of the rule of thumb model, which set explicit targets for OPEC pricing.

III. Rule of Thumb Models and the Long Run Target of OPEC

The wealth-maximization model for OPEC is based on the assumption that all variables can be observed within each quarter and that OPEC ia able to make price and production decision is response to new information each quarter. Both of those assumptions are very strong. In particular the level of world output (GDP) and non-OPEC oil output (q_{no}) in the demand function for OPEC oil, may be observable only with a lag. Production and prices in each quarter must then be set based on expectations about these variables within the context of a maximizing framework. However, if OPEC

is not a well-defined decision making entity, it may not be able to agree internally on optimal price and production each quarter, based on available information.

Hence, we surmise that OPEC periodically sets production quotas for its members and that the organization's short-run production and price response may allow for some "cheating" by smaller OPEC members and certain offsetting production adjustments by other members, principally Saudi-Arabia. It may, therefore, be entirely appropriate to use a rule of thumb model to describe the short run response of OPEC to short-term fluctuations in demand. Such a model presumes that the outcome of the cheating by some OPEC members and Saudi Arabia's response to it, result in a somewhat systematic pattern of adjustment over time. Next, we specify a rule of thumb for the short-run price response of OPEC under different assumptions about its long-run target.

A general rule of thumb price response can be specified as follow:

$$P_t - P_t^* = a(CU_{t-1} - CU_t^*);\ (a>0) \tag{2}$$

Where CU_t^* is the target capacity utilization and P_t^* is the price in period t that is consistent with that target in the long run. CU_{t-1} is the *actual* capacity utilization in the previous period. It may differ from the desired capacity utilization if short term demand for OPEC oil deviates from its long run level.

If, for example, there is a sudden surge in demand for oil in period $t-1$, then CU_{t-1} is above CU_t^*. Accordingly, the price will be increased above the level of P_t^*, consistent with long run conditions and the short run expected capacity utilization will decline in order to approach the target. Thus, the rule of thumb formulation implies that relative to some target price which is determined by expected long run demand conditions, the actual price varies *positively* with short run (temporary) fluctuations in demand.

It is assumed herein that the price increase is not sufficient to keep production constant and that there is a partial response of *both* production and prices. A producer with some degree of monopoly power would be expected to behave this way when the sources of demand fluctutaions are not known with certainty each quarter, and the degree of permanence of the demand shift is also uncertain and when there exist cost associated with changes in production. Within OPEC, such costs may perhaps take the form of *internal* costs of negotiating new production quotas and agreeing on effective methods of enforcement of such an agreement. The formulation of the price adjustment process in Eq. (2) seems also consistent with the spirit of the rule of thumb model as described in Gately (1983 and 1984).

As can be seen from Equation (2) the relationship between the desired long-term equilibrium price, P_t^*, and the desired long-term equilibrium production capacity CU_t^*, is crucial for the determination of the price P_t. Furthermore, the determination of P_t^* and the desired capacity (CU_t^*) depends on OPEC's longer run target variable. We assume in one case that capacity utilization CU_t^* is an exogenous target, and in the second case that OPEC sets a target for revenue with implications for CU_t^* and P_t^*.

The exogenous target may seem "arbitrary" and inconsistent with profit maximization but in fact it has been used by other researchers, for example Gately (1984). The argument in support of an exogenous target may be related to OPEC's desired internal resource utilization or alternatively because of its simplicity, it can be used as a proximate target in OPEC's internal deliberations. Revenue maximization on the other hand, may in fact be consistent with a generally agreed upon OPEC optimization objective. Such a target is approximately equivalent to profit maximization if marginal production costs are constant and low relative to price.[3]

Given a target, the relationship between the desired long-run price level and capacity utilization depends on what OPEC perceives to be its long-run demand function. We assume that OPEC operates, based on the following long-run demand function to determine the desired level of variables:

$$P_t^* = b_0 + b_1(q_t^* + q_{no}, t) + b_2 GDP_t \; ; \; (b_1 < 0 \; ; \; b_2 > 0) \tag{3}$$

where: $q_t^* = CU_t^* \cdot CAP_t$, with CAP_t being OPEC's actual production capacity and hence, $CU_t^* = \frac{qt^*}{CAP_t}$, by definition.

As noted earlier in the paper, the actual short-run demand function may include additional temporary influences that affect prices. Thus, the actual price P_t is influenced by changes in the desired price P_t^* when q_t^*, q_{no}, t, CAP_t and GDP_t in Eq. (3) change, as well as by temporary fluctuations in demand working through the rule of thumb mechanism.

3. Alternatively, a model could be developed that obtains the desired long term production capacity for OPEC (CU_t^*), based on optimization principles. Arguably, in such a theoretical framework CU_t^* will be a function of the expected price of oil, the expected cost of developing future OPEC oil production capacity, real interest rate and OPEC expectations with regard to future additions to petroleum reserves. For the derivation of expected costs for OPEC's future productive capacity, see Adelman (1986), pp. 17-23. A complete model for CU_t^* is beyond the scope of this paper, but it would be a laudable objective for future research.

We first assume CU_t^* to be a constant exogenous target. Inserting (3) into (2) we obtain:

$$P_t = aCU_{t-1} - aCU_t^* + b_0 + b_1 CU_t^* \cdot CAP_t + b_1 q_{no,t} + b_2 GDP_t \qquad 4(a)$$

since CU_t^* is considered constant, the testable equation then becomes:

$$P_t = k_0 + k_1 CU_{t-1} + k_2 CAP_t + k_3 q_{no,t} + k_4 GDP_t + e_t \qquad 4(b)$$

where $k_1 = a > 0$; $k_2 = b_1 CU_t^* < 0$; $k_3 = b_1 < 0$ and $k_4 = b_2 > 0$.
A dummy variable may be introduced to capture possible temporary shifts in the capacity utilization target.

Alternatively, we assume that OPEC chooses a *target revenue* for itself. Desired price (P_t^*), quantity (q_t^*), and capacity utilization (CU_t^*) in the rule of thumb Eq. (2) is then determined by Eq. (3), so as to be consistent with OPEC's target revenue. The soultion to OPEC's pricing problem in this case, is a complicated quadratic expression. For estimation purposes we use a linear price function. The expected signs of the price effects resulting from shifts in CU_{t-1}, CAP_t, $q_{no,t}$ and GDP_t can be determined by inductive reasoning given that OPEC is assumed to have a revenue target. Since Eq. (2) for the short-run price response is the same as in the previous case, it is obvious that CU_{t-1} influences P_t' in the same way.

CAP_t, the actual production capacity will have no effect on either P_t^* or CU_t^* since it does not appear in the demand function, and revenues are independent of actual capacity. Thus, the coefficient k_2 in Eq. (4b) will he zero with a target for revenues, while it is negative white a target for capacity utilization.

An increase in non-OPEC production (q_{no}) will induce a price response from OPEC under a target revenue rule. Assuming that the demand for OPEC's oil is inelastic as found in LWW (1985b), OPEC would have to raise its target revenue price P_t^*, and lower CU_t^* . Thus, the coefficient k_3 will be positive while in Eq. (4b), with a target for capacity utilization k_3 is negative.

An upward shift in GDP_t would increase demand and thus increase OPEC's revenues. To reduce revenues so as to remain on target, OPEC would lower its price if demand is inelastic. Then the coefficient k_4 would be negative while it is clearly positive given a target for capacity utilization in Eq. (4b).

By estimating Eq. (4b) and observing the signs of coefficients k_2, k_3, and k_4, we can determine whether OPEC sets a target for revenues or a target for capacity utilization.

The coefficient k_2 for actual capacity (CAP_t), will be zero under a target revenue regime. The signs of the coefficients for the variables q_{no} (k_3) and GDP_t (k_4) are unambiguously negative and positive respectively, given a target for capacity utilization, while with a target for revenues the signs depend on the elasticity of demand for OPEC oil.

Naturally, the foregoing conclusions depend on the underlying assumption that a rule of thumb pricing behavior is followed by OPEC and on the assumption about the perceived equilibrium relationship between price and quantity, as specified in Eq. (3). If an empirical test of Eq. (4) has a greater explanatory value than a test of the structural model in Eq. (1), and furthermore, if the coefficient k_1 for CU_{t-1} in Eq. (4b) is significant and positive we have a strong indication that rule of thumb pricing is followed by OPEC in the short run. Of course, the perceived relationship between desired price P_t^* and desired quantity q_t^*, cannot really be observed.

IV. Empirical Tests of Structural and Rule of Thumb Models of OPEC Pricing of Oil

In this section we present the results of regressions of the price equation for crude oil, based on a number of different specifications. We test the structural equation (1), the rule of thumb equation (4b), and a simpler rule of thumb pricing equation specified in Gately (1983) under which price changes are positive (negative) when capacity utilization is increasing (decreasing).

The results reported in Tables I and II allow us to compare a wealth maximization model which assumes that OPEC adjusts oil prices in response to specific changes in demand and cost conditions each quarter, to short run rule of thumb pricing strategies based on OPEC's desired capacity utilization or target revenue. The models were tested with quarterly data using ordinary least squares, over the period 1974-1985. In addition to reporting the results for the full 1974-1985 period, results for the subperiods 1974. 1 through 1979.1 and 1979.2 through 1985.3 are also reported.[4]

Comparing the rule of thumb specification to the wealth maximization specification for the full period in Tables I-III, one finds the explanatory value of the two formulations to be nearly equal. For the pre-1979.2 period neither of the two models explains prices

4. Most papers that deal with either rule of thumb pricing or with profit maximization models, focus on forecasting or on simulating alternative price paths for oil prices. We will not deal with those uses of rule of thumb models in this paper.

satisfactorily while in the post-1979.2 period the rule of thumb model has a slight edge. In Table III, for the full period without dummy variables, the rule of thumb model also performs better.

Other considerations also favor the rule of thumb model. One such argument is that in tests of Eq. 4(b), CU_{t-1} (see Table II) performs much better than the lagged variable q_{t-1}/GDP_{t-1} in tests of Eq. (1) (see Table I). Based on a priori considerations one would expect the latter variable to be important in a wealth maximization model. In fact though, the real interest rate variable has the strongest explanatory value in tests of Eq. (1). The interest rate variable fluctuates widely and may indeed capture short term changes in demand conditions. The fact that it is significant in the post-1979 period does not in iteslf lend strong support to the wealth maxization model. A second argument that lends support to the rule of thumb model is that our results do not indicate that a wealth maximiaing OPEC has adjusted prices sufficiently to reflect the dramatic increases in the output of non-OPEC oil, especially in the post 1979 period. Though the q_{no} variable is insignificant in the wealth maximization model, it does appear to have a significant effect on prices in the rule of thumb model in the post 1979.2 period.

An earlier paper by LWW (1985b) concluded, based on tests of the wealth maximization model, that only after 1979 did OPEC adjust prices in response to changing economic conditions, though apparently even then it did not adjust prices sufficiently in response to the rapidly growing non-OPEC production of oil.[5] The results reported in this paper indicate that before 1979.2 OPEC did not respond to changing economic conditions even by means of a simple rule of thumb. In contrast to our previous results, OPEC seems to have adjusted its prices to increased non-OPEC production in the past 1979. 2 period. However, OPEC's short term price and output response may have been insufficient from a wealth maximization point of view which could help explain why OPEC's pricing policy, even after 1979.2, was not sustainable in the longer run and in fact brought about the price collapse of 1986. It is noteworthy that the GDP variable does not

5. Between 1979 and 1985, world oil consumption has declined by about 7 percent, while at the same time the output of non-OPEC producers has *grown* by as much as 17 percent. Consequently, the share of non-OPEC producers in world output of petroleum rose from roughly 50 percent in 1979 to about 70 percent in 1985. It is also noteworthy that results contained in LWW (1985b) indicate that non-OPEC production is exogenous and determined by technical constraints. The derivation of the price equation presented in this paper can also be found in LWW (1985b). The oil production and consumption data are taken from IMF's *World Economic Outlook* , April 1987, p. 98.

Table 1. Price Equation for Wealth Maximization Model (With Dummy Included for the Full Period)

FULL PERIOD

Constant	$r_t^{(+/-)}$	$q_{no,t}^{(-)}$	$\frac{q_{t-1}^{(+)}}{GDP_{t-1}}$	$GDP_t^{(+)}$	$E_t^{(-)}$	$D^{(+)}$	
20.4	.20	−.11	560.8	−2.42	− .14	9.90	$\bar{R}^2$ = .94
[2.29]	[2.32]	[−.45]	[1.36]	[− .16]	[−4.41]	[14.08]	DW = 1.36

PRE 1979.2 PERIOD

Constant	$r_t^{(+/-)}$	$q_{no,t}^{(-)}$	$\frac{q_{t-1}^{(+)}}{GDP_{t-1}}$	$GDP_t^{(+)}$	$E_t^{(-)}$	
5.37	−.054	.48	21.24	1.83×10^{-4}	.039	$\bar{R}^2$ = 0
[1.32]	[−1.38]	[.48]	[.12]	[.27]	[1.65]	DW = 1.77

POST 1979 PERIOD

Constant	$r_t^{(+/-)}$	$q_{no,,t}^{(-)}$	$\frac{q_{t-1}^{(+)}}{GDP_{t-1}}$	$GDP_t^{(+)}$	$E_t^{(-)}$	
24.4	.37	−.30	1082.	6.95×10^{-5}	− .11	$\bar{R}^2$ = .77
[1.63]	[2.46]	[−.37]	[1.45]	[.024]	[−1.28]	DW = 1.15

Each equation presents the expected signs of the coefficients, the coefficients, and in parenthesis, the t−statistics. DW is the Durbin−Watson statistic and $\bar{R}^2$ is the adjusted R^2.

Table 2. Price Equation for Rule of Thumb Model (with Dummy Included for the Full Period)

FULL PERIOD

C	$CU^{(+)}_{t-1}$	$CAP^{(-)}_{t}$	$g^{(-)}_{no,t}$	$GDP^{(+)}_{t}$	$D^{(+)}$	
25.70	15.95	− .44	− .63	-3.71×10^{-4}	7.40	$\bar{R}^2$ = .92
[2.62]	[6.76]	[-2.26]	[-2.47]	[-.25]	[6.18]	DW = 1.33

PRE 1979.2 PERIOD

C	$CU^{(+)}_{t-1}$	$CAP^{(-)}_{t}$	$g^{(-)}_{no,t}$	$GDP^{(+)}_{t}$	
13.12	.0037	−.054	.033	-1.89×10^{-4}	$\bar{R}^2$ = 0
[1.56]	[.0020]	[-.34]	[.28]	[-.28]	DW =1.42

POST 1979 PERIOD

C	$CU^{(+)}_{t-1}$	$CAP^{(-)}_{t}$	$g^{(-)}_{no,t}$	$GDP^{(+)}_{t}$	
56.59	12.20	−.62	−1.18	-1.28×10^{-3}	$\bar{R}^2$ =.79
[4.16]	[2.74]	[-2.63]	[-2.44]	[- .54]	DW =1.35

Each equation presents the expected signs of the coefficients assuming OPEC has a target for capacity utilization, the coefficients, and in parenthesis, the t-statistics. DW is the Durbin-Watson statistic and $\bar{R}^2$ is the adjusted R^2.

turn out to be significant in any of the empirical tests, though one would expect this variable to capture the long term trend in demand. It is possible, however, that in the post 1979.2 period there was little growth and hence little variation in that variable.

In section III we argued that by estimating Eq. (4b), we could determine whether OPEC uses a target for revenue or a target for capacity utilization, by examining the signs of the coefficients for capacity, non-OPEC supply and GDP variables. Of particular importance was the coefficient for the CAP_t variable. The target revenue model implies that the coefficient k_2 should be zero while the capacity utilization model assigns it a negative sign. The results reported in Table II for this variable and the other two

Table 3. Price Equation for the Full Period (Without Dummy)

A. WEALTH MAXIMIZATION MODEL

Constant	$r_t^{(+/-)}$	$q_{no,t}^{(-)}$	$q_{t-1}^{(+)}$ GDP_{t-1}	$GDP_t^{(+)}$	$E_t^{(-)}$	
40.66	.41	1.32	−1004.5	-2.15×10^{-3}	−.31	$\bar{R}^2 = .54$
[1.92]	[1.95]	[2.39]	[− 1.05]	[− .58]	[−4.42]	DW = .58

B. RULE OF THUMB MODEL

Constant	$CU_{t-1}^{(+)}$	$CAP_t^{(-)}$	$q_{no,t}^{(-)}$	$GDP_t^{(+)}$	
63.71	23.81	−1.42	− .82	−1.24	$\bar{R}^2 = .84$
[6.07]	[8.72]	[−9.40]	[−2.34]	[− .62]	DW = 1.35

Each equation presents the expected signs of the coefficients, the coefficients, and in parenthesis, the t−statistics. DW is the Durbin−Watson statistic and $\bar{R}^2$ is the adjusted R^2.

are more nearly consistent with a capacity utilization target and are inconsistent with the target revenue model given the assumption of inelastic demand. This result is surprising since it is difficult to provide a convincing economic rationale for the target capacity utilization model, while the target revenue model is easier to justify. The above results, though, are consistent with our previous observation of the seeming lack of "rational" economic response by OPEC to the continuing increases in non-OPEC oil production.

In both models, a dummy variable plays an important role in explaining price variations in tests for the full period. It could be interpreted as capturing a shift in the capacity utilization target itself in the rule of thumb model. When the dummy variable is omitted, the explanatory power of the rule of thumb equation is still quite good, and all the explanatory variables with the exception of GDP are significant and with the expected signs (see Table III). Furthermore, it should be underscored that in order to correct for serial autocorrelation all regressions were run using the Cochrane-Orcutt procedure. However, in the regressions most seriously affected by auto correlation the results did not improve, while in others the results with respect to independent variables were not much affected.

The rule of thumb model outlined by Gately takes a slightly different form than ours. Gately simply states that oil prices should rise when excess capacity is low and falling, while prices should decline when excess capacity is high and rising. When excess capacity is above a certain level and falling or below a certain level and rising, the price is fixed. To test Gately's version of the rule of thumb model, we introduced a dummy variable in a regression of price changes on changes in capacity utilization.[6] The dummy variable took on the value of 1 when the rule was found to be true and 0 otherwise. The dummy variable was insignificant in both cases.

V. Conclusions

In this paper we have formulated and empirically tested two alternative rule of thumb pricing equations and an equation based on wealth maximization for the purpose of explaining OPEC's pricing behavior from 1974 through 1985. The rule of thumb

6. The equation tested in Gately (1983), p. 330 has as a dependent variable the percentage change in price. The explanatory variables were the same as in our rule of thumb model except that they were stated as rates of change rather than levels. We also tested a simplistic rule of thumb model that did not contain changes in non-OPEC production and GDP. The dummy variable remained insignificant. The result of these tests are available from the authors on request.

model presented in this paper is comparable in terms of its explanatory power to a structural model of OPEC's pricing behavior, but reported results with respect to some independent variables may be construed as being inconsistent with short run wealth maximization Instead OPEC seems to set price and production targets in a longer term framework while using a rule of thumb to respond to short term fluctuations in demand.

As noted earlier the rule of thumb results reported herein are most consistent with a target for capacity utilization, while being strongly inconsistent with a target for revenues. The lack of significance for non-OPEC oll production in the regression based on wealth maximization indicates that this objective apparently did not guide OPEC behavior in the period from 1979.2 through 1985. It is somewhat puzzling that OPEC appears to have had a longer term target for price and output which cannot be derived from simple optimization considerations. Although, it is possible that the problems of achieving credible output limitation agreements within OPEC has forced this organization to adopt simple targets for internal negotiationg purposes. Should this behavior continue within an OPEC "chastened" by the 1986 experience, it is possible that the organization once again will find itself in a position where the discrepancy between economic realities and OPEC's pricing and production targets will come to a head, bringing about another price collapse.

Appendix A

The variables are defined and measured as follows :

p_t–Weighted average of OPEC official and spot crude oil prices (1975 U.S. dollars).

r_t–"World"real interest rate in period t (percent), obtained by taking the weighted average of short-term interest rates in six countries–United States, United Kingdom, Germany, France, Canada, and Japan–in period t, minus a weighted average of the inflation rates for these same six countries from the middle of the period t to the middle of period t+1.

$q_{no,t}$–Non-OPEC oil production (millions of barrels/day).

q_{t-1}–Free World oil production (millions of barrels/day).

GDP_{t-1}–"World" real GDP (billions of 1975 dollars).

E_t–International value of the dollar relative to foreign currencies as an index number (1980 to 1982 equals 100).

D–Dummy variable (D=O for the period prior to 1979 : 2 and D=1 from 1979 : 2 onward).

CAP_t–OPEC's maximum sustainable production of oil (millions of barrels/day).

CU_{t-1}–OPEC's capacity utilization. It is the ratio of OPEC production to maximum sustainable capacity (decimal).

SOURCES OF DATA

p_t–OPEC oil price was computed by taking a weighted average of official and spot prices for Mideast Light-34 crude oil. Increasingly greater weight was given to the spot market to reflect its increased importance. The weights given to each were as follows :

	WEIGHT(PERCENT)	
Period	Official	Spot
1974 : 1–1979 : 1	80	20
1979 : 2–1983 : 4	50	50
1984 : 1–1985 : 3	20	80

r_t–The interest rates for the U.S., U.K., France, Germany, Canada and Japan were all short-term rates obtained from line 60c of the *International Financial Statistics* (IFS) tape. When line 60c–the 3-month Treasury bill rate–did not appear, we used line 60b, the call money rate. The inflation rates for each country were generated from the cousumer price index (CPI) of each country. The CPIs for each country were also taken from the IFS tape, line 64. The weight given to each country was equal to the sum of each country's exports and imports from OPEC as a percentage of the total for all six countries. The weights were adjusted from year to year based on the percentage for that year.

q_{t-1}–Free World Oil Production

$q_{no,t}$–and non-OPEC crude oil porduction data were obtained from the CIA, *International Energy Biweekly Statistical Review*. OPEC production used in the determination of CU also came from the above source.

GDP_t–Gross domestic product data of OECD countries were obtained from the *National Account of OECD Countries*, 1982, Vol. 2; and from *OECD Main Economic*

Indicators, July 1984 and March 1986.

E_t–Value of foreign currencies relative to the U.S. dollar were obtained from Morgan Guarantee Trust, *World Financial Market*, March 1986. For 1974 and 1975 only annual data were available; to obtain the quarterly pattern nominal data from the IFS were used.

CAP_t–Data for the period 1974-1976 were taken from the Department of Energy's *International Energy Indicators*. Data for the period after 1976 was obtained from two CIA publications, *International Oil Development* (1976-1977) and *International Energy Statistical Review* (1978-1985).

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