SHORT-TERM SUPPLY-SIDE INSTABILITY IN THE OIL MARKET

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Abstract

We assume that oil producers are either governments or firms that are regulated or taxed to act as governments. Governments' political objectives lead them to make expenditure commitments that are financed from oil, so oil producers individually seek a predetermined total oil revenue. We prove two principal theorems: (1) So long as producers have some ability to control the final destination of their oil, in short-run equilibrium there can be positive excess demand; and (2) With positive costs of operating a producer cartel, excess demand is an *increasing* function of price, and price is unstable downward in the short run. Various historical episodes—including the OPEC-led embargo in 1973/74 and the collapse in oil prices during the first four months of 1986—are consistent with the model we develop.

The model also provides insights into the behavior of markets for other commodities. It helps explain the long-run relationship between nations' wealths and their resource endowments, and provides an alternative to the Hotelling Rule. It suggests a new approach to international marketing agreements among governments.

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> *The state has itself acquired control of many of the largest undertakings or natural monopolies, has substituted public for private monopoly, and has frequently entered the field of foreign commerce not simply to determine the rules of the game, but to participate in it itself. These centralized powers may be used in such a way as to maintain economic stability or in such a way as to increase rigidities and international instability. They afford an opportunity but also involve a risk.*
>
> League of Nations, 1945

1. Introduction

Government involvement on the supply side of the oil market is so pervasive that the world oil market cannot be understood with conventional price-theoretic models. This involvement takes several forms, including state ownership of oil, state control of private production policies, state control of price, output and exploration decisions, and the imposition of high rates of taxation on private oil. These share an important feature: governments of producing countries obtain significant revenues from oil. To understand the world oil market, one therefore must understand the revenue and other objectives of governments which have come to so dominate supply.

We focus on the short term. (Indeed, under our assumptions about the short-term objectives of producing countries' governments, it is difficult to conceive of long-run supply as anything other than a succession of short runs.) We characterize oil producers as governments which pursue short-term political objectives, not wealth maximization. In particular, we assume that oil-producing countries make short-term expenditure commitments, financed in part from oil revenue, that are politically or otherwise costly to alter in the short term. This representation of oil-producing governments' objectives is central to the model we develop.

Two principal theorems—about short-run behavior in the oil market—apply when all oil producers are governments that establish fixed revenue targets:

1. So long as producers have some ability to control the final destination of their oil, in short-run equilibrium there can be positive excess demand for oil, with extra-market factors determining price; and
2. With positive costs of operating a producer cartel, excess demand is an *increasing* function of price, and price is unstable in the short run in a downwards direction.

The first theorem demonstrates the possibility of prices above market-clearing levels. However, the second theorem implies that oil prices are unstable downwards, with a tendency to fall to short-run marginal cost, in spite of oil's apparent "scarcity value" (i.e., its apparently high long-run marginal cost).

The second theorem solves an apparent paradox. Why is it that oil revenue appears

to be a stable source of government revenue in the short term (owing to high economic rents, low demand elasticity and irreversible investments), yet actual revenues have been unstable in recent years? According to the theorem, the effect of many governments—individually seeking stable and substantial revenue from oil—is that oil prices inevitably exhibit short-term instability.

These theorems help explain the sudden collapse of world oil prices in the first four months of 1986 and also the OPEC-led "embargo" of 1973/74. Our general thesis is that such episodes are logical consequences of widespread government intervention in oil. In contrast with previous literature, we do not assume that the oil market is dominated by an effective cartel of producers, or that some oil producers have behaved with unprecedented irrationality, or that the world oil market is not affected by governments. Instead, we view the oil market as being dominated by government intervention in almost all of the producing countries. Previous literature is discussed more fully in a later section.

2. Government Expenditure Commitments and Oil Revenues

Oil is particularly attractive to revenue-seeking governments with short time horizons. One reason is the magnitude of the expropriable revenues. This in turn has two sources: (1) short-run marginal cost is lower than long-run marginal cost, the latter being bounded by the cost of replacing produced oil or of producing an energy-equivalent substitute; and (2) the high likelihood of any individual exploration venture being unsuccessful implies a large quasi-rent for successful ventures. Consequently, the expropriable cash flow can be a large proportion of total revenue. Another reason for the expropriability of oil revenue is that investments in oil exploration and development are irreversible in the short term. Combined with short-term inelasticity of demand, owing to consumers' conversion costs, the short-term irreversibility of supply investments makes oil revenue an apparently stable source of government revenue.

Most oil-producing countries now exhibit either government ownership of the oil resources or high levels of taxation of oil production.[1] There are few countries in which the dominant effect of the recent oil-price collapse has been on private wealth. Consequently, governments of such countries around the world have come to depend on taxation revenues and hard currency from selling oil on the world market.

Figure 1 plots the average increase in oil revenues against the average annual increase in government expenditures for twelve oil-producing countries over the period 1972–1979.[2] Let us remind the gentle reader that these are average *annual* growth rates,

1. These are seen in First-, Second-, and Third-World countries, for example, the USSR, Nigeria, Mexico, Norway, Indonesia, Australia. As of 1985, Mexico had been planning to service its overwhelming foreign debt with oil revenue; Venezuela is in a similar position and, at a US$15/bbl price, faces an increase of US$400-500 million in its annual budget deficit; Nigeria is expected to suspend debt repayments; Ecuador receives 65% of its export revenue from oil and faces severe budgeting problems from the recent price fall; Egypt has severely cut government expenditure and increased taxes to compensate for lost oil revenue; the Soviet bloc earns 60% of its hard currency from oil; Libya has been forced to slash government expenditure; Iran and Iraq use hard currency from oil exports to finance their war; Indonesia has been severely financially embarrassed by lower oil prices and even Saudi Arabia is now reported to be operating under considerable internal pressure owing to lost government revenue. Even the term "oil-producing countries" reflects the realities of oil supply: one tends to think of countries, not firms, as oil producers.

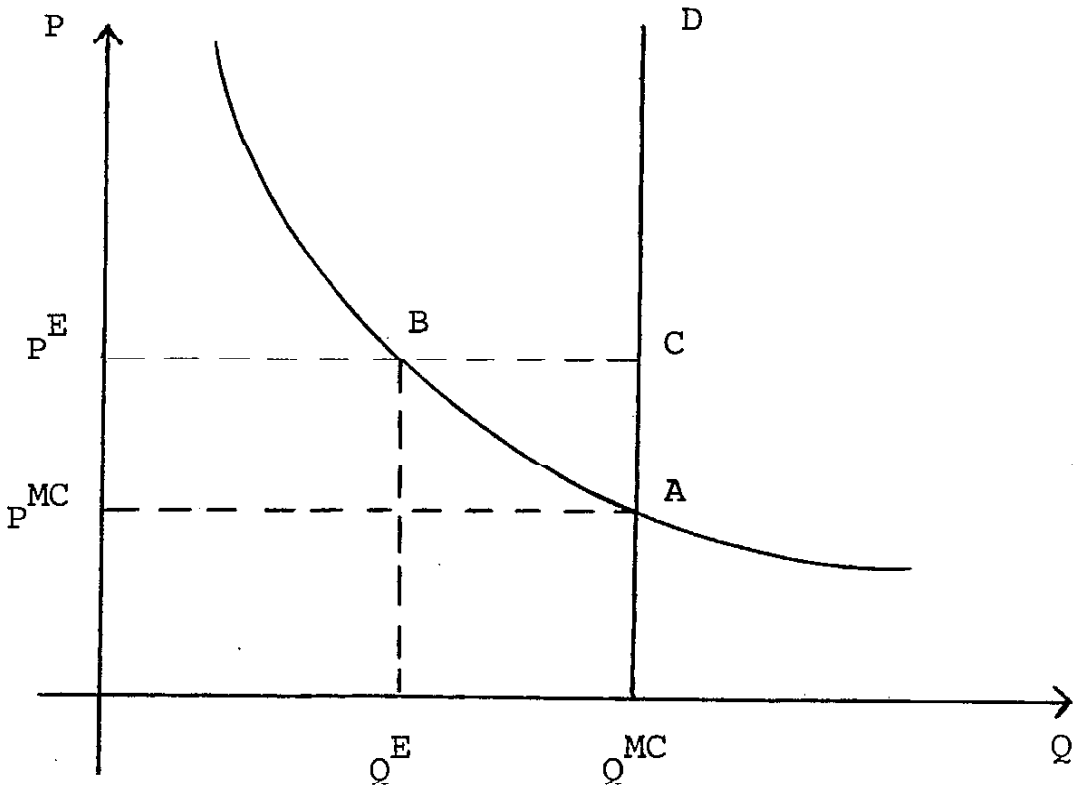

Figure 1

not rates for the seven-year period. We cannot use these data to prove our assumption that in the short run oil revenues are determined by the (inelastic) requirements for government expenditure, but they do show a close relationship over the period. The Spearman rank correlation between the average growth rates in oil income and government expenditure is 0.65, which is significant at the 0.01 level on a one-tailed test.

Conventional models of taxation assume a tax regime imposed exogenously upon producers who make wealth-maximizing price and output decisions. In the case of oil (and, we suspect, many commodities where governments dominate supply), neither is the taxation regime exogenous nor do producers maximize wealth. Thus, in analyzing the effect of taxation on the oil market, the appropriate concept of analysis is not per unit tax (dollars/bbl) or ad valorem tax (a fixed percentage of the price), but rather the government's demand for net revenue.

3. Short-Run Behavior in the Oil Market

We model the rent-seeking government as having as its prime financial objective a short-run target for net revenue R^*:

$$R^* = P.Q - \text{cost of extraction},$$

where P is the price of oil, and Q is the amount sold. (That is, given its primary objective the government is indifferent among (P, Q) sets that produce net revenue R^*.) The level of R^* cannot be varied in the short run, but can in the longer run. The short-term inelasticity of the government's revenue objective can occur through a commitment to a given flow of government expenditure or through a commitment to a given inflow of foreign exchange, or both. Such commitments are solutions to some type of political optimization, which we take as exogenous. We also model the government as having secondary, political objectives that can be satisfied in part by exploiting the queue when there is excess demand for oil.

3.1 Above-Market-Clearing Prices

We first prove that persistent prices above market-clearing levels are feasible in the short run. The analysis begins with the case of a single producer and then considers the case of many non-colluding producers.

3.1.A *Simple Model with One Producer* We initially assume (1) a single producer or an effective cartel (i.e., policing costs are zero), (2) short-run adjustments only, (3) significant costs of converting to substitutes, so that demand is perfectly inelastic[3] in the short run, and (4) the existence of a government (or perfect cartel of governments), whose objective is to attain tax revenues R^*, subject to the constraint that total sales revenue equals tax revenues plus total extraction cost:

2. The figures are given in Table A.1 in the Appendix.
3. MacAvoy (1982) cites several studies which estimate the short-run price elasticity of demand as approximately –0.1.

$$P.Q = R^* + C(Q),$$

where $C(Q)$ is the total extraction cost (including competitive capital costs).[4] For the moment we abstract from extraction costs by setting them equal to zero, to emphasize the main points of the paper.

This assumption of supply being driven by a short-run revenue target results in a backwards-sloping supply curve, which is a rectangular hyperbola and hence exhibits negative unitary elasticity of supply. It is this assumption which introduces the possibility of instability in the oil market, especially in the short run. Together with the assumption that short-run demand is completely inelastic, the backwards-sloping supply curve also results in an equilibrium with positive excess demand.[5]

Starting from market clearing, with no price rationing, we consider a supply-price rise. Under our assumptions of a short-run revenue target and inelastic demand, the supplier can maintain the target revenue by raising price and cutting quantity. In terms of Figure 2, this involves departing from market-clearing at *A* and moving up the supply curve to the left. In the short run this will result in excess demand for oil and in non-price rationing, in which case the supplier is able to exploit the queue for its political objectives.[6] The supplier will find that its secondary, extra-market goal of discriminating among buyers is satisfied while its primary goal of meeting a short-run revenue target is also satisfied. However, we may assume that the threats of trade retaliation or of military action by embargoed customers or their allies will limit the extent to which the supplier will exercise its power to discriminate by raising price and lowering quantity sold. Thus, there could be a political equilibrium, denoted by (say) point *B* in Figure 2, but there cannot be a solely market-determined equilibrium under these assumptions. Note that, if there were no secondary political objectives, then the price would be indeterminate.

The backwards-sloping supply curve means that an increase in price results in a short-run increase in excess demand, not a fall, as happens in textbook markets. Excess demand therefore is an increasing function of price, which would lead to an unstable equilibrium in the absence of extra-market factors, which we have modeled as secondary, political objectives. Starting from the market-clearing price, an exogenous expansion in demand will result at first in excess demand, with price greater than market-clearing levels, non-price rationing, and upwards pressure on prices. But price increases will only exacerbate the excess demand, given perfectly inelastic demand and a revenue-targeting supplier. This unstable process will culminate in satisfaction of the supplier's secondary objective to discriminate against some would-be buyers (but not sufficiently to result in extra-market retaliation), so that a non-market equilibrium is reached.

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4. We assume here that the government appropriates all the rent from oil production (both Ricardo and scarcity rent, as well as quasi-rent) either with a perfect lease-allocation/taxation scheme or by outright ownership.
5. The supply curve is not the textbook marginal-cost curve: for the moment we have assumed marginal cost to be zero. The effect of a constant marginal cost would be to shift the hyperbolic supply curve up. Theory tells us that an effective cartel would produce at the quantity at which marginal revenue equals marginal cost. With zero cost of extraction and perfectly inelastic demand, that would result in completely satisfied demand, at an indeterminate price.
6. Examples of such an event in the world oil market are the cases of embargo and rationing which accompanied the Yom Kippur war and the overthrow of the Shah of Iran.

3.1.B *Many Producers* We now assume (1) many competing producers, with positive costs of operating a cartel, (2) short-run adjustments only, (3) significant costs of converting to substitutes, with completely inelastic demand in the short run, and (4) that every oil-producing government faces a net-revenue or foreign-exchange target from oil sales. The short-run supply curve for the world market is the horizontal sum of the individual supply curves, and thus is itself a rectangular hyperbola of negative unitary price elasticity, given the simplifying assumption of zero extraction cost.

In the absence of perfect collusion (in which case see the analysis of Section 3.1.A above), market clearing with more than one price can occur at any time: if one supplier reduces its sales while maintaining its revenue by moving up its iso-revenue supply curve, the shortfall in supply can be met by another supplier increasing its sales by moving down its iso-revenue supply curve. However, if all suppliers have the secondary goal of discriminating among would-be buyers, then there is no pay-off to moving down one's supply curve, even if unsatisfied demand exists. Consequently, the possibility of above-market-clearing prices exists with many non-colluding producers; furthermore, producers are not constrained by competition to establish the same prices.

The existence of unsatisfied demand would provide arbitrageurs with profitable opportunities to supply would-be buyers with oil, so long as they could find producers willing to sell. Provided there are positive costs incurred by producers in policing the final destination, arbitrageurs can reduce the extent to which secondary political objectives can be satisfied. Arbitrageurs then exploit the short-run price inelasticity of demand, selling at a higher than producer price to the non-favored consumers. However, since the cost of producers policing the final destination is not infinite, there remains the possibility of effective non-price rationing.[7]

The possibility and extent of non-price rationing is further reduced by diversity among producers' secondary (non-revenue) objectives. For example, if producers are not in unanimous agreement about the consuming countries they seek to embargo, then the likelihood of an effective embargo is reduced. Similarly, consuming countries can threaten or initiate extra-market action against producers, including political and economic sanctions and military action.

In the short run, then, it is unlikely that a competitive supply market could long sustain a state of substantial excess demand. With multiple producers and positive costs of operating cartels, the possibility of prices above market-clearing levels is limited, as the post-embargo development of spot markets for oil demonstrates.

Theorem 1: So long as producers have some ability to control the final destination of their oil, in short-run equilibrium there can be positive excess demand for oil.

Proof: Since excess demand for oil in this model is a positive function of its price, there exists no stable market equilibrium. Producers' secondary goals of discrimination among would-be oil purchasers can be satisfied with positive excess demand and non-price rationing, while at the same time satisfying the short-term revenue objective. However, attempts by producers to discriminate among customers will be ineffective unless they

7. This models a situation that occurred in late 1973 when the Arab oil-producing countries embargoed the Netherlands—as well as the US—for its support of Israel. Despite their high dependence on imported oil, the Dutch were not seriously affected because of third-party support from both arbitrageurs and other oil suppliers.

have the power to control the final destination of their oil. □

3.2 Short-Run Instability at Below-Market-Clearing Prices

From the market-clearing point (P^{MC}, Q^{MC}) in Figure 2, there is no incentive for an individual supplier to reduce its price along the supply curve: so long as no suppliers increase their prices along the supply curve, the price-cutter would be unable to sell enough to meet its revenue target. Hence, price reductions are unlikely to be triggered by endogenous acts of producers.

The model really comes alive when we consider many oil suppliers competing for revenue up to their targets, and then introduce either exogenous demand contraction or exogenous supply expansion. If (say) an exogenous contraction in demand occurs, then at least some producers initially find themselves on the "long" side of the market, with excess supply. They thus are unable to meet their revenue targets. If they collude successfully, then they can move up the supply curve by raising price until the revenue target is reached at the inelastic quantity demanded. However, in the absence of perfect collusion, competition among suppliers for scarce buyers results in downwards pressure on price, which exacerbates the excess supply in the market, and hence the scramble for sales. In the absence of extraction costs, the short-run outcome, with perfectly inelastic demand, would be zero price, and no possibility of achieving the revenue target.[8] Thus, with multiple producers facing fixed short-term revenue targets, price is unstable in a downwards direction, at least in the short run.

Instability arises from the downwards-sloping supply schedule: with expenditure commitments to meet from oil revenue, governments respond to lower prices by pumping *more* oil, not less. The instability is not because of our simplifying assumption of zero extraction cost. If the cost of extraction is non-zero, and varies across producing countries, then the limit price will be the the cost of the highest-cost producer remaining in the market. Other potential producers will have left the market or be selling oil at below (domestic) cost in order, say, to generate foreign exchange or employment.[9]

For the downwards price spiral to occur, it is sufficient for one producer to fail to meet its net revenue target, provided price is initially set at market-clearing. However, if the price is above market-clearing when an exogenous contraction in demand occurs, then the unsatisfied producers must have sufficient output capacity to more than satisfy any excess demand for oil at a lower price. It seems, then, that the process is sensitive to the order in which the producing countries confront the oil glut and to the price obtaining when the exogenous demand contraction occurs.

Theorem 2: With many suppliers and positive costs of operating a cartel, excess demand is an increasing function of price, and price is unstable in the short run in a downwards direction.

Proof: Since excess demand for oil in this model is a positive function of its price, there

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8. We ignore production constraints on output, since with price-inelastic demand these are unlikely to be binding in the short run, even at very low prices.
9. This is seen in the phenomenon of "social metals," natural resource commodities the prices of which have perversely remained low despite the upturn in the world economy in 1983–84. See the discussion below in Section 6.

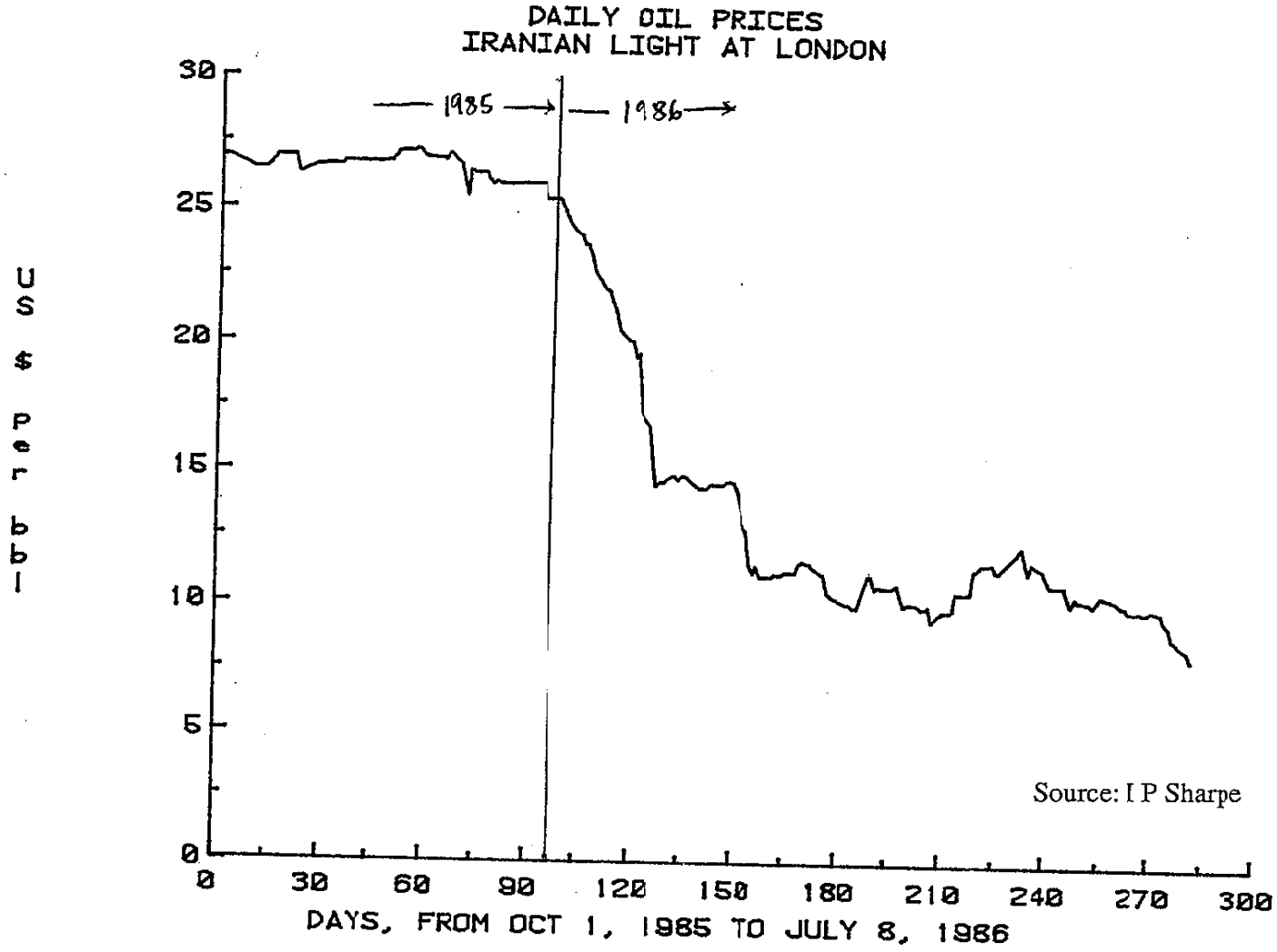
DAILY OIL PRICES
IRANIAN LIGHT AT LONDON
1985
1986
US $ Per bbl
30
25
20
15
10
5
0
0
30
60
90
120
150
180
210
240
270
300
DAYS, FROM OCT 1, 1985 TO JULY 8, 1986
Source: I P Sharpe

Figure 2

exists no stable market equilibrium at prices above short-term marginal cost. Once excess supply occurs, competition among producers to satisfy their primary revenue goal will force price to zero, or (if costs are introduced) to the cost of the marginal producer. □

4. The Longer Run

As in the textbook case, the longer-run demand for oil is more price-elastic, owing to substitution away from or towards oil, Griffin and Steele (1986). However, the short-run supply curve in this model does not translate into a textbook long-run supply curve (the lower envelope of the short-run marginal cost curves), since it is based on the sum of producers' revenue targets in any period, rather than on the cost of production. As time passes, governments revise their revenue targets, which results in shifts of the iso-revenue short-run supply curve, but there is no true long run in this model, only a succession of short runs. Given their incentives, we are not optimistic that governments of oil-producing countries will approximate wealth maximization in the long run.

We can speculate on the longer-term nature of the oil market, but here we are on weaker ground, since we are departing from the short-run model. Nevertheless, some speculation will provide insight into how the short-run model operates.

Our first theorem allows the possibility of prices above market-clearing levels. There then is no unique market equilibrium, because producers' short-term revenue objectives are satisfied at multiple prices. If there is any equilibrium (and if price is to be bounded), then that equilibrium will be of a geopolitical character. Presumably, then, episodes in which above-market-clearing prices occur are triggered by shifts in geopolitics. Thus, the 1973/74 oil embargo might be seen as resulting from the decline of influence of the US and its unwillingness at that time to exercise military power, following events that included the Viet Nam imbroglio, the Yom Kippur war, and Watergate. Furthermore, it is possible that the resurgence of US military activity under the Reagan administration was a necessary precondition for the recent decline in oil prices.

Our second theorem implies that price is unstable in a downwards direction. Thus, the precipitous fall from US$26/bbl to $10/bbl in the first four months of 1986 (as seen in Figure 3) might be seen as resulting from expansion in supply, as new oil (and new oil-producing nations) came on stream in response to the price levels established in the 1970s, together with a downwards-sloping short-term supply schedule. Recall that our model predicts that producers respond to falls in price by attempting to *increase* output. Unfortunately, our model provides no insights into timing, so we can only offer the evidence in stylized fashion.[10]

The second theorem has further implications for long-term pricing. If governments sequentially pursue short-run revenue targets, as we have assumed, then one cannot predict that oil will be priced at its "scarcity value." In our model, price is driven to short-run marginal cost as governments compete to preserve their revenue bases. For the oil price to exceed short-run marginal cost (i.e., to begin to provide a return for exploration or substitution) it is necessary for governments to abandon their revenue targets, at least some, or for them to establish an effective cartel.[11] Presumably, over the long term there

10. It is interesting to observe that the precipitous decline occurred almost immediately after the beginning of the 1986 calendar year, as if several governments and their agencies, acting independently, had formulated plans to pump more oil to meet 1986 budgeting commitments.

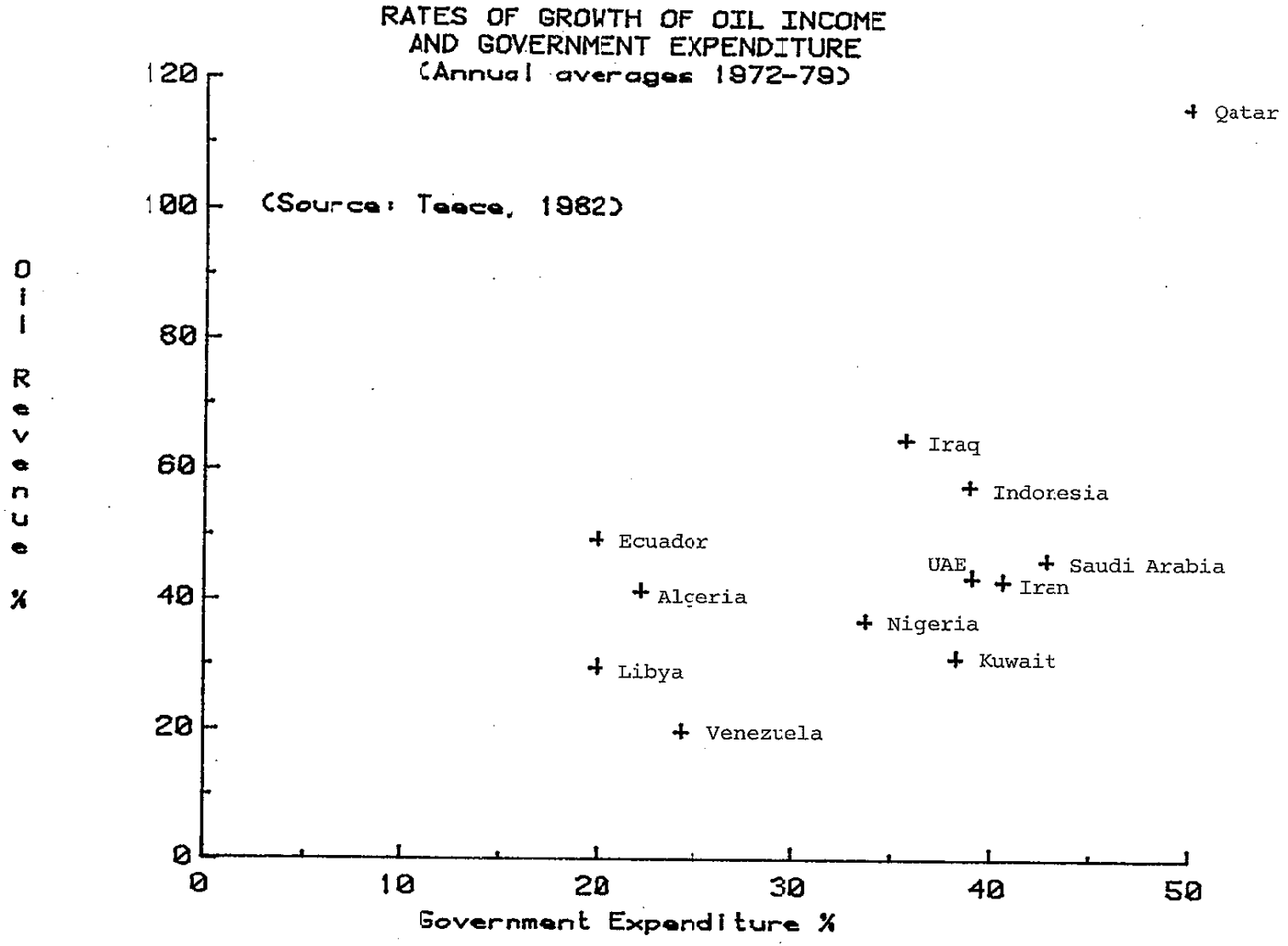
RATES OF GROWTH OF OIL INCOME
AND GOVERNMENT EXPENDITURE
(Annual averages 1972-79)
(Source: Teece, 1982)
Oil Revenue %
Government Expenditure %
0
20
40
60
80
100
120
0
10
20
30
40
50
Qatar
Iraq
Indonesia
Ecuador
UAE
Saudi Arabia
Iran
Algeria
Nigeria
Kuwait
Libya
Venezuela

Figure 3

will be episodes with and without governments intervening in the oil market via revenue targeting, so that price behavior over time will be episodic. Overall, revenue-targeting governments will tend to drive price towards short-run marginal cost, unless they can collectively learn that they normally fail to reach their targets.

The model provides a view of the determinants of national wealth. Paradoxically, many resource-rich countries are economically poor, while several resource-poor countries (Japan is the notable current exemplar) are economically wealthy. If world resource prices were continually driven to short-run marginal cost by governments' competing for revenue, then resource production would only add to GDP if the country earned Ricardian rent (i.e., produced at lower cost than the marginal producing country). Otherwise, the resource production would not augment wealth.

5. Previous Literature

The seminal contribution on commodity pricing is due to Hotelling (1931). If the oil market were free of government intervention, or if governments behaved as wealth maximizers, then oil prices would obey the Hotelling Rule: in the absence of unanticipated variations in supply or demand, prices net of extraction cost would increase at the interest rate. In our model, supply is dominated by governments that establish short-run revenue targets and thus do not make the intertemporal trade-offs that wealth maximization implies. These approaches differ radically, particularly in the importance attached by producers to the timing of revenues. Thus, under the Hotelling Rule producers are virtually indifferent about the timing of their oil sales (because the present value of gross revenue is independent of time), whereas under our characterization governments are acutely sensitive to current revenue shortfalls. One characteristic of the collapse in oil prices in early 1986 has been the competition among producers—both within OPEC and between OPEC and non-OPEC producers—to maintain their market shares. We interpret this concern with short-term market share as evidence in support of our model and against Hotelling behavior.

Modelling OPEC suppliers as having the primary goal of attaining a revenue target is not new. Ezzati (1976) relaxed the assumption of a revenue-maximizing, price-and-production strategy by a monopolistic OPEC to take account, inter alia, of differences in the need for oil revenues among OPEC countries. He plotted a backwards-sloping supply curve, and noted that excess production would result in downwards pressure on OPEC oil prices and eventual weakening or disintegration of OPEC. Crémer & Salehi-Isfahani (1980) and Teece (1982) also considered a model in which the primary OPEC goal is to satisfy expenditure requirements, in contrast to the classical cartel goal of maximizing wealth. Both papers derived a backwards-sloping short-run supply curve, and argued that so long as an OPEC country's revenue requirements are met there is no incentive for it to cheat, and that the stability of OPEC in the period 1974–80 need not have been the consequence of explicit collusion. Bohi & Montgomery (1982) presented a model with backwards-sloping supply, and noted that instabilities may result in perverse changes in price, such as a demand reduction followed by a price increase, and vice versa. Crémer &

11. We do not model the dynamics of the system, which involves both political and economic parameters and which probably is best modelled as a game. The Saudi strategy of being the "swing producer" can be seen as an abandonment of revenue targeting, in order to allow price to rise above short-run marginal cost.

Salehi-Isfahani (1980) also made this observation, but regarded this as unlikely to occur. We argue, however, that competition for revenue up to the target will result in price collapse following demand reduction.

Figure 4 plots the gross revenue outcomes of OPEC in total and Saudi Arabia in particular for the years 1973 through 1985 and then for the six months through March 1986 (the most recent period for which production data are available).[12] In the periods 1976–77 and, more recently, in 1985 through December, both OPEC in total and Saudi Arabia can be seen to be raising output while price falls, in such a way that gross revenue is maintained. The collapse of the oil price after the New Year is, we argue, a consequence of the unstable movements along the iso-revenue supply curves seen in latter 1985. That gross revenue was, for the most part, not constant, can readily be seen from Figure 4; what cannot be conclusively argued from the plot is that the producers were aiming for such targets.

It might be argued that, even if an oil-producing government had little use for a greater flow of revenue from oil production to finance domestic investment (the usual constraint on revenue requirements, according to Ezzati, Crémer & Salehi-Isfahani, and Teece) or transfer payments, such a government could still invest abroad, and so generate a return on its foreign assets. But oil not pumped and sold is not oil lost: oil in the ground remains an asset, to be pumped and sold later, at a capital gain if the price of oil has risen, as it will do as oil becomes increasingly economically scarce. This realization, together with the reluctance of several small OPEC producers to become rentiers—dependent on returns from their foreign investments—bolsters confidence in our assumption of fixed short-term revenue targets. Moreover, even if governments obtain returns on assets invested abroad, they will become independent on these revenues as well (as their expenditure commitments rise to the level of revenues). Hence, only the "capital" component of foreign investment would be a buffer against the behavior we describe.

Griffin (1985) tests four hypotheses of OPEC behavior: an effective cartel, competitive pricing with depletion of oil reserves, target-revenue satisficing, and changing property rights. Examining revenue satisficing, Griffin finds only four OPEC countries (the United Arab Emirates, Iraq, Algeria, and Indonesia) for which growth in investment needs results in a positive change in the quantity of oil produced, taking price as exogenously given, and only for Algeria are the estimated coefficients statistically significant and of the correct sign. Griffin concludes, however, that it is difficult to reject a "partial" version of revenue satisficing, in which OPEC countries are heavily influenced by revenue-target considerations, but occasionally produce in excess of revenue needs. Griffin is most enthusiastic about his results for a partial market-sharing cartel model of OPEC, in which considerations of market shares affect production decisions, but not rigidly: changes in production need not be proportional across OPEC countries. His results confirm him in his belief that OPEC has been an effective cartel, with at least partially effective output coordination.

Loderer (1985) tests the hypothesis of OPEC as an effective cartel by examining the correlation between OPEC policy changes and changes in spot oil (and future market and stock portfolio) prices during the period 1974 through 1983. He finds no evidence of an effective cartel in 1974–80, but significant evidence for the years 1980–83. The conclusion that OPEC is an effective cartel is echoed in research of Hope & Gaskell (1985), who calculate the 1983 price of oil as it would have been in a competitive market,

12. The figures are given in Table A.2 in the Appendix.

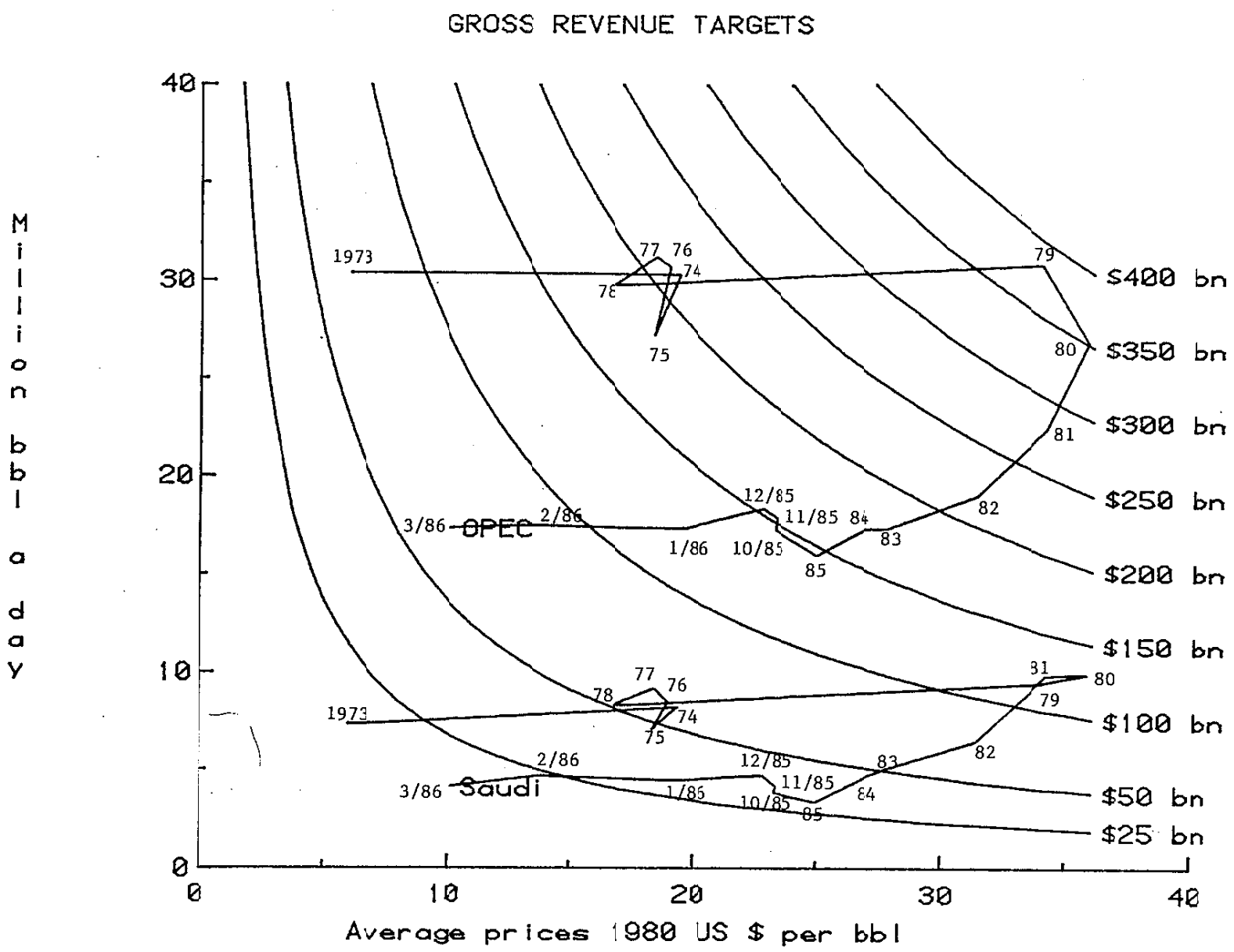
GROSS REVENUE TARGETS
Million bbl a day
40
30
20
10
0
0
10
20
30
40
Average prices 1980 US $ per bbl
$400 bn
$350 bn
$300 bn
$250 bn
$200 bn
$150 bn
$100 bn
$50 bn
$25 bn
1973
77
76
74
75
78
79
80
81
82
83
84
85
12/85
11/85
10/85
1/86
2/86
3/86
OPEC
Saudi

Figure 4

in order to compare the relative influence of depletion and the market power of the OPEC cartel. They calculate that the competitive price had an 80% chance of lying between $3/bbl and $11/bbl, with an expected price of $7/bbl, in 1983 US dollars. They conclude that collusion was responsible for the difference between actual and competitive prices in 1983, though our model also is consistent with that difference.

In making the assumption of revenue targets for oil-producing countries, we have broken with the usual assumption of wealth maximization. But, in attempting to explain the recent slump in oil prices, other researchers have found it difficult to maintain the assumption of wealth maximization without resorting to even less likely assumptions of oil-producers' behavior. Banks (1986), for instance, claims that the fall in oil price is a response by the OPEC core countries (Saudi Arabia, Kuwait, and the United Arab Emirates) to "the unprecedented irrationality" of other OPEC countries in experimenting with independent pricing schemes. We are not compelled to resort to assumptions of wealth maximizing by some producers and irrational behavior by others to explain recent events.

6. Markets Other Than Oil

There are several so-called "social metals" that might satisfy the two necessary conditions of this model: long-run marginal cost greater than short-run marginal cost, and extensive government control of production or of price and output policy, in order to attain revenue targets. The first condition follows from the natural-resource nature of metals production, in which the long-run marginal cost of production reflects the replacement cost as well as the extraction cost. That the second condition holds in some important metals markets can be seen from Table 1. Here, the extent of government intervention is understated, since the table refers to *direct* government control, ignoring de facto control over price and output via taxation and regulation of private producers.

Percentage of production under government control		
Metal	Western production	World production
copper	51	63
tin	33	44
aluminium	14	34
lead	14	39
zinc	14	36
nickel	12	44

Table 1: Social Metals

Source: *Australian Financial Review*, April 9, 1985.

In addition, several agricultural commodities are candidates for the model we propose. Rubber, sugar, palm oil and, more recently, wheat are notable examples. If our model does apply to these metals and commodities, then an implication is that prices in those markets will exhibit episodic behavior over time, with instability in the direction of short-run marginal cost.[13]

7. Conclusion

While the oil-producing government appears to be averse to risk in its short-run behavior (it adopts a short-run horizon of committing itself to a stable pattern of government expenditures), and while under some circumstances (when excess demand for its oil is positive, with an unsatisfied queue) it can achieve this stability of total revenue in the short run, its actions are destabilizing. By attempting to avoid the risk inherent in a flow of revenue highly correlated with either the quantity of oil sold (via a fixed per unit tax) or total oil revenues (via a fixed ad valorem tax), the government may well have amplified the oil-price risk faced by both itself and the rest of the world.

Under our second theorem, government revenue targeting will tend to create a lower price (equal to the marginal cost of extraction) than is economically efficient: price is driven below the socially optimal level, which reflects the replacement (opportunity) cost of oil, as well as its extraction cost. This could explain the 1986 collapse in oil prices and the "low" prices of so-called "social metals" and some agricultural commodities. It also could explain the apparent paradox of the economic poverty of many resource-rich nations, together with the comparative wealth of many resource-poor nations. Under our first theorem, there will exist periods in which prices are set at above market-clearing, with excess demand and rationing of output among politically prefereable customers. This could explain the existence of episodes such as the OPEC-led oil embargoes against the US.

13. Is it a coincidence that these markets are dominated by international marketing arrangements? Although conventional wisdom has it that these arrangements are regulations imposed on wealth-maximizing behavior (and hence result in deadweight efficiency losses), from the perspective of our model of competitive, revenue-targeting government behavior they may be Pareto-neutral at least.

Country	Oil income	Government expenditure	Time period
	%	%	
Kuwait	31.2	38.2	1972–79
Libya	29.8	20.0	1972–78
Qatar	116.0	50.0	1972–77
Saudi Arabia	46.5	42.7	1972–79
UAE	43.7	39.0	1972–79
Algeria	41.5	22.3	1972–79
Ecuador	49.6	20.0	1972–79
Indonesia	57.7	38.9	1972–78
Iran	43.1	40.5	1972–78
Iraq	65.0	35.7	1972–79
Nigeria	36.9	33.6	1972–78
Venezuela	20.0	24.3	1972–78
Simple average	48.41	33.76	1972–79

Table A.1: Rates of Growth of Oil Income, Government Expenditures (annual averages, in per cent)

Source: *OPEC Bulletin*, 1979, 1981.

Period	Price 1980US$/bbl	Saudi mbbl/d	OPEC mbbl/d
1973	6	7.34	30.44
1974	19.4	8.26	30.29
1975	18.4	7.08	27.19
1976	19.0	8.50	30.74
1977	18.5	9.20	31.27
1978	16.8	8.28	29.81
1979	34.0	9.53	30.93
1980	35.8	9.95	26.88
1981	34.2	9.83	22.49
1982	31.4	6.47	19.00
1983	27.8	5.05	17.37
1984	26.9	4.57	17.34
1985	25.0	3.38	16.02
Oct 1985	23.31	3.91	17.37
Nov 1985	23.34	4.20	17.91
Dec 1985	22.82	4.68	18.34
Jan 1986	19.68	4.45	17.35
Feb 1986	14.06	4.68	17.51
Mar 1986	10.16	4.12	17.33

Table A.2: OPEC and Saudi Arabian Crude Oil Production

Sources: *Petroleum Economist*, *Shell Briefing Service*, *I.P. Sharpe*.

Day	Date	Price	Day	Date	Price	Day	Date	Price	Day	Date	Price
1	1oct85	26.88	70	9dec85	26.65	142	19feb86	14.45	212	30apr86	9.90
2	2oct85	26.88	71	10dec85	26.25	143	20feb86	14.63	213	1may86	10.00
3	3oct85	26.88	72	11dec85	25.50	144	21feb86	14.63	214	2may86	10.58
4	4oct85	26.85	73	12dec85	26.50	147	24feb86	14.63	218	6may86	10.67
7	7oct85	26.65	74	13dec85	26.35	148	25feb86	14.75	219	7may86	11.45
8	8oct85	26.60	77	16dec85	26.40	149	26feb86	14.75	220	8may86	11.55
9	9oct85	26.50	78	17dec85	26.10	150	27feb86	14.70	221	9may86	11.70
10	10oct85	26.45	79	18dec85	25.97	151	28feb86	14.30	224	12may86	11.75
11	11oct85	26.53	80	19dec85	26.08	154	3mar86	12.60	225	13may86	11.42
14	14oct85	26.53	81	20dec85	26.00	155	4mar86	11.60	226	14may86	11.42
15	15oct85	26.67	84	23dec85	26.00	156	5mar86	11.25	227	15may86	11.60
16	16oct85	26.85	88	27dec85	26.03	157	6mar86	11.55	228	16may86	11.70
17	17oct85	27.00	91	30dec85	26.03	158	7mar86	11.15	231	19may86	12.15
18	18oct85	27.00	92	31dec85	26.03	161	10mar86	11.15	232	20may86	12.40
21	21oct85	27.00	94	2jan86	26.03	162	11mar86	11.25	233	21may86	11.95
22	22oct85	27.00	95	3jan86	25.42	163	12mar86	11.25	234	22may86	11.35
23	23oct85	26.30	98	6jan86	25.45	164	13mar86	11.25	235	23may86	11.80
24	24oct85	26.42	99	7jan86	25.35	165	14mar86	11.30	239	27may86	11.45
28	28oct85	26.65	100	8jan86	25.00	168	17mar86	11.30	240	28may86	11.08
29	29oct85	26.67	101	9jan86	24.75	169	18mar86	11.65	241	29may86	10.90
30	30oct85	26.65	102	10jan86	24.38	170	19mar86	11.75	242	30may86	10.90
31	31oct85	26.70	105	13jan86	24.05	171	20mar86	11.67	245	2jun86	10.90
32	1nov85	26.72	106	14jan86	23.75	172	21mar86	11.60	246	3jun86	10.45
35	4nov85	26.72	107	15jan86	23.75	175	24mar86	11.25	247	4jun86	10.15
36	5nov85	26.78	108	16jan86	23.20	176	25mar86	11.25	248	5jun86	10.50
37	6nov85	26.80	109	17jan86	22.70	177	26mar86	10.55	249	6jun86	10.35
38	7nov85	26.80	112	20jan86	22.05	178	27mar86	10.40	252	9jun86	10.30
39	8nov85	26.78	113	21jan86	21.95	183	1apr86	10.10	253	10jun86	10.15
42	11nov85	26.78	114	22jan86	21.65	184	2apr86	10.10	254	11jun86	10.40
43	12nov85	26.75	115	23jan86	21.25	185	3apr86	10.00	255	12jun86	10.55
44	13nov85	26.78	116	24jan86	20.50	186	4apr86	10.00	256	13jun86	10.50
45	14nov85	26.78	119	27jan86	20.10	189	7apr86	11.25	259	16jun86	10.35
46	15nov85	26.75	120	28jan86	20.05	190	8apr86	11.25	260	17jun86	10.33
49	18nov85	26.83	121	29jan86	19.45	191	9apr86	10.70	261	18jun86	10.15
50	19nov85	26.85	122	30jan86	19.65	192	10apr86	10.85	262	19jun86	10.15
51	20nov85	27.05	123	31jan86	17.33	193	11apr86	10.75	263	20jun86	10.00
52	21nov85	27.20	126	3feb86	16.75	196	14apr86	10.80	266	23jun86	10.00
53	22nov85	27.25	127	4feb86	15.25	197	15apr86	10.90	267	24jun86	10.00
56	25nov85	27.25	128	5feb86	14.50	198	16apr86	10.55	268	25jun86	9.95
57	26nov85	27.30	129	6feb86	14.70	199	17apr86	10.05	269	26jun86	10.00
58	27nov85	27.20	130	7feb86	14.70	200	18apr86	10.20	270	27jun86	10.05
59	28nov85	27.00	133	10feb86	15.00	203	21apr86	10.10	273	30jun86	9.95
60	29nov85	26.95	134	11feb86	14.80	204	22apr86	10.00	274	1jul86	9.55
63	2dec85	26.88	135	12feb86	14.95	205	23apr86	10.00	275	2jul86	9.40
64	3dec85	26.95	136	13feb86	14.95	206	24apr86	10.10	276	3jul86	8.95
65	4dec85	26.85	137	14feb86	14.80	207	25apr86	9.50	277	4jul86	8.80
66	5dec85	27.13	140	17feb86	14.45	210	28apr86	9.90	280	7jul86	8.45
67	6dec85	27.13	141	18feb86	14.45	211	29apr86	9.95	281	8jul86	8.10

Table A.3: Price of Iranian crude at London (US$/bbl)

Source: I P Sharpe

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