Non-conflicting resource pricing policies in an interdependent world

Graciela Chichilnisky, Geoffrey Heal and Amir H. Sepahban

OUR CONCERN in this paper is to analyze the optimal long-run pricing policies of oil-exporting countries. These might be described briefly as the policies which best meet their objectives, subject to the various limitations imposed on them by the realities of world economic forces.

The objectives of the oil-exporting countries have been conveniently summarized in earlier discussions in OPEC Seminars (see Sepahban, 1982), under the following four headings:

1. The conservation of hydrocarbon resources.

2. Accelerated economic and social development of their domestic economies, and in particular rapid capital formation.

3. Improved terms of trade with industrial countries.

4. Maintenance of reasonable rates of economic growth for the international community, including industrial countries.

It was shown in the above-mentioned paper that the requirements of the first of these four objectives, namely the conservation of OPEC's hydrocarbon resources, can be met by the application of Hotelling's principle of the economics of exhaustible resources, whereas the requirements of the other three objectives can be met by the use of a compact general equilibrium trade model developed at UNITAR (Chichilnisky, 1981). It was therefore recommended that attempts should be made to find the proper way to combine the main features of these two approaches into a single tool of analysis for the development of a logical strategy for the pricing and production of exhaustible resources, which would meet the requirements of all the above four objectives simultaneously.

The present paper achieves this goal by deriving the industrial countries' demand for OPEC oil as a function of price, using the general equilibrium trade model (section two), and applying this demand function to the

Prof Chichilnisky is affiliated to Columbia University, New York, and UNITAR; Prof Heal is affiliated to Columbia University; and Mr Sepahban is Adviser, International Affairs, Ministry of Petroleum, Islamic Republic of Iran.

dynamic Hotelling model (section three); thus introducing the notion of gradually increasing the scarcity of oil into the analysis. We use the derived demand function to compute the marginal revenue as a function of price, and then apply Hotelling's principle, which requires that the marginal revenue increases at a rate equal to the real rate of interest, as a condition for the maximization of the discounted sum of OPEC's revenue.

The results show that the optimal path may exhibit upward jumps in OPEC prices, especially in periods which are preceded by a period of slowly increasing or decreasing oil prices. It therefore bears some resemblance to the actual path of oil prices, which has seen oil price jumps following periods of relatively constant prices.

These new findings, together with the prospect of finding non-conflicting solutions, a feature of UNITAR's general equilibrium model, point to a useful direction of future research.

1. Introduction

The four objectives of oil-exporting countries presented above are clearly interrelated in a complex manner. For example, higher oil prices promote conservation (objective 1) and also affect the maintenance of growth in the international economy (objective 4) in several ways. The effects on consuming countries may include a positive effect through the recycling of OPEC revenues and thus increased OPEC demand for industrial goods from the North, and also a stimulus to investment through the substitution of capital for energy. And, if high oil prices lead to the development of substitutes for oil and thus eventually reduce demand, they may affect the possibilities for the development of oil-producing countries in the long run, while promoting that development in the short run, and also promoting conservation.

It is quite clear, then, that one cannot analyze the optimality of a pricing policy without an understanding of how these many complex factors are interwoven. In the remaining sections of the paper, we shall attempt to do this. The problem will be analyzed in two stages.

In section two, we shall be concerned with the macro-economic effects of oil price changes, and in particular with the effects of oil prices on the level of economic activity in the international community; and also on the prices of manufactured goods produced in oil-importing countries, and hence on the terms of trade between oil-producing and oil-consuming countries. These effects are analyzed by the use of a small general equilibrium trade model which will demonstrate how oil pricing policy relates to the second, third and fourth of the objectives mentioned above.

In section three, we move to a consideration of the long-run implications of alternative pricing policies, and we analyze alternative policies in terms of their impact on conservation, the development of substitutes for oil, and their effects on the cumulative revenues of the oil-exporting countries and hence on their development possibilities. These effects are analyzed by the use of Hotelling's principle for the economics of exhaustible resources.

Finally, synthesizing these considerations by combining the general equilibrium approach with Hotelling's principle (for the analysis of the dynamic aspects of long-run pricing policies), we shall be able to highlight some of the key qualitative features of an optimal oil pricing policy for the oil-exporting countries. Some of these features are both surprising and interesting. For example, we show that discontinuous upward jumps in price may be called for, and that under some circumstances these would be preceded by gradual drops in the price. We also show that there are conditions under which a policy beneficial to the oil exporters is also beneficial to oil consumers. Their economic interests are, in some respects at least, tied together.

Before we begin the details of our analysis, a discussion of the intellectual background is in order. The first person to develop a detailed analysis of the principles governing an optimal pricing and production policy for exhaustible resources was Hotelling, who wrote as early as 1931. His ideas went essentially unnoted for 40 years, until they were reinterpreted by Solow (1974) and developed further by Dasgupta and Heal (1974), who in particular extended the analysis to consider the possible development of substitutes. The implications of the emergence of substitutes for oil, or so-called backstop technologies, on the optimal pricing policy of OPEC has been treated in more detail by Khalatbari (1976) and further analyzed by Khalatbari and Sepahban (1980), using various assumptions of the market structure for oil and its substitute.

Our methodology here will be essentially that initially laid down by Hotelling, who showed that the optimal pricing policy will be very sensitive to certain aspects of the demand conditions facing the exporter. In most studies, demand conditions in the world oil market have not been well modelled, but have merely been summarized as an aggregate demand function relating quantity sold to price. Typically, the properties of this function have simply been assumed, or perhaps derived from a very crude analysis of the data, rather than based on any serious economic analysis.

A distinctive feature of the model described in the present paper is the derivation of the properties of this demand function from a detailed consideration of the effects of oil price changes on output, employment and pricing decisions in oil-importing countries. This draws on a model recently developed by Chichilnisky (1981), as part of the research programme at UNITAR.

2. Non-conflicting pricing policies: recent results in a general equilibrium framework

This section will summarize recent results in Chichilnisky's (1981) general equilibrium trade model. One distinguishing feature of the approach presented here is that it incorporates and analyzes explicitly cross-market effects, such as the effects of oil prices on rates of profit, output, employment and prices of industrial goods in an economy with three inputs and two produced goods. The model analyzes these effects through the endogenous responses of four prices (of capital and labour, of consumption and industrial goods) to oil prices. The model thus derives endogenously (rather than assumes) the general equilibrium demand for oil in response to alternative oil pricing policies, as well as the terms of trade between the oil exporter and the industrial country and the volume of industrial goods traded for oil. As will be shown below, this leads to rather different policy conclusions from those of the standard models, and discloses the existence of potential co-operative policies for the oil exporter and the importer that do not emerge in partial equilibrium approaches. This is due to the fact that the general equilibrium model allows the consideration of some of the positive feedback effects of increased oil prices on the economies of oil-importing countries — namely, the phenomena of the substitution of domestic capital and labour for oil as the price of oil is increased, as well as the beneficial effects of recycling OPEC revenues in generating additional demand for the exportable goods and services of oil-importing countries.

The model used here is a static general equilibrium model, and in the next section we shall consider its implications for dynamic pricing policies. It considers two regions, an oil-exporting region and another that imports oil in exchange for industrial goods. The industrial economy produces two goods: a consumption good B, and an industrial or capital good I. It uses three inputs of production: labour (L), capital (K) and oil (θ). Oil is not produced domestically.

The production equations are:

$$(1) \quad B = \min\left(\frac{L^B}{a_1}, \frac{\theta^B}{b_1}, \frac{K^B}{c_1}\right)$$

where the upper script B denotes inputs used in sector B. And, similarly:

$$(2) \quad I = \min\left(\frac{L^I}{a_2}, \frac{\theta^I}{b_2}, \frac{K^I}{c_2}\right)$$

where a, b and c are respectively the labour/output, oil/output and capital/output coefficients.

While each of these production functions has no substitution in the use of factors, the aggregate use of factors in the economy which depends on the final product mix (of B and I) has a significant elasticity of substitution at the economy-wide level, because B and I use factors differently.

Factor supplies are an increasing function of factor rewards:

$$(3) \quad L^S = \alpha(\frac{w}{p_B})$$

$$(4) \quad K^S = \beta r$$

where $\frac{w}{p_B}$ is a 'real' wage, in terms of the price of the consumption good B, and r is the rate of profit. In equilibrium, it is assumed that all wage income is consumed in sector B:

$$(5) \quad p_B B^D = wL$$

an assumption that can be relaxed somewhat without much effect on the results. When superscripts S and D denote supply and demand, the model's equilibrium conditions are:

$$(6) \quad K = c_1 B^S + c_2 I^S \qquad (\text{ie}, K^S = K^D)$$

$$(7) \quad L = a_1 B^S + a_2 I^S \qquad (\text{ie}, L^S = L^D)$$

$$(8) \quad B^D = B^S$$

(9) $I^D + X = I^S$, where X denotes exports of industrial goods (in volume) and:

$$(10) \quad P_I X = P_o \theta$$

where P_o, P_I denote the prices of oil and industrial goods respectively, and the basic good is taken as the numeraire, so that $P_B = 1$. The accounting identity of the model is Walras' Law:

$$(11)\quad P_B B^D + P_I I^D = wL + rp_I K$$

Exogenous parameters of this model are: $\alpha, \beta, a_1, b_1, c_1, a_2, b_2, c_2$.

It can be shown that, for each oil price level p_o, there is a locally unique solution of the general equilibrium of the industrial economy, which determines endogenously the following variables: all prices of goods and factors, exports of industrial goods and imports of oil, output in both sectors B and I and their consumption in the industrial country, and employment of factors, p_I, w, r, θ, X, I^S, I^D, B^S, B^D, L, K. All prices in this model are taken relative to the consumption good B.

A first result is that the rate of profit in the industrial economy will either rise or fall with the price of oil under different circumstances. This can be seen as follows. A general equilibrium solution of the model yields:

$$(12)\quad r = \frac{1}{c_2} - \frac{a_2 + p_o M}{a_1 c_2 p_I}, \quad \text{where} \quad M = a_1 b_2 - a_2 b_1$$

and:

$$(13)\quad p_I = \frac{a_2 + p_o M}{\gamma b_1 p_o (b_1 p_o - 1) + a_1}, \quad \text{where} \quad \gamma = \frac{\alpha}{\beta} \frac{c_2^2}{a_2}$$

so that:

$$(14)\quad r = \frac{\alpha c_2 b_1}{\beta a_1 a_2} (p_o - b_1 p_o^2)$$

Therefore the rate of profit in the industrial country rises with the price of oil when $p_o \leq \frac{1}{2b_1}$, and falls otherwise. The reason is that, if initially oil price levels are low, an increase in oil prices leads to increases in the price of industrial goods. The increases in industrial prices increase the supply of industrial goods which drives up the price of capital, since industrial goods are capital-intensive.

But, suppose the price of oil increases even further. This leads to a decrease in the overall demand for industrial goods and therefore to lower outputs. This drives down the price of capital. **Figure 1** illustrates the relation (14).

Since r_{max} is $\frac{1}{4}\frac{\alpha}{\beta}\frac{c_2}{a_1 a_2}$, this shows that the rate of profit r is dependent on technological conditions as well as on factor (capital and labour) responses to their rewards (ie, α and β). A second result exhibits the reaction of the volume of exports of industrial goods X to the price of oil. A general equilibrium computation shows that:

$$(15)\ X = \beta\left(\frac{a_1 r}{D} - r^2\right)$$

where $D = a_1c_2 - a_2c_1$,

so that:

$$(16)\ \frac{\delta X}{\delta r} = \beta\left(\frac{a_1}{D} - 2r\right)\frac{\delta r}{\delta p_o}$$

Therefore, if the technological relation $\frac{a_1}{D}$ exceeds twice the rate of profit, 2r, the general equilibrium volume of exports X reacts to p_o much the same as the rate of profit. So we have the following behaviour in the international market for industrial goods, as seen in **figure 2**.

Figure 2 shows there is an optimal price of oil $p_o = \frac{1}{2b_1}$, at which the oil exporter maximizes its current real revenues (in terms of industrial goods imported).

In this case, the short-run revenue-maximizing price of oil is that at which the rate of profit in the industrial economy is maximized. This is a first instance in which non-conflicting solutions may arise.

A second case is when $\frac{a_1}{D} < 2r$ for higher values of r. In this case, it is shown that the response of industrial exports to the price of oil is more

FIGURE 1

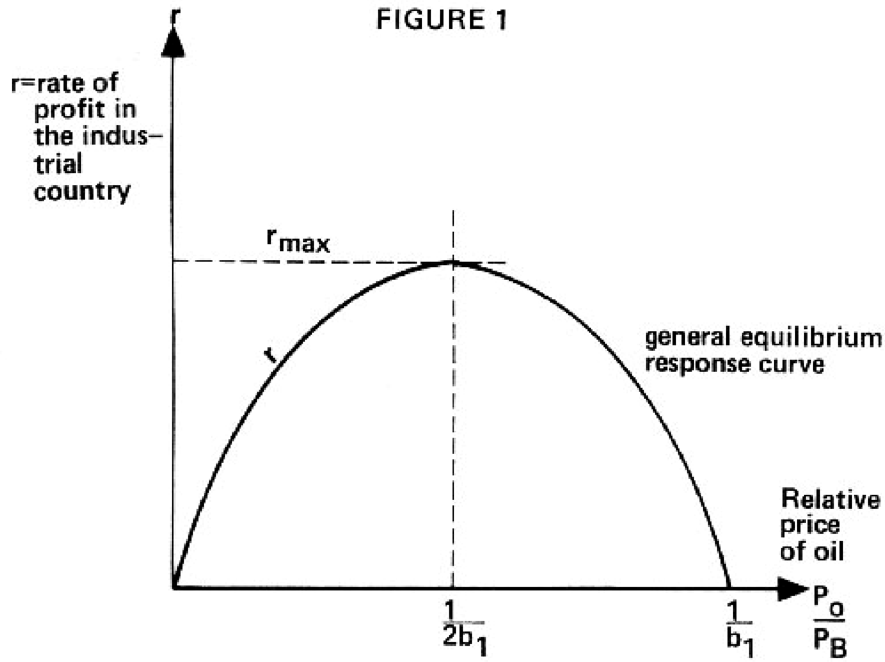
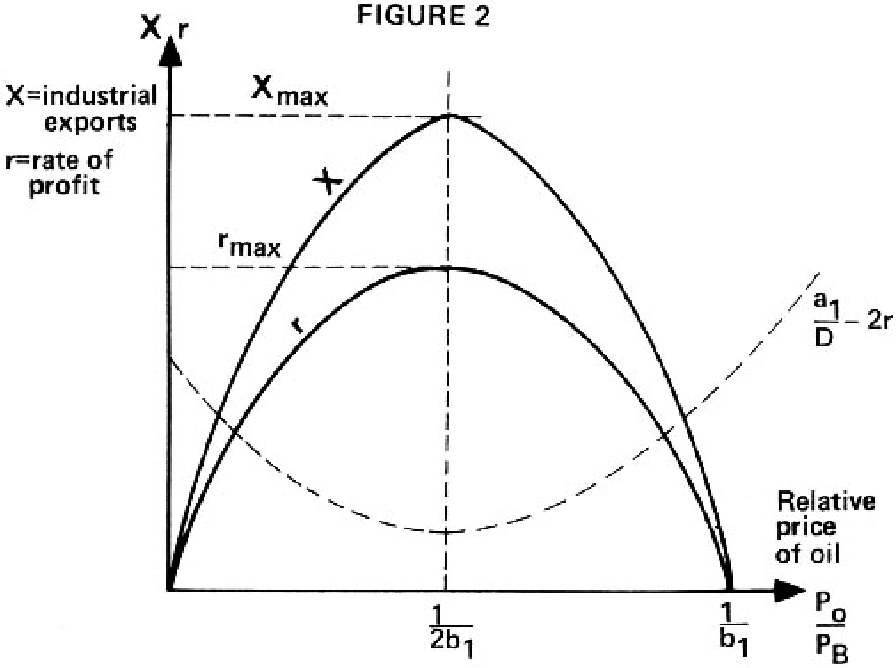


FIGURE 2



complex. In some cases ($\frac{a_1}{D} < 2r$) the volume of exports decreases even as the rate of profit r increases with the price of oil.

The explanation is simple. One finds that in this case the positive impact of the higher rate of profit on supplies of industrial goods $I^S = \frac{a_1 r}{D}$, is overcome by the positive impact of the higher profits on the demand for industrial goods within the industrial economy, $I^D = \beta r^2$. This is because industrialists demand more industrial goods when their profits are high. This effect is usually described by saying that the (positive) income effects on demand overcome the (negative) price effects, a statement that can only be made in a general equilibrium context. As a result, the difference between domestic supply and demand, which is the industrial export volume, decreases with the rate of profit when $\frac{a_1}{D} < 2r$. **Figure 3** represents this case.

In this latter case, there is a region I where the rate of profit and output of industrial goods increase, but exports decrease. The policy conclusions are different here to those of the first case ($\frac{a_1}{D} - 2r > 0$) because there are potentially two price levels which maximize the real revenues of the oil exporter, and the 'co-operative' (non-conflicting) solution is more complex.

It is worth pointing out that the amount of oil used by the industrial economy across equilibria (what may be called a general equilibrium demand curve) is in this model rather more complex than in the usual partial equilibrium models. The reason is that here we are internalizing all sorts of cross-market effects, as well as the all-important general equilibrium income effects, which as we saw above can imply very different policy conclusions. From reference 1, we can compute the cross-equilibria relation between the price of oil and the volume of oil θ^D demanded (in equilibrium) by the industrial economy.

We obtain, when $c_1 = 0$:

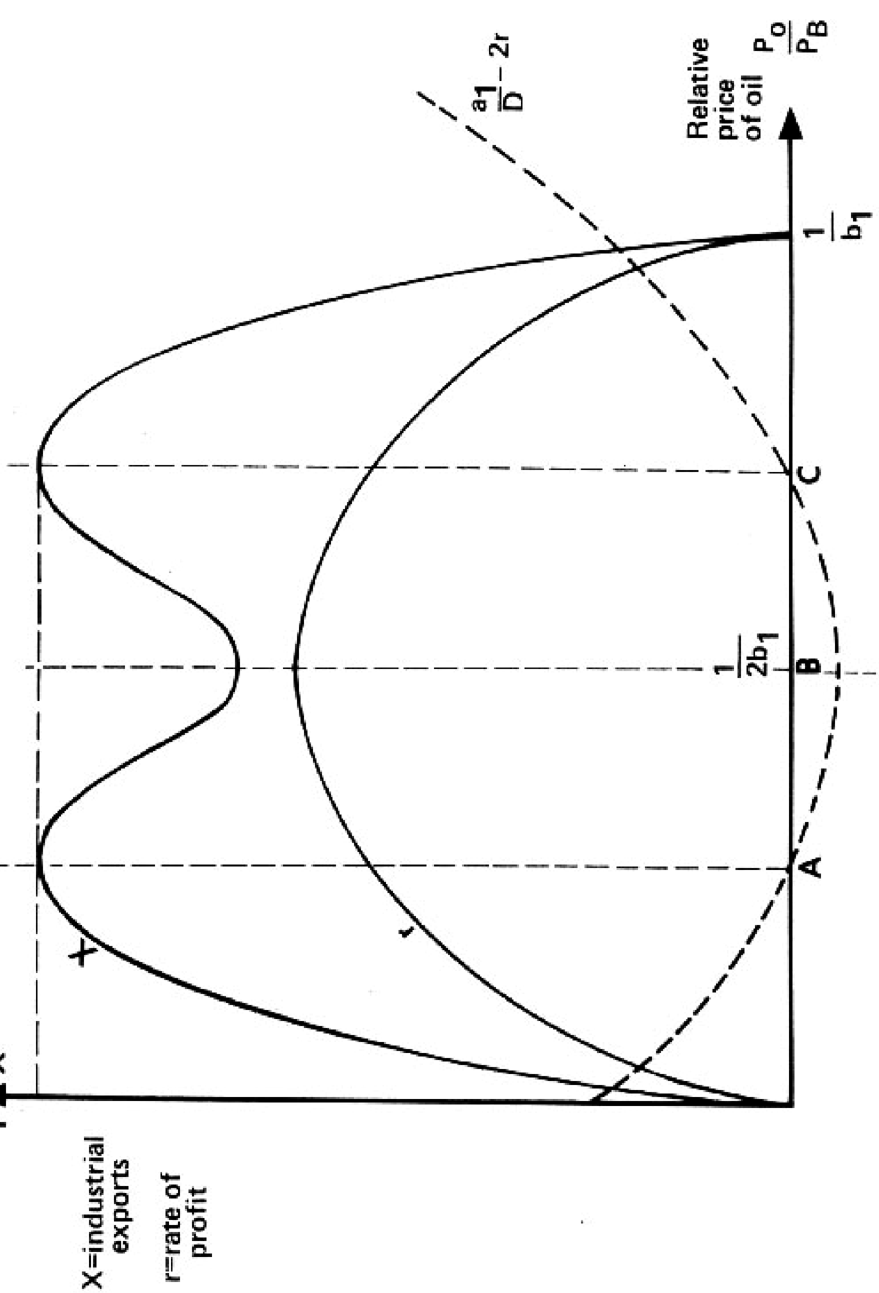
$$(17)\quad \frac{\delta\theta}{\delta p_0} = \frac{\alpha b_1 c_2 M}{D a_1 a_2}\left(1 - \frac{b_1 a_2}{M} - 2b_1 p_0\right)$$

where D is as defined following (15) and

$$M = a_1 b_2 - a_2 b_1, N = c_1 b_2 - b_1 c_2.$$

As an example, consider the case when $M > 0$. Then **Figure 4** depicts demand for oil by the industrial countries across equilibria.

FIGURE 3



X=industrial exports
r=rate of profit
r
X
x
r
A
B
C
$\frac{1}{2b_1}$
$\frac{1}{b_1}$
Relative price of oil $\frac{P_o}{P_B}$
$\frac{a_1}{D} - 2r$

FIGURE 4

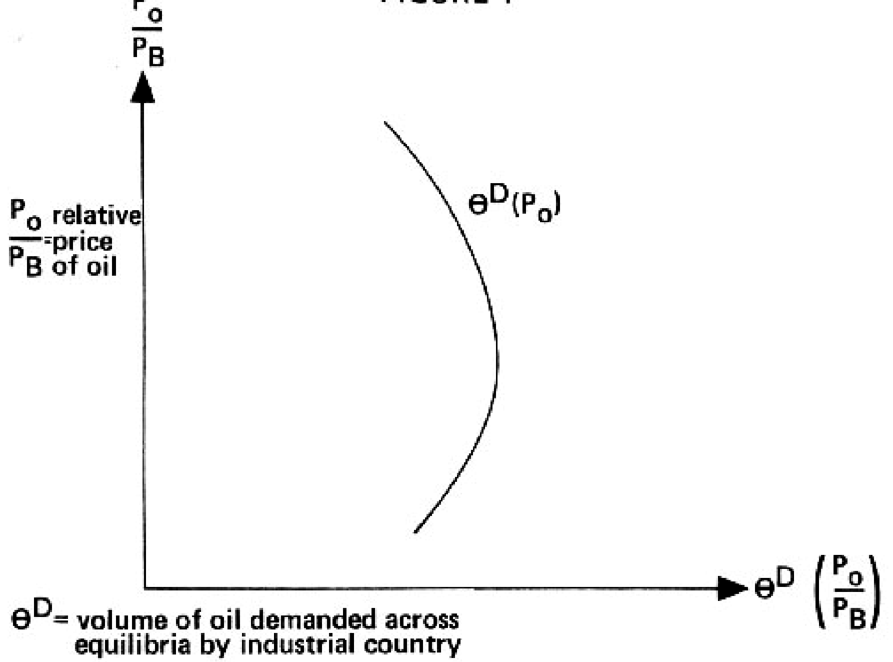
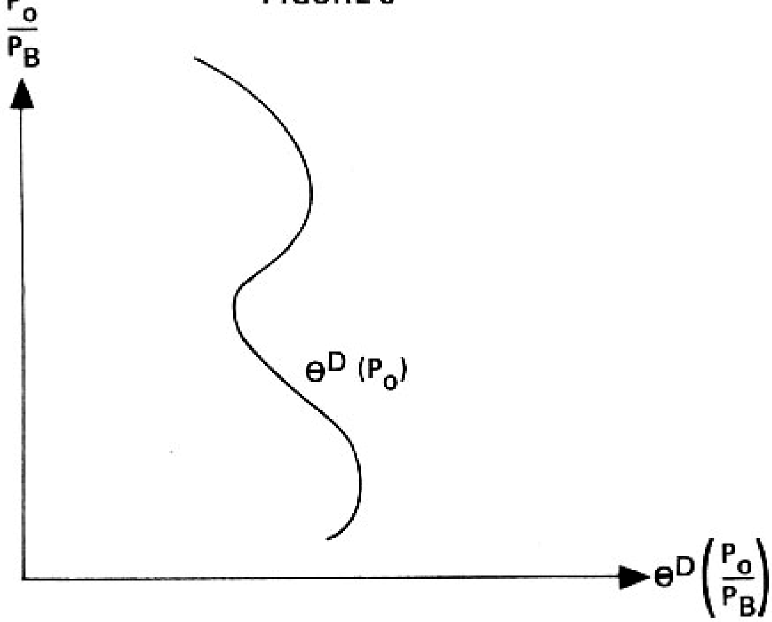


FIGURE 5



Obviously, if the square bracket term in (17) changes sign, one obtains even more complex demand behaviour as shown in **figure 5**.

The implications of such general equilibrium demand behaviour on oil pricing policies are obviously not trivial. They will be discussed further in the next section.

3. Long-run pricing policies

In this section, we consider briefly the implications of some of the earlier analysis on OPEC's dynamic long-term optimal pricing policy. There is already extensive literature on optimal long-term pricing policies for exhaustible resources, and the methodology in this area is well established (for a review, see Dasgupta and Heal, 1979). The basic principle to which one appeals is an application of the Hotelling Rule[1] (Hotelling,1931) as follows: a single (or dominant) seller of an extractive resource should control the time-path of output so that the present discounted value of the net marginal revenue from sales is the same at all dates at which a positive quantity is sold. Formally, if $MR(Q_t)$ is the marginal revenue derived from selling a quantity Q_t at date t, $MC(Q_t)$ is the marginal cost and δ is the discount rate, we require that:

$$(18)\quad (MR(Q_t) - MC(Q_t)e^{-\delta t} = \text{constant for } t, \text{such that } Q_t > 0.$$

The intuition behind this result is familiar and fairly obvious. It is that, if (18) were not satisfied, then there would be two dates, say t_1 and t_2, with $Q_{t1} > O, Q_{t2} > 0$, and:

$$[MR(Q_{t1}) - MC(Q_{t1})]e^{-\delta t_1} > [(MR(Q_{t2}) - MC(Q_{t2})]e^{-\delta t_2}.$$

So the present value net revenue from a sale at t_1 would exceed that from a sale at t_2, in which case profit-maximization would require sales at t_1 to be raised and those at t_2 to be lowered, until both net present value revenues were equal and (18) held.

Equation (18) may be rewritten as:

$$(19)\quad \dot{M}R(Q_t) - \dot{M}C(Q_t) = \delta(MR(Q_t) - MC(Q_t)) \text{ where } \dot{M}R = \frac{dMR}{dt}$$

which implies that net marginal revenue must rise at the discount rate δ — an implication of the Hotelling Rule (Hotelling, 1931).

As we are concerned here only with illustrating the general principles, we shall make the simplifying assumption that marginal extraction costs are negligible — ie, $MC(Q_t) = 0$. In this case, (19) merely requires that marginal revenue rises at the discount rate:

$$(20) \quad \frac{\dot{MR}(Q_t)}{MR(Q_t)} = \delta$$

In fact, this may be put into a more intuitive form. The marginal revenue gained from selling another unit of a good may be expressed in terms of the price elasticity of demand for that good:

$$(21) \quad MR(Q_t) = P(Q_t) \{ 1 + \frac{1}{\eta(Q_t)} \}$$

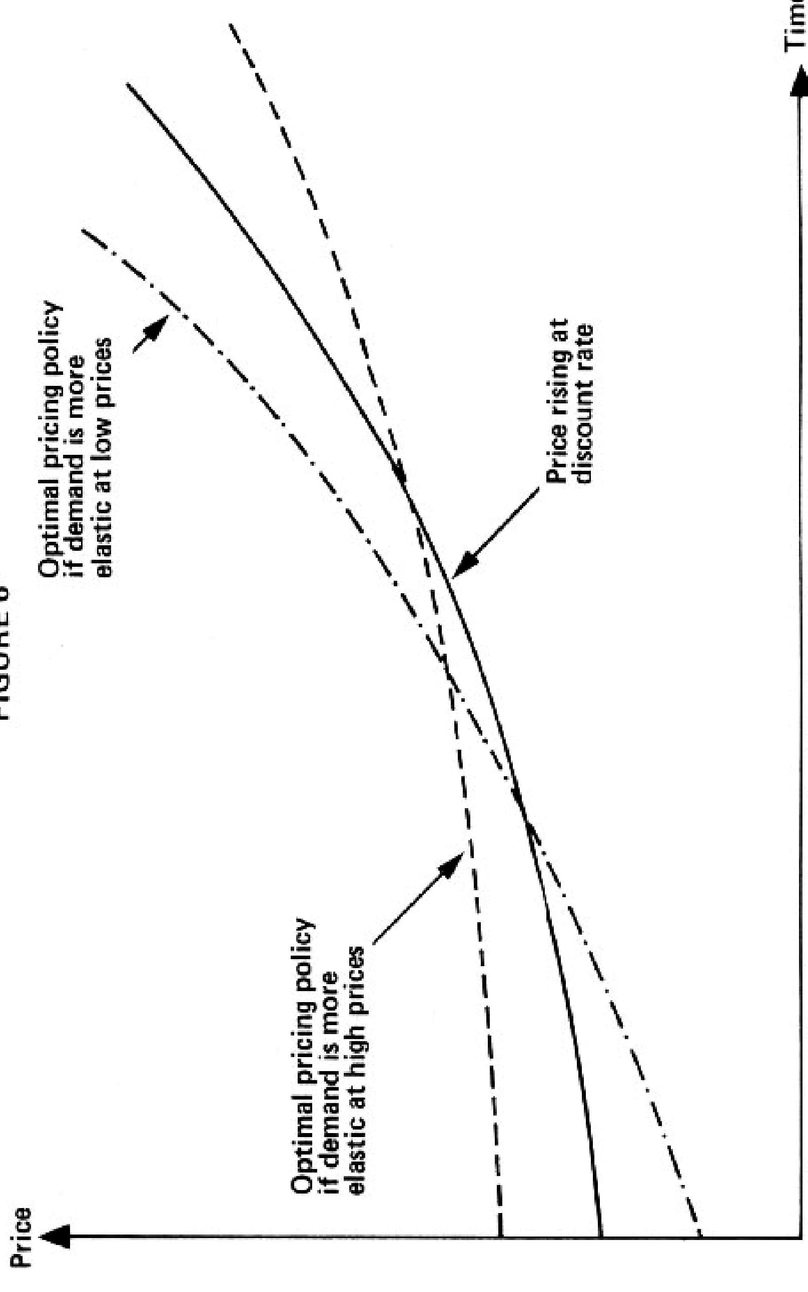
where $P(Q_t)$ is the price at which quantity Q_t can be sold, and $\eta(Q_t)$ is the price elasticity of demand at quantity Q_t and price $P(Q_t)$. (21) allows us to rewrite (19) as:

$$(22) \quad \frac{\dot{P}_t}{P_t} = \delta - \frac{\dot{\gamma}(Q_t)}{\gamma(Q_t)}$$

where $\gamma = 1 + \frac{1}{\eta(Q_t)}$.

(22) implies that, in order to maximize present value profits, the seller should adopt a pricing policy such that the price rises at the discount rate δ plus the rate $\frac{\dot{\gamma}}{\gamma}$, which depends upon the rate of change of the demand elasticity. If the elasticity of demand increases (in absolute value) as the price rises, then $\frac{\dot{\gamma}}{\gamma}$ is positive and the price should rise at less than the discount rate. Conversely, if demand becomes more elastic at low prices, then $\frac{\dot{\gamma}}{\gamma}$ is negative and the optimal policy will involve prices rising at more than the discount rate (see Dasgupta and Heal (1979), chapter 11). This is summarized in **figure 6**[2].

FIGURE 6



Possible optimal long-term price paths. The shape of the price path depends upon demand conditions: increasing elasticity flattens the path.

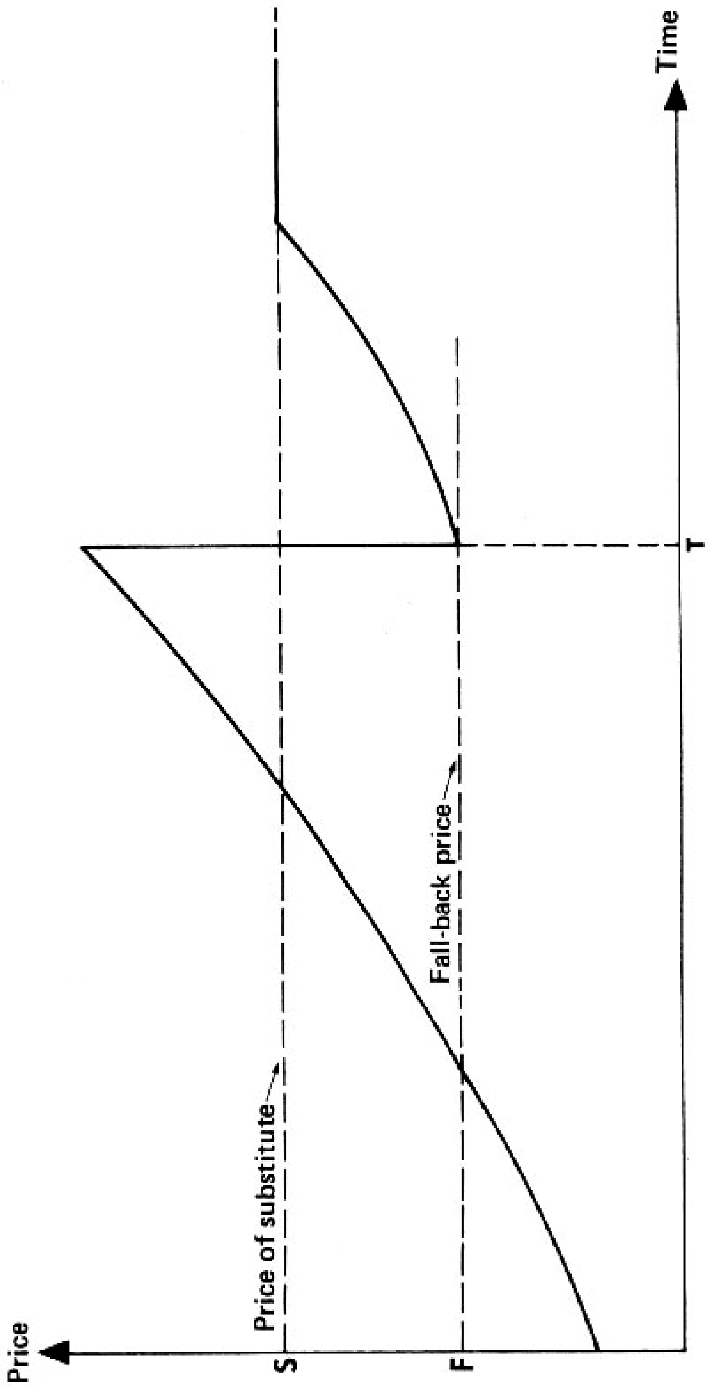
It is possible to add a number of complications to the foregoing analysis. We could, for example, reintroduce extraction costs. Or we could deal with a more complicated model of market structure than that of a dominant seller. There is extensive literature on modelling the market as divided between a dominant group of sellers and a "competitive fringe" of other sellers, which would seem to capture certain aspects of the world oil market adequately. The results for this case are qualitatively not particularly different from those outlined above.

It is also possible to introduce into the analysis a set of issues relating to technical change and the introduction of new technologies that might compete with oil. These are usually referred to in literature as "backstop technologies" — technologies which can be used to provide a substitute for oil on an effectively unlimited scale. In fact, such a possibility was implicit in our earlier analysis when we concluded that, as shown in **figure 6**, the optimal pricing policy involves a less rapid rise in prices if demand becomes more elastic at high prices. The main reason why this might happen is presumably that substitutes may be invented and introduced if the price of oil rises. If this is perceived as a real possibility, it implies that one should adopt a flatter time-profile of prices, and thus delay reaching prices high enough to trigger the introduction of competing technologies. Hence the conclusion that, if demand becomes more elastic at high prices, then prices should rise more slowly and the price path be flatter.

If there is a substitute for oil currently available on a large scale at a market price S, then this of course implies that the price of oil cannot rise above S. In this case, S provides an upper bound to the price paths illustrated in **figure 6**. If, however, the substitute is not currently available, but will be available at price S in T years' time, then, in the interim period prior to the substitute's availability, it is quite possible that an optimal pricing policy will involve prices in excess of S, with a sharp drop in the price of oil to S or below (fall-back price: F) at T when the substitute becomes available. This is illustrated in **figure 7**, taken from Khalatbari and Sepahban (1980), where this point is discussed in more detail for several market structure assumptions under conditions of uncertainty about the date of invention of the substitute.

A further refinement is to consider cases where future technology is uncertain. It would in fact be reasonable to suppose that both the price S of the substitute, and its availability date T, are uncertain and known only imperfectly. Cases of this sort are discussed in detail in Dasgupta and Heal (1974), Heal (1979) and Dasgupta and Stiglitz (1981). In these papers, it is shown that, in spite of the considerable technical problems introduced by uncertainty, simple and tractable results are still available. Essentially, these take the form of certainty equivalence theorems — ie, mathematical results

FIGURE 7



Optimum long-term price path when a substitute with price S becomes available at date T.

which tell us that, corresponding to the uncertain problem that we are really interested in, there is a simpler certain problem which has the same solution and can be solved readily.

Let us now consider the implications that this review of the long-term pricing literature has for the kind of general equilibrium model of the previous section. That model provided a framework within which one can study, in a static context, the consequences of a change in oil prices for the real revenue received by the oil exporter, the relative prices of various goods and services, and the overall configuration of the oil-importing economy. Within the context of long-term pricing, what such a model can provide is information about the demand conditions facing the exporter, and we have already seen, from equations (21) and (22) and **figure 6**, that demand conditions play a crucial role in determining the optimal long-run pricing policy.

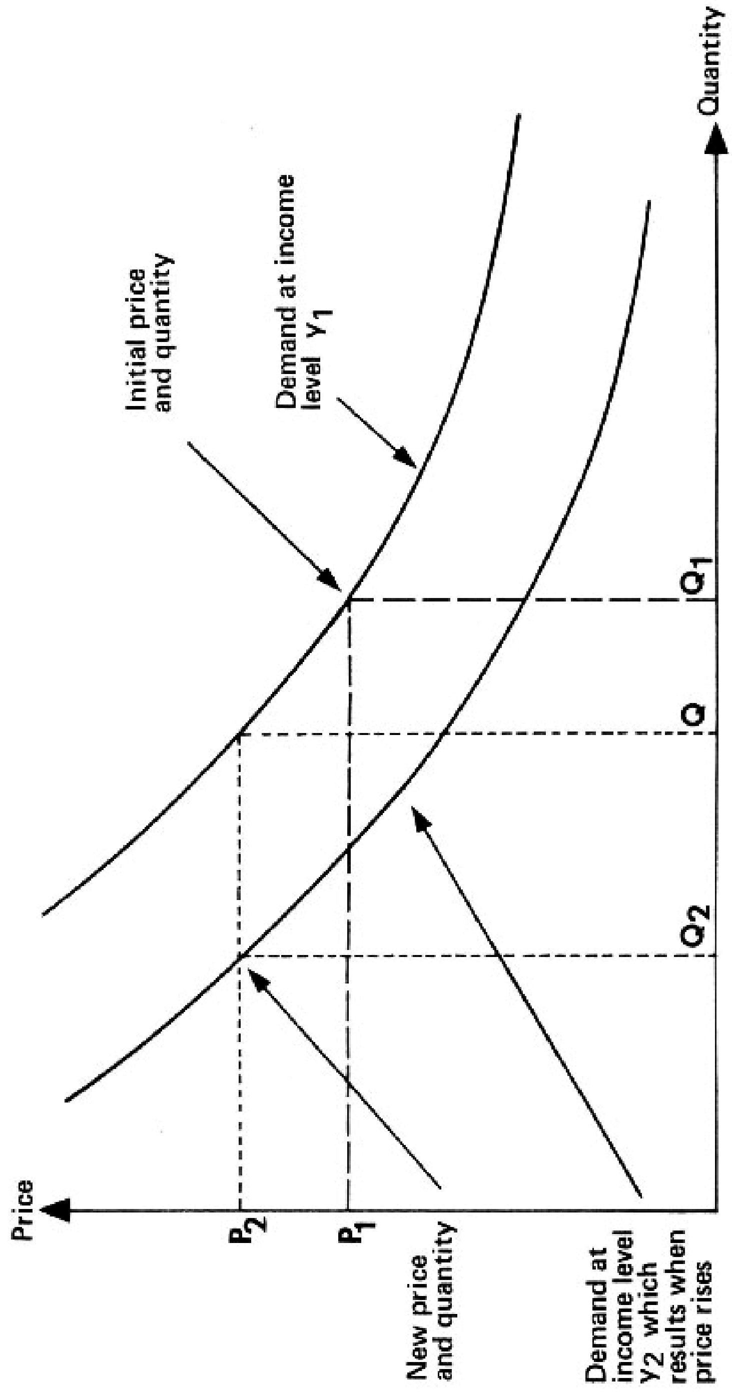
Most studies of demand conditions in the oil market are grossly oversimplified, and consequently cannot be taken seriously as a basis for policy analysis. At least two major defects are common to all of them.

The first is their neglect of the income effects that result from a price change. As was noted in the earlier sections, a rise in the price of oil may have a significant impact on income levels, output and employment in oil-consuming countries, and of course these changes in turn affect the demand for oil. In terms of the usual partial equilibrium supply and demand analysis, an increase in the price of oil reduces incomes and so shifts downward the usual demand curve, which is drawn on the assumption of fixed incomes. **Figure 8** illustrates this. A clear consequence is that any studies which assume that price changes leave income levels and demand conditions unchanged, will be seriously misleading.

A second general shortcoming of studies of demand conditions is that they neglect the impact of changes in oil prices on the prices of other goods and services — and, in particular, on the prices of the goods and services that OPEC Members buy from oil-consuming countries. Recent experience shows that these impacts may be major and, as OPEC is interested in the real purchasing power of its revenues and not just their money value, this neglect is again a serious one.

We can now see clearly the importance of the general equilibrium approach of the previous sections, as it enables us to model and analyze the effects of oil price changes both on income and on the prices of other goods and services. It hence gives us a more complete understanding of demand conditions, and thus a better basis for the analysis of long-term pricing policies. Because the general equilibrium approach gives a more complex view of demand conditions than the usual partial equilibrium approaches, working out its implications for long-term pricing will not be simple. The

FIGURE 8



An increase in price from P_1 to P_2 shifts the demand curve down, and so leads to a drop in quantity from Q_1 to Q_2 and not just to Q .

principles will of course be those outlined earlier in this section, but the details of their application will be complex. In the remainder of this section, we shall indicate in a sketchy fashion the results likely to emerge.

The first step is to interpret the implications of the general equilibrium model for the demand conditions facing the oil producer. As shown in **figure 3** of section two, reproduced on the next page, the real revenue received from oil exports may have two maxima when plotted against the price of oil. We can write the real revenue as:

$$R = \frac{Q}{p_I}(p_o) \cdot p_o$$

where Q is the quantity of oil exported, p_I the price of the industrial goods imported, and p_o the price of oil. The ratio $\frac{Q}{p_I}$ depends upon p_o.

Hence we can write:

$$\frac{\delta R}{\delta p_o} = \frac{Q}{p_I}\{\eta + 1\}$$

where η is the real elasticity of demand for oil,

$$\eta = \frac{\delta\left(\frac{Q}{p_I}\right)}{\delta p_o} \cdot \frac{p_o \cdot p_I}{Q}$$

Hence the elasticity is low when $\frac{\delta R}{\delta p_o}$ is positive, and vice-versa — formally:

$$\eta > -1 \text{ if and only if } \frac{\delta R}{\delta p_o} > 0$$

$$\eta < -1 \text{ if and only if } \frac{\delta R}{\delta p_o} < 0$$

Hence in **figure 3**, the elasticity passes −1 three times, as shown. The

FIGURE 3

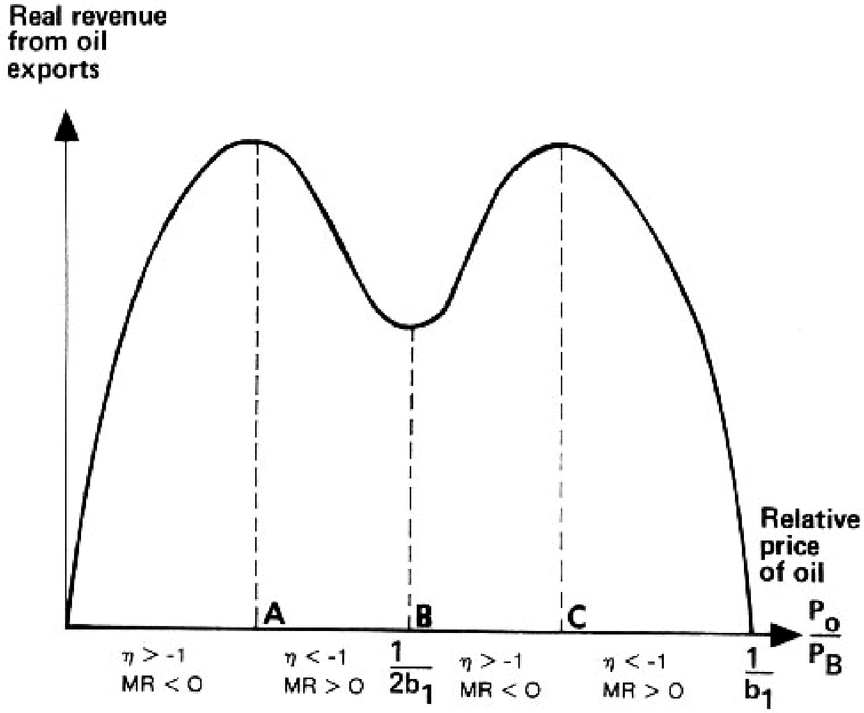
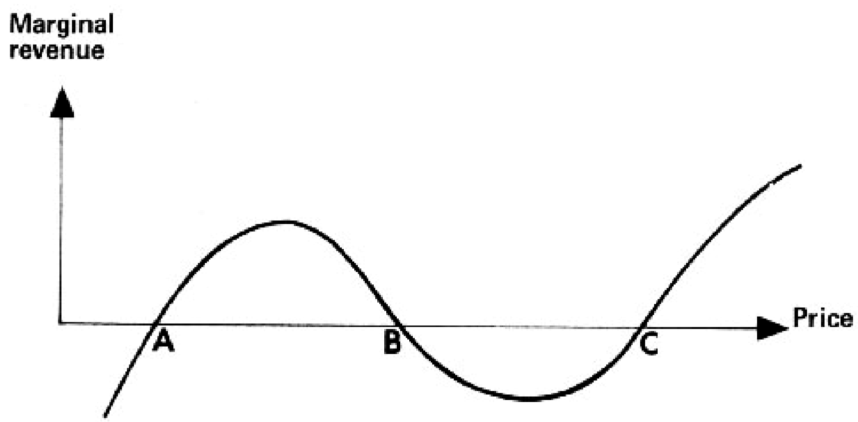


FIGURE 9



The marginal revenue schedule corresponding to figure 3.

next step is to relate the demand elasticity to marginal revenue, already done in equation (21) above:

$$(21)\quad MR = p\left(1 + \frac{1}{\eta}\right)$$

From this it is clear that marginal revenue is positive if $\eta < -1$, and vice-versa — formally:

$MR > 0$ if and only if $\eta < -1$,
$MR < 0$ if and only if $\eta > -1$,

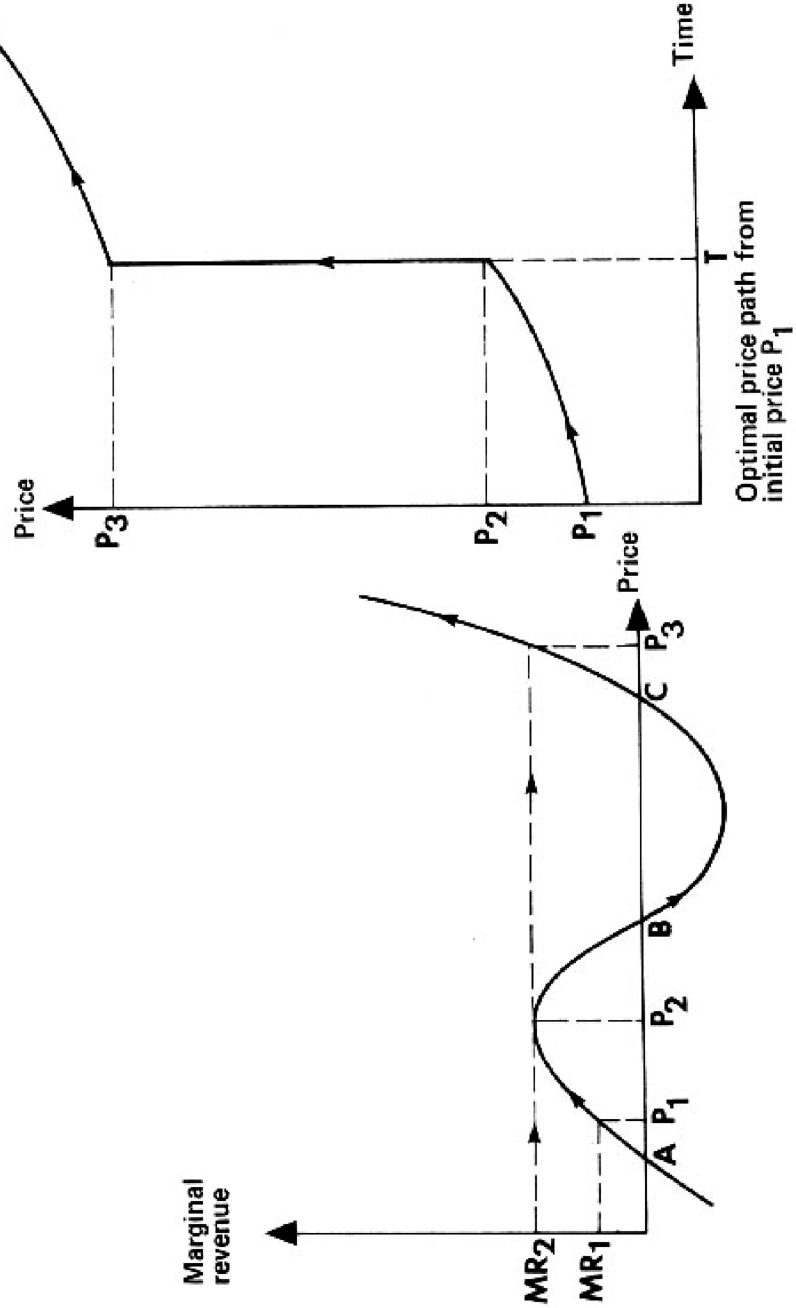
Hence in **figure 3**, marginal revenue changes sign three times as price increases, as indicated there. The same point is illustrated in **figure 9**, which plots marginal revenue against the price of oil, and shows directly the sign changes in marginal revenue that are implied by the general equilibrium analysis of demand conditions in the oil market.

We can now use this to throw some light tentatively onto the outline of an optimal pricing policy. The first basic point to note is that it will never make sense to sell where the marginal revenue is negative. It would always be possible to improve on such a situation by cutting back output and raising revenue. Hence the seller should never choose prices below A or between B and C. Optimal prices will always lie in the interval AB, or in the interval from C upwards, for these are the only prices which guarantee a positive contribution to real revenue from the last unit sold. If we were able to compute approximate values for the price levels A, B and C at which marginal revenue changes sign, we should immediately be able to place some limits on the prices that should be part of a long-term strategy.

The second point to note is that, as well as ensuring that marginal revenue is positive, the seller must ensure that marginal revenue rises over time at a rate equal to the discount rate. **Figure 9** suggests that there are several ways in which this might happen, and these are portrayed in **figures 10, 11 and 12.**

Figure 10 shows a case where the price starts at p_1 in the interval AB, and increases over time to p_2, raising the marginal revenue to MR_2. At p_2, further price increases would lower marginal revenue and, to keep this rising, it is necessary to jump from p_2 to p_3 and increase the price discontinuously.

FIGURE 10


Marginal revenue
MR2
MR1
A
P1
P2
B
C
P3
Price
Price
P3
P2
P1
T
Time
Optimal price path from initial price P1

Note that, although the price jumps discontinuously from p_2 to p_3, marginal revenue stays constant at MR_2 during the jump, and so moves up smoothly at the discount rate during the whole process. The right hand panel of **figure 10** shows the resulting price path, with its discontinuous jump.

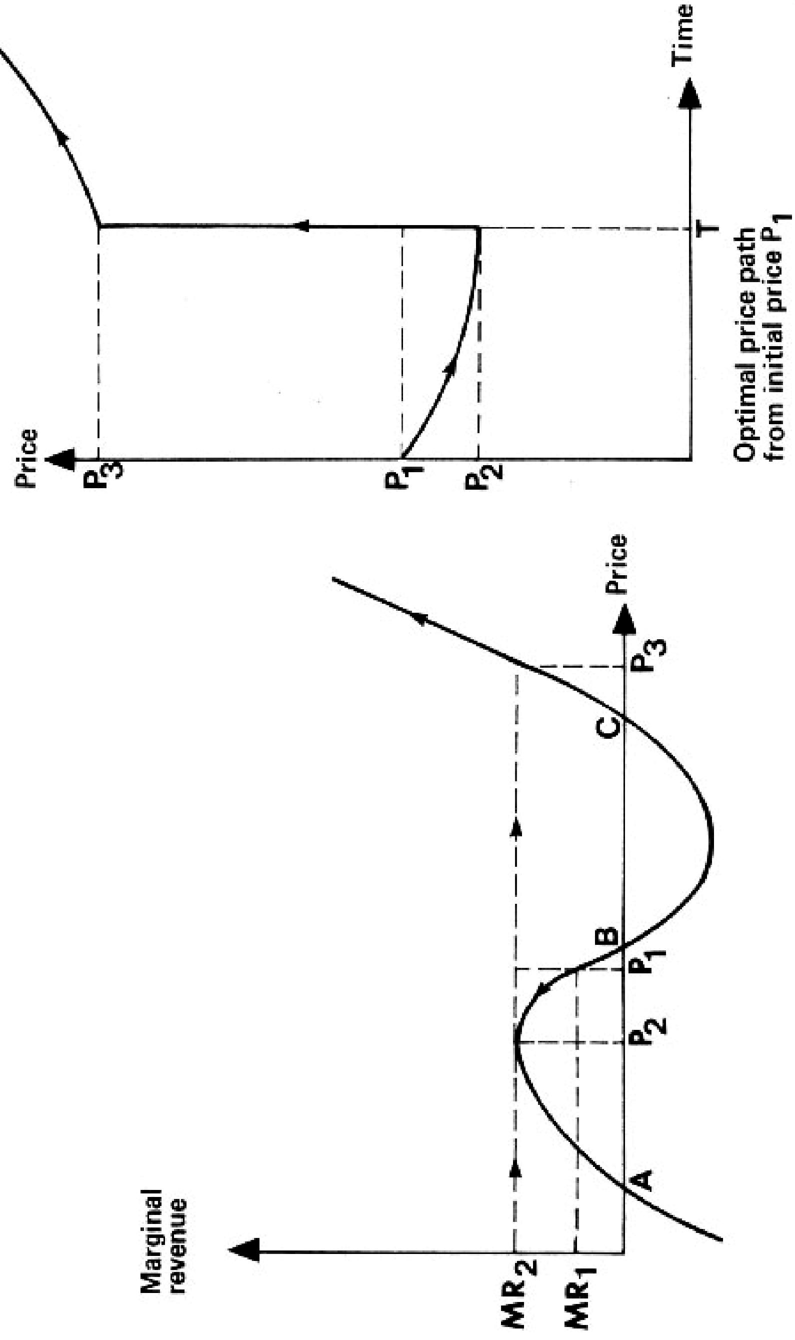
Figure 11 shows a very different possibility. Here the price starts at p_1 just below B, and falls over time to p_2. This fall in price raises marginal revenue to MR_2 when p_2 is reached, and at this point there is once again a need to make the price jump to p_3 to make marginal revenue continue rising. The resulting optimal price path is shown in the right hand panel of **figure 11**: there is a period of falling prices, followed by a sudden jump and then rising prices. Indeed, one can show that, whenever there is a period of falling prices, it will always be followed by an upward jump. One cannot help remarking that this has at least a super resemblance to the actual path of prices over the period 1950-1980 (the oil market price jumps of 1974 and 1979, which were both preceded by long periods of nominal price freeze, which meant a real price decline).

Figure 12 shows the remaining and rather simple case. The price starts at p_1 just above C, and rises steadily, forcing marginal revenue up. There are no decreases and no jumps.

We have now shown that a general equilibrium analysis of demand responses and relative price responses in the oil market may lead to some valuable insights into the possible characteristics of an optimal long-term pricing strategy. This may involve periods of falling prices, and may also involve sudden jumps in prices. It will always involve prices either within the interval AB, or above C. Whether the prices are always above C, in which case they are continuously increasing, or whether they are both between AB and above C, and so jump at certain points, will depend on a number of exogenous factors, among them the initial stock of oil. Regimes that involve only high prices — ie prices above C — will involve smoother and more predictable behaviour.

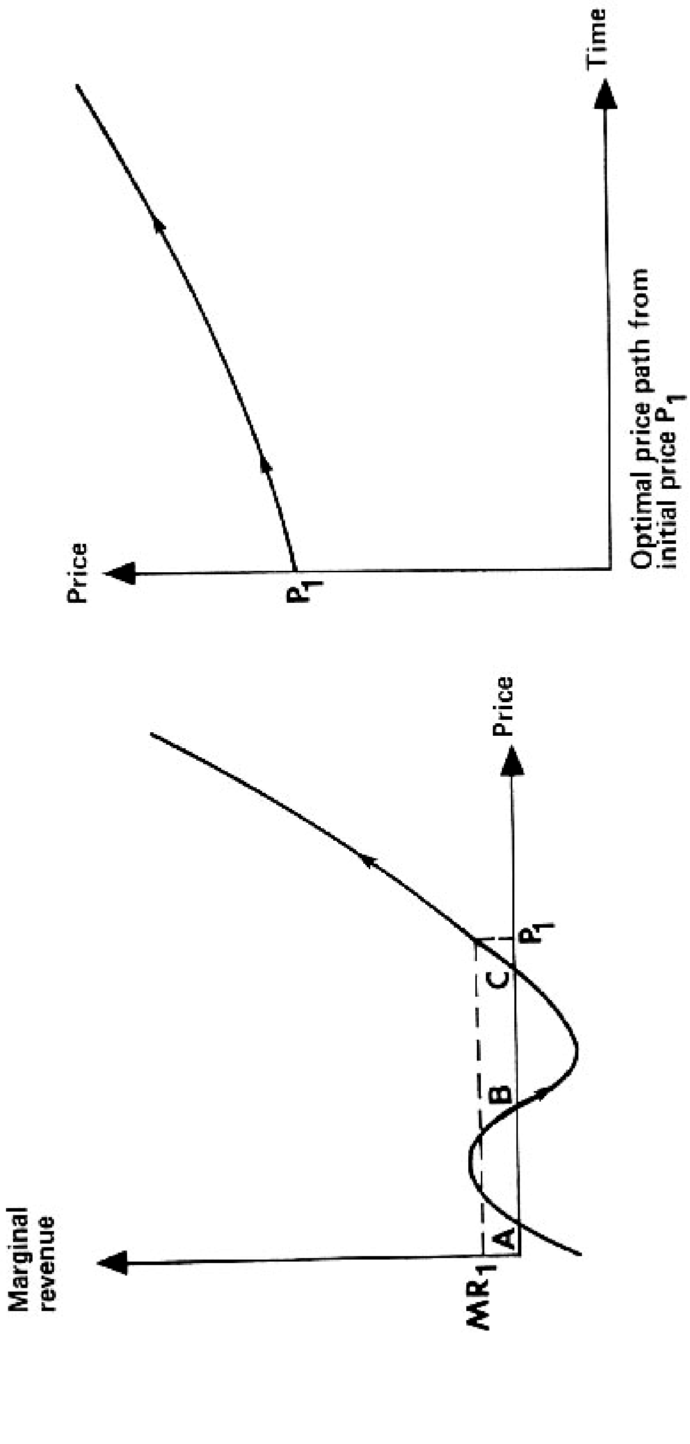
It is worth noting that, in the interval AB, both output and the rate of profit in the industrial economy are rising with the price of oil, although employment is falling. For very high values of p_0, however, output and the profit rate, as well as employment, fall as the oil price rises. We can therefore see from this that an optimal pricing policy may be characterized by some intervals which we might call non-conflicting price bands, in the sense that prices are increasing, yet at the same time some economic indicators in the consuming country are improving.

FIGURE 11



Price
P_3
P_1
P_2
T
Time
Optimal price path from initial price P_1
Marginal revenue
MR_2
MR_1
A
P_2
P_1
B
C
P_3
Price

FIGURE 12


Marginal revenue
MR1
A
B
C
P1
Price
Price
P1
Time
Optimal price path from initial price P1

Precisely which of the cases indicated in **figures 10, 11** and **12** actually occurs, and whether the co-operative aspect of optimal pricing policies is significant in the long run, are matters which can only be determined by extensive further research. Likewise, further work would be needed to introduce into this model the possible appearance of backstop technologies and substitutes for oil, possibilities which were referred to briefly above and which in reality place important constraints upon long-term pricing policies.

4. Conclusion

The set of issues governing the selection of an optimal pricing policy is very complex. An optimal policy has to be chosen in the light of the effects of oil prices on consuming countries, their effects on technological change and their effects on the terms of trade. Also of importance will be the exporting countries' development objectives, as expressed through their discount rates.

What we have shown in the previous sections is that, in spite of the complexity of these issues, one can develop a model which encompasses them all, and which is compact enough to be analytically tractable and can yield interesting qualitative conclusions. Obviously, these are very preliminary, and are suggestive rather than definitive. But, they seem to represent an avenue well worthy of further exploration.

Footnotes

1. *This rule is reviewed in Dasgupta and Heal (1979) and in Sepahban (1982). In the case of a competitive market, it predicts that the difference between prices and extraction costs will rise at the interest rate, so that its present value is constant. The monopoly case differs in that price is replaced by marginal revenue.*

2. *It can be shown that the price paths corresponding to different demand curves must intersect because they correspond to the same total consumption over time.*

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