UK Gasoline Prices:
How Fast are Changes in Crude Prices Transmitted to the Pump?

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Oxford Institute for Energy Studies

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EXECUTIVE SUMMARY

The recent dramatic fall in crude oil prices has raised expectations of a similar decrease in gasoline prices at the pump. Although gasoline prices have ultimately been reduced, the decline did not occur immediately. The response of prices at the pump to changes in crude oil prices and in the exchange value of the pound (vis-a-vis the US dollar) seems to have been sluggish.

This paper examines the historical relationship between crude oil prices, prices of refined products at the refinery gate, and prices at the pump in the UK. The questions addressed are:

(a) How long and how constant are the response lags over time?
(b) Are all cost changes passed on equally rapidly?

The study identifies four types of time lags: a recognition and decision-making lag, a cost adjustment, an uncertainty and an inventory lag. It is argued that these time lags are not additive.

Econometric models to test the price responses and measure the time lags were constructed,and estimation used data for the period 1977-85. They clearly show that variations in net-of-tax retail prices (at the pump) are almost entirely explained by changes in product prices (at the refinery gate) and in the exchange rate; but that the adjustment to these changes has been slow both when costs increased and when costs decreased. The unrestricted model suggests that the mean time lag of net-of-tax retail prices to cost changes was four and a half months. The restricted model estimates much longer time lags.

Yet the response of product prices (at the refinery gate) to crude price changes was very rapid: the time lag has a mean value of just over half a month. This indicates that prices are much stickier at the pump than at the refinery gate.

The study concludes with a qualification. The recent crude oil price decreases may be passed on to the pump faster than suggested by the historical data. There may be an asymmetry in companies' behaviour when costs rise and when they fall. As the historical data cover a long period during which crude oil prices often rose and very seldom declined, they may not have picked up this asymmetrical response.

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INTRODUCTION

The recent dramatic fall in the price of crude oil has focussed attention on the relationship between crude oil prices and retail gasoline prices in the UK. The central issue is that of how long it normally takes for the fall in costs to be felt in a fall in final prices. The purpose of this study is to investigate the relationship between these two variables over a period for which there is homogeneous data, and to see whether the lag has been constant over time and whether all cost changes are passed on equally rapidly.

The first section of the paper sketches the nature of the relationship between the variables, and describes the econometric model to be used in estimating past behaviour and testing the various hypotheses. The second section of the paper discusses the data to be used and comments on the problems associated with using the different potential sources. The third section describes the estimation of the model and the various tests, and the final section draws some conclusions from the study.

1. THE RELATION BETWEEN RETAIL GASOLINE PRICES AND CRUDE OIL PRICES

(a) The Link Between Retail Gasoline And Product Prices (Refinery Gate) The relationship between the output price and the input price is complex in this case because of a number of factors. In order to clarify this we trace the links starting with the retail prices.

The retail price of gasoline can be written as:

$$R = f\ (£P, M) \quad (1)$$

where

R is the sterling net-of-tax retail price of gasoline ("at the pump");

£P is the sterling price of refined gasoline - i.e. the ex-factory price;

M is a mark-up and allowance for other costs.

This formulation is put forward with the implication that the mark up is constant and that other costs (e.g. transport) are constant over the period. The first assumption implies, for example, that all increases in tax would be fully passed on and not absorbed in a lower mark up. Given data on tax changes it would be possible to test this directly. The absence of other cost shifts is in a sense forced on the analyst in the absence of data. It may be that a trend variable could be used to capture any such shifts. Apart from these two factors it may be that the margin has shifted for other reasons e.g. changes in the intensity of competition. The actual technology involved in this stage of transferring refined products from the refinery to the pump has probably not shifted greatly in cost terms so that we would not expect there to be large relative input price shifts involved. This should again help to keep the model simple for the first link.

The second link is to look at the actual purchase of the refined product. Much of this is imported and the market is certainly dominated by world and not local conditions. In particular, the price of products is quoted in dollars so that the purchase cost cannot be related to the retail price until the sterling/dollar exchange rate is introduced into the picture. Often the product price is quoted f.o.b. so that an adjustment to bring it up to a c.i.f. basis is required. In fact this margin is small so that variations in the product price will swamp variations in the c.i.f./f.o.b. margin, and hence the use of an f.o.b. series, if necessary, will not distort the picture too much. Putting the single version of these two links together we have:

$$R = M. \ (P/E) \qquad (2)$$

where

E is exchange rate

M is a <u>percentage</u> mark up factor.

If all adjustments to changes in product prices or the exchange rate were made instantaneously we would move immediately to the estimation of (2) and to tests for the stability of M.

However, in most markets there are lags between changes in input variables and changes in output variables. These lags occur for a number of reasons:

(i) there is a recognition and decision making lag;

(ii) there is a lag due to costs of adjustment;

(iii) a lag due to uncertainty;

(iv) a lag due to the existence of inventories.

It seems unlikely that the first lag is of any importance in this market where information is freely and readily available. The second reason for a lag is also unlikely to be a great significance since the single change of prices at retail is a low cost operation and it is unlikely that spreading out the change would be valuable. The third and fourth reasons seem the most important. If we assume that firms are unwilling, because of the structure of competition, to keep making temporary changes in prices, then they will need to be convinced that a change in their cost position (for better or worse) will remain for some time, before they are willing to react to it. Hence the first reaction to a cost change will be often a "wait and see" strategy. As it becomes clearer that the change is permanent then the price change will be introduced.

The reactions to changes in product prices and to changes in exchange rates may well be different accordingly to the above line of reasoning. Major changes in product prices will be for reasons directly connected with the oil industry and well understood by the industry. On the other hand, movements in the dollar/sterling exchange rate occur for a variety of reasons, many of which are external to the industry and which are in any case much less predictable. If this is true then it would be expected that retail prices would respond more rapidly to a product price change than to an exchange rate change.

Finally, inventories can play an important role in pricing. If items are priced on a FIFO (first in, first out) basis then, the greater the size of the inventory in relation to sales, the longer it takes before the higher priced inputs "become" higher priced outputs. With LIFO (last in, first out) pricing the size of the inventory is immaterial and there would be no lag because of the existence of inventories. A mixed policy would produce a lag which was related to the size of the typical inventory. We can see that this lag is invariant with respect to product prices or exchange rates (since the stock has already been paid for) but will vary if the inventory/sales ratio is changed. If higher oil and product prices led to smaller inventories being held after the 1979 oil price shock (or as a result of increases in real interest rates) then the lag could be expected to have shortened.

From this discussion we can see that there are good reasons to expect a lag between changes in product prices and exchange rates and changes in retail prices. This lag should exist both when general costs rise or fall, and could vary depending on economic conditions. An important consideration is that the speed of adjustment (length of the lag) could be different with respect to changes in product prices and to changes in exchange rates.

An important question is whether these different types of lags, if they exist, are additive i.e. whether a one month lag due to FIFO pricing, and an inventory equal to one month's sales, should be added to a one month lag in respect of uncertainty over changes in costs. Clearly there is no reason to expect additivity - while the inventory is being "used up" at the old prices the firm will be collecting a month's experience on costs and will be ready to decide whether it is necessary to take them into account in pricing at retail. Hence the adjustment process is dominated by the longer of the two lag processes. Of course, if the lag lengths change over time we could see a situation where the inventory dictated the lag length of one period while the adjustment lag to the new expected costs dominated in another period.

To begin with we shall assume a uniform lag structure i.e. one that does not change with economic circumstances. The standard way to formalise equation (2) into a dynamic response is to write it:

$$R = M \quad a\,(L) \quad (P/E) \tag{3}$$

where a(L) is a lag polynomial i.e.

$$R = M\ \{a_0(P/E)+a_1(P/E)_{-1}+a_2(P/E)_{-2}\ \ldots\} \tag{4}$$

where the sum of the lag weights is

$$\sum_{i=o}^{\infty} a_i = 1 \tag{5}$$

This formulation has two disadvantages from our point of view. Firstly, it constrains the speed of response to changes in product prices and to changes in the exchange rate to be the same. We can handle this generalisation by expressing (2) in logs and applying separate lag polynomials to the two elements.

$$\ln R = \ln M + b(L)\ \ln P - c(L)\ \ln E \tag{6}$$

where $\quad \Sigma\ b_i = \quad c_i \quad$ (7)

- which imposes the same effective condition as (5). The second difficulty is an econometric one. The lag structures involved in reacting to changing costs may be lengthy. This will involve loss of precision in estimation because of possible collinearity beween the lag variables. The standard way to avoid this difficulty is to rewrite the general polynomials b(L) and c(L) as ratios of polynomials, where the numerator and denominator polynomials are of low order.

$$\ln R = \ln(M) + \frac{d(L)}{w(L)} \ln P - \frac{g(L)}{w(L)} \ln E \qquad (8)$$

The restrictions that must be imposed are:

$$\Sigma\, d_i = \Sigma\, g_i \qquad (9)$$

$$\Sigma\, d_i = \Sigma\, w_i \qquad (10)$$

so that in the long run the mark up is constant.

It is important to use the same denominator polynomial so that we can rewrite the equation in a form for estimation:

$$w(L) \ln R = w(L) \ln M + d(L) \ln P - g(L) \ln E \qquad (11)$$

where w_o is set at 1 and (9) and (10) are imposed. In actual estimation (8) is a stochastic equation so that the choice of w(L) is such as to produce, if possible, serially independent error terms in (11). If the error terms are not serially independent then this is strong evidence that some variable has been omitted and that possibly the lag distribution is probably too short.

We can now illustrate for a simple set of polynomials. Let the polynomials all be of first order. The model is then:

$$\ln R_1 + w_1 \ln R_{-1} = M^{*} + d_o \ln P + d_1/ \ln P_{-1} - g_o \ln E - g_1 \ln E_{-1} \qquad (12)$$

with $1 + w_1 = d_o + d_1$ (13)

$$g_o + g_1 = d_o + d_1 \qquad (14)$$

which yields the 'restricted' equation:

$$\ln R = M^* + d_o[\ln P - \ln R_{-1} - \ln E_{-1}] + d_1[\ln P_{-1} - \ln R_{-1} - \ln E_{-1}] - g_o[\ln E - \ln E_{-1}] \qquad (15)$$

Even though there are only three lag coefficients to be estimated the actual response of prices to input costs is spread over an infinite period, but with the bulk of the adjustment coming rapidly. The average lag response is given in general from (6) by

$$\bar{b} = \Sigma i\, b_i / \Sigma b_i \qquad (16)$$

which is expressible as

$$\bar{b} = b'(1)/b(1) \qquad (17)$$

where the numerator is the first derivative of the lag polynomial evaluated at unity. Using the substitutions of (8) it can further be shown that in general

$$\bar{b} = \frac{d'(1)}{d(1)} - \frac{w'(1)}{w(1)} \qquad (18)$$

The values of the w_i and d_i can then be used to calculate the mean lags of the two input variables.

The general model we have developed is suitable for estimating the core relationship between product prices, exchange rates and retail prices. It is cast in a form that ignores two important possibilities. The first is that the force of competition may vary systematically over time so that the mark-up changes. This effect is usually related to a "pressure of demand" type variable and to model it we would need to make M vary with a measureable index. The second possibility is one which derives from the fact that many companies are vertically integrated between the retail and refining stages of the industry. In such a case gasoline is only one of the joint outputs of refining and the possibility of the market for other products influencing the pricing of gasoline must be considered.

If the demands for the different products are independent it is evident that for profit maximisation in a normal competitive market each output would be priced at the factory gate in the usual fashion and hence the retail price would be in a fixed relation to the product price (assuming that there was no substitution possible vis-a-vis the other input costs to retail sales and that these relative costs did not change). However, in a situation where firms have a certain amount of market power this power could be varied as between product prices. However, it is less easy to see why this would be expressed in the effect on retail prices since the degree of concentration in the retail market is probably low enough to put substantial long run pressure on prices. Cross subsidisation of (say) low heavy oil fuel prices by retail gasoline prices seems not a priori to be a sustainable strategy.

Given this discussion we can make equations such as (15) the starting point of our analysis and only if they fail to explain the data satisfactorily move to more complex but less precise formulations.

Finally we must consider the rate of taxation in this model. Retail prices of gasoline at the pump include a very large amount of taxation. The companies in setting the price have the choice of whether to fully "pass on" any tax increases or to fully absorb them or to partially pass them on. In terms of our full passing on (i.e. taxes are treated as any other cost) so that the long run equation becomes:

$$R = M.\ (P.T/E) \qquad (19)$$

where T is the tax "mark up" variable (i.e. the ratio of the price gross of tax to the price net of tax). In practice not all taxes are charged on an *ad valorem* basis so that there is an element of distraction in this formulation. However, for analytical convenience this model is preferable to one which attempts to model the tax incidence exactly, while the error introduced is not likely to be substantial. The dynamic equation can allow for a different speed of passing on of each of the three cost elements:

$$w(L)\ln R = M^{*} + d(L)\ln P + e(L)\ln T - f(L)\ \ln E \qquad (20)$$

If we wish to test the hypothesis that taxes are not passed on fully but wanted to keep to the hypothesis that other cost changes were fully passed, then we would need to change the equation. Effectively the coefficients on taxes would not be constrained to be fully passed on, while those on the other two cost variables would be constrained as explained above.

(b) The Link Between Product Prices (Refinery Gate) And Crude Prices The second link in the chain beween crude oil and retail gasoline involves the link from crude oil to refined product prices (at the refinery gate). This has been studied in some detail in Bacon [1] for two major crudes, Arabian Light and Nigerian Light, for the period 1976 to 1983.

To establish the nature and timing of the link from crude oil prices to product prices it is necessary to look more closely at the technology of refining. In refining crude several products are produced, each of which faces a distinct demand and has a separate price. The technology on a given plant is capable of some variation to alter the product mix according to demand conditions, but the most important feature of this market has been the changing technical capabilities of new or renovated refining plant. With a joint product, with fixed coefficients of output, and no substitution of other inputs (fuel, transport, etc.) the sum of the output of a barrel of refined oil valued at market prices less the marginal production costs should be equal to the cost of obtaining the oil (in a competitive market)

i.e.

$$\Sigma\ Z_i P_i - C = O + t \qquad (21)$$

where

P_i is price of refined product i,

Z_i is the amount of product i obtained in refining a barrel of oil,

C is cost of refining an extra barrel,

O is crude oil price f.o.b.,

t is transport cost for a marginal barrel between point of extraction and the refinery.

If we subtract the transport cost (c.i.f./f.o.b. margin) from both sides of (20) we obtain the condition that at the margin the 'netback' will equal the price of crude oil. In practice, as discussed in detail by Bacon, this condition must be generalised to take account of some important features of the oil industry. Nevertheless it contains the essential truth for our purposes of the relationship between crude prices and product prices. Suppose now that crude prices shift because of a change in supply conditions (rather than because of demand conditions). As the price of crude falls, the prices of all products will gradually have to be adjusted. The product prices need not all fall by the same percentage since this will depend in the long run on the elasticity of demand from the different products. However, we can assume that the relation between the crude price and each product price is geared to a long run proportionality and that this 'mark up' does not shift too dramatically for refined gasoline during the period. There will of course be lags in passing on the price changes for the same type of reasons as were mentioned for the lag in passing on product prices to retail prices:

(i) decision and recognition lags;

(ii) costs of adjustment lags;

(iii) lags due to uncertainty;

(iv) lags due to the presence of inventories.

Again the first two reasons are likely to be much less important than the latter two. The inventories of crude oil held by refiners, if operated on a FIFO basis, would give a steady lag in passing on prices; while the uncertainty of future crude prices would give rise to partial adjustment. Since both crude and products are priced in dollars there is no exchange rate uncertainty to deal with (although movements in the exchange rate will be felt through shifts in demand for the retail products). Hence we could write an equation of the form:

$$\ln P = \ln N + \frac{k(L)}{h(L)} \ln O \qquad (22)$$

to represent the lagged response of product prices to crude prices. In the longer run N is unlikely to be constant, as we have pointed out, but it may be sufficiently invariant to allow identification of the lags involved.

So far all the discussion has concentrated on shocks which arise on the supply side and which see the price of crude falling before the prices of products and retail prices. However, it is necessary to mention the difficulties raised by the reverse causality. With shocks arising on the demand side it could be that retail prices have to be adjusted first, that product prices follow and finally crude prices. In the case of a specific market (i.e. UK sales of retail gasoline) the impact of lower local gasoline prices on refined product prices, which are determined in the world market, is likely to be negligible. The second link is more problematic - if product prices fall then this is going to be the result of a very large shift in demand worldwide and the effect on crude prices will be equally large. If we concentrate just on the product price of gasoline the feedback is of course less but the likely simultaneity of all product prices falling together (caused by a world recession) may mean that on occasion gasoline product prices appeared to lead crude price. Without constructing a complete model of the world production/refining interaction it is not possible to be sure that a sharp identification of the lags and leads has been achieved. For the purposes of this study we can merely remind ourself of this difficulty when interpreting the evidence on the nature of the lag between refined product prices and crude oil prices.

2. THE SOURCES AND NATURE OF DATA USED

We need data on five main variables:

(i) retail gasoline prices;

(ii) factory gate product prices;

(iii) crude oil prices;

(iv) exchange rate;

(v) tax rates.

Before describing each variable in turn there are two common dimensions to be considered. The time span of the data and the frequency of observation. Ideally, to understand the dynamics of the 1986 price fall we should study previous falls in the price of crude oil. The previous episodes with substantial falls were the Autumn of 1983 (from around $33 to $28 for spot Arabian Light) and from November 1980 ($41) to July 1981 ($32). Before this there had not been a substantial fall back to 1977. This suggests that if the model could include at least 1980 it would catch the two periods of price falls. Neither of these falls was as dramatic as the fall in 1986 and the only episode of comparable magnitude was the large price <u>rise</u> from late 1979 ($13) to late 1980 ($40). In order to check whether the speed of response was asymmetric with respect to price increases and decreases it is certainly useful to go back at least to 1978.

The frequency of the data ideally needs to be high enough to match the speed of response. If the lags are of the order of one month then clearly quarterly data will completely blur the rise. In practice, monthly data is commonly available and it is hoped that the speed of response is not substantially quicker.

(i) Retail Gasoline Prices

For the UK there are a number of independent sources of information on retail gasoline prices and we briefly describe the differences in coverage between the series.

(a) Digest of UK Energy Statistics

This gives a monthly series for four star gasoline including tax. Using known values for V.A.T. and excise tax this series is converted into an ex tax price in pence/litre. The series is published on a monthly basis only from January 1981 but unpublished data were made available by Department of Energy on a monthly basis from 1977. The data is for prices paid around the 15th of each month and is supplied by oil companies. It is in effect a national average price. As an indicator of broad price trends it is clearly very useful. The data is shown in Figure 1.

(b) International Crude Oil and Product Prices

These prices for premium gasoline are given ex tax and are monthly averages. They are available from the beginning of 1977. The original source of the data is not revealed. It is very striking that this series often shows no variation - for example, the series does

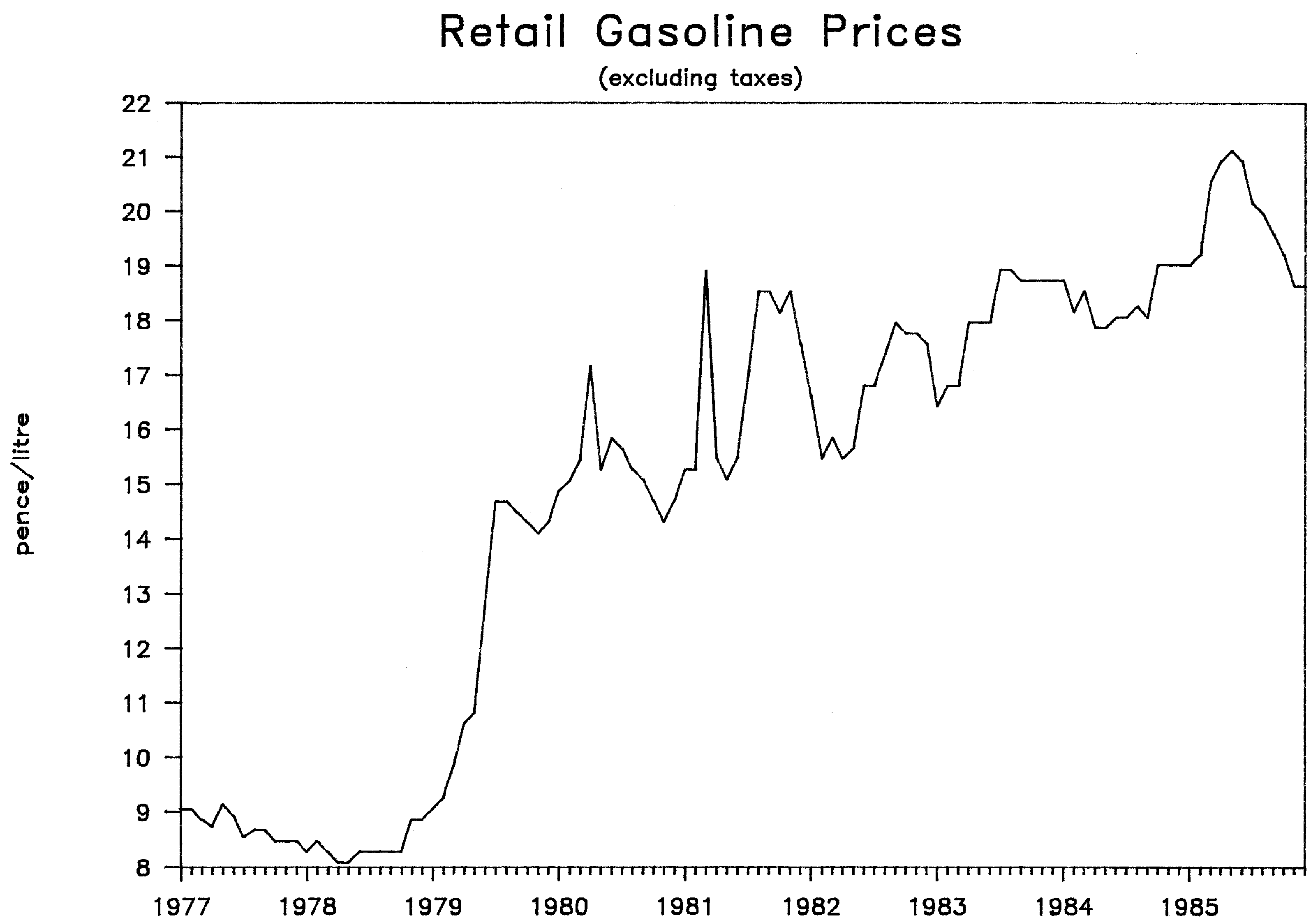

Retail Gasoline Prices
(excluding taxes)
pence/litre
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 1

not change between January 1983 and January 1984. The agreement with the data from Digest of UK Energy Statistics is often poor (almost 16% difference, for example, in early 1983). This leads us to reject the series both because of potential inaccuracies and the inability of relating it to any specific sample coverage.

(c) Petroleum Times

This source of data presents two different types of information. Firstly, on a company by company basis (14 companies) it gives scheduled prices for retailers both including and excluding tax. This information is published fortnightly and is available from the beginning of the period. These prices appear to be more of the status of "official" prices rather than prices charged at the pump on an average basis.

From April 1981 Petroleum Times also publish fortnightly a survey of actual pump prices (including tax) in 20 towns and cities, for four star (and latterly two star) gasoline. This very rich source of data would need to be simplified for the purpose of this study. We would probably have to take the mid-range price. One notable feature of these prices is that after budget changes are announced, the pump prices seem to take a fortnight or a month to react. This means that the ex-tax price in effect falls after a budget but then is restored.

The great advantage of this data is that although it is available on a much shorter period than other series it is on a higher frequency basis and this may be useful for picking up short lags.

(ii) Refined Product Prices

The main source of product prices is Platt's Oilgram Price Report. However, these are collected together in monthly averages in International Crude Oil and Product Prices and we use this secondary source for convenience. The data is for barge cargoes f.o.b. Rotterdam in dollars/tonne and is available from the beginning of 1977 (when our study starts). The series used is for gasoline 98/99 which corresponds to the four star retail price. The data is shown in Figure 2.

(iii) Crude Prices

It is with the choice of data for crude oil prices that we face the biggest conceptual problem. Refiners can choose between different crudes, and in equilibrium should be indifferent between them. The differences in refining properties and in transport costs should be reflected in the differentials for the crudes. However, the market is unlikely to be so perfect, but is instead segmented to a certain extent so that a particular crude price may not be fully reflected in a given product price in a particular market. At the same time the need to analyse a long run of data makes it difficult to use North Sea crudes since little trading in these crudes was done in the early part of the period. The main crude in the late 1970s was probably Arabian Light and there are lengthy monthly series available. However, this crude was purchased at two distinct prices - the official price and the spot market price - and these

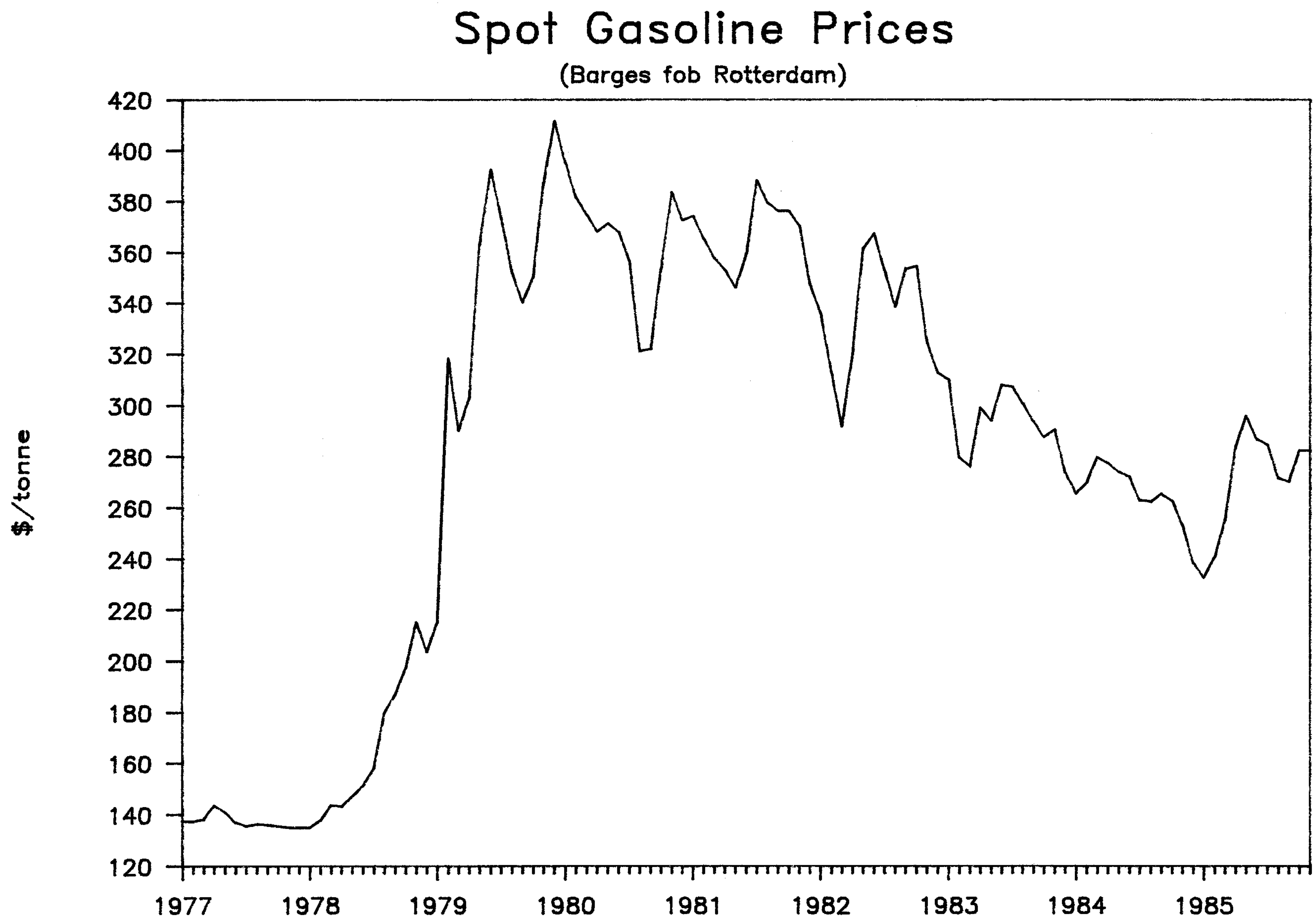

Spot Gasoline Prices
(Barges fob Rotterdam)
$/tonne
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 2

often diverged considerably. Moreover, there is evidence that both prices may have, at certain times, influenced the product prices. When crude was in short supply - i.e. there was some rationing, then the spot price was above the official price, while in terms of plentiful supply the official price was higher. It is also the case that during the first six months of 1979 there is considerable disagreement between sources of data or the values of the monthly averages[1]. Nevertheless despite these complications it is still likely that changes in spot crude prices would be reflected by changes in product prices (even if imperfectly) and that, if there are regular lags in the process these will also show up.

Accordingly, for the initial tests we use the monthly average spot price of Arabian Light which is available from the beginning of 1977 from International Crude Oil and Product Prices. The data is shown in Figure 3.

(iv) The Exchange Rate

Data on the monthly average dollar/sterling rate are taken from International Monetary Statistics and are also available from the beginning of 1977. The data on the exchange rate are shown in Figure 4.

(v) The Tax Rate

Petroleum Times includes in its monthly reports both the excise duty and the rate of VAT charged on gasoline. These give the total amount of tax payable so that a net of tax figure can be calculated. This is then related to the gross of tax price to give a gross to net tax mark-up variable.

[1] **For a fuller discussion of these matters see Bacon [1].**

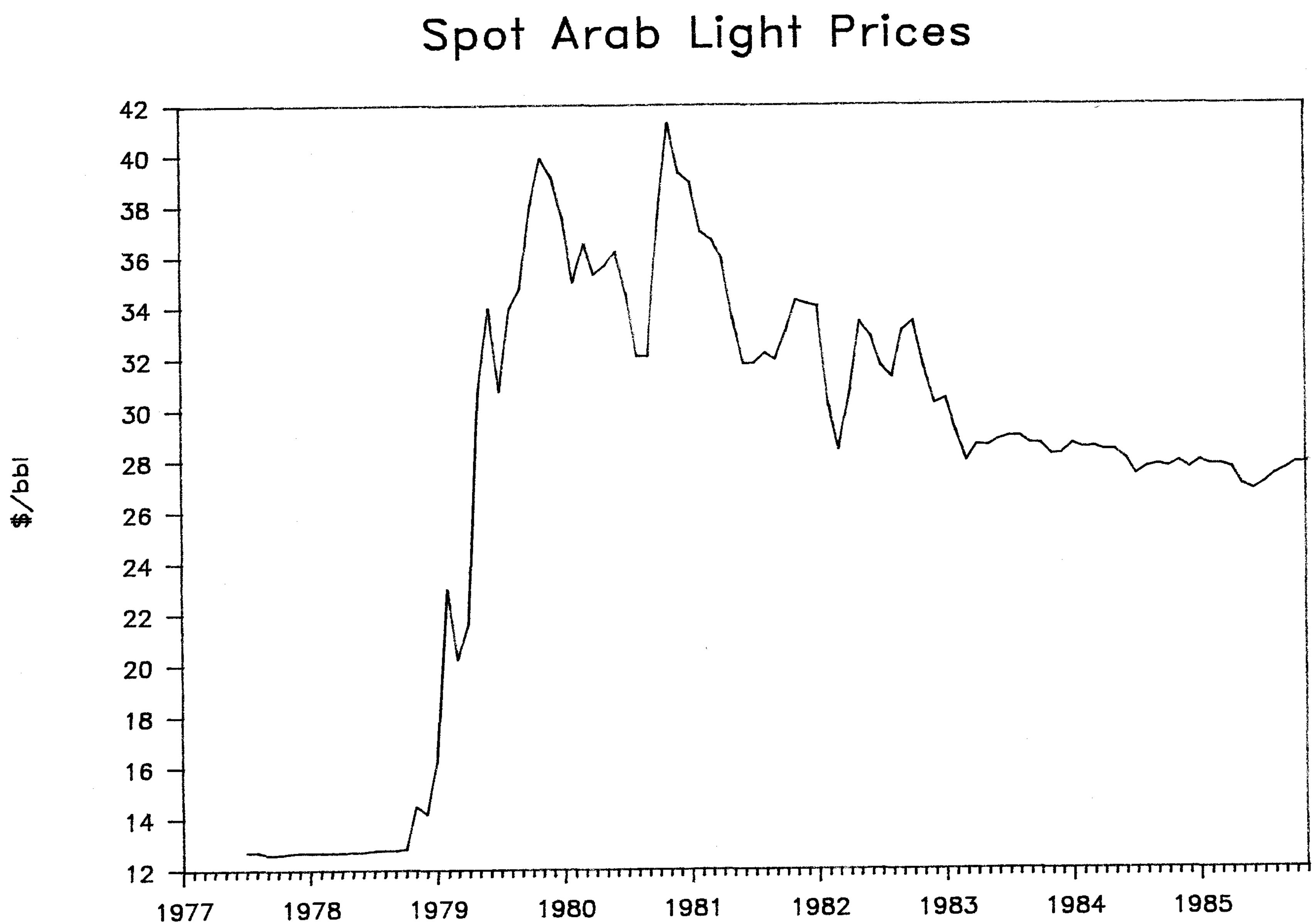

Spot Arab Light Prices
$/bbl
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 3

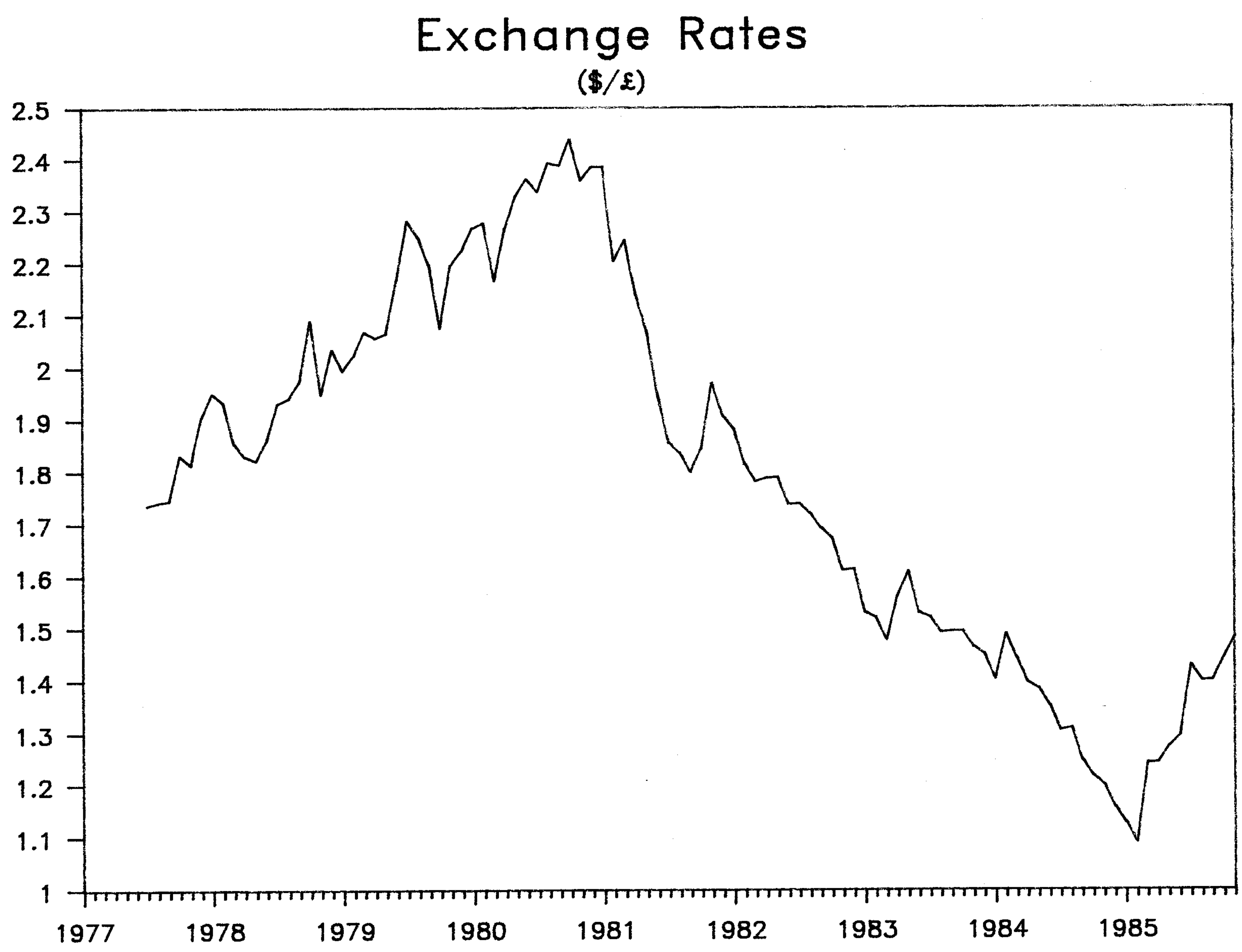

Exchange Rates
($/£)
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 4

Effectively the assumption is that this ratio will be unaffected by the degree of passing-on of taxes practised by the companies. The series is plotted in Figure 5.

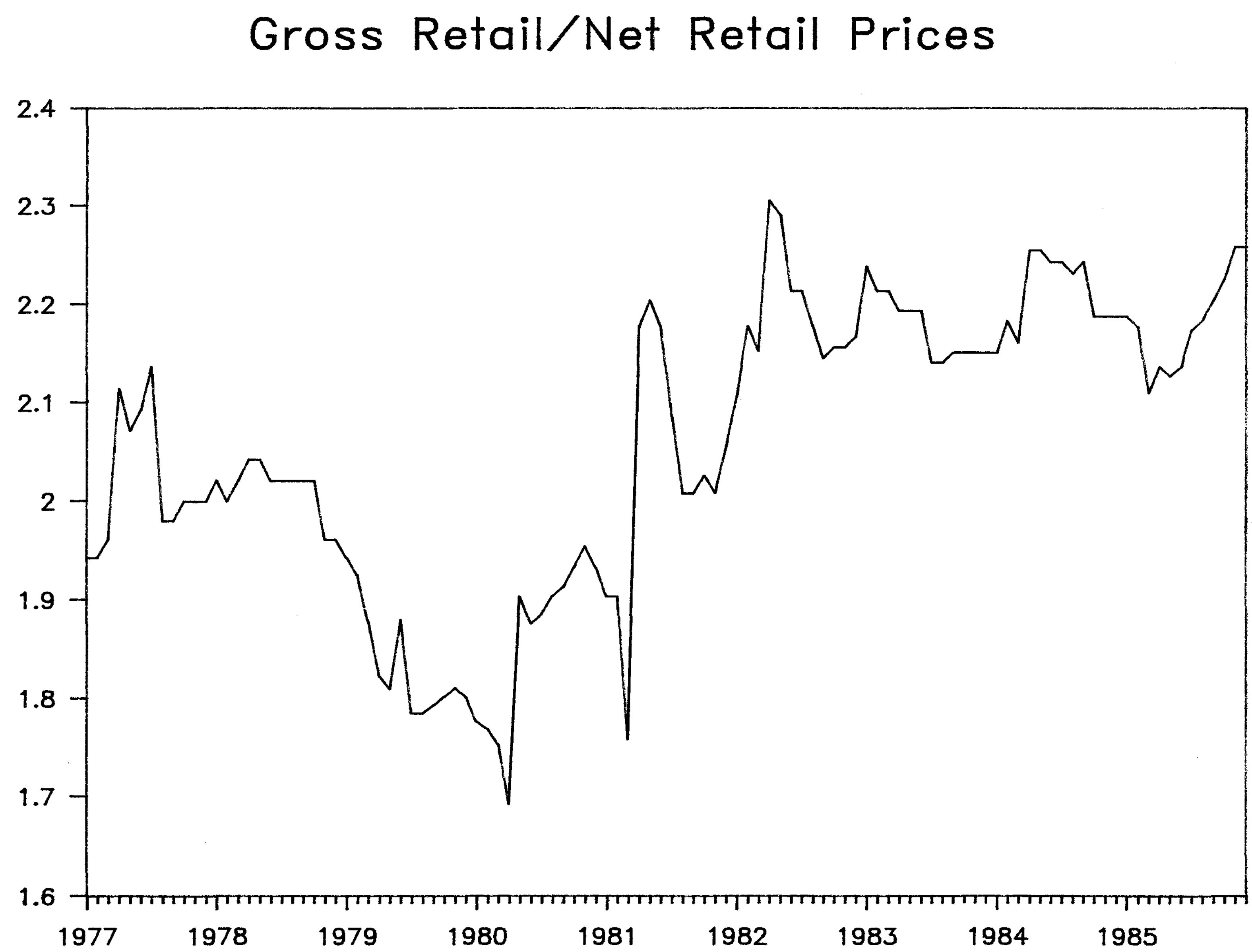

Gross Retail/Net Retail Prices
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 5

3. THE STATISTICAL RELATIONSHIPS BETWEEN CRUDE OIL, REFINED PRODUCT AND RETAIL GASOLINE PRICES

(a) Crude And Product Prices The first aspect of the actual data that we need to focus on are the broad episodes of price rises and decreases.

Starting with the crude price (Figure 1) we see that there was a very sharp rise from the end of 1978 which continued until the end of 1979. Prices then fell back until August 1980, followed by a short rise until November 1980. There was then a decline until August 1981 with some short cyclical movements until the beginning of 1983. Thereafter (until the end of our period in November 1985) there was a very slight decline. The key features are the rise in prices in 1979 and the two episodes of substantial decline in 1980 and 1981. All of these lasted long enough and were large enough to feed through to product prices and to retail prices. The minor cycles in 1982 may also help to identify timing.

The second series is the product price at the refinery expressed in dollars (Figure 2). This series started to rise in Autumn of 1978 and reached a peak in June 1979 - after a slight fall it then rose further to a new peak in December 1979. This was followed by a fall in 1980 with a low in August. After that there was some short cyclical movement until the Autumn of 1982. The price then fell into the Spring of 1983 and was fairly constant thereafter. It is clear that the broad movements in the series match and so we can turn to the formal regression models.

The first model we used was one with a very long lag structure. The lag of the product price was regressed on its own lagged values back to four periods, on a constant and on five lagged values of crude price (without imposing the long run restriction). The results indicated no support for the longer lags and so the structure was progressively simplified by reducing lag lengths one step at a time. In all these regressions it was found that two lags on the product price, the constant, the current crude price and a single lagged crude price were significant, but that nothing else was. The model was re-estimated first including eleven monthly seasonal dummy variables but none of these were significant. Finally, the single long run restriction was imposed (the sum of the coefficient on dependent and independent variables are equal). The results of the unrestricted and restricted equations are shown in Table 1.

TABLE 1: RELATION BETWEEN CRUDE AND PRODUCT PRICES (LAGS)

VARIABLE	UNRESTRICTED		RESTRICTED**
Constant	0.477	(3.47)	0.150
Product (-1)	1.071	(15.80)	1.137
Product (-2)	-0.207	(3.05)	-0.200
Crude	0.748	(11.51)	0.758
Crude (-1)	-0.660	(10.49)	-0.695
RSQ	0.980		
S.E.E.	0.040		0.042
DWS	1.869		1.794
F*(4,87)	1.13		1.45

Note: F* is the value of the test statistic for the hypothesis that there is no serial correlation of up to fourth order in the residuals.

The restricted equation is derived from a different estimating form so that the standard errors are not readily available. The estimated equation is

$$(P - P_{-2}) = \underset{(1.60)}{0.15} + \underset{(17.06)}{1.137}\,(P_{-1} - P_{-2})$$

$$+ \underset{(11.31)}{0.757}\,(C - P_{-2}) - \underset{(10.86)}{0.694}(C_{-1} - P_{-2}) \qquad (23)$$

The restricted equation is fairly close to the unrestricted equation except for the constant (even allowing for the fact that the estimated constant includes the sum of the lagged coefficients which are different in the two cases). However, the test for the single linear restriction involved yields an F value of around 11 while the critical value at 5% of F (1,100) is 3.94. The data does not agree with the restriction, but given the simplicity of the model, the questionability of the data (particularly during the crucial 1979 price rise) and the general congruence of the results there is no reason to prefer the unrestricted model which would imply a long run equation of the form:

$$P = 33.3\ C^{0.647} \qquad (24)$$

while the long run restricted equation is of the form:

$$P = 10.8C \qquad (25)$$

Once we have agreed to accept as a best first approximation the restricted equation we can turn to its dynamic properties. The equation involves two lags in the dependent variable so there is need to check whether the adjustment process is estimated as being dynamically stable. The roots of the dynamic polynomial $(1 - 1.137L + 0.200\ L^2)$ are + 1.613 and + 4.070 so that the process is stable (both roots being larger than unity) and convergence is non-cyclical (both roots being real). Using equation (18) and the values from Table I the mean lag of product prices behind crude prices is estimated as 0.67 months. By equating coefficients of powers of L in the equation:

$$w(L)b(L) = d(L) \qquad (26)$$

we find the first three values of b(i) to be:

$$b(0) = 0.758$$

$$b(1) = 0.167$$

$$b(2) = 0.010$$

Clearly there is very rapid adjustment in the current month and the subsequent month but then the rest of the process is fitted as if it stretched out a very long time. Armed with this interpretation we can look back at the key episodes.

(a) In 1979 the peak crude price was in November and the peak product price in December;

(b) In 1980 the trough crude price was in August and the trough product price was also in August;

(c) In 1980 the peak crude price was in November and the peak product price was also November;

(d) In 1981 the trough crude price was in June but the trough product price was in May (suggesting a demand side shock);

(e) In 1982 there was a trough in crude prices in March and a trough in product prices also in March;

(f) In 1982 the peak crude price was in October and there was also a peak product price in October.

All these episodes confirm that, both on the upswing and the downswing, product prices reacted very quickly to crude prices - with virtually all the adjustment of a short run nature coming within one period. There were longer run adjustments to restore the mark-up spread over a longer period which stretched out the mean adjustment to around a month. We can interpret this as suggesting that facing large shocks the market took a longer time to gradually restore the margin (or that indeed the margin was slowly changing and that this looks like a slow and very slight long run dynamic adjustment) but that the direct reaction to big changes was felt mainly within the current month and the subsequent month. The present large fall in crude prices may produce the same effect - a slow drift in the margin but very rapid adjustment in the immediate period following the shock. Clearly more sophisticated models could be developed to explicitly investigate the non-constancy of the margin.

(b) Gross Retail Prices As before we begin with a sketch of the major shifts in the three cost components of the gross (i.e. including tax) retail price of gasoline. We begin with the product price measured in dollars. As we have already pointed out in the section linking crude oil prices to product prices the dominate features are:

(i) the rise to a peak in June 1979, with a higher peak in December 1979;

(ii) a fall to a low in August 1980 followed by cyclical type movement until Autumn 1982;

(iii) a fall from Autumn 1982 to Spring 1983 followed by near constancy.

The exchange rate ($/£) has a very different course:

(i) There was a peak very early in our data series at the beginning of 1978;

(ii) A fall to May 1978 was followed quickly by a new peak in October 1978;

(iii) The series was steady until May 1979 but then climbed steadily to a new peak in October 1980;

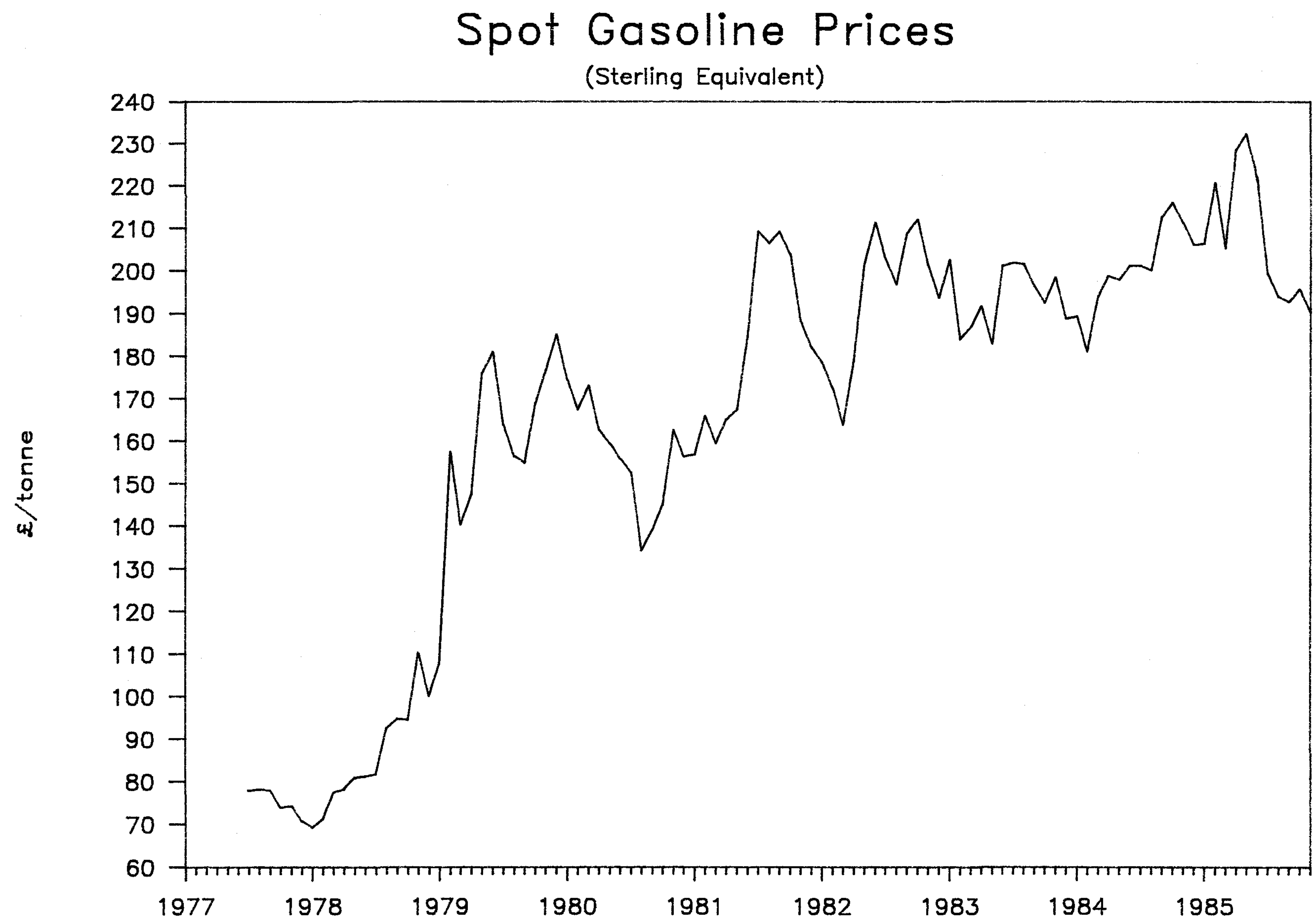
(iv) The rate then fell steadily over a long period until a low was reached in February 1985 since when there has been some recovery.

The feature of this series is that the movement up (from $1.74 at the beginning of the period) to the peak of $2.44 in October 1980 and the subsequent fall to $1.09 in February 1985 are of the same magnitudes as the changes in product prices. At the same time these two series do not peak at the same time so that they impart quite distinct shocks to retail gasoline prices.

A useful way of combining these two series is to obtain the current sterling price of products (Figure 6). This cannot be used in estimation directly as it implies equal speeds of adjustment to product price and exchange rate changes. This series climbs to a peak in June 1979, falls back a little and then reaches a new peak in July 1981. Thereafter behaviour is very cyclical with plenty of shifts up and down (of perhaps 10% in two or three months) until the end of the period.

The tax variable is very steady until October 1978 (a mark up of about 100%) but then rapidly falls to June 1979 (to 63%) because of the lack of indexation of duties. The rate was rapidly increased until it reached a peak in May 1981 (120% mark up) and since then has been cyclical. The biggest jumps have naturally tended to come at budget time or because of passive reaction to exogenous shocks (tax % falls with price rises and rises with price falls).

The first model that we investigate is an unrestricted model of the gross of tax retail price. The gross price is related to its own lagged values (up to three lags) and to the current and lagged values (up to three lags) of the tax variable, product prices and the exchange rate. Most of the longer lags are insignificant so we begin by deleting variables one at a time. At no point are lags greater than one significant, but the current dollar is never significant if combined with a lagged dollar variable. In fact there is very little to choose between models which lag the dollar or leave it unlagged and the same is true for the product price. The lagged gross tax price is always



Spot Gasoline Prices
(Sterling Equivalent)
£/tonne
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
1977
1978
1979
1980
1981
1982
1983
1984
1985

FIGURE 6

highly significant indicating that there certainly is a dynamic response to change in cost conditions. In all of these equations the tax variable is insignificant which suggests at first sight that variations in the tax variable over the period have not been reflected in variations in gross prices. However, this may well be due to the mis-specification of the variable - in effect there is simultaneity because changes in prices (caused say by changes in product prices) are causing the tax paid, as a percentage, to change (because of the temporarily fixed amounts of excise taxes). This clearly calls for better modelling of taxes before we are willing to conclude that taxes were not passed on at all during the period.

Finally we added eleven dummy variables and these were virtually all significant and negative (relative to December) which suggests that there is a clear seasonal jump in gross prices in December.

The tax variable presents a real analytical difficulty because it is both additive and multiplicative so that neither a linear nor a log-linear model can encapsulate it. The tax values are shown in Table 2:

TABLE 2: UK TAXES ON RETAIL GASOLINE

PERIOD	EXCISE TAX (P/LITRE)	PERIOD	VAT (%)
August 1977-June 1979	6.59	April 1976-June 1979	12.5
June 1979-March 1980	8.10	June 1979 -	15.0
March 1980-March 1981	10.00		
March 1981-March 1982	13.82		
March 1982-March 1983	15.54		
March 1983-March 1984	16.30		
March 1984-March 1985	17.16		
May 1985-March 1986	17.94		

The changes within the period are all excise duty changes, with the single exception of VAT shift in 1979. This makes a simple test of passing on possible. If we establish a basic model for the determinants of net of tax prices then this will be only marginally affected by any lack of full passing on of taxes (i.e. prices may be less than expected). However, the dominant changes will be in other costs so that the bias in estimation may not be very large.

This would then allow an estimate of the past budget price pre tax charge to be calculated which can be compared with the actual price charged. Such a procedure may be able to indicate in broad terms the extent to which tax changes have been absorbed or passed on.

We begin with the unrestricted model using lags of up to two periods (remembering that the gross price equation showed no significant lags of length two or three periods). This showed no significant effects for any of the lags of length 2 so that in turn each was deleted from the equation.

This produced an equation where the current values of the product price and the dollar were also insignificant (as they had been in the larger model) while the single lagged values were significant. Accordingly, these current variables were also deleted. The resulting equation with single lags on all variables and no current effects produced a highly significant equation with all variables significant and of the expected sign. The December dummy variable was not significant when tried for this equation so that it appears that any seasonality present in the gross retail price comes from variations in the margin. The results of the unrestricted equation are shown in Table 3.

TABLE 3: NET OF TAX RETAIL PRICES RELATED TO PRODUCT PRICES AND THE EXCHANGE RATE

VARIABLE	UNRESTRICTED	RESTRICTED
Constant	-0.172 (6.24)	-0.170
Retail (-1)	0.775 (27.21)	0.927
Product (-1)	0.078 (7.84)	0.073
E. Rate (-1)	-0.077 (6.46)	-0.073
RSQ	0.991	-
S.E.E.	0.011	0.012
D.W.S.	1.89	1.78
F* (4,91)	0.75	0.86

Note: F* is the value of the test statistic for the hypothesis that there is no serial correlation of up to fourth order in the residuals.

The restricted form of the equation is:

$$R = \underset{(7.27)}{-0.170} + \underset{(7.41)}{0.073}\ (P_{-1}-E_{-1}-R_{-1} \qquad (27)$$

The restricted form is very close to the unrestricted form with the exception of the lagged retail price.

The F test for the restriction is 9.2 which is clearly significant. The data does not support the restricted form, but as before we view the general agreement as good and the restricted long run form as preferable. The unrestricted long run equation is:

$$R = 0.465 \quad P^{0.347} \; E^{-0.342} \tag{28}$$

while the long run restricted equation is:

$$R = 0.097 \; (P/E) \tag{29}$$

In these models the constant cannot be directly interpreted as a mark up since R is in pence per litre and (P/E) in £ per tonne. The coefficients of the restricted equation shows that it is dynamically stark. The adjustment is however much slower than for the mark up from crude to product prices. It is noticeable that even in the unrestricted form the speed of adjustment to exchange rate shocks and to product price changes is almost identical. If there is a one unit change in product prices the coefficients of response (solving for coefficients as in the previous case) are very spread out:

$$b_o = 0$$

$$b_1 = 0.073$$

$$b_2 = 0.067$$

etc.

The mean adjustment is 13.7 months. As formulated this model implies very slow but stable adjustment to changes in exchange rates or product prices (with no reaction at all in the current month). In the light of these results we should question the performance of the estimating equation closely in order to see whether there is any evidence of serious mis-specification. Errors such as omitting variables, mis-measuring variables or mis-specifying the lag structure will tend to put into the error term an economic component that is very likely to be serially correlated.

The use of the Portmanteau statistic in F form to test for serial correlation of up to fourth order allows for the presence of the lagged dependent variable and is not biased against finding serial correlation when it is present (as is the case with the Durbin-Watson test). Given the large number of degress of freedom (93) the power of the test is likely to be good and the result was to accept the Null Hypothesis of no serial correlation. None of the estimated autocorrelation coefficients is greater than 0.1 so that there is no evidence from this source of a systematic specification error. This long lag is partially confirmed by the unrestricted equation which shows a mean lag length of 4.5 months. **Clearly the data is showing us that for some reason or another changes in costs are not passed on rapidly into changes in retail prices.** Importantly the equation appears to fit very well throughout the period. The worst fit is in February 1982 when the residual is over three times the standard error, but a single residual of this size in a data set of around one hundred observations is not exceptional.

To summarise the position we can say that variations in net-of -tax prices are almost entirely explained by changes in product prices (refinery gate), and in the exchange rate, but that the adjustment to these changes has been slow both when facing cost increases and cost decreases. This implies that at any moment in time the actual margin earned (as opposed to the long run value of the margin) has fluctuated - being squeezed when costs increased and widened when costs decreased.

We can now consider what evidence is available on the passing on of tax changes. If companies fully absorbed tax changes we would expect to see the margin on net-of-tax prices drop when the tax rate was increased. This would imply that the fitted equation would have over-predicted very noticeably at the various budget shifts (which were in March each year) and on the change in VAT in June 1979. The actual residuals are shown (measured in units of the standard error of estimate - the average residual) in Table 4:

TABLE 4: STANDARDISED RESIDUALS IN TAX CHANGE MONTHS

MARCH 1978	+0.96
MARCH 1979	-1.38
JUNE 1979	-0.75
MARCH 1980	-0.99
MARCH 1981	-0.35
MARCH 1982	-0.30
MARCH 1983	0.78
MARCH 1984	0.61
MARCH 1985	0.95

There is clearly no evidence of persistent or significant over-prediction (negative values). A check for April in each year (to allow for years in which the budget was late in March) also shows no evidence of over-prediction. This indirect test suggests that tax changes have been fully passed on and not absorbed into the net of tax price.

4. CONCLUSION

The paper has looked at the speed at which changes in crude oil prices have been passed on into refined gasoline prices (at the refinery gate) and the speed at which changes in these refined prices and exchange rates have been passed on into net-of-tax retail gasoline prices for the period 1977 to 1985.

Although there are certain problems with identifying the ideal set of data for the analysis it was felt that the monthly data outlined in Section 2 of the paper should be adequate to identify any broad trends and empirical regularities in the relationships.

The first step in the chain is the link from crude prices to product prices (refinery gate), both expressed in dollar terms. Here we found that the lag was extremely short (with a mean value of just over half a month) so that virtually all the cost change had been passed on within the current month and subsequent month (with the bulk of this falling in the current month). Although the data did not support a constant margin model the deviation between the restricted (constant long-run margin) and the unrestricted (variable long-run margin) was small. Both equations fitted the data very closely (which is important given the extreme variability of the series over the period) and picked up the major turning points. There was no evidence of systematic mis-specification from the serial correlation test.

The picture, when we turned to the link between net-of-tax retail prices, product prices and the exchange rate, is very different. Here the adjustment is very much slower both to cost increases and decreases. The speed of reaction to product price changes and to exchange rate changes appears to be the same (even in an unrestricted model). There was no evidence that lags of different lengths were involved for these two variables. The equation was a very close fit to the data and showed no evidence of mis-specification. Even in the unrestricted form the mean lag of net-of-tax retail prices to cost changes was over four months. Finally, we noted that this relationship supported the view that tax changes had generally been fully passed on.

The implications of this study of the past nine years for the present situation can be easily seen. We would predict that the fall in crude prices would have been largely seen in lower product prices (refinery gate) within a month of the fall. The "knock on" effect on (net-of-tax) retail prices will then depend on the associated movement of the $/£ exchange rate. The appreciation of the £ against the dollar that has occurred since the start of the fall in crude prices will have added to the general decline in costs. However, the effects of this change on net-of-tax prices will be very slow. The reason for the long lags involved cannot be ascribed solely to the inventory position coupled with FIFO pricing. The lag is almost certainly longer than the ratio of inventory to sales. Since we have argued that the reasons for the lags will not be additive, it is necessary to look elsewhere for an explanation. Clearly, if the majority of companies have very slowly adjusting expectations then they would respond cautiously to both cost increases or cost decreases.

A quicker response to cost decreases may be forced by vigorous competition by other retailers. The willingness of some companies to "take a chance" on price cutting plus the flexibility of motorists in shopping around for the best buy are the key factors in putting downward pressure on prices. It is here that we see a central issue for a concentrated industry. If costs rise no one firm may be anxious to push up its prices for fear of losing market share if it has miscalculated (i.e. the cost changes are not permanent), while if costs fall a cut in prices may gain market share at least temporarily. This argument applies to all firms, and if true, we would expect quicker reaction to cost falls than to cost rises. The historical data used in this study does not show an asymmetrical response to cost increases and cost decreases. On the face of it, this would suggest conventional oligopolistic behaviour (i.e. sticky prices in all situations). But the data may not be sufficiently varied to show this asymmetrical effect. Until 1986 the cost falls have been very much smaller (and usually shorter in duration) than the very large rise in crude oil prices in 1979. It may turn out therefore that the downward adjustment of retail gasoline prices, though fairly slow, is nevertheless more rapid than would be suggested by the evidence available over the last decade.

Reference

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