OXFORD INSTITUTE FOR ENERGY STUDIES

Rockets & Feathers: The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes

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1 INTRODUCTION

The determination of retail gasoline prices in the UK has long been the subject of debate. There have been three inquiries by the Monopolies and Mergers Commission (MMC), leading to the publication of the reports MMC (1965), (1979) and (1990), in which the industry was examined for evidence of non-competitive pricing and collusive behaviour. In the most recent inquiry a major point of concern was the suggestion that companies used their market power to set prices unjustifiably high relative to costs. In particular, it was suggested that when faced with cost increases companies rapidly adjusted prices upwards, but when faced with cost decreases they adjusted prices downwards more slowly, thus permitting a temporary level of high profits. This hypothesis was examined informally by the MMC, which found no evidence that the average delays of adjusting to cost increases and cost decreases were different. It also argued that in the cost increase case there was an initial delay followed by a rapid adjustment, while in the cost decrease case downward price adjustment started sooner but in a series of smaller steps. This asymmetrical pattern of adjustment, termed "rockets and feathers", was not established through econometric work but with the help of descriptive and graphical analysis of weekly company data for the period 1987-9 (MMC (1990) paras. 4.69-4.79).

Parties giving evidence to the MMC (e.g. the UK Department of Energy) were unable to find a way of testing rigorously the hypothesis of asymmetric speeds of adjustment (ibid., para. 4.18). Thus, although the report concluded that there was evidence of asymmetric patterns of adjustment it also concluded that the average lags of prices to cost increases and cost decreases were similar so that there was no evidence that the monopolistic structure of the supply of retail gasoline in the UK was leading to even temporary excess profits.

The purpose of this paper is to develop a methodology suitable for testing whether the adjustment paths to cost increases and decreases are different and for estimating both the mean lag of the price response and a measure of degree of gradualness or suddenness of the price response once started. The methodology is applied to the UK retail gasoline market for a period from 1982 to 1989 using fortnightly data. Section 2 develops a cost-plus model of pricing for retail gasoline identifying the principal costs and the sources of data to be used in the study. Section 3 develops a model of asymmetric adjustment to cost increases and decreases and discusses the properties of such models. In Section 4 the model developed in Section 3 is applied to the data described in Section 2, and the hypotheses described above are investigated. Section 5 presents the conclusions of the paper.

2 COSTS AND THE PRICING OF RETAIL GASOLINE

Retail gasoline in the UK is strongly affected by local competition but the MMC found little evidence that non-price factors were important in causing motorists to shop around. Hence we can assume that gasoline is a single good and that retailers do not attempt to react to cost changes by lowering the quality of non-price factors, but instead make any necessary adjustments via the price of gasoline itself.

Given this approach to pricing there is no short-run substitutability between the various inputs and hence it is reasonable to assume that the cost structure is additive. The principal cost of retail gasoline (net of tax and duty) is the refined gasoline itself - for example the MMC found that in 1988 the average net of tax sale price was 12.73 pence/litre of which the refined product cost 7.35 pence/litre (MMC (1990), Table 5.41). Other costs accounted for 4.37 pence/litre - these included costs of marketing and distribution and of operating the retail outlet. The various cost elements are considered in turn.

(*a*) Raw Material Costs. Much popular comment on the behaviour of retail gasoline prices draws attention to the movements in the price of crude oil. However, the link between these two sets of prices cannot be expected to be constant. Crude oil, when refined, produces several products (gasoline, diesel, heavy fuel oil, etc.). Now, even if all the markets are very competitive, so that the average of the prices for these products follows the crude oil price very closely (see Bacon (1984) and Bacon et al (1990) for evidence on this), the refinery price of gasoline will not necessarily follow the crude oil price movement. If the relative demand for (say) heavy fuel oil fell for exogenous reasons (as happened during the 1980s) then its price would drop relative to the average of product prices (and the prices of other products would rise relative to the average). Hence the gasoline price can rise relative to the crude oil just because of relative demand shifts. This effect is brought about by the relatively low degree of substitution between products for a given refining system. Accordingly it is not useful to relate the retail price of gasoline to the crude oil price. It is worth noting, however, that studies which have related the <u>average</u> price of products to the crude price have found the lag in passing on cost changes to be short (e.g. Bacon (1986)).

The relevant input cost for retail gasoline is the price of gasoline as sold by refineries. In Europe a substantial amount of retail sales is controlled by companies that are vertically integrated to the refining stage so that the input is not directly purchased. However, since a considerable amount is purchased from refineries, these open-market prices act as transfer prices (and opportunity costs) for all retailing. The major market for petroleum products in northern Europe is at Rotterdam and there is plenty of data available on ex-refinery gasoline prices in Rotterdam. These prices are quoted in dollars which means that companies in the UK must also look at exchange rates.

The studies by Bacon (1984) and by the UK Department of Energy cited in MMC (1990) para. 4.18 use monthly data on prices as published in the *Digest of UK Energy Statistics*. The use of monthly data presents a problem for studying an adjustment mechanism where some of the adjustment may be felt within a month. Evidence cited by Maddala (1977) shows that, if the data sampling interval is longer than the adjustment lag, the estimates of the speed of adjustment can be severely biased. Accordingly data with a shorter unit of time between successive observations are used here. The best such published data are the fortnightly figures reported in *Petroleum Times*. These are Rotterdam f.o.b. prices for gasoline (in barge lots) quoted in dollars per tonne. Data were available from this source from early 1981 to the end of 1989 and are shown in Figure 1. A conversion factor was used to change this series into dollars per litre.

Since any firm actually purchasing on the Rotterdam market (or using it as a marker for a transfer price) must pay in dollars, the sterling/dollar exchange rate is also important. *Petroleum Times* also published this for the same day for which the ex-refinery product price is given (or for within one day of it). This series is shown in Figure 2.

(b) Retail Price of Gasoline *Petroleum Times* appears to be the only published source of fortnightly data on actual retail prices charged. Figures are given from a survey for various cities in

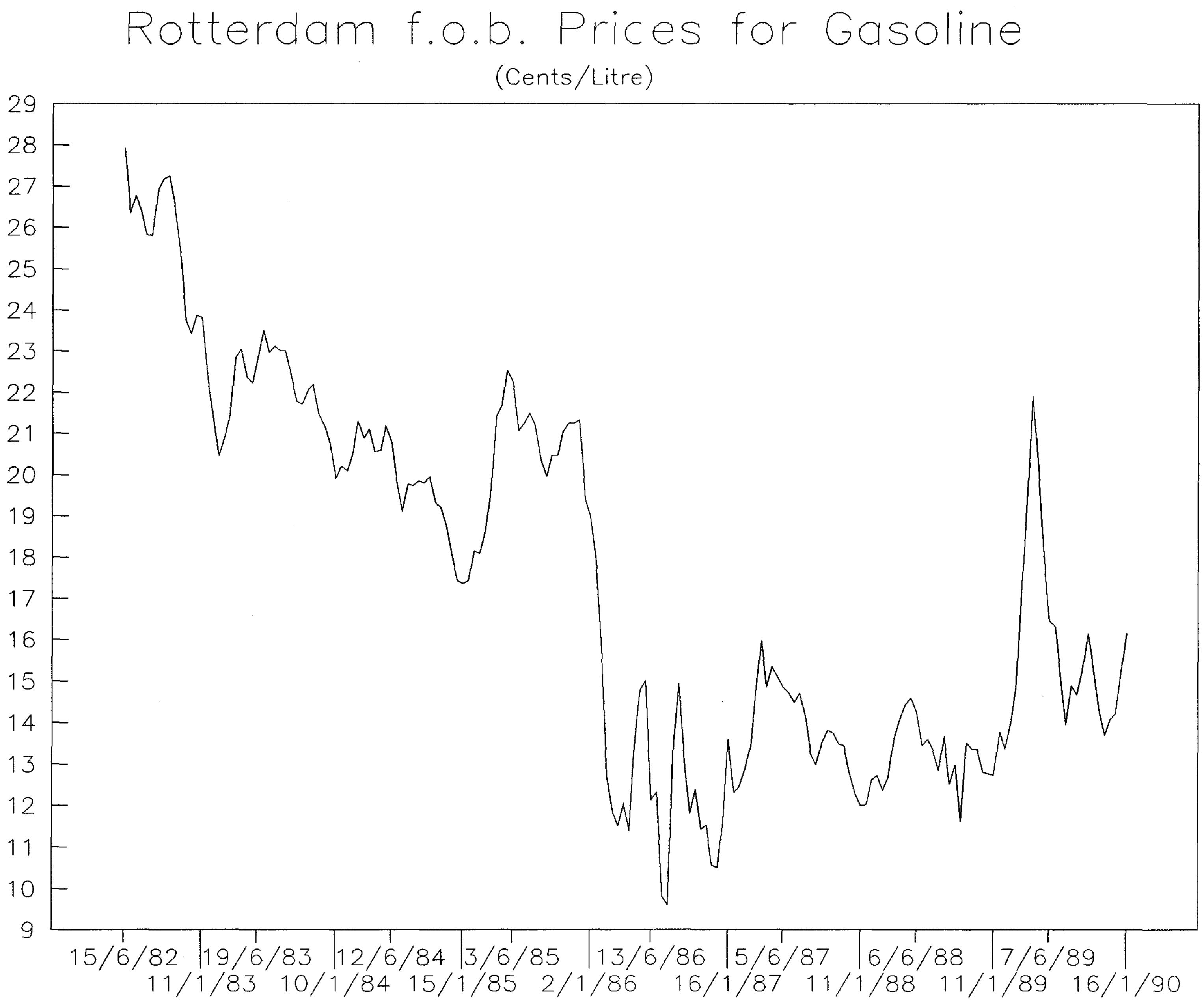
Rotterdam f.o.b. Prices for Gasoline
(Cents/Litre)
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
15/6/82
11/1/83
19/6/83
10/1/84
12/6/84
15/1/85
3/6/85
2/1/86
13/6/86
16/1/87
5/6/87
11/1/88
6/6/88
11/1/89
7/6/89
16/1/90

FIGURE 1

Sterling/Dollar Exchange Rate

(1982–9)

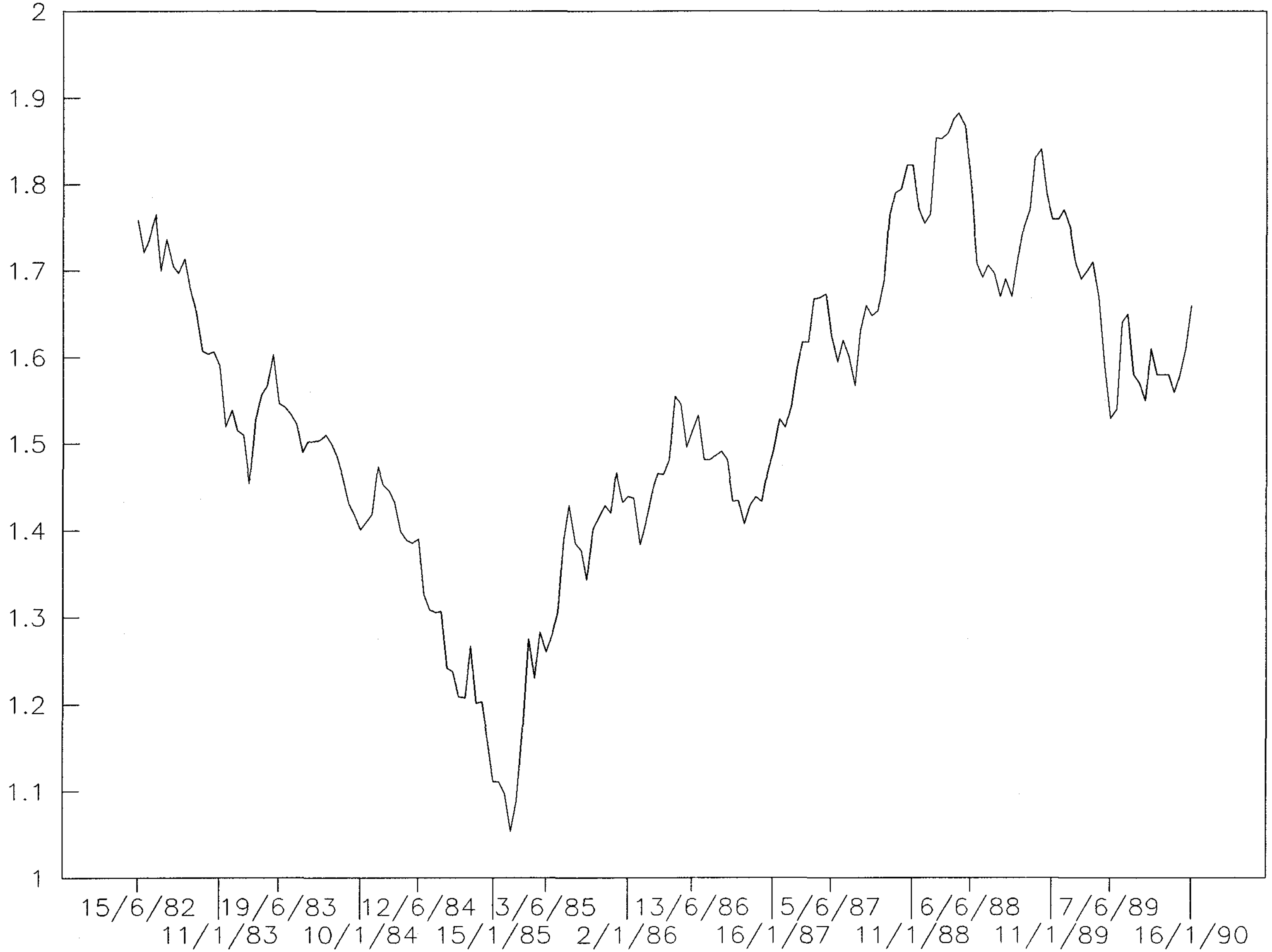

FIGURE 2

the UK. There is some variability between cities (and some variation in the coverage) so this study takes the figure for London as representing an important part of the market. The dating of the series is again within one day of the ex-refinery product price and exchange rate.

Although this series has also been published since early 1981, some of the early surveys appear unsatisfactory. In March 1982, for example, every city is quoted as sharing exactly the same price even though at every other point in the survey there are substantial differences between cities. Accordingly the sample we use for statistical testing runs from 15 June 1982 to 19 January 1990. These prices are gross of tax and duty. Early figures are given in pence/gallon and were converted to pence/litre.

(c) Other Costs. Although there are other costs involved in the transport of the product to the final point of sale and in the operating costs of retailing, no detailed data are available.

Table 1: Total Non-Product Costs of Retailing for Five Major Companies. (Pence per Litre)

1983	1984	1985	1986	1987	1988
3.85	4.03	4.07	4.14	4.18	4.37

Source: Author's calculations from MMC (1990), Table 5.41.

The annual figures for the five major oil companies quoted in MMC (1990) are presented in Table 1, and suggest that there is an underlying trend increase in the other costs of retail gasoline.

(d) Taxes and Duty. Gasoline in the UK attracts both value added tax (which has been at 15 per cent of the price-plus-duty throughout the period studied), and excise duty which has been altered annually in the Budget. Using these values a net-of-tax retail price series is constructed by deflating the gross series by 100/115 and subtracting excise duty. This series is shown in Figure 3.

Given the above data on costs we can consider a long-run (full-adjustment) model for retail gasoline prices net of taxes (assuming that no tax changes are absorbed by the retailer):

$$N = A + Bt + (P/E) \tag{1}$$

where:

N is net retail price in pence/litre;

t is a time trend;

P is the product price in US cents/litre;

E is the exchange rate in dollars/pound (cents/pence).

The additive structure reflects our assumptions about the nature of the product. The time trend reflects the average rise in other costs over the period and the constant reflects the level of such costs at the beginning of the period.

UK Net-of-Tax Retail Gasoline Price

(Pence/Litre)

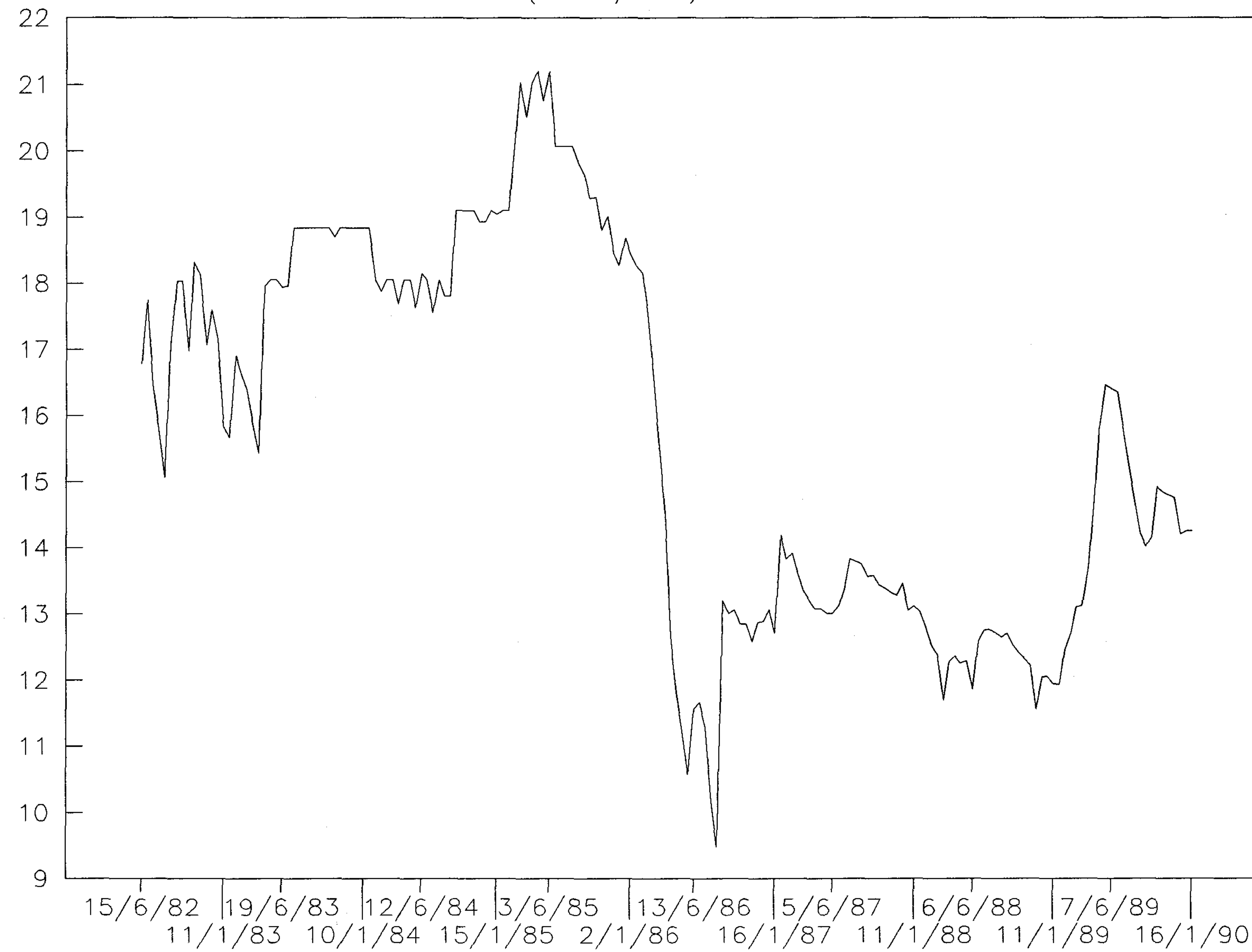

FIGURE 3

The coefficient on the sterling product price (P/E) is set to unity to reflect complete passing on of costs in the long run. This last is a testable assumption and rejection would be taken to suggest model inadequacy.

The key issue for this study is the short-run dynamics of the model. The static model is likely to be inadequate for two reasons:

(a) There are lags between the costs changing and the retailers experiencing these because of transport time and the presence of inventories;

(b) The firms, once experiencing the changed costs, may decide not to react fully immediately. Instead they may choose some partial adjustment policy. This could involve further delays in changing prices and/or a gradual series of price rises to the new equilibrium level.

Thus any econometric model seeking to establish the links between cost changes and price changes must introduce lags. Furthermore there is no reason why the time-path of adjustment to refined product prices should be the same as that to exchange rate changes. If the latter is seen as more volatile and less predictable it may be that retailers are slower to adjust to the exchange rate. The "rockets and feathers" hypothesis goes further and suggests that the time-path of upward price adjustment is different from that of downward price adjustment so that the lag structure modelled must be able to encompass such a possibility as well as the case where the mean speed of adjustment is different in the two cases.

3 THE MODELLING OF ASYMMETRIC PARTIAL ADJUSTMENT

The conventional model of partial adjustment defines a "target" or "equilibrium" level for the choice variable ($Y^T{}_t$ at time t, which is a function of certain exogenous variables X). The actual level of Y is determined by an equation of the form (2):

$$Y_t = Y_{t-1} + (1 - \phi)(Y^T{}_t - Y_{t-1}) \qquad (2)$$

where ϕ is the speed-of-adjustment parameter. For $\phi = 0$ there is instantaneous adjustment to the new equilibrium value, while as ϕ approaches unity the adjustment takes infinitely long. If the system is in equilibrium at Y^T and a new equilibrium level YT + Γ comes about, then in the first period after the change a fraction $(1 - \phi)$ of the total change occurs, the second period sees another fraction $(1 - \phi)\phi$ occur, etc. These fractions can be denoted W(t). By definition:

$$\sum_{t=1}^{\infty} W(t) = 1 \qquad (3)$$

The mean lag (conventionally defined only if all W(t) are positive) is:

$$M = \sum_{t=1}^{\infty} tW(t) \qquad (4)$$

which for model (2) gives

$$M = \frac{1}{1 - \phi} \tag{5}$$

A measure of how concentrated the lag response is about the mean lag is given by the standard deviation of the lag distribution:

$$S = \{\sum_{t=1}^{\infty} (t-M)^2 W(t)\}^{½} \tag{6}$$

The model of partial adjustment is non-linear with respect to time, i.e. the amounts adjusted in successive periods have a non-linear relation to time (a geometric decline) but they are linear at any moment in time with respect to the size of the initial disturbance Γ. If we double Γ the adjustments in each period are twice as large, and if Γ is negative instead of positive the adjustment is equal in the downwards direction to its positive value when Γ is positive.

The essence of the "rockets and feathers" hypothesis is that the adjustment process is non-linear with respect to the initial shock so that equal positive and negative shocks produce different positive and negative adjustments in some (or all) periods. There are at least two approaches to modelling this. The first is to split the sample into two, one of which contains observations where positive adjustments are being made and the other of which contains observations in which negative adjustments are being made. The two samples can be used to provide separate estimates of the upwards and downwards adjustment paths. This "switching-regimes" approach is difficult to use because it relies on a correct identification of when prices should be rising or falling. Merely looking at current or even lagged cost movements is not enough because a very large cost fall (say) could require price falls for several periods even though costs rose by small amounts thereafter hence modifying but not cancelling out the need for the current price fall. Only with a knowledge of the lag structure, which is exactly what has to be estimated, can the correct switching points be identified.

The second approach, and the one pursued in this paper, is to introduce an adjustment function which is potentially non-linear in quantities so that it encompasses the possibility of different adjustments to cost increases and decreases. A particularly simple model is the quadratic quantity adjustment model:

$$Y_t = Y_{t-1} + \alpha(Y^T - Y_{t-1})^2 + \beta(Y^T - Y_{t-1}) \tag{7}$$

This has the desirable feature that it encompasses the standard linear quantity adjustment model so that testing the hypothesis that α is zero compares the two models.

Given the various possible values for α and β, a wide range of patterns of adjustment are possible. The case where both α and β are positive is the case where adjustment to increases in costs is more rapid early on than adjustment to decreases in costs (the quadratic term is positive in both cases while the linear term changes sign); while the case where α is positive and β is negative gives faster adjustment downwards. Certain parameter values are also unstable (e.g. too large a positive quadratic term relative to a positive linear term will set off explosive adjustment upwards when costs fall).

The behaviour of (7) is that of a non-linear first-order difference equation and is described, for example, in Samuelson (1966). The mean lag for such a system depends on the size of the initial disturbance (unlike the linear adjustment model) and is most easily calculated for a particular α, β and size of disturbance by numerical methods. Calculations of the mean lag and the standard deviation of the lag are shown for a range of parameter values in the appendix.

4 EMPIRICAL RESULTS

As discussed in Section 2 we have fortnightly data on retail prices net of tax, exchange rates and ex-refinery petroleum product prices for the period from 15 June 1982 to 19 January 1990. In addition we have a time trend (taking the value 1 on 15 June 1982). The actual behaviour of net-of-tax retail prices is shown in Figure 3. There is considerable variation with prices rising from 16.8 pence/litre for 15 June 1982 to a peak of 18.7 pence/litre for 1 November 1983. This was followed by a plateau and by a further rise to a new peak of 21.2 pence/litre for 1 May 1985. After this there was an extremely rapid fall to a low value of 9.5 pence/litre for 16 August 1986, with a rapid recovery to 14.2 pence/litre for 2 February 1987. Then a static period emerged until prices suddenly rose to 16.5 pence/litre for 2 February 1989, which was followed by a steady decline to 14.2 pence/litre at the end of the period. The mean price was 15.8 pence/litre with a standard deviation of 2.9 pence/litre. The series is obviously not trend dominated and contains a good deal of short- and medium- term variability.

The model consists of two parts. First there is the target price defined in terms of current or lagged costs, etc. (as in equation 1 above), and secondly, there is a quadratic adjustment function to this target price. If we do not initially impose the restriction that all cost increases are fully passed on we can write the combined model as:

$$N(t) = N(t-1) + \alpha\{A + Bt + P^{\mu}(t-s)/E^{\delta}(t-v) - N(t-1)\}^2$$
$$+ \beta\{A + Bt + P^{\mu}(t-s)/E^{\delta}(t-v) - N(t-1)\} \qquad (8)$$

where v and s are lags to be determined. Under the hypothesis of complete passing on we would expect $\mu = \delta = 1$; while under the hypothesis of symmetric adjustment we would expect $\alpha = 0$.

Considerable experimentation with values of s and v was undertaken, including models where more than one lag on each variable were included. The preferred results were for the case where the lag on the product prices variable was one fortnight and the lag on the exchange rate variable was two fortnights.

The resulting equation performed well overall but the residual for the fortnight to 6 September 1986 was 3.4 times the standard error of the regression (moreover the coefficient on δ of 1.11 was significantly greater than unity). This observation is in fact the one corresponding to a rise in the product price from 9.5 pence/litre to 13.2 pence/litre. With such a phenomenal speed of increase (unmatched at any other time in the sample) the use of a price quoted for a day (as in our sample) can be misleading. By 6 September it must have been clear that the abnormally low product price of the period before was not going to hold and so the net price was not kept down. The model attributes some of this to the exchange rate but is still unsatisfactory. We decided to treat this as an outlier and omitted the observations for 6 and 18 September.

Two equations were then estimated - first an unrestricted equation and secondly a restricted equation imposing full passing on ($\mu = \delta = 1$) using non-linear least squares. The results are shown in Table 2. The two equations fit extremely well and the results are very close to each other. Testing that the two restrictions are consistent with the data we calculated the value of a likelihood ratio test statistic ($-2 \log \lambda$) which is 1.016.

Table 2: Estimates of Pricing Equation.

	Unrestricted	Restricted
α	0.0266 (2.09)	0.0265 (2.07)
β	0.277 (7.88)	0.281 (8.84)
A	1.899 (1.69)	2.510 (9.89)
B	0.0174 (4.12)	0.0150 (6.49)
μ	1.016 (53.4)	1
δ	1.032 (11.3)	1
Log Likelihood	-120.076	-120.584
Number of Observations	180	180
SEE	0.480	0.478
R^2	0.973	0.973
DWS	1.63	1.62

Note: Figures in brackets are "t" ratios based on estimated asymptotic standard errors.

The critical value of chi square with 2 degrees of freedom is 5.991 (using a 5 per cent test) so that we accept the null hypothesis of full long-run passing on of costs, and use the restricted equation for the rest of the analysis.

The hypothesis of asymmetric adjustment requires a test that the value of α is zero. Using an asymptotic t-statistic we can see that the model rejects the null hypothesis of symmetric adjustment to cost increases and decreases. Moreover since α and β are both positive this implies that adjustments to cost increases are more rapid than adjustments to cost decreases - there is indeed a "rockets and feathers" process in the pricing of UK gasoline. More insight into the characteristics of the adjustment process can be gained by calculating the mean lag and standard deviation of the lag for the estimated values of the quadratic adjustment process. This is done by the method described in the appendix. Since the adjustment path depends on the size of the initial shock we take the initial equilibrium price to be 15 pence/litre (net-of-tax) and consider shocks producing increases and decreases of 1 and 2 pence/litre. The results are given in Table 3. These show that the mean lag is shorter for cost rises and that the difference in the mean lag, between the cases of equal cost increases and decreases, becomes greater as the size of the total adjustment required increases. The standard deviation of the lag distribution, which is a measure of the concentration of adjustment around the mean lag, is smaller for cost rises than for cost falls. This supports the "rockets and feathers" idea that for cost rises firms react sooner and with a more concentrated increase, while for cost falls

Table 3: Mean and Standard Deviation of Lag Distribution for the Restricted Model.

Change	+1	-1	+2	-2
Mean	4.38	4.77	4.21	5.01
Standard Deviation	2.92	3.12	2.84	3.24

the process takes longer on average and is more spread out around this average. The difference between the standard deviations for equivalent cost increases and decreases also increases as the size of the adjustment required increases.

It should be noted that the mean lags are calculated for a target price related to costs one period before - which is the lag identified for the product price. For the exchange rate, which has an initial lag of two periods before any adjustment begins, the mean lags must be increased by one unit (whatever the parameter values or size of adjustment).

To summarize the results we have found that:

(a) Changes in product prices and exchange rates are fully passed on into retail prices in the long run;

(b) There is a significant degree of asymmetry in the adjustment of prices to increases and decreases in costs;

(c) For cost changes of the order of 1 pence/litre the mean lag of the price rise is 4.38 time-periods (about two months) for a rise in product prices and 4.77 periods for a fall in product prices. Using fortnightly data this implies that the adjustment is about one week slower for the cost fall. Changes in exchange rates are felt one period later giving a mean response of 5.38 time-periods to a fall in the dollar/sterling rate.

(d) The adjustment of prices to cost rises is more concentrated around the mean lag than that to cost falls, so that price rises appear to be sharper and less gradual than price falls;

(e) There is a trend increase in other costs or margins of 0.015 pence/litre per fortnight (with the value at June 1982 estimated at 2.51 pence/litre).

The differences in the mean lags identified for cost increases and decreases, although statistically significant, are not sufficiently great, at around one week, to lead to decisive rejection of the view that the UK retail gasoline market is highly competitive. However the methodology employed and the results obtained suggest that the failure to pursue this issue more systematically by the MMC may have led to a too ready acceptance of equal mean lags obtained by casual inspection of data from a relatively short period.

5 CONCLUSION

The "rockets and feathers" hypothesis of asymmetric speeds of adjustment of UK retail gasoline prices to cost increases and decreases was modelled by a quadratic quantity adjustment function. Using fortnightly data for the UK from 1982 to 1989 evidence was found that the upward adjustment process is slightly faster and the period of adjustment more concentrated than was the case when costs fell. The methodology developed is suitable for testing for asymmetric speeds of response to positive or negative stimuli in any market where this might be expected to occur.

APPENDIX

The quadratic quantity adjustment function used in the text is generated by the equation:

$$Y(t) = Y(t-1) + \alpha\{Y^T - Y(t-1)\}^2 + \beta\{Y^T - Y(t-1)\} \quad (A1)$$

where Y^T is the equilibrium level determined by outside forces. The time-path of this non-linear first-order difference equation is complex and it appears unlikely that there are easily derivable expressions for the mean lag. Moreover the mean lag itself depends on the size of any change in Y^T. In order to obtain values for the mean lag and its standard deviation, we solved equation (A1) recursively using a starting value of 15 for Y^T, Y(t) and Y(t-1). For given values of α, β and Γ (the size of the change in the target value) we traced out the subsequent values of Y(t) until they converged to the new equilibrium of 15 + Γ (using a tolerance of 0.00001). The adjustments at each stage W(t) and the mean and standard deviation of the lag distribution were calculated using (4) and (6). Results for selected parameter values are shown in Table A1 which shows that over the range tabulated there can be very considerable asymmetry both in the mean lag and in the standard deviation. As the quadratic term becomes stronger relative to the linear term the effect becomes more pronounced. For negative shocks the mean lag increases as the size of the shock increases, while for positive shocks the mean lag decreases as the shock becomes larger.

Table A1: Mean and Standard Deviation of Lags of Quadratic Adjustment Path.

Size of Shock	Quadratic Coefficient	Linear Coefficient				
		0.1	0.2	0.3	0.4	0.5
Γ = -1	0.005	11.27 (9.61)	6.07 (4.51)	4.37 (2.81)	3.52 (1.95)	3.01 (1.42)
Γ = +1		10.74 (9.34)	5.93 (4.44)	4.30 (2.77)	3.48 (1.93)	2.99 (1.40)
Γ = -2		11.56 (0.75)	6.14 (4.54)	4.40 (2.82)	3.54 (1.96)	3.03 (1.43)
Γ = +2		10.50 (9.22)	5.87 (4.40)	4.27 (2.76)	3.46 (1.92)	2.97 (1.40)
Γ = -1	0.045	14.45 (11.02)	6.74 (4.83)	4.66 (2.95)	3.69 (2.04)	3.13 (1.49)
Γ = +1		9.16 (8.49)	5.45 (4.18)	4.06 (2.64)	3.34 (1.84)	2.89 (1.35)
Γ = -2		27.32 (14.64)	7.82 (5.30)	5.07 (3.15)	3.91 (2.15)	3.27 (1.56)
Γ = +2		7.97 (7.78)	5.02 (3.94)	3.84 (2.52)	3.19 (1.76)	2.78 (1.28)

Note: The figures in brackets are the standard deviations.

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OXFORD INSTITUTE FOR ENERGY STUDIES
57 WOODSTOCK ROAD, OXFORD OX2 6FA ENGLAND
TELEPHONE (01865) 311377
FAX (01865) 310527
E-mail: publications@oxfordenergy.org
http://www.oxfordenergy.org