Anatomy of a price war

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The development of a petrol price war owes much to the structure of petrol retailing and in particular to the spatial pattern of retail outlets. Local neighbourhood, retailer competition, stimulated by consumer price sensitivity with respect to clusters of service stations, influences not only the spatial pattern of prices but may also influence the range in prices during a price war, at least at the scale of an individual city.

FROM the end of 1981, throughout the early months of 1982 a persistent petrol price war was widely reported in the media. In mid-January 1982 newspaper reports were documenting the price slide and the reasons for it, noting reasons for the overall national decline in petrol prices and also observing broad regional variations in average prices[1]. Such average price falls conceal considerable variation and this is certainly evident at the scale of individual urban areas — the scale at which most purchasers hunt for their petrol. This note outlines some findings from a study of petrol price variation within a single urban area (Sheffield). The purpose was to identify reasons for intra-urban price differences, explore the importance of neighbourhood competitiveness on price levels and in addition identify changes in the anatomy of the price surface as the war intensified in the first three months of 1982. The results confirm the importance of neighbourhood competitiveness and identify a tendency for price variation to decline, with competitiveness being concentrated at the low end of the price scale as the war intensified.

The most frequently cited explanations of spatial price variation emphasize the existence of discrete market regions each with their own local supply and demand functions. Price differences set up flows of exports and imports between regions which result in a spatially competitive equilibrium price level which is dependent on transport costs between the markets[2].

But price variation exists at many scales that almost certainly do not reflect either transport costs or the existence of spatially discrete market areas. In the case of petrol sales, market interdependence exists not only by virtue of the mobility of the consumers but also the spatial price awareness of sellers *vis-à-vis* their competitors be, these company retail outlets or independent traders. A simple model of intra-urban petrol pricing would recognize such inter-market dependence in terms of the demand function at each outlet. That consumers display such price sensitivity even over quite small price differences has been confirmed by independent research[3].

Let D_t denote the demand vector at time t. The vector is of length n, each entry referring to an individual retail outlet. Then let S_t denote the n-dimensional supply vector at time t. Then assume

$$D_t = Ap_t + c \qquad (1)$$
$$S_t = Bp_{t-1} + e$$

where p_t and p_{t-1} are the n-dimensional price vectors at times t and t-1 respectively. The vectors c and e represent vectors of constants. It is further assumed that the matrix B is diagonal, that is, the supply of petrol is scheduled and it is for the local agent to ensure that his 'market' is cleared. The diagonal elements of B are positive. A, however, is a non-diagonal matrix, the individual elements representing the degree of inter-market dependence. The diagonal elements of A are assumed negative and the off diagonal elements positive.

Finally we assume that clearance must take place in each market independently so that

$$D_t - S_t = 0 \qquad (2)$$

From (1) and (2) it follows that

$$p_t = A^{-1}Bp_{t-1} + A^{-1}(e-c)$$

and that the equilibrium price vector (p_e) is

$$p_e = (A-B)^{-1}(e-c) \qquad (3)$$

an equilibrium that is stable providing the eigenvalues of $A^{-1}B$ are less than 1 in absolute value.

Rearranging terms in (3) we obtain

$$p_e = (B^{-1}A)p_e + B^{-1}(c-e) \qquad (4)$$

Splitting the $(B^{-1}A)$ matrix into diagonal and off-diagonal elements we obtain from (4) the equilibrium price for the ith outlet:

$$p_{i,e} = \sum_{j=1}^{n} \frac{a_{ij}}{b_{ii}-a_{ii}} p_{j,e} + \frac{c_i - e_i}{b_{ii}-a_{ii}} \qquad (5)$$

where the (a_{ij}) and (b_{ij}) reference elements in the A and B matrices respectively. We note from (5) that $a_{ij}/(b_{ii}-a_{ii})$ is always positive.

The model (5) suggests the presence of mean variation in retail petrol prices (the second term in (5)) and spatial contiguity — that is the tendency for neighbouring retail outlets to charge similar prices (the coeffi-

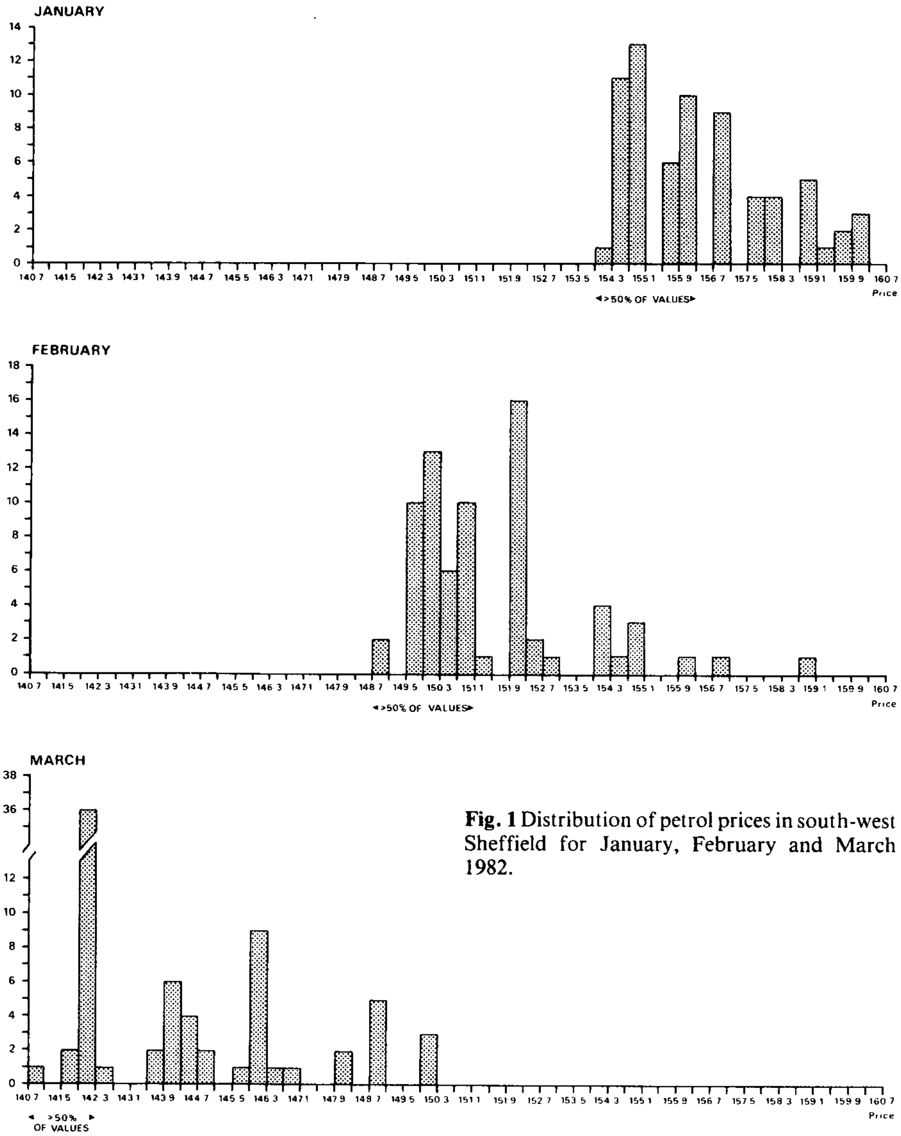

Fig. 1 Distribution of petrol prices in south-west Sheffield for January, February and March 1982.

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Table 1 Competition parameters for various petrol price ranges

	Price range		Competition parameter	log likelihood difference
January	153.9	156.0	0.80	4.06
	155.0	156.0	0.47	1.19
	156.9	157.0	−0.35	0.47
	157.8	158.0	0.97	1.11
	158.7	160.0	1.52	4.90
February	148.7	151.0	0.72	3.24
	148.7	152.0	0.97	5.31
	150.5	151.0	0.49	2.92
March	140.9	142.1	1.10	10.00
	142.0	142.0	1.14	2.90
	145.9	146.0	0.11	0.01

cient in the first term in (5)).

One other implication may be noted. Suppose in (1) it is assumed that

$$D_t = Ap_t + c + u$$

where u is an independent normal random variable so that the demand function is stochastic — a not unreasonable assumption given the high degree of mobility and the variable timing of individual consumer demand. If the slope of the demand function steepens (as it might be expected to during periods of stiff price competition when consumers become more price sensitive) then it follows that the variation in equilibrium prices (derived from the probability distribution of cutting points of the supply and demand functions) will decrease.

Data for 85 petrol stations in south-west Sheffield were collected on single days in January, February and March 1982. Advertised prices were recorded for four-star petrol and in addition the brand name was recorded together with whether the outlet also did repair work, sold cars and whether it was located on one of the principal routeways of the city of Sheffield.

A multiple regression model was run, regressing observed prices on three dummy variables (location, repair work and car sales) and two variables that identified the (x,y) coordinates of the station. The latter two variables (obtained by digitizing the map of retail outlets) were designed to pick up trend effects. In all three months the location variable (whether the petrol station was on a principal routeway or not) was significant. The partial regression coefficient suggested an average price mark up for those stations off the principal routeway of between 3 and 4 pence per gallon. In January the repairs dummy variable was also significant giving an additional 2 pence per gallon mark up. No other variables were significant. In all cases, however, the level of explanation attained was under 10%.

Figure 1 shows a frequency plot of the prices for each of the three months. During this period prices were falling — the minimum in January was 153.9 pence, by March it was 141.0 pence. During this time not only was the distribution of prices bunching increasingly around the low competitive price level but, perhaps because of the need to preserve market share, the minimum price level charged by each brand was also converging. In all three months, all companies were represented in the spread of prices but whereas in January there were considerable price differences in company minima these had more or less disappeared by March.

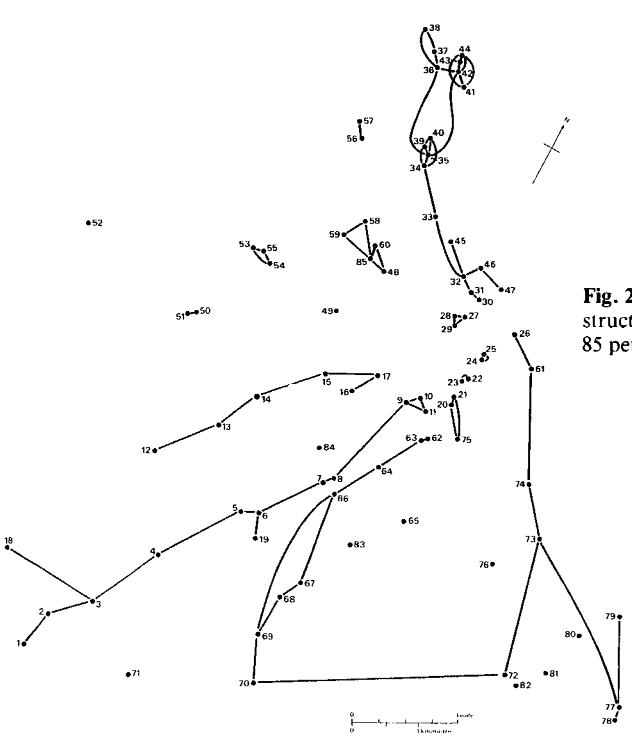

Fig. 2 Imposed edge or linkage structure for the set of 85 petrol stations.

Price competitiveness was studied at a variety of levels and not only at the low end of the price range. The intention was to see to what extent spatial price competition was maintained at all levels of pricing as the price war intensified.

Interaction models were used to test for competitiveness[4-7]. Early applications of these models was to crop yields and the study of inter-plant competiton[4,8]. Here petrol stations in the price range to be investigated were coded one and the rest coded zero. The auto-logistic model was then fit using a pseudo-likelihood estimation procedure for the two parameters α and β[6,9].

Estimation for each price range (t_2, t_2) proceeds by maximizing (numerically) with respect to α and β

$$\prod_i \frac{\exp[(\alpha + \beta y_i)x_i]}{1 + \exp[\alpha + \beta y_i]}$$

The product is over all sites that have links and

$$x_i = \begin{cases} 1 & \text{if the } i\text{th station charged in the price interval } (t_1, t_2) \\ 0 & \text{otherwise} \end{cases}$$

Then

$$y_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} w_{ij} x_j$$

where w_{ij} is 1 if site j is a neighbour (linked) site of site i and is zero otherwise. (Unlinked sites are excluded from the analysis.)

The second parameter (the competition parameter, β) is a measure of map structure, a positive value implying contiguity in the distribution of values. An approximate test of significance using the $\frac{1}{2}\chi^2$ distribution was used taking the difference in the log likelihoods for the case $\beta = 0$ and the case $\beta \neq 0$ (ref. 9).

A variety of different price ranges were investigated and some of the results are recorded in Table 1. The approximate critical value for the test is 1.92 in each case. The linkage or edge system imposed on the sites reflected first the orientation of the principal Sheffield routeways, and second, proximity, where groups of stations were close together but not actually on the same routeway. Thus the measures of competitiveness are principally with respect to proximity on or close to the main urban routeways (Fig. 2).

The evidence suggests that competitiveness increased at the low end of the price range as the price war intensified. Equally, however, perhaps because of the increasing price sensitivity of consumers, competitive interaction at prices well above the area minimum declined. □

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