Environment and Planning A 2003, volume 35, pages 2131 – 2159

DOI:10.1068/a3636

Spatial pricing in interdependent markets: a case study of petrol retailing in Sheffield

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Received 3 February 2003; in revised form 28 April 2003

Abstract. This paper reports the development of empirical models to explain spatial price variation in an urban area. Models are constructed for petrol price data collected in 1995 and 1997 in Sheffield, England. The 1995 data are modelled by using only supply-side predictors following the collection of supply-side information from field surveys of the retail sites, a site questionnaire survey, and interviews with site managers. The 1997 data are modelled by using supply-side predictors and demand-side predictors that relate to the economic characteristics of the population of consumers. This modelling is based on field surveys of the sites, a new site questionnaire survey, and a household survey. The purpose of this work is to assess supply-side and demand-side factors in explaining spatial price variation. Supply-side predictors are classified into site characteristics, location characteristics, and measures of spatial competition. We examine the relative importance of these different groups of supply-side variables in explaining price variation, with a particular interest in location and competition effects as these relate directly to the spatial and geographical aspects of the problem. Another contribution of the paper is to observe the stability of findings by contrasting the best-fitting models obtained for the 1995 price data to the best-fitting models obtained for the 1997 price data.

We find that no demand-side factors are statistically significant. For 1995 a spatial competition variable and a location variable (whether a site is attached to a supermarket) are the consistently important supply-side variables. For 1997 all three categories of supply-side variables are important.

1 Introduction

The purpose of this paper is to describe and explain spatial variation in observed retail prices for petrol in an urban area, drawing on supply-side and demand-side predictors. Interest focuses in particular on the importance of location and local spatial competition effects in explaining price variation, as these have been subjects of theoretical enquiry in the literature. We aim to contribute to the empirical assessment of the role of these effects as well as to include and hence control for the effects of other supply-side factors, in particular site characteristics, thought to be important, and demand-side factors in the case of the 1997 dataset. In addition to insights obtained from modelling the price data, some important results that emerged from surveys and interviews carried out as part of the research are also reported.

In 'spaceless' models, spatial price variation within integrated markets is often explained by transport cost differences (Takayama and Judge, 1964). In Samuelson (1952), in which buyers and sellers are grouped into regions but possess no other spatial properties, interregional price differences are explained by interregional differences in supply and demand conditions and by transport costs between the various markets. Other reasons lying behind price variation that emerge from this literature include the lack of perfect information on the part of consumers, and the market power of producers (Benson and Faminow, 1985).

'Spatial' models, in contrast, allow individual sellers and buyers to occupy dispersed locations in either a bounded or an 'infinite' (unbounded) space. For sellers

there is the decision of where to locate in a bounded market and, if location is taken as given, then each seller occupies a position within the market area and has a location relative to the market boundary and to other sellers. These relationships can be defined in terms of straightline distances or the road network, for example. There may be clusters of sellers in one part of the market whereas other sellers may occupy relatively isolated or near-boundary locations, and these locations have price implications (for example, see Fik and Mulligan, 1991). Each consumer will be aware of many sellers but, depending on where he or she lives (or works or visits for recreation, for example) and travels, each seller will be perceived differently in terms of convenience and cost. Consumers also vary in terms of their socioeconomic profile. These different elements characterise the geography of the market area and not only are they expected to influence price variation within the market area but also they are expected to induce a geography in that price variation.

The study of spatial price variation has attracted considerable research interest. Faminow and Benson (1990) show how what constitutes evidence for market integration is affected as soon as the market is specified in spatial terms where sellers compete only with near neighbours and where consumers consider only nearby sellers (see also Benson et al, 1992). A supply-side model for spatial pricing in a market in which sellers compete only with near neighbours has been constructed (Haining, 1983b) and it was shown how prices would vary spatially as a consequence. A model in which consumers had choice sets that underlay the intersite competitive structure in the market has also been constructed (Sheppard et al, 1992). In a later paper based on the same model (Haining et al, 1996) it was demonstrated how prices vary spatially under different profit objectives given different assumptions about the choice-set structure linking the sites. This choice-set structure reflected the road network of the urban area—an aspect of spatial competition also studied by Fik (1991a). There has been considerable theoretical work on understanding spatial price variation (for example, see Anderson and de Palma, 1989; Capozza and Van Order, 1989; Greenhut et al, 1987; Haining, 1985; Norman, 1986). However Mulligan (1996, page 155) has remarked that "spatial competition studies should focus more on markets having numerous firms and realistic topologies".

Empirical studies into spatial price variation have often focused on groceries (for example, see Campbell and Chisholm, 1970; Fik, 1991b; O'Farrell and Poole, 1972; Parker, 1974), but local spatial variation in grocery items can be difficult to interpret. This is because consumers typically are buying a basket of goods, and there can be complex trade-offs in both pricing (on the part of the retailers) and in what consumers purchase. In explaining price variation it can be difficult to disentangle product inhomogeneity from effects associated with location and the local competitive environment of the retailer.

In order to reduce the problem of product inhomogeneity, one option is to study a good such as petrol where, despite marketing efforts, consumers tend not to show high levels of brand loyalty (Haining, 1986). Much of the work reporting price variation for petrol has tended to stress competitive factors. Claycamp (1966) demonstrated the importance of local competition effects in a metropolitan area of southeastern USA. Similar evidence was provided by Slade's (1992) study of retail petrol price sales in Vancouver. Other studies exploring the effects of local competition and price wars on price setting include those by Allvine and Patterson (1972), Robinson and Hebden (1973), and Schendel and Balestra (1969). Also petrol price data for eighty-five stations in southwest Sheffield during an intensifying price war have been analysed (Haining, 1983a), in which a regression model was fitted to data that included four explanatory variables: location (whether or not a retail site was on a main road); whether or not car repairs were carried out at the site; whether or not cars were sold at the site; and a weighted average of prices at nearby competitor sites. Only the first and last of

these variables were consistently significant at the 5% level. In a study on St Cloud, Minnesota a similar regression-based study was carried out that included other predictors (Plummer et al, 1998). It was found that site and location variables were important. Prices were lowest at sites that concentrated only on selling petrol, had a relatively large number of pumps, sold nonbranded petrol, and enjoyed a high level of accessibility within the urban area.

Clustering of firms, especially near the centre of a bounded market, is often found wherever consumers have limited information on prices, where the acquisition of such information is not costless, and where competition is not intense (Dudey, 1990; Economides, 1993). This characterises many types of retailing activity in urban areas and has implications for spatial price variation. Fik (1988, page 42), in the context of grocery retail pricing, remarks: "spatial structure and firm density are the predominant forces which shape the geography of price." The more isolated a retailer the higher the price, presumably because the retailer is providing convenience and overall lower costs to a geographically defined subset of consumers (Benson and Faminow, 1985). Fik (1991b) notes that the clustering of retailers promotes lower overall price levels and that price patterns reflect the relative location of firms and the distance to the nearest and next-nearest rivals. The larger the number of intermediate sellers between any two sellers the weaker the linkage between their prices (Mulligan and Fik, 1989), indicating more than a simple distance-decay effect in the structure of spatial competition, although presumably there is an underlying scale effect here. Maps of petrol retailers typically show tight clusters (at intersections of main roads), strings (along principal thoroughfares), and isolated sites (on side roads), suggesting that petrol retailing only partially meets the conditions that induce clustering within an urban market. This spatial complexity is a further reason for taking an interest in petrol retailing in exploring spatial price variation.

The modelling of the 1995 prices reported here uses readily available data on supply-side factors and measures of spatial competition, but it is also informed by findings from a site questionnaire survey and interviews with site managers. Research into petrol price variation has tended to focus on the supply side (Haining, 1983a; 1983b; Slade, 1992). The modelling of the 1997 prices follows the same strategy but also includes variables that measure the economic attributes of consumers living within a fixed distance of each site. This was explored in the second dataset because of deficiencies noted in the analysis of the 1995 data. The modelling of the 1997 data is informed by findings from site and household questionnaires.

Relatively little work has been undertaken to explore demand-side factors in explaining price variation at the intraurban scale, and the evidence to date does not seem to suggest it is very important. In the context of food pricing, Fik (1988) found no link between price levels and the socioeconomic profiles of the consumer population. Findings have also been reported on consumer purchasing behaviour, for petrol, in St Cloud (Plummer et al, 1998). The household survey from that study showed no empirical evidence of significant spatial variation in the structure of household demand (Plummer et al, 1998, page 72). The St Cloud study did not reveal any relationship between consumers' economic circumstances and retail prices, although it is important to note that St Cloud is a relatively small urban area and does not display marked socioeconomic heterogeneity.

In section 2 we report on data collection for the two periods. In section 3 we summarize the main findings from the field surveys for 1995 and 1997. In section 4 we present the main findings from the 1995 and 1997 site questionnaire surveys and the 1995 site interviews. In section 5 we summarize the main findings from the 1997 household survey. In sections 6 and 7 we report the results of modelling price variation in 1995 and 1997, respectively, by means of linear regression. In section 8 we present the conclusions.

2 The Sheffield case study[1]

In figure 1 we show the locations of the petrol retail sites in 1995. The map shows the main radial routes (mainly A-rated) and the two (inner and outer) ring roads. We used these two ring roads to divide Sheffield into four areas. The area inside and including the inner ring road is designated the *city centre*; the area between the inner ring road and the outer ring road is designated the *inner area*. The *outer ring road* is classified as an area in its own right, and the area outside this is called the *outer area*.

In 1995 there were 113 petrol stations. These are identified by postcode location so that the station labelled 3001 is station 01 in postcode area S30. Most stations (89) are

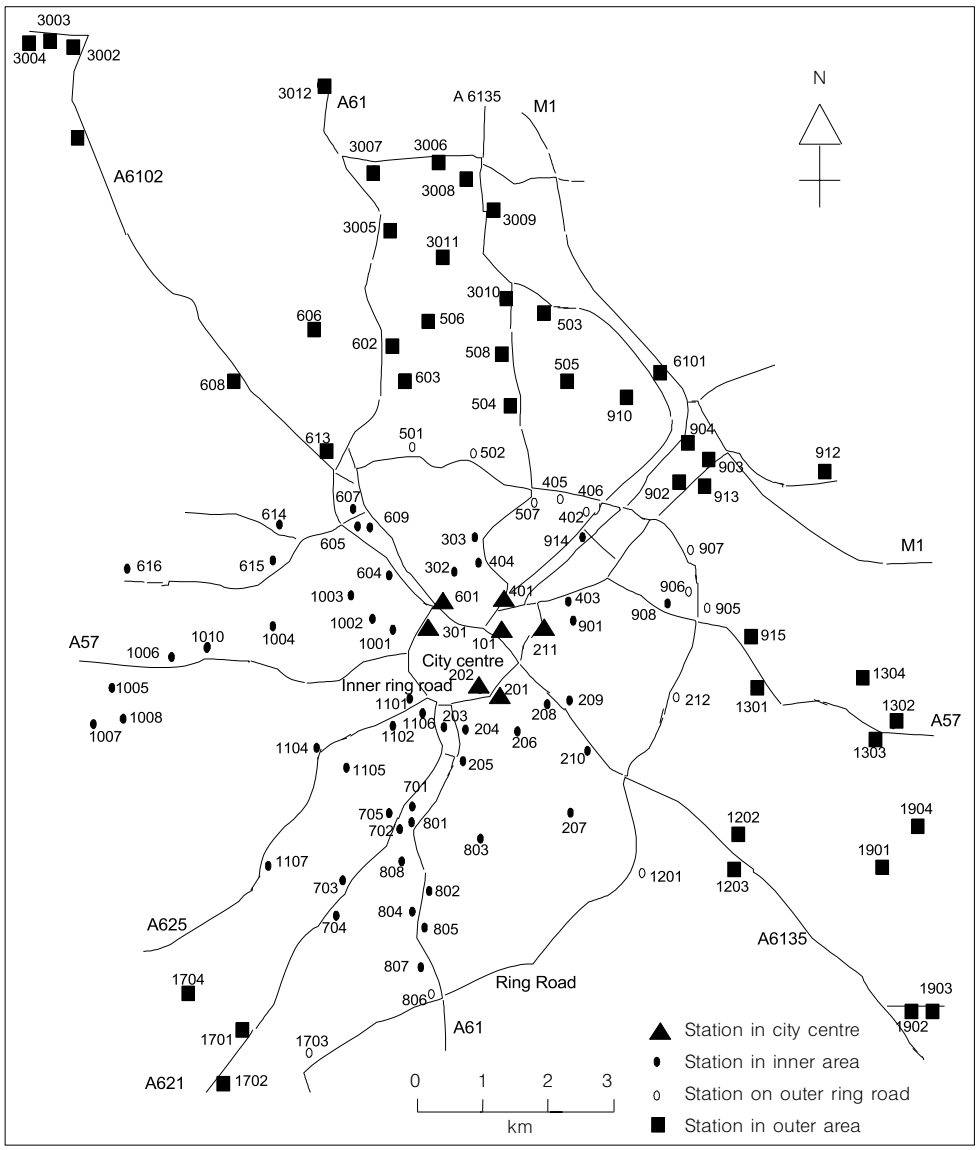


Figure 1. Sheffield: main roads and petrol stations, classified into four subareas, 1995.

[1] The data used in this research are available for downloading at http://www.geog.cam.ac.uk/people/haining/data.

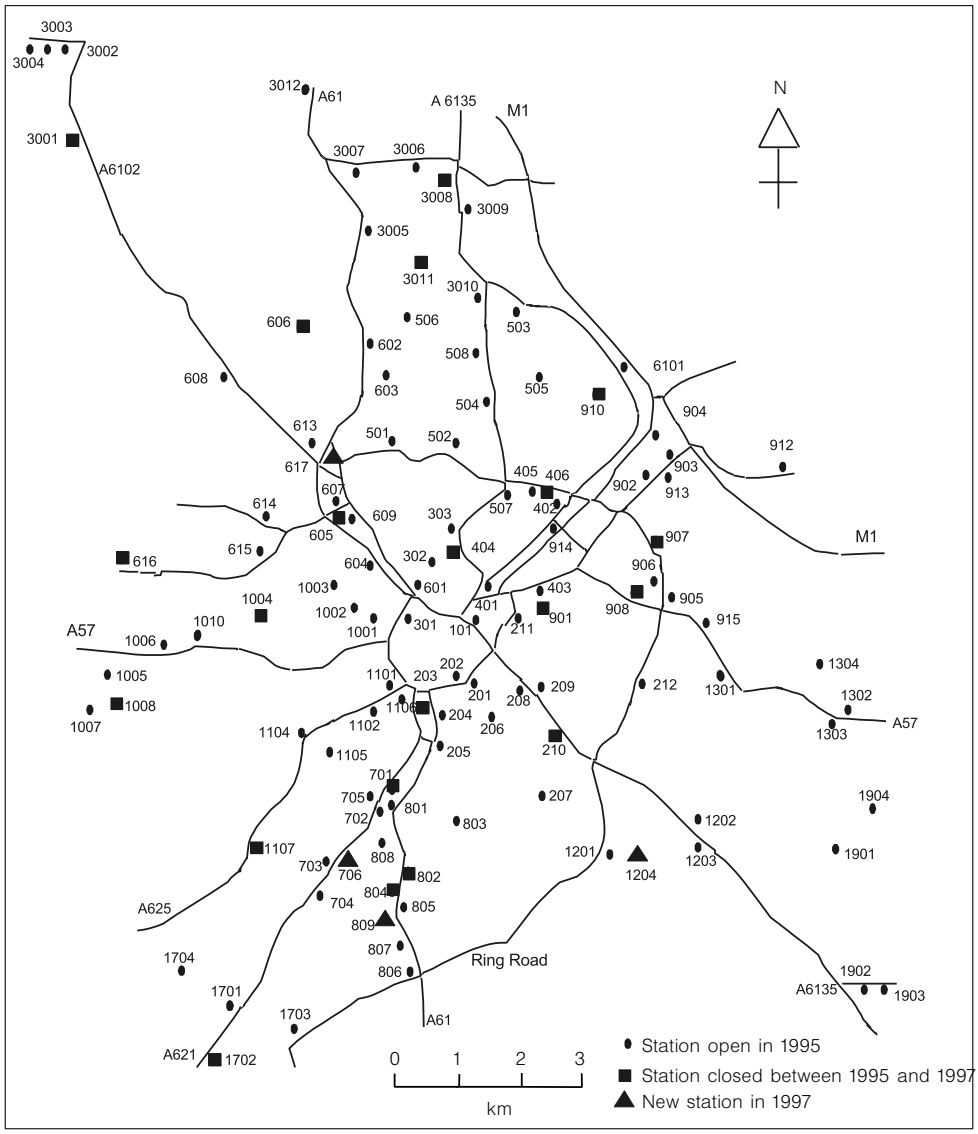


Figure 2. Petrol stations in Sheffield: sites closed and new sites opened between 1995 and 1997.

located on main roads. The city centre has 7 stations, the inner area has 51 stations, the outer ring road has 12 stations, and the outer area has 43 stations. In 1997 there were 96 petrol stations. Of the stations open in 1995, 21 had closed (15 on main roads and 6 not on main roads) and 4 new stations had opened, 3 attached to supermarkets (for new stations and closures, see figure 2).

2.1 Data type 1: field surveys in 1995 and 1997

In 1995 petrol prices were recorded in weekends in the period 7 January to 15 April at two-week intervals. In 1997 prices were recorded for six weeks, from 1 March to 5 April, at weekly intervals. One midweek census was taken in 1997 to check for within-week effects; only 9 sites had changed their prices from the weekend. No further midweek censuses were taken. Boxplots of unleaded prices for each sample period in 1995 and 1997 are shown in figure 3 (see over). Both study periods are in contrast to that of an earlier study

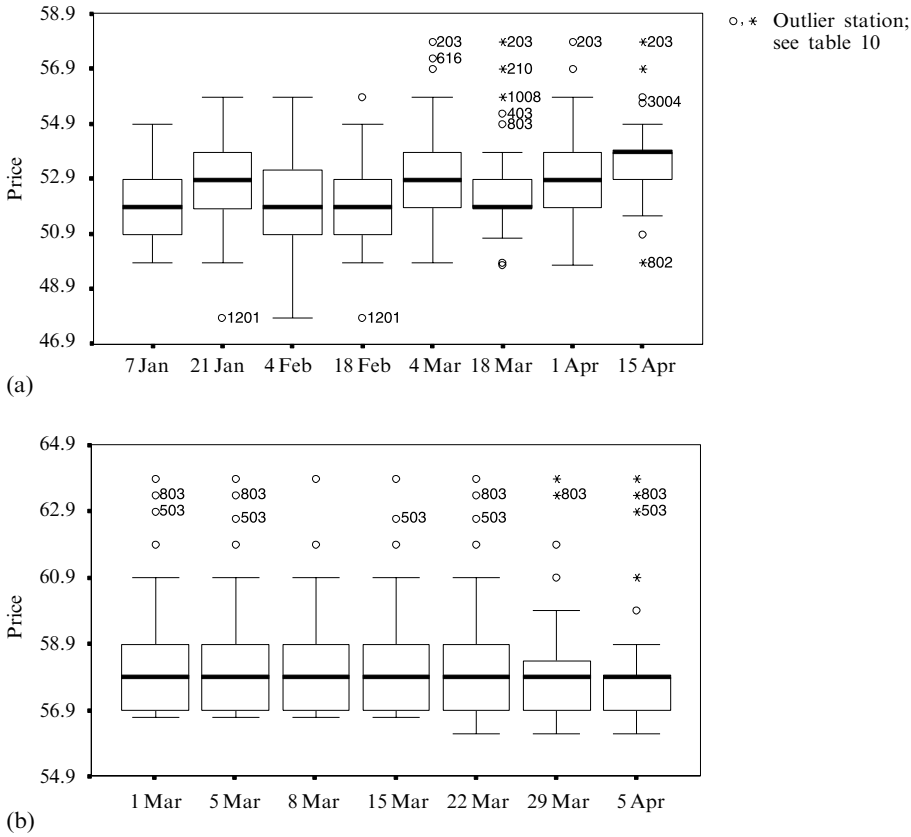


Figure 3. Box plot of prices for unleaded petrol (in pence per litre) in (a) 1995 ($n = 112$) and (b) 1997 ($n = 96$) (source: authors' survey).

of Sheffield petrol prices (Haining 1983a; 1983b, 1986; 1990). Whereas the earlier period was marked by a price war, prices in 1995 and 1997 were stable.

Location characteristics were recorded for each station. Most of these were recorded as dummy variables (yes, no): (a) on the main road (0, 1), (b) on a corner location (0, 1), and (c) attached to a supermarket (0, 1); (d) area location—city centre, inner area, outer ring road, and outer area—was recorded by using three dummy variables—(0, 0, 0), (1, 0, 0), (0, 1, 0), and (0,0,1), respectively.

Site characteristics for each station were also recorded on a binary scale. These included: (a) car-wash service provided (0, 1); (b) cars sold (1, 0); (c) garage services provided (0, 1); (d) fewer than 8 pumps (1), or 8 or more pumps (0). Appearance was reported impressionistically, with account being taken of the presence and condition of the canopy, the price posting board, and the payment office; this information was used to classify stations as either new-looking (0) or old-looking (1). Stations were further classified into 'major' (0) or 'minor' (1) brand retailers.

In 1995, 22 retail companies were represented in the Sheffield area. On the basis of the number of sites for each company and the frequency with which their sites were found on main roads, Esso, Jet, Mobil, Shell, Save, and Texaco stations were classified as 'majors' in the context of the Sheffield market. All other sites were branded 'minors'. Several of these supply-side attributes were examined in the previous empirical work of one of the present authors and are easy to record from site visits. By 1995 most sites were self-service in Sheffield, with almost no exceptions, so this attribute was not recorded.

Only prices for unleaded petrol were recorded. Unleaded petrol was the main type sold by 1995 and only one site (3011) in 1995 sold exclusively leaded petrol (so-called 'four star'). This site was eliminated from the analysis.

2.2 Data type 2: site questionnaire surveys in 1995 and 1997, and interviews in 1995

A postal questionnaire to all site managers of petrol retailing outlets was distributed in both 1995 and 1997. These data were supplemented in 1995 with a small number of interviews with site managers, selected from each of the four ownership types.

Questionnaires were mailed to all petrol retail outlets in the Sheffield area in 1995 and 1997 and the response rates were 39% (1995) and 62.5% (1997). One-sample χ^2 tests showed that in both years the samples were representative of the population in terms of those site characteristics recorded from the field surveys.

The purpose of the survey and interviews was to find out about supply-side characteristics that could not be observed from a field visit. In particular, we wished to explore the factors influencing price setting—especially the nature of any local price comparisons, and retailer sensitivity to price movements—and how such price setting might affect sales.

2.3 Data type 3: household questionnaire survey in 1997

Two wards were selected, Beauchief and Owlerton, to provide contrasting (though not extreme) proportions of high-income and low-income families. (See figure A1 in the appendix for the location of Sheffield wards.) The 1991 Census showed that 67% of households in Beauchief and 47% of households in Owlerton had cars. In Beauchief 63% of households lived in detached and semidetached houses, whereas in Owlerton only 34% lived in such houses. A further criterion in selecting these wards is that they are both a similar distance from the city centre.

A 42.2% response rate was achieved from the 500 questionnaires mailed to Beauchief households; approximately 80% of respondents had cars. A 30.7% response rate was obtained from the 700 questionnaires mailed to Owlerton households; approximately 65% of respondents had cars.

The purpose of the survey was to find out about household purchasing behaviour, including what influenced their decision on where to buy petrol, their price sensitivity, and to find out about their choice sets. Respondents were asked to state where they had bought petrol from in their most recent trips that had included a petrol purchase.

3 Findings from the field surveys.

In this section we summarize our findings on the relationship between prices and location, prices and site characteristics, and prices and the competitive environment in 1995. In section 3.4 we highlight any important differences in the 1997 survey.

3.1 Prices in relation to location: 1995

In an urban area, supermarket stations have more potential customers than do other stations. Customers who visit supermarkets may also purchase petrol from the adjacent petrol station perhaps as part of a 'one-stop shop' or because of incentives offered by the supermarket such as discounts linked to the size of the grocery purchase. Supermarket stations had a lower median price and a narrower price spread than did stations not attached to supermarkets for all eight weeks studied in 1995.

The price difference between supermarket and nonsupermarket sites was the most consistent finding. Some other patterns in the data were discernable. The median price at sites on main roads was lower than that at sites on minor roads for all weeks except 1 April, when the median price was the same. The set of city-centre sites had a lower median price than did the set of inner-area and ring-road sites in all weeks except one.

The city centre generally had the narrowest price spread as most sites charged the same price. Stations located on corner sites had a higher median price than did stations not located on corner sites in the case of five datasets, but on three weeks they had the same median price.

3.2 Prices in relation to site characteristics: 1995

Interestingly, there were no consistent relationships between site characteristics and median prices—an exploratory finding that was to be confirmed in the regression modelling on the 1995 data. There was no consistent difference in median price between majors and minors. Stations with a car-wash service had a lower median price than did the stations without a car-wash service on four survey dates, but there were no differences in the median price on the other four survey dates. There was no systematic median price difference between stations that did sell cars and those that did not sell cars. Stations providing garage services had a higher median price than did stations without garage services on half the survey dates and had the same median price on the other half. Stations with eight or more pumps had a lower median price than did stations with fewer than eight pumps on three survey dates and had the same median price on the five other dates.

3.3 Prices in relation to the competitive environment: 1995

Price differences were explored between each station and its nearest neighbour in terms of straightline distance. In over 66% of cases, price differences were less than 1p per litre, and in 82.7% of cases differences were less than 2p per litre. A few nearest-neighbour pairs had price differences of 3p or more. This usually occurred when the pair were not on the same road.

3.4 Changes noted in the 1997 field survey

In 1995 no consistent relationships were identified between site characteristics and median prices. However, in 1997 consistent relationships were noted for several site characteristics. New-looking sites had a median price that was always greater than the median for old-looking sites. Sites providing garage services had a median price that was always either greater than (6 out of 7) or equal to (1 out of 7) the median price for sites not providing garage services. The median price for major retailers was always either less than (3 out of 7) or equal to (4 out of 7) the median price for minor retail sites. In 1997 the median price for sites on main roads was always less than the median price for sites on minor roads. As in 1995, prices at supermarket sites were always less than those at nonsupermarket sites. The median price at corner sites was less on all seven census dates compared with the median price at non-corner sites. This is a reversal of the situation in 1995, when corner site prices were often higher.

4 Findings from the site questionnaire surveys and interviews

In this section we highlight our findings from the two questionnaire surveys and the interviews and remark on any significant shifts in the factors influencing price setting and the local competitive environment between 1995 and 1997.

4.1 Ownership and price setting

The surveys revealed different types of ownership relationships between petrol suppliers and retailers in Sheffield: oil-company-operated outlets, franchised outlets, independent outlets, and multisite (nonoil-company-owned) outlets such as supermarket stations. The parent company and distributors (for a brand-name corporation) usually are responsible for pricing at franchised and company-owned outlets and some independent outlets. In the case of supermarkets, their own head office seems to be responsible

Table 1. Relationship between ownership and price setting, 1995.

Ownership	Price setter			
	parent company [a]	site manager	both, in consultation	total
Independent	9	6	4	19
Franchised	17	0	3	20
Other	3	0	0	3
Total (%)	29 (69.0)	6 (14.3)	7 (16.7)	42 (100)

[a] Parent company includes distributors and head offices (supermarkets).

for setting the price, and the distributors may have little or no influence. The Morrisons supermarket chain buys its petrol from Shell but prices are not, apparently, influenced by the distributor:

"Even if Shell's petrol price goes up, we would stick at the lower price" (site manager interview).

The findings are summarised in table 1.

4.2 Price sensitivity

Price was reported in 1995 and 1997 as the single most important factor determining sales volume. In table 2 we show a measure of retailer price sensitivity for 1995; the level of sensitivity in 1997 is similar. Responses to the question about a price *increase* at competitor sites identify the size of price change required before the station will follow its competitors and increase its prices also. From table 2 we can see that most stations ignore a 0.5p per litre price difference and start responding to match the price increase when price differences get to about 1.0p per litre. Responses to the question about a price decrease at competitor sites identify the size of difference at which the station will follow its competitors and decrease its prices. Again, most stations ignore 0.5p per litre price differences and start responding to match a downward price shift only when price differences get to about 1.0p per litre. The stations that selected 'not relevant' may be divided into two groups: (1) supermarket stations such as Savacentre that consider themselves to be 'price leaders', offering the lowest price, so that they do not respond to prices at other stations, stating that other stations follow them; (2) franchised stations, where the site does not share any profit or bear any costs for a price increase or decrease. Site managers in those stations are not allowed to change prices, so site managers may think competitor pricing is not relevant to them.

Table 2. Reactions to competitors' price increase or decrease per litre (1995 survey).

	Price change (pence per litre)				Not relevant	Total
	0.5	1.0	1.5	2.0		
Number responding to price increases	6	17	1	6	12	42
Number responding to price decreases	7	15	1	7	12	42

4.3 Local competitive environment

Nearly half the respondents claimed competitors' pricing was the most important factor determining their own prices. This is likely to be an underestimate. Almost all stations reported that either competitors' prices or a decision taken by the parent company was critical to price setting. However, any decision taken by the parent company will often be based on local price information supplied by their sites in the area. It seems

reasonable to conclude that local area price levels influence price-setting behaviour. In 1995 over 85% (36) of responding stations had one or more reference stations for setting a price. We now consider which will be the competitor or reference stations for any given site.

4.3.1 *Competition with the closest stations*
Some 83% of respondents consider the price at the closest station when they set prices, and 17% do not. Among the six stations in the latter group one is a supermarket station, three are majors, and two are minors (BP and UK). Some majors and minors with a large number of pumps may not consider the price at the closest station if the closest station has a small number of pumps or is located on a minor road. Station 615 (minor) ignores the closest station 614 as it is a brand minor and is located on a minor road (see figure 1).

4.3.2 *Competition with the closest stations on the same road*
Of the 30 retailers who do consider the price at their closest competitor, 23 consider the prices at stations on the same road as themselves whereas only 7 consider prices at stations on a different road from theirs.

4.3.3 *Competition with a group of stations*
Over 60% of stations take more than one station as a price reference station for setting prices, and most of these competitor stations are located on the same road or near the same road as the respondent.

4.3.4 Competition with supermarket stations
Supermarket stations generally charged the lowest prices in 1995. Some stations may consider supermarkets as the main reference stations for setting prices, but this depends upon brand and distance to the supermarket. Supermarket stations tend to take other supermarkets as their main reference station:

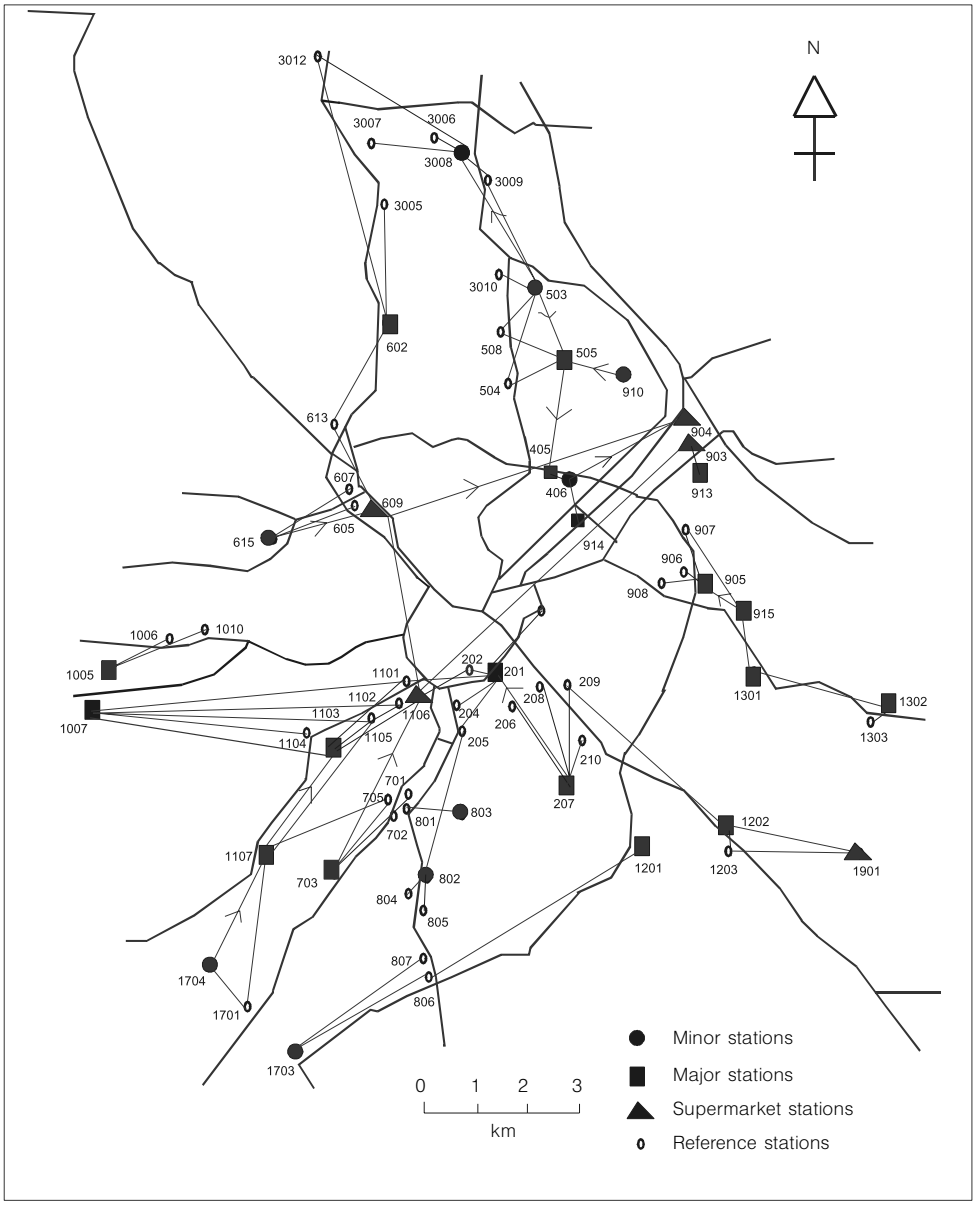
> "If in a 3–4 mile radius there was another supermarket, this would be the main reference station" (site manager interview).

Some majors consider supermarkets as basic reference stations in setting price:

> "Esso stations aim to be within 2p per litre of Safeway" (site manager interview).

However, the distance to a supermarket is important for majors and minors in their price setting. Any major or minor far from a supermarket usually does not consider the supermarket as a reference station. For instance, site 615 (see figure 1) takes the Morrisons supermarket (609) as a reference station but does not consider the prices at Safeway (1106) or Savacentre (903, 904) supermarkets as these stations are too far away.

4.3.5 *Competition levels*
From figure 4 it can be seen that most stations have more than one reference station (major, minor, or supermarket), but the geographic extent of the reference set varies. Figure 4 shows only those sites for which we have information on their reference set. A 'reference station' on the map is a station that did not respond but was cited by a station that did respond. In this case we do not know if the reference station would cite the other as in its reference set. In table 3 (see over) we list the maximum distance away of competitor stations from which retail outlets surveyed competitor prices in 1995. The results of Kolmogorov–Smirnov two-sample tests show that majors and minors have significantly different survey distances from those of supermarket stations. Selecting the 50% point on the cumulative frequency distribution against distance, we find 2.5 km is the median search radius for all stations.



Where both stations are ●, ■, or ▲ and connected by — then each is considered a reference station by the other. If stations connected by → arrowhead indicates the direction of the referencing.

Figure 4. Stations and their reference stations in 1995.

4.3.6 *Intensity of competition*

As can be seen from figure 1, petrol stations in the Sheffield area are not evenly distributed. Some areas of the city have a relatively high density of stations per square kilometre. In some areas there is a high proportion of supermarket stations and majors. The number of stations in a given area and their type may affect competitive relationships. We shall return to this issue below.

Table 3. Maximum distance to a reference station (1995 survey).

Maximum distance (km)	Number of stations [a]	Supermarket station	Major	Minor
0–0.5	5 (13.9)	0	5	0
0.6–1.0	5 (27.8)	0	3	2
1.1–1.5	5 (41.7)	0	3	2
1.6–2.0	1 (44.4)	0	0	1
2.1–2.5	7 (63.9)	0	6	1
2.6–3.0	4 (75.0)	0	2	2
3.1–3.5	5 (88.9)	1	3	1
3.6–4.0	1 (91.7)	0	1	0
5.6–6.0	2 (97.2)	1	1	0
6.1–6.5	1 (100)	1	0	0
Total	36	3	24	9

[a] The numbers in parentheses are the cumulative percentages.

4.3.7 *Changes between 1995 and 1997*

There were two potentially significant changes to the competitive environment in Sheffield and to the way petrol retailers monitored prices. First, by 1997 Esso had introduced a pricing policy ('Pricewatch'), the aim of which was to match supermarket prices. As a result, some other stations started to take as their main reference station the nearest Esso station. One of the Shell site managers (at site 301; see figure 1) said:

> "the whole structure of forecourt pricing has been affected by Pricewatch" (site 301 comments in the 1997 survey).

Second, three new supermarket stations opened close together in the southern part of Sheffield (see figure 2). These three supermarkets promised to

> "have a price guarantee policy that states we have 'unbeatable value'. We guarantee no petrol station within three miles will have lower prices than we do, nor will any supermarket petrol station within five miles. This policy governs whether we decrease prices" (site 706, Tesco).

The Safeway supermarket (1106) in the city centre took these new supermarkets as its main reference set instead of the Savecentre (sites 903 and 904) at Meadowhall. The Morrisons supermarket site (609) took Esso as its main reference station instead of the Savecentre (903, 904) and Safeway supermarkets (site 1106).

4.4 Prices and refineries

In the 1997 survey site managers were asked to identify which refinery their petrol came from. Most of the responding stations in the Sheffield area obtained their petrol from Humberside (26) or from Cheshire (4). Seven sites obtained their petrol from other refineries, including refineries in Birmingham, Nottingham, Leicester, Fawley, Leeds, and Coventry. One-way ANOVA (analysis of variance) was used to compare mean prices for unleaded petrol across these three groups of stations (that is, to compare prices of petrol obtained from Humberside, Cheshire, or 'other'). Petrol prices were not significantly different at the 5% level.

4.5 Prices and additional services

We expected that the more additional services provided at a petrol station (including limited grocery items and newsagent items) the greater the number of consumers attracted. The assumption underlying this is that petrol consumers are often on multipurpose trips when purchasing petrol. It can be argued that it is the range of other services provided by petrol retail outlets that really distinguishes between them

(and makes petrol a less homogeneous good than it might seem at first sight in the context of consumer satisfaction). One-way ANOVA was used to compare the mean price between stations categorised by the number of additional services they offered (3 – 4, 5 – 6, 7 – 10 additional services). There was a significant difference in price level between these groups of stations in 1995 ($p = 0.0627$).

4.6 Prices and sales volume

Sales volume can be classified into three categories, as shown in table 4. One-way ANOVA was used to compare mean petrol prices between stations in different sales-volume categories. The probability level for the test (0.071) indicates that there is a significant difference in price level among the three categories of stations and that stations with larger sales volumes charge lower prices.

Sales volume is not available for all stations and cannot therefore be included in regression modelling. However, at the 1% level, there is a significant and positive relationship between sales volume and number of individual pumps. The number of individual pumps will be used as a surrogate for sales volume in the regression model.

Table 4. Sales volume (1995 survey).

Category	Litres per day	Number of stations
1	< 3 000	18
2	3 000 – 6 000	11
3	6 000 – 21 000+	12
Total		41

5 Findings from the household survey

In this section we highlight findings relating to the petrol purchasing behaviour of spatially defined groups of households, and to the retail sites from which they select when purchasing petrol.

5.1 Purchasing behaviour

Most households pay for their own petrol purchases and of those who do not only 20% feel they must buy specific brands of petrol. Only about 20% of respondents across the two wards said they believed there were quality differences between brands. This leaves considerable scope for consumers to make choices on where to buy petrol based on a range of other criteria. Households were asked to rank from 1 (not important at all) to 5 (essential) the relative importance of factors in determining whether to purchase petrol from a particular station. An index was constructed based on multiplying the rank order with the number of responses and taking the sum. The larger the value of the index the more important the factor. From table 5 (see over), for Beauchief and for Owlerton, it can be seen that price is clearly the most important factor. Some location variables score quite highly, although these relate to convenience when individuals are taking particular trips (to work or shop) rather than generic attributes relating to ease of accessibility or 'visibility'.

To measure the sensitivity of consumers to price differences, households were asked to estimate the price difference per litre that would be necessary for them to switch from their current purchasing behaviour to another station. The number of respondents in each category is given in table 6 (over). About 50% claim to be sensitive to a 3p per litre or smaller differential. The figure of 3p is also the size of difference at which many retailers in the site survey said that their sales volume would be significantly affected. There was no statistically significant difference in price sensitivity between the two wards.

Table 5. Households in Beauchief and Owlerton, Sheffield: index measuring the importance of different characteristics in petrol purchases.

	Beauchief	Owlerton
Stamps and gifts sold	1.65	1.72
Friendly service	3.05	3.07
Convenient location, when one is travelling to or from shopping	3.25	3.12
Convenient location, when one is travelling to or from home or work	3.56	3.42
Location close to workplace	1.78	2.09
Location close to home	3.28	3.19
Offers points (for example, Argos card)	2.25	2.08
Price of petrol	4.13	4.09
Extra services available at the station	2.30	2.53
Petrol station accepts credit cards	3.38	2.86
Availability of free car services (for example, free air and water)	3.01	3.39

Note: because of different sample sizes comparisons can be made down columns but not across the two columns.

Table 6. Households in Beauchief and Owlerton, Sheffield: price sensitivity of consumers.

Price difference (pence per litre)	Beauchief		Owlerton	
	number of respondents	cumulative percentage	number of respondents	cumulative percentage
$\geqslant 0.5$	8	5.8	6	5.4
$\geqslant 1$	25	24.0	12	16.2
$\geqslant 2$	29	45.2	22	36.0
$\geqslant 3$	17	57.6	15	49.5
$\geqslant 4$	7	62.7	7	55.8
$\geqslant 5$	17	75.1	23	76.5
$\geqslant 6$	1	75.8	5	81.0
$\geqslant 10$	33	100	21	100
Not relevant	21		20	
Total	158		131	

Respondents were asked to give information on the type and size of their house and their average spending on petrol. We found no evidence of any relationship at the individual level between price sensitivity and these surrogates for household income. This finding suggests that demand-side factors linked to income may not be important in explaining price variation. Although this conclusion may not be true across the full spectrum of income types, nor at sufficiently aggregated levels, nonetheless it is an important finding and echoes those from the St Cloud study (Plummer et al, 1998)

5.2 Consumer choice sets and petrol purchasing

Responses showed that in both wards petrol is most frequently bought as part of a trip to work. Shopping trips and social or recreational trips also accounted for a large proportion of trips when petrol was bought. Very few respondents in either ward regularly bought petrol on school trips or made special trips to buy petrol.

From table 7 it can be seen that households regularly visit the station nearest their home, and the pattern is similar in the two wards. Consumers were asked to provide information on where they purchased petrol from in the month preceding the survey. These data were used to construct maps of choice sets (see Plummer et al, 1998). From figures 5 and 6 (see over) it can be seen that most consumers choose stations near to home.

Table 7. Households in Beauchief and Owlerton, Sheffield: petrol purchases from stations near to respondents' homes.

Response [a]	Respondents in Beauchief		Respondents in Owlerton	
	number	%	number	%
Never	1	0.6	6	4.5
Sometimes	42	26.6	36	26.9
Often	115	72.8	92	68.7
Total	158		134	

[a] Response to the question; 'How often do you purchase [petrol] from the nearby station?'

Stations vary considerably in terms of the number of times they are mentioned as being in a consumer choice set. In Beauchief, station 808 was mentioned most often (35% of consumers), followed by station 809 (22%) and station 805 (19%). In Owlerton, station 613 was most mentioned (47% of consumers), followed by station 602 (15%). Households tend to use nearby stations, but there are differences between stations in terms of the number of times they are patronised by local residents. It seems reasonable to suggest that a station with a large number of car-owning households in its immediate market area could, all things being equal, attract a higher throughflow of customers than a station with fewer car-owning households in its immediate market area. If the elasticity of demand is large in absolute value, there may be incentives for the former group of retailers to charge lower prices in order to attract a high proportion of their large immediate market.

6 Regression modelling: 1995 data

The models used here draw on readily observable supply-side characteristics augmented with additional variables identified as a result of the insights gained from the questionnaire survey and interviews. This modelling comes in two forms, utilising two views of the data: model A uses the week-by-week spatial cross-sectional data, so there are eight models, one for each date; model B uses the mean price at each site across all eight weeks.

6.1 Variables in the model

6.1.1 *The dependent variable: price*

Resistant methods (that use statistics that are not greatly influenced by small numbers of extreme values) were used to measure values on the dependent variable. In the case of regression model A, the original price data were used minus the median (a 'median-extracted' model). So, we use price at location i at time t minus the median price at time t, where the median price value is the median of the set of 112 prices in 1995 at time t. In model B, this process is applied to the set of mean prices. So the value of the dependent variable at location i is the mean price at location i minus the median of the 112 mean prices computed from the price data.

6.1.2 *Predictor variables and expected relationships*

The predictors are classified into three types (measures of location, site, and competitive environment), listed in table 8 (over). Expectations with regard to their direction of influence are given. Several variables have been included to capture different aspects of the competitive environment within which sites operate, as suggested by the questionnaire survey and interviews. The specification of the model allows us to assess location and competition factors whilst controlling site effects.

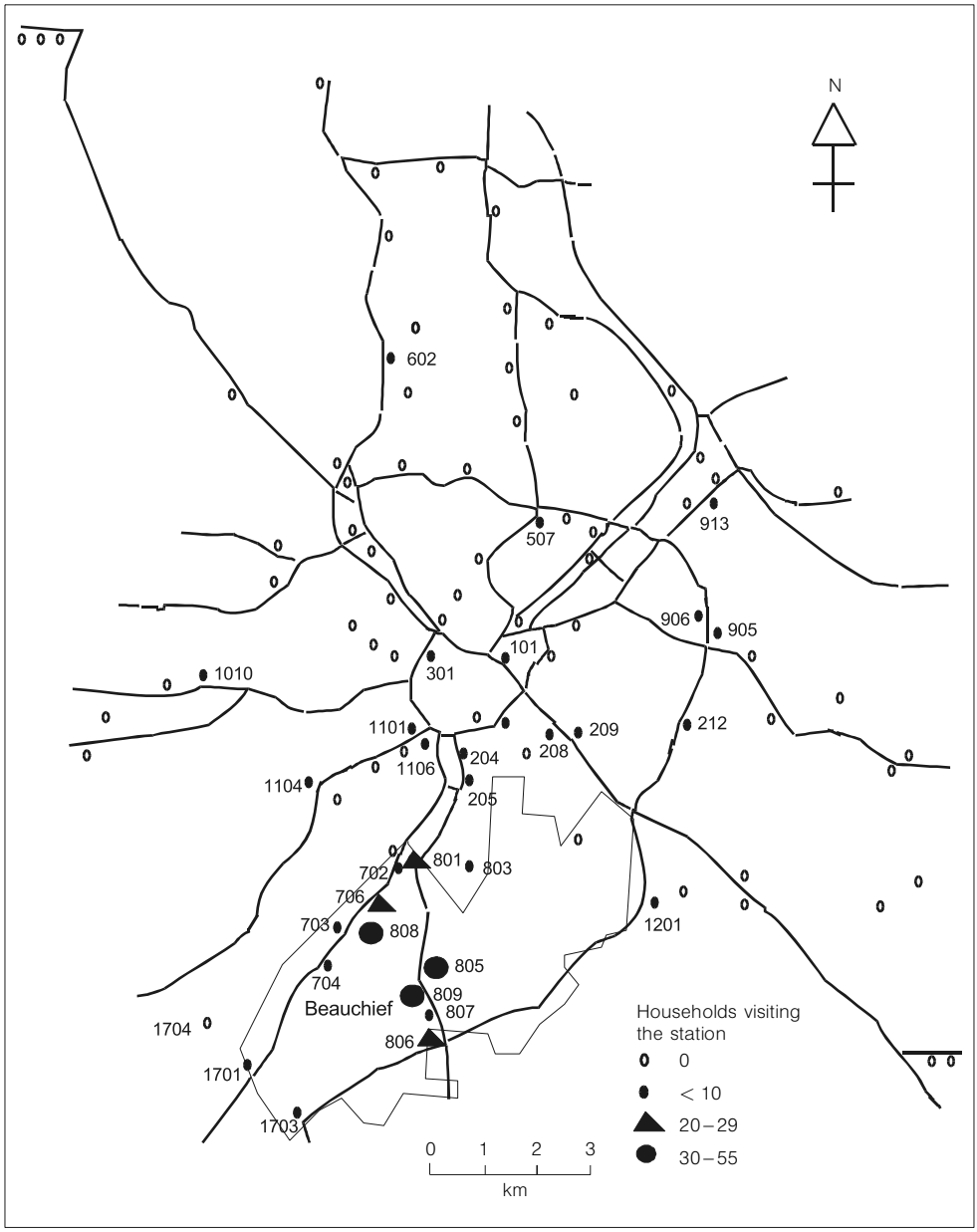


Figure 5. Stations patronised by households in Beauchief, Sheffield.

The variable NEAR measures price at the nearest-neighbour station irrespective of location. DISMKT measures the straightline distance between any site and the nearest supermarket with a petrol station. SAME measures the price at the nearest-neighbour site on the same road. INTENSITY measures competition intensity. This variable measures the number of stations and types of stations (supermarket, major, or minor) within a 2.5 km radius. The number of stations within a 2.5 km radius, excluding the station at the centre of the circle, is counted. The survey suggested that if the neighbouring stations are supermarket stations or majors then price competition is likely to be stronger than if the neighbours are all or mostly minors. So, different types of stations are given different

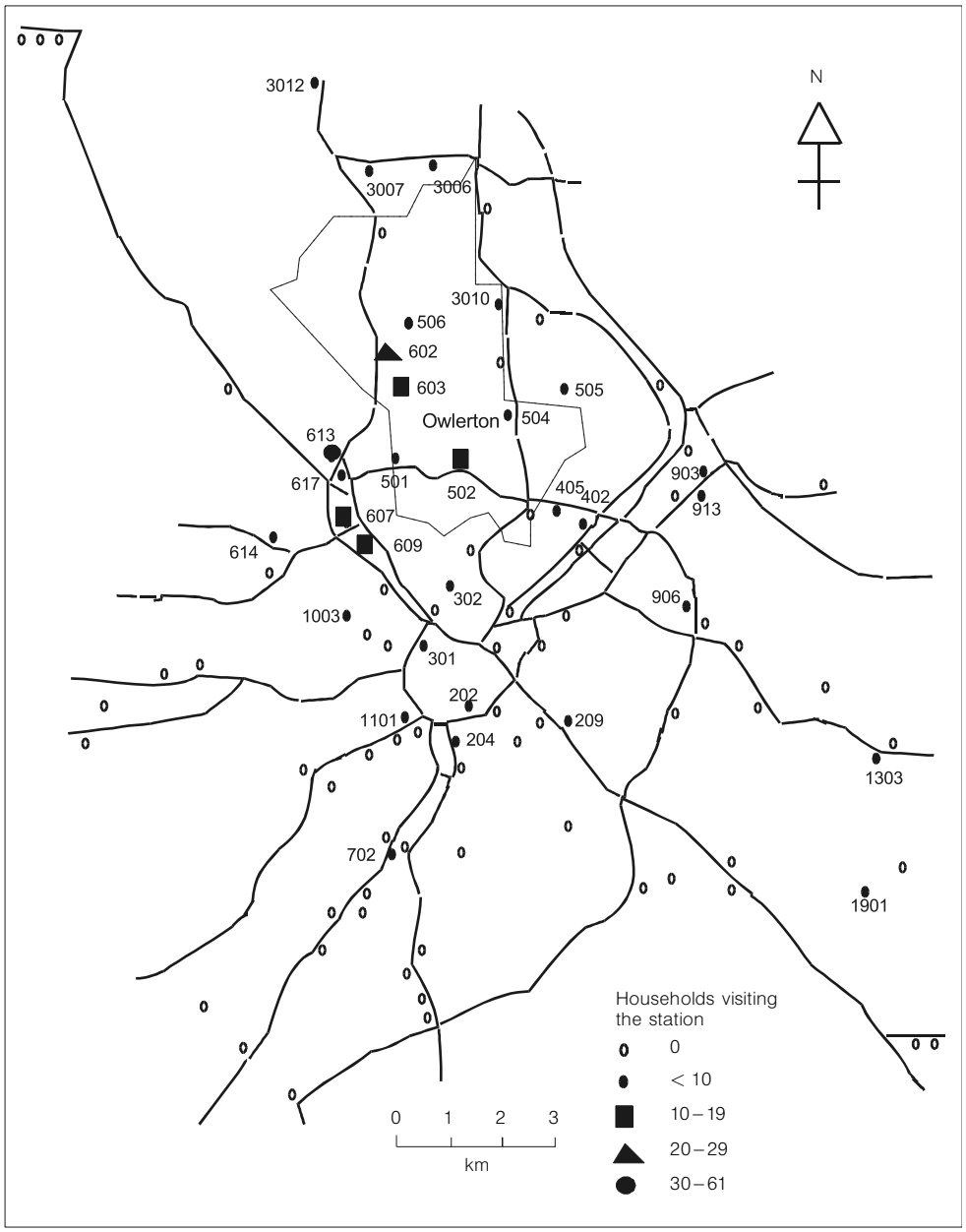


Figure 6. Stations patronised by households in Owlerton, Sheffield.

weights in the calculation of INTENSITY. Supermarket stations are given 3 points, majors are given 2 points, and minors are given 1 point. These numbers are clearly arbitrary, giving only a rank ordering of importance. The higher the score for a station the stronger the competitive environment. INTENSITY is expected to have a negative relationship with the dependent variable price.

The variable CLASSR measures the median price in the cluster of stations of which the site is a member. Stations were classified into twenty groups or clusters based on the configuration of the road network and local knowledge of traffic flows. It is, inevitably, a somewhat subjective classification. Stations located on the same

Table 8. Description of the independent variables.

Independent variable	Description	Sign[a]
Group-1 predictors (location characteristics)		
LOCATION	Station located on main road (0) or minor road (1)	+
RING	Station located on outer ring road (1) or not (0)	+
INNER	Station located in inner area (1) or not (0)	+
OUTER	Station located in outer area (1) or not (0)	+
CORNER	Station located on corner (0) or not (1)	+
MARKET	Station attached to supermarket (0) or not (1)	+
Group-2 predictors (site characteristics)		
CARWASH	Station with car-wash services (0) or not (1)	+
CARSALE	Station with car-sale services (1) or not (0)	+
GARAGE	Station with garage services (1) or not (0)	+
APPEAR	Station with new appearance (0) or old (1)	+
SIZE	Station with 8 or more pumps (0) or fewer than 8 pumps (1)	+
BRAND	Major (0) or minor (1) retailer	+
Group-3 predictors (competition characteristics)		
NEAR	Price (median-extracted) at the nearest-neighbour site	+
SAME	Price (median-extracted) at the nearest-neighbour station on the same road	+
CLASSR	Median-extracted price in the group of which the station is a member	+
DISMKT	Distance from station to the closest supermarket station (km)	+
INTENSITY	Weighted measure of the number of competitors in a circle of radius 2.5 km from the station	−
LOWPRICE	Lowest price (median-extracted) in a circle of 2.5 km radius from the station	+

[a] Expected sign of relationship.

main road or stations not located on the same road but nearby (measured by straight-line distance) were classified as one group of stations. This process of grouping did not allow any one group of stations to include stations more than 5 km apart. This 5 km rule was selected because of the identification of an average 2.5 km median search radius by stations (see section 4.3.4). We anticipate that competition may be strong amongst stations in the same group, so that price differences might be small. The twenty groupings are shown in figure 7.

The questionnaire survey shows that most petrol retailers are price-sensitive and that price competition is the most important factor for price setting. As a consequence, we include LOWPRICE to measure the lowest ('median-extracted') price amongst the other stations within the 2.5 km radius of the given station. It might be expected that LOWPRICE has a positive relationship with price.

6.2 Results

The regression models were fit by using ordinary least squares (OLS). In each case, the full set of variables was included and then nonsignificant variables were deleted until only variables significant at the 10% level remained. This is one of several approaches to regression modelling (for example, see Haining, 2003).

The OLS module in SpaceStat was used (Biomedware, http://www.biomedware.com). This also provides essential regression diagnostics, including a check for multicollinearity, the Jarque – Bera test for normality of errors, and tests for heteroskedasticity of errors (Brusch – Pagan and Koenker – Bassett tests). There are also tests for residual spatial dependence—a general Moran test for autocorrelated residuals, and several

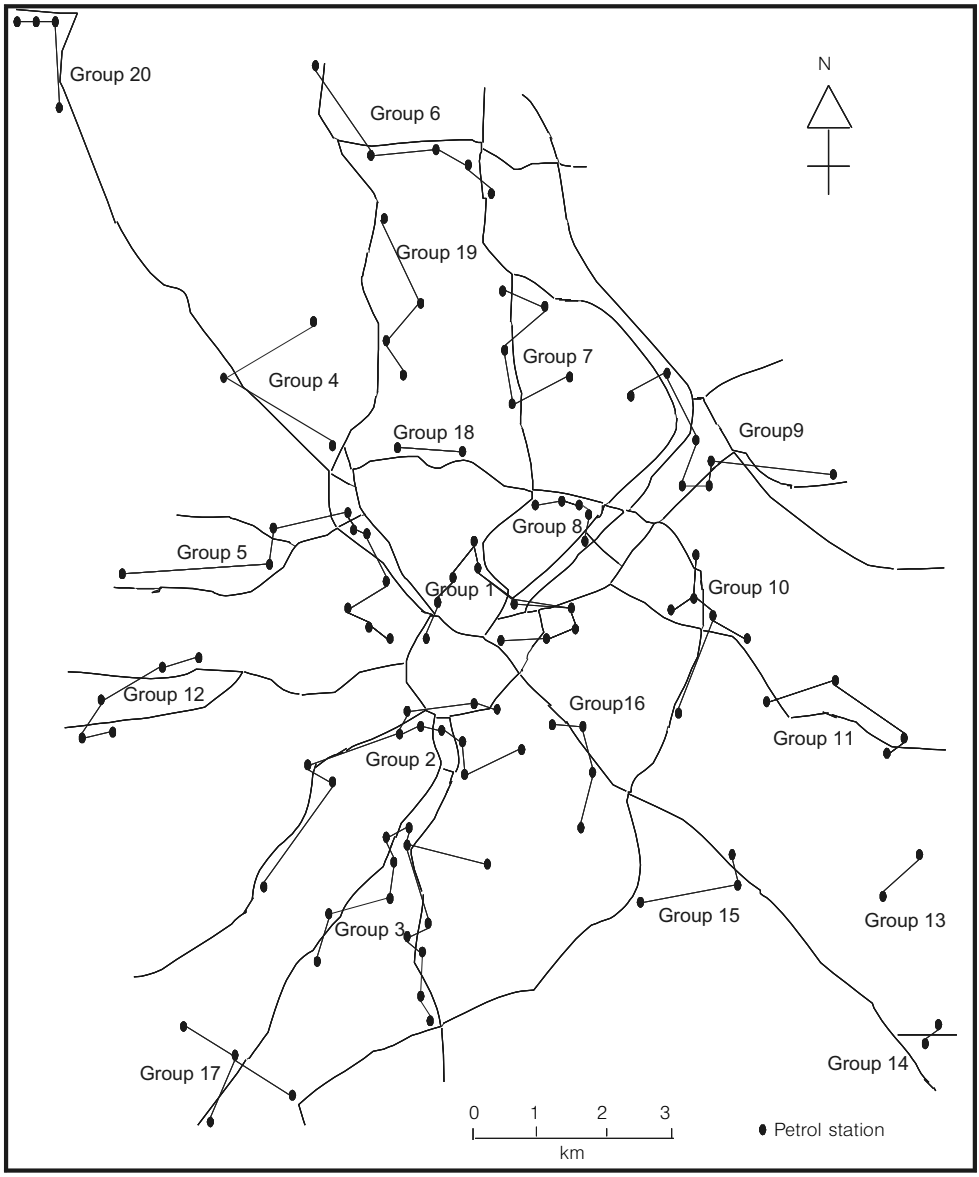


Figure 7. Groups of stations used for analysis in 1995.

Lagrange multiplier tests that can be used to suggest an alternative specification if spatial dependence is detected in the residuals (Anselin, 1988; Haining, 1990; 2003).

There were no multicollinearity problems amongst the predictors in any of the models. The largest multicollinearity condition value was 14.0, and most were less than 10.0 (values greater than 20 indicate a problem with multicollinearity). The Jarque – Bera test rejected the null hypothesis (of normality of errors) in the case of 4 March 1995, 18 March 1995, and Model B [see also figure 3(a)]. Tests for error heteroskedasticity retained the null hypothesis (of homoskedasticity) in all cases except 15 April 1995 (see table 9, over).

In the case of 7 January 1995 and 15 April 1995 the variable SAME was significant. This is, in fact, a spatially lagged form of the dependent variable, and more than half of

Table 9. Regression coefficients for variables significant at the 10% level in the final model for 1995.

Variable	7 Jan	21 Jan	4 Feb	18 Feb	4 March	18 March	1 April	15 April	Model B
APPEAR	0.48								
CLASSR	0.45	0.62	0.59	0.62	0.84	0.52	0.58	0.52	0.79
CORNER	−0.72								
LOCATION			0.61			0.66		0.55	
LOWPRICE	0.22					0.19			
MARKET	1.16	1.41	1.30	2.06	1.53	1.79	1.54	1.55	1.63
SAME								0.11	
RING				−0.98					
Constant	−0.24	−1.45	−1.21	−1.80	−1.31	−1.59	−1.51	−1.70	−1.55
$R^2 \times 100$ (%)	31.0	27.3	23.3	29.9	26.0	26.4	16.0	31.1	29.8
R^2 (adjusted) $\times 100$ (%)	27.7	26.0	21.1	27.9	24.6	23.7	14.5		28.5
p-value									
Moran	0.99	0.31	0.28	0.99	0.99	0.17	0.58	0.42[a]	0.57
Jarque–Bera	0.96	0.16	0.68	0.14	0.00	0.00	0.07		0.00
Breusch–Pagan	0.06	0.79	0.59	0.64	0.59[b]	0.91[b]	0.69	0.02[b]	0.79[b]

[a] Lagrange multiplier test for spatial error dependence.
[b] Replaced by Koenker–Bassett test.

the sites have reciprocal nearest neighbours—that is, if station A is station B's nearest neighbour, station B is station A's nearest neighbour. In these two cases, therefore, the model was refitted with use of a spatial lag representation of the variable SAME and utilising maximum likelihood to fit the model. As a result, the variable SAME was no longer significant for 7 January 1995 (at the 10% level) but remained significant in the case of 15 April 1995. This procedure was also implemented in SpaceStat.

6.2.1 Parameter estimates

In table 9 we show the regression coefficient estimates for the nine models. CLASSR and MARKET are significant in each equation. LOCATION is significant in three of the eight model A equations and has the correct sign. From table 9 we can see that in model A three types of variables—representing site characteristics (APPEAR), location attributes (MARKET, LOCATION, CORNER, and RING), and competition (CLASSR, LOWPRICE, and SAME)—appear in one or more of the equations. In classifying stations into one of four areas of Sheffield, the centre is used as the reference so that the negative sign for the ring area indicates significantly lower prices there on 18 February 1995. Model B only has two types of variables—representing location (MARKET) and competition (CLASSR).

The level of explanation (R^2) reported in table 9 varies between 16.0% and 31.1%. The level of explanation is clearly not strong. Unexplained variation may reflect further site-specific effects or other factors in price setting, including demand-side factors, which will be considered in section 6.2.3 and section 7.

6.2.2 Data issues

There are some outlier and leverage cases in the fitted models. A leverage case is an observation (i) that has a large affect on the regression fit. In table 10 we list the outliers in the models, and it can be seen that some appear several times, which indicates that these stations may represent special situations. Station 1201, with a large negative residual, charged the lowest price in the study area from 21 January to

Table 10. Outliers (standardized residuals $\geqslant 3.0$ or $\leqslant -3.0$).

	7 Jan	21 Jan	4 Feb	18 Feb	4 March	18 March	1 April	15 April	Model B
Station	0	1201	1201	203	203	203, 210	203	203, 403, 802	203
Value		−3.6	−3.3	3.12	3.75	4.11, 3.28	3.0	3.65, 3.30, −3.34	3.67

4 February 1995. At that time a section of the ring road was being rebuilt. The cheaper price was being used to attract customers and compensate for the inconvenience and difficulty in getting to the site. When the road rebuilding was finished the price went back up. Station 203, with persistent positive residuals, has a small number of pumps and a car-sale business. Station 210, with a large positive residual, has a car-wash service.

Cases 603, 609, 903, 904, 1106, 1304, and 1901 are attached to supermarkets and represent the MARKET variable. These persistently have large leverages and indicate that the significance of this variable is dependent on a few cases. However, the site questionnaire and interview data support the inclusion of this variable.

6.2.3 Mapping of residuals

The Moran test using inverse distance weights (Cliff and Ord, 1981) retained the null hypothesis of no residual spatial autocorrelations for all nine models (see table 9). These test results indicate there is no unexplained spatial variation in the datasets for 1995. However, this is a global, or 'whole-map', test and it is still of interest to look in more detail at the map of residuals.

Figure 8 (see over) shows cases with positive and negative standardised residuals for the eight versions of model A. The map for model B is very similar and is not reproduced here. If a station has negative or positive standardised residuals six or more times (out of the eight model fits) the station is shown as a negative residual case or a positive residual case, respectively. Cases with the same residual sign are often located on or near the same road. In figure 8 we highlight some of these by using the symbols + or − to denote the dominant residual sign. These areas may reflect an intense, localised area of interaction that is more intense than can be accounted for by the CLASSR variable in the regression model.

The map of residuals shows many negative residuals (prices lower than predicted by the model) in the northern area of the city and just to the southwest of the city centre. These two areas contain relatively low-income wards including Nethershire (45% car ownership), Brightside (55% car ownership), and Sharrow (38% car ownership). If demand elasticity is large in absolute value then the lower prices just to the southwest of the city centre might be a response to high levels of potential business. This would be associated with traffic from the more affluent areas of Sheffield converging on the city centre for work, shopping, or leisure. A large proportion of the positive residuals (prices higher than predicted by the model) seems to be on the outer western and southern edges of Sheffield. These are higher income areas. From the 1991 Census, Dore ward had 68% car ownership, Ecclesall ward had 81% car ownership, and Hallam ward had 76% car ownership.

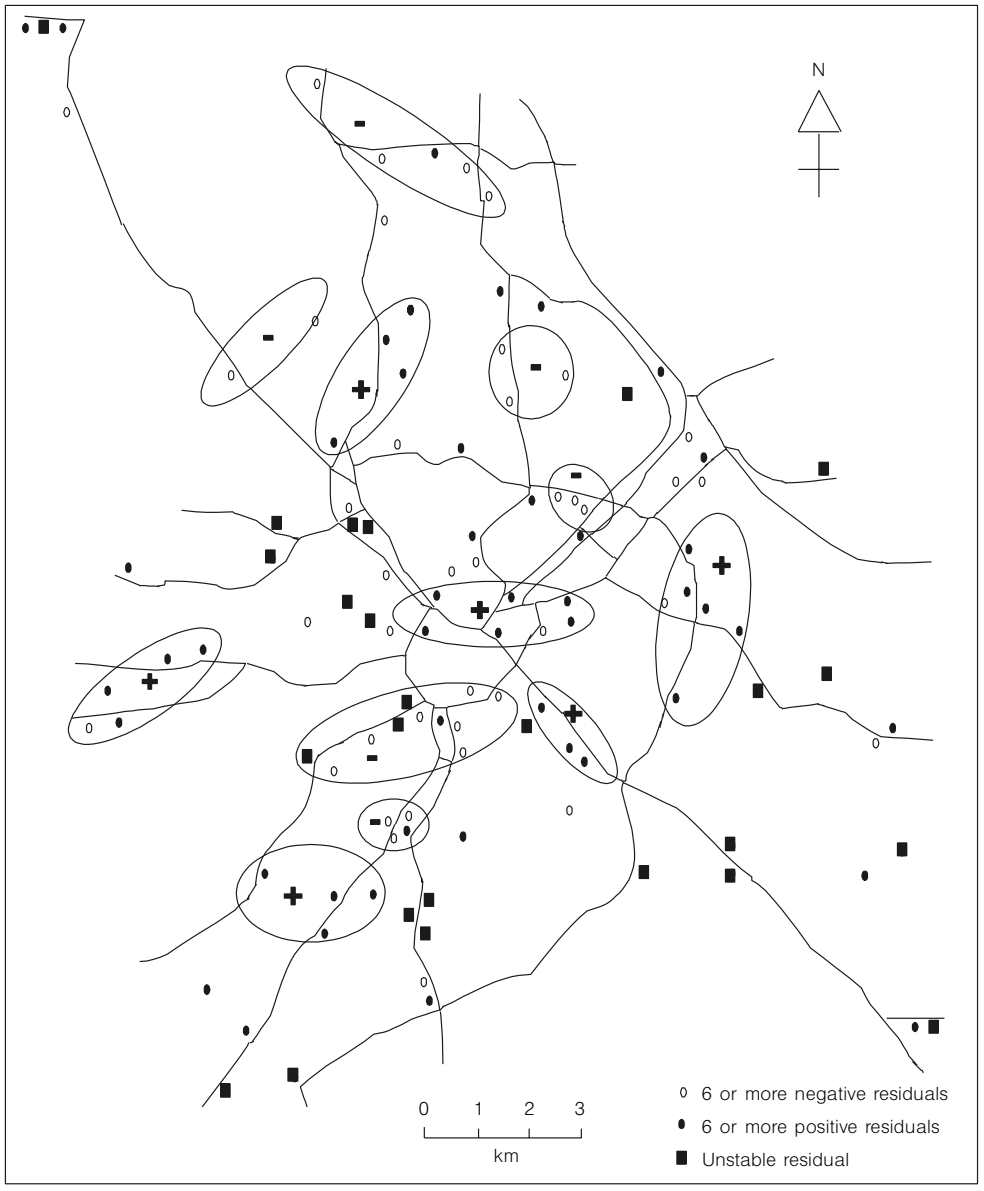


Figure 8. Mapping residuals for model A, 1995.

7 Regression modelling: 1997

7.1 Additional predictors and expected relationships

Notwithstanding findings reported in section 6, it is possible that demand-side factors need to be included in the model specification in order properly to estimate the importance of competition and location effects. So, in addition to the supply-side variables used in modelling the 1995 data, and drawing on the evidence of the household survey, a predictor measuring the amount of demand around each station (CARS) was included. Drawing on the evidence of the 1995 analysis (section 6.2.3) we included a predictor measuring the percentage of higher income households in the neighbourhood of a station (TYHOUSE). Note, however, that the household survey does not suggest that higher income households are any less sensitive to price than those on lower incomes.

The variable CARS is meant to represent operationally the level of local demand and is a count of the number of cars in a 2 km radius of the station. Stations with a large number of cars within a given radius are expected to charge a lower price (all things being equal) because of the returns to be made from successfully winning a large share of a relatively large nearby market. The variable CARS is expected to have a negative relationship with price, although this argument would only hold providing the retailer was faced with competition from other local retailers.

The variable TYHOUSE is introduced to describe the income level of the area around a petrol station. It is measured as the percentage of detached and semidetached houses in a 2 km radius. Noting the earlier caveats about the price sensitivity of individuals on different incomes, we would expect the variable TYHOUSE, which is an aggregate measure, to have a positive relationship with price. The TYHOUSE and CARS variables had to be measured with use of 1991 Census data at the enumeration district level.

7.2 Results

The same fitting procedure was followed as for the 1995 datasets. In the 1997 datasets there was again the situation that the variable SAME was significant in one dataset (1 March 1997). The procedures outlined in section 6.2 were again followed. There were no problems of multicollinearity amongst the predictors; however, there were problems of nonnormality of errors in several of the analyses according to the Jarque – Bera tests [see also figure 3(b)]. There are also problems of heteroskedasticity (see table 11). As the number of cases used for the modelling is large, we believe this problem is unlikely to undermine inference. However, this is an area requiring further examination.

Table 11. Regression coefficients for variables significant at the 10% level in the final model for 1997.

Variable	1 March	5 March	8 March	15 March	22 March	29 March	5 April	Model B
APPEAR	2.05	2.05	1.97	1.94	1.88	1.64	1.94	1.94
CARSALE	−1.17	−1.08	−0.95	−1.27	−1.08	−1.21	−1.19	−1.15
CLASSR	0.68	0.72	0.45	0.25	0.34			0.45
CORNER			0.63	0.82	0.70	0.88	0.94	0.61
DISMKT			−0.29					−0.25
GARAGE	1.31	1.14	1.21	1.21	1.15	1.24	1.11	1.18
INNER	−0.80	−0.87	−0.70					−0.63
LOWPRICE			0.65	0.51	0.35	0.52	0.66	0.58
LOCATION						0.69		
MARKET			1.11	0.88	0.81	0.88	0.94	1.09
SAME	0.14							
RING				0.78	0.93	0.93	1.00	
OUTER					0.53			
Constant	0.20	0.31	0.10	−0.47	−0.80	−1.64	−0.46	0.55
$R^2 \times 100$ (%)	57.8	55.6	60.1	56.3	56.1	56.4	49.2	59.4
R^2 (adjusted) $\times 100$ (%)		53.1	55.9	52.3	51.5	52.4	45.2	55.1
p-value								
Moran	0.053[a]	0.16	0.72[a]	0.050	0.72	0.051	0.03	0.72[a]
Jarque – Bera		0.01	0.10	0.01	0.04	0.01	0.00	0.01
Breusch – Pagan	0.00	0.01[b]	0.00	0.00[b]	0.00	0.01[b]	0.00[b]	0.01[b]

[a] Replaced by Lagrange multiplier test for spatial error dependence.
[b] Replaced by Koenker – Bassett test.

7.2.1 *Parameter estimates*
The results of the regression modelling are shown in table 11. All three types of supply-side variables—representing site (APPEAR, CARSALE, and GARAGE), spatial competition (CLASSR, DISMKT, LOWPRICE, and SAME), and location characteristics (CORNER, INNER, LOCATION, MARKET, OUTER, and RING)—are represented in the set of significant variables. However, three variables (CARSALE, DISMKT, and INNER) have perverse signs relative to our expectations. Neither of the two demand-side predictors are significant. Overall, a much higher level of variance explained has been achieved (49.2% – 60.1%) compared with the 1995 data (16.0% – 31.1%) but levels are still not high.

7.2.2 *Data issues*
The only outlier case is station 1704 in model A (29 March 1997) and model B. Station 1704 has a large positive residual. It is located in the suburban village of Dore, a high-income area that has large numbers of retired and elderly people. The garage offers a range of car services to local residents but effectively has a local monopoly. This may explain the special circumstances of this station. Four sites have large leverages and are all on the edge of the study area. Cases 3002, 3003, and 3004 are located in Stocksbridge in the northwest of Sheffield. Deletion of these four (3002, 3003, 3004, 1904) cases does not affect the statistical significance of the included variables.

7.2.3 *Mapping of residuals*
Following the approach we took in section 6.2.3 we again mapped the model residuals. In figure 9 we show the spatial pattern of residuals for model A, where a site is flagged if it has a positive (or negative) residual at least five out of seven times. Residuals with the same sign are distributed in a cluster pattern, and a large proportion of positive residuals seems to be present in the area just to the southwest of the city centre. There are two notable reversals of the situation in 1995 (see figure 8) to the north and west of the city centre (positive residual groupings becoming negative), and there are other local-area sign switches too. A large proportion of negative residuals seems to be in the northern and western areas of Sheffield.

The residuals from the 1997 data modelling display spatial structure. The Moran test, utilising inverse distance weights, shows the presence of positive spatial autocorrelation for 15 March 1997 and 5 April 1997. However, we have not, to date, been able to provide a satisfactory explanation for this nor have we been able to develop a satisfactory model that accommodates this spatial dependence. There remain systematic spatially structured features in the data that the model with supply-side and demand-side variables has been unable to capture. This is an area requiring further work.

8 Conclusions
This paper is a contribution to the analysis of spatial price variation, drawing on the theoretical literature on spatial pricing and previous empirical work to try to assess the role of supply-side and demand-side factors in explaining spatial price variation, with particular emphasis on location and competition factors.

The results of the empirical study for the 1995 data reveal some compelling evidence for the role of group competition effects and the important role of supermarkets in the Sheffield retail petrol market. Although there is evidence of localised nearest-neighbour competitive effects the regression analyses reveal evidence of similar competitive effects operating through geographically defined groups or clusters of retail outlets. The results of the regression analysis also show the importance of location attributes. The lowest prices are found at sites attached to supermarket

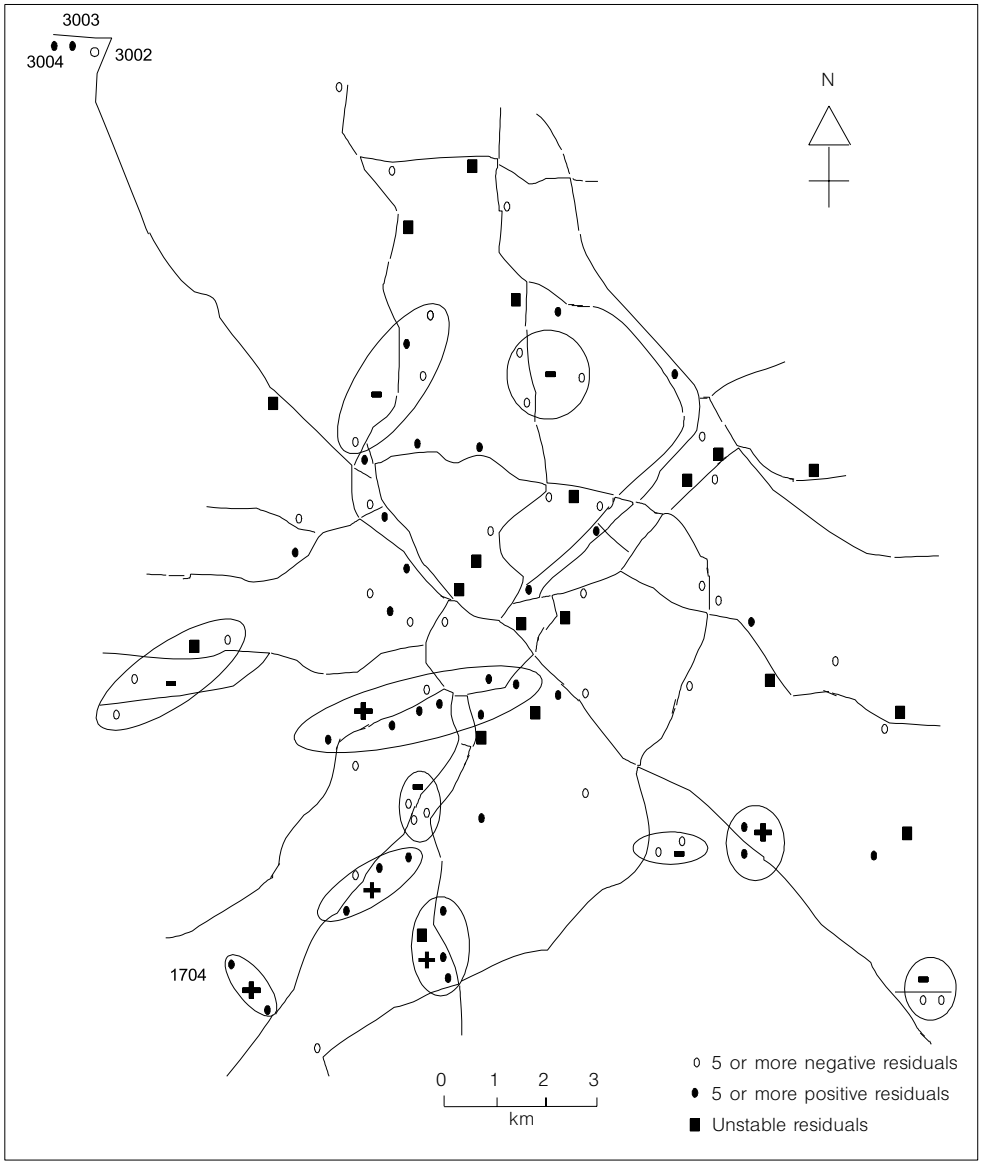


Figure 9. Mapping the residuals of model A, 1997.

stations and at stations on main roads. The results of the regression analysis show that site characteristics are not important in explaining retail price variation for 1995. Of the six site characteristics, only the appearance variable (APPEAR) was statistically significant, and in only one model.

The 1997 analysis included demand-side variables, but none of these was significant. Perhaps these need to be considered afresh and measured in different ways. What is apparent, however, is that three site attributes are consistently important (APPEAR, CARSALE, and GARAGE). Location and competition effects continue to be important (CLASSR, CORNER, LOWPRICE, and MARKET; see also the endnote to this paper). As with the 1995 analyses, results still show spatial structure in model residuals. This may indicate the need to measure attributes relating to demand or

spatial competition differently. They may indicate the need to introduce further additional variables relating to the geography of the Sheffield retail petrol market.

How far is it necessary to give further attention to the effects of possible collusion (Salop, 1986; Slade 1987) or the role of ownership structures (Haining, 1986; Shepard, 1993)? Petrol companies may be successfully segmenting the market. This is an interesting area for exploration—although it is one where it is likely to be very difficult to obtain reliable information. How far are the companies able to operate policies that enable them to charge higher prices in areas where it is believed the market will acquiesce to those higher prices? In the United Kingdom there has been a tendency for motorway service stations to charge higher prices because the market is, in a sense, captive. Market segmentation might also be operating successfully at the intraurban level, perhaps underpinned by subtle and difficult-to-measure notions of convenience, 'quality of service', and safety—or perhaps by indifference or even ignorance on the part of many consumers. This is an area requiring further investigation.

The household survey showed that consumers treat petrol as a homogeneous good. However, that does not mean that this extends to the decision about where to buy petrol. Some consumers like to purchase from stations because they attach particular importance to short waiting times or to the range of services or commodities available at that site. They may attach importance to the physical condition of the station. When consumers stop at a petrol retail outlet they are buying a commodity that has a number of attributes, "each of which yield satisfaction in consumption" (Laidler and Estrin, 1989, page 112). This satisfaction extends beyond petrol and the particular brand on sale to include attributes of the station as well as other services offered at the site (Ross, 1988). Lancaster (1966; 1971) argues it is the bundle of attributes and the satisfaction that derives from their consumption that underlies consumer choice and explains why movements in price at any one site may not translate into smooth movements in the level of consumption from that site. Lancaster's theory of consumer choice suggests that any future household survey may need to pay more attention to those attributes from which a consumer derives satisfaction when they decide to stop to purchase petrol and to the trade-offs they are willing to make between different qualities of attributes. Given the mix of attributes on offer at different retail sites (of which price is but one) we need to know where, on aggregate, consumer preferences lie in respect to these different attribute qualities. However, the situation may be more complicated. Petrol is purchased as part of a trip made for other reasons. The specific purpose of the trip (for leisure, work, or shopping) may affect how the consumer values any particular combination of attribute qualities that are present at a site. What may be valued on a journey to work (convenience and speed) may be less important on other occasions.

Endnote

Since the research for this paper was undertaken, consumer sensitivity to petrol prices may well have heightened as a consequence of campaigns such as *The Sunday Times* 'Rip off Britain' campaign, which sought to focus attention on prices in several areas of the economy. Other newspapers have engaged in similar campaigns more directly targeted at petrol. In September 2000, in common with events elsewhere in Western Europe, there was protest action on the price of petrol, lasting for three days, by, amongst others, farmers and hauliers. Supplies were disrupted for over a week. This too brought into focus the issue of petrol prices.

Acknowledgements. The research reported here was undertaken while Xiaoming Ning was on a British Council research training award and later when he was a PhD student at the University of Sheffield. The studentship was supported by grants from the CVCP and the University of Sheffield. The support of the University of Sheffield, the British Council, and the CVCP is gratefully acknowledged. Thanks go to Harvey Armstrong and Doug Watts for their help in taking this work forward, to Paul Plummer and Eric Sheppard for advice at various stages, and to Vania Ceccato for her assistance with aspects of the data analysis. Thanks are also due to three anonymous referees and the editor, who made valuable suggestions to improve the final version of the paper. All errors, of course, remain the responsibility of the authors.

Data

The data used in this research is available for downloading at http://www.geog.cam.ac.uk/people/haining/data.

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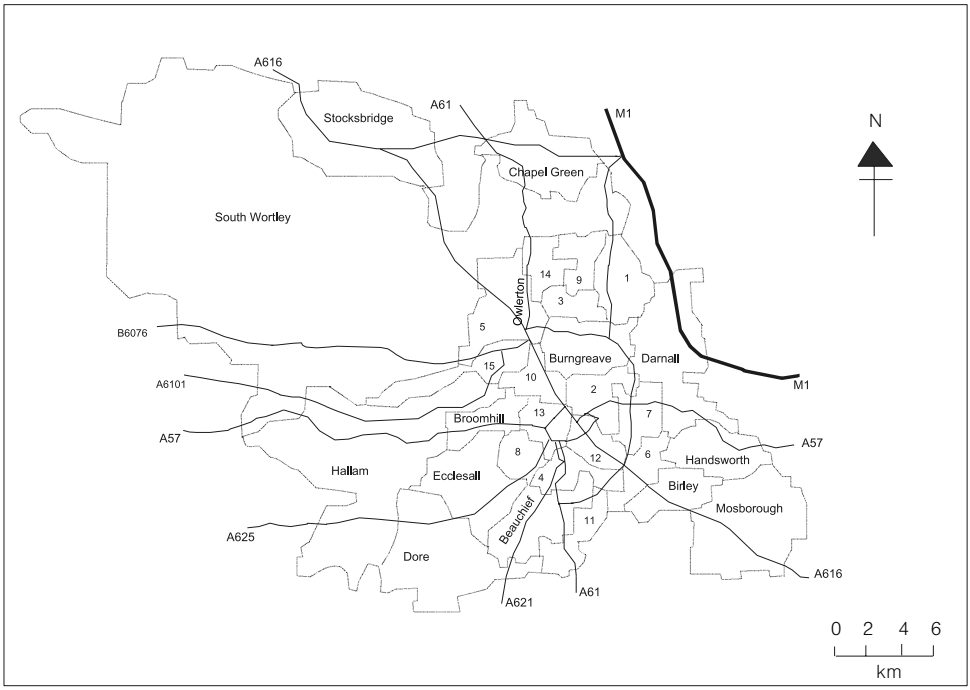
Appendix



1 Brightside
2 Castle
3 Firth Park
4 Heeley
5 Hillsborough
6 Intake
7 Manor
8 Nether Edge
9 Nether Shire
10 Netherthorpe
11 Norton
12 Park
13 Sharrow
14 Southey Green
15 Walkley

Figure A1. Wards in Sheffield.