Price Leadership in UK Food Retailing: Time Series Representation and Evidence

Tim Lloyd

Abstract

This paper analyses the price of a common basket of products sold in each of the UK's four largest retail chains to assess propositions regarding price leadership. Data used in this investigation represent weighted average prices of a large group of branded and non-branded products purchased nationally at weekly intervals over a three and half year period and cover purchases in 37 product categories. The data are analysed using vector autoregressive methods, a convenient framework for a statistical investigation of this sort, owing to the time series properties that the price data exhibit. The paper introduces the concepts of strategic and tactical price leadership. Since these correspond to parameter restrictions in the vector autoregression, the statistical tests have a economically meaningful interpretation. While the empirical findings are preliminary, they indicate that Tesco, the largest of the retail chains, acts as price leader in both the strategic and tactical senses.

Please address all correspondence to :
Dr. Tim Lloyd
School of Economics
Sir Clive Granger Building
University Park
University of Nottingham
Nottingham
NG7 2RD, UK.

tim.lloyd@nottingham.ac.uk

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I. Introduction

Competition among national food retail chains has emerged as a focal issue in public policy in recent years. In the UK this has been highlighted by the on-going statutory inquiry - the second in seven years - in to the conduct of grocery multiples by the UK's foremost anti-trust authority, the Competition Commission (Competition Commission 2007). A persistent theme in the Competition Commission's scrutiny of supermarket behaviour over this period has been retail price competition, and it is to this aspect of the public policy debate that the current paper seeks to contribute, albeit with methods and results that are of a preliminary nature. The paper evaluates propositions relating to the existence and form of price leadership among the UK's four largest grocery multiple retail chains using data relating to October 1999 to October 2002. While the industry maintains its pricing reflects unbridled competition within the sector, the recent agreement by the supermarkets to pay fines amounting to £116 million for their involvement in collusion on pricing of milk and dairy products during 2002 and 2003 casts some doubt over this (Office of Fair Trading, 2007).[1]

Being one of the most highly concentrated grocery markets in the world, the UK offers an ideal opportunity to examine the issue of price leadership: the largest four firms currently account for 76% of the grocery market, with the largest retailer, Tesco, having twice the market share of its nearest competitor and accounting for almost one in every three pounds spent on groceries in the UK (TNS Worldpanel, 2007). It should be noted however that during the period which price behaviour is formally analysed in this paper market shares of the so-called 'Big four' supermarkets, namely Tesco, Sainsbury ASDA and Safeway were 24.6%, 20.7%13.4% and 12.5% respectively (see Rickard 2006 p.260).

Supermarkets themselves readily acknowledge that prices set by their competitors represent the principal driver in their own pricing (Competition Commission 2000, pp.135). Whether a firm operates a policy whose aim is to offer persistently low prices on a wide range of products (the so called Every-Day-Low-Price, EDLP policy) or the more traditional policy reliant on deep discounts on a relatively narrow range of core products ('Hi-Lo' pricing) all major retailers routinely undertake detailed monitoring of competitor pricing, either via covert price collection or through market research companies who provide and process Electronic Point of Sale (EPOS) data on their behalf. Price surveys are typically conducted on a weekly basis and in some cases cover the entire products range, although more commonly they are confined to between 1,000 and 4,000 product lines (see Competition Commission 2000, Appendix 7.1).

For obvious reasons, competitor price monitoring is an essential ingredient of any price matching exercise, and as in other highly concentrated industries, price-matching guarantees form a key component in marketing strategy in UK food retailing. Recent examples include the "Good Food Costs Less at Sainsbury's" campaign , described by BBC news as "probably the best known advertisement in retailing" and the Tesco "Price Check" in its "Every Little Helps" campaign, whereby prices of up to 10,000 products are compared in the major retail chains. Most notably however was the "That's ASDA Price" campaign in which the retailer claimed to be the UK's 'Lowest Priced Supermarket', a claim that they were subsequently forced retract by the Advertising Standards Agency (Advertising Standards Authority 2005) following a complaint by Tesco. ASDA have

[1] Following an investigation in to the sharing of commercially sensitive information among ASDA, Tesco Sainsbury and Morrisons and Safeway and dairy processors during 2002 and 2003 all but Tesco has admittedly involvement in anti-competitive practices and agreed to paid fines of £116 million. Tesco's involvement is still the subject of the on-going investigation. See Office of Fair Trading 2007 for details.

however been winner of the Grocer Magazine 'lowest priced supermarket' for the past 10 years, an accolade which it uses widely when promoting the ASDA brand. Clearly, the label 'price leader' confers benefit to the retailer: not only does it add value to its overall brand image in mind of the price-conscious consumer but it serves to evidence the relentless competition that the supermarkets claim to face.

Price leadership is not by necesstity pro-competitive of course. Indeed, while *barometric* price leadership may directly reflect the benign pricing of a market leader responding more quickly than its rivals to changing cost and demand conditions, the practice is more commonly ascribed to the presence of anti-competitive behaviour. Two models characterise the literature, (a) *dominant firm* and (b) *collusive* price leadership (see for example, Rickard 2006; Schrefer 1990). In the former, the distribution of firm size is highly skewed such that one firm dominates an otherwise competitive fringe. The dominant firm sets its own price based upon the market demand not served by the fringe - its residual demand - and by using its market power charges above marginal cost. At this market price economic rents accrue to the leader and at least some of the firms in the competitive fringe, encouraging investment in additional capacity by the fringe and/or new entrants, which unless the dominant firm can prevent, via entry barriers or other deterrents will drive prices and the dominant firm's market share down. One option is tacit collusion with the competitive fringe and given its position of dominance, punishment of smaller rivals deviating from the set price may be a credible threat, even in the longer term. Nevertheless, where firms are more or less equally-sized selling to at least some degree differentiated products the dominant firm model of price leadership may be inappropriate.

As with the tacit collusion in the dominant firm case, collusive price leadership (Rotemberg and Saloner, 1990) is an inherently dynamic model of oligopolistic competition in which price announcements by one firm are quickly matched by rivals. While each firm will typically profit more as a price leader, whether it becomes price leader is dependent upon the balance between cost and demand conditions for the (differentiated) products it sells relative to others in the industry. The decision to lead is also based upon relative informational advantage, so that it may pay some firms to follow where another firm is better informed about the market. More generally, firms may decide to follow a leader's price change if they consider the one-off gains to deviating from the price matching policy less than the losses they would incur if the leader retaliated by reversion to a non-cooperative strategy (i.e. a persistent price war). Such a price leader-follower model may be dynamically sustainable if the threat of non-cooperative behaviour is credible. In the model, the price leader also has a strategic calculation of its own to perform. Whereas changing price in response to changes in relative demand and cost conditions induces one-off gains at the expense of the follower(s) these need to the traded-off against the likelihood that rival firms revert to non-cooperative behaviour themselves.

Tacit collusion is not confined to conduct over time but may result where firms compete in several markets, so that because of the threat of retaliation in one market, a firm may mollify it pricing behaviour in another (see Bernheim and Winston 1990). In essence, whether the fruits of tacit collusion be brokered over time or across markets, the sustainability of price leadership in these models critically depends upon the credibility of threat enforcement in the event that firms deviate from the tacitly agreed norms. Tactics that signal behaviour to rivals or commit a firm to predetermined actions are likely to bolster the sort of tacit collusion essential in price leadership and it is in this light that the price matching guarantees, so commonly observed in supermarket campaigns, that gives cause for concern. According to this line of reasoning (see Logan and Lutter 1989; Zhang

1995) price matching, particularly as part of national advertising campaigns, are effective signaling devices, not only to customers but rivals too. Price guarantees thus serve a dual purpose in the market, informing competitors of the likely response in the event of price undercutting, as well as signposting its pro-competitive credentials to potential customers. It is in this way that price matching may actually stifle competition as part of a strategy of tacit collusion, and in so doing lead to prices remaining more stable and at a higher level than would have prevailed in the full heat of open competition. Two facets of price matching are also of relevance here. First, the guarantees typically apply to a limited range of products, allowing the retailer to recoup margins on background lines excluded from the promotion. Second, in markets best described as saturated, in which total demand for food in price inelastic, market share can only be won at the expense of rivals and thus strategies that deter price competition, and foster stability even if unintentionally so, are likely to be highly attractive. In their evaluation of price matching in regional grocery markets in the US Hess and Gerstner (1991) found evidence to suggest that price competition was weaker in the presence of price matching, in that the low cost supermarkets would allow prices of price-matched products to rise more than those excluded from the policy.

One other aspect of supermarket retailing is also of relevance to the issue of price leadership. Major UK retailers all rely on price promotions (albeit to varying degrees) as an integral part of their marketing strategy. Evidence submitted to the Competition Commission's first supermarket inquiry, revealed the extent of discounting in the grocery marketeer's armory. With the exception of ASDA, the large multiples offered between 500-1,500 promotional offers at any one time, sales of which could represent up to 30% of total sales, from 20,000 or more product lines (Competition Commission 2000, p.117).[2] Even ASDA, the most notable EDLP mainstream retailer, would typically promote around 50 products per week at an average discount of 35% (Competition Commission 2000, p.80). Furthermore, the companies stated that the common practice was *not* to respond to price promotions in rivals owing to the time it takes for stocks to be amassed on promoted products. In this light it is clear why rivals might use discounting on the scale that they evidently do – they represent the only means for a retailer to obtain a price advantage that they are confident will not be matched by rivals. While promotional discounts are temporary, rarely lasting more than four weeks, providing they are rotated around the products in-store (and given large number of lines relative to those being promoted this is always feasible) retaliation by rivals is unlikely to be provoked. Promotions thus represent an acceptable means of competition and allow rivals to credibly offer seemingly pro-competitive price-matching guarantees without being seen as breaking rank from the pricing norm. Price leadership may be one way of signaling what the norm actually is. Seen in this light, promotions, price matching and price leadership are elements of imperfect competition that thrive on the oxygen of tacit collusion.

In sum, market conditions and common practices that prevail in the UK grocery sector suggest the possibility of price leadership in at least one of the three commonly acknowledged forms. While barometric price leadership is to all intents and purposes benign and would tend to result in the competitive outcome, it reflects changes in company costs. While these are not available outside the realms of a statutory inquiry, the Competition Commission could not find sufficient evidence to support such barometric leadership in their 2000 Inquiry (see below). As a result, where price leadership is detected,

[2] Average sales uplift on promoted products is typically 200% , although increases of 3,000% were reported for the most popular BOGOF-type offers. As a result, promotions are planned well in advance as part of a coordinated marketing strategy to ensure supplies are available in-store to meet antipated demand. See Competition Commission 2000, p.117.)

it is likely to be indicative of imperfect competition. Prices set by a dominant or collusive price leader tend to be above the competitive level and it is for this reason that it attracts the attention of anti-trust authorities. So while the practice of price leadership is entirely consistent with the actions of a low-cost firm wishing to advertise this advantage over its rivals, even in highly concentrated sectors, its presence is evidential of imperfect competition although nothing more.

Against this background, this paper presents preliminary results of an econometric framework indicate the presence of a price leader in the UK during the sample frame. Before the results are provided, a short review of the price leadership investigation published in Competition Commissions 2000 report is given, this being the only similar exercise published relating to the UK grocery sector. In Section III the data is presented and following an brief explanation of the empirical methodology in section IV, results are presented in Section V. The paper then concludes.

II. The Competition Commission (2000) Price Leadership Analysis

As part of their statutory inquiry in to multiple food retailers published in 2000, the Competition Commission investigated the issue of price leadership in some detail. The Commission considered econometric evidence supplied by Sainsbury and Tesco and in addition, undertook a detailed descriptive and statistical analysis of their own. The Competition Commission study analysed relationships between the weekly (promotion-inclusive) prices of 18 specific products sold by five mainstream retailers (ASDA, Morrison, Safeway, Sainsbury and Tesco) and one discounter (Aldi). The products included fresh and ambient goods in branded and own-label forms over a three year period spanning September 1996 to September 1999. [3] The analysis was designed to detect any systematic pattern in the timing of price changes, most notably price leadership, '. . . where one or two multiples consistently act as leaders for price changes with other multiples following' (Competition Commission 2000, p.135). Graphical inspection of the data on a product-by-product basis suggested that Tesco and ASDA were potential price leaders; price changes originating in Sainsbury and Safeway being unusual. The Commission noted that Morrison's prices changed little over the period and Aldi prices were largely independent of those offered by the other retailers.

Informed by this graphical evidence, the Commission performed regression analysis, confining their investigation to the prices in the 'Big Four' supermarkets, namely ASDA, Safeway, Sainsbury and Tesco. Using single equation methods, the price change of a product in one supermarket was regressed on a constant and the lagged price change of the same product in a rival, for all ($6 \times 2 = 12$) pairwise permutations of rivals and applied to each of the 18 products. Using the statistical significance of the lagged price coefficient at the 5% level as its evidential criterion, the Commission detected price leadership in 6 of the 18 products, with Tesco and ASDA found to price lead in roughly equal measure, corroborating the indications from visual inspection of the prices themselves.

The Commission then considered the responses of Sainsbury and Tesco, who were critical of the empirical approach that had been adopted on methodological and statistical grounds. They pointed to the bivariate nature of the regression models and the presence of

[3] For example, bread (800g white medium sliced own brand loaf); semi-skimmed milk (4 pint plastic own brand bottle); Wall's sausages (1lb pack, thick, fresh) Kellog's Cornflakes (750 g box); baked beans (own-label economy 400g tin) and Andrex kitchen towels (white, quilted three-pack). For the complete details see Table 1 Appendix 7.10, p.143 of Competition Commission (2000).

autocorrelated residuals in many of the price equations, short-comings which the Commission duly acknowledged in their report (Competition Commission 2000, p.149). These companies undertook extensive econometric analyses of their own but the alternative frameworks adopted were themselves criticized by the Commission. Specifically, Sainsbury's modelling had ignored the time series properties (i.e. non-stationarity) of the price data used; Tesco's definition of leadership appeared unduly restrictive[4] and both used a single equation framework for the estimation of price relationships.

Sainsbury estimated price leadership regressions using price levels of 20 products in three supermarkets. In contrast, Tesco used the price changes of 840 products in seven supermarkets, estimating price equations for individual products and in aggregate using pooled data, for both pairwise regressions and en masse using seven retailers.

Although neither exercise detected a price leader, the results reported by the two companies offered contradictory views of price leadership in the market. Whereas Sainsbury could find no evidence of price leadership in the 20 products it had selected, Tesco found that leadership was a relatively common feature among the 840 products it had analysed but because no systematic pattern of leadership/followership could be discerned among the seven retailers, Tesco concluded with Sainsbury that no retailer acted as price leader in the UK market. Given the differences in coverage and approach adopted the Commission did not attempt to reconcile the findings that the two companies presented preferring simply to note, 'These exercises were intended to show that there was no consistent pattern in price leadership or following across a broad range of products." Competition Commission 2000, p.138).

Retailers were also required to supply data on the costs of the 18 products to allow the Commission to assess whether the leadership it had detected was barometric in nature and thus reflected changes in costs of the market leaders. Using graphical and regression-based methods the Commission found generally weak correlations between costs and prices, the latter being dominated by promotions, partly funded by suppliers. In some cases, cost changes were clearly not passed on to retail prices and the use of over-riders, the repositioning of margins and persistent below-cost selling on core lines acted to blur the price:cost relationships in the products investigated. As a result the Commission did not find sufficient evidence to support barometric price leadership. The analysis did however lend weight to the message conveyed by many of the retailers in the course of the Inquiry that the principal driver behind price changes was the behaviour of competitors, particularly on certain core lines (the so called, 'known value items') (Competition Commission 2000 p.142).

In sum the Commission concluded that there was no clear price leader with in the industry, despite finding evidence of leadership in one-third of the products tested. Indeed, while the product-specific analysis facilitated detailed scrutiny of the timing of price changes they were only too aware that such specificity could only at best offer a partial view of the pricing of the 20,000 or more products typically available in the mainstream retailers. Of key concern was that intense competition may be concentrated in a very selective range of products (to the detriment of competition on the products more generally) and that it was in the interests of each retailer to maintain the *status quo*; to do

[4] In one set of models estimated by Tesco price leadership required the retailer to be the leader for at least four (from a list of six) other retailers and not being led by any of the retailers. Using this criterion, Tesco found evidence of leadership in 1.6 per cent of the 840 products considered.

otherwise may trigger a price war that would be in none of the supermarket's interests. In this respect a more broadly defined price index common to all supermarkets would have served as a useful complement to their product specific analysis, however none such series were available to them. However, data of this sort is what is analysed in Section V, details of which we now present.

III. Data

The adoption of electronic Point of Sale (EPOS) systems in UK supermarkets during the 1990s has meant that details of virtually every transaction conducted in multiple food retailers are now automatically recorded. By using a laser-read barcode or similar electronic identifier as products pass through the check-out, EPOS systems allow for a fully comprehensive and detailed record of all purchases. EPOS data include transactions in all stores (irrespective of format) owned by a retailer and take account of explicit price discounts (10% off), quantity discounts (buy-one-get-one-free) as well as loyalty card discounting. As such they offer an unparalleled (albeit privately owned) quantitative resource, unaffected by the sampling variability or the limited coverage of survey data.

The data used in this investigation derives from the EPOS data tapes that are held by Information Resources International (IRI), a leading market research agency. The data archive relate to the sales of the top UK supermarket chains, the so called, 'Big Four' (which, during the sample frame were Tesco, Sainsbury, ASDA and Safeway). IRI constructed price indices of a common basket of products sold in each of these retailers for 195 weeks over a three year and eight month period (January 1999 to October 2002 inclusive). The series, depicted in Figure 1, represent comparable national prices indices of an "all goods" basket of products for the most significant UK supermarket retailers and form the basis for the statistical investigation of price leadership reported in the following section.[5]

Key features of the data construction are set out below.[6] In order to provide a basis for comparison across retailers, the price indices are based on a common basket of products. The basket covers 36 major product categories that include fresh, chilled and frozen foods, in raw and processed forms; ambient foods (such as those in tins and packets) as well as a wide range of beverages (including soft drinks; caffeine-based products; beers, wines and spirits) and non-food items such as medicines, toiletries and pet food, (see appendix for a full list). As such the price series are broadly based and representative of consumer supermarket spending in general.[7] The categories are expenditure weighted in the price index using weights from UK consumer spending patterns and based upon the actual prices of several hundred 'indicator' products that are selected using the conventions adopted by the Office of National Statistics in compiling the Retail Price Index.

The common basket includes both branded and own-label products, for which there are separate requirements for inclusion in the list of indicator products. Specifically, only branded products sold in (at least 60% of the stores owned by) each retailer and only those

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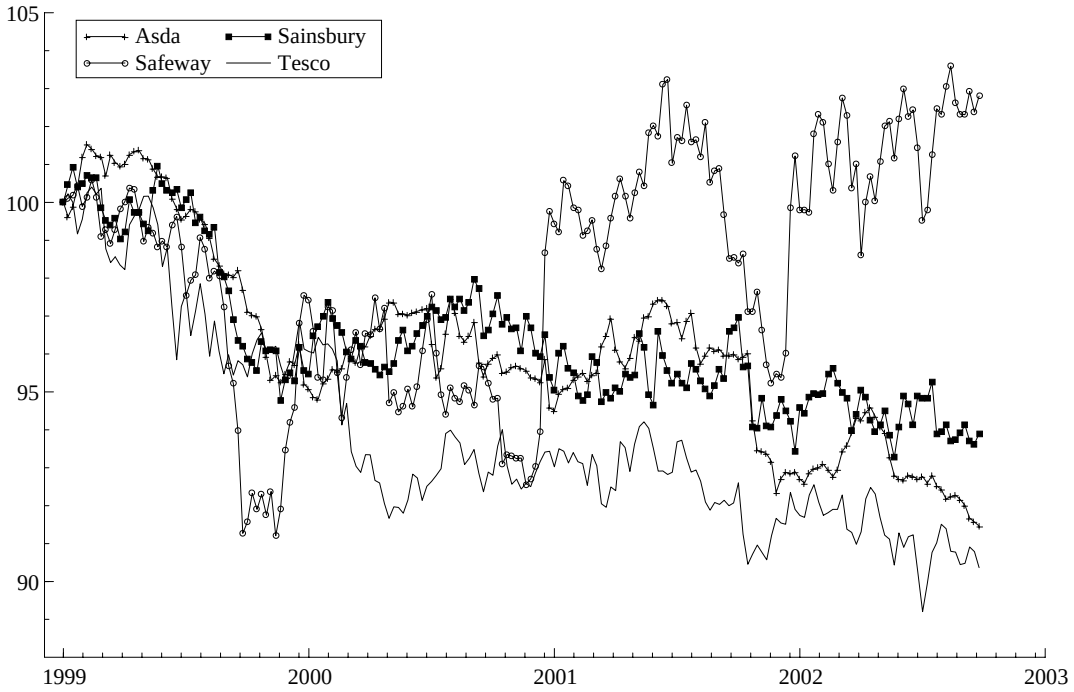
[5] I am indebted to Mr. Neil Thorington and Dr. Peter Cain of Information Resources Incorporated for granting access to these data.

[6] Further details are available upon request.

[7] Constructing the series in this way overcomes the selectivity bias noted in the CC(2000) report (p.109) and discussed in the previous section. Of course, from the retailers point of view it may be more important to price lead on certain product ranges more than other to better reflect the demands of its consumers. Whilst acknowledgement is made of nuances in demand across retailers more broadly defined all the retailers in this study occupy the middle ground in UK retailing at the time of analysis.

own-label products that can be matched with equivalent products in each of the four retailers are eligible for indicator product status.

Figure 1: All-goods Price Indices by Retailer (weekly, January 1999 to October 2002)



Of the products that meet these (branded and own-label) criteria the top (i.e. highest selling) 25 of them in each 37 categories form a shortlist from which indicator products are selected in each category. Finally, to allow for the introduction of new products and changes in consumer spending patterns over time the product composition of the basket and the weights assigned to each category are updated annually on a calendar year basis. The resulting price index for each retailer is indexed to 100 in 1999(1), subsequent observations denote the price of the common (albeit evolving) basket of goods relative to its level at the start date. While this means that comparisons of the absolute value of each retailer cannot be made, (i.e. it cannot be inferred from Figure 1 that Tesco is the 'cheapest' supermarket) the data measure price changes of identical products at high frequency (short interval between successive observations) and thus are highly suitable for the detection of price leadership at an aggregate level.

Table 1: ADF test statistics

	Levels [lag]	First Differences [lag]	Inference on levels
ASDA	-2.487 [5]	-5.302** [4]	I(1)
Safeway	-3.055 [1]	-10.11** [1]	I(1)
Sainsbury	-2.778 [2]	-13.26** [1]	I(1)
Tesco	-2.783 [5]	-8.029** [4]	I(1)

Levels regressions include a constant and time trend; those for the first difference only a constant. Lag length selected by AIC and residual autocorrelation test. Both criteria select the lag length reported in the table. 5% (1%) critical values of the ADF statistic are -3.43 (-4.01) for the levels regression and -2.88 (-3.47) for the first differences. Starred statistics indicate rejection at the 5% (*) and 1% (**) levels respectively.

Prior to the econometric analysis the data are tested for the order of integration. Results from the application of the Augmented Dickey-Fuller test to the data in levels and first differences are reported in Table 1 and confirm that the data are I(1) in levels and thus I(0) in first differences, as indeed visual inspection of the data suggests.

IV. Methodology

To allow for the possibility that the prices are non-stationary and cointegrated, the empirical analysis is couched in a vector autoregressive (VAR) framework. This modeling approach is empirically tractable and particularly well-suited to an investigation of price leadership, whose principal hypotheses boil down to restrictions of certain parameters in the estimated model. The VAR also conveniently accommodates the dynamic interactions between the prices as a group (rather than as a series of pairs) in a manner that does not impose untested exogeneity assumptions. Owing to the familiarity of the techniques only a brief sketch is provided here (see Hendry and Juselius 2001 and Juselius, 2006 for further details). It is assumed that the price series may be approximated by a VAR(p) model,

$$\mathbf{x}_t = \mathbf{\Phi}_1 \mathbf{x}_{t-1} + \mathbf{\Phi}_2 \mathbf{x}_{t-2} + \ldots + \mathbf{\Phi}_p \mathbf{x}_{t-p} + \mathbf{\Psi} \mathbf{D}_t + \boldsymbol{\varepsilon}_t \qquad (1)$$

where $\mathbf{x}_t$ is a $(k \times 1)$ vector of I(1) jointly determined prices, $\mathbf{D}_t$ is a $(d \times 1)$ vector of deterministic terms (constant and trend) and each $\mathbf{\Phi}_i$ $(i = 1, \ldots, p)$ and $\mathbf{\Psi}$ are $(k \times k)$ and $(k \times d)$ matrices of coefficients to be estimated using a (t = 1, . . .T) sample of data. $\boldsymbol{\varepsilon}_t$ is a $(k \times 1)$ vector of n.i.d. disturbances with zero mean and non-diagonal covariance matrix, $\mathbf{\Sigma}$. Rearranging (1) into its error correction form gives the VECM representation,

$$\Delta \mathbf{x}_t = \boldsymbol{\alpha} \boldsymbol{\beta}' \mathbf{x}_{t-p} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta \mathbf{x}_{t-i} + \mathbf{\Psi} \mathbf{D}_t + \boldsymbol{\varepsilon}_t \qquad (2)$$

which is particularly attractive for price leadership inference. Specifically, equation (2) decomposes the data in to linear combinations of its levels and first differences, which separates any long-run (equilibrium) relationships that exists between the prices from those that are purely temporary or short run nature. This distinction carries over into to notions of price leadership. If changes to the level of a Price A are correlated to subsequent changes in the levels of Prices B and C, then Price A leads the other prices. In this case lagged changes of Price A appear with statistically significant effects in the equations describing how changes in B and C behave. This is the notion of price leadership as commonly understood which can be detected empirically by statistical tests on the coefficients in the Γ_i matrices, known as tests of Granger-Causation (Granger, 1969). A price that is Granger-causal for all others but is not Granger-caused by any other satisfies the conditions for unidirectional Granger-Causality (see Patterson p.539 for example) and denotes price leadership, which I refer to as *tactical price leadership*, to distinguish it from strategic price leadership set out below. As with any Granger-Causality there may be mutual (i.e. bi-directional) Granger-causality (in which case, for example, A is a Granger-cause for B and B is a Granger-cause for A) or no causality. Moreover, wherever there are more than two variables a price can be unidirectional Granger-Causal for some but not all prices. We define a price to tactically lead the market (rather than all prices within the market) if it is Granger Causal for at least one price and not Granger-caused by any others.

While tactical price leadership relates to the short run dynamics between prices, as equation (2) makes clear, where there exists cointegration between the prices ($\beta \neq \mathbf{0}$), then a price may also lead others in terms of the long term evolution of prices. Such behaviour is described as *strategic price leadership* can be detected by the application of significance

tests to the error correction coefficients that comprise the loading vector (α) using standard tests of (long run) weak exogeneity. Intuitively, a variable that does not adjust to restore the equilibrium of which it is part, is exogenous to that relationship. In this sense it drives the other variables in the long run and as such can be thought of as a strategic price leader. In general, where a long run relation exists, all elements may be expected to adjust so that the equilibrium is restored. Where a price is weakly exogenous to the equilibrium of which it is part defines a strategic price leader.

In order for strategic price leadership to exist there must be cointegration among the variables hence cointegration testing forms an important part of the empirical analysis. Specifically, the VECM given by equation (2) is estimated using Johansens's (1988) maximum likelihood procedure. As there may exist up to (k - 1) cointegrating relations among the k variables in $\mathbf{x}_t$, we require some means of determining the correct number. Here we compute Johansen's Trace and Maximal Eigenvalue test statistics (Johansen, 1988), for this purpose, augmenting inference with alternative criteria as appropriate.

V. Results

To allow for at most linear trend in the price series, the VECM representation of the VAR includes an unrestricted constant and a trend that is restricted to the levels[8] Given that the data are weekly, five lags are considered to be more than sufficient to capture the dynamics among the prices. To determine the optimal lag length, model selection criteria are calculated for the VAR(p) model with p = 5, . . .,1 (see Table 2). AS can be seen from the table, while the SBC and HQC prefer a VAR(1) the AIC is indifferent between a VAR(1) and VAR(3). Model reduction tests suggests that second and third lags are significant at the 5% level, a result supported by the presence of serial correlation in the VAR(2). As a result, the VAR(3) model is selected as the benchmark specification in which subsequent testing is conducted.

Given the importance of deterministic terms to the VAR (see Juselius, 2006), we first assess whether the constant term can be restricted to the levels of the data. With a probability value of 0.61 the restriction is easily upheld and so we now use this model to test for cointegration using Johansen's (1988) reduced rank procedure. Results for the asymptotic and finite sample variants of Trace and Maximal Eigenvalue tests are reported in Table 3 and point to the presence of a single cointegrating relation at conventional levels of significance.[9] Variable exclusion tests are also reported in the table and indicate that, unlike the prices of ASDA, Tesco and Safeway, the price of Sainsbury does not enter the cointegrating relation. While this may reflect the independence of Sainsbury prices from the long term evolution of prices, this result is at odds with the data in Figure 1 which suggest that ASDA and Sainsbury appear to follow virtually identical trends. Why prices in the second largest retailer would be unimportant in explaining price trends of the Big Four is not clear, and difficult to justify economically. This apparent inconsistency can be reconciled if we allow for two cointegrating relations among the four prices each containing a triplet (i.e. J:A:T and S:A:T).

[8] Inclusion of a unrestricted trend would allow for quadratic trends in the series expressed in level.

[9] The same conclusion is reached using the benchmark model with unrestricted constant although owing to the reduction in parameters of the restricted constant model, test statistics are stronger.

Table 2: VAR(p) Model Selection Criteria (unrestricted constant, restricted trend)

Lag length (p)	System Reduction† [prob values]	Vector Autocorrelation†† [prob values]	Information Criteria SBC	HQC	AIC
5	...	0.76	8.33	7.43	6.81
4	0.21	0.70	7.99	7.25	6.74
3	0.42	0.68	7.61	7.03	6.64
2	0.03	0.00	7.38	6.97	6.69
1	0.02	0.18	7.06	6.81	6.64

†System reduction statistics are probability values of an *F* statistic evaluating the significance of the intervening lags in increasingly parsimonious compared to the VAR(5). ††Autocorrelation statistics are probability values of vector-based *F* statistics for serial correlation. See Doornik and Hendry (2001) for details.

Evidence for such relations is provided by the residuals of the cointegrating vectors which show no sign of the non-stationarity present in the price series themselves (Figure 2). Of course, the presence of cointegrating triplets of prices among the four prices implies that A:S form a cointegrating pair and all of which are confirmed at the 5% significance levels in separate testing.[10] When a second cointegrating vector is allowed for in the model, the long run variable exclusion tests now lend support for the notion that Sainsbury does form part of the (more complex) long run story (albeit at the 12% level). Proceeding on that basis we now test for price leadership.[11]

Table 3: Cointegration Analysis of VAR(3) (restricted constant and restricted trend)

Ordered eigenvalues			
0.16256	0.083884	0.053681	0.037367

Cointegration Test Statistics				
rank	Trace test (Asymptotic)	Max test (Asymptotic)	Trace test (Finite Sample)†	Max test (Finite Sample)†
0	68.79 [0.017]	34.06 [0.025]	64.49 [0.042]	31.93 [0.049]
1	34.73 [0.260]	16.82 [0.488]	32.56 [0.365]	15.77 [0.578]
2	17.91 [0.358]	10.59 [0.566]	16.79 [0.439]	9.93 [0.634]
3	7.31 [0.323]	7.31 [0.323]	6.85 [0.370]	6.85 [0.371]

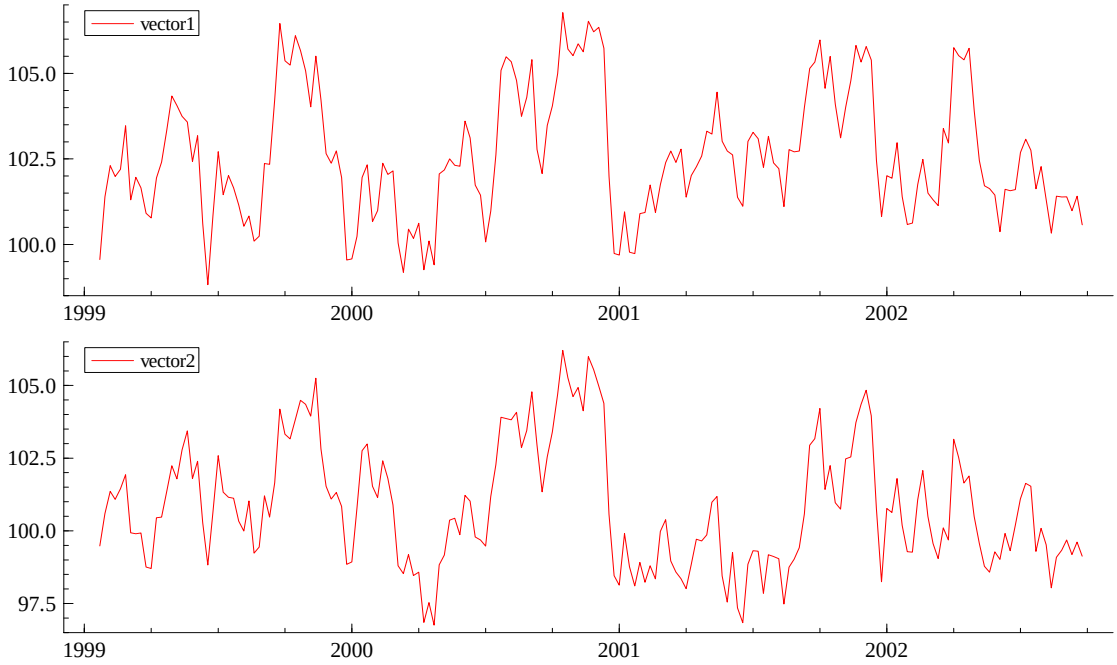
Variable Exclusion Tests	
One Cointegrating Vector	Two Cointegrating Vectors
ASDA $\chi^2(1)$ = 7.3413 [0.0067]	ASDA $\chi^2(2)$ = 10.342 [0.0057]
Sainsbury $\chi^2(1)$ = 0.28681 [0.5923]	Sainsbury $\chi^2(2)$ = 4.1179 [0.1276]
Safeway $\chi^2(1)$ = 14.484 [0.0001]	Safeway $\chi^2(2)$ = 20.137 [0.0000]
Tesco $\chi^2(1)$ = 6.9532 [0.0084]	Tesco $\chi^2(2)$ = 7.2905 [0.0261]

† Finite sample corrections to the asymptotic test statistics for cointegration are those of Cheng and Lai (1993)

[10] In the interest of space, these details are not reported, but are available upon request.

[11] Conclusions regarding tactical and strategic price leadership are unchanged if one cointegrating vector is assumed. We proceed with two simply because there seems little sense in maintaining that only one cointegrating vector exists.

Figure 2: Residuals from Cointegrating Relations



Inference on Tactical Price Leadership

As set out in the previous section Granger-causality test are used to test for tactical price leadership. This involves testing a series of zero-restrictions on lagged price changes in the VECM, the results of which are summarised in Table 4. Each row represents an equation in the VECM (i.e. dependant variable is expressed in changes). Each cell entry in plain text represents the probability value of an F statistic testing the null hypothesis that the coefficients on the price changes in the column-heading supermarket are jointly zero for the row-heading supermarket. So for example, in the ASDA equation an F test of the joint significance of the lagged changes in the Sainsbury price (at t-1 and t-2) has a p-value of 0.28 implying the Sainsbury prices are not jointly significant at the 10% level in the Asda equation. The test of lagged changes in Tesco prices in the ASDA equation yields a probability value of 0.11; on the Safeway coefficients a p-value of 0.88. These results indicate that lagged Tesco prices are borderline significant at the 10% level in the ASDA equation and that the prices of Sainsbury and Safeway are not.

Table 4: Tactical Price Leadership

Equation Δx_t	H_0: Coefficients on Δx_{t-1} and $\Delta x_{t-2} = 0$				
	Asda	Sainsbury	Tesco	Safeway	
Asda	---	0.28	0.11	0.88	**0.26**
Sainsbury	0.63	---	0.88	0.76	**0.96**
Tesco	0.85	0.40	---	0.84	**0.86**
Safeway	0.06	0.50	0.09	---	**0.03**
	0.36	**0.52**	**0.11**	**0.97**	

Figures are probability values for Granger Non-causality Tests conducted in the VECM

Reviewing the results of this test in the other equations we can see that Asda prices are Granger Causal for Safeway, Tesco prices are Granger-causal for Asda and Safeway and

that Sainsbury and Safeway prices are not Granger-Casual for any prices. In other words, no price is Granger Causal for all others. This does not however imply that there is not a tactical price leader in the market. As we have noted, to require a tactical price leader to be Granger-Causal for all rivals seems overly rigorous since the presence of a independent (tactical) pricer somewhere in the market (which is the role played by Sainsbury here) would rule out the possibility of (tactical) price leadership. Defining the tactical price leader as we have done in Section 4 requires that the price simply leads the market (rather than all rivals in the market). In terms of the statistical testing where we find a competitor whose lagged prices are jointly significant in the other equations we have a candidate for (tactical) price leadership providing that the lagged prices of its competitors are not significant in its equation. Figures in bold and the bottom of each column and at the end of each row in Table 4 represent p-values from such tests. The null that lagged Tesco prices do not affect competitors is rejected at the 11% level. Conversely, the null that lagged competitor prices do not affect Tesco has a p-value of 0.86 (entailing the prices of competitors are unimportant to the short run determination of Tesco's prices). On this basis Tesco is the tactical price leader in the market.[12]

Inference on Strategic Price Leadership

Given that the VECM contains information regarding the long run evolution of prices we can test whether any of the prices are responsible for this trending behaviour or merely respond to it. A price that is exogenous to the long run relationship of which it is part does not (by definition) adjust to maintain the equilibrium. In this sense, it drives the relationship rather than being driven by it. Since the error correction coefficients measure the rate of the adjustment to the long run relationship, strategic price leadership can be inferred from the statistical significance of these coefficients, so called (long run) weak exogeneity tests. Table 5 reproduces the error correction coefficients from each equation in the VECM (see appendix) along with their corresponding p-values. As can be seen Asda appears to correct for deviations in both equilibrium relations; Sainsbury and Safeway correct for one (the one in which they appear) and Tesco corrects to neither. This pattern suggests that Tesco is the strategic price leader and a formal test of this hypothesis evaluates the joint significance of both error correction coefficients. The resulting p-values from this $\chi^2(2)$ test of weak exogeneity are also given in the table and confirm that Tesco is indeed the strategic price leader.

Table 5: Strategic Price Leadership

	Error Correction Coefficients			
	$CIV1_{t-3}$	$CIV2_{t-3}$	H_0: Weak Exogeneity	Inference
Asda	-0.057 [0.002]	-0.037 [0.084]	[0.000]	Follower
Sainsbury	-0.031 [0.222]	0.090 [0.009]	[0.014]	Follower
Tesco	-0.006 [0.774]	0.045 [0.246]	[0.462]	Leader
Safeway	0.154 [0.002]	-0.063 [0.367]	[0.000]	Follower

[12] Note also that the p-values relate to F tests of the joint significance of coefficients for price changes at t-1 and t-2, and thus where one is significant and the other not, joint significance will tend to diluted. For this reason, it seems sensible to infer significance at the 10% level rather than the more usual 5%.

VI. Conclusion

This paper contains the results of a preliminary statistical analysis of price leadership among the 'Big Four' supermarket chains in the UK during a three year and half year period in the recent past. The data used for this purpose represent weekly price indices of a common basket of products covering 36 categories sold in ASDA, Safeway, and Tesco. Being based on such a wide range of products the result complement previous product specific analyses undertaken by the Competition Commission. Adopting vector autoregressive methods offers a number of potential advantages to the investigation of price leadership, not least of which is that it gives the opportunity to investigate a number of prices as a system rather than in pairs. The paper also introduces the concepts of tactical and strategic price leadership which relate to the pricing behaviour observed over the short and long run. Although the results are preliminary they point to the presence of a price leader in both the tactical and strategic senses. This turns out to be Tesco, the largest supermarket chain in the UK, which was also identified as a price leader (albeit with ASDA) by the Competition Commission as part of their 2000 Supermarket Inquiry.

Some caveats are however in order at this point. First, as a preliminary analysis of the data, further statistical testing is required to evaluate the robustness of the results obtained. While VARs offer many advantages in analyses of this kind, results they produce are known to be model dependent in empirical applications, owing in large part to the inherent over-parameterisation of the VAR. Although the sample size is relatively large here, caution is nevertheless warranted in the absence of a thorough sensitivity analysis. Second, results relate to a specific period of time and common basket of products and thus should not be extrapolated. Finally, although the results point to a pattern of pricing that is suggestive of collusive anti-competitive behaviour the results do not deny the possibility that the price leadership is barometric in nature, and thus benign. In addition to further statistical testing of the empirical model, the methodology requires formalisation both in terms of notions of tactical and strategic leadership and the issue of asymmetric price leadership. These are subjects of on-going research.

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Appendix: Categories and Indicators

1. BREAD	Large white loaves (sliced and unsliced), small brown loaf, large wholemeal loaf, bread rolls, pitta bread and french stick/baguette
2. CEREALS	Flour, rice, pasta, selected breakfast cereals and cereal snacks
3. BISCUITS & CAKES	Various biscuits (eg plain and chocolate-coated), crackers and cakes (eg fruit pies, sponge cakes, doughnuts and scones)
4. BEEF	Specified cuts: rump steak, braising steak, mince and topside, and beefburgers
5. LAMB	Specified cuts: loin chops and shoulder, specified cuts: loin chops and leg
6. PORK	Specified cuts: loin chops and shoulder
7. BACON	Gammon and back rashers
8. POULTRY	Fresh/chilled and frozen whole chicken and chicken pieces, frozen turkey and cooked sliced turkey
9. OTHER MEAT	Pork sausages, various cooked and canned meats, and various meat pies
10. FRESH FISH	White fish and salmon fillets
11. PROCESSED FISH	Canned tuna, fish fingers and various frozen fish and prawns
12. BUTTER	Home-produced and imported butter
13. OILS & FATS	Margarine/low fat spread and cooking oil
14. CHEESE	Cheddar (home-produced and imported), selected speciality cheese and cheese spread and slices
15. EGGS	Various sized eggs
16. MILK	Various quantities of full-fat, semi-skimmed, skimmed, and flavoured milk
17. MILK PRODUCTS	Yoghurt, fresh cream, powdered baby formula, fromage frais and chilled pot dessert
18. TEA	Tea bags and herbal/fruit tea bags
19. SOFT DRINKS	Various pure fruit juices, squashes, lemonade, cola, energy drinks, other fizzy drinks and mineral water
20. SUGAR & PRESERVES	Sugar and various jams
21. SWEETS & CHOCOLATES	Various selected popular brands of sweets, chocolates and mints
22. UNPROCESSED POTATOES	White loose and pre-packed potatoes (old and new varieties)
23. PROCESSED POTATOES	Crisps (single and multi-packs), potato flavoured snacks and frozen chips
24. FRESH VEGETABLES	Fresh tomatoes, cabbages, cauliflowers, carrots, sprouts, onions, mushrooms, cucumbers, lettuce, organic vegetable and pre-packed salads
25. PROCESSED VEGETABLES	Canned tomatoes, baked beans and sweet corn, and frozen peas
26. FRESH FRUIT	Cooking and dessert apples, pears, bananas, strawberries, grapes, oranges, grapefruit, avocado pears, peaches, organic fruit and kiwi fruit
27. PROCESSED FRUIT	Various canned fruits and salted peanuts

28. OTHER FOODS	Ice cream, selected frozen and chilled convenience foods, canned and packet foods (eg soups, spaghetti, and pasta shapes), baby food, various sauces and pickles
29. COFFEE & HOT DRINKS	Ground and instant coffees, and hot milk drink
30. BEER "OFF" SALES	Canned brown ale, lager and draught flow bitter, bottled cider, and lager
31. WINES & SPIRITS "OFF"	Whisky, vodka, gin, brandy, sherry, various white and red wines and spirit based drink
32. TOBACCO & CIGARETTES	Selected brands
33. OTHER TOBACCO	Selected brands of cigarettes, and cigars
34. HOUSEHOLD ITEMS	Washing powder and liquid, washing-up liquid and dish washer powder, stationery (pens, writing paper, envelopes, greeting cards, printer paper and clear sticky tape), battery, light bulbs, aluminum foil, toilet paper, bin liners, household cream cleaner, cleaning cloths and air freshener spray
35. PET CARE	Canned dog and cat food, dry cat food, dog mixer, cat litter.
36. CHEMISTS' GOODS	Selected medicines and surgical goods (eg contact lens solution, indigestion tablets and pain killer tablets), multi-vitamins, condoms, tampons, disposable nappies, toiletries (eg toilet soap, toothpaste, deodorants, shampoo, permanent hair colourant, disposable razors and sunscreen cream/ lotion), various cosmetics (eg lip stick, face cream, perfume and mascara), tissues and plasters

Source: Office of National Statistics

Appendix: Vector Error Correction Model of Prices

```
The estimation sample is: 1999 (4) to 2002 (39)
URF equation for: Dasda
                Coefficient  Std.Error       HCSE   t-HCSE  t-prob
Dasda_1            0.162330    0.07382    0.08146     1.99   0.048
Dasda_2           -0.177483    0.07199    0.07449    -2.38   0.018
DTesco_1          -0.0476210   0.04702    0.04652    -1.02   0.307
DTesco_2           0.0839098   0.04779    0.05244     1.60   0.111
DJS_1             -0.0550781   0.05099    0.05048    -1.09   0.277
DJS_2              0.0480305   0.05126    0.05217    0.921   0.358
DSafeway_1        -0.00513662  0.02821    0.04185    -0.123  0.902
DSafeway_2        -0.0124414   0.02752    0.02339    -0.532  0.595
CIV1_3            -0.0572444   0.01528    0.01790    -3.20   0.002
CIV2_3            -0.0376929   0.02421    0.02169    -1.74   0.084

URF equation for: DTesco
                Coefficient  Std.Error       HCSE   t-HCSE  t-prob
Dasda_1            0.0616970    0.1153     0.1059    0.583   0.561
Dasd2_2           0.00692936    0.1124     0.1027   0.0675   0.946
DTesco_1          -0.0347999   0.07344    0.08210   -0.424   0.672
DTesco_2           -0.235641   0.07464    0.09252    -2.55   0.012
DJS_1             0.00934250   0.07964    0.07843    0.119   0.905
DJS_2                0.104846   0.08006    0.07530     1.39   0.166
DSafeway_1       -0.000716369  0.04406    0.04327  -0.0166   0.987
DSafeway_2         -0.0247878  0.04297    0.03355   -0.739   0.461
CIV1_3            -0.00601945  0.02387    0.02095   -0.287   0.774
CIV2_3             0.0451706   0.03781    0.03883     1.16   0.246


URF equation for: DJS
                Coefficient  Std.Error       HCSE   t-HCSE  t-prob
Dasda_1            0.0965708    0.1073     0.1068    0.905   0.367
Dasda_2           -0.0369394    0.1046     0.1032   -0.358   0.721
DTesco_1           0.0278943   0.06834    0.06564    0.425   0.671
DTesco_2           0.0197789   0.06946    0.06741    0.293   0.770
DJS_1              -0.201550   0.07411    0.06506    -3.10   0.002
DJS_2              -0.306253   0.07451    0.08803    -3.48   0.001
DSafeway_1        -0.0196969   0.04101    0.04673   -0.421   0.674
DSafeway_2         0.0217958   0.03999    0.03848    0.566   0.572
CIV1_3            -0.0312853   0.02221    0.02555    -1.22   0.222
CIV2_3             0.0899514   0.03518    0.03414     2.64   0.009

URF equation for: DSafeway
                Coefficient  Std.Error       HCSE   t-HCSE  t-prob
Dasda_1            0.268598     0.1960     0.1556     1.73   0.086
Dasda_2            0.329374     0.1911     0.1567     2.10   0.037
DTesco_1           0.270217     0.1248     0.1258     2.15   0.033
DTesco_2           0.0112110    0.1269     0.1006    0.111   0.911
DJS_1              0.0959741    0.1354     0.1301    0.738   0.462
DJS_2                0.137233   0.1361     0.1355     1.01   0.313
DSafeway_1       -0.000547470  0.07490    0.06040 -0.00906   0.993
DSafeway_2          -0.174689  0.07304    0.06892    -2.53   0.012
CIV1_3               0.153624  0.04057    0.04797     3.20   0.002
CIV2_3             -0.0627189  0.06426    0.06940   -0.904   0.367

R^2(LR)              0.443817  R^2(LM)              0.133364
no. of observations       192  no. of parameters          40

F-test on regressors except unrestricted: F(40,680) = 2.84703 [0.0000] **
F-tests on retained regressors, F(4,179) =
    Dasda_1       1.50872 [0.202]      Dasda_2       2.58020 [0.039]*
   DTesco_1       1.79744 [0.131]     DTesco_2       3.69225 [0.006]**
      DJS_1       2.19832 [0.071]        DJS_2       6.14614 [0.000]**
 DSafeway_1     0.0602408 [0.993]   DSafeway_2       1.58185 [0.181]
     CIV1_3       8.28939 [0.000]**     CIV2_3       3.20604 [0.014]*

correlation of URF residuals (standard deviations on diagonal)
                   Dasda      DTesco         DJS    DSafeway
Dasda              0.34706      0.12877      0.21681      0.14230
DTesco             0.12877      0.54202      0.19171      0.13651
DJS                0.21681      0.19171      0.50442     0.068292
DSafeway           0.14230      0.13651     0.068292      0.92131
```

```
correlation between actual and fitted
       Dasda      DTesco        DJS          DSafeway
     0.41483      0.27114      0.35139      0.36434

Testing for Vector error autocorrelation from lags 1 to 1
 Chi^2(16)=   12.909 [0.6794]   and F-form F(16,535)=  0.75953 [0.7320]

Vector Normality test for residuals:   Chi^2(8) =   57.572 [0.0000]**

Testing for Vector heteroscedasticity using squares
 Chi^2(200)=   203.29 [0.4219]   and F-form F(200,1388)=  0.96268 [0.6282]

Testing for Vector heteroscedasticity using squares and cross products
 Chi^2(650)=   640.16 [0.6009]   and F-form F(650,1090)=  0.94054 [0.8068]
```