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RETAILERS PRICE BEHAVIOUR IN THE UK FRESH FRUIT AND VEGETABLE MARKET

Alan W. Renwick and Cesar L. Revoredo-Giha[1]

Abstract

The purpose of this paper is to study the price behaviour of fresh produce at the retail level of two leading supermarkets, Tesco and Sainsbury, with the purpose of gaining knowledge about their interaction. We focus the study on six products from the fresh fruits and vegetable group (i.e., tomatoes, Bramley's apples, white cabbage, cucumbers, Iceberg lettuce and Round lettuce) due to the fact on the one hand it is a less complex supply chain (e.g., perishable product, less number of intermediaries) and on the other hand, because during the last 20 years the group has significantly evolved with supermarkets becoming the major players in the chain. The empirical methodology consisted of using Granger causality tests to establish the relationship between the series (e.g., leader-follower) and then vector autoregressive (VAR) models and variance decomposition procedures to capture the interaction of supermarket prices by product. Overall results indicate that the competition behaviour amongst the two retailers changes by product and evolve over time.

Keywords: UK retail prices, supermarket competition, UK fresh produce market.

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I. Introduction

Cotterill (1997) described the food distribution system in the UK as one dominated by multiple retailers (i.e., supermarkets) in contrast with the US system where manufacturers seemed to be the dominant side. The description is still an accurate picture of the situation in the UK, where supermarkets have continued increasing their presence in the food market. This has been reflected on the fact that supermarkets have been subject of several investigations by the UK Competition Commission, the Monopolies and Mergers Commission and the Office of Fair Trading to determine whether they were exercising market power along the supply chain (i.e., with respect to supplier and consumers) (Cooper, 2003; Wilson, 2003).

According to Burt and Sparks (2003) in the UK, the locus of 'power' in the distribution channel shifted away from branded goods manufacturers towards retailers. In many product markets (including groceries) retailers have assumed channel leadership, utilising improved demand and customer information to develop their brand position and overall retail offer (p.237)

The evidence collected from the different analyses as regards how supermarkets exercise market power has so far been inconclusive and if something has show up from those reports is the fact that economic models do seem to fit neither the behaviour of supermarkets nor the way the compete amongst them in the market place. This is not strange as the economic literature has pointed out that typical oligopoly/oligopsony models (including here typical models of collusion) are quite simple and seem not to fit the stylised facts observed in retail markets (Sheldon, 2003).

There are several difficulties when trying to understand supermarkets' behaviour due to the complexity in their operations, as they seem to use more than one strategy, they operate on vertical (relationships with consumers and suppliers) and horizontal dimensions (relationships with other supermarkets), and even the definition of their output (and therefore, by extension on their prices) may be difficult to grasp as it may include several other components in addition to the product such as quality, services, etc.

The purpose of this paper is to focus on a narrow set of products, fresh fruits and vegetables in order to explore the behaviour of their prices in two of the main UK retailers: Tesco and Sainsbury. The analysis, which is performed on weekly data that spans approximately the last ten years, has the aim to extract from such observation stylised facts about the relationship between the two retailers. In addition to the statistical analysis in order to interpret the data we make use existing literature describing the evolution of the sector (e.g., Fearne and Hughes, 1998; Hingley et al., 2006).

As regards to the choice of fruits and vegetables as the category for the analysis, it is based, on the one hand, on the fact that it is a less complex line of products, in the sense that they are perishable, with short shelf duration and their supply chains comprise less number of agents. On the other hand, it is an interesting category which has seen an

important competition and innovation in the retail market over the past 15 years. As pointed out by Fearne and Hughes, the fresh produce department has moved from the back of the store to the front and has doubled its shelf area in store and the growth has occurred without substantial growth in consumption volume, but with significant growth in expenditure. Behind this result is the substitution of growth strategies based essentially on location and size (product range and price competitiveness) by strategies based on differentiation, with own label -fresh produce and meat in particular- at the centre.

The structure of the paper is as follows: we, first, provide a brief background of the role of supermarkets where we focus on two topics: first, the emergence of supermarkets as major players in the UK food market and second, on the evolution of supermarkets' behaviour regarding the fresh fruits and vegetables. Next, we start the empirical part of the paper analysing the statistical properties of the data, particularly their stationarity as it has implications for the subsequent methodology. As the series were found stationary in levels, the remaining parts of the empirical work consisted of a causality analysis of the series using Granger causality tests; correlation analysis; modelling the interrelationships by means of estimating vector autoregressive models (VARs) for each product and analysing their decomposition of the variance.

II. Background

This section is divided into two parts: the first part presents the evolution of the supermarkets participation in the food market and the second one concentrates on the fresh fruits and vegetables markets.

Retailers in the food market

Table 1 presents the evolution of supermarkets' share in the retailing of food. It is striking the sustained increased in the share of the three largest one from 49 per cent in 1998 to 68 per cent in 2007.

Table 1: Leading food retailers' share of main shoppers, 1998-2007 1/

	1998	2000	2002	2003	2004	2005	2006	2007
Tesco	**21.0**	**23.0**	**25.0**	**27.0**	**27.0**	**30.0**	**33.0**	**28.0**
Asda	**12.0**	**18.0**	**19.0**	**18.0**	**20.0**	**19.0**	**20.0**	**21.0**
Sainsbury's	**16.0**	**17.0**	**17.0**	**13.0**	**13.0**	**16.0**	**15.0**	**19.0**
Safeway	12.0	9.0	9.0	10.0	6.0	1.0	n/a	n/a
Morrisons	4.0	5.0	6.0	7.0	9.0	12.0	12.0	12.0
Morrisons + Safeway pro-forma	16.0	14.0	15.0	17.0	15.0	13.0	12.0	12.0
Any Co-op	3.0	5.0	3.0	4.0	4.0	3.0	4.0	3.0
Somerfield	6.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
Kwik Save	8.0	4.0	4.0	3.0	4.0	2.0	n/a	n/a
Iceland	--	1.0	1.0	2.0	1.0	1.0	1.0	1.0
Waitrose	3.0	3.0	1.0	2.0	4.0	2.0	2.0	2.0
Aldi	n/a	2.0	2.0	1.0	1.0	1.0	n/a	n/a
Marks & Spencer	--	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Any Lidl/Netto	--	1.0	2.0	1.0	1.0	1.0	2.0 2/	3.0 2/
Share of top three	49.0	58.0	61.0	58.0	60.0	65.0	68.0	68.0

Source: Mintel, 2007b.

Notes:

1/ Main shoppers are shoppers older than 15 years. 'n/a' denotes 'not available'.

2/ Includes Aldi

According to Burt and Sparks (2003) supermarkets have competed in order to increase the market shares through the additions of new stores, the acquisition of competing floor space, and the rigorous implementation of customer-focused operating strategies. These strategies have result into new store formats and locations, an emphasis on

competitive pricing, the widening of product and service ranges, and improvements in store ambience and service levels.

Smith (2006) also points out significant changes in the structure of retailing that Hingley et al. (2006) set in the last twenty years. According to Smith, traditionally retailing used to have low entry and exit barriers and the number of independent traders was, in terms of numbers, the dominant force. However, the large organisations (i.e., supermarkets) used their economies of scale to gain dominance. This is now reflected in the fact that the complexity of the large hypermarkets and supermarkets require professional managers with a range of skills. As an example of the changes and in contrast with a small grocery store, a large UK food hypermarket or supermarket is likely to be open for 24 hours a day, have a staff of 750 working at many different levels and take £2 million per week in sales.

The increasing affluence and mobility of the population, combined with the development of the strong corporate retailers, has led to the large out of town retail outlet, with large sales and car parking areas. A format in terms of presentation, choice and availability of the product in the food superstores remain successful with the consumer. Furthermore, the success of these corporations has stimulated demand and the range of goods has increased.

Burt and Sparks (2003b) summarised the changes in food retailing in the 1990s and 2000s in three key areas: First, **a change in the location of retailing**, i.e., food retailing takes place now in very different locations than previously. There have been broad trends of decentralisation of retail location and the rise of superstores. From a channel perspective this may have had advantages for the distribution of products. Second, **there has been an alteration in the format through which food retailing takes place** and retailer strategies have become more segmented. They differ in scale, design, technique and approach. This is obvious in terms of the larger store formats, but is equally true for smaller formats. A common component however is the improvement in the quality of provision. Third, **food retailers have increased in scale and power**. They are now major businesses, often being larger than the manufacturers who supply them. They can thus reorganise various relationships to suit themselves. This scale of operation brings practical and financial benefits to the business. Their professionalised management approach has changed the sector and its supply systems.

Retailers in the fresh fruits and vegetables market

Table 2 present the evolution of the sales of fresh fruits and vegetables. According to Mintel (2007), despite its inherent maturity, the market for fresh fruit and vegetables has continued to grow.

The forces behind the category growth have been several such as the trend towards healthier eating and in particular the government's '5 A DAY' campaign; the ongoing expansion of the range of convenience formats on offer; the increasing demand from consumers for ethically-sourced produce; and the strong growth in sales of fruit and vegetables which can offer specific health benefits – such as anti-oxidants in berries.

Table 2: UK retail sales of fresh, frozen and canned fruit and vegetables, 2002-06

Type	2002		2004		2006 1/		Change 2002/06
	£million	%	£million	%	£million	%	%
Fruits							
Fresh	3,762	85.2	4,101	85.6	4,338	85.6	15.3
Frozen	401	9.1	396	8.3	406	8.0	1.2
Canned	250	5.7	292	6.1	322	6.4	28.8
Total	4,413	100.0	4,789	100.0	5,066	100.0	14.8
Vegetables							
Fresh	3,158	94.7	3,427	94.7	3,796	95.4	20.2
Frozen	31	0.9	34	0.9	37	0.9	19.4
Canned	145	4.3	158	4.4	148	3.7	2.1
Total	3,334	100.0	3,619	100.0	3,981	100.0	19.4

Source: Mintel, 2007a.

Notes:

1/ Mintel estimate.

The importance of the multiple retailers in the UK food market is also reflected into the UK fresh produce (fruit, vegetable and salad) where retailers have also became more powerful. According to Hingley et al. (2006) in 1990 more than half of all UK fresh produce was sold through greengrocers but by 2000 the share of multiple retailers stood at some 83 per cent of sales in terms of value.

Table 3 shows that multiple grocers lead the retail market for fruit and vegetables, with a growth above their competitors that allowed them to slightly increase their share. It is important to note that the trend observed in table 3 is not a recent one but the product of a large number of transformations in the last 15 years.

According to Fearne and Hughes (2000) before retailers started to transform the fresh produce sector, the UK market of fresh fruits and vegetables could was characterised as being over-supplied, with a commodity orientation (i.e., lack of product differentiation), and with a stagnant annual growth.

Fearne and Hughes also mention that the role of fresh produce in the strategies of the major supermarkets has changed dramatically since the early 1990s moving towards vertical coordination concentration of their operations with fewer larger suppliers operating in dedicated (if not exclusive) supply chains for specific supermarket customers. They point out four key factors that have driven the transformation of the

fresh produce industry: (1) Supermarket strategies, (2) Food safety legislation and supply chain integrity, (3) Rationalisation of the supply base and (4) Innovation.

Table 3: UK retail sales of fruit and vegetables by outlet type, 2002-06

Outlet	2002		2004		2006		Change
	£million	%	£million	%	£million	%	2002/06 %
Multiple grocers	5,806	83.9	6,324	84.0	6,857	84.3	18.1
Greengrocers and independents	699	10.1	754	10.0	797	9.8	14.0
Others 1/	416	6.0	451	6.0	480	5.9	15.4
Total	6,920	100.0	7,528	100.0	8,134	100.0	17.5

Source: Mintel, 2007a.

Notes:

1/ Includes box schemes, farm shops, mail order, market stalls/farmers' markets

As regards of **supermarket strategies**, Fearne and Hughes highlight the existence of intense competition between the major multiples retailers (Tesco, Sainsbury's, Asda, Safeway). The nature of the competition has changed from a strategy of opening stores (absorbing the share of small retailers) followed during the 1980s and early 1990s, to a strategy of based on differentiation, with own label. They also mention that own label products account for close to one-half of all foods purchased in UK supermarkets and the fresh produce category is almost exclusively own label. Furthermore, fresh produce has become what retailers describe as a “destination” category and fresh fruit and vegetables is one of the few product categories (along with fresh meat and wine) for which shoppers will switch stores. It is also one of the two remaining categories (along with meat) which is virtually all own label and thus over which they can exert considerable influence and control. As a result, over the past 15 years, the fresh produce department has moved from the back of the store to the front and has doubled its shelf area in store and the growth has occurred without substantial growth in consumption volume, but with significant growth in expenditure. It should be noted that the search for competitive advantage and a point of difference between supermarkets has coincided, in the early 1980s, with the consumer's move towards an increasingly Mediterranean diet, driven by heightened awareness of (and concern about) health and nutrition.

With respect to the food and safety regulation, the 1990 Food Safety Act gave the process of vertical co-ordination, driven backwards from the retailer rather than forwards from the grower/processor, further impetus, with the growth of own label increasing the need for improved due diligence and tighter supply chain control. As part

of this, retailers drew up codes of practice, covering all aspects of crop management and issued them to their suppliers. The industry responded by developing a generic farm assurance scheme for domestic fruit and vegetables -assured produce- highlighting best practice in integrated pest, disease and crop management systems. Protocols have been drawn up for individual products, by growers and retailers (the NFU-Retailer Integrated Crop Management Partnership) and are now established as the baseline industry standards for safety and quality. All of the major supermarkets now require all fresh produce to come from suppliers who are members of the assured produce scheme. A genuine (and visible) quality and safety culture is a "must have" for companies who supply the multiples. For many companies this has been difficult to establish, particularly when improvements in safety and quality systems have had to come from greater efficiency and better operating practices.

As regards the rationalisation of the supply base the search for improved supply chain integrity and greater consistency in the quality of fresh produce coupled with the need to squeeze costs out of the supply chain, through greater control (either directly, through grower/co-operative partnerships or indirectly, through pre-packers with their own grower networks) has resulted in the rationalisation of the supply base, with retailers seeking to deal with fewer, larger, technically efficient and innovative suppliers. The major supermarkets now deal with just a handful of suppliers in key product areas (potatoes, root vegetables, salads, top fruit, stone fruit and soft fruit) and take every opportunity to pass responsibility (and associated costs) for quality control and procurement, storage and distribution upstream to their key suppliers, in return for which the chosen few are rewarded with volume growth. The latter is vitally important for suppliers, the bulk of whom are privately owned and struggle to generate the cash surpluses necessary to maintain the level of investment in processing plants and new product development. The race is on for retailers to find the best partners with whom to take on the competition.

Finally, **in terms of innovation**, whilst the volume of fresh produce sold as raw product still accounts for the bulk of supermarket sales, but significant year-on-year growth is almost exclusively in ready prepared vegetables and the growth is huge. The growth in sales of prepared salads is driven by the demand for greater convenience and competitive prices, which fall as new businesses enter the market or existing suppliers upgrade their offer and extend their product range. The success of prepared salads in the UK, in contrast with the experience in the USA, is largely due to the efficiency of the supply chain. In the UK prepared salads will be in the retail store within two days of harvest and consumed within five days of harvest. Thus, quality is maintained and waste is minimised. Thus, innovation drives value creation -new varieties (sweeter, juicier, crispier, improved visible characteristics etc.), new formats (pre-prepared, mixed salads, stir-fry packs etc.), extended shelf life -and production efficiency (processing, storage, packaging and logistics technology). However, the shortening of product life-cycles and lead times for introducing new products and new technology, which reduce entry barriers –the process of commoditisation- keeps the market moving on.

III. Empirical analysis

Detailed information that allows to uncover the complex relationships in the functioning of supermarkets is difficult to obtain (e.g., additional services, changes in packaging,

prices of other inputs, detailed retailing costs, product range quality, convenience via store location and access, store ambience and additional service facilities) so most of the analyses, such as the one presented in this section, has to limit itself to discover regularities (i.e., stylised facts) about supermarkets from prices. It is clear that this is a partial approach as pointed out by Burt and Sparks (2003a), as price is not the only determinant of purchases and other factors as the ones mentioned should also be included if one aims to fully analyse the competition amongst retailers.

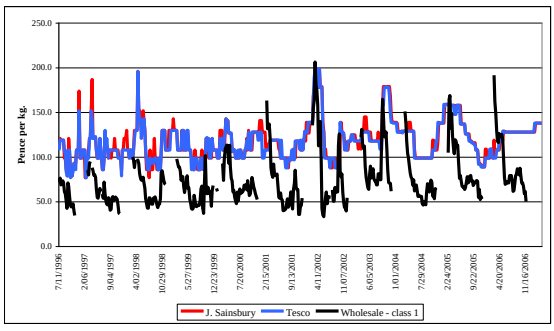
We start the empirical analysis presenting the data used for it. Next, we show the statistical properties of the data, which condition the time series approach to use. Then, as the purpose if try to infer the interrelations between supermarkets, we use causality tests to identify "leader-follower" relationships, total interrelations (double causality) or not relationship at all. In order to study possible levelling within each supermarket prices we used correlation analysis. Finally, we model the bivariate relationships by product using VAR models and the decomposition of the variance methodology.

III.1 Data

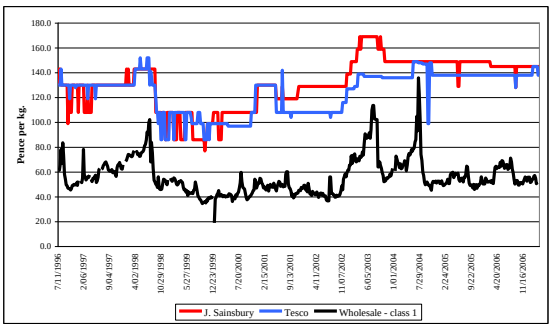
The data used consisted of two sets of prices: retail and wholesale prices. They were collected from the magazine Grower (Nexus Media Limited), a weekly magazine specialised on horticulture. The sample was available on a weekly basis for approximately 10 years (from July 1996 to March 2007), i.e., approximately 559 observations. The products selected for the analysis were: tomatoes, Bramley's apples, white cabbages cucumbers, Iceberg lettuce and Round lettuce. Figure 1 presents graphs of the retail and wholesale prices for each product.

The retail prices were collected for two supermarkets: J. Sainsbury and Tesco and they correspond to the 'supermarket price guide' published by Grower. This guide also highlights when the retailed produced is imported (although imported and domestic price are not quoted at the same time, i.e., only one of them is presented). Little is known about the construction of these prices or the size of the sample used to compute them. As regards the wholesale prices, they were also collected from Grower, however, the source was MAFF and they correspond to the weekly UK average for several markets for produce class 1.

Figure 1: Comparison of J. Sainsbury, Tesco, and wholesale class 1 prices for selected fresh fruits and vegetables

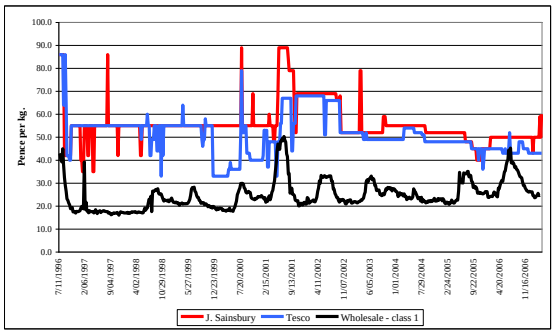


a. Tomato prices

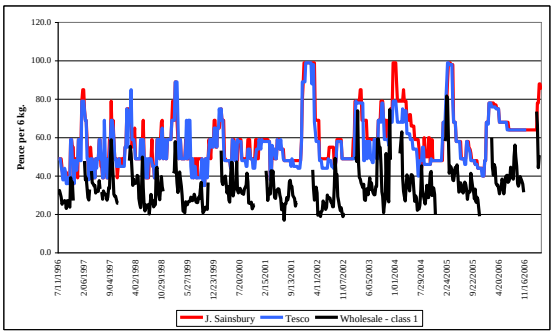


b. Bramley's apple prices

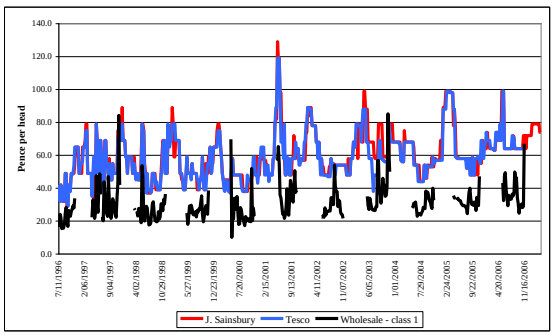
Figure 1: Comparison of J. Sainsbury, Tesco, and wholesale class 1 prices for selected fresh fruits and vegetables (cont.)



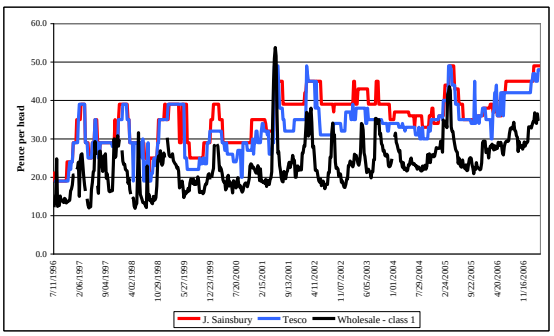
c. White cabbage prices



d. Cucumber prices



e. Iceberg lettuce prices



f. Round lettuce prices

Source: Grower and MAFF.

III.2 Statistical description of the data

Table 4 presents descriptive statistics for the price series. Despite the fact that all the graphs in figure 1 look like having a significant amount of variation, in practice, the highest variation (measured with the coefficient of variation, i.e., ratio of standard deviation to the mean) corresponded to wholesale tomato prices (approximately 39 per cent). In all cases, the variation of retail prices was below the wholesale prices, most probably explained by the fact that the wholesale price only accounts for a fraction of the retail price of the product.

Table 4 also presents results about the stationarity of the price series (i.e., whether they possess a unit root). To verify the stationarity of the series is important for two reasons: first, to avoid obtaining results based on models that reflect spurious correlations, and second, because the results indicate the path of empirical methodology to follow. This is, if the series contain unit roots then the appropriate methodology would be to use the Dolado-Lutkepohl test (Dolado and Lutkepohl, 1996) for causality instead of Granger causality tests, use vector error correction models (assuming that the series are cointegrated) instead of vector autoregressive models (VARs), and finally perform the impulse-response analysis and decomposition of the variance according to the procedure by Lutkepohl and Reimers (1992), instead of the traditional impulse-response analysis and decomposition of the variance based on the VARs models.

Table 4: Descriptive statistics of the used variables

	Units	Mean	St. Dev.	Min	Max	Skewness	Kurtosis	Season 1/	Unit roots 2/
J. Sainsbury retail price of tomato	p/kg.	118.8	21.9	77.0	199.0	1.0	4.6		I(0)
Tesco retail price of tomato	p/kg.	117.8	21.2	77.0	199.0	1.1	5.0		I(0)
Wholesale price of tomato - class 1	p/kg.	74.6	29.1	29.2	206.5	1.5	5.7	No in winter	I(0)
J. Sainsbury retail price of Bramley's apple	p/kg.	131.5	20.0	77.0	169.0	-0.5	2.7		I(0)
Tesco retail price of Bramley's apple	p/kg.	124.2	16.7	86.0	152.0	-0.6	2.0		I(0)
Wholesale price of Bramley's apple - class 1	p/kg.	56.0	14.6	19.0	135.9	1.6	6.8	All year	I(0)
J. Sainsbury retail price of white cabbage	p/kg.	55.8	9.1	35.0	89.0	1.8	7.2		I(0)
Tesco retail price of white cabbage	p/kg.	51.3	9.1	33.0	86.0	0.7	4.6		I(0)
Wholesale price of white cabbage - class 1	p/kg.	24.7	6.4	16.0	50.3	1.5	5.6	All year	I(0)
J. Sainsbury retail price of cucumber	p/unit	59.0	14.0	35.0	99.0	1.0	3.8		I(0)
Tesco retail price of cucumber	p/unit	56.7	13.4	35.0	99.0	1.1	4.2		I(0)
Wholesale price of cucumber - class 1	p/unit	34.1	9.8	17.0	81.7	1.5	6.8	No in winter	I(0)
J. Sainsbury retail price of Iceberg lettuce	p/head	60.0	14.6	29.0	129.0	0.9	4.6		I(0)
Tesco retail price of Iceberg lettuce	p/head	58.7	14.0	29.0	119.0	1.0	4.7		I(0)
Wholesale price of Iceberg lettuce - class 1	p/head	30.6	10.1	10.1	85.2	1.9	9.1	No in winter	I(0)
J. Sainsbury retail price of Round lettuce	p/head	35.7	6.7	19.0	49.0	-0.4	2.7		I(0)
Tesco retail price of Round lettuce	p/head	33.1	6.7	19.0	49.0	0.0	2.9		I(0)
Wholesale price of Round lettuce - class 1	p/head	23.4	6.2	11.9	53.8	0.9	5.1	All in year	I(0)

Notes:

1/ Indicates whether the fruit or vegetable is produced all the year.

2/ Augmented Dickey Fuller test of the null hypothesis that the series has a unit root. I(0) indicates that the series is stationary in levels. The tests were carried out at 1 per cent significance.

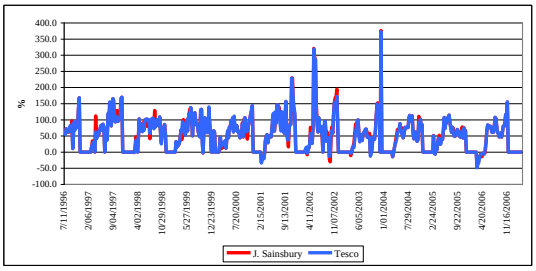
The results using Augmented Dickey-Fuller tests indicate that the series are stationary in levels; therefore, we proceed with the traditional approach.

Before proceeding with the causality testing, we estimated relative price margins between wholesale and retail prices (i.e., how much higher in percentage terms are retail prices than wholesale prices) for all the products and for each supermarket. These are presented in figure 2.

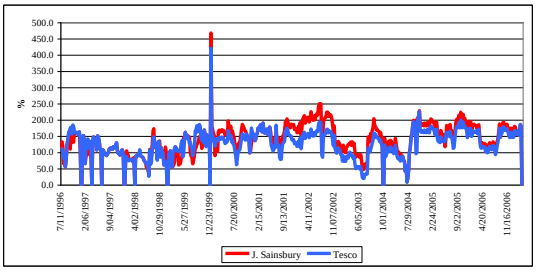
The margins vary across the different products, being the highest average margin Bramley's apples (136 per cent with a coefficient of variation of 36 per cent) and the lowest in Round lettuce (51.6 per cent with a coefficient of variation of 54.6 per cent)

In general, there is a good level of coincidence between the margins in the two supermarkets, with the series almost overlapping all over the sample. In terms of correlations they go from 0.82 in the case of cabbage and Round lettuce to 0.98 in the case of tomatoes.

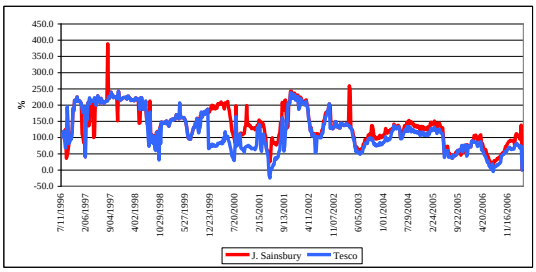
Figure 2: Comparison of J. Sainsbury and Tesco retail price margins for selected fresh fruits and vegetables



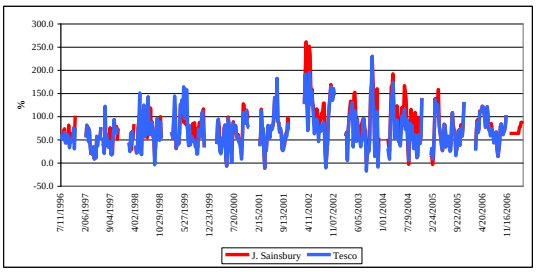
a. Tomato prices



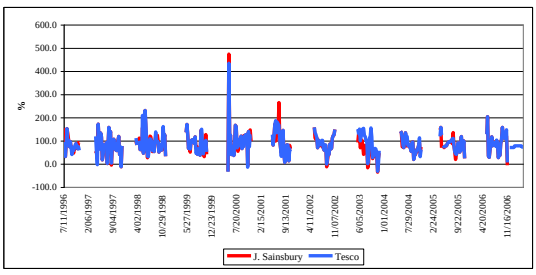
b. Bramley's apple prices



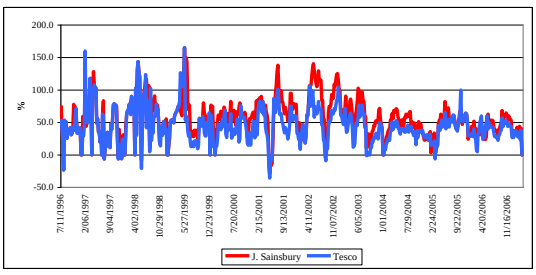
c. White cabbage prices



d. Cucumber prices



e. Iceberg lettuce prices



f. Round lettuce prices

In summary, the description of the data indicates that the price series are relatively stable, with retail prices being more stable than wholesale prices. The margins between retail and wholesale price are important and vary over time, but in general, there is a good level of coincidence between the margins observed in each supermarket.

III.3 Causality tests

The descriptive analysis shows approximately similar behaviour in terms of pricing between the two supermarkets. However, it is natural to ask whether it was always the same and whether the coincidence was not due to the fact that they are sort of 'leader-follower' relationships between the retailers. This is even more important as it was described in the previous sections supermarkets have gone through significant transformations during the period covered by the sample.

With the purpose of answering the aforementioned questions we constructed Table 5 which presents Granger causality tests for each one of the products, for the entire sample and splitting the sample into two periods based on observation of the data: July 1996 to December 2000 and January 2000 to March 2007. The level of significance chosen for rejecting the causality was 1 per cent.

The results indicate significant changes in causality across products between the two periods, therefore, it is expected that the results for the entire sample are masking part of the competition story between the retailers. Thus, in the case of tomatoes the entire sample indicates causality from Tesco to Sainsbury; however, this only reflects the result of the second part of the sample. With respect to Bramley's apples, the entire sample indicates causality from Sainsbury to Tesco, although the two sub sample indicate that there is no causality. For white cabbage the sub-samples indicate double causality, although the entire sample shows that the causality goes from Sainsbury to Tesco. In the cases of cucumbers, Iceberg and Round lettuce the entire sample indicates double causality although despite the fact that the sub-samples indicate causality in only one direction.

Due to the fact that the results from Table 4 were not conclusive as regards of the causality, we decided to run the Granger test recursively (i.e., estimating the test by adding consecutively one observation). The results are presented graphically in Figure 3.

It should be noted that more than the significance of the test per se, it is more interesting to observe the evolution of the test over time. All of them indicate changes in the causality in different periods. A significant case is tomatoes, where the causality test indicates that lack of causality (i.e., no relation at all between both price) at the beginning of the sample; however, by 2001 the causality test changes its trend and Tesco becomes clear "leader" in that market.

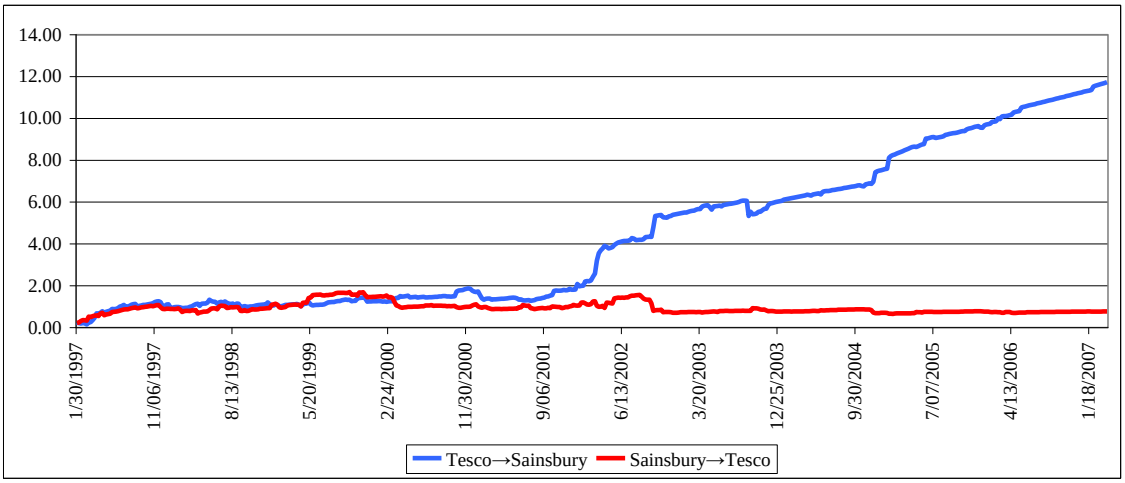
The other products reflect stories that are more complex, with interactions as being "leader-follower" over time and sudden changes. Although it is quite difficult to track the reasons behind this changes, it is clear that they are related to the all the transformations that supermarkets went through during the period and described in the previous sections.

Table 5: Granger causality tests for different samples

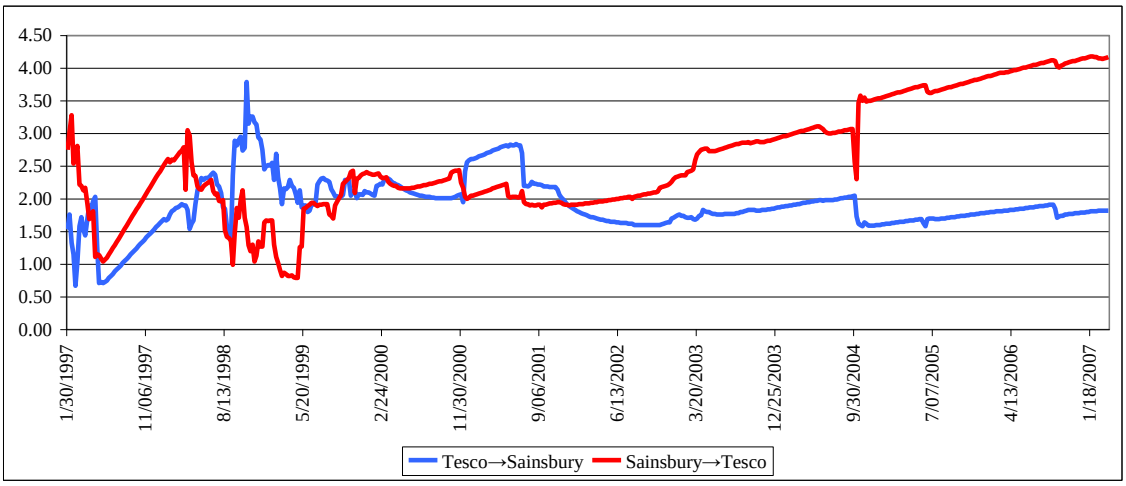
Product	Causality	Entire sample			Jul-96 - Dec-00			Jan-00 - Mar-07		
		Obs.	F test	Signif.1/	Obs.	F test	Signif.1/	Obs.	F test	Signif.1/
Tomato	Tesco → Sainsbury	553	11.7	*	228	1.7		325	18.7	*
	Sainsbury → Tesco		0.8			1.1			1.9	
Bramley's apples	Tesco → Sainsbury	553	1.4		228	2.4		325	0.4	
	Sainsbury → Tesco		3.1	*		1.4			1.4	
White cabbage	Tesco → Sainsbury	553	2.8		228	3.6	*	325	3.6	*
	Sainsbury → Tesco		6.0	*		3.0	*		4.6	*
Cucumbers	Tesco → Sainsbury	536	6.5	*	228	1.1		308	12.1	*
	Sainsbury → Tesco		4.4	*		2.5			2.6	
Iceberg lettuce	Tesco → Sainsbury	536	10.4	*	228	2.8		308	10.8	*
	Sainsbury → Tesco		5.5	*		3.0	*		2.8	
Round lettuce	Tesco → Sainsbury	553	8.9	*	228	5.6	*	325	5.2	*
	Sainsbury → Tesco		3.7	*		2.1			1.6	

Notes:
1/ "*" denotes that the null hypothesis is rejected at 1 per cent of significance. "→" indicates the direction of the tested causality.

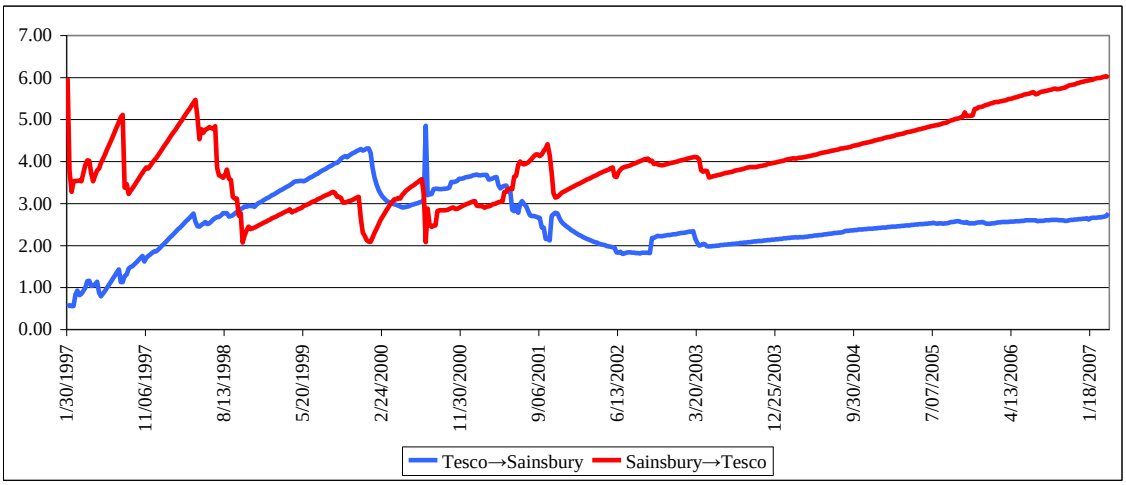
Figure 3: Recursive causality tests between J. Sainsbury and Tesco prices



a. Tomato prices

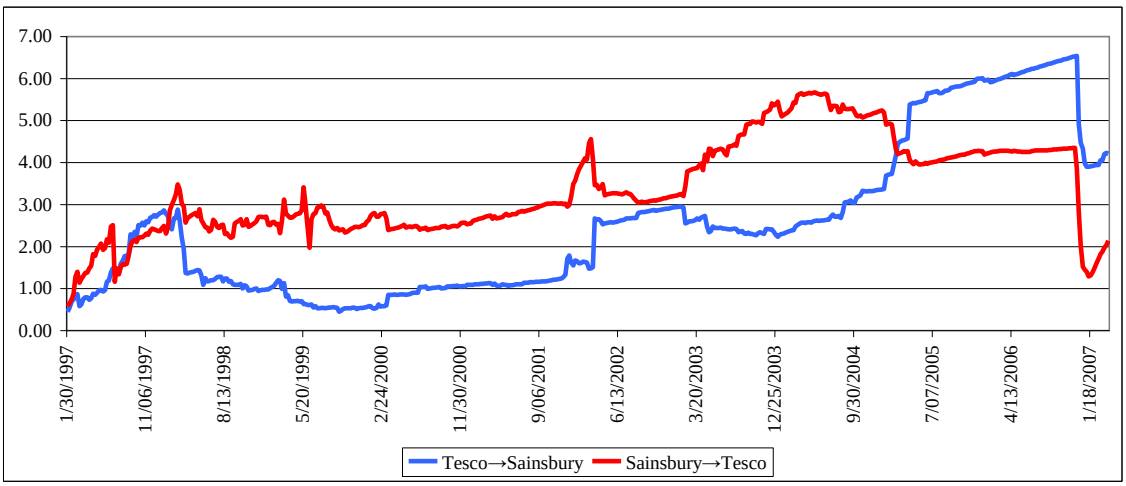


b. Bramley's apples prices

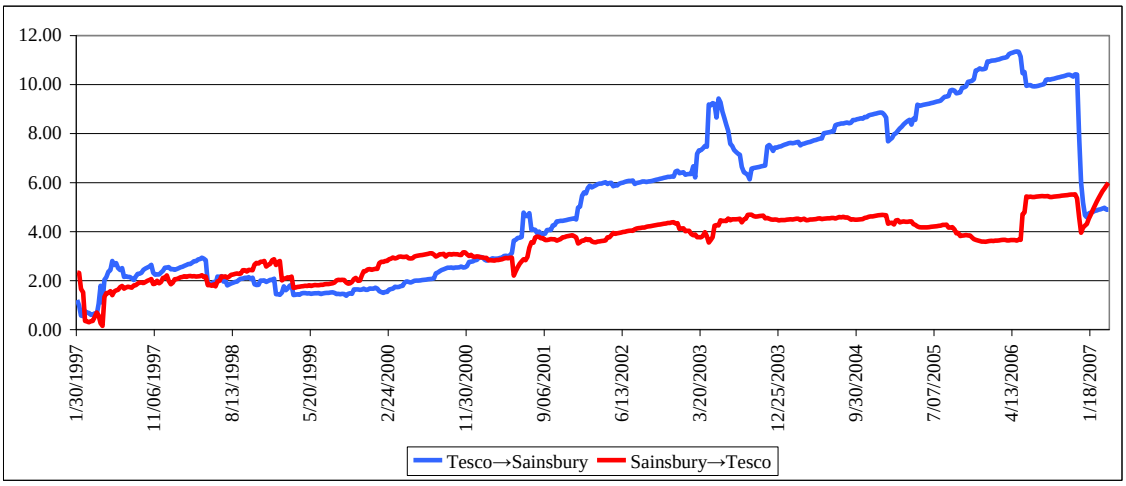


c. Cabbage prices

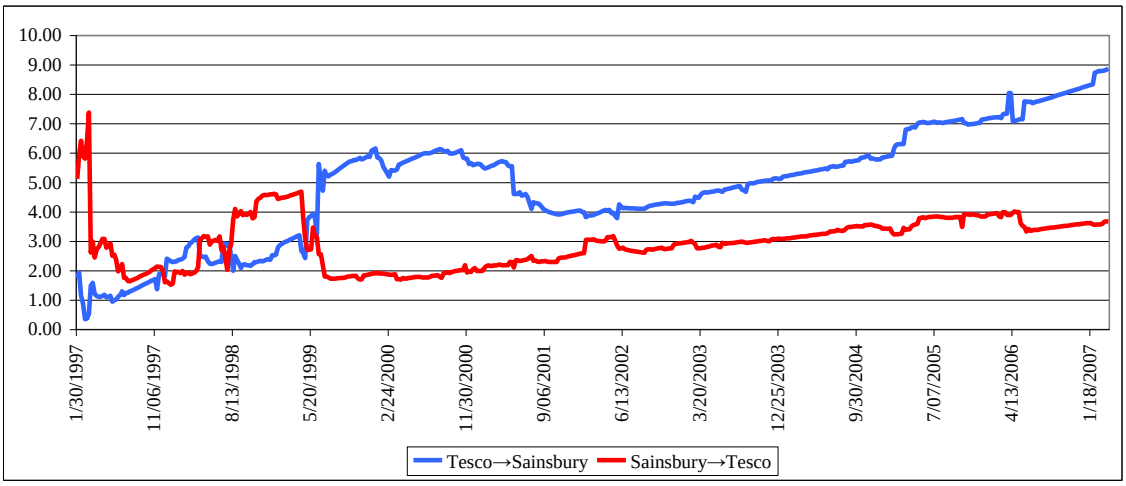
Figure 3: Recursive causality tests between J. Sainsbury and Tesco prices (cont.)



d. Cucumbers prices



e. Iceberg lettuce prices



f. Round lettuce prices

III.4 Correlation analysis

Results from the study of the Competition Commission (Cooper, 2003) indicated the supermarkets use of price reductions in some categories while keeping others at high or at a normal price (i.e., averaging) with the purpose of average out prices across the products. We tested the presence of behaviour in some of the products (excluding apples, which are less probable to be included in a salad) using correlation analysis and t tests, which are presented in Table 6.

If some sort of averaging was occurring over time one would expect negative correlation amongst the categories. The results in Table 6 indicate that none of the negative correlations was, using a t test, statistically significant. It is important to note that this result is strictly related to prices and it does not mean that this type of behaviour does not occur in other categories or that is does not occur at all as retailers have several parameters that they may modify beyond prices such as quality or services.

Table 6: Correlation coefficient amongst retail prices 1/

	J. Sainsbury					**Tesco**				
	R11	R13	R14	R15	R16	R21	R23	R24	R25	R26
R11	**1.00**	**0.01**	**0.42 ***	**0.37 ***	**0.42 ***	0.94 *	0.00	0.38 *	0.35 *	0.41 *
R13	**0.01**	**1.00**	**0.03**	**0.05**	**0.14 ***	0.03	0.57 *	0.01	0.06	0.06
R14	**0.42 ***	**0.03**	**1.00**	**0.57 ***	**0.50 ***	0.44 *	0.00	0.91 *	0.58 *	0.52 *
R15	**0.37 ***	**0.05**	**0.57 ***	**1.00**	**0.59 ***	0.38 *	-0.06	0.57 *	0.92 *	0.64 *
R16	**0.42 ***	**0.14 ***	**0.50 ***	**0.59 ***	**1.00**	0.43 *	0.02	0.51 *	0.56 *	0.87 *
R21	0.94 *	0.03	0.44 *	0.38 *	0.43 *	**1.00**	**0.02**	**0.40 ***	**0.36 ***	**0.45 ***
R23	0.00	0.57 *	0.00	-0.06	0.02	**0.02**	**1.00**	**-0.02**	**-0.05**	**-0.01**
R24	0.38 *	0.01	0.91 *	0.57 *	0.51 *	**0.40 ***	**-0.02**	**1.00**	**0.59 ***	**0.52 ***
R25	0.35 *	0.06	0.58 *	0.92 *	0.56 *	**0.36 ***	**-0.05**	**0.59 ***	**1.00**	**0.62 ***
R26	0.41 *	0.06	0.52 *	0.64 *	0.87 *	**0.45 ***	**-0.01**	**0.52 ***	**0.62 ***	**1.00**

Notes:

1/ The name Rij (e.g., R11) denotes the retail price of supermarket i (1=Sainsbury, 2= Tesco) of product j (1=tomato, 3=white cabbage, 4=cucumber, 5=Iceberg lettuce, 6= Round lettuce). * is significant at 1 per cent.

III.5 VAR models

In order to study the interaction of the retailers' prices for each one of the products, we proposed six VARs model, which are presented in Table 7.

Table 7: Bivariate VAR models for each product 1/ 2/

Tomato (1)			Bramley's apple (2)			White cabbage (3)			Cucumber (4)			Iceberg lettuce (5)			Round lettuce (6)		
	R11	R21		R12	R22		R13	R23		R14	R24		R15	R25		R16	R26
R11(-1)	0.316	0.147	R12(-1)	0.688	0.008	R13(-1)	0.699	-0.072	R14(-1)	0.579	0.200	R15(-1)	0.479	0.245	R16(-1)	0.842	0.202
	(0.068)	(0.067)		(0.045)	(0.043)		(0.044)	(0.039)		(0.047)	(0.051)		(0.076)	(0.073)		(0.047)	(0.063)
	[4.640]	[2.196]		[15.271]	[0.188]		[15.948]	[-1.839]		[12.333]	[3.937]		[6.323]	[3.356]		[18.064]	[3.207]
R21(-1)	0.520	0.645	R12(-2)	0.190	0.137	R13(-2)	0.033	0.154	R24(-1)	0.223	0.561	R15(-2)	0.065	0.073	R16(-2)	-0.052	-0.115
	(0.071)	(0.070)		(0.055)	(0.053)		(0.054)	(0.048)		(0.047)	(0.051)		(0.082)	(0.079)		(0.044)	(0.060)
	[7.355]	[9.259]		[3.467]	[2.597]		[0.616]	[3.201]		[4.727]	[11.002]		[0.799]	[0.926]		[-1.168]	[-1.915]
Intercept	8.890	12.429	R12(-3)	-0.057	-0.085	R13(-3)	0.082	0.006	Intercept	2.845	2.114	R15(-3)	-0.039	-0.297	R26(-1)	0.141	0.710
	(2.420)	(2.382)		(0.056)	(0.053)		(0.044)	(0.039)		(1.279)	(1.385)		(0.076)	(0.073)		(0.034)	(0.045)
	[3.673]	[5.217]		[-1.027]	[-1.599]		[1.870]	[0.149]		[2.225]	[1.526]		[-0.509]	[-4.061]		[4.198]	[15.674]
W1	0.141	0.155	R12(-4)	-0.033	-0.004	R23(-1)	0.129	0.702	W4	0.207	0.287	R25(-1)	0.292	0.499	R26(-2)	0.020	0.122
	(0.018)	(0.018)		(0.053)	(0.051)		(0.049)	(0.044)		(0.031)	(0.033)		(0.078)	(0.075)		(0.035)	(0.047)
	[7.761]	[8.668]		[-0.618]	[-0.081]		[2.622]	[16.059]		[6.759]	[8.676]		[3.768]	[6.670]		[0.575]	[2.593]
			R12(-5)	0.105	-0.026	R23(-2)	-0.120	0.022	Trend	0.006	0.002	R25(-2)	-0.019	-0.050	Intercept	1.722	2.011
				(0.044)	(0.042)		(0.059)	(0.052)		(0.002)	(0.002)		(0.083)	(0.081)		(0.465)	(0.628)
				[2.398]	[-0.615]		[-2.039]	[0.412]		[3.114]	[1.118]		[-0.222]	[-0.619]		[3.700]	[3.200]
			R22(-1)	0.080	0.710	R23(-3)	0.009	0.109				R25(-3)	-0.029	0.211	W6	0.0002	0.0002
				(0.045)	(0.043)		(0.048)	(0.043)					(0.079)	(0.076)		(0.001)	(0.001)
				[1.767]	[16.407]		[0.189]	[2.567]					[-0.365]	[2.781]		[0.249]	[0.168]
			R22(-2)	-0.033	-0.090	Intercept	6.674	3.634				Intercept	5.499	8.420	Trend	0.002	0.002
				(0.054)	(0.052)		(1.543)	(1.375)					(1.942)	(1.875)		(0.001)	(0.001)
				[-0.598]	[-1.725]		[4.326]	[2.644]					[2.831]	[4.490]		[2.647]	[1.919]
			R22(-3)	-0.005	0.150	W3	0.147	0.012				W5	0.281	0.292			
				(0.054)	(0.052)		(0.037)	(0.033)					(0.044)	(0.043)			
				[-0.099]	[2.886]		[3.925]	[0.354]					[6.369]	[6.864]			
			R22(-4)	0.020	0.047	Trend	-0.003	-0.001									
				(0.054)	(0.052)		(0.001)	(0.001)									
				[0.359]	[0.909]		[-2.305]	[-0.987]									
			R22(-5)	-0.019	0.103												
				(0.045)	(0.043)												
				[-0.412]	[2.369]												
			Intercept	3.860	3.410												
				(1.854)	(1.778)												
				[2.083]	[1.918]												
			W2	0.055	0.034												
				(0.022)	(0.021)												
				[2.570]	[1.640]												
			Trend	0.007	0.002												
				(0.002)	(0.002)												
				[3.387]	[1.290]												
Observations	412	412		540	540		554	554		412	412		303	303		542	542
Adj. R-squared	0.84	0.84		0.93	0.91		0.74	0.79		0.83	0.80		0.73	0.71		0.93	0.87
F-statistic	725.66	695.75		643.30	472.84		201.75	262.84		501.15	401.62		119.07	107.26		1177.63	597.33
Log likelihood	-1500.15	-1493.71		-1644.92	-1622.40		-1610.98	-1547.09		-1264.36	-1297.35		-1016.42	-1005.81		-1080.68	-1243.24
Mean dependent	117.78	117.00		131.48	124.06		55.61	51.18		57.37	55.45		55.56	54.51		35.76	33.14
S.D. dependent	23.25	22.49		20.15	16.76		8.83	8.71		12.69	12.56		13.57	12.62		6.70	6.66

Notes:

1/ Standard errors are presented in parenthesis under the coefficients and t statistics are presented in brackets. All the regression were carried by ordinary least squares.

2/ The name of the variables is as follows: Rij (e.g., R11) denotes the retail price of supermarket i (1=Sainsbury, 2= Tesco) of product j (where j is given with the heading of the regression). Wj indicates the wholesale price of product j.

The structure of the models was different for each product, some of them including trends. In all the cases the relevant wholesale price was included, being significant for all products except for Round lettuce.

The number of lags in each model was selected based on the Akaike and Schwartz criteria. Where these two criteria failed to indicate the same optimal number of lags, a decision was taken based on the properties of the residuals, which are supposed to be independent and identically distributed. We used Engle's test to study the presence of autocorrelation in the series, which was rejected in all the cases.

In addition, we computed the inverse roots of the autoregressive characteristic polynomial to verify whether they were within the unit circle and therefore that all the studied models were dynamically stable. The results indicated that all the models were dynamically stable.

The next step was to use the estimated models to compute both the impulse-response functions and the variance decomposition for each product. To do so we used the Cholesky decomposition of the error matrix with the series ordered according to their causality (using Granger causality tests) due to the fact that one should expect correlation between the error terms of the VAR equations. The impulse-response functions are not presented in the paper but they are available from the authors. Table 8 below presents the variance decomposition for each VAR.

Table 8 presents six sub-tables, one for each VAR model. Within each sub-table the panel above indicates the decomposition of the variance of the "exogenous" variable and the panel below presents the decomposition of the variance of the "follower" variable.

To understand the interpretation of Table 8, let us concentrate on the case of tomato. As the VAR system in the first period responds to a shock in the Tesco price, the variance of this price is only explained by its own shock and not by feedback from Sainsbury price (see panel above). However, for the Sainsbury price, 54.9 per cent of its variance is explained by Tesco's price shock and 45.1 per cent by its own price. It is interesting to note that whilst a significant part of the variance in Sainsbury's tomato price is explained by Tesco, the opposite is not truth.

Based on the variance decomposition it is possible to try to classify the results into three cases: first, when the leader affects the follower but receive only small feedback from it (e.g., tomato, cucumber, and Iceberg lettuce); second, when the feedback is relatively small for both supermarkets (e.g., Bramley's apple, white cabbage); and third, when the feedback received from the follower by the leader is significant (e.g., Round lettuce).

The first of the mentioned cases would indicate some sort of clear leader follower situation. The second one would be one of "related to some degree but independent", whilst the third case would show a higher degree of interaction between the supermarkets.

Table 8: Variance decomposition for each product VAR model 1/

Tomato (1)				**Bramley's apples (2)**			
Variance Decomposition of R21				Variance Decomposition of R12			
Period	St dev.	R21	R11	Period	St dev.	R12	R22
1	9.1	100.0	0.0	1	5.2	100.0	0.0
4	13.5	98.8	1.2	4	7.8	99.3	0.7
16	14.7	98.6	1.4	16	10.3	96.8	3.2
Variance Decomposition of R11				Variance Decomposition of R22			
Period	St dev.	R21	R11	Period	St dev.	R12	R22
1	9.3	54.9	45.1	1	4.9	3.6	96.4
4	14.0	77.1	22.9	4	6.8	7.8	92.2
16	15.3	80.6	19.4	16	9.6	11.8	88.2
White cabbage (3)				**Cucumber (4)**			
Variance Decomposition of R13				Variance Decomposition of R14			
Period	St dev.	R13	R23	Period	St dev.	R14	R24
1	4.5	100.0	0.0	1	5.2	100.0	0.0
4	6.4	99.2	0.8	4	7.6	93.4	6.6
16	7.4	99.2	0.8	16	8.1	91.1	8.9
Variance Decomposition of R23				Variance Decomposition of R24			
Period	St dev.	R13	R23	Period	St dev.	R14	R24
1	4.0	5.2	94.8	1	5.7	29.3	70.7
4	5.7	7.2	92.8	4	7.8	42.9	57.1
16	7.3	21.2	78.8	16	8.2	46.3	53.7
Iceberg lettuce (5)				**Round lettuce (6)**			
Variance Decomposition of R15				Variance Decomposition of R16			
Period	St dev.	R15	R25	Period	St dev.	R16	R26
1	7.0	100.0	0.0	1	1.8	100.0	0.0
4	9.9	95.2	4.8	4	3.2	91.4	8.6
16	10.2	93.3	6.7	16	4.8	68.6	31.4
Variance Decomposition of R25				Variance Decomposition of R26			
Period	St dev.	R15	R25	Period	St dev.	R16	R26
1	6.8	46.6	53.4	1	2.4	9.7	90.3
4	9.4	59.0	41.0	4	3.8	18.6	81.4
16	9.7	57.5	42.5	16	5.2	24.7	75.3

Notes:
1/ The name Rij (e.g., R11) denotes the retail price of supermarket i (1=Sainsbury, 2= Tesco) of product j (where j is given with the heading of each variance decomposition).

IV. Conclusions

The literature review indicates that supermarkets have gone through intense competition during the period of study, this competition has been at the level of product and that supermarkets have carried out important structural reforms in the way they manage the fresh fruits and vegetable sector which have had impact in each product's market.

Some of aforementioned points seem to be reflected in the price data, especially when observing the recursive Granger causality tests are estimated. Except in the case of tomatoes when a clear leadership appears after 2001, in all the other markets the stories seem to be are more complex, with interactions as being "leader-follower" over time and sudden changes.

The use of correlation analysis to test whether some sort of price averaging was occurring over time indicated a rejection of such a case. However, it should be noted that this result is strictly related to prices and it does not mean that this type of behaviour does not occur in other categories or that is does not occur at all as retailers have several parameters that they may modify beyond prices such as quality or services.

The estimation of VAR models and the subsequent variance decomposition indicated the presence of three cases that may indicate different degree of competition: the first case corresponded when the leader affected the follower but received only small feedback from it. This was found in tomato, cucumber, and Iceberg lettuce. The second case corresponded when the feedback is relatively small for both supermarkets as in Bramley's apple and white cabbage. The third case occurred when the feedback received from the follower by the leader is significant as for the Round lettuce.

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