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Healthy competition to support healthy eating? An investigation of fruit and vegetable pricing in UK supermarkets

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Abstract

Governments and public health officials are urging the public to eat more fruits and vegetables to contribute to a healthy diet. However, there is concern that a lack of effective competition amongst supermarket retailers has resulted in inflated prices for these products which are deterring consumers from eating more of these healthy foods. We investigate this by examining the nature and extent of price competition for fresh fruits and vegetables amongst UK supermarket retailers, drawing on a panel of weekly retail and corresponding wholesale market prices over a seven-year period. We find that the extent of supermarket competition varies across the products, being quite intense on some but much weaker on others, where the retailers do not fully respond to each other's prices and where the extent of their competitive interaction varies significantly with each other.

Key Words: Supermarkets, price competition, fruit and vegetables, healthy eating

JEL classifications: L13, L81, D43, I18

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1 Introduction

There is growing public health concern that consumers, especially from poorer families, are being dissuaded from eating healthy fresh fruit and vegetables, as prices have been rising faster for these healthy fresh foods than for processed foods (ODI 2015).[1] This can have major consequences on the health of people and increase the burden of health costs of treating illnesses linked with poor diets and unhealthy eating.[2] While governments seek to counter this by promoting healthy eating, like the UK's "5-a-day" campaign, high prices for fresh fruits and vegetables can be a major obstacle to achieving improved diets.[3]

Of particular concern is whether increasing concentration in grocery retailing might lead retailers to avoid intense price competition over relatively undifferentiated commodity products such as fruit and vegetables. In this context, the UK food retail sector has become increasingly concentrated over time and is now characterised as a relatively tight oligopoly with a small number of nationally competing supermarket chains. The sector has been subject to a number of investigations by the competition authorities over recent years but the popular perception is one of the industry fighting regular price wars and competition being fierce. As such, strong price competition could be expected in fresh fruits and vegetables, largely unbranded and supplied without noticeable producer power, where retail competition should be intense for perishable, and thus frequent purchases.

Media reports, however, suggest that fruit and vegetables are sold in the UK with high mark-ups and indicate ineffective price competition in the sector.[4] More substantive investigation and analyses highlight the incentives and potential for exercising market power against consumers' interests in the food retail sector (Competition Commission 2000, 2008; Smith 2004, 2006). Focusing on particular products, Lloyd (2008), Revoredo-Giha and Renwick (2012) and Seaton and Waterson (2013) provide empirical evidence that price leadership and

[1] For example, fruit and vegetable purchases in the UK fell 9.4 per cent between 2007 and 2012. While the UK government recommends that these products make up a third of people's food consumption they account for less than a quarter for average households while for the lowest income decile they accounted for less than a fifth of foods purchased (DEFRA 2013). Moreover, Jones et al. (2014) provide clear empirical evidence on prices for healthy foods being consistently higher than for less healthy foods, with a growing price gap between them.

[2] The 2010 Global Burden of Disease Study found that unhealthy diets already accounted for 14.3% of the UK's disease burden which causes an estimated cost to the National Health Service of £5.8 billion per year (Jones et al. 2014).

[3] For instance, it has been estimated that meeting the recommended 5-a-day portions of fruit and vegetables would mean that UK consumers would need to double their expenditure on such foods and this would amount to more than half of their current average annual food bill (*The Grocer* 2014).

[4] See for instance, *The Times* (2011), *The Sunday Mirror* (2011), *The Daily Mail* (2012), and *The Grocer* (2014).

potential retail price coordination exists for UK beef, fresh produce, and packaged groceries, respectively.

However, in these pricing studies either the range of products or number of retailers covered tend to be limited and they span different time periods. In contrast, we focus on fruit and vegetable prices and examine these across all seven main national supermarket chains in the UK for a period spanning 2007-2013. Importantly, this is a time period which covered economic austerity and a deep recession, which might be expected to strengthen competitive retail pricing pressures. We draw on weekly retail prices for these seven retailers and additionally utilise matching wholesale prices from the major UK fruit and vegetable wholesale markets to provide an indication of the retail supply costs. We examine the movements of wholesale and retail prices to provide an indication of pass-through rates, where high (low) pass-through rates should be indicative of more (less) competitive conditions, *ceteris paribus*. Furthermore, we examine the character and intensity of price interactions across retailers to assess the degree of product-level price competition.

The paper is organised as follows. The next section reviews the market and the related literature. Section 3 summarises the dataset of retail and wholesale prices. Section 4 reports on the pass-through analysis at the product level. Section 5 reports on the analysis of price interaction across retailers to identify the patterns of competition at item level. Section 6 discusses the results and draws conclusions on the extent and character of price competition in the market.

2 Review of the market context and related literature

UK food retailing is recognised as one of the most concentrated and differentiated retail grocery markets in the EU (Dobson et al. 2003; European Commission 2014). For the past decade, the retail grocery sector in the UK has been dominated by the "Big 4" retailers – Tesco, Sainsbury, Asda and Morrisons – operating predominantly from large-format superstores, followed by smaller chains with more specialist appeal, including upmarket retailers like M&S and Waitrose focusing on higher income consumers, convenience retailers like Co-operative Food focusing on neighbourhood retailing, or hard discount retailers, like Aldi and Lidl operating with limited product ranges, mainly private label, sold at discount prices.

Even amongst the Big 4 retailers, with three quarters of UK grocery sales, there is perceived

differentiation in respect of product ranges, services and consumer appeal. Sainsbury is seen as more upmarket, while Asda is more price focused as an "every day low price" ("EDLP") positioned retailer, with Morrisons value-oriented and the market leader, Tesco, has taken the middle ground as the retailer having the broadest appeal. The other retailers are considerably smaller but serve consumers across the socio-demographic range. As a result, we would expect that all are competing for consumer attention, perhaps especially for fresh fruit and vegetables.

The UK Competition Commission (2000; 2008) undertook detailed sector-wide investigations and concluded that generally price competition had been working effectively.[5] Detailed analysis by Smith (2004; 2006) shows how the combination of store characteristics and location affect consumer store choice and sales at the local level. However, while store choice decisions are made at a local level, the prices that these chains set are generally national, i.e. apply right across their supermarket networks. This feature is helpful in examining retail price competition as conducted here, but also means that it is straightforward for the retailers to monitor each other's prices and could offer conditions suitable for tacit price coordination.

Beyond formal competition inquiries, the media have continued to raise concerns about UK supermarkets setting high prices on fruit and vegetables and apparently avoiding intense price competition. For example, *The Times* (2011) noted that wholesale/retail mark-ups are more than 100% in most fruits and vegetables they investigated, and reported comments from industry insiders that fresh produce is one of the most profitable categories for UK supermarkets. *The Grocer* (2014) extended coverage to investigate prices in the UK against those in other EU countries. Accounting for transportation costs, it found that prices are significantly higher in the UK, and identified UK prices as being inflated due to non-cost reasons. In addition, there have been concerns about artificial price discounting on fruit and vegetables with investigations by Trading Standards about misleading price promotions where prices have been intentionally inflated before an announced price reduction or where the forms of price promotions are deliberately rotated in a way that allows the supermarket to make continual claims of the products being on "special offer" (CMA 2015).

In the academic literature, there are few papers focusing on the oligopolistic retailer competition in this market context. Seaton and Waterson (2013) examine price leader-follower patterns between Tesco and Asda for a range of packaged grocery items. Also, of more direct

[5] The Competition and Markets Authority has, though, been critical of the way that some price promotions have been used as potentially misleading by UK grocery retailers (CMA 2015).

relevance to UK fresh produce retailing, Revoredo-Giha and Renwick (2012) observe a strengthening price interrelationship between Tesco and Sainsbury, where price responses tend to be more strategic rather than straightforward direct competition. However, rather than just pairwise comparisons, there might be merit in studying how a broader set of rivals interact on pricing, which is our purpose, given the presence of significant supermarket heterogeneity which could be more important in respect of consumer search friction and the product dimension, as respectively considered by Wildenbeest (2011) and Lloyd et al. (2014).

In characterising oligopolistic competition patterns, Kim and Cotterill (2008) find that the pass-through rate is relatively low under collusion while high under Nash-Bertrand competition. This suggests that the pass-through rate could be a useful indictor for assessing competitive intensity even with the presence of persistent price dispersion (where some retailers consistently price below others). However, consistent patterns of price dispersion might be indicative of co-ordination behaviour and competition being ineffective (Rotemberg and Saloner 1990; Anderson 1987). Moreover, supermarket pricing promotions behaviour can also have a significant influence on micro-level price movements (Berck et al. 2008; Lan et al. 2015), but equally so can tactical but continuous small price changes (Chakraborty et al. 2015).

In examining pass-through rates, we follow Goldberg and Campa (2010) and Nakamura and Zerom (2010) by estimating long-run pass-through in a reduced-form specification, where we are able to measure the underlying price-cost relationship. For price interaction analysis, we examine price responses across retailers based on measuring price dispersion, the rigidity of price hierarchies and price correlation analysis to offer different perspective on how the retailers interact with each other on their fruit and vegetable prices. It importantly extends previous work focused on pairwise interaction (e.g. Seaton and Waterson 2013; Revoredo-Giha and Renwick 2012) or covering only the leading group of players (e.g. Chakraborty et al. 2014; 2015) to more general oligopolistic interaction amongst a wide set of competing firms.

3 The data

Our empirical investigation draws on weekly wholesale prices and retail prices covering major supermarket chains for an assortment of fresh fruit and vegetables over a relatively long time period. In addition, we also utilise a number of other weekly measures to capture various cost and demand effects facing retailers and consumers. These variables are included in the pass-

through regression model to control for additional price variation from input cost changes.

Our supermarket retail prices are those reported weekly on a selection of fruits and vegetables by the trade magazine "Horticulture Week" ("HW") from October 2007 to April 2013 (288 weeks). The reported prices are those offered at each of the leading UK supermarket retailers collected through store visits undertaken by price checkers from an independent marketing agency, Market Intelligence Services. For the purpose of constructing a panel dataset, we identified 26 products with regularly reported prices each week across the full year sold by all leading seven UK supermarket retailers. All 26 products count towards consumers eating their recommended "5-a-day".[6] In total, this HW retail price dataset provided a panel of 52,416 weekly prices. The retailers cover the "Big 4" mainstream supermarket retailers – Tesco, Sainsbury, Asda and Morrisons – which tend to operate with large format superstores, two "upmarket" retailers, M&S and Waitrose, and the more convenience-oriented (small supermarket format) retailer Co-operative Food. Jointly these seven retailers account for over 90% of all supermarket food sales in the UK.[7]

We collected corresponding wholesale prices of fruits and vegetables from two sources: the online service provided by the Fresh Produce Journal ("FPJ") and the website for the Department for Environment, Food and Rural Affairs in the UK ("DEFRA").[8] These are recorded as the weekly average of the spot prices sold through the main UK fruit and vegetable wholesale markets, as typically used by retailers, food processors, the catering trade, market stall holders and independent green grocers who buy through wholesale markets rather than directly contracting for supplies with farmers and food importers. Using these data, we were able to construct three different wholesale price series. The FPJ wholesale prices provided

[6] The 26 common products identified were apples (cooking), apples (eating), aubergine, broccoli, cabbage (savoy), carrots, cauliflower, celery (each), celery (hearts, pre-packed 2), courgettes, cucumber (full), cucumber (half), leek, lettuce (gem), lettuce (iceberg), lettuce (round), onion (red), onion (white), parsnip, pears (conference), radish, strawberries, swede, sweetcorn, tomatoes (loose) and tomatoes (pre-packed 6). The products in the sample were matched across retailers on a like-for-like basis with any weight differences noted along with whether the goods were imported or domestically grown.

[7] There is also some price data available on a further retailer, the hard discounter Aldi, but the data were only available on a far more limited number of products and for significantly shorter time periods, so we have not included this retailer in our sample. Nevertheless, we acknowledge that hard discounters have been growing rapidly, albeit from a small base, in the UK and so their influence has been growing, particularly after the current study period from 2013 onwards.

[8] FPJ wholesale prices are available online from

http://publisher.theengineshed.com/freshinfo/embedded_prices.php?s=r&ss=mp&fn=prod&date=&show=&pid=888&cid=&mid=&cat1=245&offset=0; and DEFFRA's wholesale prices are available online from https://www.gov.uk/government/statistics/wholesale-fruit-and-vegetable-prices.

wholesale price information listed by country (including the UK) and we used these to construct "average FPJ prices" for products which were simultaneously sourced from multiple countries, taking a simple average of the prices across the different countries. For products where the key country source switched over time (e.g. across different seasons of the year) we used "minimum FPJ prices" as the recorded lowest prices in the given week. In contrast, for products primarily sourced from the UK, we relied instead on the DEFRA recorded wholesale prices as a consistent single price series without the need to consider and treat multiple prices.

To be clear, these wholesale prices are not likely to be the same as the actual supply prices paid by the supermarket retailers, given that these major retailers frequently contract directly with growers and importers rather than purchase their supplies through these wholesale markets, which tend to cater for smaller, more specialist needs. Even so, to the extent that the wholesale markets cover the same products from the same country sources as sold in these supermarkets then the prices that the supermarkets pay for their supplies should broadly correspond with prices seen in wholesale markets. In this regard, the observed wholesale prices should be a reasonable proxy for the supermarkets' supply costs, even if at the upper end given that we might expect the retailers to use their retail buying power and bulk buying economies to negotiate the lowest possible supply prices. However, in recognising the inherent volatility of wholesale spot market prices (affected by the lumpiness of wholesale supply and demand) and also being conscious of the transfer time of the products through to retail markets, we use four-week moving averages of the selected wholesale spot prices as a cost indicator facing the supermarkets when we match these proxied supply costs against the retail prices in each given week. In addition, the way we construct wholesale prices from different sources and countries may also help to avoid simultaneous endogeneity in the pass-through regression model.[9]

Both retail and wholesale series have some missing values over the full time period, because either the retail price was not recorded by the price checker that week or because the wholesale markets were not sufficiently active that week to be recorded. Especially in the HW dataset, we have retail prices missing in the 2-3 weeks around Christmas and they are only collected bi-weekly since July 2012. There is also a relatively long gap from the end of April to the

[9] One may argue that domestic retail and wholesale prices are simultaneously determined so wholesale prices are not exogenous in the pass-through regression model. In the UK, the wholesale market for fruits and vegetables is relatively independent and most of fruits and vegetables are imported for much if not most of the year. Thus, by constructing wholesale prices using all these information, we believe our wholesale prices are exogenous to UK supermarket retail prices in the pass-through regression model.

beginning of June in 2008. Here we interpolated the missing values following other pricing studies (e.g. Pesendorfer 2002; Seaton and Waterson 2013; Hong and Li 2016) to generate continuous series. Our approach has been to interpolate missing values by applying a set of simple rules to minimise any distortions: (i) for one or two consecutive missing values, based on either the previous or next value to them, not the means between them; (ii) randomise the values according to values in the previous and following weeks. With these rules in mind, the interpolation for Christmas/New Year holiday missing values as well as bi-weekly missing values appear reasonable in generating a balanced panel for the full time period as prices hardly tend to change over these periods. However, we are more cautious about the interpolation of April-June gap in 2008, so we perform a robustness check where we take a subsample of "best period" from 16/06/2008 to 23/07/2012 according to data availability and report the corresponding results in the on-line Appendix (Tables A1 and A2).

To complement price data, we also have a number of other weekly measures. Specifically, to reflect changes in underlying distribution and transport costs for the retailers and shopping costs for consumer, we have a measure of weekly road fuel prices.[10] To reflect prices of complementary items that might go into the shopping basket especially with vegetables that represent other fresh unprocessed products, we have a weekly measure of red meat retail prices.[11] Also, in view of the products relating fresh fruit and vegetables including salad ingredients, we are conscious that the weather might impact demand and thus inventory so we use weekly average temperatures and the number of recorded weather events across the week (e.g. rain, snow, fog, etc.).[12]

4 Price pass-through analysis

In this section, we focus on whether wholesale market prices lead retail prices. We examine the response of individual retail prices to the wholesale prices at the product level, estimating

[10] These are official UK figures available from https://www.gov.uk/government/statistical-data-sets/oil-and-petroleum-products-weekly-statistics.

[11] This is based on a composite of the various red meat prices recorded weekly available from http://www.meat-prices.co.uk/.

[12] The weather data is based on daily data aggregated into weekly data from two key weather stations at London (Heathrow) and Manchester to represent the weather affecting UK consumers, as these two weather stations are closest to the two most important urban conurbations in the UK while being geographically spread with one in the southern England and one in northern England. The data is based on UK Met Office measurements sourced from http://www.wunderground.com/history/airport/EGLL/2004/7/23/DailyHistory.html?req_city=NA&req_state=NA&req_statename=NA.

a reduced-form pass-through regression model similar to those commonly used in the exchange rate pass-through literature (e.g. Goldberg and Campa 2010; Nakamura and Zerom 2010).

As an initial step, we report summary statistics on retail and wholesale prices at the product level in Table 1. The mean prices reported are in pence and "CV" represents the coefficient of variation across time and for all retailers to give an indication of the range and spread of prices for that product. For some products, wholesale and retail prices appear relatively close, which indicates the possibility of these goods being sold with low margins (or even in the case of Broccoli with an apparently negative margin, possibly reflecting supermarkets' contracts and buying power).

In the last two columns of Table 1, retail-wholesale correlations (in levels) are found to be reasonably but not especially high at 0.3-0.6 for 13 of the 26 products but are extremely low, at around 0.1 or less, for several products (notably Packaged Tomatoes and Radish where there is hardly any correlation). We also examine the correlations by first differences, to account for the fact that some price series might not be stationary, e.g. if both retail and wholesale prices rise over time with natural inflation then that could lead to overstated correlations. The first-difference correlations are substantially lower, close to zero for almost all products, which might indicate non-stationarity of prices but also strongly reflects the fact that wholesale prices are much more variable than retail prices (where the retailers can set the same prices for several weeks at a stretch).

Table 1 – Average retail and wholesale prices and correlations

Product name	Retail price (Pence)		Wholesale price (Pence)		Avg. retail-wholesale price correlation	
	Mean	CV	Mean	CV	In levels	1st difference
Apples (Cooking) kg	157	0.12	65	0.22	0.48	-0.01
Apples (Dessert) kg	173	0.12	79	0.15	0.38	0.04
Aubergine each	98	0.16	43	0.31	0.08	0.03
Broccoli kg	191	0.16	203	0.30	0.30	0.00
Cabbage (Savoy) each	79	0.16	48	0.30	0.19	0.06
Carrots kg	78	0.12	34	0.26	0.40	0.04
Cauliflower each	98	0.23	72	0.32	0.46	0.08
Celery Hearts x2	119	0.17	32	0.27	0.12	0.03
Celery each	78	0.18	19	0.32	0.21	-0.02
Courgettes kg	195	0.11	103	0.30	0.14	0.03
Cucumber Full each	78	0.17	27	0.29	0.53	0.17
Cucumber Halves	42	0.16	16	0.30	0.49	0.20

Leeks kg	238	0.14	100	0.17	0.13	0.07
Lettuce Gem x2	86	0.14	49	0.20	0.39	0.06
Lettuce Iceberg each	90	0.16	42	0.33	0.40	0.01
Lettuce Round each	57	0.13	29	0.17	0.45	0.02
Onions Red kg	105	0.18	53	0.10	0.11	0.04
Onions White kg	86	0.12	24	0.34	0.09	-0.02
Parsnips kg	164	0.15	76	0.12	0.3	0.10
Pears (Conference) kg	193	0.18	80	0.30	0.45	0.08
Radish pp150g	58	0.17	37	0.18	0.03	0.01
Strawberries 400g	234	0.29	114	0.12	0.32	0.07
Swede kg	95	0.23	39	0.17	0.27	0.06
Sweetcorn pp2	176	0.20	53	0.36	0.12	0.02
Tomatoes (Loose) kg	202	0.23	90	0.24	0.05	0.02
Tomatoes (Packaged) pp6	93	0.12	22	0.21	0.02	-0.01

As a formal examination, we estimate a reduced-form pass-through model using the panel of retail prices and wholesale prices at the product level. Using first-difference data in the estimation, we control for any potential non-stationarity in retail and wholesale price series as well as (time-invariant) unobserved retailer heterogeneity. In addition, we also attempt to include a rich set of exogenous variables to account for observed heterogeneity due to any omitted or imperfectly proxied variables in the specification. Thus, the following panel reduced-form specification is estimated for product $i = 1,\ldots, 26$, respectively:

$$\Delta p_{ijt} = \alpha_i + \sum_{k=0}^{m} \beta_{ik} \Delta w_{it-k} + \gamma_i TPR_{ijt} + \delta_i Import_{ijt} + \Gamma_i Z_t + \theta_t + v_{ijt} \qquad \forall i \qquad (1)$$

where Δp_{ijt} denotes the individual retail price change of product i in retailer j at week t. $\sum_{k=1}^{m} \Delta w_{it-k}$ is a lag distribution of the wholesale price changes of product i from week t to t - m. "TPR" refers to a dummy variable to account for any price changes due to "temporary price reductions" (e.g. price drop from regular to sale price or price return from sale to regular price) where all sale prices are identified based on Nakamura and Steinsson (2008). "Imported" refers to a dummy variable to reflect whether it is an imported price at the retail level. These two variables reflect micro-level market characteristics and vary across both retailers and products over time. They may account for a discounted supply price or higher distribution costs from overseas sourced products. Z is a vector of other exogenous variables affecting aggregate demand and supply which vary over time. Among them, we use road fuel price index to reflect changes in underlying distribution and transport costs for the retailers and shopping costs for consumer; red meat price index to reflect prices of complementary items that might go into the

shopping basket especially with vegetables; and weather temperatures and the number of recorded weather events across the week which might impact demand and inventory in view of the products relating fresh fruit and vegetables including salad ingredients.

In respect of the other terms in (1), the term θ_t is a vector of time fixed effects including sets of monthly dummies, yearly dummies, and a Christmas dummy (December-January). The monthly dummies mainly account for seasonality and yearly dummies account for structural change over year and also capture general demand change for that product in the market. The Christmas dummy controls for any Christmas holiday effect.[13] α_i is a constant at product level and therefore v_{ijt} refers to mean-zero error in each product equation. Similar to Goldberg and Campa (2010) and Nakamura and Zerom (2010), the parameter β_{ik} measures the retail-wholesale pass-through *k* weeks ago for product *i* (short run pass-through, "SRPT") and $\sum_{k=0}^{m} \beta_{ik}$ measures the cumulative pass-through or the long-run pass-through ("LRPT"). The standard error of LRPT is calculated using the Delta method. Equation (1) is estimated by product.[14] In the following analysis, LRPT is of particular interest.

Table 2 reports the estimation results. Two specifications are estimated to provide some consideration of the robustness of the pass-through estimates. In specification (1), we only include TPR and Import dummies as well as time fixed effects, while in specification (2) other control variables in Z are also included, which noticeably improve the performance of the model. In addition, we also report the results using a log-log specification to compare the robustness between pass-through elasticity and pence-to-pence pass-through in equation (1). Reassuringly, the results are similar in all specifications. The full results of Table 2 are given in the on-line Appendix (Table A4).

For the purpose of comparison, we also estimate the market-level pass-through as a benchmark including all products. Product-level fixed effects are controlled in this super panel data model. The market-level pass-through is found to be 0.178 and significant at the 1% level (following

[13] This dummy is also useful to control the effects from interpolation values for December and January.

[14] The lag selection is somewhat arbitrary. We select 4-week lags in the regression mainly due to our purpose of estimating LRPT and the economic intuition that wholesale prices might hardly affect retail prices after more than a month. In the Appendix (Table A3), we report a robustness check to see whether 4-week lag selection is too short to damage our further identification of competition intensity based on LRPT estimates. The results show that our lag selection is consistent with statistical approach applied in the literature by selecting the number of lags such that adding additional lags does not change the estimated long-run rate of pass-through.

specification (2)), indicating that a 1p change in wholesale prices results in 0.178p change in retail prices in this market. The estimated market pass-through elasticity is around 0.1%.

There is a noticeably wide range of values reported in Table 2 and different levels of statistical significance. In detail, we have six products with pass-through above the average for the set of products and significant at the 1% level (i.e. Iceberg Lettuce, Conference Pears, Cauliflower, Cucumber Halves, Cucumber Full, and Parsnips) and one (Dessert Apples) with pass-through above the average but with weak significance at 10% level. Three products (Courgettes, Loose Tomatoes, and Carrots) have pass-through rates below average with significance only at 5% or 10% level. The estimates on the other 16 products are not statistically significant.

With intensively competitive retail markets we might have expected to find strong relationships between retail and wholesale price movements for most if not all products. However, we find that only 6 of the 26 products exhibit a strong relationship, while low or insignificant pass-through rates apply to the other 20 products suggesting a less than intense competition pattern.[15]

Table 2 - Long run pass-through rates by product

Product	Level specification		Log specification	
	(1)	(2)	(1)	(2)
Apples (Cooking) kg	0.11	0.10	0.02	0.02
Apples (Dessert) kg	0.25**	0.23*	0.13**	0.11*
Aubergine each	-0.02	-0.02	0.01	0.01
Broccoli kg	0.00	-0.03	0.02	-0.01
Cabbage (Savoy) each	0.05	0.05	0.04	0.04
Carrots kg	0.19**	0.17**	0.13***	0.11**
Cauliflower each	0.36***	0.39***	0.24***	0.25***
Celery Hearts x2	0.09	0.06	0.04	0.04
Celery each	-0.18	-0.14	-0.06	-0.04
Courgettes kg	0.06**	0.06**	0.04*	0.04*
Cucumber Full each	0.58***	0.60***	0.18***	0.19***
Cucumber Halves	0.39***	0.41***	0.12***	0.13***
Leeks kg	0.27	0.24	0.13	0.11
Lettuce Gem x2	0.09	0.12	0.07	0.08
Lettuce Iceberg each	0.24***	0.24***	0.13***	0.13***

[15] The 5% and 10% significance levels are considered to be weak mainly due to the large sample size we have. According to Wooldridge (2012), only when the sample size is very small (e.g. less than 100), should we consider significance at the 5% or 10% level. While this judgement is open to question, we consider that the estimates on the inferred price-cost relationship might not be sufficiently reliable even if the estimated values are higher than others but are only weakly significant from zero.

Lettuce Round each	-0.07	-0.08	-0.06	-0.06
Onions Red kg	0.37	0.40	0.19	0.22*
Onions White kg	-0.08	-0.11	0.00	-0.01
Parsnips kg	0.88***	0.85***	0.41***	0.40***
Pears (Conference) kg	0.33***	0.34***	0.11***	0.11***
Radish pp150g	-0.09	-0.09	-0.07	-0.07
Strawberries 400g	0.67	0.64	0.29	0.29
Swede kg	0.17	0.17	0.13	0.12
Sweetcorn pp2	-0.06	-0.05	-0.02	-0.02
Tomatoes (Loose) kg	0.11*	0.12*	0.04	0.04
Tomatoes (Packaged) pp6	0.01	0.00	0.01	0.00
ALL PRODUCTS		0.18***		0.10***

Note: ***, *, * indicate significance at the 1%, 5% and 10% level, respectively.

5 Retail price interaction analysis

While the pass-through results are suggestive of ineffective price transmission at least as applied to a sizeable majority of the products, these results are only indicative. The wholesale prices we use are only illustrative of the actual (unobserved) supply prices paid by the retailers and there could be many reasons why retail prices set by the supermarkets consistently differ in their movements from the wholesale prices, especially since retailers' long-term contracts are likely to involve fixed supply prices rather than continually fluctuating spot market prices reflected in our wholesale prices. Nevertheless, the low value and frequent insignificance of the pass-through rates is still surprising given that we would expect the supply prices that the supermarkets pay not to be completely out of line with wholesale spot prices.

With this caution in mind we give further consideration to the intensity of price competition for these products.

To illustrate the range of prices applying to each product, Table 3 shows the average prices (in pence) for each item and each retailer over the whole period, with the figure for the lowest average price highlighted in bold and the highest price highlighted in italics, together with the coefficient of variation (shown in brackets below each average price). The rank order of retailers varies but Asda has the lowest or equal lowest average price on 19 of the 26 products while Co-operative Food ("Co-op") and M&S have the highest average price on 13 and 11 products respectively.

Table 3 – Average retail prices in pence (and CV) for each retailer

	Tesco	Sainsbury	Asda	Morrisons	M&S	Waitrose	Co-op
Apples (Cooking) kg	**146**	149	**146**	151	*176*	159	170
	(0.11)	(0.09)	(0.11)	(0.09)	(0.08)	(0.08)	(0.11)
Apples (Dessert) kg	164	166	**158**	168	*192*	178	181
	(0.12)	(0.10)	(0.12)	(0.11)	(0.05)	(0.09)	(0.12)
Aubergine each	93	105	**77**	96	105	*106*	102
	(0.16)	(0.08)	(0.23)	(0.14)	(0.08)	(0.09)	(0.06)
Broccoli kg	188	190	**182**	188	193	193	*204*
	(0.17)	(0.16)	(0.19)	(0.17)	(0.14)	(0.14)	(0.14)
Cabbage (Savoy) each	**72**	75	**72**	74	85	*88*	85
	(0.14)	(0.13)	(0.18)	(0.17)	(0.05)	(0.14)	(0.12)
Carrots kg	76	77	**75**	77	77	79	*83*
	(0.11)	(0.11)	(0.12)	(0.13)	(0.11)	(0.11)	(0.11)
Cauliflower each	95	98	**90**	93	103	104	*105*
	(0.23)	(0.23)	(0.24)	(0.22)	(0.21)	(0.20)	(0.20)
Celery Hearts x2	112	116	115	**108**	126	125	*131*
	(0.18)	(0.15)	(0.17)	(0.17)	(0.12)	(0.15)	(0.15)
Celery each	75	80	73	**70**	82	81	*86*
	(0.19)	(0.13)	(0.20)	(0.23)	(0.12)	(0.13)	(0.14)
Courgettes kg	184	187	**180**	185	*213*	212	205
	(0.08)	(0.09)	(0.09)	(0.08)	(0.06)	(0.08)	(0.09)
Cucumber Full each	76	77	**72**	78	80	79	*84*
	(0.17)	(0.16)	(0.20)	(0.16)	(0.15)	(0.15)	(0.14)
Cucumber Halves	40	41	**39**	**39**	42	43	*46*
	(0.15)	(0.16)	(0.15)	(0.17)	(0.15)	(0.17)	(0.14)
Leeks kg	231	245	**219**	230	235	252	*255*
	(0.14)	(0.10)	(0.15)	(0.15)	(0.16)	(0.10)	(0.12)
Lettuce Gem x2	82	84	80	**79**	*93*	89	91
	(0.11)	(0.10)	(0.12)	(0.20)	(0.09)	(0.09)	(0.12)
Lettuce Iceberg each	**84**	91	86	87	94	93	*95*
	(0.21)	(0.13)	(0.18)	(0.18)	(0.11)	(0.13)	(0.14)
Lettuce Round each	56	56	**53**	56	59	57	*61*
	(0.12)	(0.12)	(0.09)	(0.15)	(0.15)	(0.12)	(0.08)
Onions Red kg	95	97	**94**	96	*132*	112	106
	(0.08)	(0.08)	(0.07)	(0.09)	(0.23)	(0.14)	(0.09)
Onions White kg	82	83	**80**	83	*95*	87	91
	(0.10)	(0.10)	(0.11)	(0.11)	(0.08)	(0.11)	(0.10)
Parsnips kg	157	161	**150**	160	172	171	*177*
	(0.13)	(0.12)	(0.14)	(0.16)	(0.17)	(0.15)	(0.11)
Pears (Conference) kg	181	181	**180**	187	*227*	188	206
	(0.17)	(0.17)	(0.17)	(0.17)	(0.11)	(0.15)	(0.16)
Radish pp150g	57	58	54	**47**	60	61	*64*
	(0.17)	(0.17)	(0.20)	(0.12)	(0.15)	(0.13)	(0.08)
Strawberries 400g	229	234	221	225	*274*	261	**195**
	(0.23)	(0.29)	(0.25)	(0.27)	(0.26)	(0.33)	(0.11)
Swede kg	**78**	100	81	85	104	105	*108*
	(0.24)	(0.13)	(0.14)	(0.15)	(0.13)	(0.13)	(0.33)
Sweetcorn pp2	164	175	**154**	165	*197*	195	179
	(0.22)	(0.21)	(0.25)	(0.24)	(0.05)	(0.08)	(0.19)
Tomatoes (Loose) kg	190	**182**	**182**	184	*295*	**182**	201
	(0.06)	(0.12)	(0.11)	(0.12)	(0.16)	(0.12)	(0.10)
Tomatoes (Packaged) pp6	87	97	**86**	88	*98*	96	97
	(0.14)	(0.06)	(0.15)	(0.13)	(0.03)	(0.08)	(0.10)

Where retailers prices exhibit price variation over time, this is not just due to changing seasonal prices but also down to the use of temporary price reductions, such as frequently used on strawberries. Yet, it is noticeable from Table 3 that inter-retailer price variation is quite limited on some products (apples, carrots, courgettes, onions and packaged tomatoes) while price consistency is less on other items (cauliflower and celery), and yet for others varies considerably across retailers on cabbage, lettuce, radish, swede and sweetcorn.

The combination of different average prices, different rank orders and different degrees of price variation across the retailers suggests that retailers might be adopting different pricing approaches to each other at the individual item level. To investigate the nature of pricing interaction further we utilise three measures to capture different dimensions of how closely the retailers match and compete with each other on prices. First, we examine the spread of prices across the retailers for each item through a standard *price dispersion* measure in the form of the "average coefficient of variation" (*ACV*) over the sample period, defined for product *i* as

$$ACV_i \stackrel{\text{def}}{\equiv} \frac{1}{T}\sum_{t=1}^{T}\frac{\sigma_{it}}{\mu_{it}} \quad \text{where } \mu_{it} \stackrel{\text{def}}{\equiv} \frac{1}{N}\sum_{j=1}^{N} p_{ijt} \text{ and } \sigma_{it} \stackrel{\text{def}}{\equiv} \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(p_{ijt}-\mu_{it}\right)^2} \qquad (2)$$

Secondly, we consider the extent to which there is price leader churn in terms of the share of time for which each retailer *j* has the lowest price on product *i*, designated as s_{ij}, to gauge the degree of *pricing contestability*, indicating the extent to which pricing hierarchies are fluid and not rigid. The novel measure we employ is a "price leader concentration" (*PLC*) index, analogous to the Simpson diversity index (Simpson 1949) in ecology and the Herfindahl-Hirschman index (HHI) in industrial organisation, yet here calculated as the sum of squared lowest price retailer shares in a normalised form that ranges between 0 (representing even sharing amongst the retailers on who offers the lowest price) and 1 (representing complete domination by just one retailer offering the lowest price) for any given *N* firms:

$$PLC_i \stackrel{\text{def}}{\equiv} \left(\sum_{j=1}^{N}\left(s_{ij}\right)^2 - \frac{1}{N}\right)\Big/\left(1-\frac{1}{N}\right) \in [0,1] \qquad (3)$$

Thirdly, we compute price correlation coefficients between retailers *j* and *h*, for $j, h = 1, \ldots, N$, $j \neq h$, for each product *i* to examine the extent to which their prices move together over time, as an indicator of how much they constrain each other as substitutes, while taking the precaution to focus on relative values rather than absolute values in case there are spurious correlation issues (Bishop and Walker 2010, chapter 10). For our measure, we calculate the

average of all pairwise correlation coefficients for all pairs of retailers as the following variable representing the "average correlation coefficient" (*ACC*) for each product:

$$ACC_i \stackrel{\text{def}}{=} \frac{1}{N(N-1)} \sum_{j \neq h} \sum_{h \neq j} \left(\frac{\sum_t (p_{ijt} - \overline{p_{ij}})(p_{iht} - \overline{p_{ih}})}{\sqrt{\sum_t (p_{ijt} - \overline{p_{ij}})^2 \sum_t (p_{iht} - \overline{p_{ih}})^2}} \right) \in [-1, 1] \qquad (5)$$

$$\text{where } \overline{p_{ij}} \stackrel{\text{def}}{=} \frac{1}{T} \sum_{t=1}^{T} p_{ijt} \text{ and } \overline{p_{ih}} \stackrel{\text{def}}{=} \frac{1}{T} \sum_{t=1}^{T} p_{iht}$$

Table 4 reports the results for each of these three measures covering all seven retailers, but also separately for the Big 4 retailers amongst which we might expect competitive intensity to be greater if they are more strategically aligned in terms of their target market, shopper profiles, store formats, and scale economies. We would expect that the most competitively priced products are those where ACV_i and PLC_i are close to zero and ACC_i close to unity. As can be observed, there is significant variation in the values for the different products. The products which appear to exhibit the strongest competition on all three measures amongst all seven retailers are (alphabetically) broccoli, carrots, cauliflower, cucumber, and pears. Amongst the Big 4 then both types of apples and onions also feature as competitively priced. Conversely, aubergine and swede stand out as appearing to be the least competitively priced, along with cabbage, celery, radish and sweetcorn. Some products present a mixed picture. For example there is a lot of rotation with who offers the lowest price on strawberries which are subject to frequent price discounts, but typically moderately wide price dispersion and low price correlations across retailers. There are also different patterns when all retailers or just the Big 4 are compared, where item competition appears somewhat more vigorous amongst the latter, noticeably on dessert apples, onions, sweetcorn, and loose tomatoes.

Our three measures of pricing interaction capture different aspects but it is reassuring that they are correlated in the direction expected, though not necessarily with a strong magnitude. For example, the correlation between *ACV* and *PLC* is only 0.16 amongst all seven retailers but noticeably closer at 0.52 amongst the Big 4, where with the former price dispersion is more evident but rotation of the price leader can come about because of the use and timing of temporary price cuts used by all the retailers. The relationship between *ACV* and *ACC*, though, is stronger where the correlation is -0.56 amongst all seven retailers and -0.84 amongst the Big 4, highlighting that wide price dispersion and low price correlation typically go together.

Similarly, price leader concentration, indicating more rigid price hierarchies, is linked with low price correlation, where the correlation between *PLC* and *ACC* is -0.42 amongst all seven retailers and -0.45 amongst the Big 4.

Table 4 – Retail price dispersion, leader concentration and price correlations

Product name	Price dispersion ACV_i		Price leader concentration PLC_i		Avg price correlation ACC_i	
	All 7	Big 4	All 7	Big 4	All 7	Big 4
Apples (Cooking) kg	0.01	0.03	0.13	0.16	0.58	0.80
Apples (Dessert) kg	0.01	0.05	0.16	0.23	0.40	0.70
Aubergine each	0.14	0.17	0.67	0.68	0.04	0.10
Broccoli kg	0.07	0.04	0.10	0.18	0.79	0.83
Cabbage (Savoy) each	0.14	0.11	0.11	0.15	0.08	0.18
Carrots kg	0.06	0.03	0.09	0.17	0.70	0.78
Cauliflower each	0.12	0.09	0.07	0.17	0.71	0.75
Celery Hearts x2	0.15	0.11	0.04	0.14	0.21	0.41
Celery each	0.13	0.14	0.07	0.16	0.40	0.34
Courgettes kg	0.09	0.03	0.15	0.16	0.54	0.70
Cucumber Full each	0.08	0.07	0.07	0.15	0.74	0.71
Cucumber Halves	0.09	0.05	0.08	0.16	0.71	0.84
Leeks kg	0.12	0.08	0.10	0.25	0.26	0.52
Lettuce Gem x2	0.11	0.09	0.12	0.17	0.32	0.35
Lettuce Iceberg each	0.10	0.09	0.05	0.14	0.55	0.57
Lettuce Round each	0.09	0.07	0.06	0.15	0.49	0.54
Onions Red kg	0.15	0.03	0.12	0.18	0.39	0.72
Onions White kg	0.09	0.04	0.13	0.19	0.35	0.76
Parsnips kg	0.09	0.06	0.17	0.23	0.55	0.55
Pears (Conference) kg	0.11	0.03	0.08	0.17	0.71	0.92
Radish pp150g	0.16	0.14	0.29	0.40	0.23	0.51
Strawberries 400g	0.19	0.14	0.05	0.15	0.36	0.47
Swede kg	0.20	0.18	0.20	0.26	0.18	0.13
Sweetcorn pp2	0.16	0.14	0.14	0.25	0.20	0.55
Tomatoes (Loose) kg	0.22	0.05	0.06	0.13	0.39	0.63
Tomatoes (Packaged) pp6	0.09	0.08	0.07	0.18	0.08	0.54
Average	0.12	0.08	0.13	0.21	0.42	0.57

Table 4 thus shows that there is distinct variation in the extent to which different products appear to be subjected to intense price competition. As might have been anticipated, typically the bigger selling and faster moving products appear to be more competitively priced, where retailers might be more eager to satisfy shoppers who have greater price awareness and also where faster turnover means less waste and spoilage. However, as observed, there are

exceptions and it is not always a consistent pattern. Nevertheless, the statistically significant relationships identified (Table 2) on wholesale-retail pass-through rates, are largely consistent with the products we identify here as showing the strongest retail price interaction.[16]

Thus far we have focused on product-level comparisons but it might also be instructive to examine in more detail the relationship amongst the retailers to see how they interact with each other on retail prices in aggregate. A simple way to represent relative positions is with pairwise comparisons on the percentage of prices for which one retailer is higher or respectively lower priced than another retailer. Table 5 reports these results, where reading down each column shows the percentage of prices on which the named retailer is higher than its paired retailer, while reading across each row shows the percentage of price on which the named retailer is lower than its paired retailer. The difference between 100 and the sum of the two values for each pair is the percentage of prices on which they match each other with identical prices. Thus, for example, Sainsbury has 38.5% of its prices higher but only 13.0% of its prices lower than Tesco, and by calculation 48.5% of its prices are the same as Tesco. As clearly evident, the standout feature of Table 5 is the extent to which the Big 4 have a greater percentage of lower prices than the other three smaller retailers. However, more subtly, there is a mix of positions within the Big 4, where Asda has a greater proportion of lower prices and Sainsbury has a greater proportion of higher prices while Tesco and Morrisons appear to be similarly placed.

Table 5 – Pairwise retailer price comparisons

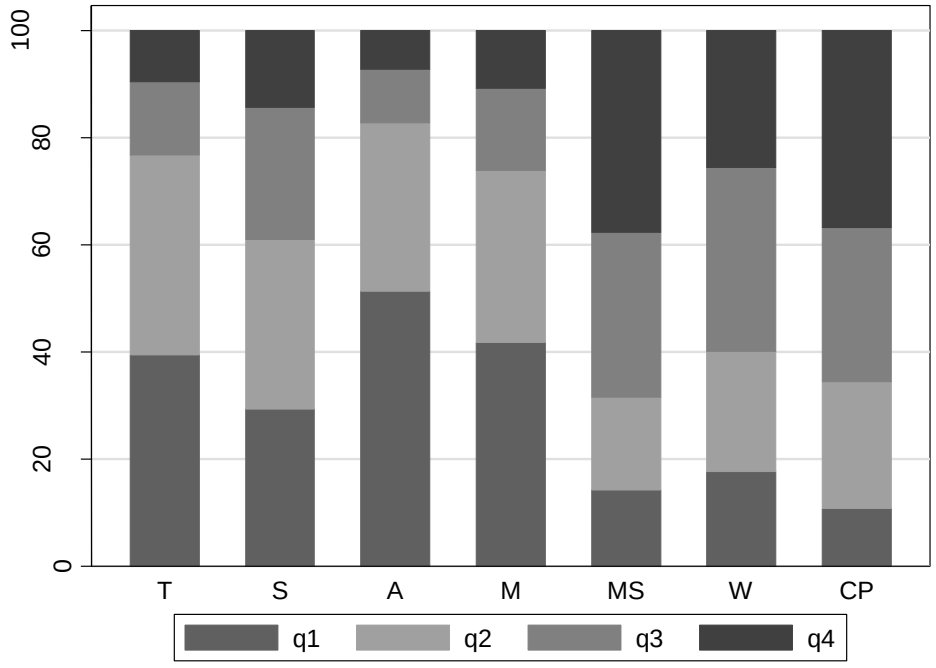
		% prices higher						
		Tesco	Sainsbury	Asda	Morrisons	M&S	Waitrose	Co-op
% prices lower	Tesco	-	38.5	13.5	29.9	66.8	66.1	82.2
	Sainsbury	13.0	-	9.7	18.2	50.8	50.4	76.4
	Asda	35.7	54.1	-	40.3	76.9	75.2	87.3
	Morrisons	25.1	41.8	13.6	-	68.2	66.2	81.0
	M&S	10.0	9.1	6.7	10.4	-	24.7	51.0
	Waitrose	11.8	10.1	8.2	13.5	37.4	-	64.0
	Co-op	10.9	14.3	8.2	11.6	39.1	28.5	-

A further way to consider these relative positions is through quantile analysis (e.g. Lach 2002) to understand more about the character of the pricing hierarchy operating amongst these seven

[16] The obvious notable exception is broccoli where its pass-through relationship was not statistically significant but as we noted the wholesale/retail price gap was negative, indicating the product is seemingly sold with a very competitive negative or at least very low margin.

retailers. We can do this by assigning each retailer to a quartile in the price distribution to analyse the evolution of the quartiles over time, undertaking this for each product and then pooling the results across all products to produce the percentage of time spent in quartiles. The results are shown in Figure 1, where q1 to q4 refer to quartiles from lowest to highest prices (i.e. $F_t(q_{t1}) = 0.25$, $F_t(q_{t2}) = 0.5$, $F_t(q_{t3}) = 0.75$). By inference, if retailers spend most of the time in the lower (respectively, higher) quartile, it indicates that they set persistently lower (respectively, higher) prices. In contrast, if they spend more equally the number weeks in each quartile then it highlights the presence of more fluid pricing hierarchies. As Figure 1 shows, the Big 4 (T = Tesco, S = Sainsbury, A = Asda, and M = Morrisons) spend most of their time in q1 and q2 while conversely the other three retailers (MS = M&S, W = Waitrose and CP = Co-op) spend most of their time in q3 and q4, and thereby indicative of persistent price dispersion even if the pricing hierarchies are not completely rigid.

Figure 1 – Quartile analysis of price hierarchy stability



Finally, we return to look at price correlations where Table 6 shows the pooled and averaged correlation coefficient values across the full set of products for each retailer pairing. Here we focus on discussing the relative levels, since we have no benchmarks for the absolute values and again need to be conscious about potential spurious correlation problems (Bishop and

Walker 2010). In relative terms, prices appear to be more strongly correlated on average amongst the Big 4, where the comparable correlations are between Sainsbury and Waitrose and between Sainsbury and the Co-op. Indeed, Sainsbury appears to play a pivotal role in linking the Big 4 to the other three retailers, where its price correlations with the three smaller retailers are stronger than those for the other three Big 4 retailers. Thus while Asda might have the highest correlations with fellow Big 4 retailers, it is Sainsbury which appears to be the most connected across all seven retailers even if it is not necessarily pricing as competitively as Asda. In contrast, M&S seems to be the most disconnected retailer, behaving quite differently in terms price movements compared to other retailers where not only do its prices tend to be relatively high but it tends to vary them less (as previously indicated in Table 3 by its high average product prices and low CV values).

Table 6 - Average price correlation matrix for the seven retailers

	Tesco	Sainsbury	Asda	Morrisons	M&S	Waitrose	Co-op
Tesco	1.00						
Sainsbury	0.55	1.00					
Asda	0.59	0.56	1.00				
Morrisons	0.54	0.55	0.60	1.00			
M&S	0.21	0.36	0.24	0.25	1.00		
Waitrose	0.39	0.56	0.39	0.40	0.43	1.00	
Co-op	0.43	0.51	0.45	0.46	0.25	0.43	1.00

6 Conclusion

Against a background of consistent concerns expressed about inflated prices for fruit and vegetables in the UK, we examine the pattern of price competition across the seven leading UK supermarkets for a set of 26 different fruits and vegetables. We investigate the extent of price competition by examining wholesale-to-retail pass-through rates and retail price interactions amongst the set of leading UK supermarket chains.

The product-level results highlight that there are differences in the way that individual products are treated. Wholesale-to-retail price transmission competition appears more direct on a quarter of the products (notably cauliflower, cucumber, iceberg lettuce, pears and parsnips), while being distinctly weaker for the other three-quarters of the products in the sample. Equally,

retail price interaction analysis indicates more vigorous competition amongst a similar set of products (consisting of broccoli, carrots, cauliflower, cucumber, and pears), suggesting some consistency in the findings across the two sets of analyses. Noticeably, one inconsistency relates to broccoli where there is little correspondence in wholesale-retail pass-through but retail pricing behaviour suggests keen competition and also the wholesale-retail margin appears very low or even negative. Its pricing pattern looks more akin to a loss leader item (if not necessarily to the extreme to which bananas are used as a loss leader – e.g. *The Guardian* 2013).

In addition to different degrees of competition at the product-level, we also find that there are significant differences in the extent to which different retailers appear to compete and interact in setting retail prices. The prices set by the smaller retail chains (M&S, Waitrose and Co-operative) are consistently higher and less responsive to competitors than those by the Big 4 retailers (Tesco, Asda, Sainsbury and Morrisons), but there is also a hierarchy within the Big 4 (where Asda tends to have lower prices than the other three but with some variation). The retail price structures we observe may be a characteristic of vertical quality differentiation amongst the retailers, where the higher prices reflect superior retail service or superior product quality. However, it could also be symptomatic of retailers understanding and adhering to a hierarchy of prices and avoiding intense price competition.

For consumers, there is clear merit in shopping around to obtain the lowest prices given that persistent and wide price dispersion is evident for most of the items studied here. No retailer universally has the lowest prices on all products, but equally there are retailers which on average have lower prices than the others and seem to be responding more competitively than some of their rivals. Reassuringly, prices do appear relatively fluid and indicative of keen competition on the bigger selling products, but less for so for the slower selling products where shopping around can perhaps pay consumers the greatest dividends.

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AES Prize Essay, 2017

Healthy competition to support healthy eating? An investigation of fruit and vegetable pricing in UK supermarkets

Hao Lan and Paul W. Dobson

On-Line Appendix

A1 - Robustness of data interpolation

To check on the robustness of the data interpolation, we use a subsample representing the "best period" with the least amount of interpolation from 16/06/2008 to 23/07/2012. Table A1 shows the summary statistics of retail and wholesale prices in terms of using the full and subsample periods, indicating that interpolation does not substantially alter the mean and CV values.

Table A1 - Retail and whoelsale prices for full and subsample periods

Product name	Full sample		Subsample	
	Retail	Wholesale	Retail	Wholesale
	Mean (CV)	Mean (CV)	Mean (CV)	Mean (CV)
Apples (Cooking) kg	157 (0.12)	65 (0.22)	153 (0.10)	60 (0.12)
Apples (Dessert) kg	173 (0.12)	79 (0.15)	171 (0.12)	78 (0.13)
Aubergine each	98 (0.16)	43 (0.31)	99 (0.16)	42 (0.31)
Broccoli kg	191 (0.16)	203 (0.30)	190 (0.13)	201 (0.25)
Cabbage (Savoy) each	79 (0.16)	48 (0.30)	78 (0.16)	47 (0.31)
Carrots kg	78 (0.12)	34 (0.26)	77 (0.10)	34 (0.29)
Cauliflower each	98 (0.23)	72 (0.32)	101 (0.22)	70 (0.33)
Celery Hearts x2	119 (0.17)	32 (0.27)	123 (0.15)	32 (0.24)
Celery each	78 (0.18)	19 (0.32)	78 (0.18)	19 (0.35)
Courgettes kg	195 (0.11)	103 (0.30)	196 (0.10)	105 (0.32)
Cucumber Full each	78 (0.17)	27 (0.29)	79 (0.17)	28 (0.29)
Cucumber Halves	42 (0.16)	16 (0.30)	42 (0.17)	16 (0.30)
Leeks kg	238 (0.14)	100 (0.17)	240 (0.14)	99 (0.16)
Lettuce Gem x2	86 (0.14)	49 (0.20)	86 (0.14)	49 (0.21)
Lettuce Iceberg each	90 (0.16)	42 (0.33)	91 (0.16)	41 (0.35)
Lettuce Round each	57 (0.13)	29 (0.17)	57 (0.12)	29 (0.16)
Onions Red kg	105 (0.18)	53 (0.10)	106 (0.16)	54 (0.10)
Onions White kg	86 (0.12)	24 (0.34)	86 (0.11)	25 (0.36)
Parsnips kg	164 (0.15)	76 (0.12)	163 (0.15)	75 (0.12)
Pears (Conference) kg	193 (0.18)	80 (0.30)	194 (0.14)	78 (0.31)
Radish pp150g	58 (0.17)	37 (0.18)	58 (0.16)	38 (0.19)

Strawberries 400g	234	114	232	113
	(0.29)	(0.12)	(0.27)	(0.11)
Swede kg	95	39	92	37
	(0.23)	(0.17)	(0.18)	(0.15)
Sweetcorn pp2	176	53	175	55
	(0.20)	(0.36)	(0.21)	(0.37)
Tomatoes (Loose) kg	202	90	206	91
	(0.23)	(0.24)	(0.23)	(0.26)
Tomatoes (Packaged) pp6	93	22	93	22
	(0.12)	(0.21)	(0.10)	(0.21)
Average	125	60	126	59
	(0.16)	(0.24)	(0.16)	(0.24)

A2 – Long-run pass-through results

Table A2 shows the long-run pass-through results based on level specification (2). First, the market-level result is similar for both the full sample and subsample, indicating robustness with our interpolation. Second, checking through the different products, there are some changes in the estimates and significance but the general conclusion and categorisation holds for the main paper. For example, Dessert apples are found to have a statistically significant estimate of long run pass-through at 1% level, but this is not sufficient to turn this product into "significant" for the pass-through category as its magnitude remains very small.

Table A2 - Long-run pass-through estimates in terms of full and sbusamples

Product	Full sample	Subsample
Apples (Cooking) kg	0.101	-0.042
Apples (Dessert) kg	0.230*	0.428***
Aubergine each	-0.024	-0.037
Broccoli kg	-0.032	-0.039
Cabbage (Savoy) each	0.045	0.034
Carrots kg	0.166**	0.266***
Cauliflower each	0.389***	0.503***
Celery Hearts x2	0.062	0.014
Celery each	-0.136	-0.056
Courgettes kg	0.062**	0.063
Cucumber Full each	0.602***	0.742***
Cucumber Halves	0.408***	0.524***
Leeks kg	0.237	0.236
Lettuce Gem x2	0.115	0.049
Lettuce Iceberg each	0.237***	0.200***
Lettuce Round each	-0.076	-0.051
Onions Red kg	0.402	0.584*
Onions White kg	-0.113	-0.257
Parsnips kg	0.851***	0.845***
Pears (Conference) kg	0.337***	0.361***
Radish pp150g	-0.086	-0.118

Strawberries 400g	0.642	0.520
Swede kg	0.172	0.081
Sweetcorn pp2	-0.049	0.007
Tomatoes (Loose) kg	0.118*	0.164**
Tomatoes (Packaged) pp6	-0.001	-0.016
COMBINED	0.178***	0.178***

A3 - Robustness of 4-week lag selection in pass-through analysis

Table A3 shows the level specification (2) for different numbers of weeks as lag lengths.

Table A3 - Long-run pass-through estimates in terms of different lags

Long run pass-through rates using different lags of wholesale prices							
Product	Lag=4	Lag=5	Lag=6	Lag=7	Lag=8	Lag=9	Lag=10
Apples (Cooking) kg	0.101	0.119	0.116	0.119	0.215	0.187	0.264
Apples (Dessert) kg	0.230*	0.136	0.126	0.130	0.071	0.039	0.095
Aubergine each	-0.024	0.014	0.039	0.004	0.042	0.006	-0.015
Broccoli kg	-0.032	-0.054	-0.035	-0.077*	-0.067	-0.063	-0.066
Cabbage (Savoy) each	0.045	0.060	0.056	0.068	0.072	-0.009	-0.027
Carrots kg	0.166**	0.185*	0.239**	0.268**	0.189	0.181	0.206
Cauliflower each	0.389***	0.411***	0.494***	0.519***	0.591***	0.520***	0.584***
Celery Hearts x2	0.062	0.034	0.063	0.111	0.085	0.068	0.125
Celery each	-0.136	-0.140	-0.020	0.005	0.057	0.083	0.228
Courgettes kg	0.062**	0.093***	0.101***	0.111***	0.101**	0.107**	0.118**
Cucumber Full each	0.602***	0.572***	0.482***	0.419**	0.400**	0.242	0.109
Cucumber Halves	0.408***	0.381***	0.351***	0.296**	0.278*	0.279*	0.245
Leeks kg	0.237	0.202	0.113	0.059	0.186	0.157	0.160
Lettuce Gem x2	0.115	0.159*	0.085	0.012	-0.001	0.022	-0.017
Lettuce Iceberg each	0.237***	0.256***	0.248***	0.266***	0.384***	0.410***	0.477***
Lettuce Round each	-0.076	-0.080	-0.214	-0.097	-0.156	-0.173	-0.149
Onions Red kg	0.402	0.276	0.321	0.240	0.314	0.321	0.184
Onions White kg	-0.113	-0.087	-0.106	-0.127	-0.064	0.075	0.143
Parsnips kg	0.851***	0.842***	0.969***	1.055***	1.145***	1.126***	0.993***
Pears (Conference) kg	0.337***	0.435***	0.520***	0.535***	0.571***	0.598***	0.568***
Radish pp150g	-0.086	-0.119	-0.173	-0.187	-0.251*	-0.266*	-0.251
Strawberries 400g	0.642	0.535	0.399	0.922	1.147*	1.800**	1.490*
Swede kg	0.172	0.152	0.039	-0.069	0.087	0.126	0.224
Sweetcorn pp2	-0.049	-0.023	0.020	0.143	0.144	0.069	0.069
Tomatoes (Loose) kg	0.118*	0.111	0.130*	0.124	0.156*	0.146	0.180*
Tomatoes (Packaged) pp6	-0.001	-0.049	-0.056	0.043	0.023	0.015	0.065

Checking through the results in the table, the products identified as “significant” pass-through in the main paper (highlighted in bold) generally hold their status, remaining statistically significant at the 1% level and with sizes larger than the market-level pass-through regardless of the lag increase. The only exceptions are cucumbers which start to lose statistical

significance with longer lags. However, this result on its own is not sufficient to reject the 4-week lag selection. In terms of the "insignificant" pass-through products, none of them are found to change results qualitatively to be considered as a "significant" pass-through with longer lags. We see courgettes becoming be statistically significant when the lag is 5, 6 or 7 weeks but the magnitude of the estimated pass-through remains smaller than the market level. On balance, then, we consider that the 4-week lag selection represents a reasonable trade-off to produce LRPT estimates for the analysis of pass-through in allowing us to maintain a large sample size and preserve the degrees of freedom.

A4 – Full results of pass-through regressions for level specification (2)

We report the full results of pass-through regression in terms of level specification (2) in Table 2 in the following table:

Table A4 - Full results of pass-through regressions - level specification (2)

Product name	w_{it-h}, h = 0,1,2,3,4					TPR dummy	Imported dummy	Z				Time Fixed effects			R^2
	0	1	2	3	4			Road fuel price change	Red meat price change	Weather temperature	Weather event	Month	Year	Christmas	
Apples (Cooking) kg	-0.030	0.038	0.023	-0.032	0.102*	-20.909***	0.000	0.056	-0.021	-0.017	0.050	Yes	Yes	Yes	0.219
Apples (Dessert) kg	0.093	0.087	-0.110	0.090	0.070	-23.582***	-0.022	-0.087	0.080	-0.110*	0.204**	Yes	Yes	Yes	0.241
Aubergine each	-0.005	-0.002	0.010	0.039	-0.066	-27.942***	-0.105	0.064	-0.018	-0.020	-0.016	Yes	Yes	Yes	0.615
Broccoli kg	-0.038	0.017	0.011	-0.013	-0.009	-50.220***	-0.008	-0.593**	-0.570**	-0.260**	0.421***	Yes	Yes	Yes	0.367
Cabbage (Savoy) each	0.069***	-0.026	-0.021	-0.001	0.023	-25.918***	0.658	0.064	0.268***	-0.061	-0.091	Yes	Yes	Yes	0.778
Carrots kg	-0.015	0.099	0.079	-0.039	0.041	-14.497***	1.125	0.023	0.208***	-0.065	0.045	Yes	Yes	Yes	0.366
Cauliflower each	0.096**	0.087**	0.008	0.075**	0.122***	-23.243***	1.950	0.042	0.111	0.150	-0.010	Yes	Yes	Yes	0.388
Celery Hearts x2	0.014	-0.052	0.114	0.017	-0.032	-35.129***	0.425	-0.066	-0.113	-0.130	-0.053	Yes	Yes	Yes	0.794
Celery each	-0.305***	0.259**	0.104	0.032	-0.224**	-28.722***	-0.939**	0.067	0.010	0.074	-0.017	Yes	Yes	Yes	0.797
Courgettes kg	0.033	-0.062**	0.061**	0.011	0.019	-31.019***	0.279	0.285	0.033	-0.027	0.139*	Yes	Yes	Yes	0.402
Cucumber Full each	0.257***	0.169	0.003	0.187*	-0.014	-17.138***	-0.603*	0.007	-0.039	0.019	0.143**	Yes	Yes	Yes	0.455
Cucumber Halves	0.197***	0.164**	-0.129**	0.114*	0.062	-7.216***	-0.129	-0.061	0.014	-0.045**	0.035	Yes	Yes	Yes	0.277
Leeks kg	0.084	0.157	-0.130	0.190	-0.063	-45.815***	0.799	0.486	-0.572**	-0.180	0.140	Yes	Yes	Yes	0.283
Lettuce Gem x2	0.138**	0.001	-0.014	-0.076	0.067	-26.980***	-0.115	-0.078	0.003	0.050	0.118**	Yes	Yes	Yes	0.732
Lettuce Iceberg each	0.001	0.101**	0.006	0.019	0.109***	-27.633***	-0.454	0.127	0.003	0.008	-0.007	Yes	Yes	Yes	0.636
Lettuce Round each	-0.017	-0.048	0.053	-0.054	-0.009	-9.437***	-0.353	-0.007	0.021	-0.020	-0.030	Yes	Yes	Yes	0.249
Onions Red kg	0.484**	-0.162	0.175	-0.062	-0.033	-22.941***	0.701*	0.116	-0.205**	-0.036	-0.030	Yes	Yes	Yes	0.341
Onions White kg	-0.089	-0.057	0.052	0.098	-0.116	-17.819***	-0.143	0.118	-0.144	-0.005	0.004	Yes	Yes	Yes	0.481
Parsnips kg	0.281*	0.339***	-0.013	-0.034	0.278***	-28.470***	0.845	0.249	0.012	0.011	0.084	Yes	Yes	Yes	0.256
Pears (Conference) kg	0.177***	0.017	-0.021	0.019	0.145**	-35.196***	0.391	0.446**	-0.089	-0.155**	0.066	Yes	Yes	Yes	0.349
Radish pp150g	0.019	-0.119***	0.036	0.014	-0.037	-16.833***	0.004	-0.006	-0.088	-0.032	0.000	Yes	Yes	Yes	0.552
Strawberries 400g	0.185	0.312	-0.064	0.266	-0.057	-68.367***	2.617	1.659**	-1.593**	0.107	-0.451	Yes	Yes	Yes	0.225
Swede kg	0.223*	0.020	-0.096	-0.004	0.029	-29.938***	0.636	-0.163	0.045	0.030	0.025	Yes	Yes	Yes	0.646
Sweetcorn pp2	-0.080	0.128	-0.031	-0.346*	0.280*	-61.666***	-0.880	-0.037	0.046	0.026	0.142	Yes	Yes	Yes	0.527
Tomatoes (Loose) kg	0.005	-0.005	0.128***	-0.003	-0.007	-42.983***	0.458	0.206	-0.143	0.029	-0.029	Yes	Yes	Yes	0.259
Tomatoes (Packaged) pp6	-0.022	0.021	0.013	-0.036	0.023	-22.195***	0.220	-0.050	-0.054	-0.023	-0.044	Yes	Yes	Yes	0.579

Note: ***, *, * indicate significance at the 1%, 5% and 10% level, respectively. Robust standard errors are omitted for simplicity but available upon request.