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Abstract: This paper examines how the frequency and magnitude of micro price rises and falls relate to macroeconomic crisis, as well as moderation. Weekly micro pricing behaviour in groceries, Britain's most important consumer market, is investigated for 370 precisely defined products matched across the leading three retailers over the moderation period 2004-7 and the crisis period 2008-10. We find significant price flexibility of a form sharply distinguished from behaviour observed in most previous work. Downward price flexibility increases markedly in 2008. Overall basket prices rise, but significantly more individual prices fall than rise in the latter period. This is consistent with retailers obscuring the fact of rising basket prices in order to push cost increases through into price rises. Tests of obfuscation in price setting suggest the large numbers of small price falls were used to disguise price rises.

Response to the Editor on 12-255R1

Dear Dr Reis,

Thank you very much for your very positive response to us on our revised paper: "Pricing in inflationary times: the penny drops". We are glad that you found that version much improved, but of course understand that when substantial changes have been made, related or additional issues are likely to arise that need work. We certainly appreciate the detailed constructive advice you have offered us on the content and structure of our paper. In consequence, we have worked hard on this revised version attached. We have attempted in the version we attach to respond fully but intelligently to your proposed changes, as well as those of the referee. We attach a separate note addressed to the referee's points.

On (1) we accept your point that the coincidence of high inflation and many price cuts is neither a "puzzle" nor a causal claim. We have therefore eliminated all claims and suggestions to this effect. More positively, we have focused the early material on establishing, through what we hope is a "killer" figure, our main fact. This becomes figure 1. It consists of three elements, a CPI index, a CPI-equivalent based on our data, and the ratio of price falls to price rises. It thereby shows that average prices are increasing at the same time as more individual prices are falling than rising. We collect the relevant facts plus minimal background in section 2, and have shortened considerably the amount of exposition that gets us to this point, cutting it to 5 pages.

We have merged sections 3 and 4 as you proposed in your point (2). In doing this, we have followed very much the lines you suggest, so that it now deals with all the robustness issues. The new section 3 contains our existing sections 3.2, 3.3 and some material relating to our measures and robustness checks in section 2, plus section 4.1. All have been somewhat streamlined. We have as you proposed cut table 2, but we do make reference to these facts both here and in (what was) section 5, since it bears on the question of competition vs. obfuscation.

We are pleased (your point 3) that you like our various analyses of what now becomes section 4 (old section 5), at the same time recognizing that this body of new material required tightening and modification in various ways. We have cut the discussion (old p19) as proposed. We have done a substantial amount of further analytical work on the various subsections in response to the referee and I feel that we have addressed the referee's concerns on each subsection in very substantial measure. More detailed comments on the changes to each subsection are made in our note to the referee.

On your final point regarding the use of the obfuscation concept by both us and Chen et al., we agree that the idea does indeed need refinement and discussion and we offer several remarks on this issue particularly when discussing Chen et al, in the introduction to what is now section 4 and again in its subsections in the current version.

At the same time, despite substantial additional material being included, the paper is now significantly shorter than before. There are several more not-for-publication appendices, though, including some of a more exploratory nature!

We hope you feel that this new version of our paper substantively addresses your remaining concerns and we look forward to your response.

Yours, Mike Waterson

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Highlights

1. Examines micro pricing behaviour across moderation and recession period for a major economy and major retail firms within it
2. Shows a pattern of individual price changes exhibiting substantially more price falls than rises, particularly in the latter period
3. Detailed insight into how nominal prices are set across firms over a seven year period
4. Significant evidence of obfuscation in pricing behaviour

Response to referee's report on 12-255 R1

We are very grateful to the referee for a further extensive, careful and constructive report on the revised version of our paper. This has prompted us to respond fully on the many good points made. As a result, we hope that you will feel the paper is still further improved. We respond according to the numbered points made in section C of your report.

1. Organization and content: We have honed the paper's message further, along the lines proposed. We merged section 3.1 into section 2. We dropped the first paragraph and table 2 of section 4. However, following the editor's advice, we retained section 3.2 and put it along with the remainder of section 4 into a new section 3. References below relate to the old sectioning for convenience of comparison.
2. We now accept your point that it is difficult to maintain that the inflation *caused* the small price falls and drop this claim. There is undoubtedly an alternative view that the events simply coincided in timing, as you say, rather than being causative. At the same time, the many small price falls along with rising basket prices are clearly a stylised fact in this period and we focus section 3 (new section 2) on demonstrating this key finding. Given your relevant points about advertising, we bring one of the Appendix tables forward into the main text in (what was) section 5.5 and engage in significantly more discussion on the issue, along with material on consumer sentiments reported in a new appendix. In relation to your final point, we make clear (in what was section 3.3) that the merger, the Competition Commission investigation and the VAT changes, can be ruled out as causing the many small price decreases.
3. Section 5.1: The referee makes a useful suggestion here: "The authors should show empirically that the times when many penny drops occurred were also times with a larger variance across sample baskets." Following this proposal, we now demonstrate that there is indeed a strong significant positive correlation between times when many price drops occurred and times with a larger variance in basket prices. We have appended to the text as a result.
4. We have cut this element of section 5.2, as proposed.
5. Section 5.2, Obfuscation vs. competition: We have now modified our position on the relationship between obfuscation vs. competition as we accept that they are difficult to distinguish. The point is important and we assert caveats to and discussion of this effect here (4.2) and at several further points in the current text, including section 3.3, the introduction to (what is now) section 4, section 4.1, 4.3 and 4.5. We take the view that firms in a closely competitive situation will seek to avoid open price wars by focusing efforts on other aspects of marketing which obfuscate the true value of one firm's product versus another's. (The pricing of loans is a classic example; in Britain domestic energy pricing is another) Thus, obfuscatory tactics can be a manifestation of fierce competition, as Ellison and Ellison (now cited) point out.
Additional regression analysis we report in the new version relating to our sample of closely matched products reveals a great variety of experience. Examining the ratio of branded to own-label product prices, some are larger in 2008 or 2009 and some smaller, with no overall preponderance. In this sense, there was no clear relative price fall of branded to own-label products' prices in these years despite there being more individual falls on the branded items.
6. Section 5.3: Temporary price changes. We accept this point, and have dropped this discussion of temporary price changes as a result, focusing instead on NSB price movements.

7. Section 5.3: Permanent price changes. Here we have adopted very closely the approach the referee recommends. We have dropped panel E of (what was) table 6. However we have retained panel F, as proposed, at the same time acknowledging the difficulty of drawing a bright line between obfuscation and competition (see point 5 above) and noting the large fraction of price cuts relating to “price check” strategies.
8. Section 5.4: We now place little weight on the point made in the first paragraph. We agree (point 9) that there is a link between the material of the second paragraph and section 5.6 and in this version we have changed ordering so that the two subsections are consecutive.

Regarding the second paragraph of 5.4 explicitly, in response to your comment wanting to see an analysis over the whole time period, we have carried out two alternative analyses over time to examine the relationship between relative inflation and the number of penny falls. Both show in different ways that when the firm is raising its prices above inflation, it also engages in a relatively large number of penny price falls. The relationships are statistically significant.

9. Section 5.6: We are pleased you like this analysis and we have extended it. Thank you for the useful reference to Berger and Vavra. In response we refined the analysis as you proposed in order to examine the relationship (“Hypothesis L”) additionally between left digit changes and *small* price falls specifically and find the links hold up well here also. Therefore we consider this finding strengthened, and we view it as an interesting new stylised fact.

D. Other comments: Thank you for these several more detailed points, including the additional references and the suggestions about simplifying tables and correcting definitions. We have dealt with all of these that remain relevant in this new version.

Pricing in Inflationary Times: The Penny Drops*

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Michael Waterson^c

Second Revised Version, April 2015

Abstract

This paper examines how the frequency and magnitude of micro price rises and falls relate to macroeconomic crisis, as well as moderation. Weekly micro pricing behaviour in groceries, Britain's most important consumer market, is investigated for 370 precisely defined products matched across the leading three retailers over the moderation period 2004-7 and the crisis period 2008-10. We find significant price flexibility of a form sharply distinguished from behaviour observed in most previous work. Downward price flexibility increases markedly in 2008. Overall basket prices rise, but significantly more individual prices fall than rise in the latter period. This is consistent with retailers obscuring the fact of rising basket prices in order to push cost increases through into price rises. Tests of obfuscation in price setting suggest the large numbers of small price falls were used to disguise price rises.

JEL numbers: L16, L81, E31

Keywords: Pricing behaviour; supermarket prices; inflationary behaviour; price indexes

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1. Introduction

A key question facing policymakers forming monetary policy to meet an inflation target is how firms set nominal prices, especially in response to shocks (Eichenbaum et al., 2011; Kehoe and Midrigan, 2015). Micro pricing studies with implications for macro modelling have been surveyed by Alvarez (2008), Klenow and Malin (2011) and Nakamura and Steinsson (2013) amongst others, but the focus is largely on the moderation period. We examine how the frequency and magnitude of micro price changes up and down relate to macroeconomic crisis, as well as moderation. We track weekly prices on a wide assortment of precisely defined grocery products from late 2003 to 2010 matched across the UK's three leading supermarket retailers, who jointly make over half of all grocery sales¹ and around a quarter of all retail UK sales, to provide detailed insights into the mechanisms key firms use to respond to significant underlying cost changes both in stable times and around the recent crisis. Our sample firms extensively used small price cuts, including many single penny cuts, as a competitive tool, which could serve to distract attention from underlying upward movements in consumer basket prices and thus smooth resistance to rising prices.

Our analysis confirms most of the received facts of earlier micro-pricing studies in respect of the period 2003-7, but documents significant changes occurring over the turbulent years 2008-10, both in the frequency and character of price changes. Price-setting behaviour does respond to macroeconomic drivers, at least those observed in the later years of the first decade. As a result, the three supermarkets we study appeared to weather the storm of 2008-9 almost unscathed. Market shares held constant against competition, sales growth remained essentially unchanged and, most significant for macroeconomics, margins on UK operations were essentially untouched.² Examining how they achieved this yields significant insights into the mechanisms behind the setting of nominal prices.

¹ Magnitudes from Competition Commission (hereafter CC, 2008). Other recent papers that have analysed cross-firm pricing in similar contexts include Kaplan and Menzies (2014), who focus on price dispersion, and Chevalier and Kashyap (2011) whose focus is consumers who shop across several outlets.

² Since around 2012, they have been affected by the growth of German discounters, Aldi and Lidl, but within our period, competition remained largely within the group of major firms. Details of their sales, margins and shares positions are given in Appendix 1.

We focus attention on a key factor, namely that consumers buy baskets of goods rather than individual products when shopping at supermarkets, but may be influenced by claims regarding individual prices.³ In particular, basket price rises are disguised in a very subtle manner, whereby more individual prices fall than rise, yet most consumers actually pay a higher basket price. In other words, the episode we investigate reveals and subsequently resolves an aggregation effect, most keenly seen from the inflationary period of early 2008, and is consistent with retailers aiming to obscure rising basket prices. Specifically, consumers may rationally be inattentive (Reis, 2006; Mackowiak and Wiederholt, 2009) to much of the detail on prices when searching for goods within supermarkets. As Chen et al. (2008) show, rational inattention is one explanation for asymmetric price adjustment. We prefer to refocus this as obfuscation, whilst accepting the difficulty in predicting the precise nature of micro pricing based upon retailer obfuscation. Our argument is that in inflationary times sellers reduce resistance to price rises by flexing multiple prices including many downward movements.

Our price data have significant strengths, enhanced by certain unique features of supermarket price setting in Britain. We observe actual shelf prices for a wide range of precisely matched grocery products across the three largest supermarket chains over seven years covering both the prosperous years of the earlier 2000's and the later turbulent years of 2008-10. A key feature is that all three firms practise uniform national pricing across Great Britain (CC, 2008) within their large supermarket outlets, rendering the prices equivalent to individual store prices.⁴ Hence we identify behavioural changes in price setting for a significant segment of the economy through a period of substantial macroeconomic change. To maintain absolute consistency, we focus on 370 products matched both across time and supermarket chains. These cover all main grocery categories, with a wide range of brands and retailer own label products, mainly processed products. This level of detail means that we can control for product type, brand origin and package size. Appendix 2 gives details on our data sources and our selection from them.

³ Midrigan (2011) fully recognizes that firms are multiproduct, but does not relate this specifically to the consumer side of the equation. An earlier empirical paper, Lach and Tsiddon (1996) also considers price setting by multiproduct forms, but does not link this directly to consumer purchase baskets. Kaplan and Menzio (2014) do consider consumer baskets of goods as an important element additional to individual product pricing.

⁴ This national pricing contrasts strikingly with local store-level pricing observed in the USA (Hosken and Reiffen, 2007; Ellickson and Misra, 2008), and "price flexing" formerly practised by Tesco and Sainsbury (CC, 2008; Smith, 2004) but abandoned to join Asda and Morrisons national pricing by 2003 (CC, 2003). Tesco and Sainsbury operate more than one format and prices in their smaller in-town convenience stores, Tesco Metro for example, may diverge. Asda and Morrisons had no smaller stores. Most Tesco and Sainsbury sales happen in their larger stores.

Supermarket purchases form a significant part of UK consumer spending and the companies involved are extremely professional. It has been estimated that the largest, the Tesco chain which had roughly 30% market share, accounts for at least 12% of British consumers' current expenditure (Verdict Research, 2008). Tesco was the world's third or fourth largest retailer by revenue (Deloitte, 2010); its rival Asda, with approximately 17% share of the British market, is a Walmart subsidiary. Sainsbury, the third largest (16%), is a long established national retailer. Price competition between them is significant. By matching across firms, we also cast indirect light on whether the common practice of using detailed data coming from a single store within an oligopolistic group might be misleading.⁵ Our sample relates most directly to that used by Ellis (2009), in being weekly and covering major UK supermarket chains, but we have more products and, most importantly from the viewpoint of analysing significant macroeconomic episodes, his data stop in early 2008.⁶ Yet the time period in 2008 where commodity price inflation was extremely rapid is of particular interest. Because of these supermarket chains' significance to the economy as a whole, their actions will impact significantly on the movement of retail price indices and so the transmission of inflationary processes nationally.

To preview results, we have four main findings. The key take-away (section 2) is that despite there being substantially more price cuts than price rises, particularly through the most turbulent period, average prices rise over time, in line with inflationary trends. This is because most price falls are very small indeed, commonly a single penny (section 3). Second in section 3 we confirm most of the existing stylised facts; there is nothing peculiar about our data, nor indeed about the sector. Overlaid on that, we find a pattern of individual item price change markedly different from the regularity exhibited by Dominick's prices in the Chen et al. (2008) study. Third (section 4), we find significant evidence consistent with obfuscation in pricing behaviour. In sum in our

⁵ As Nakamura (2008) points out, many existing studies are based on data from one supermarket chain, whereas her data, and ours, cover several store chains at a detailed level. In our case the major national chains are represented. Surprisingly, there has been comparatively little such investigation of pricing across sellers in determining price patterns over time, outside the area of energy prices (where there is a significant literature on "rockets and feathers" pricing mechanisms- Bacon, 1991; Bils and Klenow 2004; Borenstein et al., 1997; Zimmerman et al., 2011). Moreover, in food and associated household good purchases, the consumer is buying a multi-product bundle, so there are additional considerations of behaviour within the menu of goods on offer.

⁶ The firms in question normally change prices no more than weekly, hence the frequency of the data collection exercise, whilst the modal consumer shops at their particular choice amongst such stores weekly (CC, 2008, paras 3.48 to 3.50). So the difference between our sample's size and some others (e.g. Abe and Tonogi, 2010) is more apparent than real.

sample, increases in typical basket prices are disguised by falls in large numbers of individual item prices, making it significantly more difficult for the consumer to discern competitiveness in basket prices across chains. There are eleven online appendices, as mentioned in the text.

2. Pricing movements: numbers versus impact

Figure 1 establishes that on average, price rises in our basket of products aggregated using CPI weights (dotted line) closely track the official food CPI (dashed line). Our key result is that despite this, throughout the period the ratio of the absolute number of price *falls* to price rises (solid line, right hand scale) exceeds one. Moreover, we find the most inflationary period for supermarket prices coincides with the highest ratio of *falls* to rises, and (as shown in Appendix 3, figure A3a) also the largest absolute number of falls.

-Figure 1 about here-

The macroeconomic backdrop to this is of course pivoted around 2008, following from the “great moderation”, as a period of generally increasing prosperity. However, that calm period came to an abrupt halt in the first half of 2008 when retail food prices in the UK, as in many other countries, moved from gentle to rapid inflation, which was subsequently sharply reversed in association with the significant financial turmoil arising in the closing quarter of 2008. The scale of the inflationary impact on UK food prices is shown in Figure 1 through the effect on the official CPI index. Substantial and widespread rises in world commodity prices in early 2008 (detailed in Appendix figure A3b) propelled increases in producer and consumer food price inflation. Despite large supermarkets having substantial buying power, world market trends will have forced all food retailers into real price increases, because even very large retailers like Tesco are small purchasers on a world scale. We focus on the mechanisms used to implement these retail price increases.

How robust is our key result that overall prices rise whilst more prices fall than rise? Because we perform our analyses on a relatively small sample of 370 products matched across Asda, Sainsbury’s and Tesco, the sample is restricted amongst other things⁷ by the relatively narrow

⁷ The collection of data over the Christmas/New Year period is limited and erratic, for all chains and products. Our product sample is chosen to maximise completeness of observation given that. In facing a missing observations problem, our sample is no different from other alternatives which commonly suffer from a degree of missing observations – e.g. Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008). Besides this problem, the

product range and for this reason we checked elements of our analysis against a sample of 600 products drawn from the Tesco website data up until end 2008. None of the substantive conclusions are negated in this modified sample.⁸ For much of our analysis, we use posted shelf prices, but occasionally there is more clarity in using “regular” prices, prices stripped of strictly temporary sales where the price reverts after six weeks or less to the exact same price; that is, using algorithm B of Nakamura and Steinsson (2008) in the form for weekly data adopted by Nakamura (2008). We call these NSB prices; still there are many more price falls than rises in the key period.

Table 1 examines the correlation between constructed quasi-CPI indexes using our samples and the most relevant official CPI series. To generate our indexes, for each supermarket we employed the official CPI weights and applied them to the geometric mean of the price observations we had within that category, subsequently aggregating up the relevant categories to the level of the CPI index.⁹ Given the relative sparseness beyond processed products, and the high weights for alcoholic drink, we consider four official CPI indexes. The least relevant for present purposes is the headline CPI, given the nature of the products in our study, but the others are potentially closer, being focussed on food and drink in various ways. Correlations in price differences from the previous year are very high, those with the general index being weakest, as would be expected. This confirms that our sample of prices over seven years exhibits a substantially similar pattern of price movements, of broadly similar character and extent to that shown by relevant CPIs, giving credence to our sample. To put it differently, someone buying the CPI basket but confined to our sample of products would face essentially the same inflationary pressures as if buying from all CPI basket products across the entire grocery market.

data suffer from several difficulties that limit the sample given that we want to make it as compatible and complete as possible. First, coverage of products particularly from fourth chain Morrisons is limited, forcing us to exclude it. Second, gaps appear from time to time, either because the operatives collecting prices were unable to find the product or because it was sold out. Third, the product mix sold in supermarkets does naturally change over time. Fourth, because the collection process is manual, occasional mistakes are made, such as prices which appear to be for a different quantity of the product, say. Our approach has been to drop products that do not appear initially, that leave the series before the end of 2008, or that have excessive gaps in the reporting period. To combine these various constraints, a Herfindahl-type approach was adopted. More details are available in Appendix 2.

⁸ A working paper version of this paper (Chakraborty et al., 2011) includes these analyses.

⁹ This conforms closely to the approach used in the UK to calculate the official CPI. The categories used are the standard COICOP (Classification Of Individual CONsumption by Purpose, a standard OECD/ ILO classification scheme) categories; see also the discussion in section 3.3.

- Table 1 about here -

3. Representativeness of our sample

Should the macroeconomic community accept our finding of many small price cuts in the late noughties as a stylised fact? It would have little value if our sample turned out to be significantly idiosyncratic. We therefore check this possibility three different ways. First, we check whether our sample, particularly in its early period, fits with the stylised facts from studies in the past. Second, we investigate whether specific sectoral factors, as opposed to macroeconomic influences, might account for the particular manner in which our firms compete. Third, we investigate the microstructure of pricing movements in our data and compare our results with Chen et al. (2008), mirroring their tests. In this section, we demonstrate confidence in our sample's properties in all three respects, but do find substantial differences with Chen et al.

3.1 Comparisons with other micro pricing studies

Apart from findings at variance with Chen et al. (2008), do our data fit with received facts on micro pricing, or do we have a rogue sample? Two comprehensive surveys on pricing behaviour that provide a useful benchmark, the papers by Klenow and Malin ("KM") (2011) and Nakamura and Steinsson ("NS") (2013), provide facts we reproduce for comparative purposes in Appendix 4. Of these, all but one of the facts (KM's fact 10) can be examined using our sample. As we explain briefly below, a significant majority of these facts is found true also in our sample, at least for the moderation period of years 2004 to 2007.

KM's Tables 1 and 3 are comprehensive summaries of the extent of price flexibility. In this context, our prices change with average frequency, expressed on a monthly basis for the years 2004-2007 inclusive, of 19.2 (14.2) percent, the figure in brackets referring to NSB prices. This fits tightly with the change frequency of CPI data in the table for the UK (from Bunn and Ellis, 2009), and indeed most other European countries. It is substantially lower than the frequencies for scanner data, excepting Nakamura's (2008) NSB prices, but for reasons that are entirely understandable, namely that we have actual prices, not average value indices (Eichenbaum et al., 2014). Thus we can maintain KM's Facts 1, prices changing at least once per year, and 2, on sales being important for flexibility. Whereas the mean duration of a price in our sample is 9.8

weeks, the median duration is only 3.5 weeks (Dixon et al., 2014) so we can also accept NS's Fact 1, and therefore also KM's Fact 4, both these being on heterogeneity in frequency across goods.

So far as KM's fact 5, on cyclicity, is concerned, we do not have fresh produce in our main sample. However, we do have seasonal goods, such as whisky, bought mainly in the winter period, which do fluctuate in price considerably. Relatedly, price changes take place throughout the year, rather than being synchronised (KM Fact 8). Yet, as NS, Fact 4 suggests, the frequency of price change is certainly seasonal, although the pattern we observe across months is not as clear as the one they report. Our early period certainly supports KM's fact 6: price changes are big in percentage terms on average, with many small (e.g. penny) changes. As we detail later, this character does change significantly in the crisis period. KM's fact 7 on relative price changes is best examined in our sample through examining branded and own label products of the same type, see section 4.2. Suffice it to note here that there is some evidence of idiosyncratic price changes appearing to revert over time.

We find (NS fact 2) an even higher proportion of non-sale price changes being price decreases than they do, around 50% in the moderation period, and this grows much more rapidly in the crisis period, as seen in figure 1. Our finding on frequency of price increases and decreases and its link to inflation (NS fact 3) is however rather different than in NS – of course in our sample we have a wider range of circumstances than a typical pricing study. This leaves three “facts”; KM's fact 3, on reference in relation to regular prices, plus fact 9 of KM and fact 5 of NS, which are essentially different ways of expressing the same point- namely that the hazard function of price change is downward sloping. These are outside the scope of the current paper but are shown true in our sample in a companion paper (Dixon et al., 2014, Table 3 and Figure 3 respectively).

In sum, there is no indication from a consideration of the stylised facts that our sample has anything unusual about it relative to the run of other papers in the pre-crisis period. However, various changes occur in our sample in the crisis period, as has been observed in studies of countries with high inflation episodes (Gagnon, 2009; Alvarez et al., 2013).

3.2 Market shakeups in the supermarket sector?

Essentially, we claim that changes we document in pricing behaviour are the result of macroeconomic pressures, namely the crisis. It is therefore important to demonstrate there were no major changes in the industrial organisation or other aspects of the supermarket sector that might be alternative causes of the changed behaviour. We analyse the three most significant such events we observe in the relevant period but find none of them to be a driver of change in pricing behaviour starting around 2007/8. One is a shock to industry structure, the second a Competition Commission market investigation, the third is changes in value added tax (VAT).

Prior to 2003, there were five major supermarket chains in Britain. Then a major market structure change occurred through the merger of Safeway (the UK chain) with Morrisons in late 2003, concluded in early 2004. This clearly had an impact, although market share data show that shares had consolidated by around the end of 2005. Thereafter, shares of all four major supermarkets, the three we examine plus Morrisons, remained remarkably static with no real trend: Tesco 30-32%, Asda 16-18%, Sainsbury's 15-17% and Morrisons 11-13% (source: Kantar WorldPanel, various dates). Moreover, we show in Chakraborty et al. (2014) that the merger's main effect on pricing was on Safeway/Morrisons prices, which fell compared with previous Safeway prices to rest at levels closer to the other three supermarkets (closest to Sainsbury's). The merger gave true national presence to all four major chains; previously Safeway was concentrated in the South and Morrisons in the North. This timing rules out a major merger-related change in competition between the three firms we follow as between the earlier and later parts of our period.

The second candidate influence deserves more detailed investigation, in part because of its timing. It is the Competition Commission (CC) investigation and report on the Grocery industry pursued over the period 2006-2008 (CC, 2008). Market investigations by the CC can and sometimes do result in substantial changes to an industry.¹⁰ Therefore, we investigate whether the grocery investigation led to substantive, possibly implicit, impacts on the three firms we examine. The most obvious way to do this is through an event study on stock-market prices. A drawback is that Asda, being a wholly owned subsidiary of Walmart, is not quoted separately. However, Tesco, Sainsbury's and Morrisons are all quoted on the London stock exchange, and in

¹⁰ For example, a report on airports (CC, 2009) led to the breakup of the British Airports Authority in which London's three main airports, previously the same firm, were separated into three, with two sold to other parties.

all cases, the British part of the business is the dominant element. We identified six events within our period that could be tied to particular narrow time windows.¹¹ These were the publication of (i) the CC’s “emerging thinking” on 23/Jan/07; (ii) its Provisional Findings on 31/Oct/07; (iii) its “Provisional Remedies” document on 15/Feb/08; and (iv) its Final Report on 30/Apr/08; together with (v) the Competition Appeal Tribunal’s (CAT’s) upholding of Tesco’s appeal against one of the proposed remedies on 4/Mar/09 and (vi) the CAT’s remittal on 3/Apr/09 of the issue to the CC to reconsider that section of the report, together with its refusal for Tesco to appeal this remittal judgement on the same date. Using these six events plus the date of the final report on Safeway on 18/Aug/03, we tried a variety of event studies using standard techniques over the calendar years 2003 to 2013 inclusive, with the FTSE 100 index being the base comparator index.¹² Detailed results are reported in Appendix 5. In summary, there was no indication of an abnormal impact on share price returns of events (i) to (iii), nor of the earlier Safeway report. There was weak evidence of the Final Report having a *positive* impact on Tesco, if anything suggesting the market had expected more change than was actually proposed. Event (v) shows some evidence of a negative impact on Sainsbury’s and Morrisons of the Tesco appeal, but no effect on Tesco, together with some indication that the Remittal (event vi) had a negative impact on Tesco and Morrisons. To us, this investigation suggests the CC report had no substantial impact on the (anticipated) subsequent market behaviour of the industry, either during or at the conclusion of the findings.

A third possible factor impacting on industry pricing behaviour is a sequence of two changes in VAT – the national value added tax – within our period. The first, coming into effect from 1/Dec/ 2008, reduced VAT from 17.5% to 15%; the second, coming into effect from 1/Jan/2010, raised the tax to 17.5% again. Thus it is possible that increased pricing changes in these periods are related to tax changes. However importantly, food for human consumption, plus some drinks including tea and coffee, are zero-rated, so that in fact only approximately 119 of our 370

¹¹ The decision to *refer* the industry for consideration by the CC is unsuitable for an event study, because it is something that becomes more or less probable over a period of several weeks.

¹² We are extremely grateful to Dr Luigi Grossi for performing these event studies. We decided against including a sector index in addition to the FTSE100, on the grounds that to do so might minimise the impact of the report on the individual companies, because they jointly constitute such a large part of the relevant sector.

products are subject to VAT.¹³ We focus particular attention on the period around these episodes. Certainly, the VAT reduction is associated with a local maximum in our data of price falls, and the VAT increase with a maximum of price rises. However, the overall picture is mixed. The first episode is also a local maximum of price *rises*, whereas the second is followed one week later with a count of price falls exceeding the rises in the VAT week. The rises are commonly much in excess of the tax incidence, whereas many of the movements relate to products where the tax regime is unchanged. Therefore, whilst the VAT changes had some effect on prices, these effects are not significant enough to disturb our conclusions regarding overall pricing behaviour.

So, the original finding remains. Prices definitely rose rapidly in 2008, particularly the earlier part, both in the CPI and in our sample. How did the firms involved manage to raise prices to consumers to such an extent whilst maintaining their competitive position against lower cost discount stores? And how did they do it whilst actually engaging in a welter of price cuts?

3.3 Pricing microstructure and comparisons with Chen et al.

Our key finding is that the number of price *falls* relative to rises is substantially higher in the later years of our sample and the proportion of falls to rises increases greatly (figure 1) when macroeconomic pressures are greater, yet basket prices rise over the period. The resolution lies in the relative monetary magnitudes of falls and rises. More basket component prices fall than rise in absolute number terms, but falls outweigh rises particularly for all low values of pence, whereas price rises outweigh falls for almost all intermediate values, namely from around 10p onwards. The picture on price falls is to a large extent a picture of penny price falls- figure 2 shows the extent of penny price falls in our sample.

- Figure 2 about here -

Figure 3 focuses on micro movements up to 20p, examining each chain separately. To construct this, the price movements are scaled such that, if for any value of price movement each chain were making only price cuts, a value of -100 would be reached. If at that value of price movement each chain was only raising prices, then a value of +100 would be generated. Thus this figure shows both preponderance in direction and concordance amongst firms. As clearly

¹³ The precise definitions at the margin are complex and not entirely logical, being determined by case law, so in a small number of cases it is difficult for us to know for certain how specific products are classified. For example, biscuits are not VAT-able, unless *entirely* chocolate-covered.

seen, below 6p change, the price movements are predominantly falls, whereas as we move nearer to 20p, price movements are much more likely to be rises, although dominance here is not as strong as at lower levels. The other thing of significance is the extent of concordance as between firms, although Tesco and Asda both engage much more extensively in penny price cuts than does Sainsbury's.¹⁴

- Figure 3 about here -

Because our headline findings on microstructure are precisely the opposite of Chen et al.'s (2008) findings for Dominicks' prices, we must check whether this is simply a difference of methodology or whether there are real differences in behaviour. Since we come to the latter conclusion, we then investigate reasons for the differences. We examine our data using the equivalents of the key tests employed by Chen et al. We divide our sample of products into categories, using the standard statistical COICOP categories, of which our products are represented in thirteen. Mean price and other key descriptives differ significantly across these categories; the lowest mean price being for vegetables (73 pence) and the highest for spirits (£13.78). Columns 1-2 in our Table 2 set out the basic facts regarding our sample across products.

Chen et al.'s table 3 is the core of their analysis. The third column in our Table 2 is an exact repetition of their method. Immediately, we see a key difference in results. Our table represents price *falls* down to which we can reject the equality of rises and falls, whereas theirs represents price *rises*. In this respect, our results are the complete opposite of theirs. Given this, we need to engage in the intelligent equivalents of columns 4 to 6 of their table. They are concerned that inflation may be a cause of an excess of price rises, so perform splits based upon examining that. Our concern is more that deflationary periods might cause an excess of price falls. Therefore, we separate out three subsamples: a deflation sample, a low inflation sample, and a high inflation sample. We choose monthly inflation of 0.2% as a cut-off rather than 0.1% because that would result in there being too few values in the category. Again, our results are almost precisely the opposite. Table 2 employs "stretched" and smoothed PPI values (stretched because the PPI data is monthly and our price frequency is weekly). A very similar table results when we use

¹⁴ In the 600 product sample where Morrison's is included, it behaves more like Sainsbury than Tesco or Asda. Using a very different sample and methodology, Nakamura et al. (2011) also note differences across chains.

stretched but unsmoothed data. One detail difference is that the number of pence (fall in our case) over which we can reject the null hypothesis of equal numbers of rises and falls is smaller on average than in their case. Indeed, just examining the raw data, it is only up to around 6p that there is a statistical excess of price falls, in line with figure 3 above.

- Table 2 about here -

Chen et al. then engage in a number of robustness checks, for example basing it on inflation using CPI rather than PPI data. Our results on this (columns 7-9 of Table 2) show the same predominance of falls.¹⁵ However, it is noteworthy that the CPI division leaves us with an excess of falls over rises statistically significant only for 1p for most of the categories in the deflationary period (the mean being 1.38p), and in the low inflation period (mean 2.15p) but up to 4.14p mean fall in the *inflationary* period, the opposite of what might be expected. We have insufficient sample size to examine individual years at the disaggregate product level for most categories, so we cannot repeat this exercise in their Table 3, but they note their results are a little more mixed in this case.

Thus whilst Chen et al. found more small price changes were positive than negative, we find the opposite, and equally strongly. How can these two findings be reconciled? There are several possibilities. First, however, despite the apparent contrast, both findings are consistent with a broad idea they put forward, that consumers pay limited attention to supermarket prices, in the sense that they are pointed to particular changes they will like taking place, and through this the impact of other unwelcome price changes is reduced. In Chen et al., this comes via highlighting large price falls, whereas in our paper, it comes through highlighting numbers of price drops. To develop our argument a little further, envisage a 3-by-3 payoff matrix representing, for simplicity, a symmetric two-player game. Each firm is confronted with the need to raise basket prices and has three possible strategies: one to make idiosyncratic large cuts; a second to make many small cuts; a third to increase prices by less but not to reduce any prices. Appendix 6 sets the game out in more detail, arguing that the last strategy is likely to be dominated and moreover that the game quite likely has two Nash equilibria, one where both firms make idiosyncratic large

¹⁵ Here we use the general CPI (code D7BT), that is the headline CPI that consumers would recognise, on the assumption that this is what influences behaviour. Previously, in making comparisons between our prices and the CPI, we mainly used food only CPIs, in order to compare like with like.

cuts, the other where they make many small cuts. Experimental work is consistent with this possibility.¹⁶

Empirically, one of the observations our data enables is that supermarkets show some strategy differences, both across states of the economy and across supermarkets. We find that Sainsbury's adopts a somewhat different strategy to Asda and Tesco, who take rather similar paths. In particular, Sainsbury's does not consistently have more prices falling than rising; in the early period it is somewhat the reverse, more like Dominicks. Also, by way of comparison, the market positioning of Sainsbury's in the UK is probably most similar to that of Dominicks in the Chicago area – somewhat upmarket of the mass operator(s) but not the top quality chain.¹⁷ Sainsbury's does however change its pricing behaviour somewhat in the later period of our sample.

More generally, we would expect that oligopolists' pricing behaviours will be influenced by their rivals and it is therefore useful to gain information from several chains. Given this, we explore whether our result survives (a) when we confine our period of observation to the earlier years and (b) when we examine the activities of individual firms. The final three columns of Table 2 report on these investigations, illustrating by product category; in effect it uses a subset of the data reported on in the earlier columns. Of course, slicing the sample means there is increased potential to encounter small sample sizes, and this limits our results. However, two things become clear. First, the results are less true of the early period than they are of our sample as a whole, although there is a persistent predilection, across time, firms and products, for single penny falls much to exceed penny rises. Second, Sainsbury's has a lesser tendency to engage in excess price falls than either of the others, consistent with Sainsbury's falls not outweighing rises in the early years and with our impression that Dominicks is more akin to Sainsbury's than to either of the other two.

4. Can the observed price movements be attributed to obfuscation?

¹⁶ Alba et al. (1999) carry out experiments to compare subjects' reactions to these two strategies specifically and find that either can dominate in consumers' minds.

¹⁷ A *Chicago Sun-Times* retrospective on 30 January 2014 is our source for our remarks on Dominicks. Of course, shortly after the period studied in Chen et al., Dominicks was taken over by Safeway (the US chain) and ultimately collapsed in late 2013.

We propose that the peculiar patterns in price movements in our data, most obviously the large number of very small, particularly penny falls, are part of a mechanism to obfuscate or disguise underlying upward movements in prices that consumers will dislike. In this section, we examine a variety of different pieces of evidence for our assertion. For the most part, these in their different ways point strongly at the use of obfuscation.

First, what is obfuscation? Ellison (2006, pp.157-8) provides a useful summary of work on obfuscation relevant to our purpose and suggests “The most straightforward way to think about obfuscation using standard IO tools would be to regard it as increasing search costs ...”. Other papers discussing the concept include Ellison and Wolitsky (2012), Piccione and Spiegler (2012), and Gabaix and Laibson (2006), who call it “shrouding”. These papers demonstrate theoretically in various ways that the phenomenon exists in equilibrium and is not driven away by competition and they provide a few comparative statics. They are not written from a macroeconomic standpoint and do not deal in dynamics. In this section, we perform a number of experiments to evaluate whether obfuscation of price rises has occurred. However, we accept that obfuscation is more of a concept or range of activities than a predictive theory: Firms, facing potentially fierce competition, engage in acts that soften price competition through making it more difficult for consumers to make comparisons. Thus more than one type of pricing behaviour is consistent with obfuscation, with the precise form dependent upon the circumstances.

4.1 Variance in the basket cost

Gabaix and Laibson (2004) consider obfuscation as “increasing the variance of the random evaluation error in a model in which consumers have noisy estimates of the utility they receive from consuming a product ...” (quote from Ellison, 2006, p.158). In our context, this could for example be noisy estimates of the price consumers pay for, and therefore net utility they gain from, the basket of products they purchase on any particular week. In the words of Gabaix and Laibson (2004, p. 3), “Higher levels of noise increases the chance that a consumer will either overestimate or underestimate the surplus associated with the firm’s good. ... [N]oise reduces ... the elasticity of each firm’s demand curve, leading firms to raise equilibrium prices.” They show that when obfuscation is endogenous, firms respond to increased competition by increasing the

level of noise (variance), which is what underlies their findings (Gabaix and Laibson, 2004; Gabaix et al. 2013; see also Perloff and Salop, 1985) that margins shrink only slowly as competitor numbers increase.

We select baskets of size 30 and size 50, then generate, with replacement, a random sample of 100 such baskets and track the mean and the variance of this distribution, for each week of our data across each chain. The random draw is weighted by *purchase frequency*; that is the choice of a particular product in the sample is proportional to the average frequency with which that product is purchased, in order that our constructed baskets map closely to real consumer baskets.

In our context, it is extremely plausible that the recession increased demand elasticities for food products,¹⁸ which would therefore reduce retailer margins *ceteris paribus*. A simultaneous increase in noise (variance) has the potential to restore margins to their existing level. We suggest that firms' selective promotions of low prices together with unannounced price rises provide the means by which the variance in the signal increases, increasing the degree of "product differentiation" between themselves so reducing the tendency for competition and cost pressures to drive down margins. Firms have greater incentive to do this when competition intensifies. The upper panel of Table 3 examines our contention that selective promotions, plus unannounced price rises, increase variance. Correlations between the standard deviation in the basket price and number of penny drops are always strongly significant and robust to basket size and definition of price.

- Table 3 about here -

In the lower panel of Table 3, we test the null hypothesis that there is no difference between basket mean prices across chains against alternatives, across each week in the data. The natural alternative is one-sided – is my chain more expensive than another? In the case of the basket size of 30, on all but two weeks of our sample, Asda is cheaper than Sainsbury. However, in only 10 of those weeks can the null hypothesis be rejected at the 5% level in favour of the alternative that Asda is cheaper. In 40 of our weeks, Asda is cheaper than Tesco. Nevertheless, the difference is small and we never come close to rejecting the null. Nor can we reject the null in the Tesco-Sainsbury comparison. The power of the test naturally improves somewhat in the 50 item basket

¹⁸ Taking a demand function for a normal good and assuming separability in price and income is sufficient to demonstrate an increase in price elasticity at any price following a fall in incomes.

test. However, we never come close to rejecting the null of equality as between Tesco and Asda, and indeed the mean basket difference of 1.24% is small. Sainsbury is clearly somewhat uncompetitive on price, but other factors come into play as well in influencing consumers' actual store choice. In sum, for a consumer with limited information about alternatives, the differences between the chains are seldom so stark that the consumer would be reasonably certain a chosen chain was uncompetitive. Two people, even with quite similar baskets, could easily come to legitimately different conclusions about which was the cheaper.¹⁹ Nevertheless, purchasing a 50 item basket from Asda rather than Sainsbury would save over £200 a year.

4.2 Matched product subsample

Additional evidence consistent with obfuscation is provided by a matched product sub-sample. Within our sample of 370 products, we have 30 own-label products that tightly match 30 branded products, for example packets of own-label cornflakes and Kellogg's cornflakes of equal weight. This sample, although small, speaks to two issues. First, a plausible hypothesis is that consumers notice price changes, particularly increases, more on branded products than on their own-label equivalent. If so, at times of heightened awareness, price rises will focus on the own-brand version. Is this true in our sample? Second, do relative prices drift apart (which relates to KM's Fact 7)?

Regarding the first question, the upper panel of table 4 lists the percentage of price rises (falls) that are on the branded products. Two features are worth highlighting. First, price rises are slightly more common in branded goods, across years and supermarkets. However second, price falls are heavily concentrated within the branded products in years 2008 and 2009 and, to a lesser extent, 2010. This is consistent with obfuscation, or at least limited attention, on the hypothesis that consumers are more attentive to price changes and promotions on brands. However it is also plausibly consistent with competitive behaviour. But do branded prices fall relative to own label?

- Table 4 about here -

On this second question, analysis of the matched samples suggests pricing experience is extremely varied across the set of 30 products, a finding consistent with obfuscation. We ran

¹⁹ Of course, this test does not make comparisons with stores outside this set, for example the "hard discounters" which sell a more limited range of products.

separate regressions by product of the branded to own label price ratio across our whole period against dummies for 2008 and 2009, with summary results shown in the lower panel of table 4. No clear general tendency is apparent. As can be seen, many price ratios rise over one or both years, many fall, and others show a mixed picture, with a slight tendency for the ratio to rise on average in 2008 and fall on average in 2009. Hence, despite the greatly increased numbers of price cuts on branded products, there is no trend to uniformly lower branded good prices in the 2008/9 period.

4.3 Promotional pricing moves amongst the firms

One advantage of our sample over most similar studies is that we have several firms to compare. It is possible that when we are observing small price changes the main driver is competition, not obfuscation. Indeed it is difficult to draw a bright line between obfuscation and competition, since obfuscation in the Ellison- Ellison (2009) sense is a response to significant price competition. Here it is useful to think of there being two types of price changes in the data. One is a temporary price reduction (TPR), defined as a price cut (of any amount) where the price returns to the same level within six weeks. The second type is a permanent price move, consistent with the NSB definition.

Price moves that are reciprocated in terms of direction²⁰ by other firms are potentially obfuscatory, but may also be (i) initiated by producers as a promotion strategy on their products, or (ii) competitive moves amongst suppliers. We focus attention on NSB price changes, and focus entirely on single penny cuts. There are three potential subcases: (a) I may drop my price when it is above the minimum offered by my competitors; this is clearly a potentially competitive move. (b) I may drop my price by 1p when it is already below the prices set by my rivals. There is no possible competitive reason for this, so such a small price fall must be viewed as obfuscatory, (c) I may drop my price when it is equal to the minimum set by my competitors, so that it then undercuts them (albeit by a trivial amount). This might be seen either as competitive or obfuscatory. The analyses of table 5 partially split this out for the three firms. We see little evidence that Sainsbury adopts clearly obfuscatory price moves. However, there is some evidence that Tesco and, particularly, Asda, do. For Tesco, the high point is 2008, for

²⁰ For present purposes, we are deliberately using definitions that are broader than those in Seaton and Waterson (2013) in order to balance the scales against obfuscation.

Asda, 2009. Here, Asda is the most aggressive in cutting below rivals; most (~ 70%) of its moves are in category (c), so they are related to “Price Check” strategies, but might be seen either as competitive or obfuscatory.²¹ The raw figures and more detail are given in Appendix 7.

- Table 5 about here

Our contention is that penny drops are designed deliberately as an obfuscation strategy, rather than a means of competition across firms. We note that if they were primarily a means of competition, their widespread adoption by all three firms, particularly Tesco and Asda, would have led to observable drops in firm margins in the years 2008 and 2009. There is no sign (see Appendix 1) that this is the case. Rather, we suggest that they were targeted to create headlines.

To further characterise the situations in which penny drops were most prevalent, we ran regressions for each firm in which we included a set of explanatory variables, in addition to dummy controls for individual years, in order to “explain” penny drops across products. These were: whether the product is branded, if it was branded, size of the own-label share (by volume), whether the product was relatively highly priced in that firm and relative purchase frequency, i.e. the percentage of shopping trips in which it was purchased. The results are remarkably consistent across the firms and are reported in Appendix 8, table A8.1. Including dummies interactive between the variables and years reveals that the effects are special to 2008 and 2009. Brand is (unsurprisingly) positive and significant, but so is own-label share. This means that brands were more targeted in areas where people are more likely to buy the own-label variant. Relatively lower-priced products were targeted as were those with a *lower* purchase frequency. This latter is very interesting: if directly aimed at competition, we would expect items that people buy more often to be more targeted. However, if creating publicity, then targeting products which are known but less often bought involves a lower potential downside for the firm.

Importantly, our data also clearly show that the penny drops we have documented are used by firms *alongside* the more traditional TPRs, rather than being substitutes. Indeed, correlations across years between penny drops and TPRs are high for each firm, at (0.837, 0.832 and 0.683)

²¹ These findings are consistent with the finding in Seaton and Waterson (2013) that Asda consistently leads in (small) price cuts.

for (Asda, Sainsbury, Tesco) respectively. Yet they are targeted differently. Simple regressions, also reported in Appendix 8 (table A8.2), show that TPRs are used predominately on *more* frequently purchased *better-known* branded products of *higher* value. The strategies co-existed.

4.4. Advertising and consumer reactions

Our analysis so far suggests that the supermarket chains, particularly Tesco and Asda, were engaging in obfuscation of their true position that basket prices were rising, through the snowstorm of penny and other small value individual price falls that we have observed. Consistent with our view on obfuscation through promotion of price cuts, Nielsen media/Mintel estimate that advertising spend in 2008 was up on 2007 by 28.3% for Tesco, 44.4% for Asda, 11.0% for Sainsbury's (see Appendix 9, table A9.1). Nielsen does not provide a detailed breakdown on types of advertising. However, we have available a source called visit4ads.com that claims to record TV advertisements comprehensively (it does not cover other media). On inspection, their data are most complete for years 2006-2009 inclusive,²² so we draw comparisons between 2006/7 and 2008/9. Each of the approximately 1000 plus advertisements per firm per year was classified in a binary fashion as possessing or not possessing each of twelve features (e.g. did it advertise a price comparison). It is apparent from the results of this exercise, reported in table 6 below and Appendix 9, that the categories "price image", "price comparisons" across stores, "cheaper than chain X" and "hundreds of price cuts" are used much more in the latter period, particularly by Tesco and (notably) Asda. Clearly, the thousands of tiny price cuts discussed earlier were also useful in making marketing claims about being competitive and keeping prices down, providing comfort to consumers and dampening their price sensitivity. There is market intelligence evidence that the pricing strategies plus marketing spend worked, in keeping consumers searching within rather than searching across supermarkets in pursuit of presumed value.²³

-Table 6 about here-

4.5 Do penny drops facilitate pass-through?

²² In Britain, the amount of advertisement time per hour in TV is regulated. Therefore, we would expect around the same number of advertisements recorded in total (across all products) per year. This is true in these four years, but in years either side of this, the recorded numbers are much lower in our source.

²³ See Appendix 10 which collects market intelligence information on consumer attitudes on this point.

We examine the link between penny drops and pass-through by comparing weeks where the fascia's price rises are above those of the general CPI with weeks where the number of penny drops is above that company's average. The idea here is that each supermarket chain uses penny drops to differing extents. Sainsbury's uses them much less than Asda, for example. But if they are used to obfuscate, then an obvious target is to do this particularly when the company's prices are rising above the general level of (CPI) inflation. If so, there should be more cases where *relatively* large penny falls occur when the firm's inflation is above average than when it is below. More formally, our hypothesis is that the weeks of relatively intense price falls are *more* concentrated in weeks when the basket price rises more, the null being that relatively intense price falls are unrelated to the weeks when the basket price rise is above the CPI.

In our sample, there are respectively (134, 111,148) weeks for (Asda, Sainsbury, Tesco) out of 314²⁴ where the firms are raising their prices more quickly than the CPI. There are (105, 101, and 104) weeks where the firms' weekly penny price falls are more than the average number they perform. This means that if the above average penny rises across the weeks were randomly assigned, the probability that both events occurred in the same week would be (0.143, 0.114 and 0.156). The actual probabilities are (0.217, 0.175 and 0.242). Binomial tests force us to reject the null hypothesis in favour of the alternative at a very high degree of confidence. Therefore, we conclude that the penny falls are likely to be obfuscatory.

In a variant test, we examined whether there was a correlation between the (rolling 3 monthly average inflation for the supermarket relative to the relevant CPI index) and (the sum of penny drops over that rolling three month period). We found the following correlations for Asda, Sainsbury and Tesco respectively as (0.408, 0.432 and 0.198). All these values are significant at the 5% level or better. Thus, when inflation over the period was relatively high compared with food stores generally, the number of penny drops was relatively high. Taking both tests together, we conclude that the penny falls are likely to be obfuscatory.

4.6 Direct evidence through “left digit” effects

Our final and possibly strongest piece of evidence derives from the psychological literature and establishes a direct link between price rises and obfuscation. Increases in raw materials prices of

²⁴ We lose a year's observations from the sample in order to calculate annual inflation. These results refer to the complete baskets as in section 2.

the magnitude experienced in early 2008 would have been extremely difficult for supermarkets to accommodate whilst maintaining leftmost price digits on retail prices and at the same time maintaining margins. We show that the relationship between levels of leftmost digit changes and the number of small price reductions across our sample is close, indicating that noise is used to distract attention from price increases that would otherwise be noted by consumers.

There have been many studies, mostly experimental, in the area of consumer psychology investigating the left digit effect (e.g. Thomas and Morwitz, 2005; Stiving and Winer, 1997). The basic commonly confirmed finding is that consumers perceive the left digit in a price as more significant in comparing prices than the remainder of the digits.²⁵ The strength of the effect is such that we take it as a stylised fact and explore its implications for supermarket pricing policy. Supermarkets are not in the practice of trumpeting price increases; they may well find that, given an increase in a price from say 85p to 89p, few consumers notice. The left digit effect suggests this is the case, but also that an increase from 88p to 91p is much more likely to be noticed, although it is smaller. Yet in our data, whilst in the earlier years most price rises were small, less than 10p, in the later period price rises in the range 10p to 20p became markedly more common, presumably because of sharp rises in wholesale costs, as documented in Appendix 3. So we suggest that the challenge for a supermarket is how to obfuscate or disguise such a price rise. One clear possibility, given our earlier findings, is to mask it through the welter of price falls, which commonly are trumpeted. This suggests a clear testable obfuscation hypothesis:

Hypothesis L: The number of a firm's *left digit rises* in prices each week is significantly correlated with the absolute number of price *falls* within our sample; the null being that there is no significant correlation.

We examine hypothesis L using NSB prices, so as to focus on price changes that have some persistence. The results are easily stated and establish an interesting new statistic: The correlation between the number of left digit increases and absolute number of price falls across supermarkets per week is, in the order (Asda, Sainsbury, Tesco), (0.450, 0.231, 0.487). All these are highly significant at conventional levels of significance, suggesting that obfuscation is being practised.

²⁵ Many of these studies are experimental, focused on prices ending in 9 or 99. They also focus either on accurate recall of individual prices or on contemporaneous comparisons of prices. In our case, the standard experimental assumptions are not exactly met – 9 endings are not overwhelmingly common in our sample and the appropriate comparison is between this week's price and the price last time the consumer shopped for the product.

There are alternative theories that could link left digit increases and price falls. For example, Berger and Vavra (2014) demonstrate that the dispersion of price changes is large and countercyclical. When inflation is high, there will be more left digit rises; hence there is a plausible link between a large number of left digit changes and a greater number of price falls which does not require obfuscation as part of the explanation. However, the framework that Berger and Vavra develop does not incorporate asymmetries in the magnitudes of changes upwards and downwards, such as we observe. Therefore we refine our analysis by examining the relationship between left digit changes and *small* price falls specifically. There remains a significant correlation between the two series whether we consider penny price falls only or whether we take price falls in the range 1p to 5p; the correlations across the three firms in this case are (0.301, 0.192, 0.340) and (0.430, 0.245, 0.490) respectively.²⁶

In summary, there are many separate pieces of evidence that point to or are consistent with price movements in our sample, in the 2008 and 2009 period in particular, being obfuscated through the mechanism of reducing many prices by a small amount, whilst increasing a smaller number of others by larger amounts. Several of our findings are difficult to explain through straightforward competitive behaviour. As a result of obfuscation, cost increases can pass through into basket price rises, without seemingly drawing the consumer's attention too obviously to what is happening.

5. Concluding remarks

Supermarket basket prices move in quite different ways from the prices of their constituent products, at least within our sample that encompasses the largest UK chains. Within our timeframe, there is one major inflationary then deflationary incident amid general mild inflation, and we are able to observe firms' pricing behaviours before, during and after this incident. Individual prices are very flexible, but more significantly, so are basket prices. In particular, our study has shown that the period 2008-2009, where there were rapid cost movements in basic food commodities, was characterised by the UK supermarket chains raising basket prices.

²⁶ However, we note for completeness that there is no significant correlation between the *difference* in Asda and Tesco's price cuts and the difference in their numbers of left digit price rises, for example. This suggests that this particular result does not extend to *relative* obfuscation across firms.

However we cut the data, what shines out is the core response, which we argue is consistent with attempts to obfuscate, and hence to facilitate, the fact that basket prices are rising, and where the flurry of penny price drops coincided with intense marketing of “thousands of price cuts” and related retailer advertising claims. As a result, the supermarkets survived the macroeconomic turmoil relatively unscathed, with margins unaffected.²⁷

An obvious question is why, if tactics employed at the height of the crisis were successful, they are not employed all the time.²⁸ Our response is that presumably, these tactics involve a cost – at least the cost of the pennies lost in revenue – and in less inflationary times could run the risk of triggering a genuine rather than a phoney price war or, with continued use, risk being exposed to consumers as a sham, rendering them deeply suspicious of retailer announcements of “thousands of price cuts”.²⁹ Therefore, they will only be employed when the benefit exceeds the cost and risks attached.

In a contemporary report to the Treasury Select Committee, Bean (2011) (Deputy Governor of the Bank of England) noted that one of the reasons CPI inflation experience in the UK has been markedly higher than the Bank had expected is that “... we appear to have significantly underestimated the degree of pass-through from Sterling’s 2007-8 depreciation ...”. Our work relates to this quite closely. The big rise in commodity prices in early 2008 largely came from overseas. Our paper exposes the behaviour of key players in the inflationary process in their desire and ability to raise prices in a competitive environment, hence providing some explanation for this changed outcome.

²⁷ The industry’s trade magazine, “The Grocer”, remarked in its issue of 18 July 2009 that “The UK’s big four managed to dodge the cost of food inflation last year - by passing the full £5.7bn bill on to shoppers”. This is consistent with the basic data set out in Appendix 1.

²⁸ A different, later, usefully complementary dataset we are exploring suggests that for fresh produce, whilst in the recession period there were many small price falls, these subsided in 2011 and after. See Appendix 11.

²⁹ Indeed, there was considerable negative media coverage when the penny drops ploy was exposed, late in the day. For example, “How Asda rolls back its prices - by a penny”, *Daily Mail* 9/Mar/2009; “Half of Asda price cuts 'worth just 1p'”, *Telegraph* 9/Mar/2009; “The phoney supermarket price war”, *Independent* 21/Nov/2009; “Every little helps? Supermarkets accused of 'cynical manipulation' over 1p cuts”, *Guardian* 22/Feb/2010. However, media interest and consumers’ memories tend to be short-lived, and the same ploy has been exposed before (e.g. “The price is wrong”, *Telegraph* 7/Oct/2001) and so might be used again in the future.

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TABLES

Table 1

Correlations of price index differences over time, official and generated price index data

CPI measure	D7BT	D7BU	DK9O	DK9P	ASDA	Sainsbury's	Tesco	Ave	Wt ave
D7BT	1	0.6925	0.721	0.6264	0.4228	0.6877	0.4806	0.4712	0.5455
D7BU	0.6925	1	0.9927	0.9398	0.8188	0.9417	0.8528	0.8395	0.903
DK9O	0.719	0.9927	1	0.922	0.8323	0.9365	0.8654	0.8457	0.9112
DK9P	0.6216	0.939	0.9215	1	0.6999	0.879	0.7429	0.7409	0.8006

Notes:

a. November 2004- November 2010, based on five week centred moving averages.

b. Key to CPI measures: D7BT, D7BU, DK9O, DK9P are respectively: CPI all items index, Food and non-alcoholic beverages, Food, alcohol and tobacco, and Processed food and non-alcoholic beverages. Source: UK National Statistics Office.

c. Our constructed indices for the three retailers mirror the construction of the official CPI measures in applying geometric means at the sub-COICOP level and weights from the CPI across COICOP (Classification Of Individual Consumption by Purpose, a standard OECD/ ILO classification scheme) categories. The penultimate column Ave is a simple average of the three retailers, whereas wt ave weights the three retailers by their market shares.

Table 2

Price fall in pence beyond which price falls do not significantly exceed rises

		1	2	3	4	5	6	7	8	9	10	11	12
			Number		PPI	PPI	PPI	CPI	CPI	CPI	Asda	Sains	Tesco
COICOP		Number of	of	Full	Deflation	Low	High	Deflation	Low	High	2004-	2004-	2004-
ID	Category description	observations	products	sample	sample	inflation	inflation	sample	inflation	inflation	7	7	7
01.1.1	Bread and cereals	84546	77	5	3	4	6	3	3	4	3	2	2
01.1.4	Milk, cheese and eggs	46116	42	3	3	3	3	1	1	3	-	-	1
01.1.5	Oils and fats	21960	20	6	3	5	6	1	3	6	3	1	3
01.1.7	Vegetables	27450	25	3	3	3	6	1	1	3	2	1	2
01.1.8	Sugar, jam, honey, syrups, chocolates etc	36234	33	4	3	3	6	1	3	4	1	1	1
01.1.9	Food products (other)	65880	60	7	3	3	7	3	3	7	3	1	2
01.2.1	Coffee, tea and cocoa	18666	17	3	3	3	5	1	1	3	-	-	2
01.2.2	Mineral water, soft drinks and juices	5490	5	1	3	2	3	2	1	1	1	1	2
02.1.1	Spirits	23058	21	9	4	5	9	1	5	8	-	-	-
02.1.3	Beer	10980	10	1	3	3	4	1	1	1	-	-	-
05.6.1	Non-durable household goods	29646	27	5	5	3	5	1	1	3	2	1	2
09.3.4/5	Pets, related products and services	20862	19	6	3	3	6	1	4	6	1	1	1
12.1.2/3	Appliances and products for personal care	15372	14	5	5	3	5	1	1	5	2	2	2
	Total	406260	370										
	Average			4.46	3.38	3.31	5.46	1.38	2.15	4.15			
	Total weekly observations			365	83	101	181	66	94	206			

Notes:

a. COICOP - Classification of individual consumption according to purpose (a standard ILO and OECD classification scheme).

b. Stretched and smoothed PPI or CPI values are used for classification purposes.

c. These tables are calculated using similar criteria to Table 2 of Chen et al (2008). Tests are t tests for significant difference between rises and falls.

d. A number in columns 3- 12 means that price falls up to that value significantly exceed price rises. For example, in column 3 the first value means price falls significantly exceed price rises up to the value of 5p for Bread and Cereals examined across the whole sample.

Table 3

Correlations between numbers of penny drops and basket standard deviation by week

Basket size	30	50	30	50
Prices	Posted	Posted	NSB	NSB
Asda	0.320	0.317	0.370	0.317
Sainsbury's	0.390	0.390	0.363	0.380
Tesco	0.330	0.323	0.366	0.326

Testing if one supermarket's basket is cheaper than another

Tests of difference	Test	1 week		
		A < S	T < S	A < T
Basket size	30	10	0	0
	50	100	26	0
Null hypothesis: No difference in basket prices				
One-way 5% test; 10 baskets per week observed				
Weekly basket price difference in £ (% in brackets)				
Basket size	30	2.67 (4.36)	1.91 (3.08)	0.76 (1.24)
	50	3.99 (4.15)	2.80 (2.88)	1.19 (1.24)

Notes:

- "A" is for Asda, "S" for Sainsbury's and "T" for Tesco.
- Baskets are drawn randomly from our sample of 370 products, with the probability of choice corresponding to purchase frequency (shopping trips in which the good was purchased/total shopping trips).
- Numbers in the upper panel, to the right, refer to number of weeks (out of the total of 365) in which the null hypothesis of equal basket price, is rejected.

Table 4

Percentage of price rises and falls attributed to branded items

		2004	2005	2006	2007	2008	2009	2010
Rises	Asda	46.9	65.5	61.8	65.7	56.1	61.9	68.0
	Sainsbury's	43.9	63.2	52.5	59.0	57.0	60.4	59.1
	Tesco	46.5	58.7	59.7	55.6	53.8	57.5	58.1
Falls	Asda	50	52.8	68.2	57.0	82.0	86.1	73.6
	Sainsbury's	39.4	51.9	58.3	53.7	69.9	80.0	70.0
	Tesco	47.4	52.4	63.8	51.9	75.1	76.1	61.1

Significant dummy variables in a regression of branded to own label ratio by week on dummies for 2008 and 2009

	Asda	Sainsbury's	Tesco
D2008 plus	14	13	12
D2008 minus	9	6	9
D2009 plus	12	13	10
D2009 minus	13	15	16

Notes:

- a. Work is performed on parallel branded and own label product subsample (30 matched items in each sample) over the whole period.
- b. There are 30 separate regressions, one for each product.
- c. "D2008 plus" means a dummy taking on the value 1 in 2008 achieves positive significance at 5% level; other variables follow suit.

Table 5

Fraction by year of 1p NSB moves that are below minimum other then drop

	2004	2005	2006	2007	2008	2009	2010	Average
Asda %	2.4	5.5	0.9	12.9	12.4	16.8	6.1	12.7
Sainsbury's %	0	0	0	0	1.1	1.5	0	0.8
Tesco %	0	1.7	4.7	2.2	7.3	1.7	2.4	3.9

Notes:

- a. NSB prices: Prices generated using the Nakamura Steinsson (2008) Regular Price Algorithm "B".
- b. Below minimum other means price is below either of the other two firms' prices before the drop takes place.
- c. The table refers to penny price drops only
- d. All years 52 weeks except 2007 has 53 weeks and 2010 includes 44 weeks

Table 6

Patterns in advertising nature across the firms

		Promo	Price image	Price comparisons	Cheaper than X	100s of price cuts
ASDA	2006-07	88	15	0	0	3
	2008-09	287	120	102	94	36
	Proportion	3.3	8.0			12.0
SAINS	2006-07	149	1	0	0	1
	2008-09	335	22	0	0	8
	Proportion	2.2	22.0			8.0
TESCO	2006-07	345	11	11	9	1
	2008-09	476	43	27	23	21
	Proportion	1.4	3.9	2.5	2.6	21.0

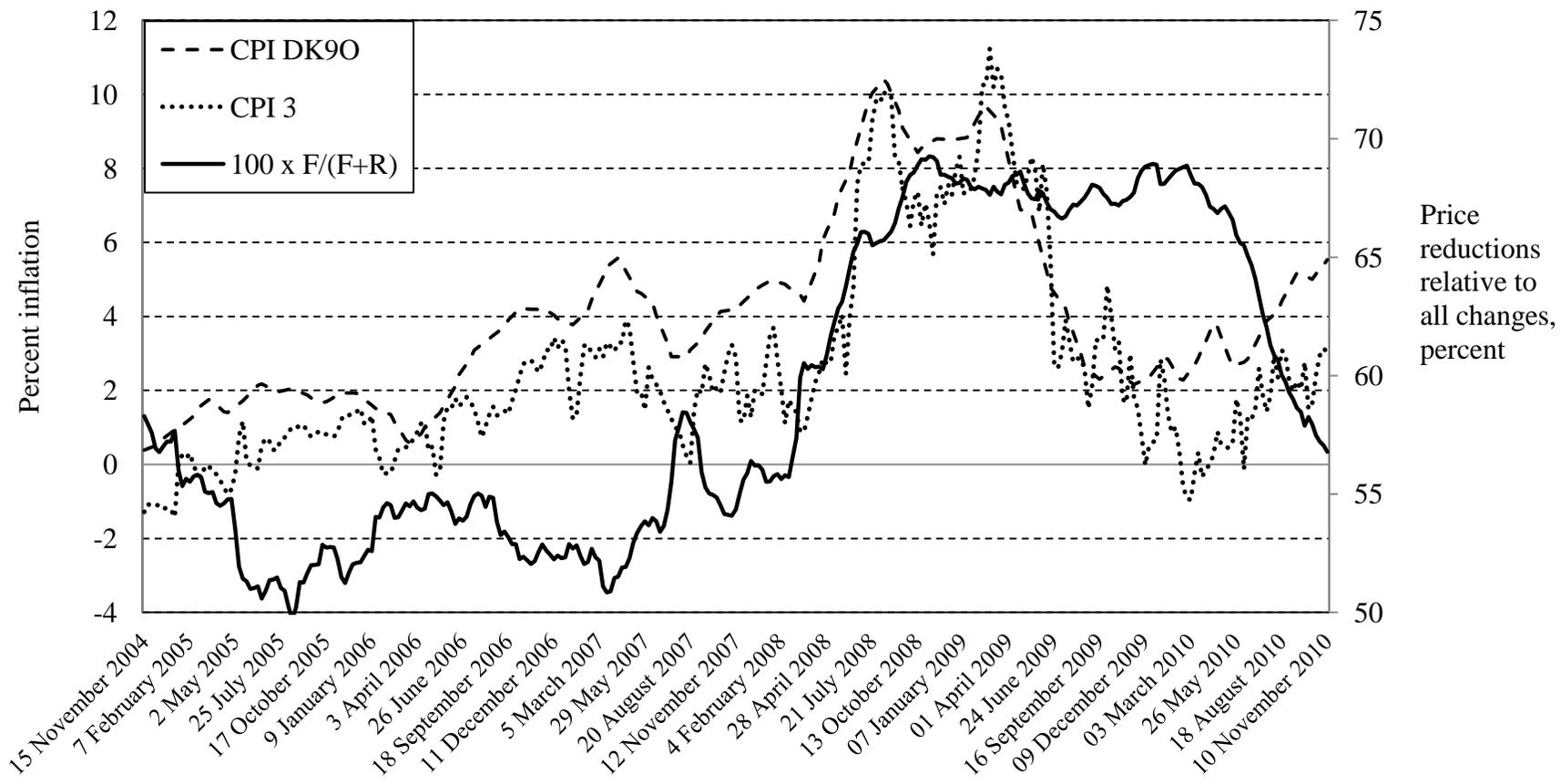
Source: Authors' analysis of TV commercials stored by visit4ads.com

Notes: These results are based on a series of binary questions as to whether the advertisement includes the stated material. More details including the full list of questions are given in Appendix 9.

FIGURES

Figure 1

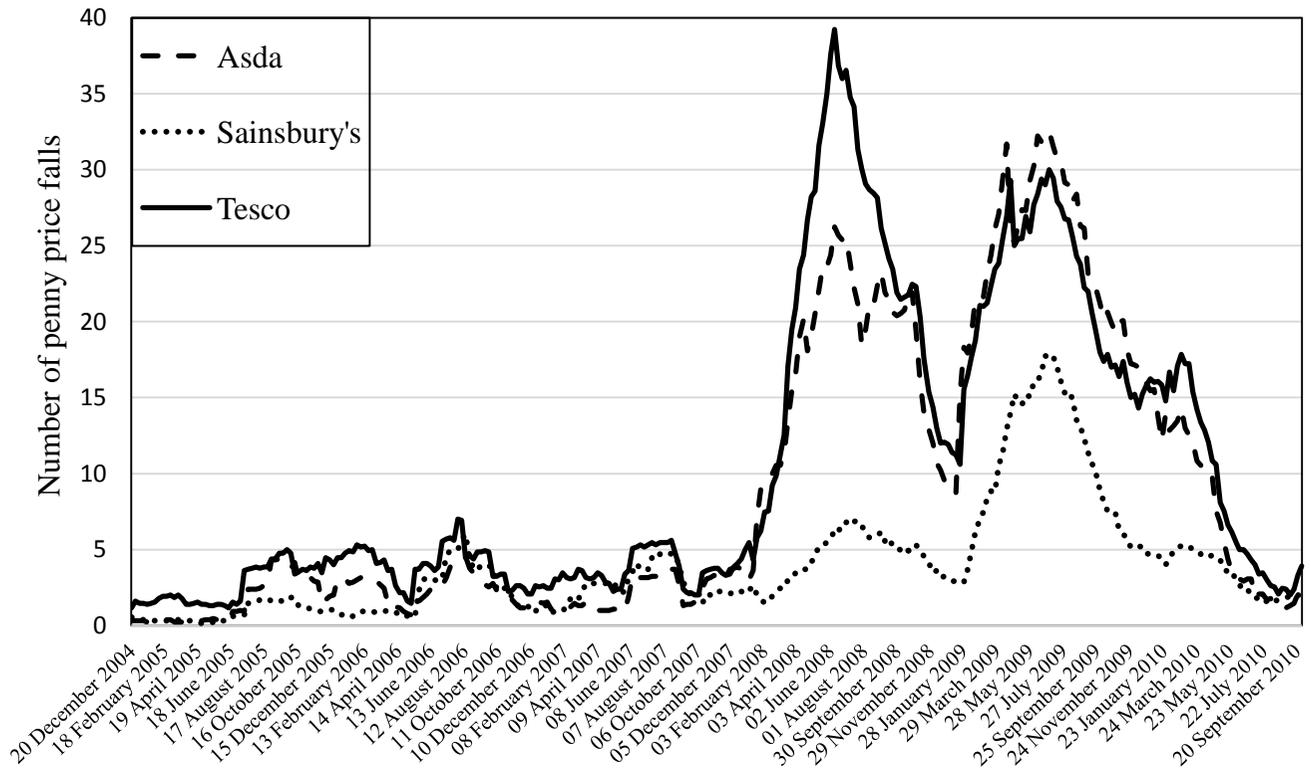
Inflation comparisons, UK CPI and constructed supermarket CPI together with percentage of price falls to total



Notes:

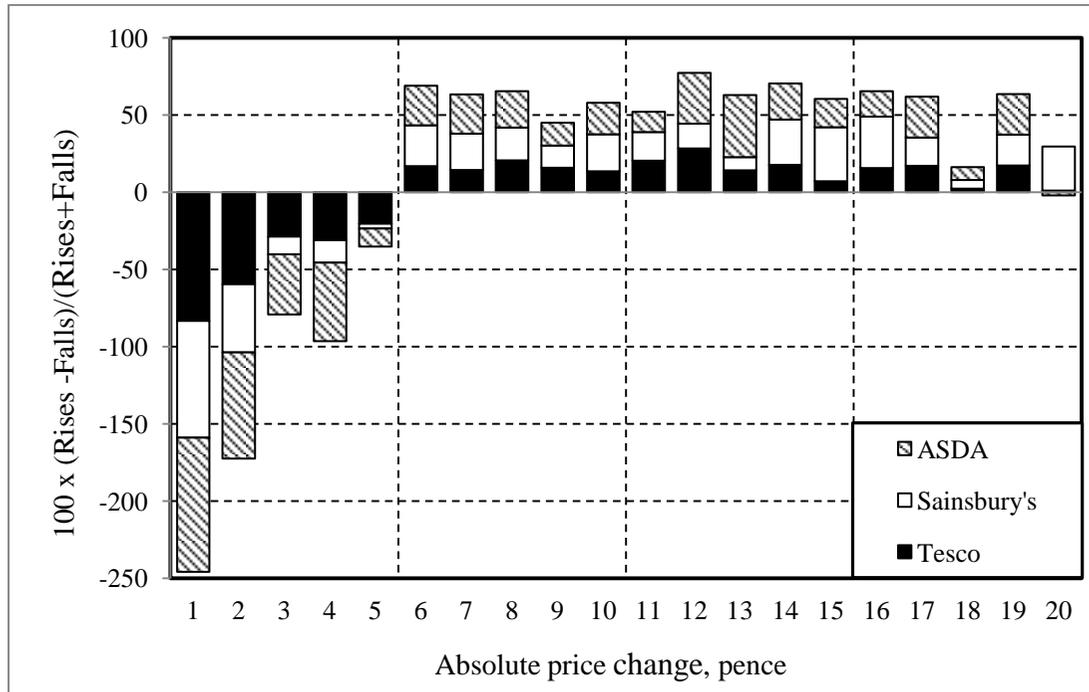
- a. Inflation measured by annual percentage change in monthly price index in each case.
- b. The UK consumer price indices (CPI) are available from ONS, DK90 relates to food, alcoholic beverages & tobacco and processed food & non-alcoholic beverages.

Figure 2
Average numbers of penny price falls by retailer



Note:
Quarterly centred moving average of the number of weekly penny price falls out of 370 products in each case.

Figure 3
Dominant price change proportions by absolute price change amount and retailer



Notes:

- Calculated from the number of X pence falls and X pence rises for each retailer in the entire dataset of 370 products.
- For each absolute price change, say Xp, the figure illustrates the relative dominance of price falls (negative values) and price rises (positive values) to total number of price changes.
- Potential maximum value for each retailer is 100, minimum value -100. Max (min) value obtained when all the price changes of that magnitude are positive (negative). Zero score implies equal numbers of falls and rises. The retailers' are summed for each pence change.

Supplementary material for on-line publication only

[Click here to download Supplementary material for on-line publication only: Penny drops Appendix material R2.docx](#)