Price flexibility in British supermarkets

Jonathan S Seaton and Michael Waterson

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# Price flexibility in British supermarkets

**Jonathan S Seaton and Michael Waterson***[1]

Loughborough University; University of Warwick

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## Abstract

This paper delivers a significantly different empirical perspective on micro pricing behaviour and its impact on macroeconomic processes than previous studies. We examine a seven year period of pricing behaviour by the major British supermarkets encompassing the recession year 2008 and the partial recovery of 2009. Several of our findings run strongly counter to established empirical regularities, in particular the high overall frequency of regular or reference price changes we uncover, the greater intensity of change in more turbulent times and the numerical dominance of price falls over rises. The pricing behaviour revealed also significantly challenges the implicit assumption that prices are tracking cost changes.

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***Corresponding author: Department of Economics, University of Warwick, Coventry CV4 7AL, UK. Phone +442476523427; fax +442476523031; email: Michael.waterson@warwick.ac.uk

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**Price flexibility in British supermarkets**

## 1. Introduction

A key question macroeconomists ask is: Are prices flexible at the micro level? It is a question on which there is growing microeconomic evidence, and some limited consensus. As an empirical question, the answer may differ from country to country and whilst most studies focus on the US, there are also examinations of other economies, in particular within the Euro area (Dhyne et al, 2005), in the UK (Ellis, 2009; Bunn and Ellis, 2011) and more recently South America (Cavallo, 2012). The findings are usefully presented as a series of "facts", as in Nakamura and Steinsson (2008; 2010) and in Klenow and Malin (2010); of course the "facts" are particularly useful if they have general application. We take an important new British sample with some clear distinguishing features and report findings at considerable variance to most that have gone before. Therefore they present new challenges for modelling. To preview, we can say unequivocally that the prices we study are flexible. But quite what that implies is unclear.

We report several powerful findings that challenge (albeit for a different sample) a number of the empirical conclusions that have been drawn in previous studies of micro pricing behaviour, whilst reinforcing some others. Our work is related most directly to those studies that have used either "regular" or "reference" prices at the individual item level and it relates to a constant set of largely processed grocery products. Its most important and distinctive feature is that it covers a seven year period which encompasses the more turbulent years 2008 and 2009, so enabling us to observe responses to a greater range of inflationary and deflationary pressures. Our work also makes significant use of a key institutional feature of supermarket pricing in Great Britain. As with Cavallo's (2012) recent paper, our prices are drawn from websites and not scanner-based, but as we explain below, we know they represent in-store prices accurately because of the uniform pricing policies the key supermarkets adopt.

Our sample challenges the previous conclusion ("fact three" of Klenow and Malin's 2010 survey) that reference price changes around once per year on average, given that we find it changes markedly more frequently. We therefore also challenge the common view (Bunn and Ellis, 2011; Klenow and Malin, 2010) that prices in the US are more flexible than in Europe. The finding of more frequent price changes in 2008 and 2009 than in earlier years is also at variance with most previous discussion regarding the relationship between frequency and inflation (e.g. Klenow and Malin's eighth finding). Furthermore, we find a very high proportion of price decreases in "regular" prices, higher even than in Nakamura and Steinsson (2008). At the same time we reinforce Klenow and Malin's sixth observation that micro price changes are not well linked with average inflation, but amongst other things in our data this is because of the unusually large numbers of small price falls.

In examining prices at the micro level, there are several definitions of price that we could adopt based on the existing literature. We choose not to favour one over another, but instead to test our findings using a range of existing definitions. We use four definitions in total and select the particular version of price definition to highlight depending on the question being examined.

Section 2 of the paper discusses these definitions and explains our approach to them. We then move on in section 3 to a description of the data at our disposal, including the institutional features that make our approach possible. Section 4 explores the various dimensions of pricing- frequency, magnitude, timing and direction. These sections are essentially empirical.

However, our findings lead us, in section 5, into a reconsideration of the meaning of flexible pricing, something that has far wider implications than for any particular sample. We suggest in the concluding section 6 that a reconsideration of the question of what is implied by (and how much can be learned from) micro price flexibility is required. There are two short appendices largely containing details on definitional issues or further information.

## 2. Definitions of prices

We make use of four basic definitions of prices. First, we have *posted prices*, those that a consumer wishing to purchase one unit of the product in store would face.[2] These show the most frequent movements in our sample. The other definitions of prices aim in different ways to capture underlying movements in prices whilst stripping out irrelevancies such as temporary sales.

Nakamura and Steinsson (2008) focus on what they call *regular prices*. As Nakamura (2010) graphically points out, certain products are subject to a form of seesaw price movement where there are frequent offers but based upon a largely unchanging regular price. Their algorithms correct for this "V" or "U" shaped price phenomenon,[3] by removing from posted prices short-term reductions that are later reinstated, in part or fully. Here we use the "B" version of their algorithm that corrects only for price cuts where price returns to its previous level, using precisely the definition for weekly data used in Nakamura (2010), so counting a price as regular if the price falls below that level for six weeks or less before returning to that level.[4] These prices we call *NSB regular* prices.

A little confusingly, Kehoe and Midrigan (2008) and Midrigan (2010) also use the term *regular price* but adopt a somewhat different algorithm. The most obvious difference is that Nakamura and Steinsson remove short-lived price cuts from the data, whereas Kehoe and Midrigan remove short-lived price rises in addition. The resultant algorithm creates a modified version of a "running mode" (Kehoe and Midrigan, 2010). We adopt a quarterly running mode and call such prices *KM13 regular*, to make the distinction from Nakamura and Steinsson clear.[5] This series is in some senses intermediate between NSB regular prices and the fourth definition, due to Eichenbaum et al (2011).

Finally then, we have *reference prices*, as defined by Eichenbaum et al. (2011). These aim to strip out short term phenomena by replacing the posted price in any week with the most common price in

[2] This represents the price on the shelf and at the till, assuming single item purchase, no coupons, etc. Our data are *not* scanner data, so it is not average selling price. Thus it is nearer to a regular price than scanner data yielding average selling price would be.
[3] Clearly, there are some complications, for example if the price "returns" to a different level, which they deal with through variant "A". There are also choices to make regarding the length of the time interval.
[4] We did attempt some experiments with the "A" version, but found sufficient ambiguities in working with our data that we do not adopt it here, choosing instead to use the Kehoe Midriban algorithm. The essential difficulty lies in unambiguously detecting a unique new regular price that is different from the current regular price when prices move in a variety of ways.
[5] More detail on our construction of this is given in the Appendix.

the quarter in which it lies, i.e. the quarterly mode.[6] We develop three slight variants, as explained in section 4 below. It follows that posted prices will be most volatile and, save in unusual circumstances, reference prices least so, also that NSB regular prices have a higher mean value than posted prices.

For some investigations, one of our four definitions will be most appropriate, but where more than one of them is potentially relevant we focus on results for one case and mention key differences with others.

## 3. Our raw data sample, institutional features and macroeconomic backdrop

We have collected and have available, week-by-week, the store prices for individual units of 370 precisely defined products over seven years from late 2003 to late 2010 for the three largest players in the British supermarket industry. A number of features of this industry make the prices set extremely useful for examinations such as this. A fuller description of the underlying data is available in Chakraborty et al. (2011).

First, there is the sector's importance and concentration. Verdict Research (2008), a market research organization, estimates that in 2007, food and grocery retailing accounted for around 42% of total UK retail spending. All three of our firms, Tesco, Asda and Sainsbury, have been growing market share gradually over our sample period and now together make the majority of grocery sales in the UK, according to Verdict research.[7] These three are major retailing companies. Tesco, the leading chain, is UK based but has presence in several other countries and is by some measures the world's number three retailer. Asda is the UK subsidiary of Walmart. Another key feature is that all three firms have, since at least the start of our period, set prices nationally across all their larger stores Competition Commission (2008). It is important to understand that this means wherever I happen to shop within Britain, in the north of Scotland, the south of England or the west of Wales, I face the same price in a Tesco (Asda/ Sainsbury) as if I had shopped in the same fascia of large store in the east of England, for example. Indeed, and crucially, it is the same price that I see on the internet, available through a home delivery service.[8] Asda operates almost exclusively larger stores, whilst the other two fascias also operate smaller stores that do not adhere precisely to this national price policy and are therefore not necessarily covered by our series. But the large stores are the place where most people would do their weekly or fortnightly major shopping expedition.[9]

Our sample starts when Tesco, the largest chain, started its "Tesco Pricecheck" website in late 2003. This was an independently collected large scale weekly comparison of precisely defined products across these three store chains plus first Safeway, then later Morrisons (which took over most Safeway stores). We supplement this with data, from 2008 to late 2010, downloaded from a website called mysupermarket.co.uk (who collected across Tesco, Asda and Sainsbury's) to create the seven

[6] As is well known, the mode of a distribution need not be (uniquely) defined. This appears not to be a significant issue for Eichenbaum et al, although we observe occasions in our data where this arises in calculating KM regular prices. The issue is discussed in our Appendix.

[7] Thus Tesco, with a 30% share, accounts for more than 1/8th of total UK consumer expenditure!

[8] This makes the practice in Britain different from that in some of the countries Cavallo (2012) observes.

[9] The weekly shop is most common, so is an appropriate frequency at which to observe prices. British consumers also "top up" at other stores (Competition Commission, 2008).

year sample. Like the "Pricecheck" sample, this reflects in-store prices. Given the overlap in time between the two samples, we are able to check for ourselves the high degree of concordance in the prices generated by the two approaches. Thus we have consistent data for Tesco, Asda and Sainsbury's over seven years.

Our 370 precisely defined products are those for which we are able to form a good quality weekly price series over the full seven year period.[10] Most are branded products (for example, Nescafe Gold Blend Coffee 200g), others are store brand products (e.g. Own label fresh single cream, 568ml) which are essentially identical across the chains. Given the approach we have adopted, our sample is heavily weighted towards packaged goods, not fresh items, [11] and it is of course biased towards products that remain unchanged over the entire period and are consistently stocked by all three firms. No product substitutions were allowed. Within this framework, it covers food and drink, low value items and those of high value. Some basic descriptive statistics are provided in Table 1. These data are the prices we work with in examining the various questions that have been posed regarding price flexibility.

**Table 1: Basic descriptive statistics of our data sample- 366 weeks and 370 products**

| **£** | **min price** | **median** | **mean price** | **max price** |
|---|---|---|---|---|
| **First period** | 0.15 | 0.99 | 1.85 | 25.99 |
| **Final period** | 0.17 | 1.24 | 2.23 | 29.99 |

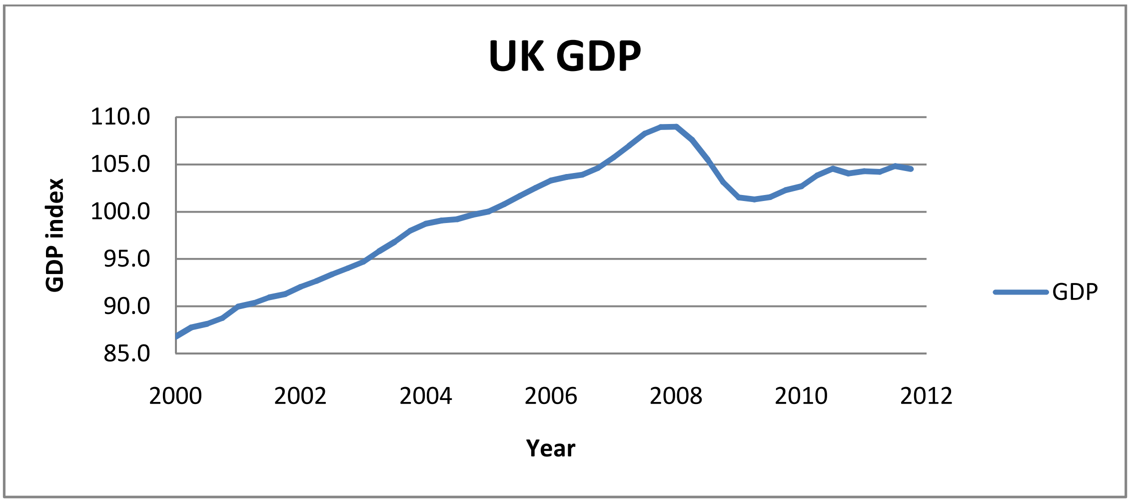
The sample most similar to ours is probably that in Bunn (2009), in that his sample also relates to UK supermarket data and is of similar product dimensions. However, there are several clear points of difference. First, his data cover a three year period, not including the years that turn out to be the most important macroeconomically, 2008 and 2009. Second, he has scanner data, relating to average selling prices, whereas we have actual item prices for products normally on sale (i.e. our sample does not incorporate temporary discounts for multi-buy, price after coupon redemption, price for damaged or date-end items). His sample covers also fresh products such as raw vegetables and meat that do not feature in our data. For our purposes, these differences are positives.

Before starting our investigation proper, we first reprise the macroeconomic backdrop which includes the development of is becoming known as the "great depression". Two key features are charted in figure 1. The upper panel shows the series for UK GDP (centred on 2005). Observe that after a long steady slow rise from the millennium there was a significant fall in 2008 almost back to the 2005 level followed by a partial recovery in 2009 and 2010 (faltering in 2011). The lower panel

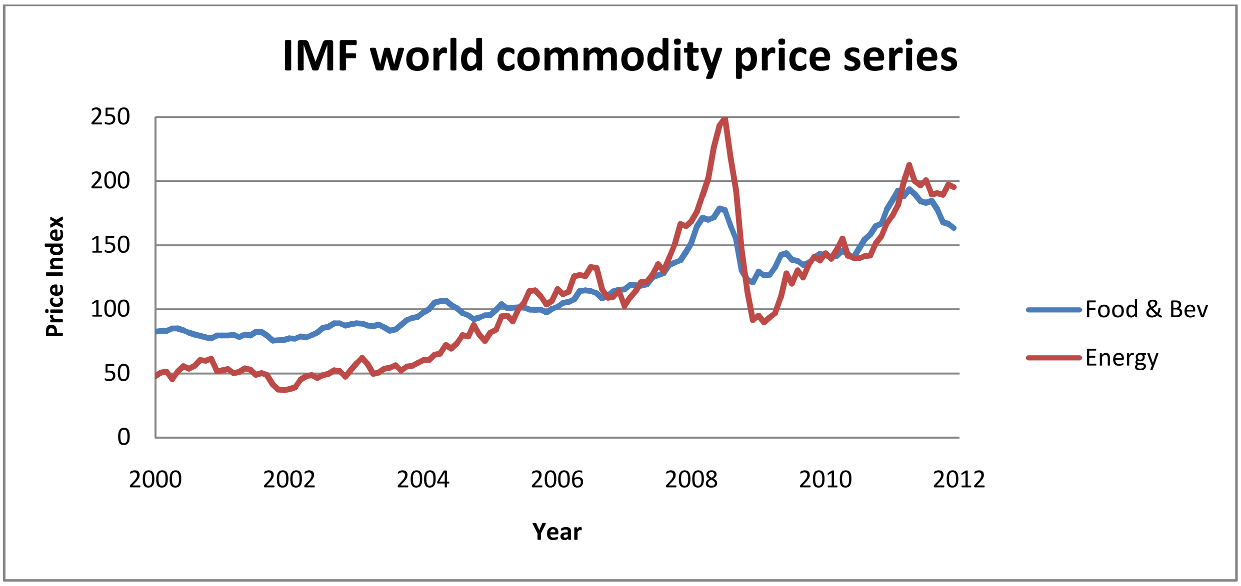
[10] The sample is clearly not random. However, appropriately weighted, it tracks the official CPI well (see Chakraborty et al, 2011 and section 5 below). As with all such studies (Nakamura, 2010), there are occasional gaps in the series, the most important of which are prices over the Christmas period in the early years. We resolve these by filling in with the minimum changes in price possible (so that for example, if price is the same before and after a 2 week gap then we fill in with the same price). In any case, as is apparent from the definition of regular and reference prices, small gaps would be filled in on all KM13 regular and on reference prices anyway, as well as most NSB regular prices.

[11] Fresh items were essentially absent from the earlier periods of the Tesco Pricecheck sample.

shows IMF indices for food and beverage and for energy commodity prices, i.e. the world market prices for key inputs into groceries such as wheat, rice, meat, orange juice, fuel and production energy inputs, etc. These, particularly energy prices which inevitably permeate the production and retailing costs of all grocery products, fluctuate somewhat but also experience a substantial upward trend from 2000 which accelerates rapidly in the early part of 2008 followed by a very sharp fall later in 2008 and a partial recovery in 2009. It is clear that 2008 and 2009 are very turbulent years and that our sample includes both a sharp upturn and a sharp downturn in activity and input costs. These are very useful features when examining pricing reactions at the micro level. Of course, most processed goods are rather complex combinations of ingredients and it would be difficult to sort out precise cost drivers for individual products, but these world cost trends are factors even the largest grocery retailers cannot avoid.




Source: ONS




Source: IMF

Figure 1: Key macroeconomic factors underlying our framework

## 4. Exploring price flexibility in its various dimensions

As Klenow and Malin (2010) note, there are several dimensions to price flexibility. Most obvious and most studied is the frequency with which prices change. We characterise this in various ways using the range of price definitions we have discussed. We then turn to upward and downward magnitude of price changes, to the cross-product timing of price changes, then finally to features of the distribution of price changes. In the subsequent sections we draw out some implications.

**Frequency of price changes**

Because casual inspection reveals a lot of price movement in our data, our natural first focus here is on reference prices, since in principle these are the least likely to be flexible. Nevertheless we find them very flexible in practice. Based upon Eichenbaum et al.'s (2011) definition of a reference price as the modal price in a quarter, we can examine the behaviour of these in our sample across the 366 weeks of data at our disposal. We develop three slight variants using the basic definition: we use (i) our last 364 observations to examine 28 quarters (this is closest to Eichenbaum et al's 2009 approach as described), (ii) data based on "calendar quarters" commencing January 2004 and ending in the third quarter of 2010 (27 quarters), (iii) data based on constructing reference prices after creating NSB regular prices (27 quarters). The results vary only very slightly as between these variants.

Overall, reference prices in our sample change far more frequently than annually, a point of considerable distinction relative to previous findings. In fact, using our first definition, we find that 90.0% of our 370 products across the three firms change reference price more than seven times in our period. The mean number of reference price changes is 12.3 over seven years, with Sainsbury's products at 11.2 times and the other two just slightly less than 13. Since the maximum number of price changes on this methodology is 27, the average product reference price changes approximately every six months. This is far more frequent than Eichenbaum et al (2011) find to be the case.

One plausible reason why we find more reference price changes than have been observed by other scholars is that our sample includes years that are more turbulent than most periods studied in previous work, with a notable exception being the findings of Gagnon (2009). Unsurprisingly, it is 2008 and 2009 where reference prices change most often. In fact, across our sample in both these years, reference price changes on around 63.2% of the possible occasions across quarters.[12]

Figure 2 contrasts the number of reference price changes in 2005, a year of modest global price movements, with the numbers for 2008 and 2009, where these movements were much starker. The median number (one) of price changes across the four quarters for our products in 2005 contrasts sharply with the median of three in 2008 and 2009 and the differences in distributions are obvious without need for statistical test. This is consistent with the frequency of price changes being a

[12] The approach in this and the following paragraph involves definition (ii) above, since it relates to calendar quarters. The quarter to quarter change is measured (using 2005 as an example, as [(Q1of 2005 –Q4 of 2004), (Q2 of 2005 –Q1 of 2005), (Q3 of 2005 –Q2 of 2005), (Q4 of 2005 –Q3 of 2005)]. Hence 2004 and 2010 observations relate only to three quarters each. It is possible that 2010 might also have seen a very high number of changes if it had consisted of four quarters. We also note parenthetically that with definition (ii), it happens that for three goods for one firm, the modal price (i.e. Reference price) was undefined in one quarter, because the posted price changed literally every week within that quarter!

function of inflation rates, or inflation rate changes. Therefore the previous US and Euro area findings of frequency being little affected by inflation may well be a finding special to the stable periods over which many such studies have been conducted, as Klenow and Malin (2010) suggest. Our results add to Gagnon's (2009) in suggesting that in more inflationary periods, the frequency of price changes does increase, hence contradicting what has been viewed as a key empirical regularity regarding frequency. The straightforward implication is that prices are not particularly sticky where underlying cost pressures are greater.

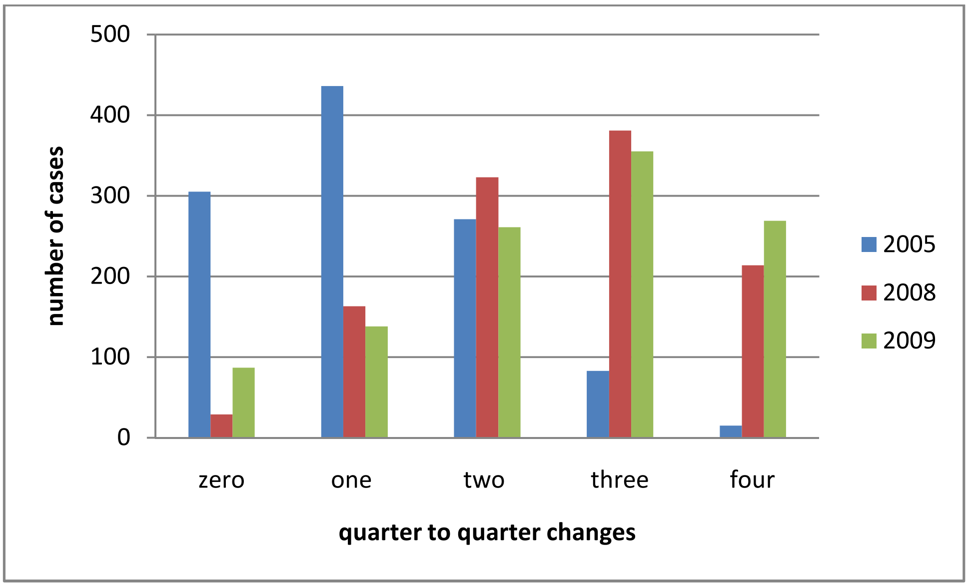



Figure 2: Number of quarterly price changes in reference prices per year across 370 products and three firms

It is useful to add to this the evidence we obtain above by examining regular prices. We first examine NSB regular prices (Nakamura and Steinsson 2008). Individual NSB regular prices across our 370 products are, broadly speaking, far from sticky. If we examine median duration of NSB regular prices, as in figure 3, we see that for around 10% of Tesco and Asda products, median price duration is only two (three) weeks! Beyond that, median durations increase and some products, particularly milk, stay more or less fixed over the whole period. But still, for around half the products in our sample, median duration is six weeks or less in Tesco and Asda. Hence it is not particularly the case that rapid price movements are confined to a small subset of products, or just to posted prices. Prices in Sainsbury's are markedly less flexible, with half the products having median duration longer than 10 weeks on this definition, probably reflecting the fact that they have engaged less directly in the price promotion strategies of their rivals.[13] These strategies commonly consisted of assertions regarding the number of product prices that had been reduced or the number of products cheaper in one chain rather than in a rival chain.[14]

[13] This also comes out in the sample overall median, which is 4-5 weeks for Tesco and Asda, twice that for Sainsbury's.

[14] Consider the following snippet from Wikipedia, commenting on supermarket price competition: " ... out of 7134 (compared to Asda) products, (Survey carried out between 9 July 2007 and 11 July 2007) Tesco is

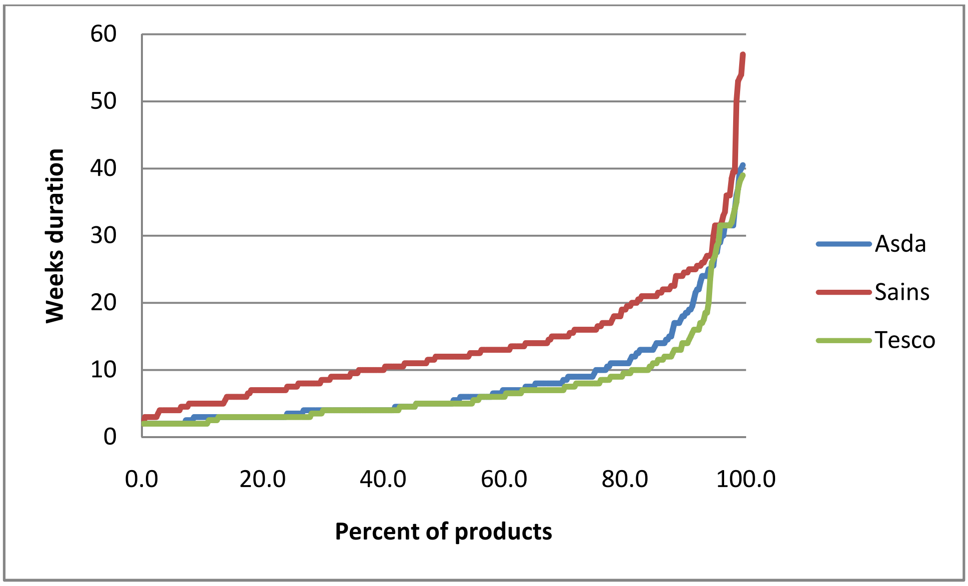



Figure 3: Distribution of median duration of NSB regular prices across our sample of products

For completeness, we carry out the same calculations for KM13 (smoothed) regular prices. The overall pattern across chains is similar, with Asda and Tesco having a very similar distribution of product durations, and Sainsbury somewhat above this. However, because this definition smoothes to a greater extent it excludes more movement than NSB regular prices, so the distribution is markedly above that for NSB regular prices. Figure 4 below shows half the distribution changes prices more frequently than every 16 weeks (i.e. more than three times a year) in Asda and Tesco, and every 19 weeks in Sainsbury. Nevertheless, these values still imply prices, under the KM13 regular definition, that are on average quite flexible, significantly more so that has been found by Kehoe and Midrigan (2010) in their sample.

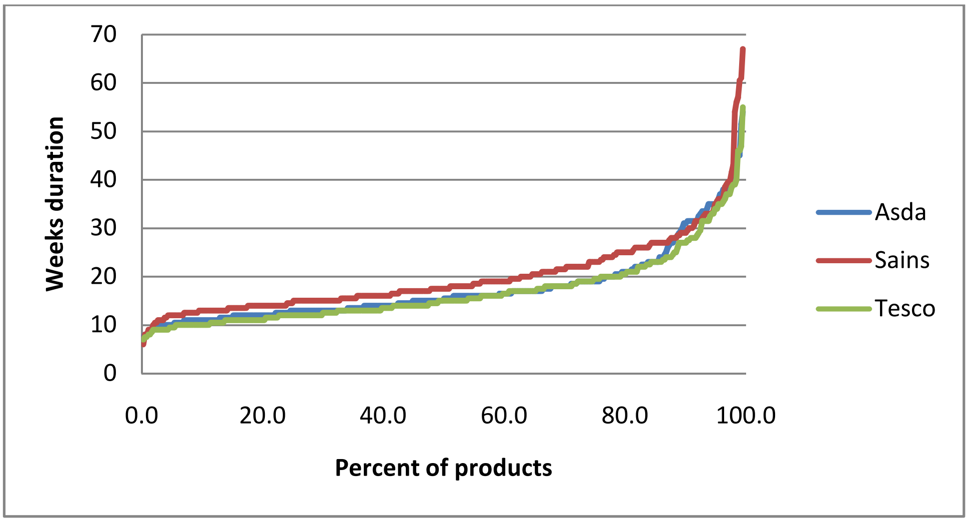



Figure 4: Distribution of median duration of KM13 regular prices across our sample of products

cheaper: 1835 (compared to 1251 the previous week), Tesco is more expensive: 975 (compared to 984 the previous week) and Tesco is the same price: 4324 (compared to 4996 the previous week)."

In sum, prices in our sample change more frequently than previously observed, whatever the definition, even considering substantially smoothed prices.

**Magnitude of price changes**

It has been widely observed that the magnitudes of micro price changes generally exceed the change in aggregate inflation (Klenow and Malin's, 2010, "sixth fact"). We confirm this, although here our data reveal several unexpected surprises. In this section the obvious "price" to use is posted price, in order to capture the full range of micro price changes.

In line with previous studies, the average size of individual product price changes, both upwards and downwards, is large compared to inflation. In terms of posted prices, the average rise (for goods where a change occurs) is over 20% of the item price, whereas price falls average 9.4% of item price. At the same time, by no means all products experience price changes- around 41% of products experience no price falls in any given year, whilst even in the most inflationary years, there are some products that experience no price rise.

The magnitudes of posted price changes are relatively constant across our three supermarkets, as can be seen from table 2 below. We observe that in the more volatile years, particularly 2008 and 2009, the size of posted price rises increases quite significantly in all chains over the changes in the earlier years. However, the average magnitude of price falls is remarkably constant across chains and years.

Table 2: Average percentage posted price change across our products by year and chain

| **Rises** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
|---|---|---|---|---|---|---|---|
| **Asda** | 13.0 | 14.3 | 18.0 | 21.3 | 23.9 | 24.4 | 21.3 |
| **Sains** | 17.6 | 13.8 | 16.8 | 21.3 | 23.8 | 20.1 | 20.5 |
| **Tesco** | 14.0 | 17.3 | 16.2 | 19.7 | 22.3 | 22.4 | 21.7 |
| **Average** | 14.6 | 15.2 | 17.0 | 20.8 | 23.3 | 22.3 | 21.1 |
| **Falls** | | | | | | | |
| **Asda** | -8.2 | -8.2 | -8.2 | -8.0 | -8.3 | -8.3 | -8.2 |
| **Sains** | -8.7 | -8.7 | -8.7 | -8.8 | -8.8 | -8.9 | -8.9 |
| **Tesco** | -9.7 | -9.7 | -9.6 | -9.6 | -9.7 | -9.7 | -9.7 |
| **Average** | -8.8 | -8.8 | -8.8 | -8.8 | -8.9 | -8.9 | -8.9 |

Note: these mean values ignore cases where no change has occurred in that year, so that a percentage cannot be calculated.

Of course, we should also remember that many of our products are relatively low value consumer products. In fact, for 45% of our products the lowest possible change, 1p, would constitute over 1% price change (i.e. the product is priced at less than one pound), whilst for 17% of our products it would constitute over 2% and, for a handful of cases, over 5%. Thus it is inevitable that when inflation is modest, some percentage price changes will be in excess of inflationary changes.

In order to counter the criticism that posted prices give a false picture of the magnitude of price changes, we repeated this analysis for our NSB regular prices. The results are given below in table 3. The magnitudes for price rises are somewhat less dramatic than those in table 2. However, they still comfortably exceed the rate of inflation. Price falls are slightly increased in average magnitude by this exercise because some small falls are removed in the process of generating NSB prices.

Table 3: Average percentage NSB regular price change across chain and year

| **Percentage magnitude** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Rises** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| **Asda** | 11.0 | 11.7 | 11.5 | 14.1 | 17.2 | 16.0 | 16.2 |
| **Sains** | 9.7 | 9.2 | 9.9 | 11.8 | 13.5 | 9.3 | 9.5 |
| **Tesco** | 10.9 | 10.5 | 10.6 | 12.1 | 16.4 | 14.1 | 13.6 |
| **Falls** | | | | | | | |
| **Asda** | -10.3 | -12.6 | -11.4 | -10.3 | -9.1 | -8.6 | -8.8 |
| **Sains** | -9.2 | -12.8 | -10.3 | -7.9 | -9.6 | -7.4 | -7.4 |
| **Tesco** | -8.9 | -9.3 | -9.2 | -8.2 | -7.9 | -7.4 | -7.3 |

**Timing of price changes**

In the analysis of prices at the micro level, another dimension that has attracted the interest of macroeconomists is the timing of these changes. The issue is analogous for example to that in examining wage setting to see whether it takes place at particular times of year. Other researchers have observed that this bunching phenomenon is not true of micro price changes (Klenow and Malin, 2010) and our findings match this, though with some novel features.

Table 4: Number of weeks in which there are NSB regular price changes in the ranges shown

| | **None** | **1 to 9** | **10 to 19** | **20 to 29** | **30 to 39** | **40 to 49** | **50 to 99** | **100 or more** |
|---|---|---|---|---|---|---|---|---|
| Rises | **6** | **48** | **93** | **78** | **51** | **33** | **52** | **4** |
| Falls | **2** | **27** | **98** | **46** | **38** | **25** | **63** | **64** |

Table 4 examines the distribution of NSB regular price changes across the weeks of our sample. It shows a rather marked divergence between price rises and price falls. Price rises are spread widely across weeks, with most weeks seeing up to around 10% of prices rising. Price falls are bunched somewhat more towards the upper end of the distribution compared with rises. There are literally only two weeks in the 365 in which there has not been at least one NSB regular price fall by one chain compared with the previous week. Most weeks see a flurry of price falls, with over 10% of weeks seeing one hundred or more falls across the chains over the week, peaking at almost 1/3 of prices falling in one particular week, a remarkable downward degree of fluidity in prices, given that these are NSB regular not posted prices.

Even when we move to the substantially smoother KM13 regular prices, there are still two weeks with over 100 price falls overall, and there is still a slight bunching towards the right end of the distribution when compared with price rises, as Appendix table A1 illustrates. But the overall message is that price movements are well dispersed throughout our period.

**Distribution of price changes**

Drawing the previous two findings together, price rises are relatively large in magnitude, both compared with inflation and with price falls, whilst there are many weeks with a large number of price falls. This leads to questions on the nature, in particular, of the many price falls observed and concerning the overall net impact of rises and falls.

Here we come to the most remarkable finding. In our sample, the distribution of the sizes of price changes, particularly price falls, is unusually asymmetric, even more so than has been observed by Klenow and Kryvtsov (2008) and Midrigan (2010), for example. Table 5 illustrates by showing of the percentage of all posted price falls observed that are penny price cuts. We see that around 1/3 of all Tesco and Asda price cuts in 2009 are penny cuts, as are around a quarter in 2008.[15] Indeed, penny price cuts constitute one sixth of all price movements whether up or down in 2008 and a remarkable 23% of all price movements in 2009.[16] In addition to penny price cuts, there is also a large, though lesser, number of price cuts of 2p in the data, as table A2 in the Appendix shows.

Table 5: Proportion of price falls that are 1p

| | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
|---|---|---|---|---|---|---|---|
| **Asda** | 0.16 | 0.19 | 0.22 | 0.12 | 0.24 | 0.36 | 0.17 |
| **Sains** | 0.11 | 0.12 | 0.27 | 0.17 | 0.19 | 0.27 | 0.16 |
| **Tesco** | 0.18 | 0.22 | 0.25 | 0.14 | 0.27 | 0.32 | 0.20 |
| **Total** | 0.15 | 0.19 | 0.25 | 0.14 | 0.24 | 0.33 | 0.18 |

Here we used posted prices, since these reveal the magnitude of individual price changes most clearly, and in particular highlight small price changes. Hence it is crucial to address the recent Eichenbaum et al. (2012) criticism regarding small price changes, specifically whether our data source is subject to criticisms they have regarding identifying such price changes in data they and others commonly use. It is not. They refer to two source types, of which only one is potentially relevant to their critique, scanner data. As they point out, scanner data has the limitation that "price" is often based upon unit value indexes and so incorporates a potentially large number of

[15] This definition of "small" price cuts is not in line with previous work such as Klenow and Kryvtsov (2008) which uses percentages, but given the small unit price of many of our products, it seems sensible to take the smallest possible unit amount of change as an indicator, rather than a small percentage.

[16] This welter of small value price cuts is the focus of our companion paper, Chakraborty et al. (2011)

promotional factors (coupons etc.).[17] Our data approximate most closely to the supplementary data set they have for 374 stores across four US states in 2004. These appear from their methodology to be the set of prices from which they would be most confident in drawing conclusions on small price changes. For completeness, we also note that there are no local sales taxes in the UK and that in fact, the majority of the goods in our sample do not attract sales taxes of any sort;[18] for the minority that do, the tax change is once per year. Tax differences are not giving rise to price effects in our data.

A further significant finding is that, throughout our period, posted price falls numerically dominate price rises both for Tesco and Asda, and also on average for Sainsbury. Figure 5 shows this position graphically, illustrating that in 2008 and 2009, there was a particularly dramatic excess, with up to around 2.5 times as many price falls as price rises. This is remarkable since it includes a period (2008 in particular) where inflation was rapid.

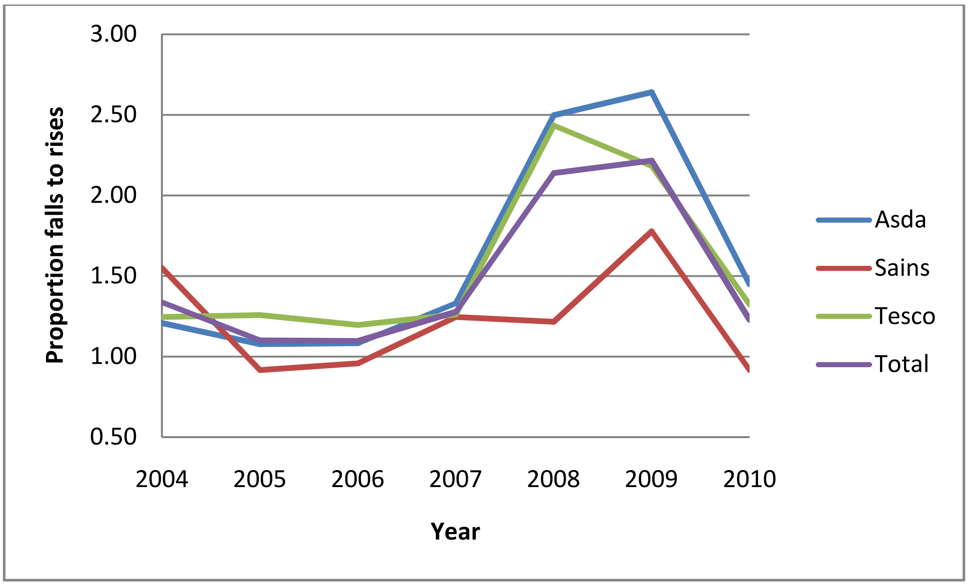



Figure 5: The ratio of posted price falls to price rises across our sample and time

Figure 6 repeats this exercise for NSB regular prices, importantly so excluding temporary sales. The pattern is different in detail from that for posted prices, but we still see the remarkable effect that there are, throughout our period, more NSB regular prices falling than rising in both Asda and Tesco, and most of the time for Sainsbury. It has previously been observed that around 40% of price movements are price falls (Bunn and Ellis, 2011) in a period of general mild inflation. We appear to have uncovered a degree of price lowering of a different order of magnitude to that previous studies have found, with well over twice as many price falls as rises in certain periods. In fact, the overall numbers are instructive, in that they highlight the overwhelming dominance of falls. We observe 24,891 posted price falls and only 15,262 rises across these years. In terms of NSB regular prices, there are 19,571 falls and 10,358 rises.[19]

[17] By the same token, our data are poor at catching promotions.
[18] Ambient and frozen food is zero rated for VAT in the UK, as are soft drinks.
[19] It might be queried why the differences between rise and fall numbers are not exactly the same. The answer is that sometimes, the V shapes excluded in the NSB algorithm incorporate two different lower prices.

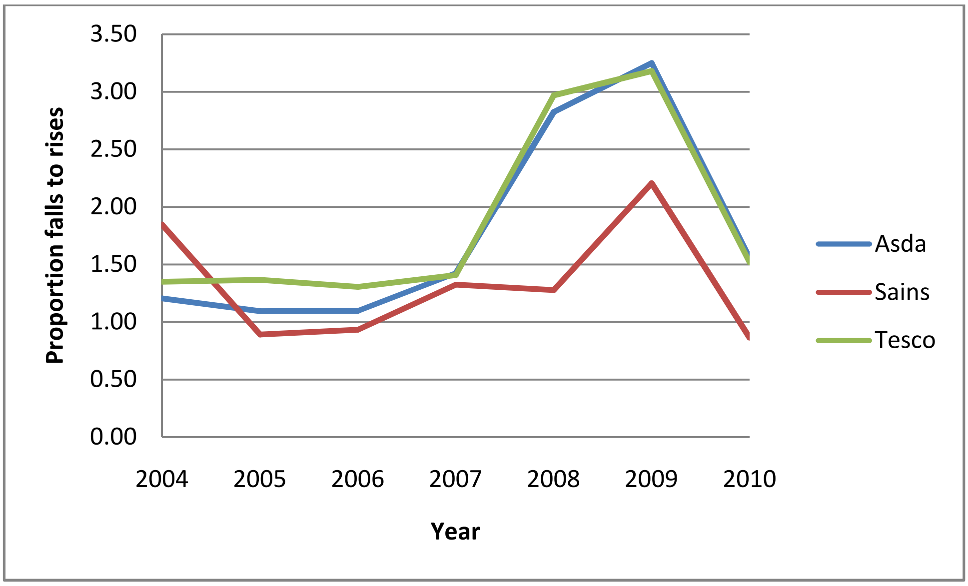



Figure 6: The ratio of NSB regular price falls to price rises across our sample and time

The obvious question is why it happened that so many price falls took place in the period and across the retailers covered by our data, in a period when, on balance, costs and prices overall were rising. We reiterate here that these are the major firms in their market, not some niche players. However, they are also in a situation of close rivalry. Over parts of the period we are examining, this rivalry took the form of claiming that in a particular chain (be it Tesco or Asda), more than x hundred prices fell over a particular week, or more than y hundred prices were cheaper at one rather than the other. To achieve this, small value price cuts clearly became a core method of competition.[20]

## 5. Implications of our findings

Our findings have a number of implications. The first relates to the consumer experience. The overall impression coming from our analysis is of prices that are very flexible in every dimension: frequency, magnitude and timing. This is true not only of posted prices but also for NSB regular prices and, in the relevant areas, KM13 regular prices and reference prices. Since these are supermarket prices, consumers will not, on the whole, be purchasing single items but will instead be buying a basket of products. It follows from our results on timing taken together with those on frequency that each week a consumer seeking to buy the same basket of products will find the overall bill changed. Thus to the extent to which it is relevant to consider the basket price, rather than the prices of individual items, this is not sticky at all.

The large number of price cuts observed does not mean that consumer basket prices are falling! Indeed, on any sensible definition of a basket, they are rising. [21] Clearly there is a composition effect at work within the magnitudes of price changes. There are many more prices falling than rising, but the falls are much smaller in percentage terms than the rises. Whilst there may be an illusion that

[20] See footnote 12 above.
[21] This can also be seen crudely to be the case from table 1 above, as well as the slightly more sophisticated analysis below.

prices generally are falling, in fact average prices and consumer basket purchases can and do rise. This is demonstrated in two related exercises we carry out below.

In the first exercise, illustrated in figure 7 below, we show weighted basket prices calculated from our data sample of 370 products, using weights equivalent to those used in the CPI. In other words, taking the NSB regular prices of our products, we allocate the products to the relevant component category of the UK CPI and construct the subcategory index using geometric means, then generate the arithmetic mean index across product categories, in such a manner as to imitate the construction of the official CPI for the UK. It is clear from the figure that the general trend of prices is upwards over our period, though not monotonically so, and that the CPI basket ends the sample period substantially more expensive than it starts, in each supermarket. As we would expect given commodity price movements, the most rapid rise in our constructed version of the CPI for these chains is in 2008. We also see that, in common with other evidence, Sainsbury's takes a somewhat different path from Asda or Tesco, with somewhat higher pricing and a slightly looser relationship to the other two.

The second exercise compares this series of prices directly with two relevant CPI indices that we call CPI1, which is the index for the food, drink and tobacco group of products, and CPI2, a narrower index covering processed food and non-alcoholic drink only. As can be seen in table 6, the overall movements in the official CPI indices are mirrored very closely by the movements in our constructed indices for each of the chains. Thus, although more individual prices fall than rise, because the price rises are larger in magnitude than the price falls, the typical basket price rises, and that roughly in line with general inflationary trends in the industry.

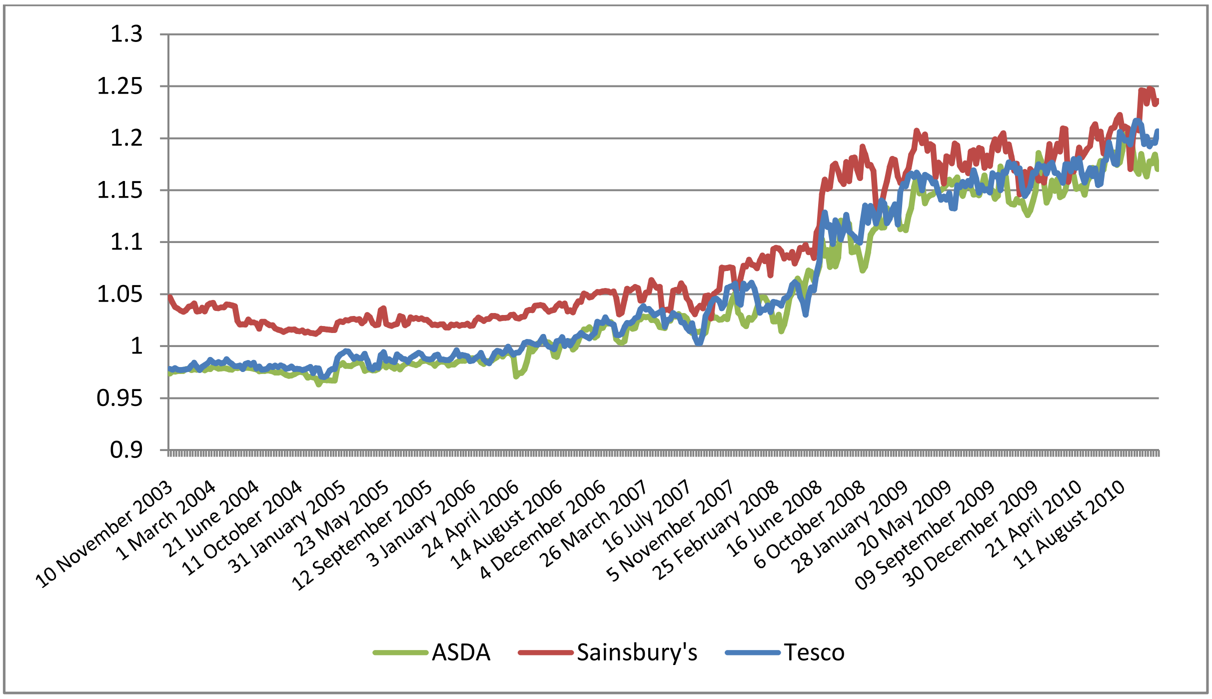



Figure 7: Price indices calculated using CPI weights from our sample of NSB regular prices

Table 6: Showing correlations between two common official CPI indices and constructed NSB regular price indices for our three chains

| **Correlations** | | **CPI2** | **Asda** | **Sains** | **Tesco** |
|---|---|---|---|---|---|
| **2003-2010** | CPI1 | 0.998 | 0.986 | 0.977 | 0.987 |
| | CPI2 | | 0.984 | 0.974 | 0.985 |

This analysis which has drawn together the various dimensions of price movements has a further very potent implication. We have shown that prices in our sample, by whatever criterion, are very flexible. But much of the flexibility appears spurious, in that it has the apparent aim of suggesting that supermarket prices are falling (which they are, in terms of raw price numbers) when the shopper is in fact most likely to pay more for a basket of goods. The staggering number of price falls we observe at various points strongly suggests this. [22]

Moreover, examination of individual price movements also strongly suggests that many of these movements do not relate to underlying movements in input costs. There are a number of reasons we say this. One is that there are clearly documented sequences where the price of an individual non-perishable product changes every week, going up one week, then falling by a penny a week over the next few weeks, before rising again. Another reason is because, to take an example, a price fall of one penny on a bottle of whisky priced at over ten pounds is not at all likely to have as its origin a fall in costs! This is not an isolated example in our data. The exemplar products posted price graphs in figures A1 and A2 in the Appendix strongly suggest prices are not closely tracking costs. In fact, it would probably be reasonable to discount all but a very small fraction of the price falls we observe which relate to one, two or another small number of pence, as being a result of cost influences.

Given that prices in these major firms are so flexible, there is a question concerning what it implies for the magnitude of menu costs. The implicit model underlying the flexibility or rigidity of prices commonly seems to be a menu costs story along the following lines (see Mankiw, 1985). Suppose an input cost rises. Does the firm raise its price? If the menu cost is too high, it decides against doing so until the underlying input cost pressure is significant enough that it outweighs the menu cost. A similar story can be constructed, for example, in relation to a negative demand shift; the price will only be shifted downward if the shift is substantial enough to outweigh the cost of changing prices.

This model ignores competition between firms and also ignores marketing pressures, as well as assuming that only this item is purchased. Supermarkets are amongst the set of retail outlets (other examples include DIY stores and restaurants) where the consumer normally shops for a basket of items. If my rival as a firm cuts the price of a particular item- be it sliced white bread or whole chickens or whisky, then they may capture some of my consumers. To prevent this, I may change some prices even if that would not have been worthwhile in the absence of the competitive action. I am selling a basket and consumer demand for any one item will be finite.[23] Ultimately, as a

[22] See our companion paper, Chakraborty et al (2011) for more on this point.

[23] In the late 1990s, there was a supermarket "price war" in Britain on baked beans (Manez, 1999), in which the price of a can of beans fell to such a level that, reportedly, revenue did not even cover the cost of the can, let alone the contents. Nevertheless, even the British public's desire for baked beans is finite, so whilst some people no doubt stocked up to some extent, with limited storage space at home the potential damage to profits was limited.

multiproduct retailer, my earnings come through revenue from the baskets sold. It will not be optimal in any case to charge a uniform markup across my product lines (Bliss, 1988). Hence with careful selection I can provide tempting special offers whilst at the same time making money on the other things consumers purchase at my store.[24]

To put things another way, when scholars calculate menu costs, one way of doing this has been to add up various elements of changing shelf labels, computer programs, etc. A good example of this careful work is Levy et al (1997). However, from our perspective, this approach would only be valid if costs are thought of more broadly. To see this, suppose your close rival reduces price. Suppose further that the cost of you reducing price, had your rival not reduced price, would outweigh the benefit you would receive. But, given that your rival has reduced price, if this would substantially reduce custom for your product, you might nevertheless find it worthwhile to reduce price to cut your losses from their pre-emptive move. The effects of your price change on revenue (to compare against the cost of the price change) depend significantly on whether you are moving along the market demand curve or your demand curve. The firm's focus in price-setting cannot be solely on the cost side.

## 6. Concluding remarks

Why have our data come up with prices that are so much more flexible than previously observed? Several possibilities can be discounted. We work from posted, not scanner, prices so that excess volatility that may be present in the latter is not an issue. The three companies are major food retailers, not idiosyncratic small players- together their sales amount to perhaps ¼ of current consumer expenditure in the UK. We can discount differences in methodology, because where relevant we have used established methodologies that smooth short term fluctuations to calculate our values. We are not working with fresh products where the market price naturally fluctuates.[25]

We are however working with data that includes the significantly more turbulent macroeconomic period prevailing in 2008 and 2009, and there are several differences on that score, as we have seen. We are also working with data on major companies where there is clear price rivalry, possibly intensified by their national presence and the national nature of their pricing structure. So the results are real, albeit that they challenge previous findings significantly.

At the same time, the findings we have documented relating to the staggering flexibility of pricing in British supermarkets imply to us that the debate on whether prices at the micro level are sticky or not now needs to move on. We have shown that, in an important category of consumer expenditure, prices are far from sticky. But this does not by any means imply that they respond to cost shocks quickly and flexibly. They may instead simply be responding to marketing pressures, which might actually drive prices further away from a relationship with costs. Because what

[24] Bliss (1988) sets out the firm's problem more formally, albeit ignoring direct competition between supermarkets. The firm faces fixed costs of staff, heating and lighting, equipment and so on. It needs to cover these costs through mark-ups across goods. Optimally, these mark-ups vary across products, dependent upon demand characteristics (roughly speaking, elasticities). Formally the problem is equivalent to a Ramsey optimisation problem.

[25] Indeed, some of the products in our sample nearest to being "fresh" are amongst those with the fewest price changes, for example milk and cream.

ultimately matters to a supermarket chain is not how much it charges for an individual product, but rather the overall margin it earns on the products it sells. If marketing pressures drive the chain to lower a massive number of prices by a single penny, whilst simultaneously raising a smaller number of prices by a larger amount, the impact on price flexibility as described by macroeconomists is very unclear. Thus our findings do not fit with models of time-dependent pricing and do not fit well with established models of state-dependent pricing either.

## Appendix:

### 1. The relationship between Nakamura-Steinsson (NS) regular prices and Kehoe Midrigan (KM) regular prices and calculation of KM regular prices

As stated in the text, there are two versions of NS regular prices. One (algorithm B) is more straightforward and unambiguous than the other, because it simply replaces any short-lived "sale" price, by the price from which the price falls and to which it returns. Algorithm A seeks also to replace sale prices in cases where the price on return is different from the price before the sale, and has a method for determining whether the price on return is a new regular price. Both are comprehensively described in Nakamura and Steinsson (2010). It is clear from their description that this should only remove prices that are below the regular price: "Sale filter B removes price patterns in which the price returns to the original price within a set number of months without going above the original price. Sales filter A is designed to also remove price patterns in which a sale is followed by a change in the regular price, i.e. asymmetric V's. For example, for the 2 month case, we require that the price return to the original regular price in the first two months after the price decline occurs. If the product remains at a low price or is not available when the price collector returns in the first two months, then the original price decline is not defined as a sale."

The idea of the NS "A" algorithm is to cut out sequences of low prices between higher values that are not themselves identical. However, we found a significant number of sequences in posted prices where there was some ambiguity involved in determining what might be the stable price, if it was not the price before the set of lower prices. The following real sequence of prices over a 13 week period illustrates the point: {3.26, 3.26, 3.26, 3.28, 3.24, 3.24, 3.26, 3.23, 3.23, 3.69}. The difficulty relates to the presence of the 3.28 in the sequence, which would not be eliminated by the algorithm. Is it a sale price or a new regular price?

KM regular prices are defined differently from either of these, although they are nearer to NSA regular prices than NSB regular prices.[26] The key difference, apparent both from the algorithm by which they are calculated and from the graphed examples in the paper, is that their approach also excludes short-lived increases in price. In that sense, they are smoothed to a greater extent than either NSB or NSA prices.

In our approach to KM regular prices, we initially took the window length, minimum appearance of the regular price in the posted price series, etc to be the same as theirs. However, we had some difficulty in generating the prices given that the mode (a key element in their procedure) was not always defined. For example, the thirteen week (again real) sequence {1.49, 1.48, 1.47, 1.88, 1.87, 1.86, 1.85, 1.84, 1.81, 1.78, 1.76, 1.75, 1.74} presents the problem that the mode is simply undefined because no price is repeated! To deal with this we manually replaced missing values for the mode with the most nearly previous regular price (this was required on more than 200 occasions). We also checked by inspection the last stage of the process, which is whether there were artificial changes in the regular price when the posted price did not change. We found that commonly, there was a lag (occasionally a lead) in the regular price. We also noted that, in the closing weeks when the underlying mode is calculated using less data, the calculation

[26] Kehoe and Midrigan (2010 footnote 3) discuss the relationship between the definitions.

produced a slightly volatile series. Having accounted for this, we did not observe aberrant movements in our calculations. However, we also found that there were a number of six week periods that appeared to constitute "sale" pricing. Hence we adopted a thirteen week running mode as the underlying framework, rather than the eleven week mode KM use.

Two example graphs are shown in figures A1 and A2 below, each for a single product from one of the three supermarkets- one is for a product where there are a large number of small price changes, the other for a product where larger price changes are more frequent. In the first, we observe that the KM11 algorithm removes most temporary falls (e.g. weeks 123-125) and temporary rises (weeks 61 and 62) but that some longer-lived price fluctuations are not eliminated, including a six week cut (weeks 43-48 inclusive) and an erratic period starting in week 187 where the posted price rose briefly, fell to a lower price than before for five weeks, then rose to a new higher price. A similar event starts in week 298, some of which is eradicated using our 13 week window that was not eliminated when an 11 week window was used. In the case of the second product, the price moves very often and in many ways, but significant amounts of this movement are eliminated given our definition of KM13 regular prices.

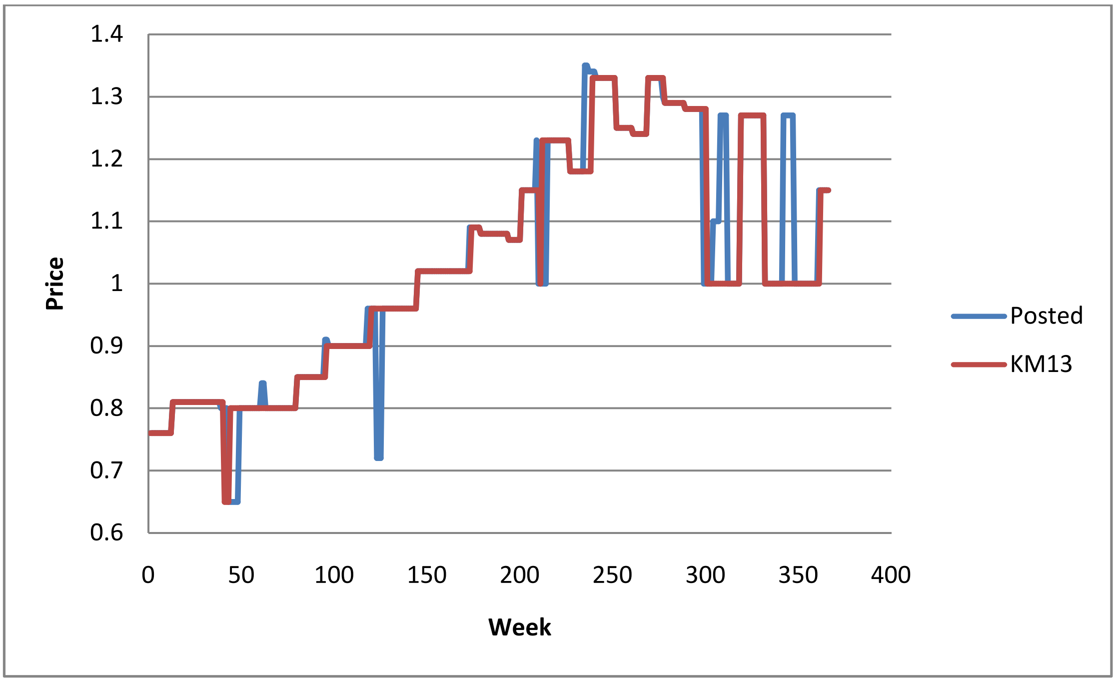



Figure A1: Posted and KM 13 regular prices relating to a bread product

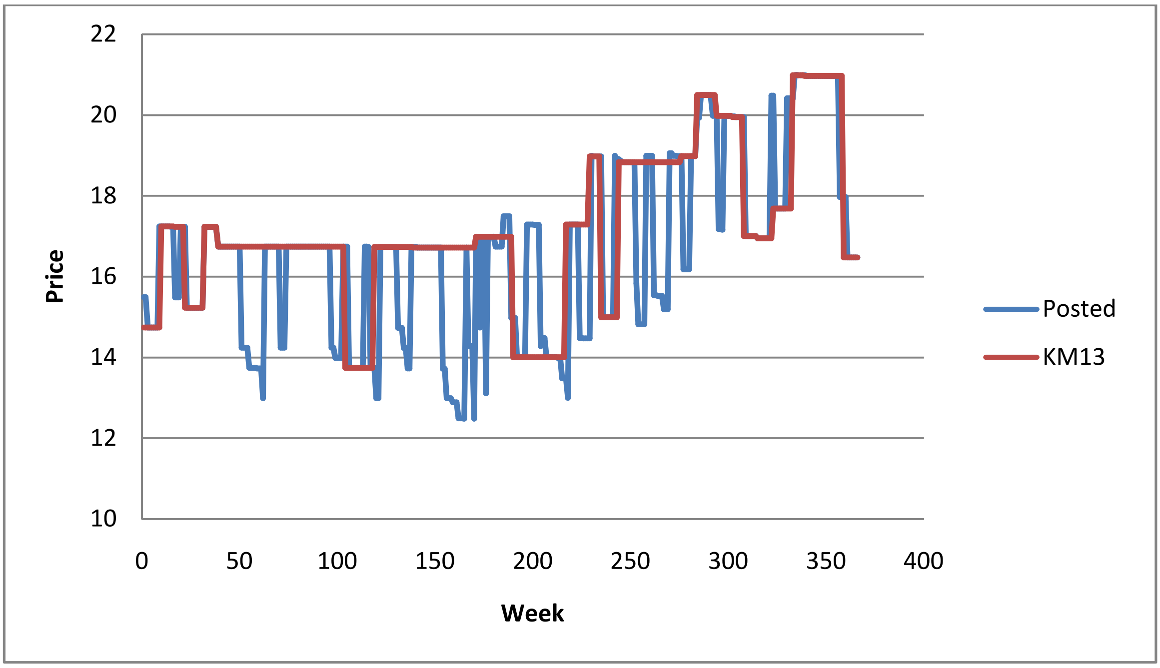



Figure A2: Posted and KM13 regular prices relating to an alcoholic drink

The first product illustrates a further feature. Although the regular price never moves when the posted price does not, there is an example of a “singleton” around period 212 where the regular price moves downward for just one period before moving up (to a different level than before).[27] Although somewhat ad hoc, it seems reasonable also to eliminate such observations when calculating KM regular prices. There were 51 such cases in total across the set of products that we eliminated manually by replacing the value with the previous regular price. Having done this, it gave us our final series, as used in the text, of KM13 (smoothed) regular prices. Even after these various changes, at least 60% of the products (80% in Asda and Tesco) in our sample have median price durations of less than 20 weeks. No direct comparisons with NSB regular prices are possible, because of the rather different methods by which they are developed.

For comparison with figures in the text and previous analyses, we append figure A3 constructed using (unsmoothed) KM11 regular prices below.

[27] The posted price stays down for several periods, which coupled with the fact that the “before” and “after” prices differ, can yield a singleton low mode, because this is, for that period, the most commonly observed price in the 13 week sequence centred on it.

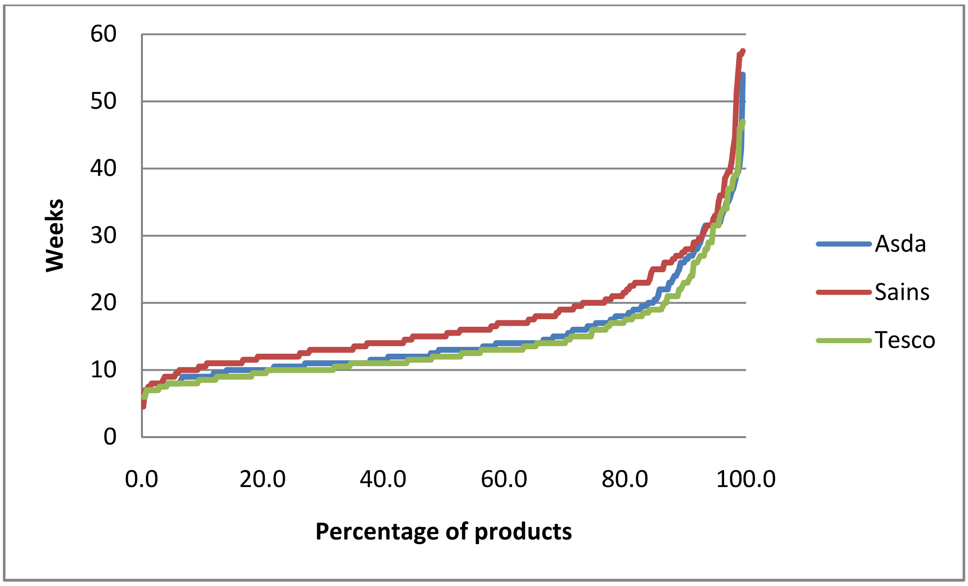



Figure A3: Median duration of price curve using KM11 regular prices.

## 2. Additional material referred to in the text

Table A1: Number of weeks in which there are KM13 regular price changes in the ranges shown

| KM13 regular prices | None | 1 to 9 | 10 to 19 | 20 to 29 | 30 to 39 | 40 to 49 | 50 to 99 | 100 or more |
|---|---|---|---|---|---|---|---|---|
| **Rises** | 1 | 66 | 129 | 101 | 34 | 23 | 11 | 0 |
| **Falls** | 2 | 44 | 129 | 88 | 49 | 30 | 21 | 2 |

Table A2: Price cuts of 2p

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| **Asda** | 32 | 47 | 34 | 68 | 496 | 240 | 78 |
| **Sains** | 37 | 27 | 17 | 74 | 121 | 154 | 79 |
| **Tesco** | 40 | 58 | 45 | 99 | 409 | 217 | 86 |

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