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Shopping around: how households adjusted food spending over the Great Recession

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Abstract

Over the Great Recession UK households reduced real food expenditure. We show that they were able to maintain the number of calories that they purchased, and the nutritional quality of these calories, by adjusting their shopping behaviour. We document the mechanisms that households used. We motivate our analysis with a model of shopping behaviour in which households adjust shopping effort and the characteristics of their shopping basket in response to economic shocks. We use detailed longitudinal data and focus on within household changes in basket characteristics and proxies for shopping effort.

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1 Introduction

Over the Great Recession households in the UK experienced adverse shocks to their incomes and large increases in the price of food. Unlike previous recessions, expenditure on food failed to keep pace with rising food prices, which has led some to infer a substantial reduction in the size and nutritional quality of households' food baskets (see, for example, Taylor-Robinson et al. (2013) and Lock et al. (2009)); similar concerns have also been raised in the US (see US Department of Agriculture (2013, 2013)). However, it is well known that equating expenditure with consumption can lead to mistaken conclusions about how households are affected by changes in their economic environment; for example, households may increase their time spent searching for lower prices (Stigler (1961)) or in home production (Becker (1965)) in order to smooth their consumption. They may also change the composition of their shopping baskets (i.e. switching from a preferred branded to a cheaper generic product) to maintain the nutritional quality of their food basket.

We are interested in the extent to which households are able to exploit various mechanisms to smooth, or "insure", the quantity and nutritional quality of their food basket in the face of adverse shocks. We add to a growing body of literature on how households alter their shopping behaviour during economic downturns. Recent evidence from the US suggests that as economic conditions worsen households spend more time shopping and pay lower prices (Kaplan and Menzio (2014b)), increase their use of sales, switch to generic products (Nevo and Wong (2014)) and switch to low-price retailers (Coibion et al. (2014)).

Our contribution to the literature is twofold. Firstly, we show that over the Great Recession households in the UK were able to maintain the number of calories they purchased and the nutritional quality of those calories by acting to reduce the (real) price that they paid for their shopping baskets. We do this using detailed household level transaction data. The period of the Great Recession saw large changes in the economic environment in the UK. In addition to declines in household incomes, food price inflation outstripped general inflation, meaning households' food budgets were subject to particular pressure. This economic turbulence provides a good opportunity to study how households are able to adapt their behaviour in response to deteriorating economic circumstances.

Our second contribution is to explore empirically the mechanisms that household used to do this. We motivate our empirical approach by setting out a model of grocery shopping behaviour, building on Aguiar and Hurst (2007), who show in a cross-section that observed reductions in expenditure at retirement do not necessarily equate to a reduction in consumption, but rather, as an individual's opportunity cost of time declines at retirement they switch away from market goods and towards home production and increased search. We incorporate the possibility that households can adjust the characteristics of their shopping basket to lower the price of their basket. Aguiar and Hurst (2007) measure how much a household pays for its basket of products, relative to the price of the basket at average prices; they then compare households cross-sectionally to study which households pay lower than average prices for their shopping baskets. We focus on *within*-household changes over time in the average price paid per calorie, both due to paying lower prices for a given set of basket characteristics (through increased shopping effort), and also due to substitution across the basket's characteristics.

We find that households changed their behaviour in such a way as to reduce the average price paid per calorie from 2005-2007 to 2010-2012. They achieved this by increasing their shopping effort (to search out better deals), by switching between non-nutritional characteristics (for example, from branded to generic products) and by substituting away from more expensive foods and nutrients (such as alcohol and protein) towards cheaper ones. This allowed households to smooth the number of calories that they bought. Although they substituted between the nutritional characteristics of their basket, we find that the overall nutritional quality of their basket did not deteriorate, and, in fact, on average slightly improved. This is of interest because a policy maker might care more about these characteristics (calories and nutrients) than other basket characteristics.

Our work relates to several literatures. Most closely related is a series of influential papers by Aguiar and Hurst (2005, 2007), who take a similar approach applied to a different setting, and Aguiar et al. (2013), who show with time use data on US households that over the Great Recession 30% of foregone market work hours were allocated to non-market work, and 7% were allocated to increased shopping effort. We relate our findings to theirs by using our model to infer the opportunity cost of time and show that it fell over the Great Recession. In a recent extension to this literature, Nevo and Wong (2014) show that US households increased the time spent shopping and in home production, so that the decline in consumption was substantially less than the decline in food expenditure.

Also related is the literature on insurance and consumption smoothing in an intertemporal setting. These papers typically focus on the response of consumption to permanent and transitory shocks to income (see, Blundell et al. (2008), Blundell and Preston (1998), Jappelli and Pistaferri (2010), Hall and Mishkin

(1982), among others). This body of work studies how households can transfer income intertemporally to smooth consumption. However, Blundell et al. (2014) show the importance of family labour supply as an insurance mechanism to wage shocks; once this, and taxes are properly accounted for, there is little evidence of additional insurance. They consider a lifecycle setup in which households choose consumption and leisure to maximize their utility; the optimal choices made by households are such that consumption is smoothed following wage shocks. We are interested in understanding the smoothness of two aspects of consumption – the nutritional quantity and quality of households' shopping baskets – and how this can result from the *intra-temporal* utility maximization of households. We show that the ability of households to re-optimize over the quantity of food, its characteristics and the time spent shopping is crucial for understanding consumption smoothing over this period.

Our results contribute to those found in the literature which suggest that nutrition and health might improve as economic conditions worsen. Strauss and Thomas (1998) show that the effect of economic shocks on nutritional status (energy intake, weight, child stature) in Russia in the late 1990s were such that individuals and households were, *"able to weather short-term fluctuations in economic resources, at least in terms of maintaining body mass index and energy intake,"* and that individuals switched to cheaper and less tasty calories in hard times. By studying variation over time across US states, Ruhm (2000) shows that diets become less healthy and obesity increases when the economic situation improves. Dehejia and Lleras-Muney (2004) find that babies conceived in recessions have a lower probability of bad outcomes such as low birth weight, congenital malformations, and post-neonatal mortality. However, Adda et al. (2009) show that permanent income shocks have little effect on a range of health outcomes.

We begin in Section 2 by describing our data and showing how expenditure, calories and nutritional quality evolved over the Great Recession. In Section 3 we outline a simple optimizing model of household grocery shopping and set out our empirical strategy. Section 4 describes how we measure households' choices of shopping effort and basket characteristics. Section 5 presents empirical estimates of the price function and quantitative estimates of how households were able to maintain calorie purchases in the face of lower real food expenditure. A final section concludes.

2 Food expenditure and consumption

We use information on food (including drinks and alcohol) that is purchased and brought into the home by a representative panel of British households over the period January 2005–June 2012. The data are from the Kantar Worldpanel and are collected via in-home scanning technology. Participants record spending on all grocery purchases via an electronic hand held scanner in the home. Purchases from all types of store – supermarkets, corner stores, online, local speciality shops – are covered by the data. The data include information on the exact price paid for the product, whether or not the product purchased was on promotion (e.g. ticket price reduction, "Buy One Get One Free", etc.), nutritional information (number of calories, amount of salt, protein, saturated fat and other information that is listed on food labels) and demographic details of the households. These data have been used in Dubois et al. (2014) and Griffith et al. (2009), and similar data are widely used in the US, for example in Aguiar and Hurst (2007); see Griffith and O'Connell (2009) and Leicester and Oldfield (2009) for further discussion of the data. Our sample includes 14,694 households and over 450,000 "shopping baskets", which we define as all purchases made by a household in a month. Households are observed in the data for over 30 months on average. Our focus is on the grocery baskets that households purchase for home consumption, which constitute over 85% of total calories purchased (see Section 5.3).

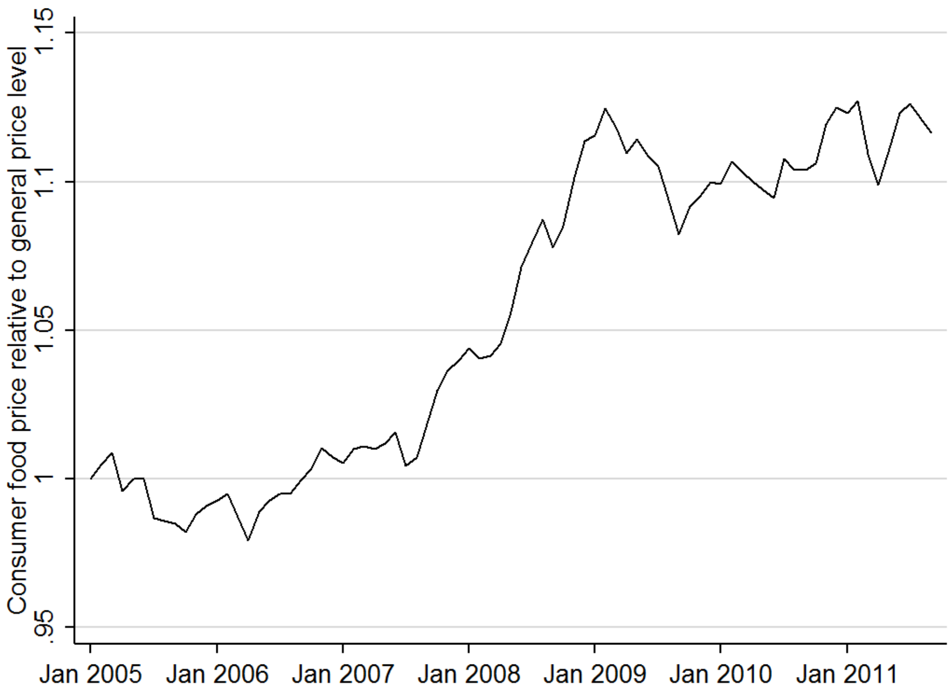
2.1 Real food expenditure and calories

In this section we describe changes in consumer grocery expenditure and calories over the period of the Great Recession. Between 2005-2007 and 2010-2012, the food and drink component of the Consumer Price Index (CPI) rose by over 26%. The CPI for all items rose by 16% over this period, meaning that the price of food relative to the overall price level rose by over 10%, see Figure 2.1.[1] In the descriptives in this section we deflate nominal food spending by the *food and drink component of the CPI.* Expressing expenditure in "real" terms helps remove the effect of rising food prices. However, the food and drink component of the CPI, broadly, measures the change in the cost of a fixed basket of food and drink products and therefore does not fully reflect the fact that households may have changed their shopping basket in response to the changes in the economic environment that they face. In our main empirical analysis in Section 5 we focus on how

[1] In addition to this there were changes in the relative prices of different food groups (see Griffith et al. (2015)).

the price households paid per calorie changed over the Great Recession, and we carefully separate out how this was affected by changes in the market environment (for instance, rising pricing level) and changes in household behaviour (changes in basked composition and increased effort expended shopping).

Figure 2.1: *Consumer price of food relative to the general price level*



Notes: The figure shows the Consumer Price Index for food and drink relative to the Consumer Price Index for all items over 2005-2011.

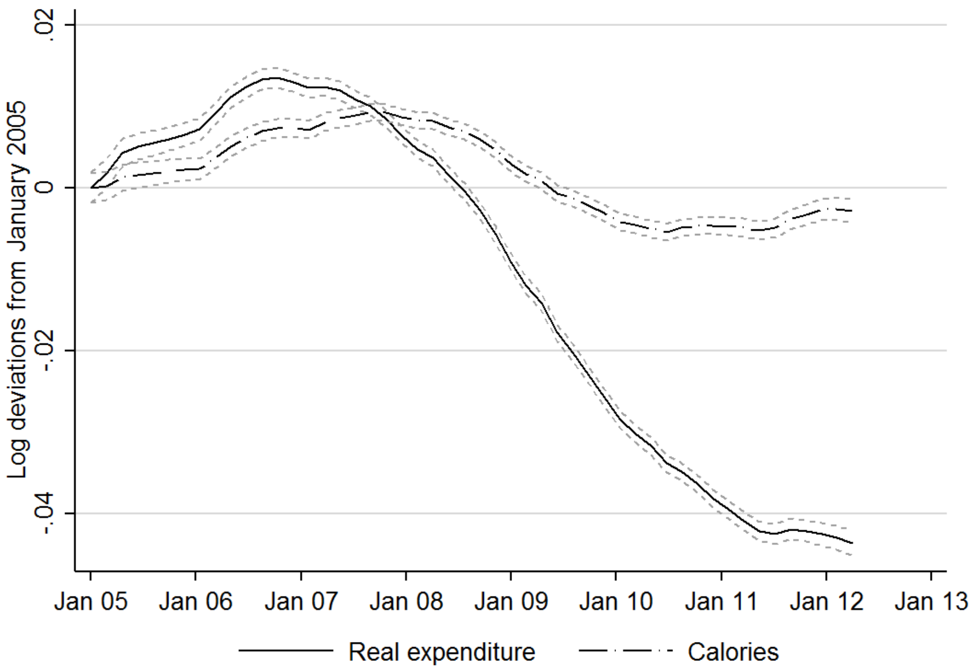
Figure 2.2 shows how real food expenditure and calories changed over 2005-2012, on average. The figure is based on within household changes, and shows average deviations in the log of real food expenditure and calories from the first quarter of our data (2005Q1) (approximately the average within-household percentage change in each month relative to the base period).[2] We express calories per "adult equivalent" per day and real expenditure per "adult equivalent" per month.[3] Figure 2.2 shows that there was a sharp decline in real food expendi-

[2]As not all households are observed in the first month, we express numbers as log deviations rather than in percentage terms.

[3]As in Dubois et al. (2014) we "equivalize" to account for differences in household size and composition using an "adult-equivalent index" based on the estimated average requirement (EAR) for energy of household members (Department of Health (1991)), which vary by age and sex. We sum the EARs of all household members and divide by 2550; this equals 1 for a household containing only one adult male aged 19-59. If the household contained one adult male, one adult female (EAR=1940) and one female infant (EAR=698) then the index would

ture in 2008. (Table 2.1 shows the average percentage change from 2005-2007 to 2010-2012). Households reduced real grocery expenditure by over 6% between the pre-recession years, 2005-2007 and the period post-recession, 2010-2012, or, in other words, households' spending on food failed to keep pace with rising food prices. This large reduction has been documented by Crossley et al. (2013), who also show that reductions in real food spending were not seen in previous recessions. However, calorie purchases remained reasonably smooth over this period, falling by only 1% between 2005-2007 and 2010-2012. The fact that households reduced calories by less than their real food expenditure indicates that they switched toward cheaper (in real terms) calories. The focus of this paper is on how they achieved this price reduction.

Figure 2.2: *Real food expenditure and calories purchased*



Notes: The figure shows the log deviations in real expenditure and calories relative to 2005Q1. Numbers are based on within household variation. Real expenditure is nominal expenditure on food at home deflated by the food and drink component of the CPI in 2008 prices. Numbers are expressed per adult equivalent. Lines are local polynomials with 95% confidence intervals shown as dotted lines.

Over the Great Recession households experienced different shocks. For example, Crossley et al. (2013) show that younger households were particularly hard

be 2.035=(2550+1940+698)/2550; this means that if the household purchased 5188 calories this would be "equivalized" to 2550 and so be comparable to a single adult male purchasing 2550 calories.

hit. In the UK, the incomes of households towards the bottom of the income distribution were largely protected from the immediate impact of the Great Recession by the benefit system (Brewer et al. (2013)). It is possible that the smoothness in calories seen at the average masks differences across households. We look at the changes in real expenditure and calories purchased by demographic composition of the household and by the employment status and income of the household.

Table 2.1: *Changes in real food expenditure and calories, per adult equivalent*

	Real expenditure (£ per month)			Calories purchased (per day)		
Households	2005-2007	2010-2012	% change	2005-2007	2010-2012	% change
All	114.52	107.27	-6.33	2300	2274	-1.10
pre-school children	94.15	82.21	-12.68	2011	1931	-3.99
school aged children	93.00	83.60	-10.10	2041	1948	-4.57
adults	116.65	110.72	-5.08	2288	2295	0.29
pensioners	129.09	121.69	-5.73	2530	2497	-1.32
working high income	111.43	102.68	-7.85	2028	2011	-0.86
working mid income	108.41	99.72	-8.02	2150	2099	-2.37
working low income	98.97	92.51	-6.53	2170	2131	-1.81
unemployed	105.64	98.70	-6.57	2271	2230	-1.78

Notes: Real expenditure is nominal expenditure on food at home deflated by the food and drink component of the CPI in 2008 prices. Real expenditure is per adult equivalent per month; calories are per adult equivalent per day. % changes refer to the average within household percentage change. "Pre-school" denotes households with a child aged between 0 and 5; "school age" are households with the youngest child between 6 and 17. "Adults" are households where everyone is 18 or older and everyone is aged below 65. "Pensioner" households are those in which at least one member is aged 65 or over. Working households are those in which the head of the household works more than 8 hours a week. Income is measured using information on occupation and education contained in social grade; grade AB/C/DE correspond to high/middle/low income. The percentage change is the average within-household change in each variable.

We distinguish households by whether they include pre-school children, school-aged children (and none at pre-school ages), adults (non-pensioner households without children), and pensioner households. There is considerable policy interest in how households with young children have been affected by the recession. For example, US Department of Agriculture (2013) argue that in the US food insecurity is more prevalent in households with children under six than in the whole population, and changes in food purchasing decisions, particularly those that affect nutritional quality, may have important health consequences for young children (see, for instance, Currie (2009) and Case et al. (2005)).

Table 2.1 shows the levels in 2005-2007 and 2010-2012 and percentage changes in real monthly expenditure on food at home per adult equivalent and calories purchased per adult equivalent per day for the different household types.[4] On average, the nominal food expenditure of all household types failed to keep pace with the rise in food prices, meaning that real expenditure fell. Households with pre-school children reduced real expenditure by the most at 12.7%; households with school age children also experienced a relatively large reduction of 10.1%. In addition, households with children (both pre-school and school age) reduced the number of calories that they purchased per adult equivalent, although by much less than real expenditure. This is in contrast to households without children, who reduced real expenditure by about half the amount as households with children. Adult households did not, on average, reduce calories, while pensioner households reduced calories by less than one-third the amount that households with children did.[5] Despite differences in the magnitude of the changes across households, smoothing of calories is evident for all household types: calorie purchases declined by much less than the falls in real expenditure, indicating a switch to calories that cost less in real terms.

We also look at how these patterns vary by the income level of the household. We group households according to their work status and income: households in which the head of the household works more than 8 hours a week are deemed to be "working", the remaining households are either "unemployed" or pensioner households. "Working" households are further divided by income. We use information on the occupation and eduction of the main earner contained in a variable called social grade to measure income.[6] High income households include higher and intermediate managerial, administrative and professional occupations (social grades A and B); middle income includes clerical and junior managerial, administrative

[4]For reasons of parsimony, in tables throughout the paper we compare the period 2005-2007 with 2010-2012. The intervening period, 2008-2009, was characterized by reductions in real incomes and rising food prices; after 2009 incomes remained depressed and the food price level remained high. Typically numbers for 2008-2009 lie somewhere in between numbers for the pre- and post-recession periods.

[5]One potential concern is that, because we are looking *within* household, as children age they may purchase more foods outside of the home, and this might in part be driving our results. To check this we use repeated cross-sectional data from the *Living Costs and Food Survey 2005-2011* and find that the change in total calories (from all food) per adult equivalent per day is -2.9% for households with pre-school children and -3.5% for households with school age children.

[6]See http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade for details.

and skilled manual occupations (C), and low income include semi- and unskilled manual workers (D and E). There is a strong correlation between income and the social grade classification – on average, households in social grade A have a main income earner with a net annual income of almost £40,000, whereas those in grade E have a main income earner with a net annual income of less than £5,000.

Reductions in real food expenditure are largest for working households with high and middle levels of income. However, working households with higher levels of income cut back on their calories by the least, while working households at the middle of the income distribution reduced their calorie purchases by the most, indicating that high income working households reduced the price per calorie they paid for their groceries by more. The numbers shown are evidence for smoothing of calorie purchases by households across the income distribution – the real expenditure of all groups declined, but calorie purchases fell by much less.

The data suggest that the experience of households of all types was mostly similar – large declines in real food expenditure were accompanied by smaller falls in calorie purchases. Households with children stand out us having the largest adjustments. Although different households experienced different income (wage and asset price) shocks, all households were subject to higher food prices – from 2005-2007 to 2010-12, the consumer price of food rose by 10% more than the consumer price of all goods (see Figure 2.1). It is likely that this price shock was an important reason why households' real food expenditure fell. The stability of calorie purchases over this period is due to households switching to cheaper (in real terms) calories. In Section 5 we investigate the mechanisms by which they did this; however first we describe how the nutritional quality of households' grocery baskets changed over this period.

2.2 Nutritional quality

In the previous section we showed that, although real expenditure declined markedly over the recession, the number of calories that households purchased remained relatively stable. Households achieved this by lowering the average real price per calorie that they paid for their shopping basket. A possible concern is that a switch to cheaper calories could lead to a reduction in the nutritional quality of those calories (see, *inter alia*, Lock et al. (2009) and US Department of Agriculture (2010)). It has been well documented (e.g. US Department of Agriculture (1997), US Department of Agriculture (2000)) that there are cross-sectional differences in the nutritional quality of food purchases, with richer households purchasing food of a higher nutritional quality, on average. We observe this in our data, but our focus is to consider the *within*-household variation in the nutritional quality of food purchased over the Great Recession.

Measuring nutritional quality is complex; households made changes that improved nutritional quality in some dimensions and reduced nutritional quality in other dimensions. For example, over the recessionary period, the share of calories from protein fell for almost all households; this is generally considered to be "bad" for nutritional quality, as most UK households purchase less protein than the recommended amounts. In the other direction the share of calories from saturated fat declined; this is generally considered to be "good" for nutritional quality, because most households purchase more saturated fat than the recommended amounts. These changes in the nutritional composition of shopping baskets are such that it is not immediately obvious whether nutritional quality improved or worsened over this period.

To gain a better understanding of the overall changes in the nutritional quality of households' shopping baskets we use the United States Department of Agriculture's (USDA) Healthy Eating Index (HEI) (see US Department of Agriculture (2007)). The HEI gives a score between 0 and 100 based on the density (i.e. amount per 1000 calories) of different food groups and nutrients in a basket. US Department of Agriculture (2007) comment that density standards are appealing, *"not only because they allow a common standard to be used, but because they have the advantage of being independent of an individual's energy requirement."* This means that changes in the HEI will largely abstract from changes in the quantities of nutritional components purchased that arise due to changes in the total number of calories purchased. The HEI is used by Beatty et al. (2014) to analyze changes in the dietary quality of the US population over the 1989-2008 period.

We are interested in how the nutritional quality of a household's shopping basket compares to the one they purchased prior to the Great Recession. We calculate the average within household change in the HEI and its component scores between 2005-2007 and 2010-2012, shown in Table 2.2. The overall average HEI increases by around 1.5% over this period; this is small relative to the cross sectional variation; the standard deviation of the HEI across households is 10. However, it represents an aggregation of some larger changes that go in offsetting directions, for example, a shift away from vegetables, grains, milk and meat was offset by a reduction in the saltiness of food purchased and a lower calorie share of saturated fat. This suggests that, although households adjusted the relative composition of nutrients and food groups in their baskets, potentially in ways

Table 2.2: *Changes in the Healthy Eating Index*

	Max score	Mean in 2005-2007	Change to 2010-2012	% change to 2010-2012
HEI 2005-2007	100	49.0	0.72	1.5
of which				
"Good" change			1.45	3.0
"Bad" change			-0.72	1.5
which consists of:				
Total fruit	5	3.06	-0.02	-0.7
Whole fruit	5	3.36	0.08	2.4
Total vegetables	5	3.20	-0.13	-4.1
Dark green/orange veg	5	1.61	0.00	0.0
Total grains	5	3.69	-0.03	-0.8
Whole grains	5	1.55	-0.11	-7.1
Milk	10	5.28	-0.05	-0.9
Meat	10	7.96	-0.22	-2.8
Oils	10	4.93	-0.18	-3.7
Sodium	10	6.42	0.93	14.5
Saturated fat	10	2.70	0.27	10.0
Calories from SoFAAS	20	5.22	0.18	3.4

Notes: Column 1 shows the maximum score for the overall HEI and each component; column 2 shows the mean of the overall HEI and the component scores in 2005-2007; column 3 shows the mean within household change in the scores to 2010-2012; column 4 shows the percentage change in the mean within household change in the scores. "Good change" (shown in row 2) is the sum of the positive changes in the bottom panel; "Bad change" (shown in row 3) is the sum of the negative changes in the bottom panel. "Calories from SoFAAS" is the share of calories from solid fat, added sugar and alcohol.

that reduced their utility, they did so in such a way as to maintain the average level of nutritional quality in the basket.

Table 2.3: *Changes in the Healthy Eating Index, by type of household*

Households	Mean HEI 2005-2007	Change to 2010-2012	(%)	*of which:* "Good"	"Bad"
All	49.0	0.72	(1.5%)	1.45	-0.72
pre-school children	48.7	1.52	(3.1%)	3.02	-1.51
school aged children	46.1	1.03	(2.2%)	1.90	-0.87
adults	47.8	1.46	(3.1%)	1.93	-0.46
pensioners	51.5	-0.23	(-0.4%)	0.91	-1.14
working high income	49.6	0.87	(1.8%)	1.78	-0.91
working mid income	48.0	1.03	(2.1%)	1.78	-0.75
working low income	46.6	2.01	(4.3%)	2.44	-0.43
unemployed	46.7	1.11	(2.4%)	1.67	-0.56

Notes: Column 1 shows the mean HEI score for each households group in 2005-2007; the second column shows the mean within household change to 2010-2012 within each group; column 3 shows this in percentage terms. Columns 4 and 5 show the "Good" and "Bad" changes calculated within each group in the way described in Table 2.2. Household group definitions given in the notes to Table 2.1.

We also look by the different household types, see Table 2.3 (a more detailed breakdown is shown in Table A.1 in the Appendix). Households with pre-school children improved their HEI score by the most: despite a relatively large fall in the contribution of vegetables and meat, they improved with respect to fruit, salt, saturated fat and alcohol by more than enough to compensate. The HEI score of the shopping baskets of pensioner households declined slightly: unlike households with pre-school children, they did not decrease their saturated fat purchases by enough to compensate for the switch away from meat and vegetables. However, pensioner households had the highest HEI scores to begin with. There is a cross-sectional correlation between average nutritional quality and income: households with higher incomes have a higher HEI score than households in the lowest income band. The magnitude of the difference in the average HEI score between high and low income households is similar to that found by Beatty et al. (2014) in the US. However, low income working households improved the nutritional quality of their shopping basket by more than working households with higher income; primarily by switching towards fruit, away from saturated fat and alcohol and reducing the salt content of their grocery purchases.

Overall, it seems that households were not only able to smooth the number of calories that they purchased, but also maintain the nutritional quality of these calories. In the next section we set out a model of grocery shopping in which households choose the number of calories, the characteristics of these calories and their shopping effort to maximize their utility. This model helps clarify the mechanisms households may have used to broadly maintain the number and nutritional quality of their calorie purchases, and helps inform our empirical approach.

3 A model of grocery shopping

3.1 Model

We consider the decisions that a household makes over its grocery shopping. Our set up shares a number of features in common with that in Aguiar and Hurst (2007); households choose the total amount of groceries to buy and how much time to allocate to shopping and home production (specifically, cooking). Spending more time shopping allows households to lower their expenditure on groceries, but they incur a cost of time. We extend Aguiar and Hurst (2007) to also model the choice a household makes over the characteristics of their grocery basket. We are particularly interested in its nutritional characteristics. This modification turns out to be important for studying how households adjust their shopping behaviour in response to economic shocks.

We model the household's utility from food consumption (v) as depending on the total number of calories in its shopping basket, C, and a K dimension vector of basket characteristics, $\mathbf{z}$. Grocery basket characteristics include the nutritional and food group composition of the basket, the share of the basket from branded products, and the time required to prepare calories for consumption (we denote this by z', which is an element of $\mathbf{z}$). Note that inclusion of calories in the objective function does not imply that relaxation of the household's budget constraint will translate directly into more calories. Calories is one argument of many in the household's utility function – the household will trade off a larger shopping basket with improvements in the nutrient and quality content of the basket. In addition, the relationship between utility and calories, all else equal, may be highly concave – at low level more calories may increase utility by a large amount, at moderate or high levels more calories may increase utility only infinitesimally.

We denote the price that the household pays per calorie for its grocery basket $P = P(e, \mathbf{z}; \phi)$. P depends on how much effort the household expends shopping, e. All else equal, more time shopping results in a lower price paid for groceries, because the shopper finds better deals (that is we expect $\partial P/\partial e < 0$, although it is likely that there are diminishing returns to shopping effort, meaning $\partial^2 P/\partial e^2 >$

0). The characteristics of the shopping basket, $\mathbf{z}$, can also affect the price paid per calorie. For example, increasing the share of calories from protein will likely increase the price per calorie, while increasing the share of generic rather than branded products will likely decrease the price per calorie. Finally, we denote by ϕ other factors that affect the price per calorie the household pays for its groceries, including for example, common time varying factors, such as the prices at which firms offer food in the market, regional-time varying factors, such as local market conditions, household level characteristics, such as shopping efficiency, and household-time varying characteristics, such as caloric requirements of the household.

Spending more time shopping has the advantage of potentially lowering the household's monetary expenditure on groceries, but it has the downside of leaving less time for the household to engage in leisure or market work. We denote the opportunity cost of time by ω. Like other characteristics of the grocery basket, the preparation requirement may affect the price per calorie, but unlike other characteristics preparation is also costly in terms of time.

We assume that preferences over total calories and characteristics are weakly separable from other arguments in the household's utility function, and that choices other than those over $(e, \mathbf{z})$ do not enter directly into the price function. This implies that changes in work status affect household's choices through changing the resources that are available to spend on food and the opportunity cost of time, but not through altering the relative desirability of different basket characteristics or the marginal rate of substitution between calories and any given characteristic.

The household's problem can be stated as a cost minimization problem given by:

$$\min_{e,\mathbf{z},C} P(e, \mathbf{z}; \phi)C + \omega(e + z'), \tag{3.1}$$

$$s.t. \quad v(C, \mathbf{z}) = \bar{v}. \tag{3.2}$$

The household's choice over consumption of non-food and over leisure and labour supply are captured in the opportunity cost of time ω, and the total resources allocated to food consumption is captured in $\bar{v}$. We assume that the household does not select zero shopping effort ($\partial p/\partial e \to -\infty$ as $e \to 0$ ensures this), or zero leisure or cooking time (appropriate Inada conditions on the utility function ensure this).

The first order condition for shopping effort is:

$$-\frac{\partial P}{\partial e}C = \omega, \tag{3.3}$$

i.e. the household puts effort into shopping up to the point where the marginal gain in terms of lower food expenditure equals the opportunity cost of time. This optimality condition can be used to infer the household's opportunity cost of time, providing a measure that has the advantage that it allows us to remain agnostic about the workings of the labour market. The first order condition for the choice of total calories is:

$$P = \lambda\frac{\partial v}{\partial C}, \tag{3.4}$$

where λ is the Lagrange multiplier on the household's constraint (3.2) and can be interpreted as the reciprocal of the marginal utility of more resources allocated to food consumption (either an extra £ of expenditure or an extra £ worth of time spent shopping). Condition (3.4) says that the household will select the number of calories that equates the marginal cost of more calories with the marginal utility of calories (converted into monetary terms through multiplication by λ).

The first order condition for the choice of characteristic k (where $z_k \neq z'$) is:

$$\frac{\partial P}{\partial z_k}C = \lambda\frac{\partial v}{\partial z_k}. \tag{3.5}$$

Interpretation is similar to the calorie first order condition: for each characteristic k, the household will choose the quantity that equates its marginal cost with the marginal utility from that characteristic (expressed in monetary terms). For the cooking requirement characteristic, the first order condition is $\left(\frac{\partial P}{\partial z'}C + \omega\right) = \lambda\frac{\partial v}{\partial z'}$.

The ratio of condition (3.5) and (3.4) yields the marginal rate of substitution between calories and characteristic k:

$$\frac{\partial v/\partial z_k}{\partial v/\partial C} = \frac{\partial P}{\partial z_k}\frac{C}{P}. \tag{3.6}$$

At the optimum, the number of extra calories the household needs as compensation for a marginal loss in the amount of characteristic k to remain indifferent to the change equals the ratio of the marginal costs of characteristic k and calories.

Our approach differs from that of Aguiar and Hurst (2007) because we are interested not only in substitution from money to higher time input, but also substitution between different characteristics of the shopping basket. The price index used by Aguiar and Hurst (2007) measures how much a household pays for its basket of products, relative to the price of the basket at average prices. Their interest is then to compare cross-sectionally, differences in this measure of relative basket cost - what households pay a lower price than average for their fixed shopping basket? In contrast, our price function measures the price a household pays per calorie, and our interest is in how this changes (within household) through time due both to the household paying lower prices given basket characteristics, but also due to substitution across the basket's characteristics.

This framework is well-suited to studying how households adjust their shopping behaviour in response to deteriorations in the economic environment that they face. We use the model to analyse changes over the period spanning the Great Recession. Households in the UK experienced reductions in their real incomes, driven by slow nominal wage growth and reductions in asset prices; in the US there were also substantial falls in real incomes, although rising unemployment played a more central role. Importantly, households also faced much higher food prices. In problem (3.1)-(3.2) this would lead to changes in the resources the household had available for food consumption, v, the opportunity cost of time, ω and the market prices of foods, captured by ϕ.

The negative economic shocks experienced over the recession led to a reduction in $\bar{v}$, meaning that households were made worse off. However, we observe empirically that the number of calories purchased by households and the nutritional quality of these calories remained stable. We are interested in how households were able to adjust their time spent shopping and *other aspects* of consumption, e.g. the share of their calories from generic products, in order to smooth the size and nutritional quality of their shopping baskets. How households can do this can be illustrated by a simple example. Suppose that a household gets utility from a good that is branded, z_b, a generic good, z_g, and a nutrient characteristic, z_n, that is provided in differing degrees by each good. Following an inward shift of their budget constraint the household shifts to a lower indifference curve but will also adjust the relative consumption of z_b and z_g; possibly adjusting z_b and z_g to maintain z_n (analogous to the number of calories, or their nutritional quality), despite being made worse off.

Our empirical strategy is to specify a parametric form for the price per calorie function $P(e, \mathbf{z}; \phi)$ and use this to estimate the sensitivity of the price per calorie that households paid for their grocery baskets to the choice variables $(e, \mathbf{z})$.

3.2 Empirical functional form

At this point it is useful to introduce a household index h and a time index t. We have panel data on households' daily food purchases, but to consider the household's entire shopping basket we aggregate each individual household's purchases to the monthly level; we observe each household for many months (on average 31 months). We measure the price per calorie that household h pays for its groceries in period t, P_{ht}, as a weighted average of the transaction prices that the household pays for the individual products in its grocery basket. Let i index a product (i.e. a barcode or UPC), s index a store and d index a date. Let c_i denote the number of calories in product i and p_{isd} the market price of product i in store s on date d. P_{ht} is given by:

$$P_{ht} = \sum_{isd \in t} \left(\frac{p_{isd}}{c_i} \right) w_{hisd}, \tag{3.7}$$

where $\frac{p_{isd}}{c_i}$ is the price per calorie of product i in store s on date d. The weights are given by:

$$w_{hisd} = \frac{c_i b_{hisd}}{\sum_{i's'd' \in t} c_{i'} b_{hi's'd'}}, \tag{3.8}$$

where $b_{hisd} \in \{0, 1, 2, ...\}$ is the number of purchases of product i from store s on date d by household h. It is through their choice of products, b_{hisd}, that households are able to change the average price they pay per calorie. Similarly, each characteristic of the shopping basket is defined as a weighted average of the "amount" of the characteristic in each product in the basket.

Total calories purchased by a household in a month is given by:

$$C_{ht} = \sum_{isd \in t} c_i b_{hisd}. \tag{3.9}$$

We do not directly observe the time that a household spends shopping; we use a vector of shopping trip characteristics to proxy shopping effort, outlined in Section 4.1.

As our baseline specification we assume that the price function, $P(\mathbf{e}, \mathbf{z}; \phi)$, can be approximated by a log-log specification (Triplett (2004), Aguiar and Hurst (2007)); we show in the robustness section that our results are robust to an alternative polynomial specification. Specifically, we consider:

$$\ln P_{ht} = \alpha \ln \mathbf{e_{ht}} + \beta \ln \mathbf{z_{ht}} + \gamma \mathbf{x}_{ht} + \tau_{ht} + \eta_h + \epsilon_{ht}. \tag{3.10}$$

τ_{ht} denote region-time effects – we include a separate set of 90 month dummies for each of 10 broad regions of the Great Britain. η_h denote household fixed effects and $\mathbf{x_{ht}}$ denote time varying household demographics (including age of the youngest child, age of the main shopper, the household's recommended calorie requirement and main shopper employment status).[7]

In our main specification we assume that the coefficients on the basket characteristics are fixed over time. Each of these coefficients capture the effect of a household including a marginally larger quantity of a characteristic in their shopping basket, holding everything else fixed, on the per calorie price of the basket. We aim to capture the effect of changes in basket characteristics on price paid per calorie in response to the main changes to the economic landscape over the Great Recession, shocks to household income and general food price inflation. It is possible that the marginal cost to a household of each characteristic changed over this time period (for instance due to changes in the relative price of different food types). Therefore, in the robustness section (Section 5.3) we present results where we allow time varying coefficients on the characteristics. This does not change our results qualitatively.

To consistently estimate the parameters in equation (3.10) we require that past, current and future realizations of the right-hand side variables are uncorrelated with the error term. Define $\mathbf{e_h} = (\mathbf{e}_{h1}, ..., \mathbf{e}_{hT})$, $\mathbf{z_h} = (\mathbf{z}_{h1}, ..., \mathbf{z}_{hT})$, $\mathbf{x_h} = (\mathbf{x}_{h1}, ..., \mathbf{x}_{hT})$ and $\boldsymbol{\tau_h} = (\tau_{h1}, ..., \tau_{hT})$; a sufficient condition for identification of the parameters of interest is that the household choice variables $(\mathbf{e_h}, \mathbf{z_h})$ are strictly exogenous, conditional on the other covariates:

$$\mathbb{E}(\epsilon_{ht}|\mathbf{e_h}, \mathbf{z_h}, \mathbf{x_h}, \boldsymbol{\tau_h}, \eta_h) = 0, \quad t = 1, \ldots, T. \tag{3.11}$$

This is a crucial assumption that we now discuss in further detail.

3.3 Identification

We are interested in identifying the causal effect of households' choice variables $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$ on the price per calorie they pay for their grocery basket (i.e. how much does a marginal change in a characteristic, or a marginal change in shopping effort change the price per calorie of household's grocery basket). Our identification strategy exploits *differential within household* variation in shopping choices. We rely on the idea that variation in $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$ over this period was largely driven

[7] A number of variables entering e and z are bounded between 0 and 1, for these we take the log of 1 plus the variable.

by changes in households' budget constraints, arising from the effects of changing labour market circumstances, wage expectations and increasing real food prices.[8] The inclusion of household fixed effects, region-time effects and time-varying demographics will help mitigate a number of issues of potential concern.

The main concerns with identifying this relationship (i.e. reasons why condition (3.11) might not hold) include: (i) the possibility that we are capturing a relationship between product characteristics and price that is driven by supply and not by demand, and (ii) the possibility that household choices over products vary in ways other than through, but correlated with, the choice variables of interest (i.e. omitted variable bias). We consider these in turn.

First, product characteristics and prices are clearly related through the supply relationship - firms set prices as a function of product characteristics. We require market prices to be uncorrelated with the household choice variables $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$, conditional on the household fixed effects, region-time effects and demographics. We rely on variation in market prices that arise due to food price inflation, exchange rates (for imported foods and inputs), competitive conditions and due to changes in aggregate market conditions feeding into firms' price setting decisions. We control for region-time variation in prices, which might, for example, be driven by regional variation in supermarket coverage. We control for the availability of food offered on sale, outlined in Section 4.1.

The second possible issue arises if there is an omitted variable (affecting price per calorie of grocery baskets) that is correlated with one of our choice variables of interest. The fact that we include region-time effects and household fixed effects means a problem would arise only if an omitted variable varied over time differentially across households. An example of a possible omitted variable is productivity differences in shopping technology across households within region. For instance, some households may be particularly adept at searching for good deals and consequently may pay less than other households for their groceries. Such households may spend less time shopping and may have preferences that lead them to select different basket characteristics than other households. However, it seems likely that much of the difference in shopping technology would be fixed over time and therefore controlled for by household fixed effects.

Nonetheless, it is possible that households' shopping technology and preferences over individual food products may change over time in such a way that is

[8] The model we outline assumes households solve a two-stage allocation problem, in which case an increase in real food prices is essentially an income effect with respect to the lower level food allocation stage.

not captured by the included basket characteristics and leads to a lower price per calorie. Possible reasons for this include changes in household demographics (e.g. the birth of a baby might lead to preferences for a different basket of goods), or the employment status of its members (Browning and Meghir (1991)). To control for such changes we include a vector of time-varying household characteristics, including the age of the youngest child, the age of the main shopper and the calorie requirement of the household (see Department of Health (1991)). The inclusion of the household's calorie requirement also captures the potential for economies of scale in grocery purchases, i.e. shopping for more people might allow households to reduce the price that they pay per calorie in ways not captured by the characteristics of the basket, $\mathbf{z_{ht}}$. We control for whether the main shopper and head of household work full time or part time; this will wipe out some of the variation in shopping effort that arises from changes in work status that we hope to capture, but it will control for variation that arises due to preferences that are correlated with work.

Of course in the end we cannot rule out that our estimates might be influenced by omitted variable bias, for example, when a household is buying for a party the basket, and the price per calorie, might vary from their usual levels, and so will their shopping and basket characteristics. This would be a problem if these characteristics are omitted from our measures and are correlated with them.

4 Measuring shopping behaviour

We measure the price that each household pays for its grocery basket in each period, which we express per calorie, P_{ht} (constructed as described in Section 3.2). In 2005-2007 the average nominal price was £1.56 per 1000 calories. By 2010-2012 this had increased by 30p to £1.86. This increase was driven both by changes in the market prices that households faced *and* by changes in the decisions that households made over the characteristics of their basket and their shopping effort. In this section we set out how we measure the household choice variables, $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$. We use these in Section 5.1 to separate out the part of the change in price paid per calorie that was due to household behaviour. We show that the contribution of changes in household behaviour was to decrease the price per calorie households paid for their groceries, allowing them to purchase a similar number of calories at lower levels of expenditure than otherwise would be the case.

4.1 Shopping effort

An important determinant of the price that households pay for their groceries is how much time and effort they allocate to shopping. For example, the shopper will decide how much time to spend comparing prices and searching for good deals on a shopping trip – the more time she spends comparing prices the less she is likely to pay per calorie for a grocery basket with a given set of characteristics. The shopper must also decide how frequently to shop, and how many different stores to visit. More frequent shopping and visiting more stores provides the opportunity to compare prices across days and retailers, potentially allowing the shopper to find better value products.

This is partly facilitated by the fact that identical products are often sold at different prices in different stores. Kaplan and Menzio (2014a) show that in the US there is a high degree of dispersion in the price at which an identical good is sold across stores, within a given geographic market and period of time. Eden (2013) documents price dispersion across goods sold in supermarkets in Chicago and shows that prices are more dispersed for goods in which there is higher uncertainty about aggregate demand. Aguiar and Hurst (2007) argue that older US households exploit this by both shopping more frequently and spending more time shopping, which allows them to pay less for a fixed basket of groceries than it would cost at average prices. Conversely, it is possible that households may find better deals by making less frequent trips and instead buying a larger share of their basket on each trip. Kaplan and Menzio (2014b) use US time use data to show that employed people spend between 13% and 20% less than unemployed people and scanner data to show that the prices paid by employed workers are 2% higher than those paid by unemployed workers.

We do not directly observe the amount of time households allocate to grocery shopping. We proxy shopping effort using outcome measures from our data. Table 4.1 describes these measures, showing the average value across households in 2005-2007 and 2010-2012, as well as the average within household change and percentage change between these two periods.

The first row of Table 4.1 shows the average number of shopping trips households make per month and the second row shows the average number of separate retailers that they visit. Between 2005-2007 and 2010-2012 households did not change the number of shopping trips that they undertook but they did increase the number of different retailers that they visited. A particularly relevant type of retailer is the discounters; in the third row we report the average share of calories

Table 4.1: *Proxies for shopping effort*

	2005 -2007	2010 -2012	Change	% change
Number of shopping trips (Ntrips)	14.87	14.87	-0.00	-0.00
Number of chains visited (Nstores)	3.70	3.83	0.13	3.44
Share of calories from discounter (DISCOUNTER)	10.24	11.85	1.61	15.67
Share of calories bought on sale (SALE)	24.84	33.93	9.09	36.60
Share of available calories on sale (SALE_AV)	17.19	22.71	5.51	32.06

Notes: The numbers are the mean of each variable in 2005-2007 and 2010-2012 and the average within household change and percentage change. Variable names are shown in brackets. SALE_AV is not a measure of shopping effort; rather we control for it when estimating the price function and, conditional on it, interpret SALE as a measure of shopping effort.

bought from discounters, which increased from 2005-2007 to 2010-2012. Discounters are chains that advertise lower prices compared with other retailers; they are generally less conveniently located and offer a less attractive shopping experience. It is unusual for a household to buy its entire grocery basket at a discounter, because they typically offer a restricted range of products. The share of calories a household purchases at discounter outlets averages 10%. This compares to an average of around 25% in the largest single retailer, Tesco, and over two-thirds in the biggest four supermarkets (Tesco, Asda, Morrisons and Sainsbury's) combined. In the UK the main discounters are Aldi, Iceland, Kwik Save, Lidl and Netto. Prices paid at discounters are typically lower than those paid at other supermarket chains, although much of this is due to differences in the grocery basket composition, meaning that it is important to control for basket characteristics.

Our fourth proxy for shopping effort is designed to capture the amount of time households spend shopping *while in the store*. We measure how intensively households make use of sales as the share of calories they purchase on sale. The idea is that buying a larger than average share of groceries on sale, conditional on basket characteristics, indicates more effort in the shop seeking out the products that the household wants that are on sale. For this interpretation to be valid it is important to account for changes in the number of calories that are available on sale. We therefore control for the share of available calories on sale in the supermarkets that the household visited. Since we also include household fixed effects, this means that the coefficient on the share of calories purchased on sale in the price regression reflects the impact of buying more calories on sale *than the household normally does and holding fixed the share of available calories on sale.* Table 4.1 shows that the share of calories purchased on sale increased substantially from 25% in 2005-2007 to just under 34% in 2010-2012. The share of calories available on sale also increased, but by less - from 17% in 2005-2007 to 23% in 2010-2012. The increase in share of calories available on sale is evident (and of a similar magnitude) across all main food groups.

Note that an important feature of the US grocery market is the availability of coupons that can be collected from newspapers and magazines and can be used to lower the transaction price of specific grocery products. Nevo and Wong (2014) show that, in the US, over the recession increased coupon usage was an important channel through which consumers increased their shopping effort. In contrast, in the UK coupons are not an important feature of the grocery market. Most UK supermarkets do have store loyalty cards. Typically these allow consumers to accumulate points in proportion to their total in store spend, which can be used to lower future grocery bills. For example, the Nectar store card gives customers a point worth 0.5p for every £1 spent in Sainsbury's. These points are collected passively and therefore do not represent increased shopping effort in the way increased coupon usage does in the US market.

4.2 Basket characteristics

As well as choosing shopping effort and total calories, households choose the characteristics of their shopping basket, $\mathbf{z_{ht}}$. Basket characteristics include the nutritional characteristics (share of calories from the macronutrients and major food groups, and the amount of the micronutrients) and other characteristics including the share of calories that are bought as budget store brands (i.e. generics) rather than branded products, and package size (to reflect non-linear pricing and bulk discounts). Households may have reduced the price they pay for their groceries without changing the nutritional composition of their calories by adjusting these other characteristics.

Table 4.2 details the nutrient characteristics that we include in $\mathbf{z_{ht}}$. These include the share of non-alcohol calories from each of the macronutrients – protein, saturated fat, unsaturated fat, sugar and non-sugar carbohydrates. All calories are derived from macronutrients (and alcohol), meaning that the shares sum to one. The table shows that between 2005-2007 and 2010-2012, on average, households switched towards carbohydrates (sugar and non-sugar) and unsaturated fat and away from calories from protein and saturated fat. We also include the amount of fibre and salt per 100g in the shopping basket in $\mathbf{z_{ht}}$. Households, on average, have increased the fibre intensity and reduced the salt intensity of their groceries. It is likely that the marginal impact on price paid per calorie of changing nutrients will vary across nutrients because the cost of producing foods with different nutrients varies and because firms might price nutrients differently (for example, Stanley and Tschirhart (1991) find different hedonic prices for nutrients in breakfast cereals). We also control for the nutritional composition of shopping baskets by including in $\mathbf{z_{ht}}$ the share of calories from each of 11 (exhaustive) food groups. Between 2005-2007 and 2010-2012 households, on average, switched towards fruit, grains, poultry and fish, and prepared foods and away from vegetables, red meat and nuts, drinks and alcohol.

We do not have time-use data so do not directly measure how much time households allocated to cooking. However, by controlling for both the nutritional and food group composition of households' grocery baskets, we are able to proxy for the cooking requirement of households' calories (to the extent that cooking times vary across these food groups). For example, if a household switches from purchasing vegetables and raw meats to purchasing processed or prepared foods this indicates a reduction in the required cooking time of its shopping basket. Although we can control for this, we are not able to separately identify how an additional minute of cooking time affects price paid per calorie from the preferences people have over nutrients and food groups.

Table 4.3 details the other (non-nutrient) characteristics we include in $\mathbf{z_{ht}}$. The measure in the first row is the share of calories from budget store brand (or generics). In the UK, there are two types of store brand product: budget and standard. Standard store brands are similar to national brands – they are advertised by the supermarkets, comparably priced and are generally of similar quality to equivalent national brands. In contrast, budget store brands are seldom advertised, are typically sold in plain packaging and are sold for substantially lower prices. The average unit price of budget store brands (across 110 product categories and 16 retailer chains) is just under £2, compared to an average of over £4 for the largest national brand in each product category (Griffith et al. (2015)). Budget store brands are similar to generic brands in the US market. All else equal, it is likely that households value budget store brands less than branded products, and there is evidence that households substitute towards generic products when economic conditions worsen (see Gicheva et al. (2010), Kumcu and Kaufman (2011)). Between 2005-2007 and 2010-2012 households switched to buying a larger share of their calories from generic products.

Griffith et al. (2009) present evidence of strong non-linear pricing in the UK grocery market. Households are able to lower the per calorie price they pay, while

Table 4.2: *Nutrient characteristics*

Share of calories from:	2005 -2007	2010 -2012	Change	% change
Protein (shr_prot)	14.88	14.76	-0.12	-0.81
Saturated fat (shr_sfat)	14.83	14.59	-0.23	-1.57
Unsaturated fat (shr_ufat)	22.64	22.79	0.15	0.67
Sugar (shr_sug)	22.73	22.82	0.09	0.41
Non-sugar carbohydrates (shr_othcarbs)	24.92	25.03	0.11	0.43
g per 100g of:				
Fibre (fibre)	1.12	1.19	0.07	6.32
Salt (salt)	0.50	0.49	-0.00	-0.10
Share of calories from:				
Fruit (shr_Fruit)	5.08	5.28	0.20	3.86
Vegetables (shr_Veg)	6.97	6.43	-0.54	-7.81
Grains (shr_Grains)	16.40	16.65	0.24	1.48
Dairy (shr_Dairy)	9.53	9.49	-0.04	-0.46
Cheese and fats (shr_CheeseFats)	11.73	11.73	0.01	0.06
Poultry and fish (shr_PoultryFish)	3.09	3.30	0.21	6.87
Red meat and nuts (shr_RedMeatNuts)	8.34	7.84	-0.51	-6.07
Drinks (shr_Drinks)	1.87	1.82	-0.04	-2.36
Prepared sweet (shr_PrepSweet)	19.06	19.53	0.47	2.47
Prepared savory (shr_PrepSavory)	14.78	14.82	0.04	0.30
Alcohol (shr_Alcohol)	3.14	3.11	-0.04	-1.15

Notes: The numbers are mean of each variable in 2005-2007 and 2010-2012 and the average within household change and percentage change. Variable names are shown in brackets.

keeping other attributes of their shopping basket fixed, by switching to larger pack sizes of the brands they purchase. To capture this we include the share of calories purchased in "big" pack sizes. We define a product as having a "big" pack size if its size is above the median pack size of all transactions involving products belonging to the same brand. The second row of Table 4.3 shows that households switched to buying smaller pack sizes between 2005-2007 and 2010-2012.

Table 4.3: *Other basket characteristics*

Share of calories from:	2005-2007	2010-2012	Change	% Change
Generic products (GEN)	10.92	12.97	2.05	18.75
Big pack sizes (BIG)	32.31	30.86	-1.46	-4.51

Notes: The numbers are mean of each variable in 2005-2007 and 2010-2012 and the average within household change and percentage change. Variable names are shown in brackets.

5 Empirical results

In this section we present estimates of the relationship between price paid per calorie and households' choice variables $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$, see equation (3.10). We use the estimates to quantify the contribution that changes in households' behaviour made to the change in the average price that they paid for their shopping basket, and we explore the importance of various margins of adjustment. It was by lowering the average price per calorie of their shopping baskets that households were able to smooth their calorie purchases over this period; the results in this section show that they did this by increasing their shopping effort, switching to generic products and substituting across nutrients, which, although reducing their utility from consumption, did not adversely impact the nutritional quality of their grocery basket. We also show that the relative importance of these different mechanisms does not differ much across household types.

5.1 Estimates of price function

Table 5.1 shows the estimates of the coefficients in equation (3.10). Column (1) shows the estimated coefficients omitting household fixed effects. In column (2) we include household fixed effects. The difference in coefficient estimates is marked. For instance, the absolute value of the sales coefficient more than halves once we include household fixed effects; there are differences in household shopping technology, which leads them to pay a lower price per calorie and that are correlated with their use of sales. A similar change is evident for the other choice variables, underlining the importance of exploiting differential within household changes in behaviour. In column (3) we also control for time-varying household characteristics (age of youngest child, age of main shopper, household calorie requirement and employment status). This has much less impact on the coefficient estimates. In what follows we use the coefficient estimates from column (3).

The unconditional correlation between price paid per calorie and number of shopping trips is negative, but Table 5.1 shows that once we control for other choice variables and household fixed effects, the estimated coefficient on number of shopping trips is positive, although small. Conditional on shopping basket characteristics, household caloric requirements and fixed attributes of households, undertaking an additional shopping trip results in a slight increase in price per calorie. This result differs from Aguiar and Hurst (2007), who find that older households pay lower prices because they shop more frequently than other households. Our setting differs in that we focus on within household changes in behaviour, rather

Table 5.1: *Coefficient estimates*

	(1) $\ln(P_{ht})$		(2) $\ln(P_{ht})$		(3) $\ln(P_{ht})$	
ln(Ntrips)	-0.031^{***}	(0.001)	0.021^{***}	(0.001)	0.022^{***}	(0.001)
ln(Nstores)	0.045^{***}	(0.001)	0.010^{***}	(0.001)	0.010^{***}	(0.001)
ln(DISCOUNTER+1)	-0.068^{***}	(0.003)	-0.065^{***}	(0.002)	-0.066^{***}	(0.002)
ln(SALE+1)	-0.348^{***}	(0.003)	-0.143^{***}	(0.003)	-0.141^{***}	(0.003)
ln(SALE_AV+1)	-2.148^{***}	(0.012)	-0.578^{***}	(0.011)	-0.577^{***}	(0.011)
ln(GEN+1)	-1.119^{***}	(0.003)	-0.501^{***}	(0.003)	-0.499^{***}	(0.003)
ln(BIG+1)	-0.467^{***}	(0.003)	-0.218^{***}	(0.003)	-0.216^{***}	(0.003)
ln(shr_sug+1)	0.361^{***}	(0.012)	0.141^{***}	(0.009)	0.142^{***}	(0.009)
ln(shr_sfat+1)	1.941^{***}	(0.014)	1.098^{***}	(0.012)	1.094^{***}	(0.012)
ln(shr_ufat+1)	1.025^{***}	(0.014)	0.379^{***}	(0.011)	0.374^{***}	(0.011)
ln(shr_prot+1)	5.512^{***}	(0.019)	4.073^{***}	(0.015)	4.063^{***}	(0.015)
ln(fibre)	-0.004^{***}	(0.001)	-0.063^{***}	(0.001)	-0.064^{***}	(0.001)
ln(salt)	-0.026^{***}	(0.001)	-0.010^{***}	(0.000)	-0.010^{***}	(0.000)
ln(shr_Fruit+1)	2.402^{***}	(0.010)	1.602^{***}	(0.009)	1.595^{***}	(0.009)
ln(shr_Veg+1)	0.578^{***}	(0.007)	0.459^{***}	(0.006)	0.459^{***}	(0.006)
ln(shr_Dairy+1)	-0.327^{***}	(0.009)	-0.005	(0.008)	-0.005	(0.008)
ln(shr_CheeseFats+1)	-0.554^{***}	(0.010)	-0.249^{***}	(0.008)	-0.245^{***}	(0.008)
ln(shr_RedMeatNuts+1)	-0.549^{***}	(0.010)	-0.084^{***}	(0.008)	-0.080^{***}	(0.008)
ln(shr_PoultryFish+1)	-0.843^{***}	(0.014)	-0.566^{***}	(0.011)	-0.559^{***}	(0.011)
ln(shr_Drinks+1)	1.147^{***}	(0.013)	0.949^{***}	(0.011)	0.948^{***}	(0.011)
ln(shr_PrepSweet+1)	0.333^{***}	(0.007)	0.289^{***}	(0.006)	0.289^{***}	(0.006)
ln(shr_PrepSavory+1)	0.608^{***}	(0.007)	0.657^{***}	(0.006)	0.658^{***}	(0.006)
ln(shr_Alcohol+1)	2.485^{***}	(0.008)	2.163^{***}	(0.008)	2.162^{***}	(0.008)
Region-time effects	Yes		Yes		Yes	
Household fixed effects	No		Yes		Yes	
Time varying hh characteristics	No		No		Yes	

Notes: Estimated with 466,341 observations on 14,694 households' monthly grocery purchases over 2005-2012. Time varying household characteristics include age of the youngest child, the age of the main shopper, calorie requirement of the household and employment status of household main shopper and household head. Standard errors in parentheses. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

on cross sectional comparisons. We also find little impact of visiting an additional retailer on price paid per calorie – the coefficient is positive, but as we show below, economically very small. Our other two measures of shopping effort turn out to be more important. Buying a larger share of calories from discounters, all else equal, lowers price paid per calorie. Purchasing more calories on sale, conditional on controlling for how much food is available on sale, leads to a reduction in price paid per calorie. Both of the "other basket characteristics" have the expected coefficient sign: purchasing a higher share of calories from generic products, or switching towards larger pack sizes acts to lower price paid per calorie, all else equal.

The coefficients on the macronutrients (sugar, saturated fat, unsaturated fat and protein) measure the effect of these characteristics on price per calorie relative to the omitted category, non-sugar carbohydrates. Protein is considerably more expensive than the other macronutrients; non-sugar carbohydrates are the cheapest. More fibrous and more salty food acts to lower price per calorie. The food group coefficients capture the effect on price per calorie relative to grains (the omitted category). The coefficients suggest that, all else equal, increasing the share of calories from alcohol and fruit increases price per calorie by the most, and increasing the shares of cheese and fats and poultry and fish lowers price per calorie by the most. Poultry and fish are a relatively expensive source of calories; the negative coefficient for this group is explained by the fact that we control separately for the share of calories from protein in the regression, and they are a relatively cheap source of protein.

5.2 Importance of different adjustment mechanisms

In Section 2 we showed that households smoothed the amount of calories they purchased over the Great Recession. They did this by acting to reduce the (real) price per calorie of their shopping baskets both through increased shopping effort, and by switching to food products that were cheaper in per-calorie terms. In this section we use the estimates from the price function to quantify how important each of the choice variables were in allowing them to do this.

Table 5.2 summarizes these results. The average price per calorie households paid increased by 17.7 log points (around 19.4%) between 2005-2007 and 2010-2012. This increase was driven largely by factors outside households' control, such as general food price inflation (the food and drink component of the CPI rose strongly and more quickly than general prices over this time - see Section 2.1). Had households not changed their shopping behaviour the average price per calorie would have increased by 20.3 log points (around 22.5%). Changes in within household behaviour led to a 2.6 log point (approximately a 3.1%) reduction in price paid per calorie. The bottom three rows of Table 5.2 show the contribution made by changes in shopping effort, nutrient characteristics (including food groups) and other characteristics. Increased shopping effort acted to lower the average price paid per calorie by 1.06 log points; changes in the nutrient characteristics acted to lower it by 0.93 log points; changes in the other characteristics of the shopping basket acted to lower price paid by 0.60 log points. All three mechanisms were important in allowing households to smooth their consumption over this period.

Table 5.2: *Changes in log price paid per calorie; estimates from model*

	All households
Change in $\widehat{\ln(P_{ht})}$	17.74
Change in $\widehat{\ln(P_{ht})}$, no behavior	20.34
Change in $\widehat{\ln(P_{ht})}$, due to behavior	-2.59
of which	
shopping effort	-1.06
nutrient characteristics	-0.93
other characteristics	-0.60

Notes: Numbers are the average within household change. Row 1 is change in predicted $\ln(P_{ht})$*. Row 2 is change in predicted* $\ln(P_{ht})$ *holding fixed the choice variables* $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$*. Row 3 is change in predicted* $\ln(P_{ht})$ *holding fixed all variables other than the choice variables* $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$*. All numbers are multiplied by 100.*

In Table 5.3 we present further details of the contribution of changes in each choice variable to the overall 2.6 log point decline in price paid per calorie. The use of sales (holding fixed the amount of calories available on sale) is the most important mechanism that households used. A switch towards buying more calories from generic products was important in reducing price paid per calorie, leading to a 0.84 log point reduction. Substitution to smaller pack sizes acted to increase price paid per calorie by 0.24 log points.

The reduction in price per calorie through changing the nutritional characteristics was principally due to a switch away from protein, saturated fat and alcohol (all relatively costly per calorie) and towards fibre, non-sugar carbohydrates and vegetables (which are relatively cheap per calorie). Although households changed the nutritional composition of their shopping basket, as we showed in Section 2.2, this did not lead to a fall in the overall nutritional quality of the basket for two reasons. First, the reasonably large differences in the relative prices of nutrients means that even small changes in the nutritional balance of the basket can have a considerable impact on its price. Second, households substituted across nutrients and food groups in such a way that the "good" changes offset the "bad", allowing them to maintain the same average nutritional quality as they had purchased prior to the recession. Households switched towards cheaper characteristics (e.g. generic products) and away from more expensive characteristics (e.g. protein, alcohol) in such a way as to maintain the number of calories they were able to purchase and the average nutritional quality of these calories.

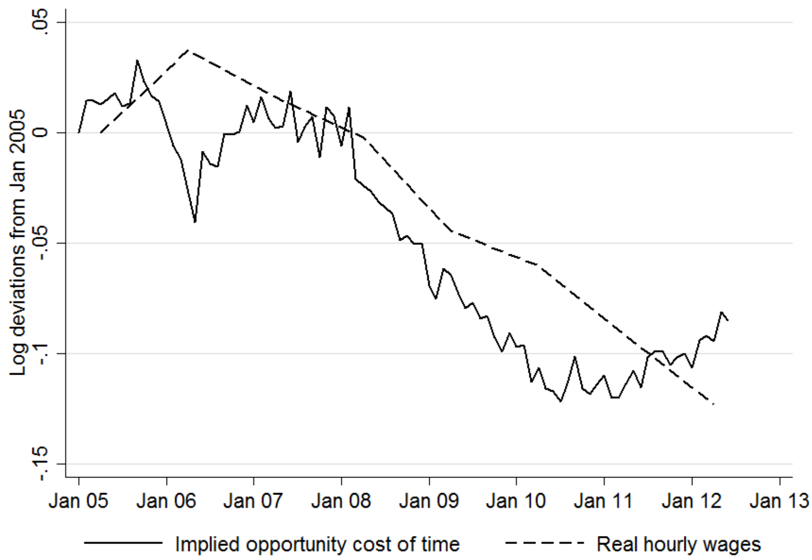
Table 5.3: *Contribution of choice variables to change in price paid per calorie*

	Contribution	% total reduction
Shopping effort:		
Number of shopping trips	-0.02	0.8
Number of chains visited	0.03	-1.2
Savings from discounter	-0.09	3.5
Savings from sales	-0.97	37.6
Total	-1.06	40.8
Nutrient characteristics:		
Protein	-0.43	16.7
Saturated fat	-0.22	8.5
Unsaturated fat	0.05	-1.9
Sugar	0.01	-0.4
Fibre	-0.39	15.1
Salt	0.06	-2.3
Fruit	0.28	-10.6
Vegetables	-0.23	8.9
Dairy	0.00	0.0
Cheese and fats	-0.00	0.0
Poultry and fish	-0.11	4.3
Red meat and nuts	0.04	-1.6
Drinks	-0.04	1.6
Prepared sweet	0.11	-4.3
Prepared savory	0.02	-0.8
Alcohol	-0.08	3.1
Total	-0.93	35.8
Other characteristics:		
Share from generic products	-0.84	32.6
Share of groceries from big pack sizes	0.24	-9.3
Total	-0.60	23.1
Total	-2.59	100.0

Notes: The first column reports the contribution each variable made to the fall in price paid per calorie. The contribution is given by the product of the coefficient in column 3 of Table 5.1 and average change in log of the transformed variable, controlling for fixed effects (multiplied by 100). The second column reports the percentage of the total reduction in price paid per calorie made by each variable.

We argue that the use of sales (conditional on the availability of products that are offered on sale) is a proxy for effort or time spent shopping. The model we outline in Section 3.1 (condition (3.3) in particular) implies that we can use observed changes in households' shopping effort and their grocery purchases to infer how the opportunity cost of time has varied over time. As Aguiar and Hurst (2007) point out, this measure of the opportunity cost of time has the advantage that it allows us to be agnostic about households' behaviour in the labour market. Given the functional form we assume for the price function, we can write the opportunity cost of time as $\omega_{ht} = -\alpha \frac{\tilde{P}_{ht} C_{ht}}{1+e_{ht}}$ where $\tilde{P}_{ht}$ is expressed in "real" terms (meaning that variation over time in $\tilde{P}_{ht}$ captures changes in price paid per calorie resulting from changes in household behaviour; general food price inflation is removed). The solid line in Figure 5.1 plots the average path of the implied opportunity cost of time over 2005-2012. Over this time period households reduced their real food expenditure, but increased their shopping effort (as measured by our proxy), and this suggests a fall in the opportunity cost of time. As a comparison the dashed line shows real mean gross hourly wages. Our estimate of the opportunity cost of time tracks the cost of time as measured by mean wages reasonably closely.

Figure 5.1: *Implied opportunity cost of time*



Notes: Solid line shows deviations of logged opportunity cost of time from its value in January 2005, after deseasonalising and controlling for fixed effects, and is smoothed using a 7-point moving average. The dashed line plots real hourly wages: mean gross hourly wages from the Annual Survey of Hours and Earnings deflated using the food and drink component of the CPI.

In Section 2 we showed that households of all types acted to smooth their calorie purchases over the recession, despite large declines in real food expenditure. We explore whether the ways in which they did this varied across households of different types, both by household composition and household income. Table 5.4 repeats the analysis above for the different household groups. The first three columns show the average change, the change in the absence of any behavioural change and the change due to households' adjustments in behaviour. The remaining columns separate the change due to behaviour into the contributions made by households' decisions over: shopping effort, nutrient characteristics and other characteristics. Tables A.2 and A.3 in the Appendix break this down and provides details of the contribution made by each of the individual choice variables that we include in the price regression.

Table 5.4: *Changes in log price paid per calorie, by household composition*

	(1)	(2)	(3)	(4)	(5)	(6)
	Change in $\widehat{\ln(P_{ht})}$			Change due to behaviour, *of which:*		
	Total	no behaviour	due to behaviour	Shopping effort	Characteristics: Nutrient	Other
All	17.74	20.34	-2.59	-1.06	-0.93	-0.60
pre-school children	13.98	19.16	-5.19	-1.66	-2.76	-0.77
school aged children	18.57	19.80	-1.23	-1.36	0.37	-0.24
adults	17.74	20.31	-2.57	-1.00	-0.99	-0.59
pensioners	18.13	20.66	-2.53	-0.87	-0.93	-0.73
working high income	16.14	19.73	-3.58	-1.26	-1.56	-0.76
working mid income	17.45	20.03	-2.57	-1.22	-0.79	-0.57
working low income	18.35	20.39	-2.04	-1.14	-0.23	-0.68
unemployed	18.06	20.34	-2.27	-1.15	-1.02	-0.10

Notes: Column 1 is change in predicted $\ln(P_{ht})$*. Column 2 is change in predicted* $\ln(P_{ht})$ *holding fixed the choice variables* $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$*. Column 3 is change in predicted* $\ln(P_{ht})$ *holding fixed all variables other than the choice variables* $(\mathbf{e_{ht}}, \mathbf{z_{ht}})$*; columns 4-6 show the contribution of changes in shopping effort, nutrient characteristics and other characteristics to the change due to behaviour shown in column 3. All numbers are multiplied by 100. Household group definitions shown in the notes to Table 2.1.*

Households with pre-school children acted to decrease the per calorie price they paid by over 5 log points – more than other household types. Approximately 30% of this was due to increased shopping effort and, in particular, a greater use of sales. Households with young children also switched to buying more of their groceries in the form of generic products. The remaining reduction in the average price per calorie is due to changes in the nutritional composition of their shopping basket, mainly through a fall in the share of calories bought as protein and saturated fat. As shown in Section 2.2, this did not lead to a fall in the average nutritional quality of the baskets purchased by these households. Households with school-age children also reduced the price that they paid per calorie, but by less than households with younger children: the majority of the fall is due to an increase in the use of sales.

Households without children (both pensioner and non-pensioner) changed their behaviour in similar ways to each other. The overall effect of changes in their shopping behaviour was to reduce the price they paid per calorie by around 2.5 log points. Like other household types, households with no children lowered their price paid per calorie by making greater use of sales, and like households with pre-school children, they switched towards cheaper nutrients and food groups.

The results are similar when we conduct the analysis across households of different income levels. Working households with higher income reduced the price they paid per calorie by the most – by over 3.5 log points. They saved 1.3 log points through greater use of sales. Working households with middle levels of income also increased their use of sales; the big difference between these and higher income households is that the latter group switched more towards cheaper nutrients. Low income working households and unemployed households increased their shopping efforts by similar amounts, but while low income working households substituted more to generic products, unemployed households opted to switch between nutrients to reduce the price they paid per calorie.

Although the relative importance of the different mechanisms varies somewhat, every household type (apart from those with school-age children, who switched to more expensive nutrients) used all three mechanisms to smooth their calorie purchases over this period. Even for those household types for which substitution across nutrient characteristics was particularly important, the average nutritional quality of the baskets of these household types remained stable over this period: households acted to smooth both the quantity and nutritional quality of food purchased over the recessionary period.

5.3 Robustness

5.3.1 Functional form of price equation

To check that our results are not driven by the double-log functional form we assume for the price function, we repeat the analysis using an alternative polynomial specification:

$$P_{ht} = a_1\mathbf{e_{ht}} + a_2\mathbf{e_{ht}}'\mathbf{e_{ht}} + b_1\mathbf{z_{ht}} + b_2\mathbf{z_{ht}}'\mathbf{z_{ht}} + \gamma\mathbf{x}_{ht} + \tau_{ht} + \eta_h + \epsilon_{ht}, \tag{5.1}$$

maintaining the same exogeneity assumption (3.11). Rather than repeat all tables from Section 5 we note that both the baseline and polynomial specification predict approximately a 3% fall in average price paid per calorie due to variation in household behaviour and in the first two columns of Table 5.5, for each specification, we report the percentage contribution that each of changes in shopping effort, nutrient characteristics and other characteristics made to this reduction. This shows that both specifications yield similar results.

We also estimate the double-log model letting the coefficients on the basket characteristic, $\mathbf{z}$, vary across the pre, during and post Great Recession time periods. This allows for the possibility that differential inflation across food products may have changed the implicit relative price of characteristics. In the third column of Table 5.5 we summarize the results from this specification. Allowing for time-varying characteristic coefficients yields an even larger impact of household behaviour on price paid per calorie; reinforcing our findings. The relative contribution of each channel of adjustment is broadly similar to our baseline model (results available from the authors on request).

Table 5.5: *Changes in log price paid per calorie, alternative specification*

	Specification		
	Double-log (baseline)	Polynomial	Time varying $\mathbf{z}$ coefficients
% change in P_{ht} due to behavior	-3.1	-3.0	-4.8
share due to			
shopping effort	40.8%	45.6%	49.0%
nutrient characteristics	35.8%	34.1%	28.7%
other characteristics	23.1%	20.3%	22.2%

Notes: Row 1 is the percentage change in P_{ht}, holding fixed all variables other than the choice variables ($\mathbf{e_{ht}}, \mathbf{z_{ht}}$). It shows average within household changes. Rows 3-5 show the fraction of the decline that is attributable to each set of choice variables. Column 1 of this table corresponds to the bottom 4 rows of Table 5.2; here the numbers are percentage changes rather than changes in log points.

5.3.2 Food out

Our data are very detailed for food purchased for home consumption, in particular allowing us to measure price and nutrients very accurately. We do not have the same kind of detailed information on purchases of food that is consumed outside the home (e.g. restaurant food and takeaways). However, from the Living Costs and Food Survey (LCFS) we know that although food out (which includes takeaways and food eaten in restaurants) constitutes approximately 36% of total food expenditure, it accounts for only 12-13% of total calories purchased. Therefore, nutritionally, food at home is by far the most important component of households' total food consumption.

We use the data to look at the changes in real expenditure and calories for food at home, which fell by around 6% and 1% respectively - similar changes to those we see in the Kantar data (shown in Table 2.1). Real expenditure and calories from food out both fell by around 10%. However, the LCFS shows that overall expenditure on food (in and out) fell by 7% between 2005-2007 and 2010-2012 and calories fell by just 2%: the pattern of consumption smoothing is evident across total food purchases, not just for food at home.

Table 5.6: *Changes in food at home and food out*

Real expenditure (£ per adult equivalent per month)	2005-2007	2010-2011	Change	% change
Food at home	121.02	114.00	-7.02	-5.8
Food out	70.45	63.76	-6.69	-9.8
Calories (per adult equivalent per day)				
Food at home	2505	2478	-27	-1.1
Food out	381	342	-39	-10.3

Notes: Data from the Living Costs and Food Survey 2005-2011. Real expenditure on food at home is nominal expenditure on food at home deflated by the CPI component for food and drink at home (in 2008 prices). Real expenditure on food out is nominal expenditure on food out deflated by the CPI component for food eaten out (in 2008 prices). Real expenditure is per adult equivalent per month; calories are per adult equivalent per day.

5.4 Summary of results

In summary, in the UK over the Great Recession reductions in household income were coupled with strong food price inflation. The price of the CPI food and drink basket rose by more than the general price level between 2005-2007 to 2010-2012. In Section 2 we present a number of key facts about household food spending over this period: i) average food spending failed to keep pace with rising food prices as measure by the CPI (and so real food expenditure fell), ii) the average amount of calorie purchases fell only slightly, and by less than expenditure, and iii) the nutritional quality of calorie purchases was stable. These facts indicate that households responded to the deteriorating economic circumstances by switching to calories that were cheaper in *real* terms and the nutritional quality of their food baskets did not decline.

Households may have achieved this by altering the composition of their food basket, or by increasing their shopping effort, thereby acting to lower the price they paid for a fixed basket of groceries. To understand the relative importance of these factors we study how the price per calorie that households paid for their groceries changed over 2005-2012. The price that households paid per calorie rose in nominal terms, not surprising given the large increases in food price levels. However, once we strip out the effect of changes in the general level of food prices and other factors related to the supply side, such as the availability of goods on sale, we find that changes in household behaviour acted to lower the average price households paid per calorie for their groceries. In particular, we find that holding fixed the market environment (i.e. prices and the quantity of food on sale), changes in households' behaviour acted to reduce the price paid per calorie by 3.1%; over 40% of this was due to increased shopping effort, and the remaining reduction was due to changes in the characteristics of the basket of foods that households purchased. This general pattern is evident across all household types, although households with children made larger adjustments than other household types, on average.

6 Conclusions

Aguiar and Hurst (2005) make a convincing case that observed falls in food expenditure at retirement do not translate into falls in consumption. Rather, households increase time spent shopping and in home production to hold their food consumption broadly constant over retirement, in part due to the fall in their opportunity cost of time. Nevo and Wong (2014) and Coibion et al. (2014) show that US households used similar mechanisms to cope with the Great Recession. In this paper we show that in response to *unexpected* worsening in the economic environment households acted to smooth two aspects of their consumption – total calories and their nutritional quality – by increasing their shopping effort and adjusting other aspects of consumption, namely the characteristics of their shopping basket. This provides a further explanation for how households are able to use alternative mechanisms to partially insure themselves against adverse shocks (Blundell et al. (2014)).

We use detailed longitudinal data on grocery purchases that span the period of the Great Recession. Over this period the economic environment deteriorated substantially. Households were subject to depressed real wages, higher unemployment and asset price reductions. At the same time, food prices rose sharply. While some households may have been shielded by the benefit system from the income and asset price shocks associated with the recession, all households faced increases in the price of food relative to the overall price level. We show that households changed their shopping behaviour in ways that lowered the average per calorie price of their shopping basket. Spending more time shopping and substituting across characteristics of the shopping basket (which would have made households worse off), nonetheless allowed them to maintain their calorie purchases while reducing their real food expenditure.

The reduction in average price per calorie has raised concern that people have switched to foods of poorer nutritional quality. We show that much of the decline in per calorie spend was driven by margins of change which do not involve altering the nutritional quality of food baskets: households expended more effort shopping (in particular increasing their use of sales) and switched to lower priced generic products. Nevertheless, for most household types, there was substitution towards cheaper nutrients and food groups. Using a single index measure of diet quality we quantify the nutritional importance of these changes and show that the average nutritional quality of food purchases did not materially fall. Our overall conclusion is that households are better able to weather economic turbulence than is suggested by merely looking at their aggregate food expenditure.

A Additional Tables

Table A.1: *Changes in the Healthy Eating Index*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
				Household type				Employment status and income			
								Working; income:			
	Max score	Mean score	All households	Pre-school children	School age children	No children, no pensioners	Pensioner households	High	Middle	Low	Unemp.
Mean HEI in 2005-2007	100	49.0	49.0	48.7	46.1	47.8	51.5	49.6	48.0	46.6	46.7
Total change to 2010-2012			0.72	1.52	1.03	1.46	-0.23	0.87	1.03	2.01	1.11
of which											
'Good' change			1.45	3.02	1.90	1.93	0.91	1.78	1.78	2.44	1.67
'Bad' change			-0.72	-1.51	-0.87	-0.46	-1.14	-0.91	-0.75	-0.43	-0.56
			which consists of changes in the component scores:								
Total fruit	5	3.06	-0.02	0.12	-0.05	0.02	-0.05	-0.05	-0.05	-0.07	0.04
Whole fruit	5	3.36	0.08	0.26	-0.07	0.18	0.03	0.11	0.05	0.03	0.19
Total vegetables	5	3.20	-0.13	-0.34	-0.05	-0.04	-0.20	-0.12	-0.12	-0.13	-0.02
Dark green/orange veg	5	1.61	0.00	-0.07	0.07	0.09	-0.09	0.05	-0.00	0.09	0.10
Total grains	5	3.69	-0.03	0.08	0.01	-0.04	-0.07	-0.07	-0.00	0.10	0.02
Whole grains	5	1.55	-0.11	-0.38	-0.14	-0.08	-0.06	-0.26	-0.18	-0.03	-0.08
Milk	10	5.28	-0.05	-0.59	-0.31	0.07	0.06	-0.21	-0.15	-0.11	-0.12
Meat	10	7.96	-0.22	-0.13	-0.06	-0.17	-0.33	-0.20	-0.13	-0.03	-0.17
Oils	10	4.93	-0.18	0.09	-0.20	-0.14	-0.30	0.02	-0.11	-0.06	-0.17
Sodium	10	6.42	0.93	1.31	0.93	1.00	0.77	1.10	1.11	0.95	0.93
Saturated fat	10	2.70	0.27	0.80	0.60	0.24	0.06	0.34	0.41	0.66	0.38
Calories from SoFAAS	20	5.22	0.18	0.36	0.28	0.33	-0.05	0.16	0.21	0.61	0.43

Notes: Row 1 shows the mean overall HEI score for all households (column (3)) and each household type (columns (4)-(11)) in 2005-2007; row 2 shows the average within household change in the HEI from 2005-2007 to 2010-2012. This is the sum of the changes in the component scores; these are shown in the bottom panel of the table. 'Good change' (shown in row 3) is the sum of the positive changes in the bottom panel; 'Bad change' (shown in row 4) is the sum of the negative changes in the bottom panel. Column (1) shows the maximum score for each component; these sum to 100 (the maximum score for the HEI). Column (2) shows the mean component score in 2005-2007 across all households. "Calories from SoFAAS" is the share of calories from solid fat, added sugar and alcohol. The group "Pensioners" within the "Employment status and income" division are identical to the group of households in "Pensioner households", shown in column (7).

Table A.2: *Contribution of choice variables to change in price paid per calorie, by household composition*

	Households with children		Households without children	
	Youngest child is: Pre-school	School age	No pensioners	Pensioners
Shopping effort:				
Number of shopping trips	-0.13	-0.14	0.02	-0.01
Number of chains visited	-0.02	-0.02	0.04	0.03
Savings from discounter	-0.13	-0.02	-0.07	-0.12
Savings from sales	-1.38	-1.18	-0.99	-0.78
Total	-1.66	-1.36	-1.00	-0.87
Nutrient characteristics:				
Protein	-1.42	1.04	-0.39	-0.77
Saturated fat	-0.71	-0.49	-0.20	-0.07
Unsaturated fat	-0.01	0.12	0.01	0.04
Sugar	0.10	-0.04	0.03	0.00
Fibre	-0.54	-0.36	-0.42	-0.32
Salt	0.08	0.07	0.07	0.04
Fruit	0.33	-0.07	0.46	0.30
Vegetables	-0.44	-0.06	-0.14	-0.34
Dairy	0.00	0.01	-0.00	-0.00
Cheese and fats	0.06	-0.01	-0.01	0.02
Poultry and fish	-0.13	-0.24	-0.09	-0.09
Red meat and nuts	0.02	0.01	0.03	0.06
Drinks	0.06	0.30	-0.13	-0.09
Prepared sweet	0.31	-0.09	0.11	0.18
Prepared savory	0.11	0.06	-0.27	0.31
Alcohol	-0.58	0.10	-0.05	-0.19
Total	-2.76	0.37	-0.99	-0.93
Other characteristics:				
Share from generic products	-1.11	-0.43	-0.75	-1.02
Share of calories from big packs	0.34	0.19	0.17	0.29
Total	-0.77	-0.24	-0.59	-0.73
Total	-5.19	-1.23	-2.57	-2.53

Notes: The table reports the contribution each variable made to the fall in price paid per calorie. The contribution is given by the product of the coefficient in column 3 of Table 5.1 and average change in log of the transformed variable, controlling for fixed effects (multiplied by 100). "Pre-school" denotes children aged between 0 and 5; "school age" between 6 and 17. "Pensioner" households are those in which at least one member is aged 65 or over.

Table A.3: *Contribution of choice variables to change in price paid per calorie, by employment status and income*

	Working; income:			
	High	Middle	Low	Unemployed
Shopping effort:				
Number of shopping trips	-0.02	-0.05	-0.03	-0.07
Number of chains visited	-0.00	0.02	0.04	0.01
Savings from discounter	-0.10	-0.07	-0.09	-0.04
Savings from sales	-1.14	-1.12	-1.06	-1.05
Total	-1.26	-1.22	-1.14	-1.15
Nutrient characteristics:				
Protein	-0.64	-0.18	0.69	-0.09
Saturated fat	-0.24	-0.28	-0.53	-0.37
Unsaturated fat	0.17	0.05	0.04	0.02
Sugar	0.00	0.02	-0.01	0.01
Fibre	-0.42	-0.39	-0.35	-0.48
Salt	0.08	0.08	0.06	0.05
Fruit	-0.04	0.13	0.19	0.35
Vegetables	-0.21	-0.20	-0.21	-0.08
Dairy	0.00	0.00	0.00	0.00
Cheese and fats	-0.10	-0.03	0.01	0.03
Poultry and fish	-0.13	-0.16	-0.22	-0.08
Red meat and nuts	0.02	0.03	0.01	0.02
Drinks	0.08	-0.02	0.07	-0.05
Prepared sweet	0.09	0.09	-0.05	0.07
Prepared savoury	-0.24	-0.23	-0.13	-0.03
Alcohol	0.04	0.31	0.22	-0.40
Total	-1.56	-0.79	-0.23	-1.02
Other:				
Share from generic products	-0.88	-0.72	-0.99	-0.37
Share of groceries from big pack sizes	0.12	0.16	0.31	0.27
Total	-0.76	-0.57	-0.68	-0.10
Total	-3.58	-2.57	-2.04	-2.27

Notes: The table reports the contribution each variable made to the fall in price paid per calorie. The contribution is given by the product of the coefficient in column 3 of Table 5.1 and average change in log of the transformed variable, controlling for fixed effects (multiplied by 100). Working households are those in which the head of the household works more than 8 hours a week. Income is measure using social grade; grade AB/C/DE correspond to high/middle/low income.

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