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Relative prices, consumer preferences, and the demand for food

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Abstract Shocks to world commodity prices and the depreciation of sterling led to a large increase in the price of food in the UK. It also resulted in large changes in the relative prices of different foods. We document these changes, and consider how they affected the composition of households' shopping baskets. We isolate the impact of changes in relative food prices from variation in preferences using data on purchasing decisions made by a representative panel of British households. We show that changes in relative food prices led to a worsening in the nutritional quality of households' shopping baskets, though this was partially mitigated by offsetting changes in preferences.

Keywords: prices, preferences

JEL classification: D12, Q11

I. Introduction

The real price of food that consumers face (i.e. the price of food relative to the overall price level) increased sharply from the end of 2007 to the beginning of 2009 and has remained high since then. There has been considerable public and policy concern about the impact that this, and the contemporaneous deep recession, has had on households' ability to purchase a nutritious diet (Taylor-Robinson *et al.*, 2013; Anderson *et al.*, 2013). The increase in the average price of food was accompanied by big changes in the relative prices of different food groups; the latter has been less well studied and yet may also have important consequences for the balance of households' diets. We document the changes in relative prices and describe concurrent changes in the foods that households purchased. We estimate a model of demand

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that relates food choices to prices and nutrient characteristics. This allows us to study the impact of changing relative food prices and preferences on households' food purchases.

Our interest lies in understanding how the large changes in relative prices affected the nutritional quality of households' shopping baskets. If we were simply to look at how the nutritional composition of grocery baskets has evolved over time, this would potentially conflate the effect of relative food prices with other possible changes. For instance, it is possible that food preferences for specific foods and nutrients might have changed over time. Government policy has actively tried to change eating behaviour in the last decade: the '5-a-day' policy was introduced to encourage people to consume more fruit and vegetables, and information campaigns have highlighted the dangers of high salt and saturated fat consumption. In order to isolate the effect of prices on the nutritional characteristics of households' shopping baskets we estimate the demand system proposed by Dubois *et al.* (2014), hereafter DGN.

Our results suggest that changes in relative prices had an important impact on households' food purchasing behaviour, but that there were also changes in preferences for both nutrients and food groups over this period. For example, calories from fruit increased, and calories from ready meals fell, despite the relative price of fruit increasing and that of ready meals falling. The reason for this was shifts in preferences that offset the effect of relative price changes—e.g. preferences for sugar declined, while preference for fruit increased. Failure to control for these changes in preferences and other factors would lead to an inaccurate estimate of the impact of price movements on nutrition over this period.

We use the DGN model, which allows consumers to have preferences over both food groups and nutrients. This model nests both demand systems over products, such as the Almost Ideal Demand System (Deaton and Muellbauer, 1980) and over characteristics, such as the discrete choice model (McFadden, 1973; Berry *et al.*, 1995). For a discussion of how this model fits within the broader demand literature, see DGN. In order to take the model to data, we follow DGN and make functional form assumptions that are somewhat restrictive: they do not allow for income effects within households, and they limit the extent to which price effects can be non-linear. DGN use the model to analyse how much of the differences in food purchasing choices across the US, UK, and France can be explained by differences in prices, preferences, and attributes of foods. Rather than making a cross-sectional comparison of food purchases across countries, we use the model to explore how differences in relative prices over time impacted households' shopping baskets, controlling for changes in preferences over food groups and nutrients.

The structure of the rest of this paper is as follows: in the next section we document the changes in relative food prices and discuss some of the main reasons for these changes. In section III we describe the data and the patterns in food purchasing behaviour over our period of analysis. Section IV sets out the demand model that we use, followed by our estimates from the model. In section V we present the results that isolate the effect of changes in relative food prices from other potentially confounding factors. A final section concludes and summarizes.

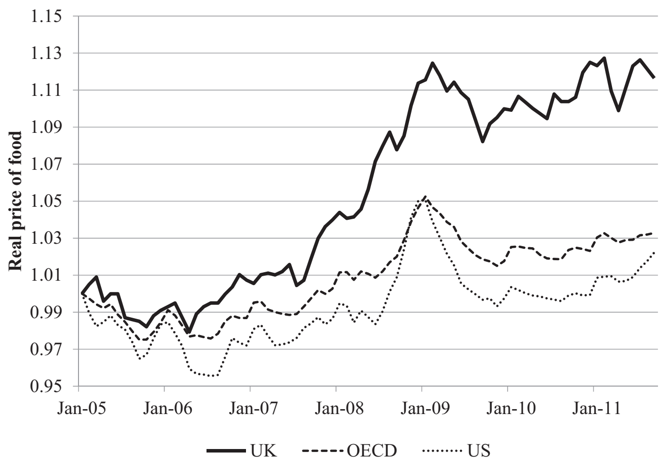
II. Food prices

In the UK the consumer price of food (relative to the consumer price for all goods) began to rise at the end of 2007, continued rising throughout 2008, and remained high.

Figure 1 (*a*) shows that this increase was higher and more persistent in the UK than in other OECD countries. The food price increase in 2008 came after a prolonged period of decline in the real price of food in the UK; Figure 1 (*b*) shows that over the previous three decades food prices rose more slowly than the price of other goods in the UK. Despite the recent increase in the price of food relative to the overall price level, food is still cheaper in the UK than in the rest of Europe.[1]

Figure 1: Real consumer food price increases

(*a*) Real consumer price of food in selected OECD countries



(*b*) Real consumer price of food in UK since 1975

Notes: Figure 1(*a*) plots the real price of food in the UK, the US, and the OECD average since 2005. Data is from OECD.Stat; lines show the consumer price index (CPI) for food over the CPI for all goods, relative to January 2005. Figure 1(*b*) plots the real price of food in the UK since 1975. Data are from the UK Office for National Statistics; the line shows the retail price index (RPI) for food over the RPI for all goods, relative to January 1975.

[1] In 2009 the real price level of food in the UK was 3 per cent below the EU average, see http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-28062010-AP/EN/2-28062010-AP-EN.PDF.

This marked increase in the consumer price of food was largely driven by a big depreciation in sterling and large increases in world commodity prices. At the beginning of 2008 there was a sharp fall in the price of sterling—for example, in the preceding 5 years, £1 was worth approximately €1.50; by the middle of 2008, this had fallen to almost €1.10.[2] The Department for Food and Rural Affairs (2010) documents the factors that contributed to the 2007/2008 agricultural price spikes. It shows that international (US dollar) reference prices for grains and oilseeds rose steeply in 2007 and the first half of 2008. There was also a large rise in the price of crude oil, which increased energy costs throughout the domestic food chain. Nonetheless, the magnitude of the price increases was not the same across all agricultural commodities. Some food commodities, such as meat, sugar, cocoa, tea, and coffee, experienced much smaller price increases than others, such as maize and rice. The sterling depreciation and large increases in world commodity prices are likely to have raised costs for UK food producers and sellers. However, the transmission between exchange-rate movements and commodity prices into the prices consumers face in the supermarket is complex, and cost shocks are not necessarily passed on one-for-one to consumers (see, *inter alia*, Kim and Cotterill, 2008; Nakamura, 2008; Nakamura and Zerom, 2010; Goldberg and Hellerstein, 2013; Bonnet *et al.*, 2013).

These factors affected food types differentially, meaning that the consumer prices of some food types rose by more than others. Consequently, there were large changes in the relative prices of different food groups. To simplify our analysis, in what follows we consider two distinct time periods: the years 2006–7 and 2010–11. The intervening period, 2008–9, was characterized by a high degree of volatility in food prices and the timing of price changes was not uniform across commodities. Comparison of these two periods allows us to compare household behaviour in two distinct economic environments.

Figure 2 shows the percentage changes in the relative prices of 13 food groups between 2006–7 and 2010–11. These numbers are computed using transaction level grocery prices; we give more details on the data in the following section. For each food type we compute the average price of products in that group and divide this by the average price of all food products. The figure shows the percentage change in the price of each food group relative to the overall price of food. The changes in prices are substantial. For example, the price of ready meals, pizza, and packaged meals fell by almost 7 per cent relative to the overall price of food, whereas the price of beans, nuts, and eggs increased by almost 8 per cent more than the overall food price. The relative price of ready meals and processed sweet food (including cakes, biscuits, and confectionery), generally considered to be less healthy, fell, while the relative prices of fruit and vegetables increased somewhat. It is likely that these considerable relative price changes affected households' food purchasing decisions and, hence, the nutritional quality of their shopping baskets.

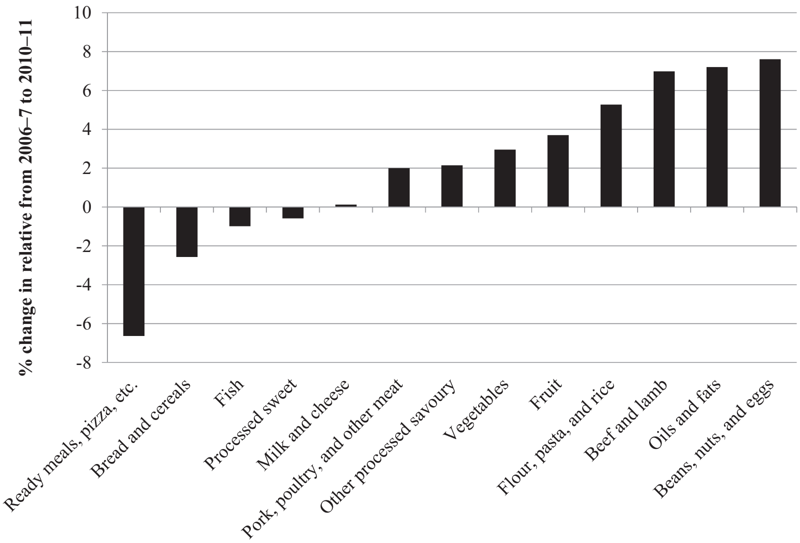
III. Changes in food purchasing behaviour

We focus on food bought for preparation and consumption at home (i.e. excluding takeaways and restaurant meals). This constitutes around 85 per cent of the calories purchased by households.[3] We use data on the grocery basket (excluding drinks and alcohol) purchased and brought home by a nationally representative sample of British

[2] Monthly average spot exchange data from Bank of England.

[3] Authors calculations using the *Living Costs and Food Survey 2008–2011*.

Figure 2: Changes in relative prices of different food groups



Notes: Bars show the percentage change in the relative price of each food group. Relative price is equal to the quantity-weighted average price of products within each food group over the quantity- weighted average price of all food products. Data used are described in section III; numbers are presented in Table 3.

households over the period 2006–11. The data are from Kantar Worldpanel. Households are recruited via stratified sampling and are offered vouchers from high street retailers as compensation for participation. Households record purchases using handheld scanners and upload till receipts, which allows Kantar to verify the accuracy of the scanner data. Kantar collect the nutritional information on individual food products from manufacturer databases and from product packaging. For further information on the data see Griffith and O'Connell (2009) and Leicester and Oldfield (2009). Other papers that discuss the use of these types of data, and compare them to other sources of information, include Einav *et al.* (2008) and Lusk and Brooks (2011).

Our sample contains over 22,000 households and we aggregate across purchases made by households within each year-quarter. We compare two periods, 2006–7 and 2010–11, which broadly accords with before and after the large shift in relative prices. We drop households that do not record any purchases for at least 14 days in each quarter (due to, for instance, being on holiday), and households that are present for fewer than two quarters in each period.

Table 1 shows the mean (across the distribution of household-quarters) calorie purchases, in total and from the macronutrients: protein, fat, and carbohydrates; we break fat down into saturated and unsaturated fat and we break carbohydrates down into sugar and non-sugar. All the numbers are expressed per person per day. We 'equivalize' to account for differences in household size and composition.[4] The table shows that

[4] To do this, we construct 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 gender. We sum the EARs of all household members and divide by 2,550; this equals 1 for a household containing only one adult male aged 19–59. If the household contained 1 adult male (EAR=2,550), 1 adult female (EAR=1,940), and one female infant (EAR=698) then the index would be 2.035=(2,550+1,940+698)/2,550; this means that if the household purchased 5,188 calories this would be 'equivalized' to 2,550 and so be comparable to a single adult male purchasing 2,550 calories.

Table 1: Mean calorie and macronutrient purchases across time periods

	2006–7	2010–11	% change
Total calories	1,775	1,767	–0.5
from protein	263	259	–1.7
from saturated fat	266	258	–3.0
from unsaturated fat	435	435	–0.1
from sugar	347	343	–1.1
from non–sugar carbohydrates	464	473	1.8
Proteins (g)	65.8	64.7	–1.7
Saturated fat (g)	29.6	28.7	–3.0
Unsaturated fat (g)	48.3	48.3	–0.1
Sugar (g)	92.4	91.4	–1.1
Non–sugar carbohydrates (g)	123.8	126.0	1.8
Real expenditure (£)	2.28	2.25	–1.2

Notes: Numbers are the mean of the distribution of household-quarters in each period. Calories are inferred from the quantity of macronutrients purchased. Real expenditure is nominal expenditure deflated by the price of all food, indexed to the first quarter of 2006. All numbers are per adult equivalent per day (equivalization described in footnote 4). The % change is the percentage change in the mean across the two periods.

calories per person per day fell slightly between 2006–7 and 2010–11. However, this masks larger changes in the composition of calories from the different nutrients: calories from protein fell by 1.7 per cent, while calories from saturated fat fell by 3 per cent. There was an increase in calories from non-sugar carbohydrates. The table also shows that there was a decline in 'real' expenditure over this period—households' nominal spending on food failed to keep pace with rising food levels. We define real expenditure as nominal expenditure deflated by the price of all food, which is indexed to the first quarter of 2006. This strips out the effect of the general food price inflation over this period. In what follows, all prices and expenditure are expressed in real terms, i.e. deflated in the way described above.

We are interested in how the changes in the relative prices of different foods affected the nutritional composition of households' shopping baskets. In our data we have information on more than 250,000 products (defined as a barcode, or universal product code (UPC)). To make the model tractable we aggregate these into 13 food groups; following the approach taken in DGN the food groups are based on goods that have similar nutritional composition. Table 2 shows the mean calories (per 100g) from each of the macronutrients in each food category. There is considerable variation in the calorie composition across the food groups. Meat and fish are high in protein, with beef and lamb containing more fat (both saturated and unsaturated fat) than pork, poultry, or fish. Milk and cheese, and oils and fats are very high in saturated fat. Processed sweet food is high in both sugar and saturated fat. The grains (bread, cereals, flour, pasta, and rice) contain the most carbohydrate calories, on average.

Table 3 shows the mean (across household-quarters) expenditure levels (per person per quarter) in 2006–7 and 2010–11, and the percentage change between these two periods. The group with the largest expenditure level is processed sweet food; while the expenditure level declined slightly, the expenditure share (not shown) of this group increased. Vegetables, milk and cheese, pork and poultry, and ready meals and pizza also have expenditure levels greater than £20 (which equates to an expenditure share of above 10 per cent). The smallest group is flour, pasta, and rice, with an expenditure level

Table 2: Calories from macronutrients, by food group

		Fat		Carbohydrates	
	Protein	**Saturated**	**Unsaturated**	**Sugar**	**Non-sugar**
Fruit	3.6	1.4	2.3	55.0	6.8
Vegetables	8.5	2.2	11.3	10.3	17.3
Bread and cereals	36.2	11.4	25.7	29.0	166.6
Flour, pasta, and rice	33.3	8.1	15.4	6.7	196.2
Milk and cheese	37.3	74.8	41.7	23.8	3.5
Oils and fats	21.8	170.2	309.2	4.7	3.9
Beef and lamb	81.2	48.7	60.9	0.5	1.0
Pork, poultry, and other meat	77.2	34.3	56.2	3.0	8.7
Fish	67.1	14.4	48.1	3.3	26.0
Beans, nuts, and eggs	62.0	45.1	172.5	17.0	19.7
Processed sweet	20.7	66.0	60.0	125.8	98.6
Ready meals, pizza, etc.	34.9	33.3	58.4	7.4	67.0
Other processed savoury	16.5	20.0	80.3	30.5	68.6

Notes: Calories are per 100g. Figures are the mean across the distribution of household quarters in both periods (2006–7 and 2010–11). Within each household-quarter the nutrients in each category is an average across all products bought, with each product given equal weight.

Table 3: Relative prices and expenditure levels, by food group

	Relative price (£ per kilo)			Expenditure (£ per quarter)		
	2006–7	**2010–11**	**% change**	**2006–7**	**2010–11**	**% change**
Fruit	1.48	1.54	3.70	15.90	16.06	0.96
Vegetables	1.17	1.21	2.96	23.29	22.64	–2.79
Bread and cereals	2.13	2.08	–2.57	18.24	17.67	–3.13
Flour, pasta, and rice	1.56	1.64	5.28	3.10	3.56	14.78
Milk and cheese	1.14	1.14	0.12	23.84	23.52	–1.34
Oils and fats	2.55	2.73	7.21	8.00	8.56	6.90
Beef and lamb	4.88	5.22	6.98	11.03	10.51	–4.78
Pork, poultry, and other meat	4.01	4.09	2.00	28.86	28.53	–1.17
Fish	5.16	5.11	–0.99	10.25	9.63	–6.11
Beans, nuts, and eggs	3.02	3.24	7.61	4.75	5.07	6.75
Processed sweet	3.43	3.41	–0.58	31.99	31.78	–0.67
Ready meals, pizza, etc.	3.13	2.92	–6.64	22.58	21.24	–5.95
Other processed savoury	2.57	2.62	2.15	19.51	19.93	2.15

Notes: Numbers are the mean of the distribution over household-quarters. Relative price is equal to the quantity-weighted average price of products within each food group divided by the quantity- weighted average price of all food products. Expenditure is real (deflation described in the text) and is expressed in £ per person per quarter. Percentage changes are the percentage changes in the means from 2006–7 to 2010–11.

of £3.10 in 2006–7, rising by almost 15 per cent in 2010–11. The table also shows the relative price level of each food group in 2006–7 and 2010–11 and the change between these two periods. The most expensive food groups are fish and meat, the cheapest are milk and cheese and vegetables. As shown in Figure 2 the largest relative price changes were in ready meals, pizza, and packaged food, and beef and lamb.

Changes in relative prices affect the expenditure shares of food groups in two ways: (i) by inducing households to change the quantities of each group that they buy and (ii) by changing the cost of a fixed quantity of each group. For example, an increase in the relative price of fruit could lead consumers to substitute away from fruit (i.e. reduce its *quantity* share), but it also means that the same quantity costs more following the price increase. The first effect would act to decrease the expenditure share, the second to increase it—the combined effect is ambiguous. To strip out the second effect, we look at the calorie shares of the food groups.

Table 4 shows the mean and changes in the number and share of calories from each food group. Processed sweet food constitutes over 20 per cent of total calories, both because of its large expenditure share and its high calorie content. Milk and cheese and oils and fats also have high calorie shares. There is some correlation between the relative price changes and the changes in the calorie shares. For example, the relative price of vegetables increased over 2 per cent and its calorie share declined by more than 7 per cent. Bread and cereals experienced a relative price fall and an increase in its calorie share. The large increase in the relative price of beef and lamb was accompanied by an 11 per cent decline in its calorie share. However, the pattern is not observed for all food groups—the relative price of fruit and its calorie share both increased, as did the relative price and calorie share of flour, pasta, and rice.

These descriptive statistics do not tell us what the causal effect of the relative price changes were on the composition of households' shopping baskets. It is likely that other changes contributed to the shifts in households' food purchasing behaviour. We use a demand model to identify the causal effect of relative price changes on food purchasing decisions.

IV. Demand model and estimation results

DGN introduce a demand model in which a household chooses continuous quantities of a large number of food products in order to maximize their utility. Their utility depends directly on the quantity consumed of each product and on the characteristics of the

Table 4: Calorie levels and shares, by food group

	Calories (per person per day)			Calorie shares (%)		
	2006–7	2010–11	% change	2006–7	2010–11	% change
Fruit	78	79	1.32	4.32	4.37	1.24
Vegetables	139	129	–6.95	7.71	7.16	–7.06
Bread and cereals	280	288	2.81	15.61	16.02	2.62
Flour, pasta, and rice	82	85	3.90	4.52	4.71	4.27
Milk and cheese	218	216	–0.80	12.09	12.05	–0.32
Oils and fats	209	206	–1.22	11.17	11.03	–1.29
Beef and lamb	46	40	–11.48	2.50	2.22	–11.05
Pork, poultry, and other meat	146	145	–0.94	8.05	7.99	–0.73
Fish	33	32	–2.03	1.81	1.78	–1.77
Beans, nuts, and eggs	30	30	–0.05	1.63	1.64	0.89
Processed sweet	383	382	–0.22	20.40	20.46	0.33
Ready meals, pizza, etc.	159	159	0.12	8.96	9.02	0.65
Other processed savoury	151	151	0.25	8.64	8.61	–0.32

Notes: Numbers are the mean of the distribution over household-quarters. Percentage changes are the percentage changes in the means from 2006–7 to 2010–11.

food products (i.e. their nutritional composition). At its most general, the model nests classical demand models in product space, such as the Almost Ideal Demand model, and those in characteristics space, such as the discrete choice demand model. Classical demand models, in which preferences are defined over goods, typically rely on the assumption of weak separability of preferences over individual products within broad aggregates, such as food groups; for example, the decision over whether to buy beef or lamb (i.e. products within the meat group) is independent of the decision over whether to purchase an oven pizza or pre-prepared lasagne (i.e. products within the ready meals group). An attractive feature of the DGN model is that it relaxes this assumption by creating an interaction between products in different food groups through the characteristics that they supply. However, in order to take the model to data, we follow DGN and make functional form assumptions that restrict income and price effects.

DGN show that under these assumptions, expenditure can be written as a function of the nutrients in each food group, household-specific preferences for food groups, and food-group-specific time effects. For the full derivation see DGN. Let households be indexed by i, food groups by j, food products by k, and time periods by t. The model generates the estimating equation:

$$\exp_{ijt} = \sum_{c} \beta_c z_{ijct} + \delta_{ij} + \zeta_{jt} + \varepsilon_{ijt} \tag{1}$$

where exp_{ijt} is real expenditure (nominal expenditure divided by the average price of all food, indexed to January 2006) by household i on food group j at time t.

The first term on the right-hand side sums over c nutrients (protein, saturated fat, etc.): z_{ijct} is the amount of nutrient c that household i gets from group j at time t, and the coefficients β_c tell us about the preferences for the different nutrients. The term δ_{ij} is a household-category fixed effect, which captures differences in preferences for food groups across households (some households like fruit more than others, while others prefer meat). ζ_{jt} is a time-category fixed effect, which captures variation in preferences over time (fruit might be more preferred in summer since it is of higher quality). The final term ε_{ijt} is an error term that will capture other unobserved shocks, which we need to be uncorrelated with the other variables on the right-hand side. However, it is quite likely that the error term is correlated with the z_{ijct} (making the variable endogenous), because the amount of a nutrient purchased is a function of the quantity purchased, and so is expenditure (i.e. exp_{ijt} equals price multiplied by quantity while z_{ijct} equals nutrient intensity times quantity). To deal with this endogeneity problem we follow the same instrumental variable (IV) strategy as used by DGN.

We estimate equation (1) separately in 2006–7 and 2010–11, both with and without instrumenting the nutrient variables. This allows all the parameters in equation (1) to vary across the two time periods; this will capture any changes in preferences over the period. An observation is a household-quarter-category. Table 5 shows the estimated coefficients (i.e. the $\hat{\beta}_c$) for each of the included nutrients. We allow the preference for protein to differ depending on whether it comes from an animal or not. We do not measure animal and non-animal protein, so to proxy this, we define animal protein to be all protein from the following categories: milk and cheese; oils and fats; beef and lamb; pork, poultry, and other meat; fish; and beans, nuts, and eggs. Protein from all other categories is classed as 'non-animal protein'.

Table 5: Coefficient estimates

	OLS		IV	
	2006–7	**2010–11**	**2006–7**	**2010–11**
Animal protein	13.41***	13.08***	9.05***	8.15***
	(0.032)	(0.029)	(0.421)	(0.372)
Non-animal protein	24.17***	22.79***	5.53***	5.48***
	(0.084)	(0.074)	(0.546)	(0.509)
Saturated fat	8.65***	7.82***	0.97**	1.41***
	(0.065)	(0.058)	(0.351)	(0.317)
Unsaturated fat	1.60***	2.26***	0.31*	0.30*
	(0.031)	(0.028)	(0.130)	(0.121)
Sugar	2.48***	2.38***	0.72***	0.35***
	(0.013)	(0.011)	(0.085)	(0.070)
Non-sugar carbohydrates	–1.25***	–0.99***	–2.33***	–2.24***
	(0.018)	(0.017)	(0.129)	(0.131)
Observations	746,500	878,625	746,500	878,625

Notes: Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The first two columns in Table 5 present the coefficient estimates from fixed effects OLS regressions. All the regressions include household-category and category-quarter fixed effects. However, these results potentially suffer from endogeneity, so the next two columns present estimates from fixed effects instrumental variable regressions. The instruments are unweighted average nutrients of products purchased in each quarter by households shopping in the same retail chain in the same area.

All calories in food are derived from these macronutrients: the calorie content of food is a weighted sum of grams of these macronutrients.[5] If households cared only about calories, the coefficients on the nutrients would be equal to the weights. However, Table 5 shows that the coefficients on the nutrients are mostly statistically different from zero, and statistically different from these weights. Animal protein is the most preferred nutrient, and non-sugar carbohydrates the least. The confidence intervals on the $\hat{\beta}_c$ for sugar do not overlap over the two periods, suggesting that preferences for sugar declined significantly from 2006–7 to 2010–11.

In Table 6 we present the average household-category and category-quarter fixed effects across household-quarters within each category. These are interpretable as either preference parameters, or unobservable period-specific attributes of the products. For each period these are:

$$\bar{\sigma}_j = \frac{1}{IT}\sum_{it}\hat{\sigma}_{ijt} = \frac{1}{IT}\sum_{it}\left(exp_{ijt} - \sum_{c}\hat{\beta}_c z_{ijct} \right) \quad (2)$$

where exp_{ijt} is the dependent variable, z_{ijct} the independent variables, an $\hat{\beta}_c$ the estimated coefficients from the regression defined by equation (1). I is the total number of households and T the number of year-quarters. The table shows that the highest preferences are for vegetables, ready meals, and processed sweet foods. There were changes in the relative preferences for the different categories from 2006–7 to 2010–11. Preferences for many categories increased, although those for vegetables, bread and cereals, fish, and

[5] Weights are 3.75 calories for each gram of carbohydrates (sugar and non-sugar), 4 calories for each gram of protein (animal and non-animal), and 9 calories for each gram of fat (saturates and unsaturated).

Table 6: Preferences for categories

	2006–7	2010–11	% change
Fruit	14.52	15.46	6.5
Vegetables	24.50	23.62	–3.6
Bread and cereals	22.15	21.60	–2.5
Flour, pasta, and rice	5.14	5.66	10.2
Milk and cheese	12.41	13.37	7.8
Oils and fats	6.19	6.61	6.7
Beef and lamb	6.80	7.00	3.0
Pork, poultry, and other meat	15.12	16.22	7.3
Fish	7.24	7.15	–1.2
Beans, nuts, and eggs	3.75	4.15	10.8
Processed sweet	30.10	30.95	2.8
Ready meals, pizza, etc.	22.18	20.79	–6.3
Other processed savoury	19.71	20.25	2.7

Notes: Numbers are the mean of the household-category and category-quarter fixed effects across household-quarters, within each category. Percentage change is the percentage change from 2006–7 to 2010–11.

ready meals declined. The largest increases were for flour, pasta and rice, and beans, nuts, and eggs, although these were still the least preferred food categories.

V. Counterfactual analysis

In this section we explore how the changes in relative prices and other factors have affected households' food purchases. To do this, we take the average household in 2006–7 and change their shopping environment and preferences in turn. We start with the 'average' household in 2006–7; the purchases of this household exactly replicate the average consumption by category observed in the data. For full details of the counterfactual analysis, see DGN.

The counterfactual simulations we consider are defined by four variables: (i) food prices, (ii) nutrient preference parameters, (iii) category fixed effects, and (iv) product attributes. Food prices are the average price of each category, shown in Table 3. The nutrient preference parameters are the estimated $\hat{\beta}_c$, shown in Table 5. The category fixed effects are the average of the household-category and category-quarter fixed effects, presented in Table 6. Product attributes are the average nutrient intensity in each category (i.e. grams per 100g of protein, fat, etc.). These are a function of the choice of food products made by households *within* each food group. We consider three different scenarios, which involve changing each of these variables in turn:

Scenario A: everything except food prices at the 2006–7 (pre-period) averages (nutrient preferences, price of the outside good, category fixed effects and product attributes); food prices at the 2010–11 (post-period) average;
Scenario B: food prices and nutrient preferences at the 2010–11 (post-period) average; everything else (price of the outside good, category fixed effects and product attributes) at the 2006–7 (pre-period) average;
Scenario C: everything at the 2010–11 (post-period) average except product attributes; product attributes at the 2006–7 (pre-period) average.

In each simulation we calculate the implied quantity of each food group and macronutrient bought. This allows us to compare the effect of changes in food prices with the impact of changes in preferences and other factors on the average composition of households' shopping baskets.[6] Note that for this interpretation of our counterfactual results to be correct, it is necessary to assume that any changes in preferences are not driven by changes in relative prices.

Table 7 shows the results of the counterfactual analysis, broken down by food group. Column (1) shows the average numbers in 2006–7; columns (2)–(4) show the numbers from the counterfactual scenarios described above, and column (5) shows the average numbers in 2010–11. The first panel presents the counterfactual expenditures and calories from each of the food groups under the different scenarios. The second panel presents the percentage change of each column compared to column (1), i.e. the 2006–7 period.

Comparison of columns (1) and (2) shows the effect of just the relative price changes. These led to falls in the calories from all food groups apart from bread and cereals, fish, processed sweet food, and ready meals. There was a large decline in calories from beef and lamb as a result of the relative price changes. Comparison of columns (1) and (3) incorporates the effect of the changes in the nutrient preferences. A fall in the preference for animal protein led to further declines in the calories from beef and lamb, and pork and poultry. A decline in the preference for sugar led to a reduction in the number of calories from processed sweet food. Comparing columns (1) and (4) adds in the effect of the changes in the preferences for the different food categories. The increase in the preference for fruit means that the number of calories from this group increases slightly, despite the large decline in its relative price. In contrast, there was a fall in the preference for vegetables, which leads to a further decline in the calories from this group. Households are also estimated to like ready meals less, offsetting the increase in calories that would have occurred from its relative price fall. The differences in the counterfactual scenarios indicates the importance of not imputing a causal relationship from the descriptive statistics—e.g. had nothing else changed, the calories from fruit would have declined, whereas in reality, they increased.

We can also see evidence of this by looking at the changes in the macronutrients under the different counterfactual scenarios. Table 8 shows a similar breakdown as Table 7, but across nutrients rather than food groups. As a result of the changes in relative prices, calories from animal protein declined. There was a further reduction due to a fall in the preference for animal protein. However, preferences for the food groups beef and lamb, and pork and poultry (which are high in animal protein) rose, mitigating, to some extent, the overall decline in animal protein. The fall in calories from sugar was due mainly to a decline in the preference for sugar—this was offset, to some extent, by an increased preference for processed sweet food. Comparison of columns 4 and 5 also suggest that substitution across products within food groups played a role: households switched to food products (within each food group) that were more calorie-dense and contained more saturated fat, but contained less protein per 100g.

Measuring the nutritional quality of diet, or food purchases, is a difficult task: its complexity often means that changes in different dimensions of nutritional quality can go in different directions. Whether or not the chosen level of a nutrient or food group is 'healthy' or not, often depends on the starting level of the nutrient. However, there

[6] For a more detailed explanation of the method used to do this, see Dubois *et al.* (2014, pp. 21–3).

Table 7: Counterfactual analysis: food groups

	(1)	(2)	(3)	(4)	(5)
Scenario:		A	B	C	
Prices in:	pre	post	post	post	post
Nutrient preferences in:	pre	pre	post	post	post
Price of outside good in:	pre	pre	pre	post	post
Category fixed effects in:	pre	pre	pre	post	post
Product attributes in:	pre	pre	pre	pre	post
Calories and food groups					
Expenditure	2.63	2.61	2.54	2.59	2.59
Calories	1,951.8	1,929.1	1,889.8	1,926.9	1,939.8
from					
Fruit	79.31	76.22	73.51	79.97	80.73
Vegetables	136.21	132.46	132.25	127.48	126.97
Bread and cereals	267.91	273.78	274.76	270.49	274.09
Flour, pasta, and rice	74.52	72.01	73.22	78.78	77.27
Milk and cheese	237.94	237.39	218.22	234.32	235.66
Oils and fats	204.65	187.34	191.97	200.87	202.12
Beef and lamb	48.24	43.32	41.39	42.58	42.65
Pork, poultry, and other meat	150.64	145.48	136.19	142.92	145.99
Fish	33.73	34.20	32.89	32.06	33.05
Beans, nuts, and eggs	28.93	26.41	25.86	28.88	30.09
Processed sweet	374.96	377.28	365.90	373.22	375.20
Ready meals, pizza, etc.	159.97	171.63	172.78	160.74	160.22
Other processed savoury	154.81	151.59	150.86	154.59	155.74
Calories compared to column (1)					
Fruit		–3.89	–7.31	0.83	1.79
Vegetables		–2.75	–2.91	–6.41	–6.79
Bread and cereals		2.19	2.55	0.96	2.30
Flour, pasta, and rice		–3.38	–1.76	5.71	3.69
Milk and cheese		–0.23	–8.29	–1.52	–0.96
Oils and fats		–8.46	–6.19	–1.85	–1.23
Beef and lamb		–10.20	–14.20	–11.73	–11.59
Pork, poultry, and other meat		–3.43	–9.59	–5.12	–3.09
Fish		1.39	–2.48	–4.95	–2.02
Beans, nuts, and eggs		–8.71	–10.60	–0.16	4.00
Processed sweet		0.62	–2.42	–0.47	0.06
Ready meals, pizza, etc.		7.29	8.01	0.48	0.16
Other processed savoury		–2.08	–2.55	–0.14	0.60

Notes: Numbers are per person per day; 'pre' refers to the 2006–7 period; 'post' refers to the 2010–11 period.

are some nutrients of which almost everyone consumes too much (saturated fat, sugar) and some of which most people consume too little (protein, fruit, vegetables). We can use our results to comment on the relative price changes that acted to improve average nutritional quality, and those that acted to reduce it.

Holding preferences constant, Table 7 shows that calories from fruit and vegetables would have fallen as a result of the relative price changes, while Table 8 shows that calories from animal protein would also have declined following the price changes. These would have acted to decrease the average nutritional quality of households' shopping baskets. However, Table 8 also shows that calories from sugar and saturated fat would also have fallen as a result of the price changes, acting to increase average nutritional quality. These declines must be compared with the overall decline in calories of 1.16 per cent—compared to this, the declines from animal protein and fruit and vegetables were

Table 8: Counterfactual analysis: nutrients

	(1)	(2)	(3)	(4)	(5)
Scenario:		A	B	C	
Prices in:	pre	post	post	post	post
Nutrient preferences in:	pre	pre	post	post	post
Category fixed effects in:	pre	pre	pre	post	post
Product attributes in:	pre	pre	pre	pre	post
Calories and nutrients					
Expenditure	2.63	2.61	2.54	2.59	2.59
Calories	1,951.8	1,929.1	1,889.8	1,926.9	1,939.8
from					
Animal protein	164.4	159.4	149.6	156.9	159.7
Non-animal protein	129.1	130.7	130.4	128.8	128.4
Unsaturated fat	472.2	458.3	452.2	463.3	474.6
Saturated fat	306.5	300.5	291.5	300.9	296.5
Sugar	380.0	377.8	365.5	377.7	376.3
Non-sugar carbohydrates	499.7	502.5	500.7	499.2	504.3
Comparison to column (1):					
Calories		–1.16	–3.18	–1.28	–0.62
Animal protein		–3.05	–9.02	–4.52	–2.83
Non-animal protein		1.21	0.98	–0.24	–0.56
Unsaturated fat		–2.94	–4.24	–1.87	0.51
Saturated fat		–1.96	–4.90	–1.83	–3.25
Sugar		–0.58	–3.80	–0.59	–0.96
Non-sugar carbohydrates		0.56	0.20	–0.10	0.91

Notes: Numbers are per person per day; 'pre' refers to the 2006–7 period; 'post' refers to the 2010–11 period.

much larger than the falls in saturated fat and sugar. Therefore, it seems likely that the changes in relative prices (controlling for preference changes) may have led to a slight fall in the average nutritional quality of households' shopping baskets.

VI. Summary and conclusions

In this paper, we document the changes in the relative prices of different food groups and use a demand model to isolate the impact that these changes had on the food purchases of a panel of British households. The results suggest that over this time period there was a complex interplay of factors, including changes in prices and preferences, which led to households altering their food purchasing behaviour. Although the changes in the various components of nutrition are somewhat ambiguous, the effect of relative prices appears to have slightly worsened the average nutritional quality of households' shopping baskets.

In 2008 there were large increases in food prices, but the magnitude of these increases differed across food groups, leading to large changes in the relative prices of foods. For example, the price of ready meals, pizza, and packaged food declined by almost 7 per cent relative to the price of all food, while the relative price of beef and lamb rose by over 7 per cent. However, there were also concurrent changes in the preferences over both nutrients and food groups. Notably, the estimates from our demand model suggest that preferences for sugar declined between 2006–7 and 2010–11. Households' preferences over different food groups also changed. In the absence of any change in preferences (i.e. if only relative prices changed), the calories from fruit would have declined. In reality, calories from fruit increased because households are estimated to have increased their preference for fruit.

Various policies have been suggested that aim to change people's diets through altering relative prices, for example, introducing a tax on saturated fat, or on the sugar content of soft drinks. However, this paper illustrates the importance of appropriately modelling demand for food when trying to evaluate the effects of these policies. We use the food price shocks of 2007–8 to identify the impact of relative price changes on nutrition, while controlling for potentially confounding factors. Our results suggest that, while relative prices undoubtedly affect households' food purchases in important ways, the failure to model appropriately differences in other factors (such as preferences) can lead to a mis-estimation of the causal impact of prices on nutrition.

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