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Rachel Griffith
Lars Nesheim
Martin O'Connell

The Institute for Fiscal Studies
Department of Economics, UCL

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An ESRC Research Centre

Institute for Fiscal Studies, 7 Ridgmount Street, London WC1E 7AE **Tel:** 44 (0)20 7291 4800 **Email:** info@cemmap.ac.uk **www.cemmap.ac.uk**

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Rachel Griffith
IFS and University of Manchester

Lars Nesheim
CeMMAP, IFS and UCL

Martin O'Connell
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Abstract

There is policy interest in using tax to change food purchasing behaviour. The literature has not accounted for the oligopolistic structure of the industry. In oligopoly the impact of taxes depend on preferences, and how firms pass tax onto prices. We consider a tax on saturated fat. Using transaction level data we find that the form of tax and firms' strategic behaviour are important determinants of the impact. Our results suggest that an excise tax is more efficient than an ad valorem tax at reducing saturated fat purchases and an ad valorem tax is more efficient at raising revenue.

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Correspondence: rgriffith@ifs.org.uk, l.nesheim@ucl.ac.uk, martin_o@ifs.org.uk

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1 Introduction

There has been a recent surge of interest in using taxes to curb poor food consumption behaviour by individuals. In 2009-2010 at least 17 US States proposed additional taxes on sugary drinks, and in January 2010 Denmark introduced a 25% tax increase on ice cream, chocolate and candy, as well as a tax on soft drinks (Danish Ministry of Taxation, 2009). Recently the OECD has called for the implementation of a package of measures, which include taxing unhealthy foods, in low and middle income countries to help fight growing obesity (Cecchini et al, 2010). These proposals are in response to concerns about the growth in diet related chronic diseases, although they would also bring in welcome additional tax revenue.

Saturated fat is a major contributor to the increase in diet-related health problems, as it raises blood cholesterol and high blood cholesterol is a leading contributor to the onset of cardiovascular disease. In the UK the average person consumes 20% more saturated fat than is recommended (FSA, 2009) and in 2006 the treatment of cardiovascular disease cost the national health service £14.4 billion (British Heart Foundation, 2009). In the US, the government states that "most Americans need to decrease their dietary intakes of saturated fat" to decrease their risk of elevated levels of blood cholesterol (US Department of Health and Human Services et al, 2005).

The impact of these taxes on consumer behaviour and tax revenue will depend not only on how consumer demand responds to price changes but also on how firms respond in terms of the prices they set. In perfectly competitive markets these effects are relatively straightforward to estimate. However, the markets in which most food products are sold are better typified by differentiated product oligopoly. When firms have market power these taxes may be over or undershifted (Seade (1987), Anderson et al (2001)). Existing studies of fat and sugar taxes have failed to account for this. In oligopoly settings the impact of a tax depends on a number of factors including the form of tax, the curvature of demand, and the details of firm behaviour. In particular, when multi-product firms are the norm, as is the case in retail food markets, product portfolios also matter. A firm's ability to pass a tax increase through to consumer prices depends on the positioning of its portfolio of products in the product space.

In this paper we consider the potential to use taxes to curb consumption of saturated fat in this context. We compare the performance of an excise and an ad valorem tax applied to the market for butter and margarine. We estimate a structural model that allows for product differentiation, rich consumer heterogeneity, substitution to the outside option and quantity choice. We use the model to compute the impacts of the respective taxes, allowing for strategic pricing behaviour by multi-product firms. We use microdata on individual purchase transactions with detailed information on an extensive list of product and household characteristics. We find that accounting for firms' strategic behaviour is critically important for evaluating taxes in this setting. In our specific empirical application, the excise tax is slightly more efficient than an ad valorem tax in terms of the cost per unit reduction in saturated fat purchased. In part, this is driven by the fact that an excise tax is a function only of products' saturated fat content (and not price). Conversely, the ad valorem tax succeeds in raising more revenue (reminiscent of Suites and Musgrave (1953) who show that in monopoly, an ad valorem tax is more efficient at raising revenue).

The application we consider is to the UK market for butter and margarine. The precise quantitative results depend on the particulars of this market. However, the results have broader qualitative implications. Almost all retail markets are differentiated product markets, with many dominated by large multi-product firms. Our results demonstrate the empirical importance of accounting for this (when evaluating the impact of proposed tax policy reforms) by estimating a structural demand system that allows differentiated products, flexible demand patterns and that accounts for asymmetries in firm sizes and product portfolios.

Our work relates to several strands in the literature. The most directly related in terms of the policies considered is the empirical literature that considers the impact of taxes on fat, and includes Chouinard et al (2007), Smed et al (2007), Leicester and Windmeijer (2004), Marshall (2000) and Acs and Lyles (2007).[1] These authors have used continuous choice demand models, have aggregated food products into commodity groups and assumed 100% pass-through. In these papers, consumers respond to the tax by substituting *between* food categories. Substitution within a category is ruled out. In contrast, we use a discrete choice demand model and data that is disaggregated at both the household and product level, and compute firms' profit-maximising response to the tax. We allow households to substitute both *within* a food category as well as to the outside option. In our model, products within a food category (e.g. different butter products) are seen by consumers as highly substitutable. We show that within category substitution is empirically important, as butter and margarine products are highly differentiated in terms of their intensity of saturated fat; the saturated fat content of butter varies from 23.7g to 57g per 100g and for margarine from 0g to 26.6g.

Also closely related is the empirical literature that considers evidence on pass-through from reduced-form studies. Besley and Rosen (1999) exploit variation in State and local sales taxes in the US and look at the impact on prices of a number of products. They find a wide variety of effects, including evidence of overshifting for a number of goods. Delipalla and O'Donnell (1998) analyse the incidence of cigarette taxes in several European countries. Using cross border variation in the composition of the overall tax burden between excise and ad valorem taxes,

[1] Papers that consider sin taxes on other goods include Adda and Cornaglia (2010), Bulow and Klemperer (1998), Goolsbee et al (2010) and Hines (2007).

they find that excise taxes have a larger impact than ad valorem taxes on consumer prices and that, unlike ad valorem taxes, excise taxes are overshifted in several countries. Kenkel (2005) uses data on how the price of alcoholic beverages changed in Alaska in response to increases in the tax levied on alcohol and finds pass through tends to be greater than 100%. Relative to this literature we estimate a structural model which allows us to conduct ex ante analysis of the impact of tax. Our results broadly accord with the reduced form literature - we find pass-through of an excise tax is higher than an ad valorem tax and greater than 100%.

A number of papers in the theoretical literature consider taxes in oligopoly markets with a homogenous good.[2] Seade (1987) shows that in a homogenous good Cournot market, if the elasticity of the slope of the inverse demand curve is sufficiently large, firms will react to an excise tax by increasing producer prices. He also shows that if the elasticity is large enough, firms' profits may increase in response to the tax. Delipalla and Keen (1992) show that in a homogenous good Cournot model, overshifting is more likely for an excise tax than for an ad valorem tax. Unlike an excise tax, an ad valorem tax reduces firms' marginal revenues, inducing them to expand output. Anderson, de Palma and Kreider (2001) show that these results extend to a model of symmetric differentiated demand and Bertrand competition. However, the results are ambiguous if firms are not symmetric. Further, while their results provide a great deal of intuition about the forces governing the impacts of different types of taxes, it is not clear precisely how their results extend to empirically relevant cases in which firms are asymmetric not only in costs but also in the mean levels of utility that their products provide, and in which there are multi-product firms. Hamilton (2009) shows that the superior performance of the ad valorem tax does not hold in a model with multi-product firms and non-symmetric differentiation, but again, it is not clear how these results extend to more complicated market settings. Our results provide the first empirical look at how these forces play out in an actual market setting with differentiated products, consumer heterogeneity and asymmetric multi-product firms.

Our analysis follows the empirical industrial organisation literature, particularly Berry, Levinsohn, Pakes (1995, 2004) and Nevo (2001). Like these studies, we estimate a flexible discrete choice demand model and combine our demand estimates with a model of the supply side of the market. This enables us to estimate products' marginal costs, thereby allowing us to simulate the impact of a tax on market equilibrium. Our work is also related to a number of papers in the industrial organisation literature which seek to estimate the extent to which cost

[2] See, inter alia, Seade (1987), Stern (1987), Besley (1989), Delipalla and Keen (1992), Skeath and Trandel (1994) and Hamilton (2008). Most assume Cournot competition. Exceptions include Kay and Keen (1983), which considers monopolistic competition, Delipalla and Keen (1992), which considers a model of conjectural variations and Stern (1987) which considers a range of models including Cournot oligopoly and monopolistic competition. See also Bulow and Klemperer (1998).

shocks are passed through to prices in the food industry, including Kim and Cotterill (2008), Nakamura (2008) and Nakamura and Zerom (2008).

The structure of the rest of the paper is as follows. The next section outlines a model of consumer and firm behaviour. Section 3 presents the data and econometric results. Section 4 discusses the impact of introducing different forms of tax on saturated fat and a final section concludes.

2 Model

We first describe household behaviour and then firm behaviour.

2.1 Household behaviour

We assume that the benefit that a household obtains from purchasing butter and margarine is weakly separable from the benefit from other goods. Each household $i \in (1, \ldots, I)$ chooses to purchase one product, defined by brand $j \in (0, 1, ..., J)$ and pack size $s \in (1, ..., S_j)$. The set of products includes the outside good ($j = 0, s = 1$). There are J distinct butter and margarine brands ($j > 0$), each of which is available in S_j different pack sizes. We refer to a product as a particular (j, s) pair. Households live and shop in different markets, indexed $m = 1, ..., M$, defined by month-region pairs.[3]

We specify a random coefficients discrete choice demand system.[4] Preferences vary with both observable and unobservable demographic characteristics, which allows for flexible substitution patterns. The payoff to a consumer from a product depends on the product's characteristics and its price. Each household chooses the product that provides them with the highest payoff.

For the outside good, we assume household utility is

$$u_{i01m} = \delta_0 + \sum_r z_i^r \delta_1^r + \varepsilon_{i01m}$$

where z_i^r for $r = 1, ..., R$, is a vector of observable household characterstics. We interact the payoff provided by selecting the outside option with observable household characteristics to allow for heterogeneity in choices to buy or not. The parameter δ_0 captures the baseline payoff from the outside option and for each r, δ_1^r captures the variation in payoffs across households due to z_i^r. Including the outside option allows households to respond to a tax by purchasing butter and margarine less frequently or not at all.

[3]In our empirical application, price and region dummies are the only product characteristic that varies across markets.

[4]See for example, Boyd and Mellman (1980), Berry, Levinson and Pakes (1995, 2004), McFadden and Train (2000), Train (2003) and Nevo (2000, 2001).

For all inside goods ($j > 0$), we assume that the payoff u_{ijsm} for household i from product (j, s) takes the form,

$$u_{ijsm} = \sum_k x_{jsm}^k \beta_i^k + \xi_j + \varepsilon_{ijsm} \tag{1}$$

$$\beta_i^k = \beta_0^k + \sum_r z_i^r \beta_1^{kr} + \eta_i^k \tag{2}$$

where x_{jsm}^k are $k = 1, \ldots, K$ observable product and market characteristics, ξ_j are unobservable brand characteristics, and ε_{ijsm} is an unobservable stochastic term.

We allow households to have heterogeneous preferences over the observed product characteristics x_{jsm}^k through the coefficients β_i^k. These coefficients vary both with observable household characteristics z_i^r, indexed $r = 1, ..., R$ and unobservable household characteristics η_i^k. We assume $\eta_i \sim N(0, \Sigma)$, ε_{ijsm} are i.i.d. Type 1 extreme value random variables, and that ξ are drawn from an unknown distribution.

The marginal payoff of product characteristic k depends on a constant term β_0^k and parameters β_1^{kr} that capture variation in marginal payoffs across households due to observable demographics. In our application, some product characteristics do not vary within brand. As a result, some parameters in (1) and (2) are not identified. To make clear what parameters are identified in our setting, we partition the $(K \times 1)$ vector of product characteristics into the set K_1 that vary within brand, and the set K_2 that are constant within brand. We substitute (2) into (1), and rewrite (1) as

$$\begin{aligned} u_{ijsm} &= \sum_k \left(x_{jsm}^k \beta_0^k + \sum_r z_i^r x_{jsm}^k \beta_1^{kr} + \eta_i^k x_{jsm}^k \right) + \xi_j + \varepsilon_{ijsm} \qquad (3) \\ &= \delta_j + \sum_{k \in K_1} x_{jsm}^k \beta_0^k + \sum_{k,r} z_i^r x_{jsm}^k \beta_1^{kr} + \sum_k \eta_i^k x_{jsm}^k + \varepsilon_{ijsm} \end{aligned}$$

where

$$\delta_j = \xi_j + \sum_{k \in K_2} x_{jsm}^k \beta_0^k \tag{4}$$

For $k \in K_1$, the parameters $\left(\beta_0^k, \beta_1^k\right)$ are identified. For $k \in K_2$ only the parameters β_1^k are identified.

In summary, the variables $\eta_i = \left(\eta_i^1, ..., \eta_i^K\right)$, $\xi = (\xi_1, ..., \xi_J)$ and $\varepsilon_{im} = (\varepsilon_{i01m}, \varepsilon_{i11m}, ..., \varepsilon_{iJSm})$ are unobservable stochastic terms. The vectors $\beta_0 = (\beta_0^1, ..., \beta_0^K)$ for $k \in K_1$, $\beta_1 = \left(\beta_1^{11}, \beta_1^{12} ..., \beta_1^{KR}\right)$, $\delta = (\delta_0, ..., \delta_J)$, $\delta_1 = \left(\delta_1^1, , ..., \delta_1^R\right)$ and Σ are parameters to be estimated. Note that to identify the price elasticity of demand we do not need to separately identify ξ and β_0^k for $k \in K_2$. Price is one of the product characteristics in the set K_1. We assume all other product characteristics do not change after we introduce the tax.

2.2 Identification

The UK retail food market is characterised by close to national pricing, with some, but only little, cross-sectional variation in the price of each product. However, there is variation across time and within brand across different pack sizes. We identify the coefficients on price primarily through these two sources of variation: (1) variation in product price over time, and (2) variation in unit price across pack sizes within brand, although we also allow for variation in prices (and costs) across broad regions.

A standard concern in the industrial organization literature is that unobservable product characteristics lead to correlation between the error term and price resulting in inconsistent estimates of the price coefficients. We believe that this is not a concern in our application for several reasons. Our data allow us to control for very detailed product characteristics minimising the risk of correlation between the errors and price driven by the presence of unobservable product characteristics. A regression of prices on the product characteristics in our data produces an R^2 of 0.94. In particular, we include a large number (101) of brand-level fixed effects and pack size dummies meaning that we control for unobservable product characteristics that do not vary within brand and unobservable product characteristics that do not vary within pack size. In addition, product characteristics in this market do not change rapidly if at all. These factors justify the belief that this source of endogeneity is unlikely to be important in our application.

A second potential source of endogeneity in prices arises if firms change prices and simultaneously engage in unobserved promotional activity that stimulates demand. A particular concern raised by Hendel and Nevo (2006) is that sales promotions may lead consumers to substitute intertemporally which, if not modelled, can substantially bias demand estimates. However, butter and margarine are perishable and so not easy to store for long. In our data, households rarely purchase more than one pack of butter and margarine at a time. Therefore we do not believe that stocking up is a major issue in this market.

Another common concern in the literature is that prices may be measured with error due to imputation of missing prices. We do not have the same problem with missing prices that is highlighted by, for example, Erdum, Keane and Sun (1998). Most supermarkets in the UK operate national pricing policies, following a recommendation by the UK Competition Commission (2000). This means that if we see a product purchased at any branch of the supermarket we know that this is the price that will be charged at other branches. In practice this means that we have very few missing prices.

2.3 Firm behaviour

As is common in the empirical industrial organisation literature, we assume that producers set prices and compete in a Bertrand-Nash game, holding the menu of products on offer constant. See Nevo (2001) for example. Let $S_{jsm}(p_m)$ be the market share of product (j,s) in market m when the vector of prices in the market is p_m. Let F_f be the set of products sold by firm $f \in (1,...,F)$. Then, the profits for firm f in market m are given by

$$\Pi_{fm} = \sum_{(j,s)\in F_f} (p_{jsm} - c_{jsm}) N_m S_{jsm}(p_m) - K_{jsm}. \tag{5}$$

where c_{jsm} is the marginal cost of product (j,s) in market m, K_{jsm} is the fixed cost of selling the product in market m and N_m is the size of the market. Note that we hold N_m fixed when we compute new equilibria. Since our model includes the outside option not to buy butter and we observe people who choose not to buy, N_m remains constant when we simulate the introduction of a tax. We interpret N_m as a measure of the population which is invariant to changes in tax policy.

In this setting, the first-order conditions for firm f are given by

$$S_{jsm}(p_m) + \sum_{(k,t)\in F_f} (p_{ktm} - c_{ktm}) \frac{\partial S_{ktm}(p_m)}{\partial p_{jsm}} = 0 \tag{6}$$

for all $(j,s) \in F_f$. Since most firms are multi-product firms, there is a vector of equations for most firms.

We use the first-order conditions to estimate firms' marginal costs and to compute counterfactual equilibria. Since we observe p_m and estimate $\left(S_{jsm}, \frac{\partial S_{jsm}}{\partial p_{ktm}}\right)$ for all $(j,s) \in F_f$ and $(k,t) \in F_f$ and for all f, we can recover marginal costs. For each f, we recover the marginal cost of each product in each market, c_{jsm} by inverting the system of equations (6). After computing c_{jsm} for all (j,s) and m, we simulate counterfactual equilibria that result from the imposition of various taxes.

Equilibria are computed as follows. Let p_{fm} be the vector of prices for products produced by firm f in market m and let p_{-fm} be the vector of prices of all other firms in the market. A Nash equilibrium in this market is a vector of prices $p_m = (p_{1m},...,p_{Fm})$ such that, for each f, given p_{-fm}, p_{fm} satisfies (6). For each tax, we compute an equilibrium using a Gauss-Newton based non-linear equation solver to find a price vector p_m that satisfies (6) for all f.

3 Data and econometric results

We use data from the Kantar (formerly TNS) World Panel for calendar year 2006 on all purchases of food brought into the home by 16,637 households. Households record purchases of all items bought using handheld scanners and record prices from till receipts. The data contain a large set of product attributes (at the barcode level) as well as household characteristics.[5]

We focus on the category butter and margarine because it is the single food category that accounts for the highest proportion of saturated fat purchases made by UK households, accounting for 13.3% of total annual saturated fat purchases.[6] For each household we choose a random shopping trip during calendar year 2006.[7] That is, we assume that decisions to purchase butter and margarine do not affect the probability of shopping and they are independent across trips. We define a 'shopping trip' as all goods purchased by a household on a single day.[8] We exclude shopping trips in which less than five purchases were made and consider only products that we observe being purchased at least five times in each month.[9] After taking a random sample of shopping trips, we observe 4,488 purchases of butter or margarine, with 12,149 households choosing the outside option not to purchase any butter or margarine on that trip. Of the purchases, 1,721 are of 50 different butter products and 2,767 are of 92 different margarine products.

3.1 Product and household characteristics

Our data contain information on product characteristics including price, the nutritional content of each individual product (from the information label on the package), brand, whether the product is from an own-brand budget (generic) range, pack size and, if the product is margarine, its type (whether it is healthy label, standard or margarine made with polyunsaturated fatty acids (pufa)). The top panel of Table 1 lists the mean and standard deviation of the product characteristics across our sample of observed purchases. Brand level fixed effects are not shown - there are 101 brands encompassing 142 different products (details are provided in the Web Appendix). We control for product pack size, meaning that our model identifies the coefficient on price by exploiting variation in prices across markets and within brand variation in unit price across products with different pack sizes. For products that were not purchased we use the average price of each product in each market. A market is defined as a region-month. We include three regions - the South-East, South-West and North of Great Britain, meaning there are 36 markets and therefore 36 different prices for each product.

[5]See Leicester and Oldfield (2009) for further information on the data, and Griffith and O'Connell (2009) for further discussion of the nutrition component of the data.

[6]Together dairy products (cheese, butter, margarine, milk, ice cream and cream) contribute 35.1% to the average households purchases of saturated fats. Snacks and meat are also significant contributors.

[7]Using more than one trip per household is not feasible given current constraints on computer memory and processing power.

[8]We exclude a small number of households which only purchase very infrequently (fewer than 125 items purchases over the year), and purchases where recorded values are extremely large or small.

[9]We exclude 146 products, each of which have a market share of less than 0.9% and which together account for 6% of butter and margarine purchases in 2006.

The household characteristics that we use include income (banded into five categories), social class, household size, household structure, whether the main shopper is overweight or obese and region. The bottom panel of Table 1 reports the mean and standard deviations for household characteristics across the households in our sample.

Given our estimates of individual demand, we must aggregate from our sample to the market level to compute market equilibria. To do this we weight the data in two ways. First, because we take one random shopping trip per household we weight each household by its shopping frequency. Under the assumption that purchase decisions are independent across trips, this provides an estimate of the expected number of purchases per year. Second, we use sample weights provided by Kantar to weight up the sample to the level of the UK population. These weights correct for over- or under-sampling of some household types.[10]

3.2 Market structure and firms

The manufacturer of each product is identified in our data. This is essential in order to model firm pricing responses. The 142 butter and margarine products are produced by 18 firms. Table 2 lists the manufacturers (ordered by market share), the number of products they sell, their market share, and lists each firms' highest selling product.

There are three types of firm. The three largest firms - Unilever, Dairy Crest and Arla - each produce over 15 products and together they account for over half the market. Unilever and Arla specialise in a certain type of product; their products tend to be clustered in one part of the characteristics space. Unilever produces 19 relatively low fat, expensive margarine products. Arla produces a range of butter products. Dairy Crest is slightly different, it produces a group of butter products clustered together in characteristics space and a group of margarine products clustered in another part of the characteristics space. The second category comprises the big four supermarkets. They all produce several own-brand products that span the characteristics space. Tesco, for instance, produces everything from a small pack of expensive French butter to a very large, very low priced pack of margarine. The final category consists of a number of firms with relatively small market shares who each produce at most six products.

3.3 Estimation results

We estimate the model by maximum likelihood.[11] The model contains 208 parameters. There are too many to discuss in detail here in the main text. Instead, we provide a brief summary.

[10]Sampling weights are not used in estimation because sample selection is based on exogenous demographics, not on the endogenous choice of butter purchases.

[11]To evaluate the likelihood and its gradient, we use Gauss-Hermite quadrature to approximate the multi-dimensional integral for the mixed logit model.

The full set of parameter estimates are shown in Tables A.1 and A.2 in the Web Appendix. The baseline price coefficient is negative, and large in absolute terms. Most households reduce their demand in response to an increase in price. We allow for preferences to vary with observable household characteristics by interacting them with product characteristics. We also allow for random preference variation for price and saturated fat content through the inclusion of random coefficients. We find that there is substantial heterogeneity both in terms of observed household characteristics and unobserved characteristics. Next we discuss the elasticities implied by our parameter estimates.

3.3.1 Elasticities

We calculate household level own- and cross-price elasticities for each product. We then compute market-level elasticities for each product by aggregating across households weighting by the predicted household-level 'market shares', the frequency that each household shops and household sampling weights (which gross up to the UK population). The formulae for the aggregate elasticities are standard and are detailed in the Web Appendix.

The estimated market own-price elasticities are all negative and greater than one in absolute magnitude. The average own-price elasticity is -2.44. The market cross-price elasticities (apart from a small number of exceptions) are positive, suggesting that consumers view the products in the market as substitutes. The model produces a 142x142 matrix of elasticities for all products. Rather than reproduce the entire matrix, in Table 3, we show elasticities for two subsets of products.

We show the own- and cross-price elasticities corresponding to six butter products produced by the leading butter producer in the market (Arla whose leading brand is Lurpak) and five margarine products produced by one of the supermarkets (Asda). Each entry in the table shows the elasticity of demand for a product in column 1 with respect to the price of a product in row 1. The upper-left section of the table displays the Lurpak butter products' elasticities and the bottom right-hand sections displays the Asda margarine products' elasticities. A standard multinomial logit model with no heterogeneity in household preferences would yield cross-price elasticities that are constant within each column. In our results, that is not the case. The heterogeneity in preference (along observable and unobservable dimensions) ensures our model can generate flexible substitution patterns.

Comparing the cross-price elasticities within each column shows that the Lurpak products are closer substitutes to Lurpak products than to Asda margarine products and vice versa. A change in the price of a Lurpak product has a larger impact on other Lurpak products than on Asda margarine products. Similarly, a change in one of the Asda product's prices has a larger impact on the other Asda products than on the Lurpak products. These patterns accord with prior beliefs and would be ruled out ex ante in a model with no preference heterogeneity.

3.3.2 Marginal costs

We recover the marginal cost for each product in each market by inverting the first order conditions (6) for each firm. The weighted average estimated marginal cost is 56p, which compares to the average price in the market of £1.01 (Table 1). The average price-cost margin is 0.45.

There is considerable heterogeneity across products. Moreover, products have similar markups despite quite different market shares. This would be ruled out in a standard multinomial logit model with single product firms. For example, consider the four margarine products with the largest market share, shown in Table 4. Flora Light Low Fat Spread 500g (produced by Unilever) is a very similar product to Clover Dairy Spread 500g (produced by Diary Crest). However, the Unilever product has lower marginal cost and higher margin, reflecting Unilever's larger scale production and the market power they derive from their portfolio of products. A similar comparison holds for I Can't Believe It's Not Butter (I.C.B.I.N.B) Dairy Spread 500g and St Ivel Utterly Butterly Dairy Spread 500g.

The table also includes the standard deviation of each product's marginal cost across the 36 markets. There is some variation in marginal costs across markets. This contributes to across market price variation. Nonetheless, the variation in marginal costs for each product across markets is much less than the variation across products.

Table 5 shows mean marginal costs and margins across markets for three groups of products. The first panel includes four own-brand budget butter products with 250g pack sizes; in the second panel we show five 500g margarine products, which all advertise themselves as tasting like butter; in the third we show four 250g butter products that are made by one firm.

The products chosen in the first two panels are very close in characteristics space to one another and therefore are likely to be close competitors. The products have similar marginal costs, as one would expect for similar products. The final panel of the table illustrates how marginal cost and margins vary within firm for 250g butter products as 'quality' changes. For this particular firm higher quality products tend to have higher marginal costs, but lower margins.

Table 6 lists the 18 firms that together produce the 142 products in the market. It shows the average marginal cost, price and margin of their products and their total annual variable profits. The three market leading firms all have mean marginal costs at least as large as the market average. This is driven by the fact that their products are relatively high end, reflected in the fact that the mean price of their products is at least as large as the market average. Comparison of products produced by these three firms and comparable products produced by other firms highlights that, conditional on price, the three dominant firms actually tend to have lower marginal costs. For instance, in panel 2 of Table 5 the Unilever product has a very similar price to its competitors and a marginal cost which is between 3 and 6 pence lower. Notice also the average firm margins vary from 0.37 for Yeo Valley - which produces a premium butter - to 0.67 for Netto - which produces very inexpensive margarine products.

4 Impact of introducing a tax

We use our structural estimates to compute new equilibria after the introduction of tax on saturated fat. Equilibria are computed as discussed in Section 2.3. We consider both an excise tax and an ad valorem tax. In each case, households respond by substituting between brand, between pack sizes and to the outside option (i.e. purchasing less frequently). Firms respond by adjusting prices.

The impacts of introducing an excise and an ad valorem tax are quite different. The excise tax tends to be overshifted to consumer prices while the ad valorem tax tends to be undershifted. This has differing implications for equilibrium market shares and profits. It also influences the effectiveness of the tax in achieving a reduction in the amount of saturated fat households purchase.

In this section we highlight three important results. First, we show that taking account of how firms respond is important. Neglecting to do so (as has been the norm in the existing literature) leads to large errors when evaluating the impact of introducing a tax. Moreover, the sign of the error for one form of tax is the opposite of the sign for the other form.

Second, we highlight how multi-product firms can partially shield themselves from the impact of the tax. Some firms are better able to do this because of the portfolio of products they sell. In addition, the extent to which they can do this varies with the form of tax.

Third, we analyse the overall costs and benefits of each tax and look at how these vary across individuals. Comparing an excise tax with an equivalent ad valorem tax (meaning they raise the same revenue in the absence of firm response), we show that the excise tax has a much larger effect on purchasing. because firms pass-through more than 100% of the tax. In contrast, the ad valorem tax is passed-through by less than 100%. As a result, the excise tax leads to a greater reduction in saturated fat purchased. Using cost per 1kg reduction in saturated fat as a measure of cost effectiveness, this implies that the excise tax is more efficient at reducing saturated fat. Firm profits are reduced by more with the ad valorem tax than the excise tax while compensating variation suggests that consumer losses (abstracting from any health benefits) are larger with the excise tax than the ad valorem. Tax revenues are higher with the ad valorem tax.

4.1 Form of tax

We consider an excise tax that is proportional to saturated fat content. As a result, with a tax rate of τ_e, the post-tax marginal cost of product (j, s) is

$$c^{\tau}_{jsm} = c_{jsm} + \tau_e sat_{js} \tag{7}$$

where sat_{js} is the saturated fat content of product (j, s) and c_{jsm} is the product's pre-tax marginal cost in market m. We consider a tax rate of 10p per 100 grams of saturated fat, so $\tau_e = 0.1$. Effectively, the excise tax increases the marginal costs of all products by an amount proportional to their saturated fat content. In the absence of any response by firms (i.e. assuming 100% pass-through), this causes product prices to increase by the same proportion. The wedge between consumer and producer prices is independent of the level of prices.

In contrast, an ad valorem tax introduces a wedge between consumer and producer prices that is proportional to price levels. As with the excise tax, we consider an ad valorem tax that is proportional to saturated fat content. In this case, with an ad valorem tax rate of τ_{av}, the consumer price of product (j, s) is

$$p^{\tau}_{jsm} = (1 + \tau_{av} sat_{js})\, p_{jsm} \tag{8}$$

where p_{jsm} is the producer price and p^{τ}_{jsm} is the consumer price in market m. To make the initial levels of the excise and ad valorem taxes comparable, we choose τ_{av} so that the (expenditure weighted) average price increase in the absence of any firm response (i.e. 100% pass-through) is the same in both cases. That is, both taxes produce the same revenue in the absence of consumer and firm response. This gives us an ad valorem tax rate of $\tau_{av} = 0.09$. In the absence of any response by firms, the percentage price increase produced by the tax is proportional to the volume of saturated fat.

4.2 New market equilibria

We compute the new Nash pricing equilibria, as described in Section 2.4, holding the portfolio of products fixed. The response we estimate is a short-run rather than long-run effect. While it is clear that long-run considerations, such as the entry and exit of products, are potentially important (Anderson et al, 2001, Hamilton, 2009, Draganska et al, 2009), we observe little variation in portfolios across markets. Nor do we have information about fixed costs of marketing of products. Therefore, our data do not allow for an investigation of long-run effects.

The excise tax results in higher equilibrium prices than the ad valorem tax. The ad valorem tax makes increasing producer prices more costly (in terms of lost demand) than an excise tax does because firms must increase consumer prices by more under the ad valorem tax to achieve a given increase in producer prices. This in turn results in lower equilibrium prices.

Under the excise tax, allowing firms to respond results in an average price increase of 19p, compared to 13p with no response. Pass-through is 145% on average and is almost always above 100%. It ranges from 92% for Flora Light Spread 1Kg to 240% for Flora Diet 500g.[12] Price increases tend to be higher for products with higher saturated fat content.

Under the ad valorem tax, allowing firms to respond results in an average price increase of 6p, compared to 8p with no response. Pass-through is 81% on average and is almost always below 100%. It ranges from 2% for Flora Proactive Light Spread 250g to 112% for Flora Diet. As under the excise tax, the prices of high saturated fat products tend to increase by the most.

The first two columns of Table 7 show pass-through at the firm level (averaged across products, weighted by market share) under each tax. There is considerable variation in pass-through across firms in equilibrium. For both the excise and the ad valorem tax Unilever, the largest firm in the market, has the highest pass-through.

Under both taxes the prices of relatively high fat products increase on average by more than lower fat products, so households substitute away from relatively high fat products towards lower fat alternatives, and towards the outside option. Because the excise tax results in higher equilibrium prices than the ad valorem tax, the excise tax generates more substitution, both towards the outside option and among the butter and margarine products. While the broad pattern of substitution towards relatively low fat products is similar for both taxes, the size of substitution is much less for the ad valorem tax. The market share of the outside increase from 73.6% to 79.1% under the excise tax and to 76.2% under the ad valorem.

Both taxes result in a fall in aggregate profits, but the fall is considerably larger under the ad valorem tax (a 14.7% reduction versus a 9.6% reduction). Under the excise tax the market power that firms have enables them to reoptimise prices, and this in turn lessens the reduction in profits. Under an ad valorem tax, firms' ability to reoptimise prices is less beneficial in terms of allowing them to lessen the profit reduction associated with the introduction of the tax. The last two columns of Table 7 show the percentage reduction in each firm's profits. Under the excise tax the three market leaders - Unilever, Dairy Crest and Arla - all suffer smaller proportional profit reductions than the supermarkets. In contrast, under the ad valorem tax the three market leading firms do not seem to fare any better in terms of the proportional fall in profits, than the other firms in the market do.

Table 8 summarises the aggregate (annual national) impact of introducing the two taxes. The first column shows total expenditure, total variable cost (marginal cost times quantity), and total (variable) profit in the pre-tax equilibrium. The remaining columns show how these figures change in response to the taxes. They also show how consumer welfare changes, reporting an

[12] The statistics in this and the next paragraph are computed after excluding three products whose marginal cost estimates are unstable. Each of these products have market shares below 0.5%.

estimate of compensating variation for each change.[13]

A comparison of columns 3 and 5 shows the difference in aggregate predictions for the two forms of tax when we compute firms' pricing responses. Under the excise tax, tax revenue is about £3.3 million lower in Nash equilibrium than it is in the equilibrium with the ad valorem tax. In addition, the cost to consumers' in terms of compensating variation is £26.8 million higher. Under the excise tax, consumers require more compensation to make them indifferent to the tax's imposition (abstracting from any expected health gains arising from lower fat consumption). And, since there is more substitution away from butter and margarine or towards lower fat (and lower taxed) products, less revenue is raised. However, a corollary of these higher costs and lower tax revenues, is that the excise tax succeeds in inducing a 24.5% reduction in the amount of saturated fat purchased as butter and margarine. In contrast, the ad valorem tax achieves a lower reduction of 13.7% (discussed in Section 4.4 and shown in Table 12).

Comparing the results with and without firm response for the excise tax (columns 2 and 3) in Table 8 shows the importance of modelling firms' pricing response. Since firms optimally increase their producer prices when faced with the tax, in the case of the excise tax, ignoring firm response leads to an overestimate of tax revenues and the reduction in profits caused by the policy and an underestimate of compensating variation. In the case of the ad valorem tax, the errors are reversed. In this case, assuming 100% pass-through leads to an underestimate of tax revenues and the reduction in profits caused by the policy and an overestimate of compensating variation.

Conclusions about the cost and efficacy of the two forms of tax based on the assumption of no firm response are therefore likely to be quite wrong. For instance, under the assumption of 100% pass-through, the two taxes result in similar costs and reductions in saturated fat purchases (18.8% for the excise tax and 16% for the ad valorem tax). In contrast, the difference is much more substantial (24.5% versus 13.7%) when firms can respond by changing prices.

4.3 Impact of multi-product firms

As discussed at the beginning of Section 4, some of the results above depend on the portfolios of products owned by the firms. Firms can potentially insulate themselves from competition by the choice of their portfolio. It is interesting to draw out the role that product portfolios have on the estimated effects. To do this, we conduct the following counterfactual experiment. Suppose the products in the market were all produced by single product firms. How would the tax impacts differ from those under the existing ownership structure? We compute three

[13] Details of how we compute compensating variation are given in the Web Appendix.

new equilibria, one with single product firms and no tax, one with single product firms and an excise tax and one with single product firms and an ad valorem tax.

4.3.1 Comparison of pre-tax equilibria: multi- and single-product firms

A multi-product firm that produces several imperfect substitutes charges higher prices than several separate firms marketing the same products would have done in equilibrium. Table 9 measures the strength of this effect. For each firm it shows average price and profits in the multi-product firm equilibrium and in the counterfactual single product firm equilibrium. It also shows the difference between the multi-product and single product equilibria prices and the percentage difference in profits. So, for instance, in the multi-product firm equilibrium Unilever charges an average price of £1.12, while the average equilibrium price for Unilever's products in the single product firm equilibrium is £1.00. The prices of Unilever's products are 12 pence higher than the prices of the same products in the single product firm equilibrium.

Two points are noticeable. First, the dominant three firms are the only ones that have a significant price premium (i.e. a positive difference between prices in the multi and single product firm equilibria). These firms produce products clustered in characteristic space. In the single product firm equilibrium, these products are fierce competitors. In contrast, in the multi-product firm equilibrium, these three firms each benefit from dominating a portion of the characteristics space. If Unilever wants to increase the price of one of its products, it can be confident that a considerable portion of the lost demand on that product will shift to its other products. Note also the effect is stronger for Unilever and Arla than for Dairy Crest which splits its products between two distinct clusters. The second noteworthy point is that all firms benefit from existing in a multi-product firm equilibrium; they all earn higher profits from their products than the profits earned on these products if they were all produced by single product firms. The three dominant firms are able to increase equilibrium prices, which softens competition for all firms. This effect arises in large part from our assumption of Nash-Bertrand competition.

4.3.2 Impact of a tax in single product firm equilibria

As in the multi-product firm case, pass-through of the excise tax is greater than 100% on most products. The average pass-through is 130%, which is lower than the multi-product case. Pass-through of the ad valorem tax is less than 100% for most products, although it is above 100% for a significant number of lower fat products. The average pass-through is 89%; slightly higher than in the multi-product firm equilibrium.

For both taxes substitution occurs between products and to the outside option. With the excise tax, the amount of substitution is considerably less than in the multi-product firm equilibrium (as prices rise by less) and with the ad valorem tax it is slightly higher. With the excise tax, total profits fall by 3.44%, which is considerably less than in the multi-product firm case. This is because average pass-through is lower, and pre-tax prices are lower, meaning demand is less elastic. With the ad valorem tax total profits fall by 11.26%, also less than in the multi-product firm case.

4.3.3 Comparison of tax impacts

In the pre-tax equilibrium two firms, Unilever and Arla, who both have portfolios of products clustered in characteristics space, charged higher equilibrium prices relative to the counterfactual single-product firm equilibrium. Table 10 shows average pass-through by firm under the two ownership structures and under the two taxes. Under the excise tax, the increase in pass-through in the multi-product firm equilibrium (relative to the single product firm one) is largest for these two firms. To the extent that consumers see their products as being closer substitutes with one another, Unilever (and Arla) are able to increase prices by more in response to the introduction of the tax than several single-product firms selling the same products would in the single-product firm equilibrium. For other firms, average pass-through is also higher. In the ad valorem case, average pass-through is less in the multi-product firm equilibrium with a few exceptions. These exceptions include Unilever and Arla, as in the excise tax case they benefit from clustering their products together in characteristics space.

To illustrate the factors driving this portfolio effect, for each firm, we compute the cross-price elasticities between products owned by the firm and compare them with the cross-price elasticities between products owned by the firm and products that are owned by its competitors. Consider Unilever and Tesco. Recall Unilever produces 19 relatively homogeneous margarine products, while Tesco produces 18 products with quite varied characteristics. Figure 1a shows results for Unilever. The left panel shows the distribution of cross-price elasticities for Unilever products with respect to the prices of all other Unilever products. The right panel shows the distribution of the cross-price elasticities of demand for Unilever products with respect to the prices of all other products (produced by other firms). Comparing the panels shows that Unilever products are relatively close substitutes. This explains why Unilever is able to pass-through more of the tax than several single-product firms selling the same products could.

Figure 1b shows the results for Tesco. The left panel shows the cross-price elasticities for Tesco products with respect to the prices of all other Tesco products. The right panel shows elasticities with respect to the prices of all other products (produced by other firms). In contrast to Unilever, Tesco products are not closer substitutes to one another than products produced by other firms. Tesco's profits from butter and margarine are not insulated from competition in the same way that Unilever's are. Tesco is unable to exploit being a multi-product butter and margarine seller to the same extent as Unilever.[14]

Table 11 displays results for all firms. For brevity we report only the means of the distributions. The table reveals a similar pattern. The within-firm average cross-price elasticities of Arla and Dairy Crest products are both higher than the between-firm average cross-price elasticities. For the supermarkets, the between-firm average elasticity is actually higher. Unlike firms who specialise in producing butter and margarine, supermarkets may have other aims, not just to maximise butter and margarine profits.

4.4 Policy impact

How effective are the taxes at achieving the policy goal of reducing saturated fat consumption?

We define the economic cost of each policy as the sum of the fall in firm profits plus compensating variation minus tax revenues. This corresponds with the traditional dead weight loss associated with taxation. This is reported in Table 8. However, one of the purposes of taxing saturated fat may be to reduce consumption and improve health. It therefore is informative to calculate the economic cost associated with achieving a given reduction in saturated fat purchases. This can then be compared with the expected benefits of a corresponding fall in consumption.

Using the reduction in households' saturated fat purchases and our definition of the economic cost of the policy, we compute the average cost of achieving a 1kg reduction in households' annual saturated fat purchases from butter and margarine. This is shown in Table 12. The cost per kg under the excise tax is £3.52 and the cost under the ad valorem tax is £3.74 (when we model firms' pricing responses). This suggests an excise tax may be more cost effective at reducing saturated fat purchases.

We also show the portion of the cost of achieving a 1kg reduction in each households' annual saturated fat purchases that is borne by consumers. We do this using the compensating variation associated with the policies. We report the average consumer cost in the last row of Table 12 - it is £5.01 per kg for the excise tax and £5.34 for the ad valorem tax (when we model firms' pricing responses).

4.4.1 Variation across households

The aggregate figures in Table 12 summarise the effects of introducing the taxes. However, they mask considerable heterogeneity in responses across households. Figure 2 illustrates this heterogeneity by plotting the cumulative density functions of the consumer cost of achieving a 1kg reduction in annual saturated fat purchases across all households. The solid line is the

[14] Although, of course, Tesco sells many other products and this analysis abstracts from interactions between its butter and margarine pricing decisions and decisions for all other products.

density for the excise tax and the broken line is the density for the ad valorem tax. In each case the costs range from around £4 to £8. At each quantile of the distributions the consumer cost under the ad valorem tax is greater. The variation does not seem to be correlated with observable household characteristics.

Finally, since we observe the entire shopping basket of each household for an entire year, we can calculate the total annual amount of saturated fat purchased by each household and compute the proportion of household energy purchased in the form of saturated fat. According to the UK Department of Health,[15] people should aim to consume no more than 11% of their energy in the form of saturated fat. In our sample, the mean proportion of energy purchased as saturated fat is 15.1% with a standard deviation of 2.7%. We calculate the mean reduction in saturated fat purchases from a butter and margarine tax over households in each decile of the distribution. Figure 3 plots the results. It shows that the policy induces the smallest reduction in saturated fat purchases for those households that purchase the smallest fraction of their energy as saturated fat. The largest reduction is achieved by households in the sixth decile.

5 Summary and Conclusion

There is considerable policy interest in using tax as an instrument to change food purchasing behaviour (and raise revenue). The existing literature that considers the impact of such taxes has assumed complete pass-through, has not accounted for the oligopolistic structure of the food industry and has ruled out ex ante substitution across products within broad food categories.

We provide estimates of the effectiveness of different forms of tax in altering food consumption behaviour. We use micro data to model consumer substitution across products, frequency of purchase and quantity and we model firms' strategic pricing responses. We compute the impact of these taxes on consumption, the incidence of the tax on consumers and firms, and the deadweight loss. Our results suggest that modeling firm behaviour is crucial to obtaining an accurate picture of the impact of a tax. They also show that the portfolio of products that firms own is an important determinant of the impact the tax will have on individual firms and they suggest that an excise tax is a more efficient way of achieving a given reduction in saturated fat purchases.

We provide an estimate of the short run impact of the introduction of a tax on saturated fat; further work and additional data are needed to evaluate the long-run impacts of such policies. To evaluate long-run impacts, we would need evidence on entry and exit from the market or on the costs of entry and exit.

[15] See Report to the Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Poilcy (1991)

Our results provide evidence on the demand impacts of the tax, on the distributional effects of the tax and on the cost. To justify these type of sin taxes, the impacts calculated in this paper need to be weighed against expected health gains, distributional goals and any inefficiencies that might exist due to market imperfections related to health and nutrition.[16] If individuals are fully informed about the impact of saturated fat, and if the social costs of saturated fat consumption are fully internalised by the individual, then government intervention to curb saturated fat consumption will not be welfare improving. If individuals are not fully informed about the fat content of foods or the optimal fat consumption, or for some reason are not fully rational, there may be some efficiency gain from these taxes.[17] Alternatively, since both state and private insurance markets do not condition insurance premiums on fat consumption, even if consumption choices are privately optimal, there may be an efficiency gain from these taxes.

[16]FSA (2009) :"It has been estimated that reducing saturated fat intakes to within recommended levels could result in approximately 3500 UK deaths averted annually and should improve the quality of life of many more people, saving the UK economy about £1bn each year"

[17]See, inter alia, Armstrong (2008) and Griffith and O'Connell (2010).

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Table 1: Mean values of product characteristics

		Mean	Standard deviation
Product characteristics			
Price in £	(price)	1.02	0.48
Saturated fat volume in g	(saturates)	112.90	55.92
Sodium volume in g	(sodium)	2.91	1.87
Pack size 250g	(250g)	0.32	0.47
Pack size 500g	(500g)	0.50	0.50
Pack size 1Kg	(1Kg)	0.17	0.38
Pack size 2Kg	(2Kg)	0.002	0.04
Budget brand	(budget)	0.12	0.33
Butter	(butter)	0.38	0.49
Healthy margarine	(healthy)	0.15	0.35
PUFA margarine	(pufa)	0.19	0.39
Standard margarine	(standard)	0.28	0.45
Household characteristics			
Income < £10,000pa	(0k-10k income)	0.13	0.33
£10,000pa < Income < £20,000pa	(10k-20k income)	0.28	0.45
£20,000pa < Income < £30,000pa	(20k-30k income)	0.23	0.42
£30,000pa < Income < £40,000pa	(30k-40k income)	0.15	0.36
Income > £40,000pa	(40k+ income)	0.20	0.40
Household in social classes A, B or C1	(upper)	0.48	0.50
Household size	(hh size)	2.64	1.31
Couple with children	(couple with kids)	0.31	0.46
Single parent household	(single kids)	0.04	0.20
Household with children	(no kids)	0.46	0.50
Pensioner household	(pensioner)	0.18	0.39
Main shopper not overweight	(bmi 25-)	0.23	0.42
Main shopper overweight	(bmi 25+)	0.30	0.46
Main shopper bmi not reported	(bmi missing)	0.47	0.50
Household is in South East of UK	(seast)	0.42	0.49
Household is in South West of UK	(swest)	0.24	0.43
Household is in North of UK	(north)	0.34	0.47

Notes: Product characteristics are the mean across the 4,488 observed purchases of butter and margarine products. PUFA is margarine made with polyunsaturated fatty acids. The share of the outside option is 0.74.

The household characteristics are the mean across the 16,637 households in our sample. Main shopper overweight is based on self-reported measures of height and weight. Overweight is defined as a body mass index (BMI=weight (in Kg) over height (in m) squared) over 25. South East includes the government administrative regions East of England, East Midlands, South East and London and south-west includes the administrative regions South West, West Midlands and Wales. Social class is A (upper middle class - higher managerial, administrative or professional), B (middle class - intermediate managerial, administrative or professional) C1 (lower middle class - supervisory or clerical, junior managerial, administrative or professional); the omitted category is C2 (skilled working class - skilled manual workers) D (working class - semi and unskilled manual workers) and E (those at lowest level of subsistence - state pensioners or widows (no other earner), casual or lowest grade workers).

Table 2: Manufacturers

Manufacturer	Number of products	Market share	Best selling product
Unilever Bestfoods	19	28.83%	Flora Light Low Fat Spread 500g
Dairy Crest Foods Ltd	17	20.48%	Clover Dairy Spread 500g
Arla Foods	16	17.65%	Lurpak Lighter Slightly Salted Spreadable 500g
Tesco Food Stores Ltd	18	11.61%	Tesco Value Blended 250g
Asda Stores Ltd	14	5.73%	Asda Smart Price Blended 250g
J Sainsburys	16	4.21%	Sainsbury Basic English 250g
Morrisons Ltd	13	3.14%	Morrisons English 250g
Lidl UK GMBH	6	1.65%	Lidl Slightly Salted German 250g
The Kerrygold Co. Ltd	3	1.43%	Kerrygold Standard Irish 250g
Matthews Foods Plc	4	1.40%	Pure Soya Spread 500g
Aldi Stores Ltd	5	1.38%	Aldi Blended 250g
Evan Rees Ltd	1	0.96%	Hollybush English 250g
Lactalis Beurres Et Frmgs	1	0.47%	President French Unsalted 250g
Netto Ltd	3	0.38%	Netto Veg Spread 500g
Yeo Valley Farms Ltd	1	0.22%	Yeo Valley Blended Organic 250g
C.W.S. (Co-op)	2	0.18%	Co-Op Creamery Blended 250g
Waitrose Ltd	1	0.16%	Waitrose English 250g
Somerfield Stores Ltd	2	0.13%	Somerfield Unsalted English 250g
Total	142	100.00%	

Note: The table shows the manufacturers of the 142 products we include in our data. The reported market shares are based on the 4486 observed purchases of butter and margarine used in estimation and the best selling product for each firm is the firm's product with the highest market share. Manufacturers are ordered by market share.

Table 3: Matrix of selected aggregate own and cross price elasticities

		Lurpak Slightly Salted Danish Butter						Asda Margarine				
		250g	500g	Spreadable 250g	Spreadable 500g	Lighter Spreadable 500g	Lighter Spreadable 250g	Natural Sunflower PUFA 500g	Soft 500g	Best for Baking 500g	Reduced Fat 500g	Low Fat Sunflower Spread 500g
Lurpak Slightly Salted Danish Butter	250g	**-2.6838**	0.0188	0.0180	0.0538	0.0589	0.0168	0.0014	0.0001	0.0009	0.0006	0.0013
	500g	0.0079	**-2.6263**	0.0175	0.0308	0.0331	0.0162	0.0009	0.0001	0.0006	0.0003	0.0009
	Spreadable 250g	0.0082	0.0189	**-2.6828**	0.0549	0.0610	0.0172	0.0013	0.0001	0.0009	0.0006	0.0013
	Spreadable 500g	0.0075	0.0101	0.0168	**-2.4443**	0.0182	0.0157	0.0008	0.0001	0.0006	0.0002	0.0008
	Lighter Spreadable 500g	0.0074	0.0099	0.0167	0.0171	**-2.4404**	0.0158	0.0009	0.0001	0.0006	0.0002	0.0009
	Lighter Spreadable 250g	0.0081	0.0184	0.0182	0.0542	0.0607	**-2.6757**	0.0013	0.0001	0.0009	0.0006	0.0013
Asda Margarine	Natural Sunflower PUFA 500g	0.0058	0.0091	0.0125	0.0261	0.0295	0.0119	**-2.0816**	0.0002	0.0014	0.0011	0.0018
	Soft 500g	0.0054	0.0074	0.0114	0.0210	0.0239	0.0108	0.0019	**-1.8778**	0.0016	0.0012	0.0019
	Best for Baking 500g	0.0055	0.0085	0.0120	0.0245	0.0281	0.0114	0.0019	0.0002	**-2.0791**	0.0012	0.0019
	Reduced Fat 500g	0.0046	0.0048	0.0095	0.0135	0.0152	0.0089	0.0019	0.0002	0.0015	**-1.2395**	0.0019
	Low Fat Sunflower Spread 500g	0.0057	0.0090	0.0125	0.0260	0.0296	0.0119	0.0018	0.0002	0.0014	0.0011	**-2.0819**

Notes: Reported elasticities are weighted averages of household elasticities. The numbers give the percentage change in demand of the product in column 1 with respect to the price of the product in row 1.

Table 4: Marginal costs for four largest market share margarine products

Manufacturer	Product	Market Share	Mean Price	Marginal Cost Mean	Marginal Cost Standard Deviation	(Price – Mc)/Price
Unilever Bestfoods	Flora Light Low Fat Spread 500g	3.83%	0.95	0.53	0.03	0.44
Dairy Crest Foods Ltd	Clover Dairy Spread 500g	3.45%	1.09	0.67	0.09	0.39
Unilever Bestfoods	I.C.B.I.N.B Dairy Spread 500g	3.45%	0.76	0.41	0.07	0.46
Dairy Crest Foods Ltd	St Ivel Utterly Butterly Dairy Spread 500g	3.29%	0.76	0.45	0.06	0.41

Notes: Mean price, marginal cost and margin is a weighted average across all markets. The standard deviation of marginal cost is calculated across markets. I.C.B.I.N.B stands for I Can't Believe It's Not Butter.

Table 5: Marginal costs for comparable products

Manufacturer	Product	Market Share	Mean Price	Marginal Cost Mean	Marginal Cost Standard Deviation	(Price – Mc)/Price
Supermarkets' 250g Budget Butters						
Aldi Stores Ltd	Aldi Blended 250g	0.37%	0.53	0.29	0.00	0.46
Asda Stores Ltd	Asda Spread Blended 250g	2.08%	0.53	0.28	0.00	0.47
Morrisons	Morrisons Bettabuy English 250g	0.60%	0.53	0.28	0.00	0.47
Tesco Food Stores Ltd	Tesco Value Blended 250g	3.91%	0.53	0.28	0.00	0.48
500g Buttery Margarine Products						
Asda Stores Ltd	Asda You'd Better Believe It's Butter Dairy Spread 500g	0.53%	0.76	0.46	0.04	0.40
Dairy Crest Foods Ltd	St Ivel Utterly Butterly Dairy Spread 500g	3.29%	0.76	0.45	0.06	0.41
J Sainsburys	Sainsbury's Butterlicious 500g	0.39%	0.77	0.47	0.04	0.40
Tesco Food Stores Ltd	Tesco Butter Me Up Spread 500g	1.13%	0.75	0.44	0.05	0.41
Unilever Bestfoods	I.C.B.I.N.B Dairy Spread 500g	3.45%	0.76	0.41	0.07	0.46
250g Tesco Butters Of Varying Degree Of Quality						
Tesco Food Stores Ltd	Tesco Value Blended 250g	3.91%	0.53	0.28	0.00	0.48
Tesco Food Stores Ltd	Tesco Creamery Blended 250g	3.83%	0.58	0.32	0.00	0.46
Tesco Food Stores Ltd	Tesco Organic Danish 250g	3.45%	0.88	0.53	0.02	0.40
Tesco Food Stores Ltd	Tesco Finest French 250gm	3.45%	1.03	0.63	0.04	0.38

Notes: Mean price, marginal cost and margin is a weighted average across all markets. The standard deviation of marginal cost is calculated across markets. I.C.B.I.N.B stands for I Can't Believe It's Not Butter.

Table 6: Manufacturer costs, prices and margins

Manufacturer	Number of products	Predicted market share	Mean marginal cost (£)	Mean price (£)	Mean (Price – Mc)/Price	Total annual variable profit (£m)
Unilever Bestfoods	19	28.54%	0.56	1.12	0.49	76.55
Dairy Crest Foods Ltd	17	20.38%	0.58	1.01	0.42	41.42
Arla Foods	16	18.13%	0.78	1.39	0.43	52.77
Tesco Food Stores Ltd	18	11.49%	0.45	0.76	0.43	17.59
Asda Stores Ltd	14	5.64%	0.39	0.68	0.46	7.78
J Sainsburys	16	4.19%	0.43	0.73	0.44	6.09
Morrisons Ltd	13	3.15%	0.38	0.66	0.45	4.26
Lidl UK GMBH	6	1.68%	0.33	0.60	0.45	2.12
The Kerrygold Co. Ltd	3	1.46%	0.60	1.00	0.40	2.80
Matthews Foods Plc	4	1.42%	0.55	0.89	0.38	2.33
Aldi Stores Ltd	5	1.39%	0.44	0.75	0.43	2.03
Evan Rees Ltd	1	0.97%	0.29	0.53	0.46	1.15
Lactalis Beurres Et Frmgs	1	0.48%	0.60	0.96	0.38	0.84
Netto Ltd	3	0.37%	0.15	0.37	0.67	0.40
Yeo Valley Farms Ltd	1	0.23%	0.71	1.13	0.37	0.46
C.W.S. (Co-op)	2	0.18%	0.50	0.81	0.39	0.26
Waitrose Ltd	1	0.16%	0.45	0.75	0.40	0.23
Somerfield Stores Ltd	2	0.14%	0.58	0.94	0.38	0.23
Total	142	100.00%	0.56	1.01	0.45	219.32

Notes: Average marginal cost and average margin are averages across the products produced by the firm, weighted by the products' market share. Manufacturers are ordered by market share.

Table 7: Equilibrium after introduction of tax, firm level results

Manufacturer	Pass through		Change in profits	
	Excise tax	Ad valorem	Excise tax	Ad valorem
Unilever Bestfoods	165%	98%	-5.00%	-10.60%
Dairy Crest Foods Ltd	137%	60%	-10.30%	-16.70%
Arla Foods	154%	89%	-9.20%	-19.70%
Tesco Food Stores Ltd	138%	76%	-17.60%	-15.20%
Asda Stores Ltd	133%	73%	-16.80%	-12.30%
J Sainsburys	136%	78%	-15.70%	-13.10%
Morrisons Ltd	136%	76%	-19.30%	-13.70%
Lidl UK GMBH	137%	80%	-13.60%	-7.70%
The Kerrygold Co. Ltd	149%	97%	-15.70%	-21.30%
Matthews Foods Plc	148%	96%	-7.50%	-10.60%
Aldi Stores Ltd	136%	78%	-16.10%	-15.50%
Evan Rees Ltd	135%	74%	-28.60%	-15.00%
Lactalis Beurres Et Frmgs	149%	95%	-10.60%	-13.90%
Netto Ltd	122%	35%	-22.90%	-6.50%
Yeo Valley Farms Ltd	141%	92%	-6.90%	-14.00%
C.W.S. (Co-op)	142%	92%	-9.10%	-9.50%
Waitrose Ltd	144%	91%	-16.50%	-13.90%
Somerfield Stores Ltd	139%	90%	-7.20%	-9.80%

Notes: Pass through and profits under the observed multiproduct firm ownership, holding marginal costs, product selection and firm product portfolio fixed. Manufacturers are ordered by market share.

Table 8: Equilibrium after introduction of tax, overall results

All figures in £m		*Excise*		*Ad valorem*	
	Base	*No firm response*	*Firm response*	*No firm response*	*Firm response*
	1	2	3	4	5
Expenditure	490.70	469.90	461.99	468.47	470.73
		-4.24%	*-5.85%*	*-4.53%*	*-4.07%*
Estimated variable cost	271.38	235.19	222.83	234.81	239.51
		-13.33%	*-17.89%*	*-13.48%*	*-11.74%*
Firm variable profits	219.32	190.76	198.34	189.73	187.12
		-13.02%	*-9.56%*	*-13.49%*	*-14.68%*
Tax revenue		43.94	40.81	43.93	44.11
Compensating variation		48.68	66.53	48.40	39.75
Cost: change in firm profits + tax revenue - compensating variation		**-33.29**	**-46.70**	**-34.06**	**-27.84**

Notes: We aggregate the predictions from our demand model across households, weighting by the number of shopping trips households go on in 2006 and household demographic weights. This yields results at the national level for year 2006. Estimated variables costs equal the sum across products of marginal cost times quantity.

Table 9: Comparison of prices and profits in multi product firm and single product firm pre-tax equilibria

Manufacturer	Number of products	Average price (£) with existing portfolio of products	Average price (£) if all products were produced by single product firms	Difference (£)	Profits (£m) with existing portfolio of products	Profits (£m) if all products were produced by single product firms	Percentage Difference in Profits
Unilever Bestfoods	19	1.12	1.00	*0.117*	76.55	68.41	*11.91%*
Dairy Crest Foods Ltd	17	1.01	0.96	*0.043*	41.42	37.48	*10.50%*
Arla Foods	16	1.39	1.28	*0.107*	52.77	45.60	*15.72%*
Tesco Food Stores Ltd	18	0.76	0.75	*0.018*	17.59	16.17	*8.82%*
Asda Stores Ltd	14	0.68	0.67	*0.008*	7.78	7.21	*7.85%*
J Sainsburys	16	0.73	0.72	*0.010*	6.09	5.60	*8.84%*
Morrisons Ltd	13	0.66	0.65	*0.006*	4.26	3.94	*8.24%*
Lidl UK GMBH	6	0.60	0.59	*0.002*	2.12	1.98	*6.90%*
The Kerrygold Co. Ltd	3	1.00	0.99	*0.011*	2.80	2.48	*12.94%*
Matthews Foods Plc	4	0.89	0.89	*0.005*	2.33	2.10	*10.60%*
Aldi Stores Ltd	5	0.75	0.74	*0.010*	2.03	1.86	*9.05%*
Evan Rees Ltd	1	0.53	0.54	*-0.003*	1.15	1.08	*6.70%*
Lactalis Beurres Et Frmgs	1	0.96	0.96	*-0.004*	0.84	0.75	*11.31%*
Netto Ltd	3	0.37	0.37	*0.004*	0.40	0.38	*5.43%*
Yeo Valley Farms Ltd	1	1.13	1.13	*-0.001*	0.46	0.41	*13.71%*
C.W.S. (Co-op)	2	0.81	0.81	*0.002*	0.26	0.24	*9.20%*
Waitrose Ltd	1	0.75	0.75	*-0.002*	0.23	0.21	*8.88%*
Somerfield Stores Ltd	2	0.94	0.94	*0.003*	0.23	0.21	*11.60%*

Notes: Average price and profits are reported for the observed multiproduct firm ownership structure and under the counterfactual ownership structure where all products are produced by single product firms. Also the difference in price and the percentage difference in profits under these scenarios are reported. Manufacturers are ordered by market share.

Table 10: Comparison of pass-through in multi and single product firm equilibria

	Excise tax			Ad valorem		
Manufacturer	**Existing portfolio of products**	**Single product firms**	***Difference***	**Existing portfolio of products**	**Single product firms**	***Difference***
Unilever Bestfoods	165%	132%	*32%*	98%	89%	*9%*
Dairy Crest Foods Ltd	137%	128%	*9%*	60%	69%	*-9%*
Arla Foods	154%	132%	*21%*	89%	67%	*22%*
Tesco Food Stores Ltd	138%	129%	*9%*	76%	93%	*-16%*
Asda Stores Ltd	133%	127%	*6%*	73%	88%	*-14%*
J Sainsburys	136%	128%	*8%*	78%	93%	*-15%*
Morrisons Ltd	136%	128%	*7%*	76%	90%	*-14%*
Lidl UK GMBH	137%	130%	*7%*	80%	88%	*-8%*
The Kerrygold Co. Ltd	149%	137%	*12%*	97%	62%	*35%*
Matthews Foods Plc	148%	140%	*8%*	96%	100%	*-4%*
Aldi Stores Ltd	136%	127%	*8%*	78%	86%	*-8%*
Evan Rees Ltd	135%	129%	*7%*	74%	75%	*0%*
Lactalis Beurres Et Frmgs	149%	141%	*8%*	95%	102%	*-7%*
Netto Ltd	122%	117%	*6%*	35%	64%	*-29%*
Yeo Valley Farms Ltd	141%	137%	*3%*	92%	98%	*-7%*
C.W.S. (Co-op)	142%	137%	*5%*	92%	100%	*-7%*
Waitrose Ltd	144%	136%	*8%*	91%	95%	*-4%*
Somerfield Stores Ltd	139%	133%	*6%*	90%	97%	*-7%*

Notes: Average pass through is reported under the observed multiproduct firm ownership structure and under the counterfactual ownership structure where all products are produced by single product firms. Also the difference in pass through is reported. Manufacturers are ordered by market share.

Table 11: Cross-price elasticities within and between firms

				Mean cross-price elasticity	
Manufacturer	**Number of products**	**Predicted market share**	**Mean own price elasticity**	**product owned by firm**	**product produced by other firm**
Large manufacturers					
Unilever Bestfoods	19	28.54%	-2.405	0.0160	0.0058
Dairy Crest Foods Ltd	17	20.38%	-2.465	0.0126	0.0069
Arla Foods	16	18.13%	-2.570	0.0175	0.0061
		11.49%			
Supermarkets with own-brand products		5.64%			
Tesco Food Stores Ltd	18	4.19%	-2.431	0.0054	0.0081
Asda Stores Ltd	14	3.15%	-2.314	0.0029	0.0080
J Sainsburys	16	1.68%	-2.392	0.0021	0.0083
Morrisons Ltd	13	1.46%	-2.309	0.0016	0.0079
Lidl UK GMBH	6	1.42%	-2.274	0.0020	0.0073
Aldi Stores Ltd	5	1.39%	-2.385	0.0023	0.0078
		0.97%			
Small manufacturers		0.48%			
The Kerrygold Co. Ltd	3	0.37%	-2.536	0.0050	0.0077
Matthews Foods Plc	4	0.23%	-2.636	0.0030	0.0086
Evan Rees Ltd	1	0.18%	-2.171	-	0.0067
Lactalis Beurres Et Frmg	1	0.16%	-2.660	-	0.0088
Netto Ltd	3	0.14%	-1.584	0.0006	0.0059
C.W.S. (Co-op)	2	28.54%	-2.589	0.0009	0.0084
Waitrose Ltd	1	20.38%	-2.520	-	0.0079
Yeo Valley Farms Ltd	1	18.13%	-2.724	-	0.0092
Somerfield Stores Ltd	2	11.49%	-2.622	0.0008	0.0086

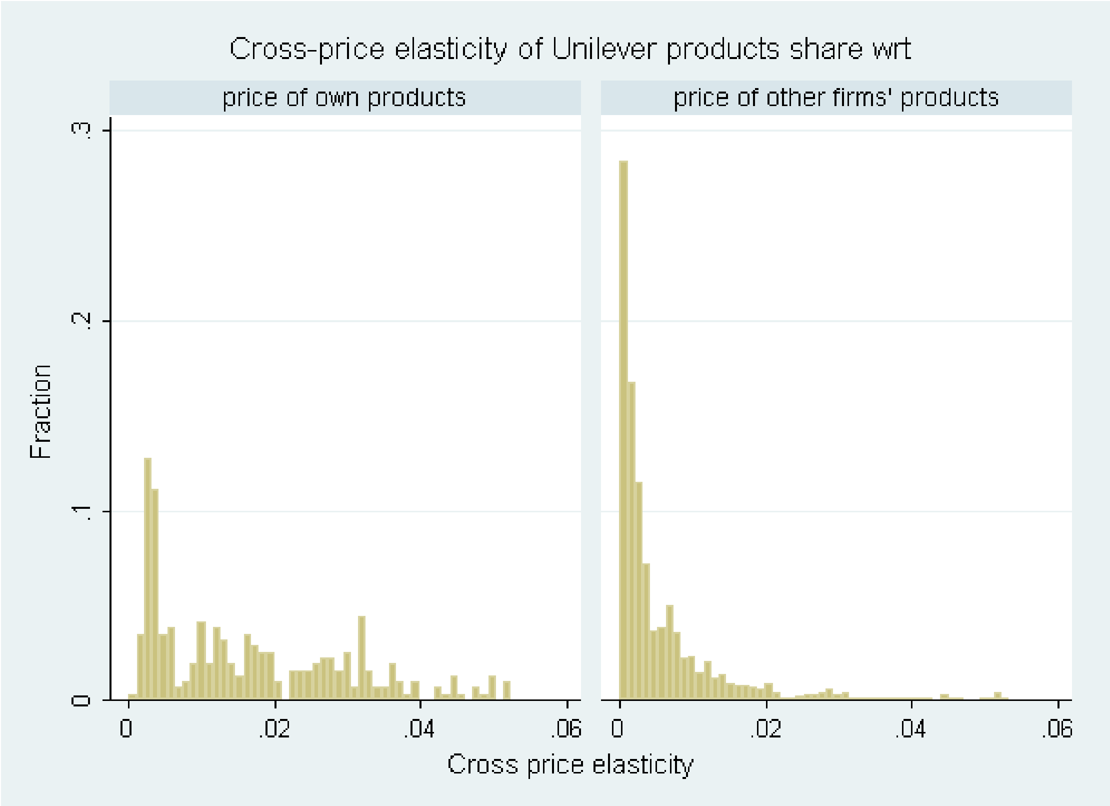
Notes: Own price elasticities are weighted averages across the market elasticities of products produced by the manufacturer. Cross price elasticities are weighted averages across the market elasticities of products produced by the manufacturer. They refer to the change in demand for the manufacturer's 'average' product with respect to the price of another product (either owned by the same firms or by another firm). Manufacturers are ordered by market share.

Table 12: Aggregate impact of excise and ad valorem tax

		Excise		*Ad valorem*	
	Base	*No firm response*	*Firm response*	*No firm response*	*Firm response*
Saturated fat purchased (millions of kg)	**54.09**	**43.94**	**40.81**	**45.41**	**46.65**
		-18.75%	*-24.54%*	*-16.04%*	*-13.74%*
Mean cost of a 1kg reduction in saturated fat (£)		3.28	3.52	3.92	3.74
Mean compensating variation per 1kg reduction in saturated fat (£)		4.60	5.01	5.58	5.34

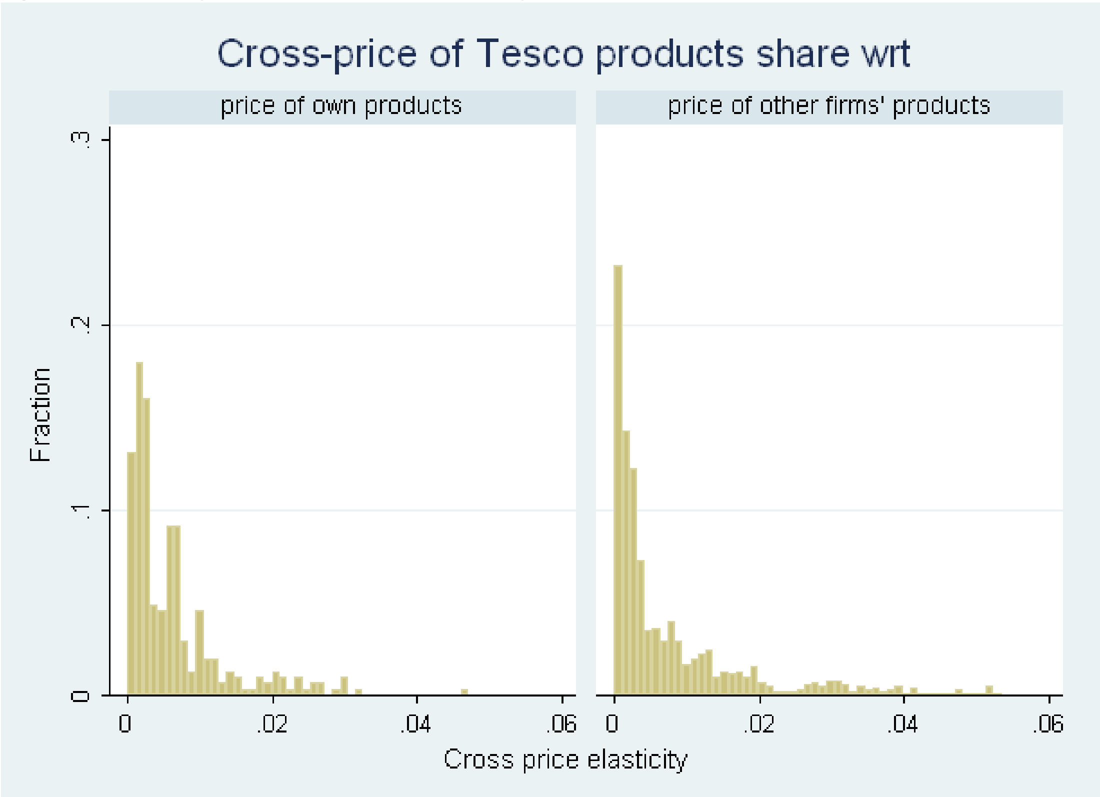
Notes: We aggregate the predictions from our demand model across households, weighting by the number of shopping trips households go on in 2006 and household demographic weights. This yields results at the national level for year 2006.

Figure 1a: Cross-price elasticities for Unilever products



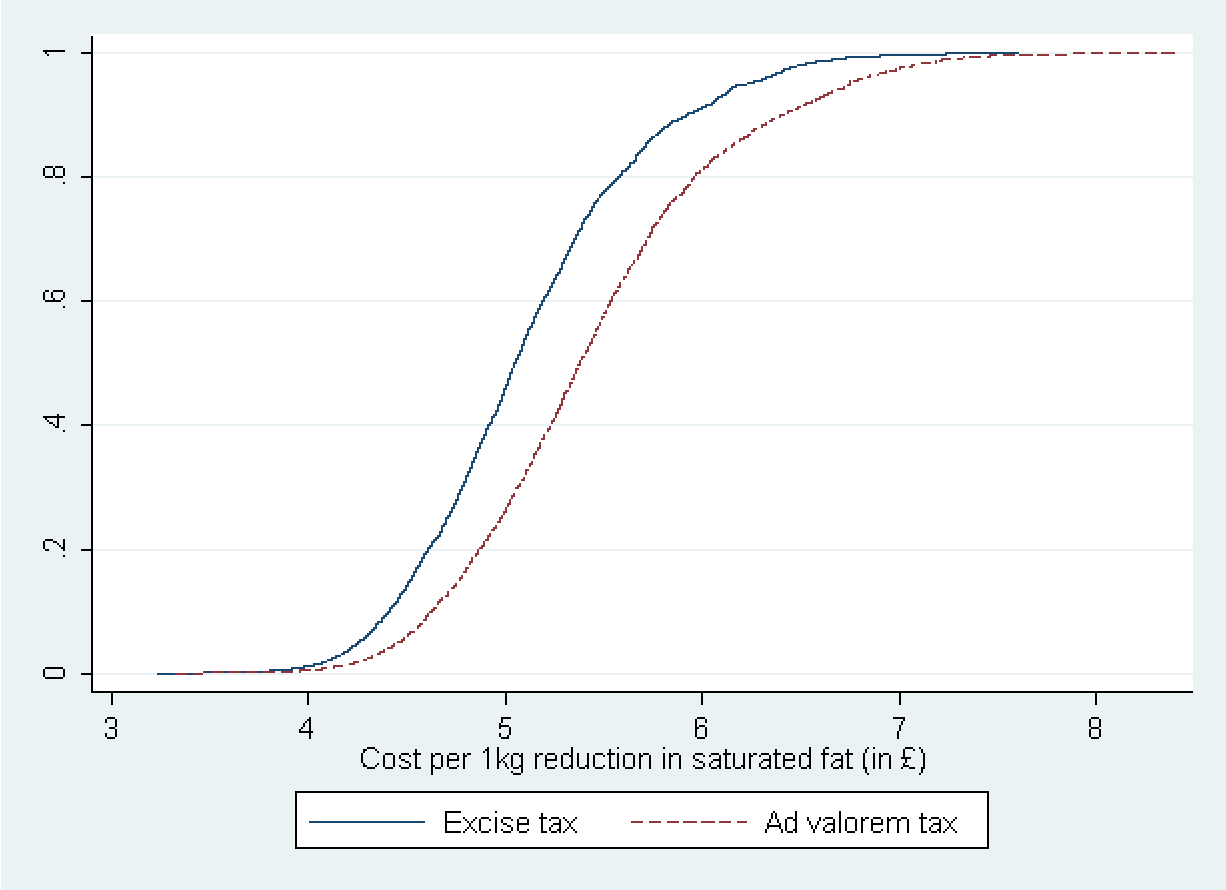
Notes: The left-hand graph show the distribution of cross-price elasticities between the 19 products that Unilever produces; the right-hand graph shows the distribution of the cross price elasticities between Unilever products and all other products in the market that are not produced by Unilever.

Figure 1b: Cross-price elasticities for Tesco products



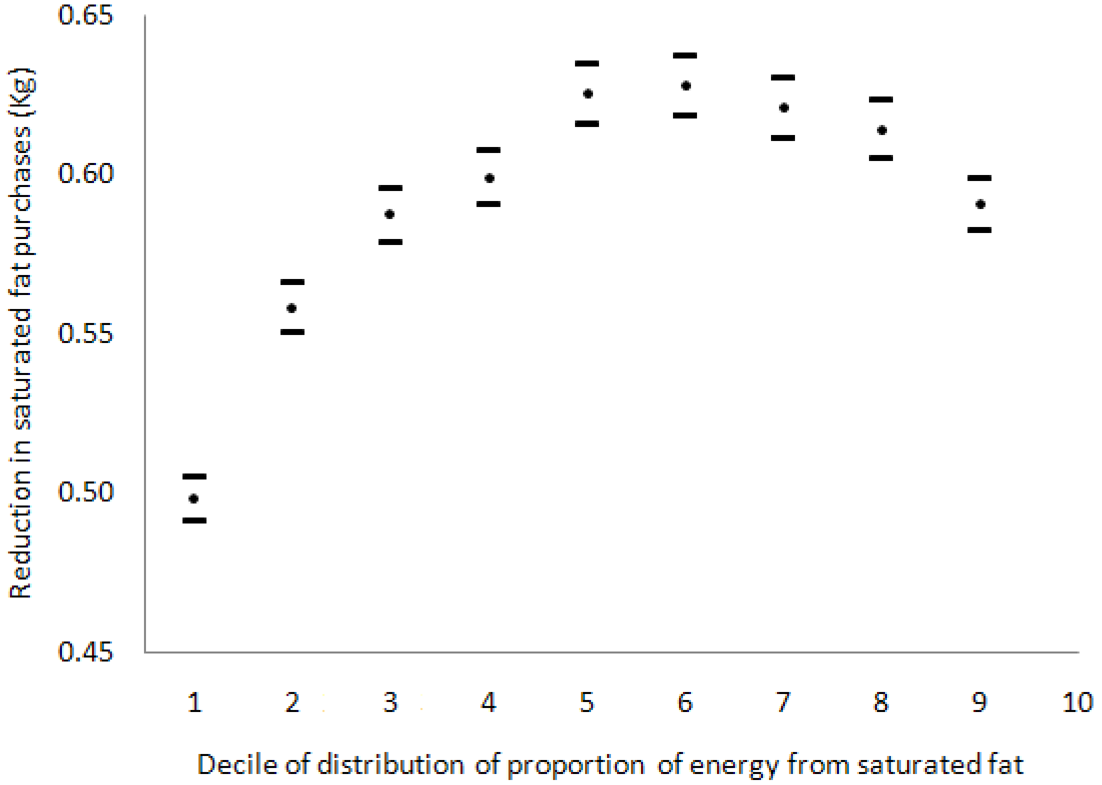
Notes: The left-hand graph show the distribution of cross-price elasticities between the 18 products that Tesco produces; the right-hand graph shows the distribution of the cross price elasticities between Tesco products and all other products in the market that are not produced by Tesco.

Figure 2: Compensating variation per 1kg reduction in saturated fat, distribution across households



Notes: For each household we compute the annual compensating variation associated with the introduction of each tax, along with the reduction in the amount of saturated fat they purchase. This figure shows the distribution of the ratio of these two numbers.

Figure 3: Annual reduction in saturated fat induced by the excise tax, by proportion of energy purchased as saturated fat



Notes: For each household we calculate the proportion of annual energy purchased as saturated fat and split the resulting distribution into deciles. This figure reports the average reduction in saturated purchased induced by the excise tax for households in each decile.

Web Appendix: Sin taxes in differentiated product oligopoly

Rachel Griffith
IFS and University of Manchester

Lars Nesheim
CeMMAP, IFS and UCL

Martin O'Connell
IFS and UCL

November 24, 2010

1 Price elasticities

The estimated coefficients allow us to calculate own and cross-price elasticities for each product and each household. We compute market elasticities for each product by aggregating across households and weighting by the frequency that each household shops and the household sampling weights (which gross up to the UK population).[1] We assume that the preference shocks determinining purchase decisions are i.i.d. across trips, and that the number of shopping trips per year is fixed (i.e. is not influenced by the price of butter).

A household is defined by its vector of characteristics z_i. Denote the unconditional probability that a household with characteristics z_i chooses option (j, s) at price p_{jsm} on a single shopping trip as

$$\pi_{js}\left(z_i, p_{jsm}\right) = \int L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right) \phi\left(\theta_2\right) d\theta_2 \tag{1}$$

where θ_1 is the vector of non-stochastic coefficients, θ_2 is the vector of random coefficients and where

$$L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right) = \frac{e^{V_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right)}}{\sum_{k,t} e^{V_{kt}\left(z_i, p_{ktm}, \theta_1, \theta_2\right)}} \tag{2}$$

is the probability that z_i chooses (j, s) conditional on θ_2.

The price elasticity of household z_i on a single trip is

$$\epsilon_{ijs} = \frac{\partial \pi_{js}\left(z_i, p_{jsm}\right)}{\partial p_{jsm}} \frac{p_{jsm}}{\pi_{js}\left(z_i, p_{jsm}\right)} \tag{3}$$

where

$$\frac{\partial \pi_{js}\left(z_i, p_{jsm}\right)}{\partial p_{jsm}} = \int \frac{\partial L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right)}{\partial p_{jsm}} \phi\left(\theta_2\right) d\theta_2. \tag{4}$$

[1] The household sampling weights correct for over sampling of some demographics by the market research firm. Sampling weights are not used in estimation because sample selection is based on exogenous demographics, not on the endogenous choice of butter purchases.

Let $w_m(z_i)$ be proportional to the inverse of the probability that a household with characteristics z_i, observed in market m is included in the sample, let $\sum_{i \in n_m} w_m(z_i) = 1$ and suppose n_m households are observed in market m. Then the market share of product (j, s) on a single trip is

$$s_{jsm} = n_m^{-1} \sum_{i \in n_m} w_m(z_i) \pi_{js}(z_i, p_{jsm}).$$

The market (single trip) demand elasticity is

$$\begin{aligned} \frac{p_{jsm}}{s_{jsm}} \frac{\partial s_{jsm}}{\partial p_{jsm}} &= n_m^{-1} \sum_{i \in n_m} w_m(z_i) \frac{p_{jsm}}{s_{jsm}} \frac{\partial \pi_{js}(z_i, p_{jsm})}{\partial p_{jsm}} \\ &= n_m^{-1} \sum_{i \in n_m} \frac{w_m(z_i) \pi_{js}(z_i, p_{jsm})}{s_{jsm}} \epsilon_{ijs}. \end{aligned} \quad (5)$$

Let T_i be the proportion of total shopping trips by all households in the market taken by household i. Assuming that the probability of purchase is identical on all trips, the annual market size is

$$S_{jsm} = n_m^{-1} \sum_{i \in n_m} T_i w_m(z_i) \pi_{js}(z_i, p_{jsm})$$

and the annual market elasticity is

$$\begin{aligned} \frac{p_{jsm}}{S_{jsm}} \frac{\partial S_{jsm}}{\partial p_{jsm}} &= n_m^{-1} \sum_{i \in n_m} T_i w_m(z_i) \frac{p_{jsm}}{S_{jsm}} \frac{\partial \pi_{js}(z_i, p_{jsm})}{\partial p_{jsm}} \\ &= n_m^{-1} \sum_{i \in n_m} T_i w_m(z_i) \frac{\pi_{js}(z_i, p_{jsm})}{S_{jsm}} \epsilon_{ijs}. \end{aligned} \quad (6)$$

A similar procedure yields the market level cross price elasticities.

2 Estimated coefficients

Table A.1 reports the non-brand fixed effect estamated coefficients. The first column reports the mean impact of the product characteristics that vary within brand. The coefficients on price, the nutrient variables and the pack size dummies are identified from the within brand variation in these characteristics (and across market variation in the case of price). The second column reports the estimated variance of the random coefficients. We allow for random preference variation for price and saturated fat content. The remaining columns report the coefficients on the product-household characteristic interactions. The negative, and large in absolute terms, coefficient on price means that most households reduce their demand in response to an increase in price. The interactions between price and observable household characteristics allow the mean coefficient on price to vary with observables and the random coefficient on price allows for random variation in households' responsiveness to price. The coefficients on the interactive terms broadly accord with intuition; for instance, large households prefer larger pack sizes and higher income households have a distaste for own-brand budget products. The δ_j that we include in our model are brand level fixed effects, and Table A.2 reports the estimated brand fixed effects.

2.1 Compensating variation

We consider the impact on consumers of the tax by calculating the compensating variation. For each household this is

$$CV_i = \frac{\ln\left(\sum_{j=0}^{J} e^{V_{ij}^{NEW}}\right) - \ln\left(\sum_{j=0}^{J} e^{V_{ij}^{OLD}}\right)}{\frac{\partial V_{ij}^{OLD}}{\partial p}}. \tag{7}$$

Where V_{ij}^{OLD} and V_{ij}^{NEW} are pre and post tax utility respectively. The first term in the numerator of (7) is the expected utility under the new prices and the second is expected utility under the old prices. The denominator is equal to the marginal utility of income under some assumptions outlined in Small and Rosen (1981). The formula takes account of utility from the inside options ($j > 0$)and the outside option ($j = 0$). It varies across households because: (i) some households have a high utility from the outside option and therefore are very likely to buy the outside option and hence have small impacts, (ii) some households have high utility for an option that does not have close substitutes and so do not switch (inelastic demand), (iii) some households are readily willing to switch to a lower fat product, and (iv) household's price sensitivity in the denominator varies.

References

Small, K and Rosen, H (1981) "Applied welfare economics of discrete choice models" *Econometrica* 49, 1, 105-130

Table A.1: Estimated coefficients

	mean	*variance*	*bmi 25+*	*bmi missing*	*hh size*	*10-20k income*	*20-30k income*	*30-40k income*	*40k+ income*	*north*	*couple with kids*	*pensioner*	*single kids*	*swest*	*upper*
budget					0.0172	-0.1075	**-0.4971**	-0.4543	**-0.6757**						
					(0.0589)	(0.2173)	(0.2401)	(0.2617)	(0.2571)						
butter			0.1127	0.0528	0.1180	-0.0543	0.0957	0.2158	0.1473	0.0648	-0.0799	-0.0718	-0.6475	-0.2976	0.0780
			(0.2897)	(0.2546)	(0.1125)	(0.3087)	(0.3329)	(0.3657)	(0.3709)	(0.1540)	(0.2978)	(0.2440)	(0.6689)	(0.1651)	(0.1606)
health			0.2025	-0.1656	0.0204	0.1996	0.2025	0.0754	0.2722	0.1529	-0.4587	-0.0360	-0.5628	-0.0461	-0.1669
			(0.3447)	(0.3058)	(0.1066)	(0.2871)	(0.3132)	(0.3468)	(0.3496)	(0.1574)	(0.3084)	(0.2490)	(0.6665)	(0.1700)	(0.1586)
price	**-5.2624**	**5.6399**	0.2617	**0.3923**	-0.0945	0.0446	-0.0001	0.2111	0.4118	-0.0207	0.0175	-0.0621	0.0915	0.1350	-0.0556
	(0.5916)	(1.3227)	(0.1752)	(0.1606)	(0.0904)	(0.2317)	(0.2498)	(0.2706)	(0.2682)	(0.1159)	(0.2014)	(0.1826)	(0.6957)	(0.1261)	(0.1128)
pufa			-0.0448	-0.1424	-0.0799	0.0386	0.1041	0.0540	0.2471	0.1827	-0.1826	-0.0369	-0.7517	0.1440	-0.0443
			(0.2615)	(0.2259)	(0.0826)	(0.2245)	(0.2485)	(0.2791)	(0.2842)	(0.1256)	(0.2310)	(0.1868)	(0.5652)	(0.1316)	(0.1275)
250g					**-0.1805**										
					(0.0641)										
500g	**2.7263**														
	(0.2229)														
1kg	**4.5431**														
	(0.5580)				**0.2690**										
2kg	**10.2859**				(0.0989)										
	(0.9336)														
saturates	**-0.0085**	0.0000	-0.0002	-0.0020	0.0006	0.0021	0.0012	0.0002	0.0017	0.0002	-0.0036	0.0019	0.0010	0.0013	-0.0010
	(0.0030)	(0.0000)	(0.0019)	(0.0018)	(0.0007)	(0.0027)	(0.0029)	(0.0032)	(0.0032)	(0.0014)	(0.0020)	(0.0019)	(0.0050)	(0.0015)	(0.0014)
sodium	-0.0849		0.0284	0.0277	-0.0061	-0.1018	-0.1205	-0.1126	**-0.1935**	-0.0709	**0.1547**	**-0.1463**	-0.0270	**-0.0959**	-0.0398
	(0.1139)		(0.0604)	(0.0548)	(0.0317)	(0.0804)	(0.0869)	(0.0953)	(0.0960)	(0.0415)	(0.0662)	(0.0621)	(0.1632)	(0.0446)	(0.0429)
outside			0.3425	0.0976	**-0.3683**	0.0672	-0.1224	-0.1695	0.0526	0.0602	0.3215	**-0.5062**	0.1536	-0.2101	-0.0918
			(0.3453)	(0.2995)	(0.1590)	(0.2822)	(0.3082)	(0.3431)	(0.3495)	(0.1493)	(0.3273)	(0.2457)	(0.6672)	(0.1559)	(0.1506)

Notes: 16,637 households. Standard errors in parenthesis; coefficients in bold are significant at 5% level. The coefficient in the "mean" column is identified from within brand variation, the "variance" column reports the variance of the random effect. The definitions for the product and household characteristics are given in Tables 1 and 2, expect for outside (the outside option fixed effect). Brand fixed effect estimates are omitted from this table and presented in Table A.2.

Table A.2: Estimated brand fixed effects

Brand	Number of products	Coefficient
Outside option	1	**0.983**
		(0.396)
Aldi Beautifully Butterfully	1	**-4.960**
		(0.666)
Aldi Butter	1	**-2.207**
		(0.428)
Aldi Olive Gold Reduced Fat Spread	1	**-4.652**
		(0.659)
Aldi Spreadable	1	**-2.623**
		(0.660)
Aldi Sunflower Low Fat Spread	1	**-6.335**
		(0.629)
Anchor Butter	2	**-0.658**
		(0.274)
Anchor Spreadable	2	-0.454
		(0.256)
Anchor Spreadable Lighter	2	**-1.229**
		(0.273)
Asda Best For Baking Margarine	1	**-6.051**
		(0.706)
Asda Creamery	1	**-2.212**
		(0.496)
Asda GFY Sunflower Spread	1	**-5.831**
		(0.561)
Asda Natural Sunflower Pufa	2	**-5.705**
		(0.308)
Asda Olive Gold Reduced Fat Spread	1	**-4.056**
		(0.645)
Asda Organic Butter	1	**-2.589**
		(0.844)
Asda Smart Price Other	1	-0.325
		(0.313)
Asda Smart Price Reduced Fat Spread	1	**-6.324**
		(0.597)
Asda Soft Margarine	2	**-8.207**
		(0.879)
Asda You'd Butter Believe It	3	**-4.268**
		(0.257)
Bertolli Spread	3	**-1.977**
		(0.256)
Clover Standard Dairy Spread	3	**-0.690**
		(0.252)
Co-op Buttery Spread	1	**-5.511**
		(0.752)
Co-op Creamery	1	**-2.779**
		(0.921)
Country Life Butter	2	-0.343
		(0.289)
Country Life Shirgar Butter	1	**-2.934**
		(1.014)
Country Life Spreadable	2	**-1.565**
		(0.290)
Flora Buttery	1	**-2.532**

		(0.2460
Flora Diet	1	**-3.161**
		(0.323)
Flora Light Spread	3	**-1.813**
		(0.290)
Flora No Salt Pufa	1	**-3.969**
		(0.552)
Flora Pro Active Lighter Spread	1	0.688
		(0.457)
Flora Pro Active Light Olive Spread	1	-0.575
		(0.673)
Flora Pufa	3	**-2.082**
		(0.217)
Gold Lightest	1	**-4.345**
		(0.351)
Gold Low Fat	1	**-3.675**
		(0.326)
Gold Omega 3 Light	1	**-3.824**
		(0.375)
Hollybush Butter	1	**-1.386**
		(0.295)
I Can't Believe It's Not Butter Dairy Spread	2	**-1.758**
		(0.249)
Kerrygold Butter	1	**-0.898**
		(0.296)
Kerrygold Softer Butter	2	**-1.655**
		(0.339)
Lidl Butter	1	**-2.075**
		(0.370)
Lidl Olive Gold Reduced Fat Spread	1	**-4.525**
		(0.549)
Lidl Sunflower Low Fat Spread	2	**-6.606**
		(0.658)
Lidl Spread	1	**-5.105**
		(0.562)
Lidl Spreadable Butter	1	**-2.075**
		(0.846)
Lurpak Butter	3	**-0.624**
		(0.292)
Lurpak Spreadable	3	-0.116
		(0.258)
Lurpak Spreadable Lighter	2	-0.400
		(0.257)
Morrisons Butterbuy Other	1	**-1.860**
		(0.355)
Morrisons Butter For You Sunflower Spread	1	**-6.579**
		(0.631)
Morrisons Other	1	**-0.854**
		(0.289)
Morrisons Reduced Fat Spreadable	1	**-4.288**
		(0.933)
Morrisons Soft Margarine	2	**-8.895**
		(0.833)
Morrisons Sunflower Pufa	2	**-5.647**
		(0.623)
Mountain Maid Butter	1	**-3.018**
		(0.934)

Morrisons Better By Far Spread	1	**-5.078**
		(0.517)
Morrisons Bettabuy Soft Spread	1	**-6.857**
		(0.675)
Morrisons Olive Reduced Fat Spread	1	**-3.940**
		(0.436)
Morrisons Organic Butter	1	**-2.542**
		(0.892)
Morrisons Packet Margarine	1	**-7.677**
		(1.004)
Netto Olive Reduced Fat Spread	1	**-5.811**
		(0.933)
Netto Sunflower Low Fat Spread	1	**-7.222**
		(0.914)
Netto Vegetable Spread	1	**-6.520**
		(0.811)
President Butter	1	**-0.909**
		(0.347)
Pure Organic Reduced Fat Spread	1	**-3.764**
		(0.620)
Pure Soya Spread	1	**-3.683**
		(0.279)
Pure Sunflower Spread	1	**-4.837**
		(0.816)
Sainsbury Be Good To yourself Light Sunflower Spread	1	**-6.694**
		(0.880)
Sainsbury Blue Label Packet Margarine	1	**-5.839**
		(0.910)
Sainsbury Other	2	**-1.999**
		(0.337)
Sainsbury Be Good To Yourself Olive Gold	1	**-5.647**
		(0.821)
Sainsbury Butterlicious	3	**-4.420**
		(0.289)
Sainsbury Olive Gold Margarine	3	**-4.300**
		(0.330)
Sainsbury Organic Other	1	**-2.593**
		(0.978)
Sainsbury Sunflower Pufa	2	**-5.583**
		(0.317)
Sainsbury Basics Butter	1	**-0.736**
		(0.322)
Sainsbury Basics Reduced Fat Soft Spread	1	**-6.996**
		(0.814)
Somerfield Olive Reduced Fat Spread	1	**-5.001**
		(0.833)
Somerfield Other	1	**-3.252**
		(0.828)
St Ivel Utterly Butterly	3	**-1.979**
		(0.231)
Stork Packet Margarine	1	**-2.001**
		(0.278)
Stork Non-Pufa Margarine	2	**-3.582**
		(0.225)
Tesco Baking Margarine	1	**-5.334**
		(0.4940
Tesco Butter Me Up	2	**-3.278**

		(0.251)
Tesco Creamery	1	**-1.181**
		(0.296)
Tesco Finest Other	1	**-3.189**
		(1.023)
Tesco Healthy Light Olive Spread	1	**-4.576**
		(0.821)
Tesco Healthy Living Low Fat Spread	2	**-5.131**
		(0.342)
Tesco Olive Gold Reduced Fat Spread	3	**-3.432**
		(0.236)
Tesco Organic Danish Butter	1	**-1.689**
		(0.618)
Tesco Soft Margarine	1	**-9.027**
		(0.899)
Tesco Spreadable Butter	1	**-2.834**
		(0.856)
Tesco Sunflower Pufa	1	**-4.546**
		(0.318)
Tesco Value Blended Butter	1	-0.007
		(0.311)
Tesco Value Soft Spread	1	**-7.179**
		(0.638)
Tesco Low Cholesterol Sunflower Spread	1	**-4.951**
		(0.588)
Vitalite Pufa	1	**-2.774**
		(0.255)
Waitrose Butter	1	**-2.646**
		(0.879)
What Not Butter Spread	1	**-4.670**
		(0.805)
Willow Dairy Spread	2	**-3.201**
		(0.254)
Yeo Valley Organic Butter	1	-1.196
		(0.716)
Yorkshire Butter	1	**-2.754**
		(0.933)

Notes: 16,637 households. Standard errors in parenthesis; coefficients in bold are significant at 5% level.