Sin taxes in differentiated product oligopoly: an application to the butter and margarine market

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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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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.

In this paper we consider the potential to use taxes to curb consumption of saturated fat, accounting for the possibility that consumers may substitute between highly substitutable products belonging to the same food category, and for the oligopolistic structure of the market. Existing studies of fat and sugar taxes have failed to account for this.[1]

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)).

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.

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. In addition, we allow utility to be a nonlinear function of price so that the curvatures of the demand functions are not constrained a priori. 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

[1] Including Chouinard et al (2007), Smed et al (2007), Leicester and Windmeijer (2004), Marshall (2000), Acs and Lyles (2007) and Marette et al (2008).

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. This application is of considerable interest in itself. 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 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).[2] 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.

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

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, 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%.

Another related empirical literature looks at the extent to which fluctuations in exchange rates are passed on to the local prices of imports. Goldberg and Verboven (2001), Hellerstein (2008), Goldberg and Hellerstein (2007) and Nakamura and Zerom (2010) document the reduced form evidence on exchange rate pass through and estimate structural models which seek to account for this evidence. In contrast to the reduced form evidence on pass through of taxes, this literature suggests that pass through of exchange rate fluctuations to final prices is incomplete. These papers highlight that an important reason for this is the presence of local non-traded cost components which are immune to exchange rate fluctuations and drive a wedge between the price of inputs subject to exchange rate fluctuations and final consumer prices.[3] The taxes we consider are imposed at the retail, rather than wholesale, level meaning no such wedge exists.

A number of papers in the theoretical literature consider taxes in oligopoly markets with a homogenous good.[4] Seade (1987) shows that in a homogeneous 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 homogeneous 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

[3] The other determinants of incomplete pass through are mark-up adjustment and nominal price rigidities.

[4] 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).

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

Three somewhat novel features of our analysis distinguish it from the existing literature. First, our data contains highly disaggregate detailed information for a representative sample of the entire UK market for butter and margarine. We observe those who purchase as well as those who choose not to purchase. We control for 101 brand fixed effects, detailed product characteristics, pack size and monthly brand level advertising. We assume that these characteristics capture all market level variation in product characteristics and demand shifters. This assumption of no product level unobservables after controlling for brand-level fixed effects is the same as that discussed in Bajari and Benkard (2005). We exploit price variation across products, across pack sizes and across time. Second, we allow the indirect utility for each product to be a nonlinear function of price. As a result the model does not constrain the curvatures of the demand curves. Because the curvatures of the demand curves are key determinants of equilibrium pass-through, this ensures that our model allows for flexible patterns of pass-through. Finally, we include a large number of interactions of household demographics with product characteristics including and price. We use a penalized likelihood method to "select" the model that best fits the data according to a Bayes Information Criteria. Under the assumption, that the true number of nonzero parameters is finite, this method consistently selects the correct model.

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.[5]

We specify a random coefficients discrete choice demand system.[6] 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

$$u_{i01m} = \delta_0 + \sum_r z_i^r \beta_1^{0r} + \varepsilon_{i01m}$$

where z_i^r for $r = 1, ..., R$, is a vector of observable household characteristics. 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.

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

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

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

(j, s) takes the form,

$$u_{ijsm} = \sum_k x^k_{jsm}\beta^k_i + \xi_j + \varepsilon_{ijsm} \quad (1)$$

$$\beta^k_i = \beta^k_0 + \sum_r z^r_i \beta^{kr}_1 + \eta^k_i \quad (2)$$

where x^k_{jsm} are $k = 1, \ldots, K$ observable product and market characteristics, ξ_j are brand fixed-effects, and ε_{ijsm} is an unobservable stochastic term. Included in the vector of product characteristics are monthly brand-level advertising expenditures and a set of functions of price $\{B_l(p_{jsm})\}^L_{l=1}$. The advertising expenditures capture monthly variation in brand-level demand shifters. The functions of price allow utility to be a nonlinear function of price.

We allow households to have heterogeneous preferences over the observed product characteristics x^k_{jsm} through the coefficients β^k_i. These coefficients vary both with observable household characteristics z^r_i, indexed $r = 1, ..., R$ and unobservable household characteristics η^k_i. 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^k_0 and parameters β^{kr}_1 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 (across markets or across pack sizes), and the set K_2 that are constant within brand. We substitute (2) into (1), and rewrite (1) as

$$\begin{aligned} u_{ijsm} &= \sum_k \left(x^k_{jsm}\beta^k_0 + \sum_r z^r_i x^k_{jsm}\beta^{kr}_1 + \eta^k_i x^k_{jsm} \right) + \xi_j + \varepsilon_{ijsm} \quad (3) \\ &= \delta_j + \sum_{k \in K_1} x^k_{jsm}\beta^k_0 + \sum_{k,r} z^r_i x^k_{jsm}\beta^{kr}_1 + \sum_k \eta^k_i x^k_{jsm} + \varepsilon_{ijsm} \end{aligned}$$

where

$$\delta_j = \xi_j + \sum_{k \in K_2} x^k_{jsm}\beta^k_0 \quad (4)$$

For $k \in K_1$, the parameters $\left(\beta^k_0, \beta^k_1\right)$ are identified. For $k \in K_2$ only the parameters β^k_1 are identified.

In summary, the variables $\eta_i = \left(\eta^1_i, ..., \eta^K_i\right)$, $\xi = (\xi_1, ..., \xi_J)$ and $\varepsilon_{im} = (\varepsilon_{i01m}, \varepsilon_{i11m}, ..., \varepsilon_{iJSm})$ are unobservable stochastic terms. The vectors $\beta_0 = (\beta^1_0, ..., \beta^K_0)$ for $k \in K_1$,

$$\beta_1 = \left(\beta^{01}_1, \beta^{02}_1, ..., \beta^{11}_1, \beta^{12}_1 ..., \beta^{KR}_1\right),$$

$\delta = (\delta_0, ..., \delta_J)$, 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 $k \in K_2$. The functions $\{B_l(p_{jsm})\}_{l=1}^L$ are included in the set K_1 of product characteristics that vary within brand. 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 or unobserved promotional activity 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, brand-level monthly advertising expenditure and pack size dummies. Hence, we control for unobservable product characteristics that do not vary within brand conditional on monthly advertising expenditure 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 concern discussed for example by Hendel and Nevo (2006) is that static demand models may overestimate price sensitivity because they ignore the possibility that consumers may stock up in response to temporary price cuts or sales. We do not believe this is a major issue in the UK butter and margarine market. Firstly, butter and margarine are perishable and so costly to store for long periods. In our data, households rarely purchase more than one pack of butter and margarine at a time. Secondly, temporary price promotions are not an important feature in the UK butter and margarine market. Nearly all purchases in our sample are purchase at regular prices not at promotional prices.

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.[7]

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.[8] For each household we choose a random shopping trip during calendar year 2006.[9] 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.[10] 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.[11] 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, brand-level monthly advertising, 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

[7]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.

[8]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.

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

[10]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.

[11]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.

across markets and within brand variation in unit price across products with different pack sizes. 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.

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.[12]

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 firms. 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.

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

3.3 Estimation results

We estimate the model by penalized maximum likelihood (see for example Fan and Li, 2001). Let $\theta_1 = (\beta_0, \beta_1, \delta)$ and $\theta_2 = \Sigma$ and let K_{θ_1} be the total number of parameters in θ_1. For each value of a penalty parameter λ we solve

$$\max_{\{\theta_1,\theta_2\}} \left\{ L(\theta_1, \theta_2) + \lambda \sum_{k=1}^{K_{\theta_1}} |\theta_{1k}| \right\}$$

where $L(\theta_1, \theta_2)$ is the log-likelihood function. As λ increases in magnitude, the solution of the penalized problem projects the unpenalized likelihood solution onto hypercubes of increasing volume and hence sets many elements of θ_1 to zero. We choose the value of λ to minimise the Bayes Information criterion (BIC)

$$BIC(\lambda) = -2 \ln L\left(\widehat{\theta}(\lambda)\right) + K(\lambda) \ln(N)$$

where N is the sample size and

$$K(\lambda) = \sum_{k=1}^{K_{\theta_1}} 1(\theta_{1k} \neq 0).$$

In the complete empirical model, we included price, price squared and price cubed and included random coefficients on price and the butter dummy variable.[13] To evaluate the likelihood and its gradient we approximated the integral across the distribution of random coefficients with the tensor product of two one dimensional Gauss-Hermite quadrature rules each with 5 nodes.[14]

The BIC is minimised by a model with 175 non-zero parameters, 90 brand fixed effects plus 85 additional parameters. After selecting this model, we estimated its parameters and their standard errors in a second stage direct maximisation of the likelihood. Parameter values excluding the brand fixed effects are reported in Table A1.

Coefficients on price and price cubed are significant as are interactions of these variables with income and household size. In the relevant price region, utility is a strictly decreasing function of price for all households with high probability. The highest income group is less price sensitive. Low income groups are more likely to buy "budget" butter. Advertising expenditures increase demand. BMI does not have a significant effect. Households with more people buy larger pack sizes. Overall, there is substantial heterogeneity both in terms of observed household characteristics and unobserved characteristics. Next we discuss the elasticities implied by our parameter estimates.

[13] We also tested alternative models with additional random coefficients on the outside option and on saturated fat content. We do not reject the model that excludes these additional random coefficients.

[14] For a subset of models tested, results were not sensitive to increasing the number of quadrature nodes to 10 per dimension nor to using sparse grid rules to approximate the integral.

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 -1.57 and the market cross-price elasticities (apart from a small number of exceptions) are positive. The model produces a 142x142 matrix of elasticities for all products in each of the 36 markets. Rather than reproduce the entire matrix, in Table 3, we show elasticities for two subsets of products, averaged across markets.

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 expectations 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 29p, which compares to the average price in the market of £1.01 (Table 1). The average price-cost margin is 0.75.

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. Note that the estimated marginal costs for the margarine products are very low. The margarine products are estimated to be very price inelastic.

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 large three manufacturers make substantially more profits than other firms in the market - together making 76% of the market's total annual variable profits. Unilever and Dairy Crest both have average marginal costs below the average for the market and average margins above the market average, while Arla has an average marginal cost above and average margins below the market average. Notice also the average firm margins vary from 0.49 for The KerryGold Co. - which produces a range of butter products - to 0.97 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 a roughly equivalent ad valorem tax (*meaning they raise the same revenue in the absence of any consumer or 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 amount. 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 consumer or firm response 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 $\tau_{av} = 0.09$.

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 for firm response results in an average price increase of 19p, compared to 10p with no response. Pass-through is 188% on average and is above 100% for nearly three quarters of the products. It ranges from -123% for Flora Pufa 250g to 724% for Morrisons Better for you Sunflower Spread 500g. 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 3p, compared to 6p with no response. Pass-through is 57% on average and is usually below

100%. It ranges from -91% for St Ivel Utterly Butterly 250g to 242% for Asda Low Fat Sunflower Spread 500g. As under the excise tax, the prices of high saturated fat 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 the excise tax, Aldi and Unilever pass-through 240% and 233% respectively while Yeo Valley and Somerfield pass-through 101% and 119% respectively. For the ad valorem tax, Netto's pass-through is -34% while Lactalis Beurres passes through 113%.

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 average probability of selecting the outside increases from 73.6% to 77.7% under the excise tax and to 74.6% under the ad valorem.

Both taxes result in a fall in aggregate profits, but the fall is larger under the ad valorem tax (a 10.9% reduction versus a 7.3% reduction). The excise tax is equivalent to an increase in costs. Firms can recoup part of the increased costs through higher prices. Higher prices reduce demand but do not increase taxes. Under an ad valorem tax, firms' ability to recoup tax costs through higher prices is dampened because increased prices result in higher taxes. The last two columns of Table 7 show the percentage reduction in each firm's profits. Under both taxes all firms suffer a reduction in profits. Unilever, the market leading firm, suffers a 5.2% fall under the excise tax and a 8.7% fall under the ad valorem tax (which are lower than the corresponding overall falls in aggregate profits).

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 estimate of compensating variation for each change.[15] These tables present an estimate of the net cost of introducing a fat tax. They do not quantify any potential health benefits from reduction in saturated fat consumption.

Columns 3 and 5 show predictions of aggregate variables in new equilibria resulting from the two taxes. In the excise tax equilibrium, tax revenue is £1.7 million lower than in the ad valorem tax equilibrium. In addition, the cost to consumers in terms of compensating variation

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

is £94.2 million higher. In the excise tax equilibrium, consumers require more compensation to restore them to their base welfare level. 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 17.4% reduction in the amount of saturated fat purchased through purchases of butter and margarine. In contrast, the ad valorem tax achieves a lower reduction of 6.1% (discussed in Section 4.4 and shown in Table 12).

Comparing the results with and without firm responses, one can see the importance of modelling firms' pricing responses. In the excise tax case (columns 2 and 3 in Table 8), since firms respond to the excise tax by raising before-tax prices, ignoring firm response leads to overestimates of tax revenues and profit reductions and an underestimate of consumer costs. In the ad valorem tax case (columns 4 and 5 in Table 8), before-tax prices fall and the errors are reversed. In this case, assuming 100% pass-through leads to underestimates of tax revenues and profit reductions 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 misleading. For instance, under the assumption of 100% pass-through, the two taxes result in similar costs and reductions in saturated fat purchases (13.4% for the excise tax and 11.9% for the ad valorem tax). In contrast, the difference is much more substantial (17.4% versus 6.1%) when we account for firm price responses. In addition, firms may respond in the short-run by adjusting advertising expenditures and in the long-run by changing product characteristics or by changing the portfolio of products sold in the market. Quantifying these responses is beyond the scope of this paper. A shift in advertising spending toward lower saturated fat products, would

firms may also respond by adjusting advertising expenditures.

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 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 £1.03. The prices of Unilever's products are 9 pence higher than the prices of the same products in the single product firm equilibrium.

Two points are noticeable. Several firms have a price premium (i.e. a positive difference between prices in the multi and single product firm equilibria). Arla has the largest premium - on avarage its products are 21p higher than the would be in the counterfactual world of exclusively single products firms. This reason for this is that Arla's products are very closely positioned in characteristics space and they therefore have relatively high cross price elasticities meaning consumers see them as being highly substitutable. In the single product firm equilibrium, these products are fierce competitors. In contrast, in the multi-product firm equilibrium, Arla benefits from dominating a portion of the characteristics space: If it 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. 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 156%, which is lower than the multi-product case. Pass-through of the ad valorem tax is less than 100% for most products, and is 27% on average; lower than in the multi-product firm equilibrium.

As in the multi-product firm equilibrium, the price increases cause some substitution towards the outside option. With the excise tax, the amount of substitution towards the outside option is similar than in the multi-product firm equilibrium, but with the ad valorem tax the average probability of selecting the outside option only increases very slightly. Under the excise tax, total profits fall by 8.5%, and under the ad valorem tax they fall by 11.5%. In each case the fall is greater than in the multi-product firm equilibrium; multi-product firms are less adversely affected by the introduction of either tax since they are partially shielded from the effects by consumers substituting among products in their portfolio.

4.3.3 Comparison of tax impacts

Table 10 shows average pass-through by firm under the two ownership structures and under the two taxes. Under the excise tax most firms either have lower pass-through in the multi-product equilibrium (relative the single product counterfactual equilibrium) or they have an average pass-through rate that is only slightly higher. There are three main exception. One is Matthews Foods - a small firm which makes a range of relatively low fat margarines. The other two exceptions are Unilever and Arla - two of the largest firms in the market, each of which has large portfolios of products clustered in characteristics space. 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. Similarly for the ad valorem tax, the dominant three firms have larger differences than other firms in the multi-product firm versus single-product firm equilibrium average pass-through rates.

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.[16]

[16] Although, of course, Tesco sells many other products and this analysis abstracts from interactions between

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 £15.23 and the cost under the ad valorem tax is £17.96 (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 £17.28 per kg for the excise tax and £20.47 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 density for the excise tax and the broken line is the density for the ad valorem tax. In each

its butter and margarine pricing decisions and decisions for all other products.

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,[17] 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 modelling 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.

Our results provide evidence on the demand impacts of the tax, on the distributional effects

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

of the tax and on the costs. 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.[18] 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.[19] 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.

[18] 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"

[19] 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	28.41%	Flora Light Low Fat Spread 500g
Dairy Crest Foods Ltd	17	20.19%	Clover Dairy Spread 500g
Arla Foods	16	18.38%	Lurpak Lighter Slightly Salted Spreadable 500g
Tesco Food Stores Ltd	18	11.58%	Tesco Value Blended 250g
Asda Stores Ltd	14	5.78%	Asda Smart Price Blended 250g
J Sainsburys	16	4.13%	Sainsbury Basic English 250g
Morrisons Ltd	13	3.06%	Morrisons English 250g
Lidl UK GMBH	6	1.58%	Lidl Slightly Salted German 250g
Aldi Stores Ltd	5	1.47%	Aldi Blended 250g
The Kerrygold Co. Ltd	3	1.46%	Kerrygold Standard Irish 250g
Matthews Foods Plc	4	1.40%	Pure Soya Spread 500g
Evan Rees Ltd	1	0.96%	Hollybush English 250g
Netto Ltd	3	0.50%	Netto Veg Spread 500g
Lactalis Beurres Et Frmgs	1	0.49%	President French Unsalted 250g
C.W.S. (Co-op)	2	0.18%	Co-Op Creamery Blended 250g
Waitrose Ltd	1	0.16%	Waitrose English 250g
Yeo Valley Farms Ltd	1	0.15%	Yeo Valley Blended Organic 250g
Somerfield Stores Ltd	2	0.14%	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 250g	Lighter Spreadable 500g	Natural Sunflower PUFA 500g	Soft 500g	Best for Baking 500g	Reduced Fat 500g	Low Fat Sunflower Spread 500g
Lurpak Slightly Salted Danish Butter	250g	**-1.9388**	0.0487	0.0301	0.1508	0.0281	0.1581	0.0003	0.0001	0.0002	0.0003	0.0003
	500g	0.0042	**-2.7249**	0.0107	0.1349	0.0097	0.1423	0.0000	0.0000	0.0000	0.0000	0.0000
	Spreadable 250g	0.0127	0.0507	**-1.9083**	0.1589	0.0267	0.1679	0.0003	0.0001	0.0002	0.0003	0.0003
	Spreadable 500g	0.0036	0.0365	0.0093	**-2.6855**	0.0085	0.1088	0.0000	0.0000	0.0000	0.0000	0.0000
	Lighter Spreadable 520g	0.0128	0.0498	0.0287	0.1576	**-1.9113**	0.1674	0.0003	0.0001	0.0002	0.0003	0.0003
	Lighter Spreadable 500g	0.0038	0.0379	0.0097	0.1068	0.0090	**-2.6170**	0.0000	0.0000	0.0000	0.0000	0.0000
Asda Margarine	Natural Sunflower PUFA 500g	0.0022	0.0050	0.0048	0.0154	0.0045	0.0164	**-1.0870**	0.0003	0.0007	0.0009	0.0008
	Soft 500g	0.0024	0.0041	0.0052	0.0122	0.0049	0.0131	0.0011	**-1.0703**	0.0009	0.0011	0.0011
	Best for Baking 500g	0.0023	0.0047	0.0049	0.0144	0.0047	0.0155	0.0010	0.0004	**-1.1343**	0.0010	0.0010
	Reduced Fat 500g	0.0025	0.0027	0.0051	0.0077	0.0048	0.0083	0.0011	0.0004	0.0009	**-0.7572**	0.0011
	Low Fat Sunflower Spread 500g	0.0022	0.0050	0.0048	0.0154	0.0045	0.0165	0.0008	0.0003	0.0007	0.0009	**-1.0885**

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	3.91%	0.95	0.01	0.02	0.99
Dairy Crest Foods Ltd	Clover Dairy Spread 500g	3.52%	1.12	0.18	0.23	0.84
Unilever Bestfoods	I.C.B.I.N.B Dairy Spread 500g	3.38%	0.78	0.03	0.03	0.96
Dairy Crest Foods Ltd	St Ivel Utterly Butterly Dairy Spread 500g	3.04%	0.77	0.06	0.05	0.93

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	0.22	0.01	0.58
Asda Stores Ltd	Asda Spread Blended 250g	2.11%	0.53	0.21	0.01	0.61
Morrisons	Morrisons Bettabuy English 250g	0.60%	0.53	0.21	0.01	0.60
Tesco Food Stores Ltd	Tesco Value Blended 250g	3.95%	0.53	0.19	0.01	0.64
500g Buttery Margarine Products						
Asda Stores Ltd	Asda You'd Better Believe It's Butter Dairy Spread 500g	0.55%	0.76	0.07	0.04	0.91
Dairy Crest Foods Ltd	St Ivel Utterly Butterly Dairy Spread 500g	3.04%	0.77	0.06	0.05	0.93
J Sainsburys	Sainsbury's Butterlicious 500g	0.34%	0.77	0.08	0.04	0.90
Tesco Food Stores Ltd	Tesco Butter Me Up Spread 500g	1.15%	0.76	0.06	0.04	0.92
Unilever Bestfoods	I.C.B.I.N.B Dairy Spread 500g	3.38%	0.78	0.03	0.03	0.96
250g Tesco Butters Of Varying Degree Of Quality						
Tesco Food Stores Ltd	Tesco Value Blended 250g	3.95%	0.53	0.19	0.01	0.64
Tesco Food Stores Ltd	Tesco Creamery Blended 250g	0.94%	0.58	0.23	0.01	0.60
Tesco Food Stores Ltd	Tesco Organic Danish 250g	0.17%	0.88	0.40	0.02	0.54
Tesco Food Stores Ltd	Tesco Finest French 250gm	0.02%	1.03	0.47	0.04	0.55

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	28.41%	0.22	1.12	0.87	122.88
Dairy Crest Foods Ltd	17	20.19%	0.22	1.01	0.80	76.86
Arla Foods	16	18.38%	0.61	1.38	0.57	68.74
Tesco Food Stores Ltd	18	11.58%	0.22	0.78	0.73	31.25
Asda Stores Ltd	14	5.78%	0.17	0.64	0.75	13.21
J Sainsburys	16	4.13%	0.23	0.73	0.70	10.02
Morrisons Ltd	13	3.06%	0.21	0.64	0.69	6.43
Lidl UK GMBH	6	1.58%	0.15	0.59	0.75	3.35
Aldi Stores Ltd	5	1.47%	0.23	0.72	0.74	3.48
The Kerrygold Co. Ltd	3	1.46%	0.53	0.99	0.49	3.26
Matthews Foods Plc	4	1.40%	0.10	0.90	0.91	5.38
Evan Rees Ltd	1	0.96%	0.23	0.53	0.58	1.42
Netto Ltd	3	0.50%	0.03	0.37	0.97	0.81
Lactalis Beurres Et Frmgs	1	0.49%	0.46	0.96	0.52	1.16
C.W.S. (Co-op)	2	0.18%	0.24	0.82	0.69	0.49
Waitrose Ltd	1	0.16%	0.37	0.75	0.51	0.29
Yeo Valley Farms Ltd	1	0.15%	0.54	1.13	0.53	0.43
Somerfield Stores Ltd	2	0.14%	0.27	0.95	0.69	0.45
Total	142	100.00%	0.29	1.02	0.75	349.93

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	233%	21%	-5.19%	-8.65%
Dairy Crest Foods Ltd	184%	42%	-6.44%	-9.77%
Arla Foods	149%	102%	-11.26%	-18.26%
Tesco Food Stores Ltd	170%	54%	-8.87%	-10.08%
Asda Stores Ltd	180%	56%	-7.33%	-7.27%
J Sainsburys	169%	65%	-7.35%	-8.67%
Morrisons Ltd	169%	65%	-8.13%	-8.23%
Lidl UK GMBH	211%	53%	-4.15%	-4.52%
Aldi Stores Ltd	240%	53%	-7.52%	-9.87%
The Kerrygold Co. Ltd	145%	108%	-12.09%	-18.25%
Matthews Foods Plc	218%	7%	-2.59%	-5.92%
Evan Rees Ltd	122%	56%	-14.28%	-9.33%
Netto Ltd	207%	-34%	-9.44%	-7.16%
Lactalis Beurres Et Frmgs	140%	113%	-4.69%	-9.38%
C.W.S. (Co-op)	178%	99%	-2.09%	-5.41%
Waitrose Ltd	132%	89%	-6.90%	-9.48%
Yeo Valley Farms Ltd	101%	78%	-4.13%	-9.50%
Somerfield Stores Ltd	119%	68%	-2.89%	-6.03%

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	490.36	484.99	491.47	479.43	486.52
		-1.10%	0.23%	-2.23%	-0.78%
Estimated variable cost	140.42	120.7	122.28	116.56	128.25
		-14.04%	-12.92%	-16.99%	-8.67%
Firm variable profits	349.93	317.49	324.54	318.09	311.89
		-9.27%	-7.26%	-9.10%	-10.87%
Tax revenue		46.79	44.65	44.78	46.38
Compensating variation		126.29	162.18	148.77	67.97
Cost: change in firm profits + tax revenue - compensating variation		**-111.94**	**-142.92**	**-135.83**	**-59.64**

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	1.03	0.09	122.88	120.55	1.93%
Dairy Crest Foods Ltd	17	1.01	0.95	0.06	76.86	74.66	2.95%
Arla Foods	16	1.38	1.18	0.21	68.74	65.55	4.87%
Tesco Food Stores Ltd	18	0.78	0.71	0.07	31.25	29.39	6.34%
Asda Stores Ltd	14	0.64	0.59	0.06	13.21	12.36	6.86%
J Sainsburys	16	0.73	0.67	0.06	10.02	9.35	7.25%
Morrisons Ltd	13	0.64	0.60	0.04	6.43	5.92	8.75%
Lidl UK GMBH	6	0.59	0.50	0.09	3.35	3.11	7.65%
Aldi Stores Ltd	5	0.72	0.63	0.09	3.48	3.21	8.25%
The Kerrygold Co. Ltd	3	0.99	1.00	0.00	3.26	2.94	11.03%
Matthews Foods Plc	4	0.90	0.76	0.14	5.38	5.22	3.21%
Evan Rees Ltd	1	0.53	0.53	0.00	1.42	1.24	14.44%
Netto Ltd	3	0.37	0.34	0.03	0.81	0.78	4.50%
Lactalis Beurres Et Frmgs	1	0.96	0.95	0.00	1.16	1.02	13.72%
C.W.S. (Co-op)	2	0.82	0.77	0.04	0.49	0.45	7.08%
Waitrose Ltd	1	0.75	0.74	0.02	0.29	0.26	14.22%
Yeo Valley Farms Ltd	1	1.13	1.13	0.00	0.43	0.38	13.18%
Somerfield Stores Ltd	2	0.95	0.96	0.00	0.45	0.43	5.58%

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	233%	131%	*102%*	21%	-41%	*62%*
Dairy Crest Foods Ltd	184%	180%	*4%*	42%	2%	*40%*
Arla Foods	149%	108%	*41%*	102%	72%	*29%*
Tesco Food Stores Ltd	170%	190%	*-20%*	54%	36%	*19%*
Asda Stores Ltd	180%	179%	*1%*	56%	54%	*3%*
J Sainsburys	169%	168%	*2%*	65%	51%	*13%*
Morrisons Ltd	169%	165%	*4%*	65%	48%	*17%*
Lidl UK GMBH	211%	227%	*-16%*	53%	49%	*3%*
Aldi Stores Ltd	240%	245%	*-5%*	53%	46%	*7%*
The Kerrygold Co. Ltd	145%	154%	*-9%*	108%	121%	*-13%*
Matthews Foods Plc	218%	100%	*119%*	7%	2%	*4%*
Evan Rees Ltd	122%	121%	*1%*	56%	54%	*2%*
Netto Ltd	207%	203%	*4%*	-34%	-60%	*26%*
Lactalis Beurres Et Frmgs	140%	151%	*-10%*	113%	113%	*0%*
C.W.S. (Co-op)	178%	164%	*14%*	99%	52%	*47%*
Waitrose Ltd	132%	142%	*-10%*	89%	84%	*4%*
Yeo Valley Farms Ltd	101%	117%	*-16%*	78%	92%	*-13%*
Somerfield Stores Ltd	119%	118%	*1%*	68%	77%	*-8%*

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

Manufacturer	Number of products	Predicted market share	Mean own price elasticity	Mean cross-price elasticity: product owned by firm	Mean cross-price elasticity: product produced by other firm
Large manufacturers					
Unilever Bestfoods	19	28.41%	-1.32377	0.009189	0.00197
Dairy Crest Foods Ltd	17	20.19%	-1.36621	0.006073	0.004362
Arla Foods	16	18.38%	-2.28373	0.040391	0.002666
Supermarkets with own-brand products					
Tesco Food Stores Ltd	18	11.58%	-1.48279	0.003679	0.006937
Asda Stores Ltd	14	5.78%	-1.40025	0.001826	0.006992
J Sainsburys	16	4.13%	-1.51959	0.001709	0.00745
Morrisons Ltd	13	3.06%	-1.55913	0.001923	0.007938
Lidl UK GMBH	6	1.58%	-1.43651	0.001701	0.00687
Aldi Stores Ltd	5	1.47%	-1.46074	0.001299	0.006669
Small manufacturers					
The Kerrygold Co. Ltd	3	1.46%	-2.09969	0.009135	0.008272
Matthews Foods Plc	4	1.40%	-1.11751	0.001354	0.00449
Evan Rees Ltd	1	0.96%	-1.73912		0.009395
Lactalis Beurres Et Frmg	3	0.50%	-1.93877	0.000424	0.003263
Netto Ltd	1	0.49%	-0.87869		0.009141
C.W.S. (Co-op)	2	0.18%	-1.57078	0.000176	0.007203
Waitrose Ltd	1	0.16%	-1.9723		0.009315
Yeo Valley Farms Ltd	1	0.15%	-1.90327		0.009031
Somerfield Stores Ltd	2	0.14%	-1.55816	0.000105	0.006902

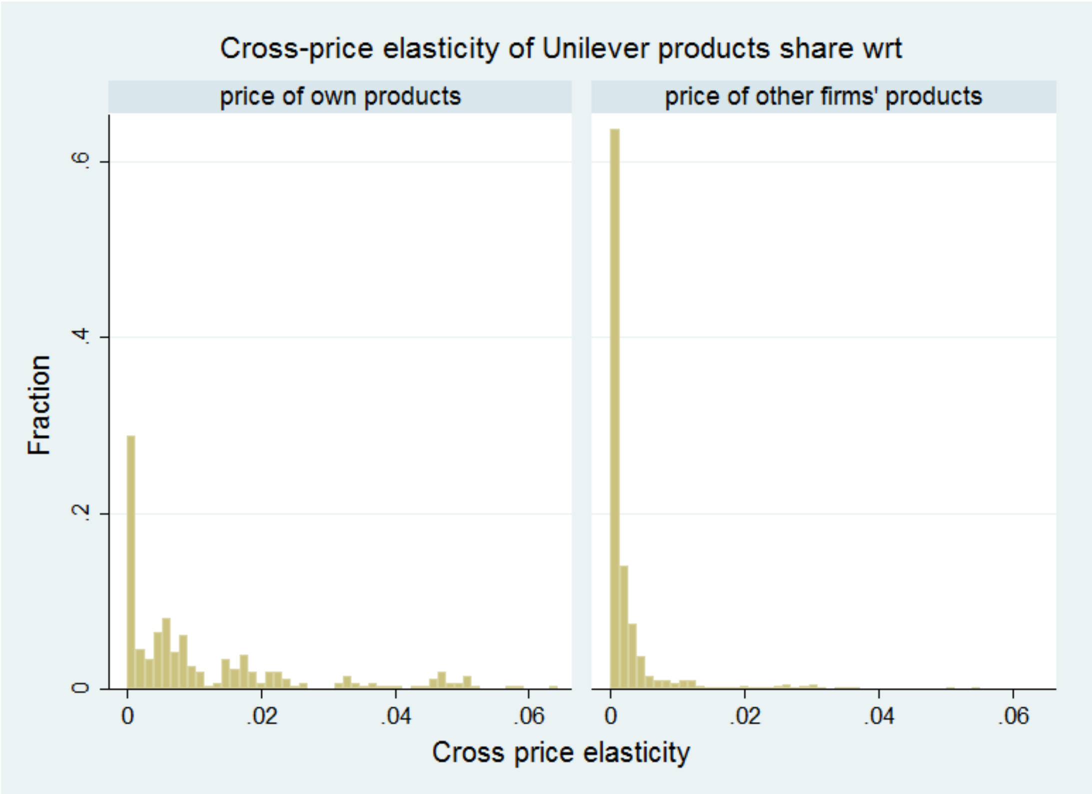
Notes: Own price elasticities are weighted averages across the market elasticities of products produced by the manufacturer. Cross price elasticities are weighted averages across the market elasticities of products produced by the manufacturer. They refer to the change in demand for the manufacturer's '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)	**54.03**	**46.79**	**44.65**	**47.58**	**50.71**
		-13.40%	-17.36%	-11.94%	-6.14%
Mean cost of a 1kg reduction in saturated fat (£)		15.46	15.23	21.07	17.96
Mean compensating variation per 1kg reduction in saturated fat (£)		17.45	17.28	23.08	20.47

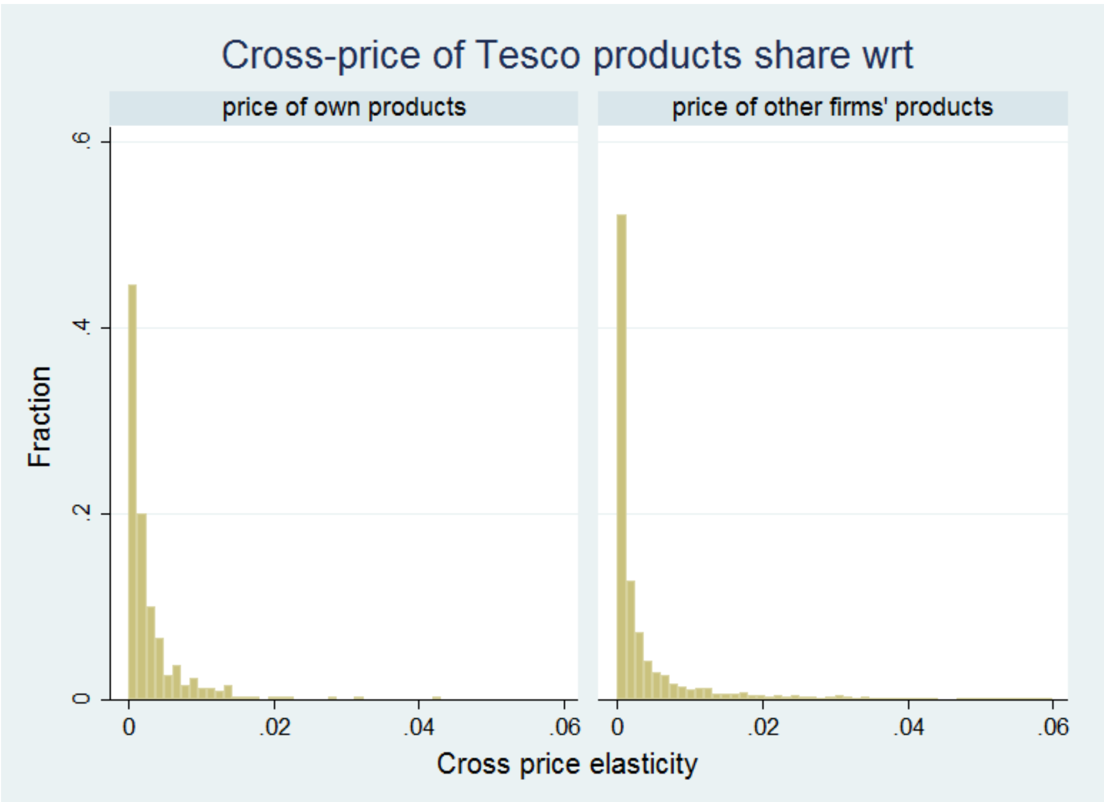
Notes: We aggregate the predictions from our demand model across households, weighting by the number of shopping trips households go on in 2006 and household demographic weights. This yields results at the national level for year 2006.

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

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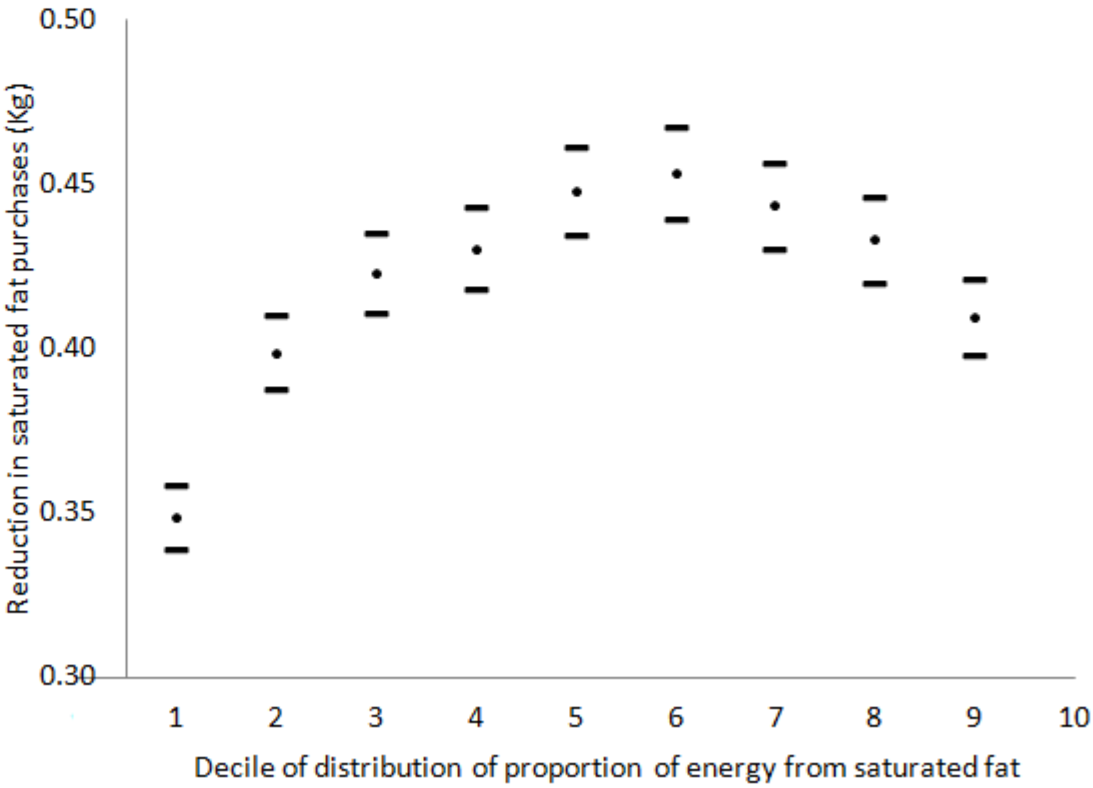
Notes: For each household we compute the annual compensating variation associated with the introduction of each tax, along with the reduction in the amount of saturated fat they purchase. This figure shows the distribution of the ratio of these two numbers.

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.

	_mean	_sig2	_i2	_i3	_i4	_i5	_hhsize	_cokids	_pens	_sikids	_bmi3	_bmim	_north	_swest	_upper
prc	**-3.2357**	**8.1363**	0.0000	0.0971	0.0000	**0.7271**	0.0000	-0.2347	0.0000	0.0000	0.0000	0.2637	0.0000	0.0000	-0.0807
	(0.5593)	(2.0062)	(0.0000)	(0.1854)	(0.0000)	(0.3198)	(0.0000)	(0.3032)	(0.0000)	(0.0000)	(0.0000)	(0.2631)	(0.0000)	(0.0000)	(0.1095)
prc2	0.0000		0.0632	0.0000	0.0000	-0.0504	**-0.2057**	0.0000	0.0000	0.0000	-0.2007	0.0731	0.0000	0.0801	0.0000
	(0.0000)		(0.0693)	(0.0000)	(0.0000)	(0.1336)	(0.0902)	(0.0000)	(0.0000)	(0.0000)	(0.2191)	(0.1085)	(0.0000)	(0.0520)	(0.0000)
prc3	**-0.3647**		0.0000	0.0000	0.0695	0.0000	**0.0800**	0.0342	-0.0058	-0.0855	0.1545	0.0000	0.0045	0.0000	0.0000
	(0.0651)		(0.0000)	(0.0000)	(0.0357)	(0.0000)	(0.0397)	(0.0555)	(0.0309)	(0.0583)	(0.0987)	(0.0000)	(0.0217)	(0.0000)	(0.0000)
exp	**0.2445**														
	(0.0707)														
exp_l	0.0283														
	(0.0640)														
budg			0.0000	**-0.4415**	**-0.4766**	**-0.5920**	**-0.0725**								
			(0.0000)	(0.1410)	(0.1542)	(0.1562)	(0.0344)								
volsat	**-0.7096**		0.0013	0.0005	-0.0002	0.0007	0.0005	-0.0031	0.0022	0.0045	-0.0006	-0.0020	0.0003	0.0017	-0.0008
	(0.2255)		(0.0016)	(0.0017)	(0.0019)	(0.0019)	(0.0006)	(0.0017)	(0.0015)	(0.0026)	(0.0015)	(0.0014)	(0.0012)	(0.0012)	(0.0011)
volsod	-0.1684		-0.1092	**-0.1327**	**-0.1317**	**-0.2168**	-0.0083	**0.1592**	**-0.1601**	-0.0607	0.0336	0.0189	**-0.0879**	**-0.1114**	-0.0370
	(0.1020)		(0.0570)	(0.0616)	(0.0663)	(0.0660)	(0.0245)	(0.0536)	(0.0534)	(0.0957)	(0.0487)	(0.0439)	(0.0373)	(0.0414)	(0.0350)
but		**9.0309**	-0.1313	0.0774	0.3634	0.2061	**0.2280**	-0.4315	0.1675	**-1.0049**	0.1187	0.0314	-0.0218	-0.3572	0.2205
		(1.8583)	(0.2543)	(0.2710)	(0.2886)	(0.2889)	(0.0875)	(0.2374)	(0.2148)	(0.4415)	(0.2077)	(0.1854)	(0.1605)	(0.1880)	(0.1503)
health			0.0000	0.0000	0.0000	0.0000	-0.0168	-0.3208	0.0000	0.0000	0.1312	-0.2384	0.1332	0.0000	-0.1320
			(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0545)	(0.1813)	(0.0000)	(0.0000)	(0.1536)	(0.1396)	(0.1124)	(0.0000)	(0.1027)
pufa			-0.0479	0.0000	0.0000	0.1061	-0.0840	-0.1345	0.0000	**-0.5043**	-0.0500	-0.1554	0.1597	0.1657	0.0000
			(0.0983)	(0.0000)	(0.0000)	(0.1097)	(0.0443)	(0.1467)	(0.0000)	(0.2559)	(0.1255)	(0.1110)	(0.0987)	(0.1018)	(0.0000)
sz2	**2.3143**														
	(0.1904)														
sz3	**3.5934**														
	(0.4531)														
sz4	**6.4604**														
	(0.8087)														
small							**-0.2259**								
							(0.0522)								
large							**0.3076**								
							(0.0736)								
outside			-0.0784	-0.2299	**-0.4182**	0.0000	**-0.4493**	0.2243	**-0.4479**	0.4205	0.0937	0.0000	0.0000	**-0.3049**	0.0000
			(0.1605)	(0.1819)	(0.1877)	(0.0000)	(0.0886)	(0.2385)	(0.1570)	(0.2868)	(0.1508)	(0.0000)	(0.0000)	(0.1248)	(0.0000)