Comparing pass-through of excise and ad valorem taxes in differentiated product oligopoly with multi-product firms: empirical estimates using micro data

Rachel Griffith
IFS and UCL

Lars Nesheim
CEMMAP, UCL and IFS

Martin O'Connell
IFS

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Abstract

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In imperfectly competitive markets the impact of excise and ad valorum taxes will depend on consumer preferences, and on the extent to which firms pass the taxes on to consumers in higher prices. We consider a tax on saturated fats. We use a discrete choice demand model and household purchase level data to estimate responses to a fat tax.

JEL:

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

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1 Introduction

Taxes are used in many countries as a way of curbing consumption of "sin" goods such as alcohol, cigarettes and fuel, and of raising revenue. These taxes usually take the form of either excise or ad valorem taxes. In perfect competition these taxes are equivalent, and are shifted 100% on to consumer prices. However, when firms have market power taxes may be over or undershifted, depending on the curvature of demand and firm behaviour. In monopoly ad valorem taxes are known to be more efficient at raising revenue (Suites and Musgrave (1953)), however, in oligopoly models things become more complicated, and the impact of taxes will depend on a number of factors including demand curvature, firm behaviour, and ownership structure, among other things. Many of the markets in which these taxes are used are typified by differentiated product oligopolies with multi-product firms. Relatively little is known about the properties of these taxes in such markets.

In this paper we estimate a structural model of demand in a differentiated product oligopoly with multi-product firms and compare the performance of an excise and an ad valorem tax. Our empirical application considers a substantive current policy issue - the potential to use taxes to curb consumption of saturated fat, which is a major contributor to the increase in diet-related health problems. Our contribution incorportates several recent advances in the literature to study pass-through and efficiency of excise and ad valorem taxes. We estimate a structural model that allows for strategic pricing behaviour, multi-product firms, rich consumer heterogeneity in preferences, substitution to the outside option, and that embeds the quantity decision. We use rich micro data on individual purchase transactions, and that contain detailed information on product and household characteristics. We apply the model to an economically relevant and important policy question, but believe that the results have application beyond this particular setting. Our results suggest that taking account of firms' strategic behaviour is important, and that an excise tax is if anything slightly more efficient than an ad valorem tax in terms of the cost per reduction in saturated fat purchased.

A number of papers in the theoretical literature consider taxes in oligopoly markets with a homogenous good.[1] Seade (1985) 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. Hamilton (2008) shows that the superior performance of the ad valorem tax does not hold in a model with multi-product firms and non-symmetric differentiation.

[1] See, inter alia, Seade (1985), Stern (1987), Besley (1989), Delipalla and Keen (1992), Skeath and Trandel (1994) and Hamilton (2008). Most assume Cournot competition, except Kay and Keen (1983), which considers monopolist competition, and Delipalla and Keen (1992), which considers a model of conjectural variations.

The empirical literature on pass through includes reduced form studies with results that are broadly consistent with the predictions of the theoretical models. Besley and Rosen (1999) exploit variation in state and local sales taxes in the US on a number of disaggregated products. They find a wide variaty of shifting patterns, 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.

We consider a tax on saturated fat in the UK market for butter and margarine. Why are we interested in such a tax? The recent rise in diet-related health problems have led to calls for taxes on certain types of food. Policymakers and nutrition researchers have expressed concern that individuals eat too much saturated fat.[2] The UK Food Standards Authority states that, *"The UK is currently eating 20% more saturated fat than UK Government recommendations."* (FSA, 12 Feb 2009) Consumption of saturated fat is associated with heart disease and other negative health outcomes. High saturated fat intake can raise cholesterol levels in the blood. High cholesterol levels are a risk factor for heart and circulatory diseases such as coronary heart disease, heart attacks, angina and stroke - or cardiovascular disease. Cardiovascular disease is the most common cause of death in the UK and in 2006 was responsible for about one in

[2] See, inter alia Ascherio et al (1999), Hu et al (1997) Stoeckli and Keller (2004), Willett (2001) and de Agostini (2007).

three premature deaths (FSA (2009)). Taxes are one possible policy response to reduce consumption. We focus on butter and margarine because this is the food category that accounts for the largest share of saturated fat purchased (approximately 15% for the average UK household).

The literature specifically considering taxes on fat includes Chouinard et al (2007), Smed et al (2007), Leicester and Windmeijer (2004), Marshall (2000) and Acs and Lyles (2007). These authors have used data aggregated to the level of food categories (e.g butter, ice cream, cheese ...), have focused on estimating the effect of a fat tax on substitution *between* food categories and have assumed 100% pass-through. In contrast, we estimate firms' profit-maximising response to the tax, use data that is disaggregated at both the household and product level, and allow for both substitution *within* food category and to the outside option. Products within a food category (e.g. different butter products) are seen by consumers as highly substitutable. Our aim is to capture this potentially important margin of substitution, which has not been included in previous estimates of the impact of a fat tax. Substitution along this margin is potentially important as butter and margarine products are highly differentiated in terms of the intensity of saturated fat (as we show below).

We do not show whether a tax on saturated fat would be welfare improving. We provide estimates of the effectiveness of different forms of tax, and the non-health related costs. These costs need to be set against any expected health gains. Nonetheless, before turning to our analysis it is worth making a brief comment on what role policy has to play in influencing individuals' saturated fat consumption. If individuals are fully informed about the impact of saturated fat, and if the impact of saturated fat consumption are fully internalised by the individual, then there is little reason to think that government intervention would be welfare improving. However, individuals may not be fully informed about the fat content of foods or the optimal amount of fat an individual should consume.[3] Even if individuals are rational in their private choices and consume individually optimal quantities of fat, consuming fat increases the risks of negative health outcomes and may increase the likelihood of high health costs. Since health costs are covered both by state provided and privately provided insurance, and since such increased risks of high health costs are not priced into the insurance system, there is an externality. Private consumption of fat thus raises the public cost of health insurance.[4] Public policy may have a role to play if the government has better information about the negative consequences of fat consumption or the fat contents of foods or about health insurance externalities. However, government intervention also imposes costs that could reduce welfare in the form of lost consumer surplus and lost profits. We may be interested not only in the efficiency properties of any government intervention but also in who bears the burden of the tax. In this paper, we provide evidence on how different forms of tax on saturated fat would affect consumption and who would bear the burden of the tax.

The structure of the rest of the paper is as follows. The next section outlines

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

[4] FSA (2007) :"It has been estimated that a reduction in average saturated fat intakes from the current level of 13.3% to the recommended 11% of food energy would equate to approximately 3,500 annual UK deaths averted, or yield an aggregate potential benefit of more than £2.4 billion"

the model we use. Section 3 discusses the data. Section 4 presents our results and a final section concludes. Further information on how we estimate the model are provided in an Appendix.

2 Model

We first describe household behaviour and then firm behaviour.

2.1 Household behaviour

We model household demand for butter and margarine assuming that utility from butter and margarine products is separable from utility from other goods. We assume that each household $i \in (1, \ldots, I)$ chooses to purchase one product, which is defined by brand $j \in (0, 1, ..., J)$ and pack size $s \in (0, 1, ..., S_j)$. The set of products includes the outside good ($j = 0, s = 0$). There are J distinct butter and margarine brands ($j > 0$), each of which is available in S_j different pack sizes ($s > 0$). 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 standard random coefficients discrete choice demand system.[6] We allow preferences to vary with both observed demographic variables and unobserved random coefficients. This allows for a demand system that can model very flexible substitution patterns and exploit the detailed demographic and product characteristic information in our data.

[5] In our empirical application price will be the only product characteristic that varies over markets (i.e. over time and region).

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

The payoff to a consumer depends on the product's characteristics. Households choose the product that provides them with the highest payoff. We assume that the payoff u_{ijs} for household i from product (j,s) takes the form,

$$u_{ijs} = \sum_{K} x_{jsm}^{k} \beta_{i}^{k} + \xi_{j} + \varepsilon_{ijs} \tag{1}$$

$$\beta_{i}^{k} = \overline{\beta}^{k} + \sum_{r} z_{ir} \beta^{krO} + \eta_{i} \beta^{kU} \tag{2}$$

where x_{jsm}^{k} are $k = 1, \ldots, K$ observed product characteristics, which consumers may have heterogenous preferences over captured by β_{i}^{k}, ξ_{j} are unobserved product characteristics, which have a common valuation across households and are constrained to be constant across pack sizes within brand, and ε_{ijs} are unobservable stochastic terms that we assume are i.i.d. Type 1 extreme value random variables.

We allow the coefficients on the observable product characteristics β_{i}^{k} to vary across households with observable household characteristics z_{ir}, indexed $r = 1, ..., R$ and unobservable households characteristics η_{i}.

The mean payoff of product characteristic k is given by $\overline{\beta}^{k}$, β_{r}^{kO} capture variation in marginal payoffs across households due to observable demographics and the random coefficient β^{kU} captures variation due to unobservable household specific factors. We partition the $(Kx1)$ vector of product characteristics into the set K_1 that vary within brand, and the set K_2 that are constant within brand. Substituting (1) into (2) yields:

$$
\begin{aligned}
u_{ijs} &= \sum_k \left(x^k_{jsm}\overline{\beta}^k + \sum_r z_{ir} x^k_{jsm} \beta^{kO}_r + \eta_i x^k_{jsm} \beta^{kU}_i \right) + \xi_j + \varepsilon_{ijs} \qquad (3) \\
&= \delta_j + \sum_{k \in K_1} x^k_{jsm}\overline{\beta}^k + \sum_{K,r} z_{ir} x^k_{jsm} \beta^{krO} + \sum_K \eta_i x^k_{jsm} \beta^{kU}_i + \varepsilon_{ijs}
\end{aligned}
$$

where

$$\delta_j = \xi_j + \sum_{k \in K_2} x^k_{jm} \overline{\beta}^k \qquad (4)$$

The variables $\beta^U_i = \left(\beta^{1U}_i, ..., \beta^{KU}_i\right)$, $\xi = (\xi_1, ..., \xi_J)$ and $\varepsilon_i = (\varepsilon_{i11}, ..., \varepsilon_{iJS})$ are unobservable stochastic terms. We assume $\beta^U_i \sim N(0, \Sigma)$, ε_i are i.i.d. Type 1 extreme value random variables, and that ξ are drawn from an unknown distribution. The parameter vectors $\overline{\beta} = (\overline{\beta}^1, ..., \overline{\beta}^K)$ for $k \in K_1$, $\beta^O = \left(\beta^{11}, ..., \beta^{KR}\right)$, $\delta = (\delta_1, ..., \delta_J)$ and Σ are parameters to be estimated. Note that the model does not separately identify ξ and $\overline{\beta}$ for $k \in K_2$. Since price belongs to K_1 and we assume all other product characteristics do not change after we introduce the tax, this is not important for the purposes of our analysis.

We allow households to choose the outside option of not purchasing butter or margarine. The value of the outside option is given by

$$u_{i00} = \overline{\xi}_0 + \sum_r z_{ir} \xi^r_0 + \varepsilon_{i00}$$

We interact the payoff provided by selecting the outside option with observable household characteristics, so $\overline{\xi}_0$ captures the baseline payoff from the outside options and ξ^r_0 capture the marginal payoffs across households due to observable demographics. Including the outside option allows for households to respond to a tax by either stopping consuming both butter and margarine or by purchasing the products less frequently.

2.2 Identification

Our model identifies the coefficient on price through two sources of variation: (1) variation in product price over time (there is very little variation across regions), and (2) variation in unit price across pack sizes within brand. 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 unobserved product characteristics. In particular, since we include brand level fixed effects and pack size dummies we control for unobserved product characteristics that do not vary within brand and unobserved product characteristics that do not vary within pack size. If there are unobservables that vary across pack size differentially for different brands, this would induce correlation between the error term and price and lead us to inconsistently estimate the price coefficient. However, we argue that after controlling for the rich set of product characteristics that we have it is unlikely that this source of endogeneity is important.

A second potential source of endogeneity in prices arises if firms temporarily change prices and simultaneously engage in unobserved promotional activity that stimulates demand. As discussed below, the UK market is characterised by close to national pricing, meaning there is little cross-sectional variation in the price of a product. There is differential time series variation in product prices, however we believe that promotional activity is not very important in the butter and margarine market.[7]

We estimate the probability of purchasing butter and margarine on a single shopping trip. Total demand for butter over a year is the probability of purchase multiplied by the number of trips the household makes, i.e. we assume that the change in the price butter and margarine that results from the tax does not affect the frequency with which households shop.[8]

2.3 Price elasticities

The estimated coefficients allow us to calculate all products' own and cross-price elasticities for each household. Aggregating across households in a given market and weighting by the frequency that household shop and household sampling weight which gross up to the UK population, we compute market elasticities for each product. The household sampling weights correct for non-random selection into the sample.[9] We assume that the preference shocks determinining purchase decisions are i.i.d. across trips, and that the number of trips per year is fixed.

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

$$\pi_{js}\left(z_i, p_{jsm}\right) = \int L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right) \phi\left(\theta_2\right) d\theta_2 \tag{5}$$

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

[7] Evidence: product is perishable, so not very easy to store, therefore it is unlikely that intertemporal substantially baises our estimates ala Hendal and Nevo (2006). We do not have the same problem with missing price that is highlighted, for example, by- Erdum, Keane and Sun (1999). We use TNS data from the UK [explain why not a problem].

[8] Stocking up is not a major issue in the market for butter and margarine - households rarely purchase more than one pack at a time and butter and margarine are perishable.

[9] Sampling weights are not required for estimation because sample selection is based on exogenous demographics, not on the endogenous choice of butter purchases.

coefficients and where

$$L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right) = \frac{e^{V_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right)}}{\sum_{k,t} e^{V_{kt}\left(z_i, p_{ktm}, \theta_1, \theta_2\right)}} \tag{6}$$

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

$$\epsilon_{ijs} = \frac{\partial \pi_{js}\left(z_i, p_{jsm}\right)}{\partial p_{jsm}} \frac{p_{jsm}}{\pi_{js}\left(z_i, p_{jsm}\right)} \tag{7}$$

where

$$\frac{\partial \pi_{js}\left(z_i, p_{jsm}\right)}{\partial p_{jsm}} = \int \frac{\partial L_{js}\left(z_i, p_{jsm}, \theta_1, \theta_2\right)}{\partial p_{jsm}} \phi\left(\theta_2\right) d\theta_2. \tag{8}$$

Let $w_m\left(z_i\right)$ 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 $\sum\limits_{i \in n_m} w_m\left(z_i\right) = 1$ and suppose n_m households are observed in market m. Then the market share of product (j, s) on a single trip is

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

The market (single trip) demand elasticity is

$$\begin{aligned} \frac{p_{jsm}}{s_{jsm}} \frac{\partial s_{jsm}}{\partial p_{jsm}} &= n_m^{-1} \sum_{i \in n_m} w_m\left(z_i\right) \frac{p_{jsm}}{s_{jsm}} \frac{\partial \pi_{js}\left(z_i, p_{jsm}\right)}{\partial p_{jsm}} \\ &= n_m^{-1} \sum_{i \in n_m} \frac{w_m\left(z_i\right) \pi_{js}\left(z_i, p_{jsm}\right)}{s_{jsm}} \epsilon_{ijs}. \end{aligned} \tag{9}$$

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

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

and the annual market elasticity is

$$\begin{aligned}\frac{p_{jsm}}{S_{jsm}}\frac{\partial S_{jsm}}{\partial p_{jsm}} &= n_m^{-1}\sum_{i\in n_m} T_i w_m(z_i)\frac{p_{jsm}}{S_{jsm}}\frac{\partial \pi_{js}(z_i,p_{jsm})}{\partial p_{jsm}} \\ &= n_m^{-1}\sum_{i\in n_m} T_i w_m(z_i)\frac{\pi_{js}(z_i,p_{jsm})}{S_{jsm}}\epsilon_{ijs}.\end{aligned} \tag{10}$$

A similar procedure yields the market level cross price elasticities.

2.4 Firm behaviour

We assume that producers set prices and compete in a Nash-Bertrand game, holding the menu of products on offer constant. Profits for firm f which produces and sells products $(j,s)\in F_f$ in market m are given by

$$\Pi_{fm} = \sum_{(j,s)\in F_f}(p_{jsm} - mc_{jsm})\, M s_{jsm}(p) - C_{js} \tag{11}$$

where $s_{jsm}(p)$ is the market share of product (j,s), and depends on the vector of prices of all other products in the markets, p, M is the market size, mc_{jsm} is the marginal cost of product (j,s), which we allow to vary across markets and C_{js} is the fixed cost associated with the product. Note M includes the share of the outside option.

The firm's first-order conditions are given by

$$s_{jsm}(p) + \sum_{(k,t)\in F_f}(p_{ktm} - mc_{ktm})\frac{\partial s_{ktm}(p)}{\partial p_{jsm}} = 0. \tag{12}$$

We observe p and estimate s and $\frac{\partial s_{ktm}(p)}{\partial p_{jsm}}$ so we can recover the marginal cost of each product in each market, mc_{jsm}.

Let p_f be the vector of prices of firm f and let p_0 be the price of the outside good. Given a firm f, let p_{-f} be the vector of prices of all other firms. A Nash equilibrium in this market is a vector of prices $p = (p_0, p_1, ..., p_F)$ such that, given p_{-f}, p_f satisfies (12) for all f.

After computing mc_{jsm} for all (j, s) and m, we simulate a counterfactual equilibrium that would result if a tax were imposed. To compute the new equilibrium, we stack the first-order conditions of all firms and use a Gauss-Newton method to search for a zero to the system.[10]

3 Data

We use data from the TNS World Panel for calendar year 2006. We observe all purchases of food made and brought into the home by 16,637 households throughout the course of 2006. Households record purchases of all items bought using handheld scanners and record prices from till receipts. The data also contain a large set of product attributes (at the barcode level) as well as household characteristics. See Leicester and Oldfield (2009) for further information on the TNS data, and Griffith and O'Connell (2009) for further discussion of the nutrition data.

We focus on 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 on average across households.[11] For each household we choose a random shopping

[10] We impose upper bounds on prices equal to twice the highest price in the market to ensure that an equilibrium exists. This upper bound is required because a small number of products with small market shares have unbounded profits when the tax is imposed. In such cases, the search for an equilibrium price leads to regions of the price space that are far from those observed in the data. We believe that our demand estimates are valid as long as equilibrium prices are near their initial equilibrium levels, but not when we try to extrapolate to regions of the price space that are far from the initial levels.

[11] Together dairy products (cheese, butter, margarine, milk, ice cream and cream) contribut-

trip during calendar year 2006. We define a 'shopping trip' as all goods purchased by a household on a single day.[12] 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.[13] After taking a random sample of shopping trips we observe 4,486 purchases of butter or margarine, with 10,656 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.[14]

3.1 Product characteristics

Our data contain information on product characteristics, including the nutritional content of individual products (from the information label on the package), brand, whether the product is from an own-brand budget 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)). Table 1 lists the mean and standard deviation of the product characteristics across our sample

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ing 35.1% to the average household purchases of saturated fats. Snacks and meat are also significant contributors. Our calculations accord with other data. NDNS 2000/2001 suggest that fat spreads including butter account for 11% of saturated fat in the diets of UK adults. Mintel (2005) reported a decline in volume sales of yellow fats (butter, margarine and spreads) by 3% between 2000 and 2004, which it attributed to a general decline in home cooking and baking, as well as a greater reliance on foods prepared outside of the home. Butter is the one category of fat spread that appeared to be bucking this trend with a rise of 8% in volume sales between 2002 and 200438. Defra (2007) show a continuation of this trend with an 8.3% rise in household purchases of butter in 2005-6. See FSA (2007), Henderson et al (2003), Gregory et al (2000).

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

[13] This excludes [**X**] butter and margarine products.

[14] We include all products in each households' choice set, i.e. we can think of the household making a shopping list at home, where they decide which products to purchase. In future work we would like to incorporate information about the consumers' choice set, driven for example by store choice.

of observed purchases.

We also know the manufacturer of each product. This is essential in order to model firm pricing responses. The 142 butter and margarine products are produced by 18 firms. Table 5 lists the manufacturers (ordered by market share), their market share, the number of products they sell, and lists each firms' highest selling product.

Previous studies on the impact of a fat tax have typically looked at substitution between food categories (e.g. from butter to ice cream) but not within food categories (e.g. from one butter product to another).[15] However, if the saturated fat content of products within the same food category varies, within food category substitution may be an important margin of substitution. Figure 1 shows the distribution of saturated fat content per 100g across all the butter and margarine products in our sample. The saturated fat content per 100g varies from 0g to 57g, has mean 27.5g and median 24g. Within butter products there is considerable variation; the butter product with the least saturated per 100g has 23.7g, while the one with the most has 57g; similarly for margarine, the saturated fat per 100g ranges from 0g to 26.6g. We capture substitution between these products, as well as substitution to the outside option.

3.2 Price

Price is an important product characteristic. We calculate the average price of each product in each market. A market is defined as a region-month. We include

[15] For example Chouinard et al (2007), who analyse the implications of the intoduction of a tax on the fat content of dairy products, have data on purchases and attributes of several categories of dairy produce (butter, ice cream, natural cheese etc.).

three seperate regions, meaning there are 36 markets and therefore potentially 36 different prices for each product (assuming we observe each product purchased in each market and their price varies across all markets). Our data contain detailed product characteristics, which can explain most of the price variation - in a hedonic regression of log price on all the product characteristics included in our model using market price and including brand fixed effects, the product characteristics explain 97% of the variation in price.

In our empirical specification we include brand level fixed effects. There are 101 brands and 142 different products, meaning several brands include multiple products contained in households' choice sets. We also 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. Figure 2 shows the relative importance of across market price variation (both regional and monthly) and non-linear pricing for one example brand - Clover Dairy Spread. In all markets the unit price of the 250g pack size is higher than for the 500g and 1Kg pack sizes. In some markets the 500g pack has the lowest unit price, in others the 1Kg pack does. For products from this particular brand there is a considerable amount of price variation through time (and this varies by product), and there is less across regions. In a hedonic price regression including time and region dummies, the size dummies and the time dummies are both jointly statistically significant, while the region dummies are not statistically significant.[16]

[16] [Insert description about underlying price variation driving changes in average prices]

3.3 Household characteristics

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. Table 2 reports the mean and standard deviations for household characteristics across the households in our sample.

To aggregate our results from the household to the market level we need to weight the data in two ways: (i) households shop with different frequencies, and this may be correlated with the predicted probabilities; the probability that we estimate applies equally to each trip; we weight up by the number of trips the household undertook in the year to the household's "aggregate" purchases over the year; (ii) in the TNS data some types of households are under or over sampled; we weight up to get the demographic composition of UK households.

4 Estimation results

4.1 Coefficient

Table 3 shows the estimated coefficients from our mixed logit demand model for butter and margarine. An appendix describes the estimation methodology. The first column reports the mean impact of the product characteristics that vary within brand (this is the $\overline{\beta}_k$ in equation (1)). 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 δ_j that we include are brand level fixed effects (not reported in Table 3). The second column reports the estimated standard deviation 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.

4.2 Elasticities

Using the estimated coefficients we calculate own and cross-price elasticities for all the products for each household. Using the household level elasticities we calculate market own and cross-price elasticities for each product, as described in equation **(9).** Figure 3 shows the distribution of market own-price elasticities across the 142 products.[17] The weighted average own-price elasticity is -2.44 and the standard deviation is 0.45.

Table 4 reports the mean (across markets) market own and cross-price elasticities for the ten products. The upper left hand panel reports own and cross-price elasticities for the five highest market share butter product, the bottom

[17] The product with an elasticity less than 1 is Clover Dairy Spread 1ig. It is one of the two with unstable marginal costs (it varies between -£16 and £110). We have set the cost to 0 in markets where it negative and equal to price in those where it is above price.

right panel for the five highest market share margarine products and the remaining two panels report cross-price elasticities between the butter and margarine products. The elasticities are plausible; the percentage increase in demand for Tesco Value Blended 250g when the price of Asda Blended 250g is increased is higher than for the other products - both of these products are low priced own-brand butters. The reverse is also true. The percentage increase in demand for Clover Dairy Spread 500g when the price of Flora Light Spread 500g increases is higher than for the other products, with the next highest increase in demand for Flora Light Spread 1Kg. Consumers see the alternative brand of margarine in the same pack size as a better substitute for Flora Light Spread 500g than the same brand 1Kg pack.

In the butter and margarine market there are a few firms that produce a large portfolio of products (see Table 5). The cross-price elasticities between products produced by the same firm, and how they compare to the cross-price elasticities of products produced by other firms, will play an important role in determining pass-through (see Anderson et al (2001a) and Hamilton (2008)). We analyse the patterns of pass-through below. Table 7 shows the mean own-price elasticity across products for each manufacturer (weighted by market share), and the mean cross-price elasticities (weighted by market share) for two groups of products - those products within the same firm and in other firms.

The three large firms, each of which have a large portfolio of products, have a higher cross-price elasticity with products that are owned by the same firm, than with products outside the firm. These firms have portfolios of products that consumers see as close substitutes. The same is not true of the medium-sized and smaller manufacturers, the cross-price elasticities are lower with products owned by the same firm, than with products owned by other firms.

4.3 Marginal costs

We recover the marginal cost for each product in each market using (12). The weighted average estimated marginal cost is 56p (from Table 1 we see that the average price in the market is £1.01) and the standard deviation is 27p. The average price-cost margin is 45% and the standard deviation is 9%. For all products the average estimated marginal cost is positive and less than price.

In Table 6 we show marginal costs for a selection of products. In the first panel we show the ten products with the highest predicted market share; in the second panel we show five own-brand budget butter products with 250g pack size; in the third panel we show six 500g margarine products, which all purport to taste like butter in their title; and in the final panel we show four 250g butter products that are made by one firm. The mean and standard deviation of marginal cost is calculated across the 36 markets.

The top panel illustrates that there is a significant degree of heterogeneity in marginal costs across products. The reported standard deviations are all small indicating that the variation in marginal cost across market for a given product is much smaller. The margin on a 500g pack of Flora Light is slighly higher than on a 1Kg pack. The second and third panels show that the marginal costs of products that are likely to be close competitors is similar. Unilever, the largest firm in the market, enjoys the highest margin on the similar margarine products.

The final panel 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.

5 Simulation of impact of taxes

We use our structural estimates to simulate new equilibria after the introduction of a tax on saturated fat. We consider an excise tax and an ad valorem tax. We allow firms to respond to the tax by altering producer prices, and we allow households to respond by substituting between butter and margarine products and to the outside option.

We start by considering the impact of each tax in the absence of firm response. We then show pass-through of the tax when we allow firm response, and look at the changes in shares and profits. Finally we consider the impact on individual households and the overall impact on consumer and producer surplus and tax revenue.

5.1 Form of taxes and impact in the absence of firm response

We consider an excise tax that takes the form

$$mc_j^{\tau} = mc_j + \tau sat_j \tag{13}$$

where sat_j is the saturated fat content of product j and τ is the tax rate. We consider a tax rate of 10p per gram of saturated fat, so $\tau = 0.1$.

We consider an ad valorem tax that takes the form

$$p_j^{\tau} = (1 + tsat_j)\, p_j. \tag{14}$$

To make the taxes comparable we choose the tax rates t such that the (expenditure weighted) average price increase in the absence of tax is the same across the two taxes (this means that tax revenue collected with 100% pass-through is the same under the two taxes). This gives us a tax rate of $t = 0.08$.

In the absence of any response by firms, so assuming 100% pass-through, the excise tax increases price in way that is linear in the volume of saturated fat, while the price increase resulting from the ad valorem tax depends also on the initial price of the product. Figure 4 shows the price increases in pence for each of the 142 products resulting from the excise tax (the solid dots) and the ad valorem tax (the circles). However, the proportional price increase resulting from the the ad valorem tax is a linear function of saturated fat, see Figure 5, while the proportional price increase resulting from the excise tax varies.

5.2 Firm response

We compute the new Nash pricing equilibria under each tax as described in Section 2.4. Firms' pricing responses will depend on demand curvatures (the own and cross-price elasticities) and the portfolio of products the firm (and other firms) hold. In evaluating the new equilibrium we hold the portfolio of products fixed, so the response we estimate can be thought of as the medium, rather than long-term effect.[18]

Figure 6 shows how much of the tax is passed-through onto prices, and how this is related to the saturated fat content of the products. Each dot represents one of the 142 products. The horizontal line indicates 100% pass-through (i.e.

[18] In future work we would like to explore the effect of allowing firms to remove some products from the market, e.g. see Draganska, et al (XXXX).

no firm response).

With the excise tax pass-through is almost always above 100% in the Nash equilbrium, while for the ad valorem tax it is almost always below 100%. Average pass-through with the excise tax is 154%, and is higher for lower saturated fat products. It ranges from 92% for Flora Light Spread 1Kg to 240% for Flora Diet 500g .[19]

With the ad valorem tax pass-through averages 84% and is lowest for the lower saturated fat products. It ranges from 2% for Flora Proactive Light Spread to 236% for Flora Proactive Olive Spread.

How does pass-through vary across large and small firms? Figure 7 compares pass-through under the excise tax for Unilever's products with the products owned by the 9 small manufacturers shown at the bottom of Table 7. Unilever is the largest firm in our sample, owning 19 margarine products which account for 28.5% of the market. The figure shows how pass-through varies with the own-price elasticity of the products. It is clear that for any level of own-price elasticity Unilever is able to pass-through a greater amount of tax than the smaller manufacturers.

Pass-through depends on how the own and cross price elasticities, of both products owned by the firm and those outside the firms' control, change with price. The theoretical literature has shown, in the case of single product firms, a key determinant of the degree of pass through is how sensitive own price

[19] This graph omits three products with instable marginal costs: for Flora Proactive Olive Spread 250g (761% pass–through) and Gold Lowest Extra Light 250g (621% pass-through) which has 0g of saturated fat.

elasticities are to changes in price - if demand for a product rapidly becomes more elastic as its price increase, all else equal, pass through for that product will be lower. In our setting, the portfolio of products owned by firms will also play an important role. For instance, its large portfolio of products protects Unilever's products, and allows Unilever to re-optimise prices in an advantagous way. Figure 8 show the cross-price elasticities of Unilever's products with respect to other Unilever products (left-hand side) and other products not owned by Unilever (right-hand side). The fact that the cross-price elasticities between Unilever's own products are higher indicates that the firm has a portfolio of products where consumers consider as reasonably close substitutes. Dairy Crest (17 products with market share of 20.4%) and Arla (16 products with 18.1% market share) are also able to exploit their market share, though not to same extent.

When we look at mid-size manufacturers, Figure 9, which are all large supermarket chains that have a small range of own-brand products, we see that they fare no better than the small manufacturers. Figure 10 shows the cross-price elasticities for Tesco products with respect to other Tesco products (left-hand side) and other products not owned by Tesco (right-hand side). The cross-price elasticities in the two groups look fairly similar.

Figures 11 and 12 make the same comparisons between the larger and smaller manufacturers in the case of the ad valorem tax. While the largest firms do better, this is less the case than with the excise tax. With ad valorem taxes the amount of the tax is a function of the price, which makes residual demand more price elastic, and so reduces equilibrium price-cost margins.

Table 8 shows how firm profits change as a results of the introduction of the taxes. The largest firms - Unilever, Dairy Crest and Arla - all suffer a greater reduction in profits when the ad valorem tax is introduced. However, for a number of smaller firms the excise tax results in a bigger fall in profits.

5.3 Impact on households

The model allows households to respond to the introduction of the tax by changing the amount of saturated fat they purchase along three margins. Firstly, they can substitute toward the outside option. The average probability that a household selects the outside option increases from 73.6% to 79.1% in the case of the excise tax and 76.2% in the ad valorem. Secondly, households can substitute within butter and margarine products to lower fat products. Figure 13 shows the change in predicted market share of the 142 butter and margarine products by the saturated fat intensity (per 100g). [to be completed] Thirdly, households may respond to the tax by substituting to products with different pack sizes. [to be completed]

The overall effect of is that households cut back in the amount of saturated fat they purchase in the form of butter and margarine by 24.5% in the case of the excise tax, and by 13.8% in the ad valorem. There is, however, a lot of variation in how different households respond, shown in Figure 15, with all household cutting back by substantially less under the ad valorem tax. Table 9 shows how the response varies by observable household characteristics. We see that the biggest reduction in expenditure and saturated fat purchased is for lower income households and households with children.

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

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

The first term is the expected utility under the new prices. The second is expected utility under the old prices. The denominator is equal to the marginal utility of income under some assumptions in Rosen and Small (1981) or McFadden (1981, 1995). 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. The two columns on the left of Table 9 show the compensating variation per 1kg reduction in saturated fat.

5.4 Overall effects

Table 10 summarises the overall impact of the two forms of tax. The first column shows expenditure, quantity (weighted by marginal cost, so total marginal cost), profit and the amount of saturated fat purchased before the tax. The second and third columns show the changes with the excise tax, first with no firm response and then in the Nash equilibrium where firms respond by reoptimising price. The fourth and fifth show the ad valorem tax.

In the case of the excise tax firms' response leads to a greatre reduction in expenditure, a lower reduction in profits, greater reduction in compensating variation and greater overall costs. With the ad valorem tax allowing firms to respond leads to a slightly lower reduction in expenditure and compensating variation, but a greater reduction in profits. The overall cost is reduced as a result of firm response.

In the second panel we see that saturated fat purchases are reduced by more with the excise tax, and the impact of firms' response in the case of the excise tax is to reduce saturated fat purchases even further. This is in contrast to the ad valorem tax, where the impact of firms' response is to lead to less of a reduction in saturated fat.

In the final panel we compare the costs of the tax with the reduction in saturated fat. We compare the costs to the consumers alone, in terms of compensating variation, and the costs including profits and tax revenue. With the excise tax we see that the impact of firms' response is to increase the cost of reducing saturated fat purchases by 1kg, while with the ad valorem tax firms' response reduces the cost per kg. However, the cost per kg reduction in saturated fat is lower with the excise tax than with the ad valorem tax, even after allowing for firms' pricing responses.

Figure 18 shows the cumulative density of compensating variation per 1kg of saturated fat reduction per household.

6 Summary and Conclusion

[to be written]

7 Appendix A: Estimation

We estimate the random coefficient logit model given in (3) with brand fixed effects as in (**??**). Dropping the i subscripts, we have

$$u_j = \delta_j + \sum_{k,r} \beta^O_{kr} z_r x_{jk} + \sum_{k=1}^{K_U} \beta^U_k x_{jk} + \varepsilon_j$$

with

$$\begin{aligned} \delta_j &= \gamma(x_{j1}) + \sum_{k \in K_1} \overline{\beta}_k x_{jk} \\ \gamma(x_{j1}) &= \gamma(x_{j'1}) \text{ if } x_{j1} = x_{j'1}. \end{aligned}$$

The variable u_j is the payoff the household obtains from product j. We assume that $\beta^U \in \mathbf{R}_d$ with

$$\beta^U \sim N(0, \Sigma).$$

We estimate the model by maximum likelihood. Assume that for each household the data have been sorted so that option 1 is the option chosen. Let $P\left(\beta^U\right)$ be the probability that a household chooses option 1. Then

$$P\left(\beta^U\right) = \frac{1}{1 + \sum_{j \neq 1} \exp\left(v_j\left(\beta^U\right) - v_1\left(\beta^U\right)\right)}$$

where we define

$$v_j\left(\beta^U\right) - v_1\left(\beta^U\right) = (\delta_j - \delta_1) + \sum_{k,r} \beta^O_{kr} z_r (x_{jk} - x_{1k}) + \sum_k \beta^U_k (x_{jk} - x_{1k}).$$

Define the change of variable

$$\beta^U = \sqrt{2}\Sigma^{0.5}\varepsilon.$$

The likelihood for a single household can be written as

$$L = \log\left(\int P\left(\sqrt{2}\Sigma^{0.5}\varepsilon\right)\frac{e^{-\varepsilon'\varepsilon}}{\pi^{1.5}}d\varepsilon\right). \tag{15}$$

We approximate the integral in (15) with

$$L \approx \log\left(\sum_i \frac{w_i}{\pi^{0.5K_U}} P\left(\sqrt{2}\Sigma^{0.5}\varepsilon_i\right)\right) \tag{16}$$

where $\{(w_i, \varepsilon_i)\}_{i=1}^N$ are the weights and nodes for a d dimensional integration rule.

When d is small $(d \leq 9)$, we use the tensor product of d one dimensional Gauss-Hermite quadrature rules with n points in each dimension. The Gauss-Hermite integration rule is exact for polynomials of degree $2n - 1$. Since the integrand $P\left(\sqrt{2}\Sigma^{0.5}\varepsilon\right)$ is a smooth function of ε, this integration rule is much more accurate than Monte Carlo integration.

This method uses an integration rule with $N = n^d$ nodes. Given our current computing resources, rules with $N \leq 2{*}10^6$ are feasible. When d is large $(d > 9)$, we use Monte Carlo integration with $w_i = \pi^{0.5d}$ and with $N \leq 2,000,000$.

The likelihood for the data is the sum of (16) across households. We compute (16) and its analytic gradient and compute the values of $\left(\overline{\beta}, \beta^O, \Sigma\right)$ that maximise this likelihood.

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Table 1: Mean values of product characteristics

Product characteristic		Mean	Standard deviation
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

Notes: Numbers are calculated using the 4,488 purchases of butter and margarine that we use to estimate our model. The share of the outside option is 0.63. PUFA is margarine made with polyunsaturated fatty acids.

Table 2: Mean household characteristics

Household characteristic		Mean	Standard deviation
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: Mean across 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 3: Estimated coefficients

	mean	*standev*	*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 "standev" column reports the standard deviation 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). Fixed effects for 101 brands are included in the regression but are not reported (available from authors on request).

Table 4: Mean own and cross price elasticities between five butter and margarine products with the largest predicted market shares

	Predicted market share	Tesco Value Blended 250g	Lrpak Lgtr S/S Sprdb Dan 500g	Cty.L Standard 250g	Lrpak S/S Sprdbl Danish 500g	Asda Sp Oth Blended 250g	Flora Light Lw Ft Spread 500g	Clover Dairy Spread 500g	I.C.B.I.N.B Dairy Spread 500g	St Ivel Utrly Btrly D/Spd 500g	Flora Light Lw Ft Spread 1kg
Tesco Value Blended 250g	3.91%	-2.144	0.033	0.021	0.030	0.015	0.038	0.037	0.030	0.029	0.031
Lurpak Lighter S/S Sprdb 500g	2.56%	0.014	-2.393	0.016	0.014	0.008	0.045	0.048	0.027	0.025	0.024
Country Life Standard 250g	2.31%	0.026	0.046	-2.454	0.043	0.013	0.043	0.043	0.031	0.029	0.041
Lurpak S/S Spreadable 500g	2.29%	0.015	0.014	0.017	-2.396	0.008	0.045	0.049	0.027	0.025	0.022
Asda Sp Oth Blended 250g	2.08%	0.028	0.032	0.020	0.030	-2.162	0.038	0.038	0.031	0.029	0.032
Flora Light Low Fat Spread 500g	3.83%	0.022	0.057	0.020	0.052	0.012	-2.631	0.051	0.032	0.031	0.062
Clover Dairy Spread 500g	3.45%	0.021	0.059	0.019	0.054	0.011	0.049	-2.684	0.033	0.031	0.065
I.C.B.I.N.B Dairy Spread 500g	3.45%	0.024	0.046	0.019	0.042	0.013	0.044	0.047	-2.503	0.032	0.051
St Ivel Utterly Butterly D/Spd 500g	3.29%	0.024	0.047	0.019	0.042	0.013	0.044	0.047	0.033	-2.523	0.052
Flora Light Low Fat Spread 1kg	2.59%	0.014	0.023	0.014	0.020	0.008	0.048	0.052	0.029	0.028	-2.543

Notes: Elasticities are weighted averages across the 16,637 households in our sample. They are weighted by the probability of purchase and household sampling weights. The household sampling weighted account for the frequency with which firms shop and correct for non-random sampling. The elasticities describe the change in demand for the row product with respect to the price of the column product. The elasticities in the upper-left square are between butter products and those in the lower-right are between margarine products. The lower-left and upper-right give mean cross-price elasticities between the butter and margarine products. I.C.B.I.N.B. stands for I Can't Believe It's Not Butter.

Table 5: Manufacturers

Manufacturer	Number of products	Market share	Average marginal cost	Average price-cost margin	Product With Largest Market Share
Unilever Bestfoods	19	28.54%	0.56	0.49	Flora Light Low Fat Spread 500g
Dairy Crest Foods Ltd	17	20.38%	0.58	0.42	Clover Dairy Spread 500g
Arla Foods	16	18.13%	0.78	0.43	Lurpak Lighter S/S Sprdb 500g
Tesco Food Stores Ltd	18	11.49%	0.45	0.43	Tesco Value Blended 250g
Asda Stores Ltd	14	5.64%	0.39	0.46	Asda Sp Oth Blended 250g
J Sainsburys	16	4.19%	0.43	0.44	Sainsbury Basic English 250g
Morrisons Ltd	13	3.15%	0.38	0.45	Morrs English 250g
Lidl UK GMBH	6	1.68%	0.33	0.45	Lidl Slightly Salted German 250g
The Kerrygold Co. Ltd	3	1.46%	0.60	0.40	Kerrygold Standard Irish 250g
Aldi Stores Ltd	5	1.39%	0.44	0.43	Aldi Blended 250g
Matthews Foods Plc	4	1.42%	0.55	0.38	Pure Soya Spread 500g
Evan Rees Ltd	1	0.97%	0.29	0.46	Hollybush English 250g
Lactalis Beurres Et Frmgs	1	0.48%	0.60	0.38	President French Unsalted 250g
Netto Ltd	3	0.37%	0.15	0.67	Netto Veg Spread 500g
Yeo Valley Farms Ltd	1	0.23%	0.71	0.37	Yeo Valley Blended Organic 250g
C.W.S. (Co-op)	2	0.18%	0.50	0.39	Co-Op Creamery Blended 250g
Somerfield Stores Ltd	2	0.14%	0.58	0.38	Somerfield Unsalted English 250g
Waitrose Ltd	1	0.16%	0.45	0.40	Waitrose English 250g

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

Table 6: Marginal costs for some example products

Manufacturer	Product	Market Share	Mean Price	Marginal Cost Mean	Marginal Cost Standard Deviation	(Price – Mc)/Price
10 Products With Highest Market Share						
Tesco Food Stores Ltd	Tesco Value Blended 250g	3.91%	0.53	0.28	0.00	0.48
Unilever Bestfoods	Flora Light Lw Ft 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 Utrly Btrly D/Spd 500g	3.29%	0.76	0.45	0.06	0.41
Unilever Bestfoods	Flora Light Lw Ft Spread 1kg	2.59%	1.83	1.08	0.07	0.41
Arla Foods	Lrpak Lgtr S/S Sprdb Dan 500g	2.56%	1.83	1.00	0.03	0.45
Dairy Crest Foods Ltd	Cty.L Standard 250g	2.31%	0.71	0.41	0.03	0.43
Arla Foods	Lrpak S/S Sprdbl Danish 500g	2.29%	1.85	1.02	0.03	0.45
Asda Stores Ltd	Asda Sp Oth Blended 250g	2.08%	0.53	0.28	0.00	0.47
Supermarkets' 250g Budget Butters						
Aldi Stores Ltd	Aldi Blended 250g	0.37%	0.53	0.29	0.00	0.46
Asda Stores Ltd	Asda Sp Oth Blended 250g	2.08%	0.53	0.28	0.00	0.47
J Sainsburys	Sains Blended S/S 250g	0.33%	0.65	0.37	0.01	0.42
Morrisons	Morrs Bttby 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						
Aldi Stores Ltd	Aldi Beautifully Btrflly 500g	0.26%	0.64	0.37	0.02	0.42
Asda Stores Ltd	Asda Youd Bttr Blv It D/S 500g	0.53%	0.76	0.46	0.04	0.40
Dairy Crest Foods Ltd	St Ivel Utrly Btrly D/Spd 500g	3.29%	0.76	0.45	0.06	0.41
J Sainsburys	Sains Butterlicious 500g	0.39%	0.77	0.47	0.04	0.40
Tesco Food Stores Ltd	Tesco Butter Me Up Sprd 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 Value Blended 250g	3.91%	0.53	0.28	0.00	0.48
	Tesco Creamery Blended 250g	3.83%	0.58	0.32	0.00	0.46
	Tesco Organic Danish 250g	3.45%	0.88	0.53	0.02	0.40
	Tesco Fnst 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.

Table 7: Cross-price elasticities within and between firms

manufacturer	number products	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	0.285	-2.405	0.0160	0.0058
Dairy Crest Foods Ltd	17	0.204	-2.465	0.0126	0.0069
Arla Foods	16	0.181	-2.570	0.0175	0.0061
Supermarkets with own-brand products					
Tesco Food Stores Ltd	18	0.115	-2.431	0.0054	0.0081
Asda Stores Ltd	14	0.056	-2.314	0.0029	0.0080
J Sainsburys	16	0.042	-2.392	0.0021	0.0083
Morrisons Ltd	13	0.031	-2.309	0.0016	0.0079
Lidl UK GMBH	6	0.017	-2.274	0.0020	0.0073
Aldi Stores Ltd	5	0.014	-2.385	0.0023	0.0078
Small manufacturers					
The Kerrygold Co. Ltd	3	0.015	-2.536	0.0050	0.0077
Matthews Foods Plc	4	0.014	-2.636	0.0030	0.0086
Evan Rees Ltd	1	0.010	-2.171	-	0.0067
Lactalis Beurres Et Frmg	1	0.005	-2.660	-	0.0088
Netto Ltd	3	0.004	-1.584	0.0006	0.0059
C.W.S. (Co-op)	2	0.002	-2.589	0.0009	0.0084
Waitrose Ltd	1	0.002	-2.520	-	0.0079
Yeo Valley Farms Ltd	1	0.002	-2.724	-	0.0092
Somerfield Stores Ltd	2	0.001	-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).

Table 8: Firm profits

Manufacturer	Profits (£m)	Profits Excise (£m)	Profits Ad Valorem (£m)	Number products
Aldi Stores Ltd	2.032	1.705	1.718	5
		-16.1%	*-15.5%*	
Arla Foods	52.77	47.901	42.371	16
		-9.2%	*-19.7%*	
Asda Stores Ltd	7.779	6.474	6.823	14
		-16.8%	*-12.3%*	
C.W.S. (Co-op)	0.264	0.24	0.239	2
		-9.1%	*-9.5%*	
Dairy Crest Foods Ltd	41.422	37.164	34.489	17
		-10.3%	*-16.7%*	
Evan Rees Ltd	1.149	0.82	0.977	1
		-28.6%	*-15.0%*	
J Sainsburys	6.095	5.139	5.295	16
		-15.7%	*-13.1%*	
Lactalis Beurres Et Frmgs	0.84	0.751	0.723	1
		-10.6%	*-13.9%*	
Lidl UK GMBH	2.116	1.828	1.953	6
		-13.6%	*-7.7%*	
Matthews Foods Plc	2.326	2.151	2.08	4
		-7.5%	*-10.6%*	
Morrisons Ltd	4.26	3.438	3.677	13
		-19.3%	*-13.7%*	
Netto Ltd	0.401	0.309	0.375	3
		-22.9%	*-6.5%*	
Somerfield Stores Ltd	0.235	0.218	0.212	2
		-7.2%	*-9.8%*	
Tesco Food Stores Ltd	17.591	14.496	14.918	18
		-17.6%	*-15.2%*	
The Kerrygold Co. Ltd	2.798	2.358	2.203	3
		-15.7%	*-21.3%*	
Unilever Bestfoods	76.551	72.73	68.471	19
		-5.0%	*-10.6%*	
Waitrose Ltd	0.23	0.192	0.198	1
		-16.5%	*-13.9%*	
Yeo Valley Farms Ltd	0.463	0.431	0.398	1
		-6.9%	*-14.0%*	

Notes: Column one gives pre-tax predicted profits. Column 2 and 3 give predicted profits after the excise and ad valorem tax are introduced respectively. Percentage change is in italics.

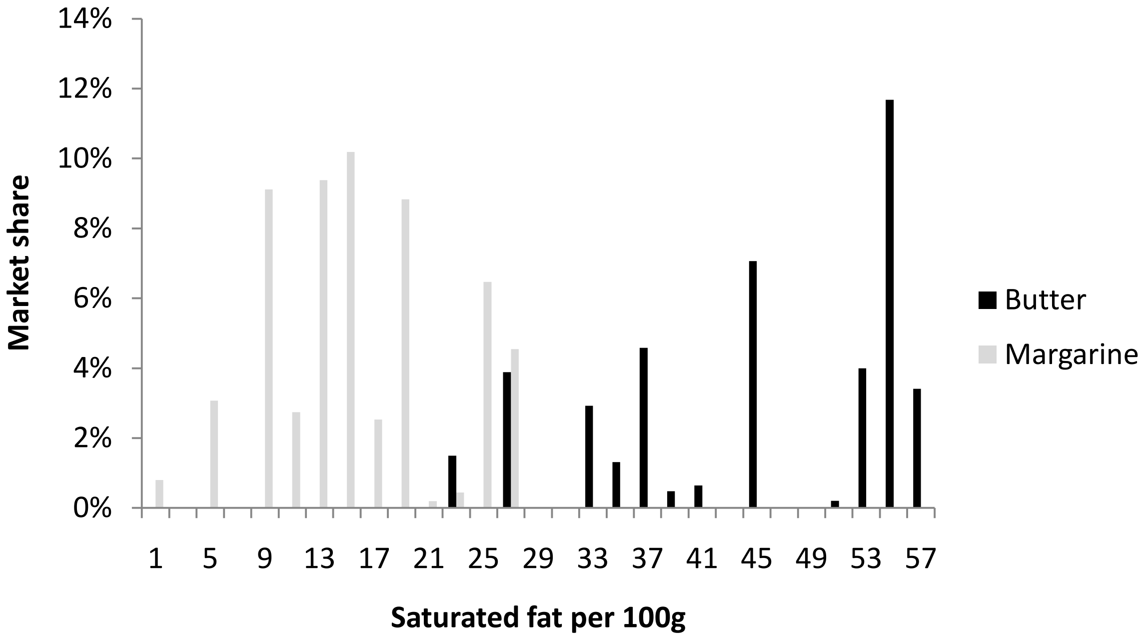
Table 9: Mean compensating variation per 1kg reduction in saturated fat, by household type

	% reduction in saturated fat		*Mean compensating variation of a 1kg reduction in saturated fat (in £)*	
Household characteristic	*excise tax*	*ad valorem tax*	*excise tax*	*ad valorem tax*
1 hh member	24.3	13.1	5.17	5.51
2 hh member	24.1	13.3	5.21	5.57
3 hh member	23.9	13.8	5.16	5.48
4 hh member	24.9	14.5	4.90	5.21
5 hh member	26.9	15.7	4.43	4.73
Couple with kids	24.9	14.6	4.91	5.20
Single parent	24.4	14.5	4.97	5.13
No kids	23.8	13.3	5.27	5.64
Pensioners	25.5	13.4	4.86	5.22
Inc <10k	25.3	13.8	4.83	5.13
10k<Inc <20k	25.3	14.1	4.85	5.14
20k<Inc <30k	25.5	14.4	4.84	5.10
30k<Inc <40k	24.0	13.5	5.17	5.57
Inc>40k	22.0	12.9	5.71	6.17
Normal BMI	26.6	14.7	4.60	5.29
Obese	24.6	13.9	5.01	5.36
North	24.9	14.0	4.96	5.29
South-east	24.5	13.9	5.04	5.36
South-west	23.9	13.2	5.29	5.64
Upper class	24.1	13.5	5.21	5.58
Lower class	24.8	14.0	4.94	5.25
All households	24.5	13.8	5.08	5.41

Table 10: Overall effect

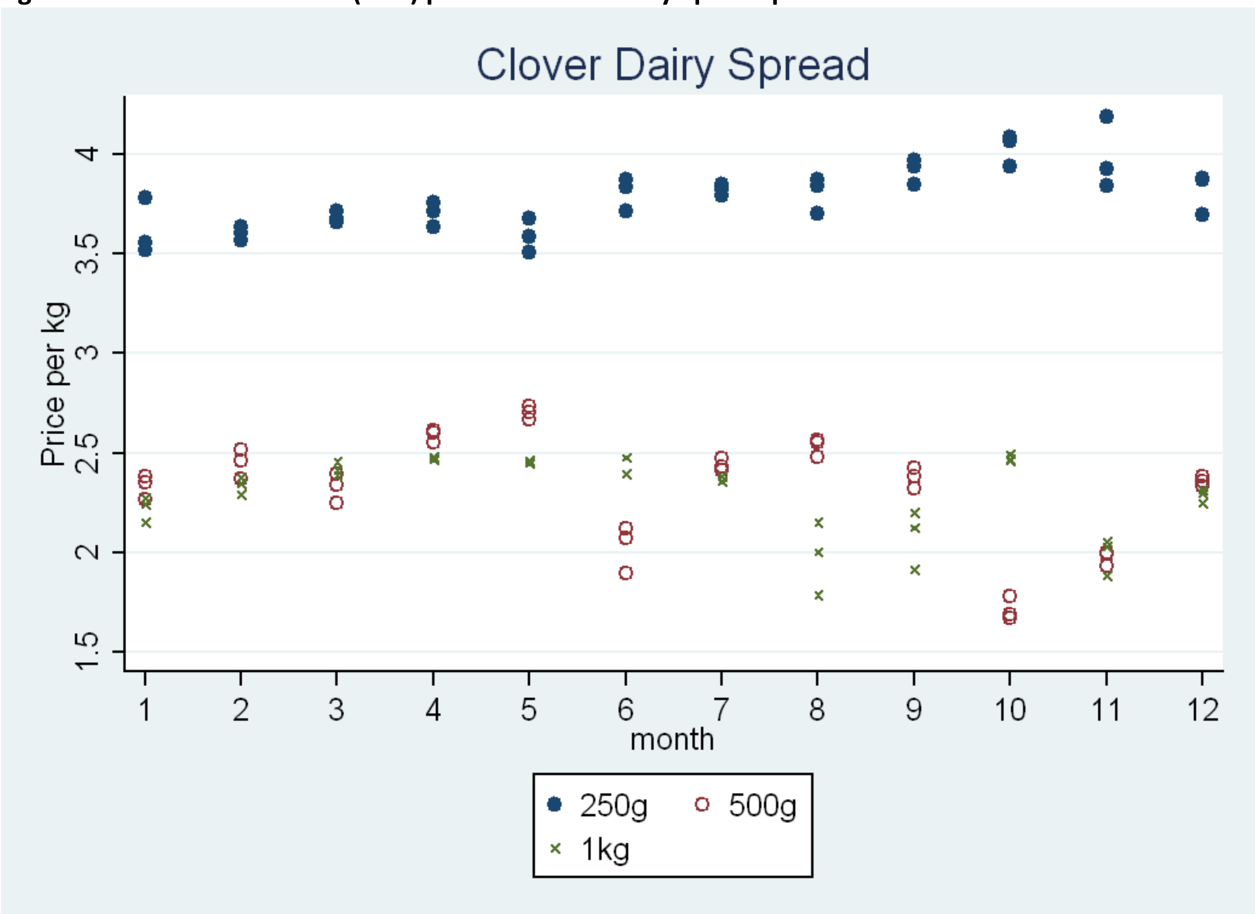
All figures in £m		*Excise*		*Ad valorem*	
	Base	*No firm response*	*Firm response*	*No firm response*	*Firm response*
Expenditure	490.70	469.90	461.99	468.47	470.73
		-4.24%	*-5.85%*	*-4.53%*	*-4.07%*
Quantity (weighted by marginal cost)	271.38	235.19	222.83	234.81	239.51
		-13.33%	*-17.89%*	*-13.48%*	*-11.74%*
Firm 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**
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 compensating variation per 1kg reduction in saturated fat (£)		4.60	5.01	5.58	5.34
Mean cost of a 1kg reduction in saturated fat (£)		**3.28**	**3.52**	**3.92**	**3.74**

Figure 1: Distribution in saturated fat per 100g across butter and margarine products



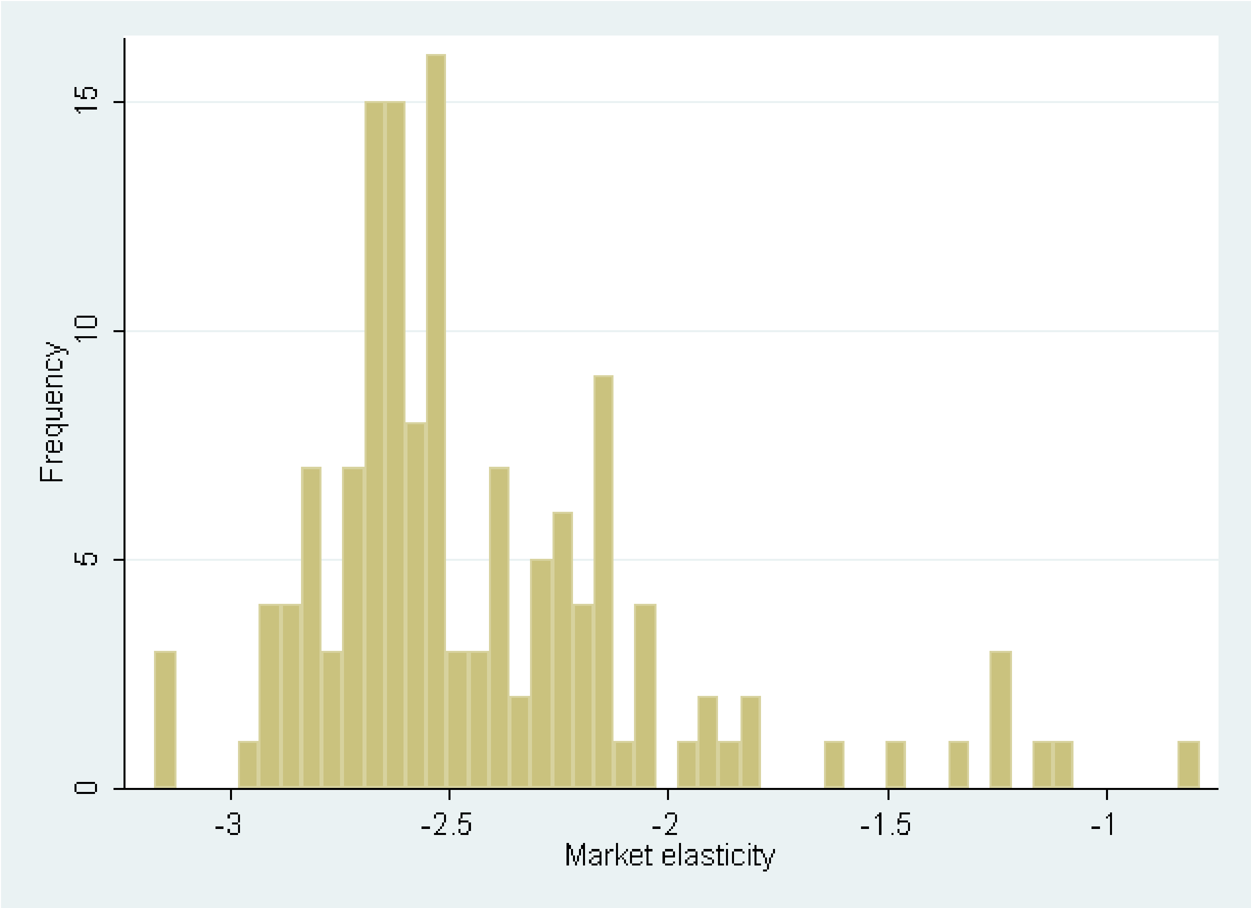
Notes: Market share is based on number of observed sales made throughout 2006.

Figure 2: Variation in market (unit) price of Clover Dairy Spread products



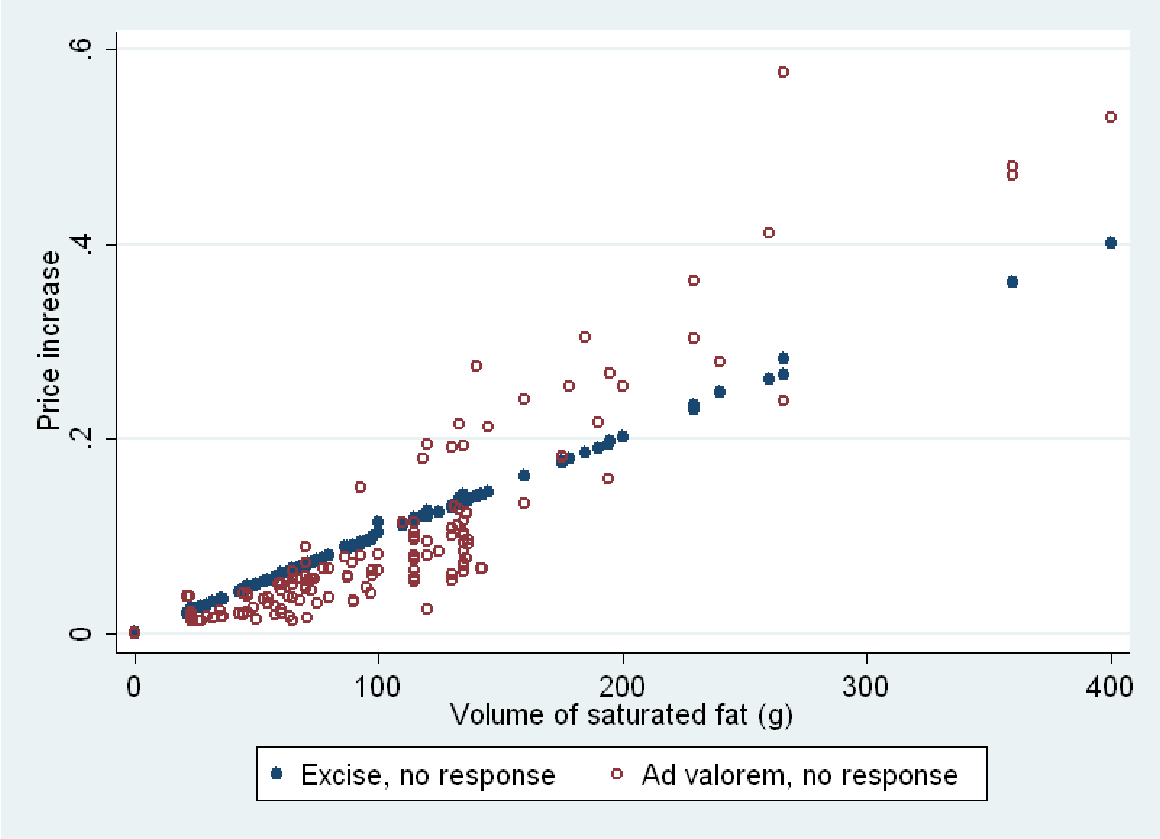
Notes: Within each month there are 9 prices – three for each product/pack size (one for every region). Prices are market level – they are calculated as a weighted average of the prices observed in each market.

Figure 3: Market own-price elasticities



Notes: Distribution of 142 market own-price elasticities.Market elasticities are constructed from individual elasticities and weighted by predictedprobability of purchase and household sampling weights.

Figure 4: Price increase with no firm response

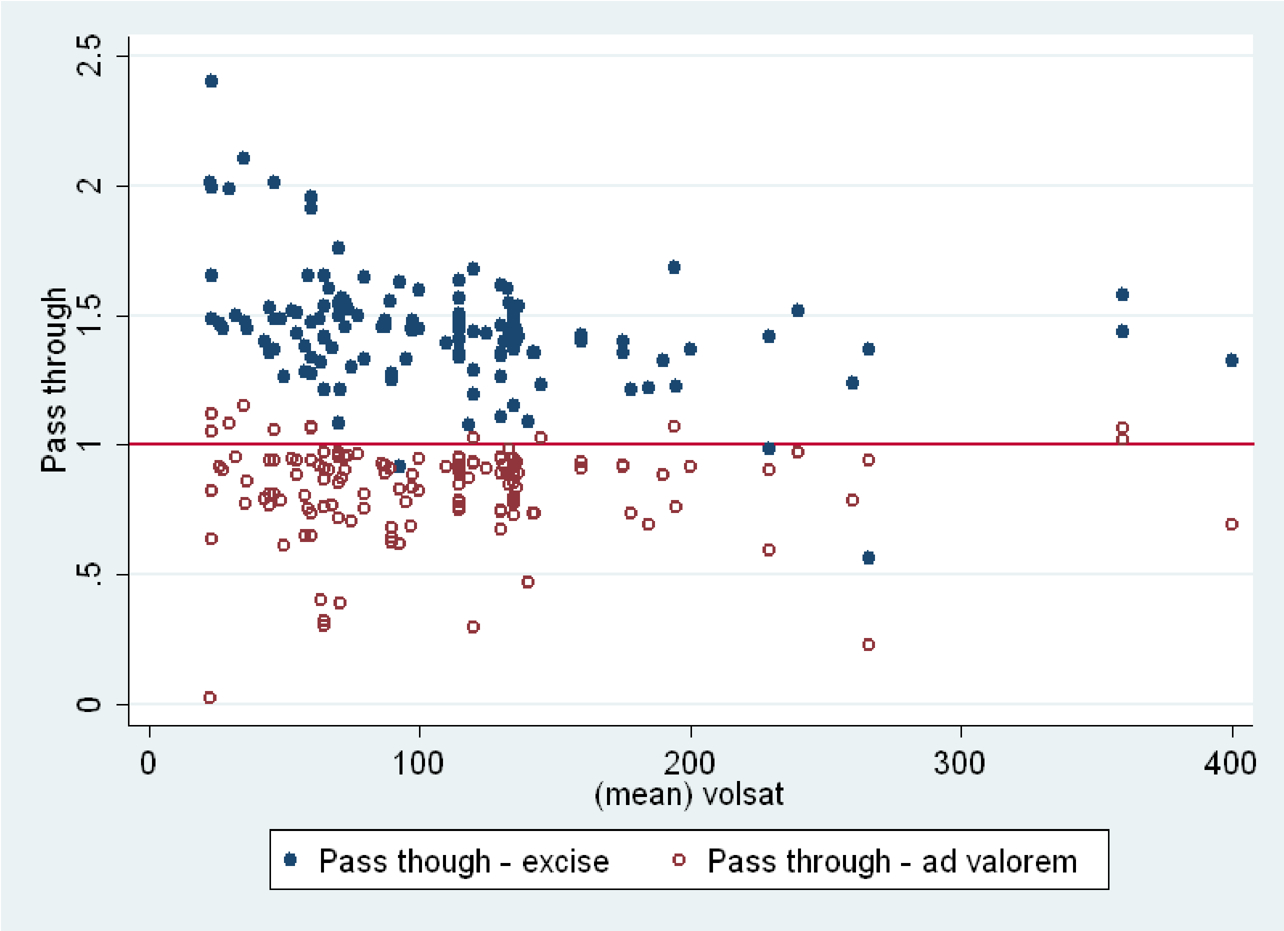


Notes: Each dot represents one of the 142 products. The y-axis is the change in price in £ (i.e. 0.2 equals 20 pence) from applying the tax with no firm response.

Figure 5: Proportional price increase with no firm response

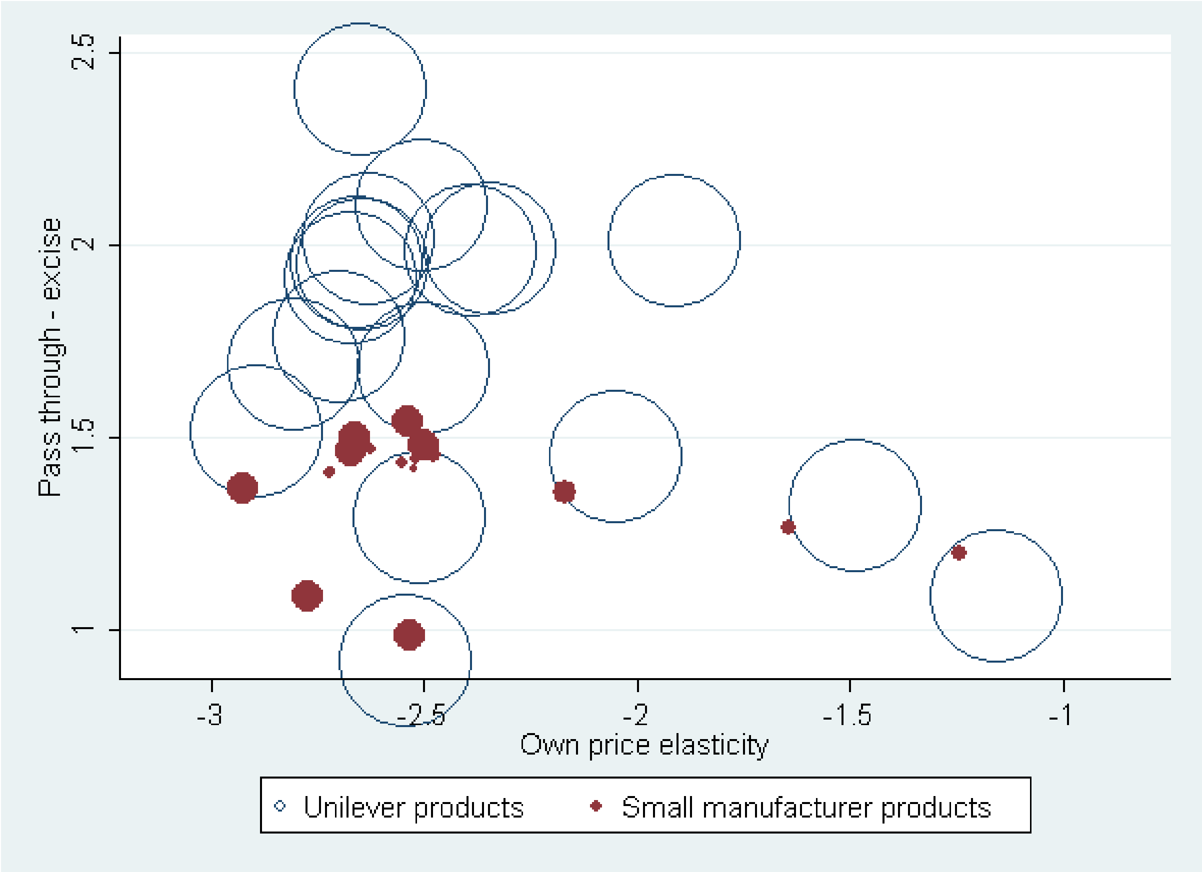
Notes: Each dot represents one of the 142 products. The y-axis is the proportional change in price from applying the tax with no firm response.

Figure 6: Pass-through with firm response



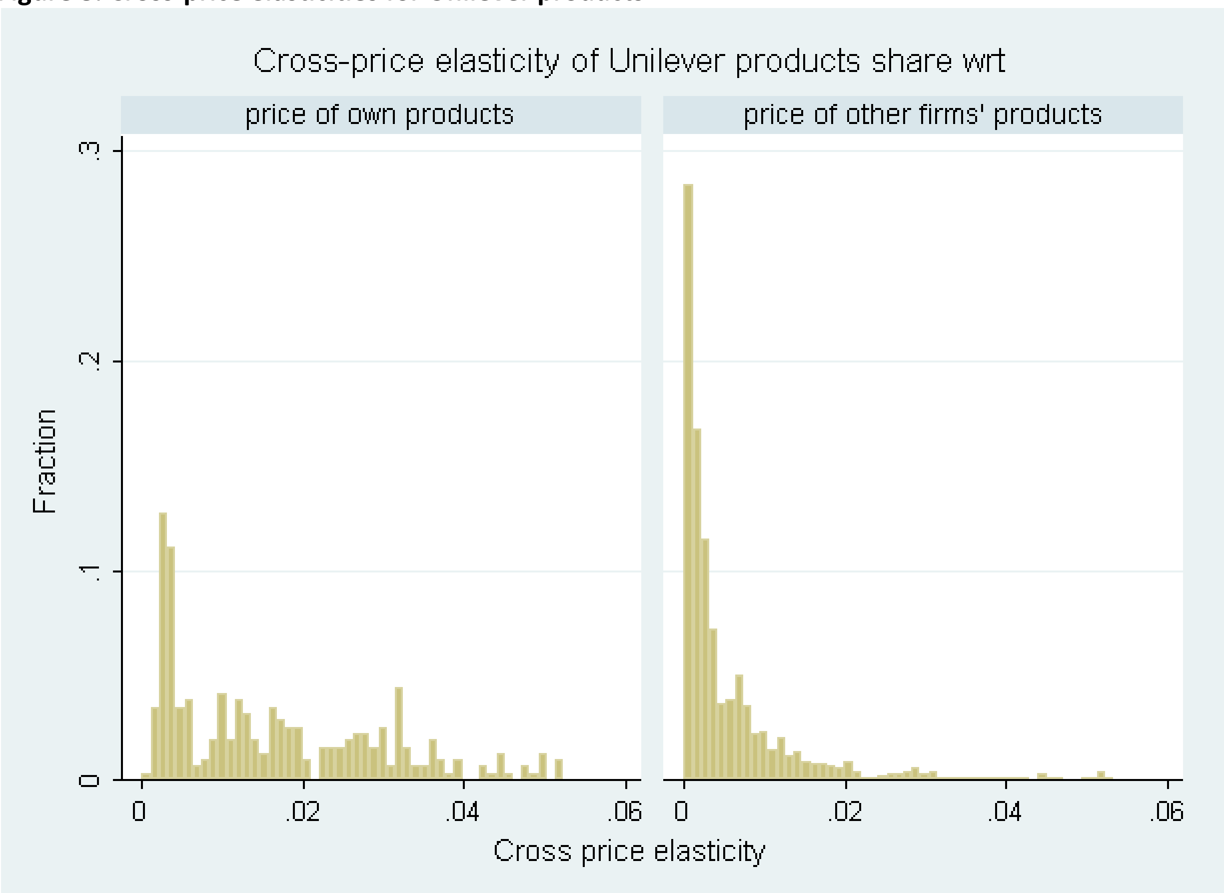
Notes: Each dot represents one of the 142 products. The y-axis is pass-through in the Nash Equilibrium when we allow firms to respond by changing prices. Pass-through is the price in Nash Equilibrium minus the base price divided by the price with no firm response minus the base price.
[x-axis should read "Volume of saturated fat in (g)]

Figure 7: Pass-through in Nash equilibrium for Unilever products, excise tax



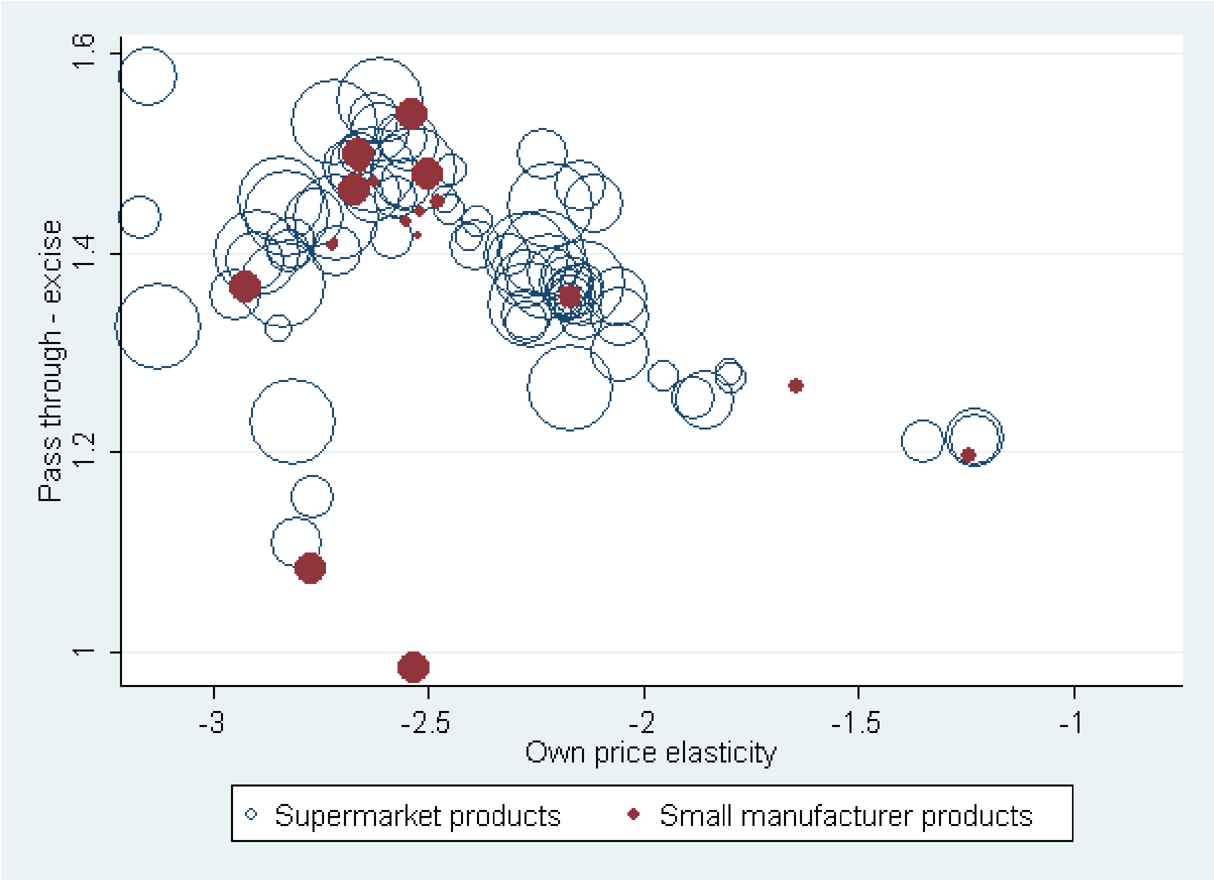
Notes: Each dot represents a products. The x-axis is the market own-price elasticity of the product. The y-axis is the rate of pass-through of the excise tax. The size of the dot is determined by the firms' market share.

Figure 8: Cross-price elasticities for Unilever products



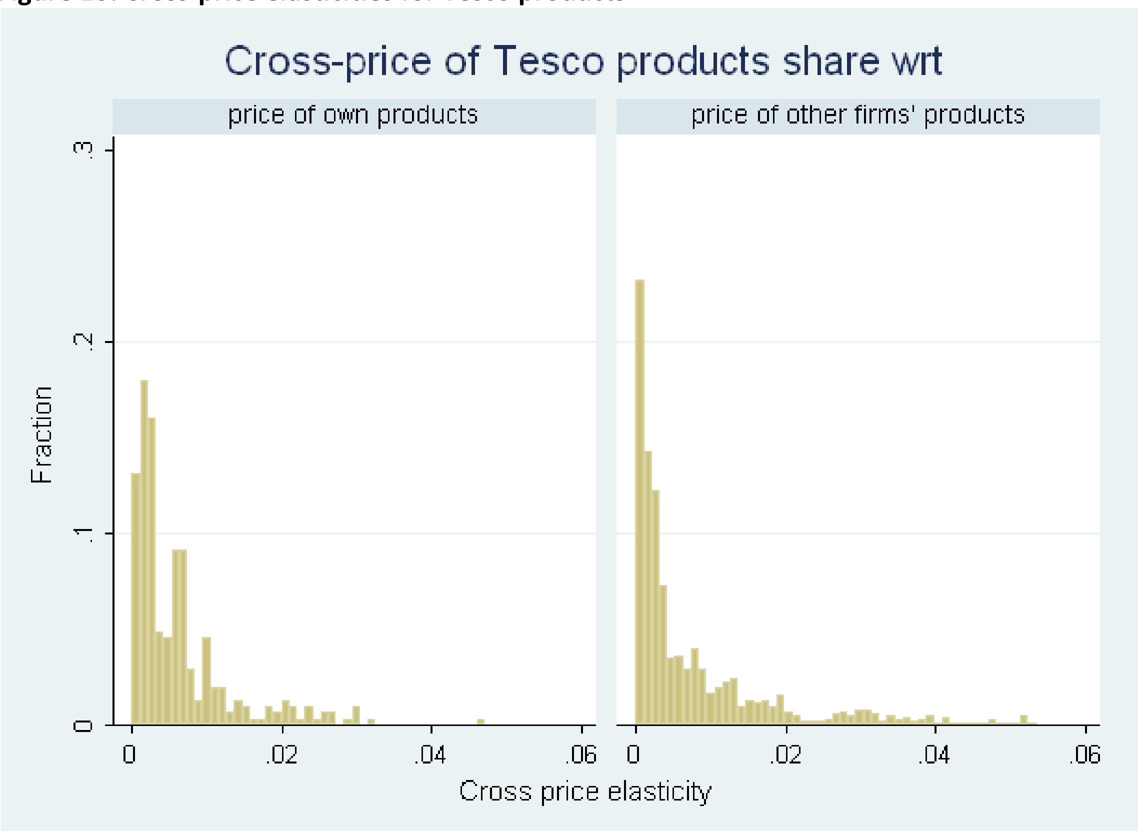
Notes: The left-hand graph show the distribution of cross-price elasticities between the 19 products that Unilever produces; the right-hand graph shows the distribution of the cross price elasticities between Unilever products and all other products in the market that are not produced by Unilever.

Figure 9: Pass-through in Nash equilibrium for Supermarket own-brand products, excise tax



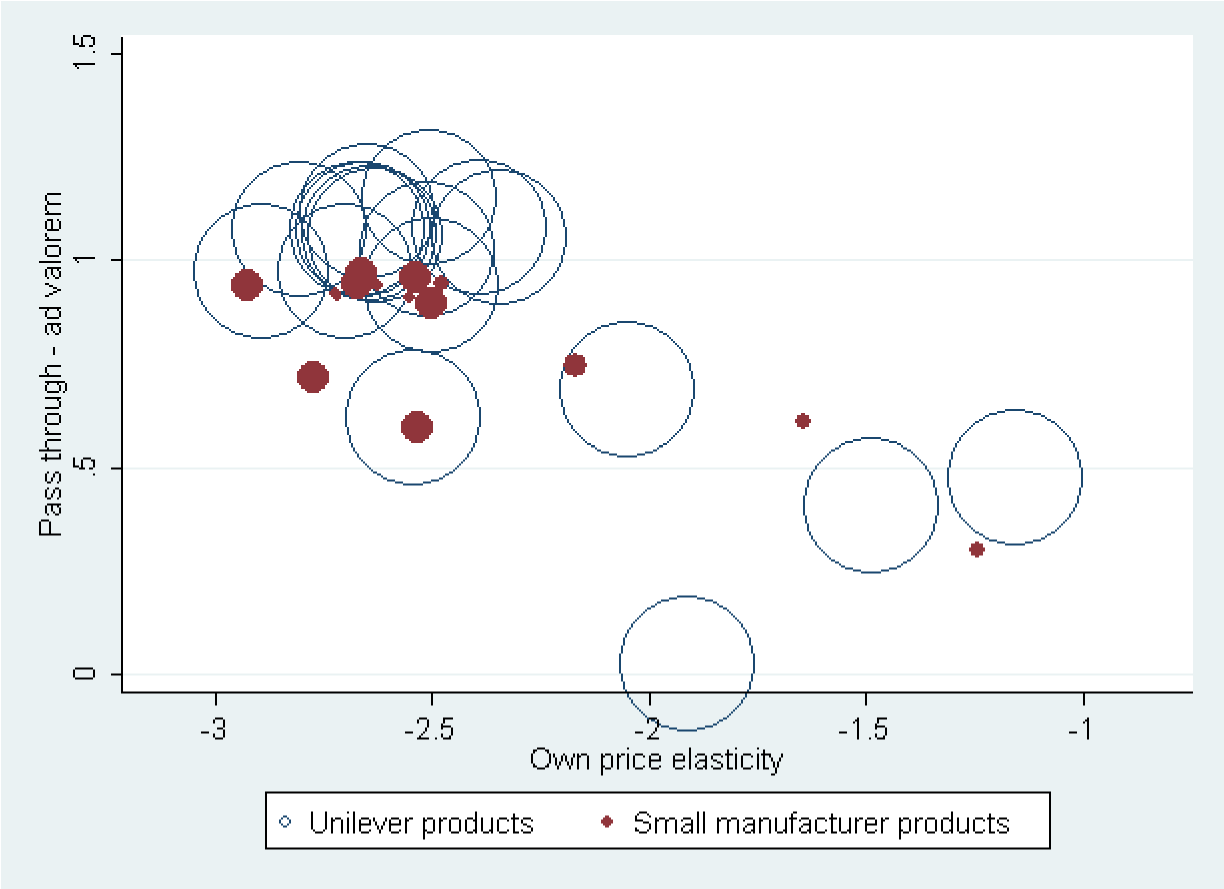
Notes: Each dot represents a producs. The x-axis is the market own-price elasticity of the product. The y-axis is the rate of pass-through of the excise tax. The size of the dot is determined by the firms' market share.

Figure 10: Cross-price elasticities for Tesco products



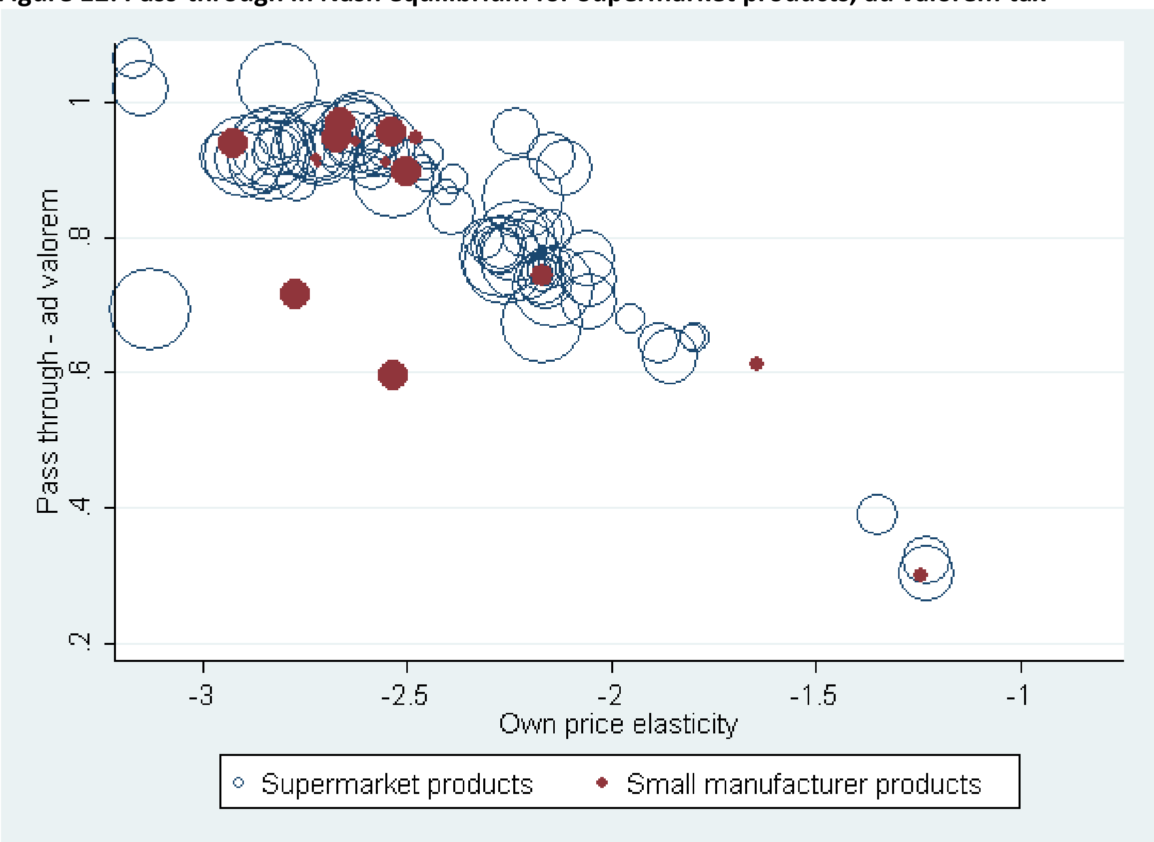
Notes: The left-hand graph show the distribution of cross-price elasticities between the 18 products that Tesco produces; the right-hand graph shows the distribution of the cross price elasticities between Tesco products and all other products in the market that are not produced by Tesco.

Figure 11: Pass-through in Nash equilibrium for Unilever products, ad valorem tax



Notes: Each dot represents a products. The x-axis is the market own-price elasticity of the product. The y-axis is the rate of pass-through of the excise tax. The size of the dot is determined by the firms' market share.

Figure 12: Pass-through in Nash equilibrium for Supermarket products, ad valorem tax



Notes: Each dot represents a products. The x-axis is the market own-price elasticity of the product. The y-axis is the rate of pass-through of the excise tax. The size of the dot is determined by the firms' market share.

Figure 13: change in predicted market share, by saturated fat intensity
[to be included]
Notes: Each dot represents a products.

Figure 14: % reduction in sat fat by household
[to be included]

Figure 15: Compensating variation per 1kg reduction in saturated fat, distribution across households