Assessing the welfare impact of taxing sugar: how does design matter? An empirical evidence from the UK soft drink market

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Abstract

Policymakers have increasingly implemented nutritional taxes to influence consumer behavior toward healthier diets. Their efficiency highly depends on their design. Both theoretical and empirical literature suggest that taxes should be proportional to the harm caused. Yet, none of the nutritional taxes implemented to date have a strictly linear design. Instead, they generally feature tiered designs with thresholds that vary in proximity. Can these tiered taxes be optimal, and if so, how should their main components be set? Our paper introduces a framework for evaluating the optimality of a wide range of tax designs, from taxes proportional to sugar content to tiered tax designs with varying numbers of thresholds and threshold locations, integrating the social cost of sugar and consumption pattern heterogeneity. We show that tiered designs perform incredibly well with even a very small number of thresholds. In our application, only three thresholds are necessary to reach 98% of the maximum welfare increase.

Keywords: Tax design, Welfare, Sugar tax

JEL classification: D62, H21, H30, I18, Q18

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1 Introduction

In recent decades, policymakers have implemented ”sin taxes” primarily to steer consumer choices toward healthier food options by targeting products considered harmful to society and individuals, such as alcohol, tobacco, and soft drinks. The taxes aim to reduce demand by increasing their prices and generate revenue for the government. The design of the tax plays a crucial role in altering agent behaviors. To date, more than 50 countries have implemented taxes on sugar-sweetened beverages (SSBs).[1] However, the design of these taxes varies significantly from one country to another. The majority of designs implemented by regulators in the last 20 years include some tiered aspect (e.g. France, UK, Spain, Chile). A notable aspect is that there has not been a sugar tax implemented that is strictly proportional to sugar content,[2] although it was theoretically and empirically shown it is the optimal design (Allcott et al., 2019a; O'Connell and Smith, forthcoming).

Can these tiered sugar-based taxes be optimal and if so, how should the main components of the taxes be set? Should all products be taxed, or only those with high sugar content? If it is the latter, which sugar tax threshold should be set? Should tax rates be proportional to sugar content, or is it preferable to allow flexibility in tax levels based on sugar content? Is the level of taxation properly calibrated in relation to the social costs of sugar consumption? This paper aims to address the questions by analysing how the different components of tax design affect total welfare. Specifically, we propose a framework for evaluating the optimality of tax design, integrating the social cost of sugar, where three components of the design can vary: the number of thresholds, the location of the thresholds (in g/100mL), and the tax rates (in euro cents/L). This

[1] Obesity Evidence Hub (2022) show a list of implemented policies and different tax designs.

[2] Quasi linear sugar tax have been implemented but all have a threshold. For example, taxes at a rate of approximately 0.15 and 0.40 US cents for each gram of sugar over an initial threshold of 4 g/100 mL have been implemented in South Africa and Sri Lanka, respectively.

setting enable to cover a large variety of tax designs, from tax proportional to sugar content to tiered tax design with varying numbers of thresholds.

To achieve this objective, our focus will be on the UK market of non-alcoholic beverages, where the consumption of soft drinks has emerged as a notable concern, prompting the government to enact the Soft Drinks Industry Levy (SDIL) tax in 2018. We will use rich scanner data obtained from a representative panel of UK households in 2017. Daily household purchases of differentiated products are provided in this dataset.

This paper contributes to the existing literature that focuses on the optimal design of taxes. The recent literature (Allcott et al., 2019a; O'Connell and Smith, forthcoming) extend the theoretical results of Pigou (1934) and Diamond (1975) on the optimality of taxation at the marginal cost of the externality to the particular case of "sin taxes". Allcott et al. (2019a) show that the optimal tax on sugar-sweetened beverages should be based on sugar content and that volumetric taxation is less efficient. O'Connell and Smith (forthcoming) validate these results in case of market power. In our study, we extend their analyses to all existing designs where sugar is taxed, including tiered sugar-based tax.

Our paper is also related to Griffith et al. (2019), who discuss the optimal multiple tax system for alcoholic beverages. They show that in the presence of nonlinear externalities and when heavy consumers differ in their consumption patterns, multi-rate taxes are optimally more efficient than single-rate taxes. Our approach does not focus on the functional form implications of the externality, but aims to determine the optimal number of thresholds, their location, and the optimal tax levels, considering the heterogeneity in consumption patterns.

Finally, our paper is related to the large literature on nutrition policy evaluation, in particular on soft drink sugar taxes with empirical structural estimates. In particular, Dubois et al. (2020) show that the soft drink tiered sugar-based tax implemented in the

UK partially failed to target the groups whose behavior the regulator would most like to influence. Our framework, which integrates the social cost of sugar and accounts for heterogeneity in demand, shows that tiered sugar-based taxes can be optimal.

The methodology employed is based on the classic counterfactual evaluation in structural industrial organization from the seminal papers (Berry et al., 1995, 2004). To enrich this evaluation, a regulatory framework is provided where total welfare includes consumer surplus, firm profit, tax revenue, and the cost of externalities induced by excess sugar consumption. These negative externalities result in healthcare costs associated with treating conditions caused by sugar consumption, such as weight gain, type 2 diabetes, and cardiovascular disease (Allcott et al., 2019b). Including the cost of externalities allows for a comprehensive measure of welfare that accounts for the potentially divergent effects on consumers, firms, the government, and health. In order to estimate the four components of the welfare, we rely on the three-step structural econometric strategy used by Bonnet and Réquillart (2013). In the first step, we estimate a discrete choice model of demand allowing for substitutions both between and within varieties of non-alcoholic beverages. This estimation approach identifies household-specific preference parameters and the demand curves for the non-alcoholic beverage market. In the second step, we model the supply side as an oligopoly proposing differentiated products and competing *à la Nash* in a Bertrand game, in the spirit of Berry et al. (1995) and Nevo (2001). We use the estimated demand curves to identify the price-cost margins for each product and the unit costs of production for firms. Finally the third step is the simulation of the counterfactual.

Our results provide policymakers with useful insights on the effects of tax design. The magnitude of the externality cost plays a critical role in determining the optimal design and the potential necessity for intervention. Furthermore, tiered designs perform as well as linear sugar taxes, sometimes better, even with a very small number of thresholds. In our application, only three thresholds are necessary to reach 98% of the maximum welfare increase. We also advise policymakers to avoid volumetric taxes in this context. They do not lead to an increase in welfare (Allcott et al., 2019a; Grummon et al., 2019).

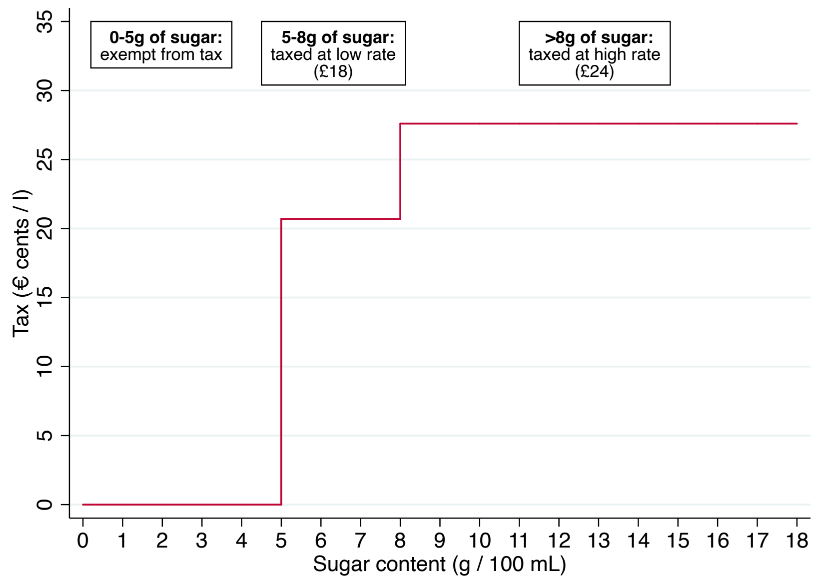
The paper is organised as follows. Section 2 presents the institutional background and describes the non-alcoholic beverage market in the UK. Section 3 details the demand and supply models and provides elasticity estimates. Section 4 explains the regulatory framework and simulation methods. Section 5 provides the main results. Section 6 concludes.

2 Institutional background and data

2.1 Institutional background on the Soft Drinks Industry Levy

In 2018, the United Kingdom took a significant step in addressing the public health concerns surrounding excessive sugar consumption by implementing the Soft Drinks Industry Levy (SDIL). This tax was part of the government's broader strategy to tackle rising rates of obesity and related health issues, particularly among children. The SDIL targeted sugar-sweetened beverages, which are major contributors to high sugar intake levels within the population. The design of the tax is characterized by a two-tiered approach based on the total sugar content of products. Beverages with a sugar content above 8 gram of sugar per 100 mL face a high tax rate (24 pounds per liter), while those with a sugar content between 5 to 8 gram per 100 mL are subject to a lower rate (18 pounds per liter) and those with less than 5 gram of sugar per 100 mL are exempt from the tax (see Figure 1). Pure fruit juices and drinks with high milk content are exempt from the tax.

Figure 1: Design of the SDIL



Notes: This figure provide details on the design of the SDIL tax implemented in the UK. The y-axis plot the tax rate (in euro cents per L) and the x-axis represents the sugar content of products (in gram per 100 mL).

2.2 Data

We use representative consumer panel data from Kantar Worldpanel in the UK. We focus on the non-alcoholic beverage market which is one of the main contributors to sugar intake (22% for children, 33% for adolescents and 21% for adults, Public Health England (2018)). The data contains daily home-scan records of food product purchases, along with household and product characteristics such as brand, size, quantity, price, sugar, and fat content.

Demographic characteristics. The consumer panel consist of 24,586 households. We categorize households according to their composition (number and age of children), obesity status (proportion of obese or overweight adults) and socio-economic class (see Appendix B.1 for details).

Market definition. Non-alcoholic beverages include sugar-sweetened beverages (SSBs), fruit juices and flavoured waters, and milk-based drinks.[3]

Product definition. We define products on the non-alcoholic beverage market by crossing information on the firm (*e.g.*, Coca-Cola Company), the brand (*e.g.*, Coca-Cola, Fanta, Sprite, ...), the drinks sub-category,[4] and other product characteristics (diet or regular characteristic for SSBs;[5] presence of added sugar and flavour for fruit juices). We get a set of 402 distinct varieties of beverages (hereafter, called alternatives) that we consider in our analysis. Additional details are provided in Appendix B.3.

Prices. The price of each alternative is calculated as the weighted ratio of total expenditure in euros over the total quantities in litres or kilogram of all items belonging to the alternative in the corresponding four-week period.[6] The weights used are Kantar period-specific household sample weights.[7]

2.3 Descriptive statistics

Price. Non-alcoholic beverages have an average price of 0.67 (Table 7). Products with added sugar are on average less expensive. The most expensive sub-categories are smoothies and energy drinks. There is no unequivocal pattern between price and diet characteristics: depending on the sub-category, diet products can be more or less expensive than regular products (Table 8).

Purchases. Households purchased on average 65 litres per capita per year, among which 44 litres of beverages have added sugar (Table 9). Only 13% of non-alcoholic

[3]We exclude water and products that are not ready-to-drink (*e.g.* syrup, powdered drinks, cocktail mixers).

[4]We create 14 different sub-categories of non-alcoholic beverages: *e.g.* sugar-sweetened beverages, fruit juice, milk-based drinks. See Table 6 for details.

[5]Kantar provides sugar content data for the UK and Spanish markets, while for the French dataset, we sourced this information from Oqali's nutritional data (Menard et al., 2011) and conducted additional research using brand websites and the Open Food Facts website (Open Food Facts, 2012).

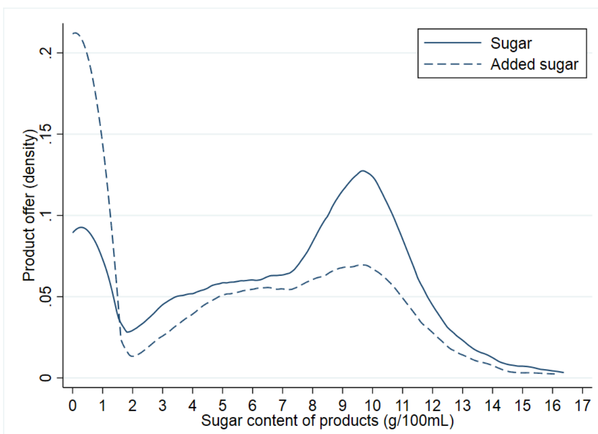
[6]The following conversion rate is used: 1 pound = 1.15 euros

[7]These weights are calculated by Kantar. They ensure that the panel is representative and correct for reporting biases related to periods away from home.

beverages purchases by households have a sugar content above 8 g per 100 mL. A large proportion of non-alcoholic beverages purchases by households are beverages with a sugar content between 0 and 5 g per 100 mL. 14.4% of Kantar households purchase more than the equivalent of one can (330 mL) per day per capita (Figure 8a).

Sugar distribution. The distribution of sugar in the products offered on this market shows two peaks: one for products containing no sugar and one for products containing around 10 grams of sugar per 100ml (Figure 2). 34% of products have less than 5g of sugar per 100 mL, 20% of products have between 5g and 8g of sugar per 100 mL and 46% of products have more than 8g of sugar per 100 mL.

Figure 2: Distribution of the sugar content of the non-alcoholic beverage supply



Notes: This figure plots the distribution of sugar and added sugar content of the supply of products.

3 Demand and supply models

The market is modelled by combining a flexible discrete-choice model of demand for differentiated products with a supply model assuming an oligopolistic competition. The estimation method is in two steps. First, we estimate a demand model in order to understand household preferences for non-alcoholic beverages and biscuit purchases. Second, using the estimated consumers' substitution patterns, we model the supply side to determine pricing strategies and alternatives' marginal cost.

3.1 The demand model

We consider a flexible discrete-choice model to estimate the demand and obtain the price elasticities for every alternatives. We opt for this type of demand models because it is imperative to accurately evaluate policy impacts on specific markets. Specifically, we use a random coefficient logit model (RCLM) (Berry et al., 1995; McFadden and Train, 2000). In this model, preferences over product characteristics are specified in a flexible manner, as it allows for both observed and unobserved heterogeneity in the intercept and slopes of the utility function.

3.1.1 The random coefficient logit model

Following Revelt and Train (1998), let t denote the index of time ($t = 1, \ldots, T$), i the index of the household in the sample ($i = 1, \ldots, N$) and j the index of the product inside the choice set of differentiated products ($j = 1, \ldots, J_t$) at time t.

Utility. The indirect utility function V_{ijt} for household i buying product j in period t is given by

$$V_{ijt} = \alpha_i p_{jt} + X_{jt}\beta_i + \epsilon_{ijt} \tag{1}$$

where p_{jt} is the price of product j in period t, α_i is the marginal disutility of the price for household i, ϵ_{ijt} is an individual error term, X_{jt} is a vector of observed product characteristics and β is the vector of associated parameters that capture the taste for product characteristics.

We assume that parameter α_i varies across households. Indeed, households can have a different price disutility. It can be rewritten as

$$\alpha_i = \alpha + \pi DM_i + \sigma \nu_i \tag{2}$$

where α is the mean marginal disutility of the price for all households, π the vector of parameters associated to demographic characteristics DM_i and ν_i measures the unobserved heterogeneity of the households. We denote $P_\nu(.)$ the distribution of parameter ν.

We can divide the indirect utility between a mean utility $\delta_{jt} = \alpha p_{jt} + X_{jt}\beta + \xi_{jt}$ where ξ_{jt} captures all unobserved product characteristics and a deviation from this mean utility $\mu_{ijt} = (\sigma \nu_i + \pi DM_i) p_{jt}$. Hence the indirect utility is given by

$$V_{ijt} = \delta_{jt} + \mu_{ijt} + \epsilon_{ijt} \tag{3}$$

We also interact food product variables characterizing the nutritional composition of products with household characteristics (i.e. sugar content of SSBs, fruit juices, and biscuits, lipid content of biscuits, and whether the non-alcoholic beverage is diet). Table 10 summarizes the demand specification for each market.

Outside option. The household can decide not to buy one of the considered products. The utility of this option is normalised to zero. The indirect utility of choosing the outside option is written as $V_{i0t} = \epsilon_{i0t}$.

Market share. We assume that ϵ_{ijt} is independently and identically distributed as an extreme value type I distribution. The conditional probability that household i chooses product j in period t is:

$$s_{ijt}(\nu) = \frac{exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J_t} exp(\delta_{kt} + \mu_{ikt})} \tag{4}$$

The market share of product j in period t is (Nevo, 2001):

$$s_{jt} = \int_{A_{jt}} \left(\frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J_t} \exp(\delta_{kt} + \mu_{ikt})} \right) dP_\nu(\nu) \tag{5}$$

where A_{jt} is the set of households who have the highest utility for product j in period t, a household is defined by the vector $(\nu_i, \varepsilon_{i0t}, ..., \varepsilon_{iJt})$ and P_ν is the cumulative distribution function of ν which is typically assumed to be standard normal.

Elasticity. The random coefficient logit model generates a flexible pattern of substitutions between products. We can then write the own-price and cross-price elasticities of the market share s_{jt} as:

$$\theta_{jkt} = \frac{\partial s_{jt}}{\partial p_{kt}} \frac{p_{kt}}{s_{jt}} = \begin{cases} \frac{p_{jt}}{s_{jt}} \int \alpha_i s_{ijt}(1 - s_{ijt})\phi(\nu_i)\mathrm{d}\nu_i & \text{if } j = k \\ -\frac{p_{kt}}{s_{jt}} \int \alpha_i s_{ijt} s_{ikt} \phi(\nu_i)\mathrm{d}\nu_i & \text{otherwise} \end{cases} \tag{6}$$

where $\phi()$ is the density function of $P_\nu(.)$.

3.1.2 Identification

This method relies on the assumption that all product characteristics X_{jt} are independent of the error term ϵ_{ijt}, which can be decomposed into a product-specific error term and an individual error term, $\epsilon_{ijt} = \xi_{jt} + e_{ijt}$. However, there is empirical evidence that unobserved factors included in ξ_{jt} can be correlated with observed characteristics X_{jt}, producing endogeneity problems (Berry, 1994). Such unobserved characteristics can be promotions or advertising, for example. For instance, promoted products are often moved to the front of the shelf, advertised, and sold at a lower price at the same time. Since we do not have any information on advertising expenditure spent by firms, the estimated impact of observed prices on demand will then capture both a true price effect and the effect of unobserved marketing efforts. Prices may also be endogenous if some unobserved characteristics are positively valued by consumers, who are thus ready to pay a premium for them. This may be taken into account by firms in setting their prices.

We use a control function approach as in Petrin and Train (2010) to account for price endogeneity, using the set of instruments reported in Table 11. More details on the approach and results on the first stage are presented in Tables 12 in Appendix.

3.2 The supply side

Firms are likely to adjust to exogenous shocks, and ignoring their strategic behaviour may lead to biased estimates of the effect of public policies (Griffith et al., 2010; Bonnet and Réquillart, 2013; Allais et al., 2015). The simulation of the effects of policy shocks on the market equilibrium therefore requires a structural model of the supply side. Below, we assume that only price strategies are implemented by firms in reaction to tax. Other strategic firms' reactions, such as modifying the set of products or products reformulation, are beyond the scope of our assessment.

We consider F firms that compete in prices on the considered market and sell products to consumers and set prices. At each period, the firm maximizes its profit, conditional on the demand parameters and other firms' prices, holding the set of products offer and every other observed and unobserved characteristics constant:

$$\Pi_{ft} = \sum_{j \in G_{ft}} [M_t(p_{jt} - c_{jt})s_{jt}(p)] \tag{7}$$

where G_{ft} is the set of products sold by firm f in period t, M_t is the size of the market in period t, p_{jt} is the price of product j in period t, c_{jt} is the constant marginal cost to produce and sell product j in period t, $s_{jt}(p)$ is the market share of product j in period t given the vector of product price p.

The equation of prices of products $j \in G_{ft}$ is determined with the first order conditions:

$$s_{jt}(p) + \sum_{k \in G_{ft}} [M_t(p_{kt} - c_{kt}) \frac{\partial s_{kt}}{\partial p_{jt}}] = 0 \; \forall j \in G_{ft} \tag{8}$$

We recover estimates of firms' margins $\gamma_{jt} = p_{jt} - c_{jt}$ for each product using the first order conditions and estimates of the demand model. Using equation (8), the vector of margins $\gamma_t = (p - c)_t$ can be written in matrix notation.

$$\gamma_t = (p - c)_t = -\Big(\sum_{f=1}^{F} I_{ft} S_{pt} I_{ft} \Big)^{-1} \Big(\sum_{f=1}^{F} I_{ft} s_t(p) \Big) \tag{9}$$

where I_{ft} is the ownership diagonal matrix $(J_t \times J_t)$ of firm f in period t with elements $I_{ft}(j, j)$ equal to 1 if product j is produced by firm f in period t and zero otherwise, S_{pt} is the matrix $(J_t \times J_t)$ of the first derivatives of all market shares with respect to all prices in period t, $S_{pt} = (\frac{\partial s_{kt}}{\partial p_{jt}})_{(j=1,\ldots,J_t; k=1,\ldots,J_t)}$ and $s_t(p)$ is the vector of product market shares in period t. We then derive estimates of marginal costs, given observed prices.

3.3 Results on demand and supply

3.3.1 Demand estimates

The estimates from the random coefficient logit model are presented in Table 13. Price has a significant and negative impact on utility for all populations. Price unobserved heterogeneity is also substantial. Households from the poor and average classes are more sensitive to price than rich households. Households prefer diet products to regular products. Households have high brand loyalty (brand fixed effect estimates, not displayed in the Table, are large compared to the other preferences parameter estimates) and the choice of the brand prevails over the taste for sugar.

3.3.2 Elasticities and demographic characteristics

When comparing the elasticities by household characteristics, we found that the demand of the non-alcoholic beverage is the most elastic for households with 7-16 years old children, households with all adults overweight or obese and poor households (Table 14). We find that the sweeter the non-alcoholic beverage, the more elastic the demand for products with a sugar content above 0 and strictly below 10 grams per 100 mL (Table 15). It is also interesting to note that the elasticities of non-alcoholic beverages with a sugar content above 10 g per 100 mL remain almost constant. The results are valid for all household characteristics considered. Furthermore, all previous results in Table 14 are still valid for all sugar content considered.

4 An empirical framework to assess the impact of sugar taxes on total welfare

4.1 Definition of a tax design

We consider that a tax design is defined by three parameters that the regulator has to pick: i) the number k of thresholds, ii) a vector ρ of dimension k with the location of thresholds (in g/100mL) and iii) a vector ω of dimension k with the tax level for each threshold (in € cents/L). We can then consider a mapping between these parameters and the resulting tax amount for each product: the vector $\tau(k, \rho, \omega)$ of dimension J contains the tax amount supported by each product j for the tax design defined by (k, ρ, ω).

This way of defining taxes encompasses all tax designs where the tax rate increases with the sugar content. This notably includes several implemented tax designs: a volumetric tax (by setting the number of thresholds to 1 and the location of the threshold at 0 g/100mL, all products are taxed at a single tax rate, which is equivalent to a volumetric tax) and a linear tax or a tiered tax with proportional tax rate within each tier (by proposing a number of thresholds equal to the number of distinct sugar values in the market).

4.2 Counterfactual simulations

4.2.1 New equilibrium prices

The introduction of a tax will change the marginal cost of each product, which will lead to a potential change in their price. From the firms' profit maximization program defined in section 3.2, we estimate a vector of marginal costs that we denote $\hat{c}_t = p_t - \gamma_t = (\hat{c}_{1t}, \ldots, \hat{c}_{jt}, \ldots, \hat{c}_{J_t})$. For any tax design, we retrieve a new cost vector c_t^τ by adding the tax cost to the estimated marginal cost $(c_t^\tau = \hat{c}_t + \tau)$.

Knowing the maximization program of the firms and the new vector of marginal costs, we can then retrieve the new equilibrium prices. We find the new equilibrium prices vector in period t, denoted $p_t^\tau = (p_{1t}^\tau, \ldots, p_{J_t}^\tau)$, using the following optimizing programme:

$$\min_{\{p_{jt}^\tau\}_{j=1,\ldots,J_t}} || \underbrace{p_t^\tau - \gamma(p_t^\tau)}_{\hat{c}_t(p_t^\tau)} - c_t^\tau || \tag{10}$$

4.2.2 Objective function: change in total welfare

We assess the effect of different tax scenarios by comparing the effect on total welfare. We provide a regulatory framework where the regulator takes into account consumers' welfare, firms' profit, tax revenue and additionally, the external costs of excessive sugar consumption. The change in total welfare (equation 11) is the sum of the changes in consumer surplus (equation 12), firm profit (equation 13), fiscal revenue (equation 14) and externalities after the implementation of a tax[8].

$$\Delta W_t(\tau) = \Delta W_t^C(\tau) + \Delta W_t^{\pi}(\tau) + \Delta W_t^{\text{tax}}(\tau) + \Delta W_t^{SC}(\tau) \tag{11}$$

Consumer surplus. Following McFadden (1981) and Small and Rosen (1981), we compute the change in consumer surplus as:

$$\Delta W_t^C(\tau) = M_t \int \frac{ln[\sum_{j=0}^{J} exp(V_{ijt}^{\tau})] - ln[\sum_{j=0}^{J} exp(V_{ijt})]}{\alpha_i} \mathrm{d}P_\nu(\nu)\mathrm{d}P_D(D) \tag{12}$$

where V_{ijt}^{τ} is the post-tax indirect utility.

Firms profit. The change in firms profit is defined by:

$$\Delta W_t^{\pi}(\tau) = M_t\Big(\sum_{f=1}^{F}(\sum_{j\in J^f} I_{ft}\gamma_t(p_{jt}^{\tau})s_{jt}^{\tau}) - \sum_{f=1}^{F}(\sum_{j\in J^f} I_{ft}\gamma_t^{est}s_t^{est})\Big) \tag{13}$$

where s_{ijt}^{τ} is the post-tax market share, γ_t^{est} , s_t^{est} are the estimated pre-tax margins and market shares and J^f the set of products of firms f.

Tax revenue. The amount raised by the implementation of the sugar tax is defined as follows[9]:

$$\Delta W_t^{\text{tax}}(\tau) = M_t(\tau \cdot s_t^{\tau}) \tag{14}$$

where q_t is the quantity of sugar per kilogram of products.

Externality - social cost of sugar. While our structural model allows us to compute the change in consumer surplus, firm profit, and tax revenue resulting from the implementation of a tax, the social cost of sugar is exogenous. We consider that the social cost of sugar is represented by the healthcare externality stemming from the treatment

[8] We give equal weights to each welfare component

[9] The tax is not subject to VAT in the UK so we only consider the amount raised through the implementation of the sin tax.

of conditions resulting from excess sugar consumption. We obtain the social cost of sugar (κ) from the estimate provided by Rischbieth et al. (2020), which is 27 € per kg of sugar. Additionally, we consider a lower bound at 10 € per kg of sugar for sensitivity analyses. The change in the externality is computed as:

$$\Delta W_t^{SC}(\tau) = \kappa \cdot M_t(q_t \cdot s_t^{\tau} - q_t \cdot s_t^{est}) \tag{15}$$

4.2.3 Optimal tax design

Eventually, we are able to find the optimal parameters of a tax design to enhance total welfare. For each tax design, we know the changes in welfare (section 4.2.2) induced by the new equilibrium prices (section 4.2.1). For a specified number of thresholds k, we look for the optimal combination of thresholds location $\rho^\star$ and tax rates $\omega^\star$ that maximize the increase in total welfare. In other words, for any fixed k $\in \mathbb{N}$, the optimal tax design $\tau^\star(k, \rho^\star, \omega^\star)$ is obtained with the following maximization program:

$$(\rho^\star, \omega^\star) = \underset{(\rho,\omega)}{\arg\max}\, \Delta W_t(\tau(k, \rho, \omega)) \tag{16}$$

5 Results

In this section, we provide evidence regarding the optimal design for sugar taxes within our context. We also highlight the importance of considering externalities related to sugar consumption.

We first disregard the strategic behavior of firms regarding pass-through. We assume that firms fully pass on the tax, resulting in the new equilibrium prices being the observed prices increased by the tax amount. This assumption enables us to isolate the demand-side effects arising from the tax implementation.

5.1 Evidence on the optimal design of sugar taxes

We provide some evidence on the optimal design of sugar taxes. In this section, we set the social cost of sugar at 27 euros per kg.

Theoretical optimal linear design. From the theoretical economic literature on externalities, the optimal approach for a linear design is to set the tax rate equal to the social cost. We now compare how empirically obtained optimal tiered taxes perform compared to the theoretically optimal linear tax.

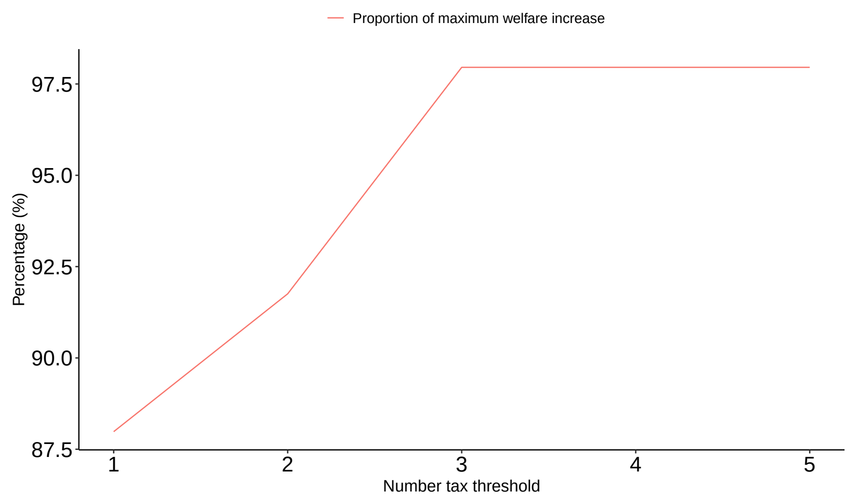
Theoretical optimal tiered design and empirical application. Following section 4.2.3, we are able to find the different parameters (number of thresholds, location of thresholds and tax rates at each threshold) to get the optimal tax design. Figure 4d shows how an hypothetical regulator would design a tiered tax with an infinite number of thresholds.[10] This would result in a taxation scheme very similar to a linear tax design at the social cost, as the black and orange lines are very close throughout the sugar distribution of products. Our theoretical first best with a maximum number of thresholds performs slightly better (232 million euros) at increasing the total welfare compared to the linear taxation at the social cost of sugar (223 million euros). In comparison, the best one-threshold design leads only to an increase by 204 million euros (Table 1).

Choice of a reasonable number of thresholds. However, in practice, implementing such a policy where the regulator would need to determine the tax rate for every possible value of sugar content seems unfeasible. This would mean that the manufacturer should know the exact amount of sugar in each product and could be punished if an error is revealed during an inspection. The possibility of an error is lower if we con-

[10]We can notice from the definition of a tax design, that any design $\tau(k,\rho,\omega)$ with $k < k'$ is included in the design $\tau(k',\rho,\tau)$. Hence for any $k < k'$, we have that $\Delta W_t^{SC}(\tau^\star(k,\rho_k,\omega_k)) \leq \Delta W_t^{SC}(\tau^\star(k',\rho_{k'},\omega_{k'}))$. A trivial maximum of threshold k_{max} exists and is equal to the number of different sugar values in the market. The theoretical first best of these designs $\tau(k,\rho,\omega)$ is obtained at $k = k_{max}$. Hence, we compare how the best linear design and our theoretical first best with a number maximum of threshold perform.

sider a wider range of sugar content intervals. We show that significant welfare gains can be achieved with only a small number of thresholds. In the UK soft drink market, we find that only three thresholds are sufficient to narrow the welfare gap (Figure 3).

Figure 3: Welfare increase according to the number of thresholds



Notes: This figure plots the percentage change in welfare according to the number of thresholds.

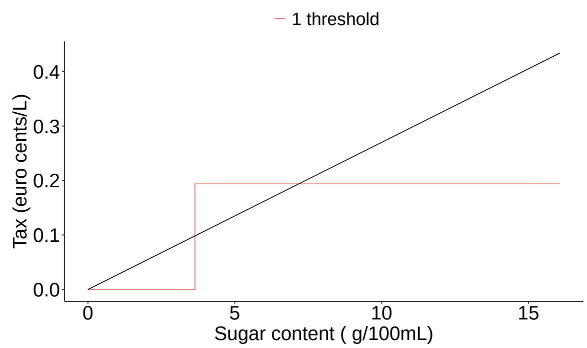
Comparison of the tiered designs. We then compare the optimal k-threshold designs (obtained with the maximization program presented in section 4.2.3) for one, two and three thresholds (Figure 4). We also compare these optimal design to the SDIL tax implemented in 2018 (Figure 7).

Optimal design with one, two and three thresholds. With one threshold, only products with sugar content above 3.51 grams per 100mL would be taxed, at a flat rate of 0.194 euros (Figure 4a). This would result in an increase in total welfare by 204 million euros (Table 1). With two thresholds, products with less than 2.51 grams of sugar per 100mL would be exempt from the tax, products with sugar content between 2.51 grams and 10.01 per 100mL would be taxed at 0.143 euros and products with more than 10.01 grams of sugar per 100mL would be taxed at 0.268 euros (Figure 4b). This would result in an increase in total welfare by 213 million euros (Table 1). With three thresholds, products with less than 0.26 grams of sugar per 100mL would be exempt from the tax, products with sugar content between 0.26 and 3.51 per 100mL would be taxed at 0.051 euros, products with sugar content between 0.26 and 5.95 per 100mL would be taxed at 0.119 euros and products with more than 5.95 grams of sugar per 100mL would be taxed at 0.231 euros (Figure 4c). This would result in an increase in total welfare by 228 million euros, which is 98% of the welfare gain obtained with the highest number of thresholds (Table 1).

Comparison with the SDIL tax. The SDIL tax is designed with two thresholds but the parameters are set differently compared to the optimal tax with two thresholds. The thresholds are located differently: the first threshold is set at 5g/100 mL and the second threshold is set at 8g/100 mL (compared to 2.51 and 10.01 g/100mL for the optimal design), hence more products are exempt from the tax but more products are subject to the high tax level. Both tax rates are higher in the SDIL compared to the optimal design. We can notice that the SDIL design performs quite well compared to the optimal designs: our counterfactual simulates a welfare increase of 197 million euros for the SDIL, which is about 85% of the maximum welfare increase (obtained with the maximum number of thresholds) and 92% of the welfare increase obtained with the optimal two-threshold design (Table 1).

Figure 4: Comparison of tiered tax designs

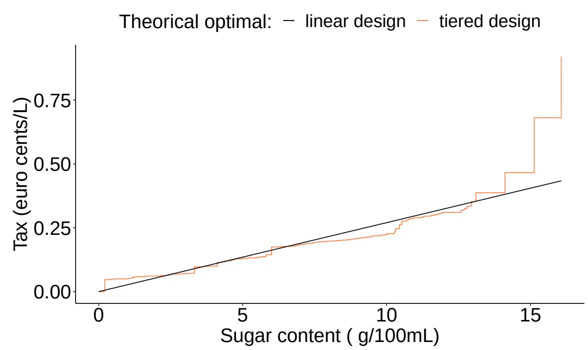
(a) One threshold $(k = 1)$



(b) Two thresholds $(k = 2)$

(c) Three thresholds $(k = 3)$

(d) Max. number of thresholds $(k = k_{max})$



Notes: The first three figures plot the optimal tiered tax design with one, two and three thresholds respectively (in red). The fourth figure plots the theoretical optimal tiered tax design (in orange). The optimal tax rates and location of thresholds are obtained empirically from the maximization program presented in section 4.2.3. The black line corresponds to the theoretical optimal linear tax design where the tax rate is set at the value of the social cost. The y-axis plots the tax rate (in euro cents per L) and the x-axis displays the sugar content of products (in grams per 100 mL).

Welfare decomposition. Table 1 shows the welfare variation induced by these designs, as well as their decomposition. The decomposition of welfare variations shows that in all counterfactuals, firms' profits are the least impacted. Some firms may greatly lose from the taxation but on average it would be compensated by the increase in market shares of other firms. Another important aspect of the decomposition is the order of magnitude of the different parts. The consumer surplus loss (column 4) is in the range of the decrease of the externality (column 6) and the total welfare variation is on the same magnitude as the tax revenue.

Table 1: Welfare variation decomposition

Counterfactual	Change (millions euros) in Total welfare $\Delta W_t(\tau)$	Firm profit $\Delta W_t^{\pi}(\tau)$	Consumer surplus $\Delta W_t^{C}(\tau)$	Tax revenue $\Delta W_t^{\text{tax}}(\tau)$	Externality $\Delta W_t^{SC}(\tau)$
Linear design					
Theoretical best	223	-12	-442	246	438
Tiered design					
Theoretical best	232	5	-471	286	412
1 threshold	204	-9	-378	205	386
2 thresholds	213	-11	-387	215	397
3 thresholds	228	6	-474	289	407
SDIL	197	-8	-371	170	406

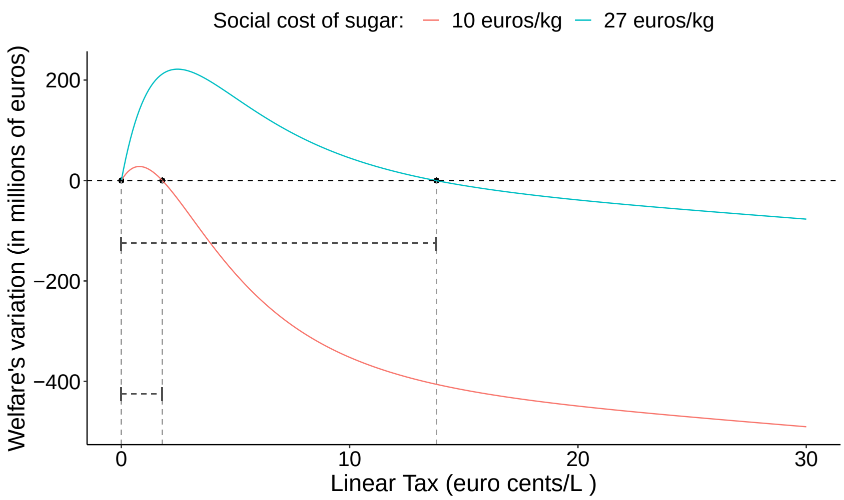
Notes: This table plots the changes in total welfare (column 2) and in the different components of total welfare: firms' profit (column 3), consumer surplus (column 4), tax revenue (column 5) and externality (column 6).

5.2 The large influence of the social cost of sugar

The estimate of the social cost of sugar plays a key role in the analysis. We now compare our two estimates: 10 euros per kg (lower bound) and 27 euros per kg (average).

Linear tax. We begin by comparing the welfare variations associated with the two estimates in a linear design. As the social cost of sugar rises from 10 to 27 euros per kg, the highest welfare gain also increases from 27 to 223 millions euros (Figure 5). Additionally, we observe that the range of tax rates resulting in welfare improvements significantly expands with an increase in the social cost of sugar. While only tax rates below 0.018 euros lead to welfare improvements with a social cost of 10 euros per kg, this range extends to tax rates up to 0.138 euros with a social cost of 27 euros per kg. Therefore, the magnitude of the externality cost plays a critical role in determining the optimal design and the potential necessity for intervention.

Figure 5: Welfare change in linear taxation with tax rate



Notes: This figure plots the variation in welfare that would result from implementing a linear tax according to different tax rates. The y-axis plots the variation in welfare (in millions of euros) and the x-axis displays the different tax rates for a linear tax (in euros cents per liter). The red line corresponds to the social cost estimated at 10 euros per kg and the blue line corresponds to the social cost estimated at 27 euros per kg.

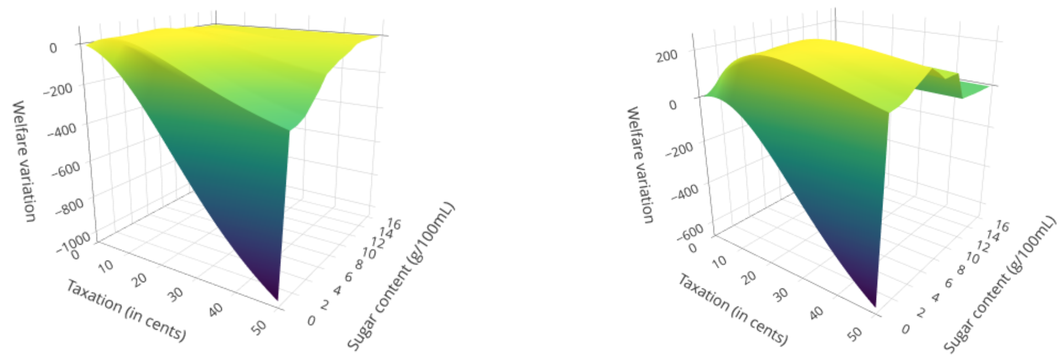
One-threshold design. We then examine a tiered design with a single threshold, where products below the threshold remain untaxed, while those above the threshold are taxed at a flat rate. Figures 6a and 6b show a mapping of the variation in welfare for a one-threshold tax design with two different estimates of social costs. To get welfare gains with the low social cost estimate, the tax rate must be lower, and the threshold location must be higher (*i.e.* fewer products taxed) compared to the high social cost estimate. This reinforces our finding that having an accurate measure of the social cost of sugar is crucial for the regulator, as it changes both the optimal design and the shape of the maximization problem encountered by the regulator.

Volumetric tax. Another immediate observation is the ineffectiveness of volumetric taxation. From our definition of a tax design, we can have a volumetric tax by setting the number of thresholds to 1 and the location of thresholds at 0g/100mL. In the left part of both graphs, where all products are taxed, we observe a steep decline in welfare as the tax rate increases. Hence, for both social costs of sugar consumption, we can see that any volumetric tax would reduce total welfare. Moreover, as tax rates increase, total welfare further decreases.

Figure 6: Comparison of welfare changes using two estimates of social sugar costs in a one-threshold tax design

(a) Sugar cost at 10 €per kg

(b) Sugar cost at 27 €per kg



Notes: These figures plots the variation in welfare that would result from the implementation of a one-threshold tax according to different tax rates and different threshold locations, using two different estimates of social sugar costs. The left-hand side figure is with the sugar cost estimate of 10 euros per kg and the right-hand side figure is with the sugar cost estimate of 27 euros per kg. The z-axis plots the variation in welfare (in millions of euros), the x-axis displays the different tax rates (in euros cents per liter) and the y-axis represents the location of the threshold (in grams per 100 ml).

Table 2 displays the decomposition of the welfare variation when the social cost of sugar is set to 10 euros per kg (whereas it was 27 euros per kg in Table 1). Coming back to the insights of Figures 6a and 6b, we understand how crucial the estimates of social cost are for policymakers. Should the social cost of sugar be at 10 euros per kg, the implementation of the SDIL would have been detrimental. This design would in that case deeply hurt the consumer surplus while having a very limited effect on the externality generated by the sugar consumption (Table 2).

Table 2: Welfare variation decomposition using an estimated social cost of sugar equal to 10€ per kg of sugar

	Change (millions euros) in				
Counterfactual	Total welfare $\Delta W_t(\tau)$	Firm profit $\Delta W_t^{\pi}(\tau)$	Consumer surplus $\Delta W_t^{C}(\tau)$	Tax revenue $\Delta W_t^{\text{tax}}(\tau)$	Externality $\Delta W_t^{SC}(\tau)$
Linear design					
Theoretical best	26	-5	-219	170	80
Tiered design					
Theoretical best	37	8	-241	201	69
1 threshold	26	-2	-157	125	60
2 thresholds	33	5	-244	206	66
3 thresholds	36	8	-241	201	68
SDIL	-59	-8	-371	170	150

Notes: This table plots the changes in total welfare (column 2) and in the different components of total welfare: firms' profit (column 3), consumer surplus (column 4), tax revenue (column 5) and externality (column 6), assuming a social cost of sugar of 10 euros per kg of sugar.

6 Conclusion

Many sugar taxes have been implemented in the form of tiered taxes, contradicting what is advocated by theoretical and empirical literature. However, real-world implementations might differ from economic theory due to feasibility constraints. In this paper, we investigate how other tax designs would perform compared to the theoretical optimal linear tax. We introduce a comprehensive framework for evaluating the effect of tax designs on total welfare, accounting for the externality generated by excess sugar consumption and for the heterogeneity in patterns of consumption. We consider all taxes with a rate increasing with sugar content, ranging from designs proportional to sugar content to tiered structures with varying threshold numbers. For the empirical analysis, we focus on the UK market of non-alcoholic beverages. We show that comparable welfare gains to those of the linear tax can be obtained with a tiered tax with a small number of thresholds. In our application, only three thresholds are necessary to reach 98% of the maximum welfare increase.

In further steps, we aim to enhance this analysis in several ways:

- We plan to look more carefully at the heterogeneous effects of taxes on rich and poor households.
- We intend to replicate this work with other European countries that have also implemented tiered taxes on the soft drink market (*e.g.*, France and Spain).
- We plan to explore whether our findings regarding the design of sugar taxes on soft drinks remain applicable in another market. Specifically, we will examine the biscuit market, which has not yet been subject to taxation, despite biscuits being recognized as significant contributors to sugar intake.

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A Institutional background

Figure 7: Design of the taxes implemented in the non-alcoholic beverage markets in France, the UK, and Catalonia

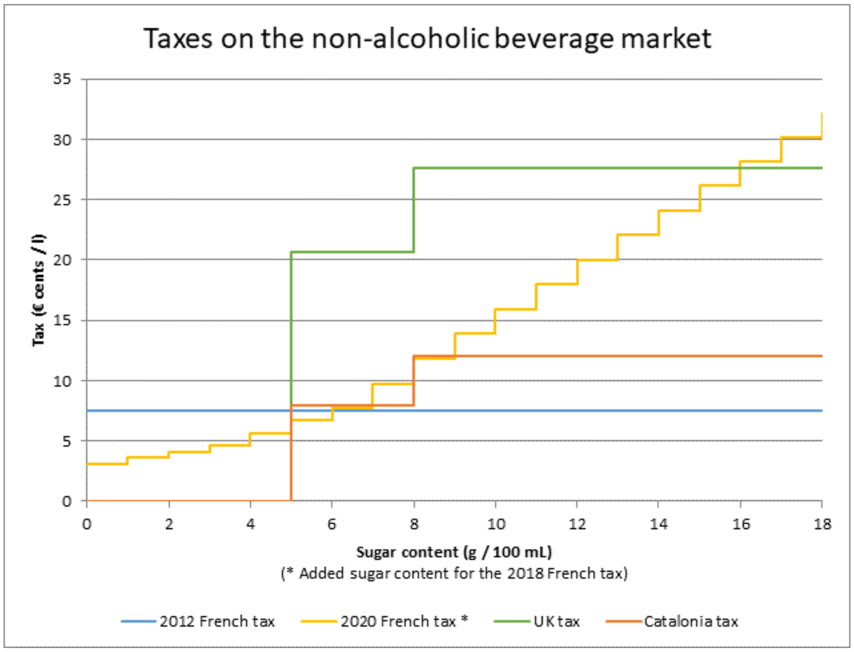


Table 3: Taxes implemented in the non-alcoholic beverages markets in France, the UK, and Catalonia

	France		UK	Catalonia
Year	2012	2018	2018	2017
Targeted soft drinks	All with added sugar or artificial sweeteners	All with added sugar or artificial sweeteners	All with added sugar	with added sugar
	Exempt: milk-based drinks and drinks with more than 1.2% alcohol by volume			
Nutrient taxed		Added sugar	Sugar	Sugar
Design	Flat tax 0.753€/l	Progressive 15 thresholds (see Figure 7)	Two tiered tax 0-5g/100mL sugar: no tax 5g-8g/100mL sugar : 0.207 €/l $\geq$ 8g/100mL sugar : 0.276 €/l	Two tiered tax 0-5g/100mL sugar: no tax 5g-8g/100mL sugar : 0.080 €/l $\geq$ 8g/100mL sugar : 0.120 €/l
Tax subject to VAT	yes (5.5%)	yes (5.5%)	no	yes (10%)
Tax subject to VAT	yes (5.5%)	yes (5.5%)	no	yes (10%)

B Data

B.1 Demographics

Definition of obese and overweight. Adults with BMI, defined as weight (in kg) divided by the square of the height (in m), above 30 are considered as obese, and individuals with BMI ranging between 25 and 30 are considered as overweight. The final dataset contains only households with no missing value on adults' BMI in the analysis. We exclude 1,765 households 6,353 households (21%).

Definition of socio-economic class. It is based on the socio-professional categories.

Table 4: Household characteristics in Kantar panel

	N	%
Household composition		
Without children	16,093	65
With children below 6 years old	2,960	12
With children 7-16 years old	3,668	15
With children both below 6 and 7-16 years old	1,865	8
Obesity status		
No overweight or obese adults	5,972	24
Some overweight or obese adults	8,184	33
All overweight or obese adults	10,430	43
Socio-economic class		
Rich	5,262	21
Average	13,912	57
Poor	5,412	22
All	**24,586**	

B.2 Market definition

Table 5: Summary of the market definition

Sub-categories	Included?
Sugar-sweetened beverage	yes
(cola, iced tea, lemonade, fruit-flavoured drink, sport and energy drink, tonic, other)	
Fruit juice	yes
(pure fruit juice, nectar, smoothie, fruit juice with milk)	
Flavoured water	yes
Milk-based drink	yes
Water	no
Syrup, powdered drink, cocktail mixer	no

The preliminary data cleaning excludes the products that do not enter the market definition and products considered as price outliers[11]. Purchases from households with a sample weight equal to 0 are also excluded, that is we consider purchases of households who are fully active in the period.

B.3 Products

B.3.1 Details on the definition of products

Sub-categories. The sugar-sweetened beverage category is made up of colas, iced tea, fruit-flavoured drinks, flavoured water, tonic water, lemonade, energy drinks, and other SSBs. The fruit juice category includes nectar, fruit juice made from concentrate, pure fruit juices and smoothies. Milk-based drinks are made up of flavoured milk.

[11] We also exclude products with price outliers because they might be errors or they are not a direct substitute for standard non-alcoholic beverages. Products with a price higher than 10 euros per litre are considered price outliers.

Table 6: Non-alcoholic beverages sub-categories

Sugar sweetened beverages (SSB)	
Colas	✓
Iced teas	with Other SSBs
Fruit-flavoured drinks	✓
Flavoured waters	✓
Tonic waters	✓
Lemonades	✓
Energy drinks	✓
Other SSBs	✓
Fruit juice	
Nectars	✓
Fruit juice (from concentrate)	with Pure fruit juice
Pure fruit juice	✓
Smoothies	✓
Milk-based drinks	
Flavoured milks	✓

Notes: A sub-category specified as "with Other SSBs" means that the purchases of this category are grouped with those of the Other SSBs or Pure juice category, respectively.

Added sugar. The information on products containing added sugar is provided.

Additional details on the products definition. Beverages of a given sub-category with a small purchase occurrence are aggregated either with similar products of the same firm or in a hypothetical product defined as other firm/other brand of the sub-category. Additionally, private labels are aggregated in one firm and one brand.

B.3.2 Market structure

Table 7 presents a summary of the market structure with the definition of alternatives. The UK market is characterized by a higher number of national brands, resulting in a higher number of non-alcoholic beverages alternatives. Mean prices in Table 7 are calculated as the weighted ratio of total expenditure in euros over the total quantities in litres of all drinks purchased.

Table 7: Market structure

Number of firms	78
Number of national brands	151
Number of sub-categories	11
Number of alternatives	402
Number of observations	1,319,069
Mean price (per litre)	0.78 €
Mean price of non-alcoholic beverages with added sugar (per litre)	0.67 €

Note: The number of observations refers to the number of Kantar references purchased per household, date and store. If on a given date and in a given store, a household buys 3 bottles of 1L of Coke, this is an observation, but if a household buys 2 bottles of 1L of Coke and 1 bottle of 1.5L, this is 2 observations.

B.3.3 Descriptive statistics

Table 8 presents the average market share, price and sugar content in g per 100 mL of the sub-categories of non-alcoholic beverages.

Table 8: Average market share, price and sugar content of each sub-category

	Share %	Price €/l	Sugar g/100ml
Sugar-sweetened beverages			
Colas	**26.8**	**0.8 (1.0)**	**3.1 (5.0)**
Regular	29.6	0.8 (1.3)	10.3 (1.5)
Diet	70.4	0.8 (0.4)	0.0 (0.0)
Fruit-flavoured drinks	**12.2**	**0.9 (0.8)**	**3.4 (3.8)**
Regular	73.2	1.2 (0.6)	6.1 (3.2)
Diet	26.8	0.5 (1.1)	0.4 (2.3)
Flavoured waters	**22.2**	**0.4 (0.7)**	**0.3 (1.3)**
Regular	1.4	0.8 (1.1)	4.7 (1.6)
Diet	98.6	0.4 (0.6)	0.2 (0.1)
Tonic waters	**3.1**	**0.9 (1.2)**	**1.8 (2.7)**
Regular	45.8	1.2 (1.3)	4.3 (1.8)
Diet	54.2	0.7 (1.3)	0.3 (1.4)
Lemonades	**5.0**	**0.4 (1.1)**	**1.8 (4.2)**
Regular	40.0	0.5 (1.3)	4.9 (3.3)
Diet	60.0	0.3 (0.3)	0.1 (0.1)
Energy drinks	**5.8**	**1.4 (0.9)**	**5.4 (5.2)**
Regular	74.5	1.4 (0.9)	7.0 (3.1)
Diet	25.5	1.5 (1.0)	0.2 (0.2)
Other SSBs	**3.5**	**0.7 (1.1)**	**3.6 (4.4)**
Regular	46.7	1.0 (1.1)	9.4 (2.5)
Diet	53.3	0.6 (1.2)	0.1 (1.6)
Fruit juices			
Nectars	**5.6**	**1.1 (0.6)**	**7.2 (3.5)**
Regular	70.9	1.1 (0.6)	7.2 (3.5)
Diet (no added sugar)	29.1	0.9 (0.4)	2.5 (2.2)
Pure fruit juice	**11.7**	**1.2 (0.9)**	**9.8 (2.7)**
Smoothies	**1.5**	**2.9 (0.9)**	**10.7 (1.2)**
Regular	72.7	2.7 (0.7)	10.5 (1.1)
Diet (no added sugar)	27.3	3.6 (0.9)	11.2 (1.5)
Milk-based drinks			
Flavoured milks	**2.6**	**1.7 (1.3)**	**9.2 (2.5)**
Diet	92.9	1.7 (1.4)	9.4 (2.3)
Regular	7.1	2.0 (1.1)	5.6 (2.5)

Notes: Price and sugar columns: Mean (standard deviation)

Figure 8: Purchase of non-alcoholic beverages across Kantar households

(a) All SSBs (b) SSBs with added sugar

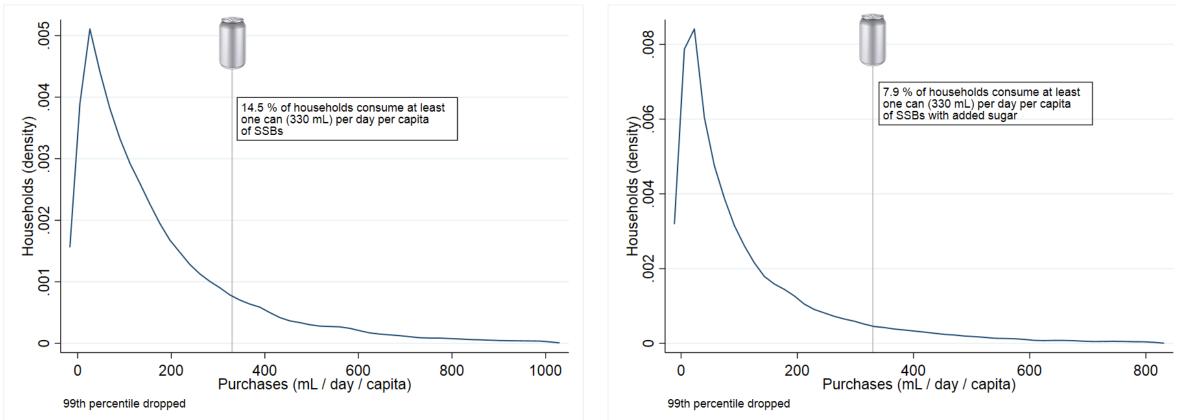
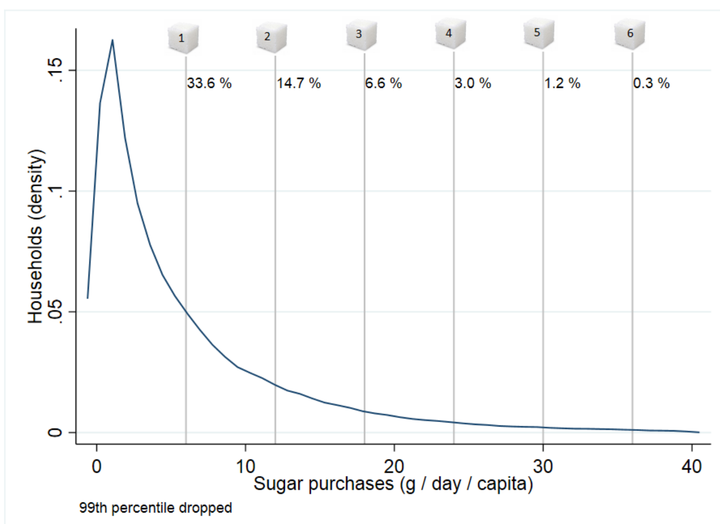


Figure 9: Sugar purchases across Kantar households



Notes: 33.6 % of households consume more than one sugar cube per day per capita

Table 9 provides a comparison of the purchase of non-alcoholic beverages per capita per year across households with respect to household composition, obesity status and socio-economic class. Households with children between 7 and 16 years old are the highest consumers and households with children between 0 and 6 years old are the lowest consumers. Mean purchase increases gradually with the proportion of adults who are overweight or obese within the household. Furthermore, poor households buy more than rich households.

Table 9: Households purchases

Mean quantity (l/capita/year) (standard deviation)	All beverages	Added sugar
Household composition		
No children	67 (85)	46 (68)
Children below 6	45 (54)	30 (44)
Children 7-16	76 (74)	53 (60)
Children both below 6 & 7-16	53 (57)	36 (46)
Obesity status		
None overweight or obese	53 (73)	37 (61)
Some overweight or obese	63 (71)	44 (58)
All overweight or obese	73 (87)	50 (68)
Socio-economic class		
Rich	59 (68)	38 (55)
Average	65 (79)	45 (62)
Poor	70 (88)	51 (73)
All	65 (79)	44 (64)

C Demand

C.1 Estimation

Table 10: Summary demand specification

Price	$\alpha_i = \alpha + \alpha_{\text{child(i)}} + \alpha_{\text{obesity(i)}} + \alpha_{\text{class(i)}} + \sigma\nu_i$
Preferences	$\beta = (\beta_{brand}\ \beta_{category}\ \delta_{Diet(i)}\ \rho_{SugarSD(i)}\ \rho_{SugarFruitJuice(i)})$

α is the mean marginal disutility of the price

α_{child}, α_{obesity} and α_{class} are associated with the household composition, obesity status and socioeconomic class

β_{brand} and $\beta_{category}$ are brand and category fixed effects

$\delta_{Diet(i)}$ is the coefficient associated with diet products

$\rho_{SugarFruitJuice(i)}$ is the coefficient associated with the sugar content for fruit juices

Note: When the parameter $\delta_{Nutrient(i)}$ or $\rho_{Nutrient(i)}$ is indexed by household i it indicates that the variable associated to the parameter is interacted with household composition characteristics

Table 11: Summary instrumental variables

IV	Number of competing products offered by other firms within the product category
	Total sugar content of competing products within the nutritional category
	Glass input price

Notes: The nutritional category refers to the regular or diet characteristic for SSBs, milk-based drinks and to the three levels of sugar content for fruit juices "Low sugar-sweet", "Sugar-sweet" and "High sugar-sweet" (these three sugar levels are based on the terciles of the sugar content distribution and are computed for each category separately).

Table 12: Results on price equation

	Coefficient (se)
Instrumental variables	
BLP instruments	
Number of competing products offered by other firms within the product category	-0.01*** (0.00)
Total sugar content of competing products within the nutritional category	-0.00*** (0.00)
Cost shifter (input prices)	
Glass	-0.00*** (0.00)
Exogenous variables	
Diet	0.11*** (0.04)
Sugar (Soft drinks)	0.07*** (0.01)
Sugar (Fruit juices)	0.28*** (0.01)
Brand fixed effects	yes
Category fixed effects	yes
IV joint significance test	F(3,5035) = 35.97
	Prob > F = 0.0000
Observations	5,182
R^2	0.944

Notes: Cost shifters are ONS price production indices (https://www.ons.gov.uk/economy/inflationandpriceindices). They are not likely to be correlated with unobserved determinants of demand for non-alcoholic beverages. The non-alcoholic beverages industry only represents a very small share of the demand for those inputs, which justifies the absence of correlation between input prices and unobserved determinants of the demand for non-alcoholic beverages. Estimators' standard errors (se) are in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.2 Results

We found that households with young children are less sensitive to price and households with children above 7 years of age are more sensitive to price than households without children. Households with overweight or obese individuals are more sensitive to price than households with no overweight or obese individuals. Results also suggest that households prefer diet to regular products. The preference for diet products is stronger for households with children. Households with children have a higher taste for sugar. For a given brand and a given regular or diet characteristic, households prefer products with more sugar both for SSBs and fruit juices.[12].

[12]The sugar coefficient for SSBs should be interpreted with caution. There is variability in the sugar content only if a brand sells different categories of products, for example "fruit-flavoured drinks" and "other SSBs". We estimate the preference for sugar inside these brands. Hence the coefficient does not represent the absolute preference for sugar but rather preference between products for a given brand.

Table 13: Estimates of the random coefficient logit model

Price (p_{jt})	
Mean (α)	-6.84 (0.00)
$\times$ children below 6 years old	0.13 (0.00)
$\times$ children 7-16 years old	-0.03 (0.00)
$\times$ average class	-0.24 (0.00)
$\times$ poor class	-0.35 (0.00)
$\times$ at least one obese	-0.12 (0.00)
$\times$ all obese	-0.15 (0.00)
Standard deviation (σ)	1.64 (0.00)
Pure juice	3.35 (0.00)
Fruit drink	0.64 (0.00)
Fruit juice with milk	
Diet	1.02 (0.00)
$\times$ children below 6 years old	0.13 (0.00)
$\times$ children 7-16 years old	0.07 (0.00)
Sugar (SSBs)	0.16 (0.00)
$\times$ children below 6 years old	0.03 (0.00)
$\times$ children 7-16 years old	0.02 (0.00)
Sugar (fruit juices)	0.03 (0.00)
$\times$ children below 6 years old	0.05 (0.00)
$\times$ children 7-16 years old	0.04 (0.00)
Fixed effects	
Sub-category	yes
Brand (NBs & PLs)	yes
Error ($\hat{\eta}_{jt}$)	4.09 (0.00)
Observations 1,364,000	
Log-likelihood -2.32081e+10	

Note: standard errors of coefficient estimates are in parentheses.

Table 14: Own-price elasticities household characteristics

Household composition	
Without children	-8.93
With children below 6 years old	-8.84
With children 7-16 years old	-9.01
With children below 6 and 7-16 years old	-8.92
Obesity status	
No overweight or obese	-8.84
At least one overweight or obese	-8.95
All overweight or obese	-8.98
Socio-economic class	
Rich	-8.73
Average	-8.96
Poor	-9.08

Notes: Own-price elasticities are calculated at the alternative level. For a given household characteristic, it is the mean elasticity computed across all the alternatives' own-price elasticities.

Table 15: Own-price elasticities by sugar content and household characteristics

	Sugar content (g/100mL)					
	0	] 0 ; 5 [	[5 ; 8 [	[8 ; 10 [	[10 ; 12 [	≥ 12
All households	**-7.17**	**-6.90**	**-9.53**	**-10.18**	**-10.13**	**-10.12**
Household composition						
Without children	-7.16	-6.89	-9.54	-10.19	-10.14	-10.13
With children below 6	-7.11	-6.84	-9.44	-10.08	-10.03	-10.03
With children 7-16	-7.23	-6.95	-9.62	-10.27	-10.22	-10.21
With children below 6 & 7-16	-7.18	-6.90	-9.52	-10.16	-10.11	-10.11
Obesity status						
No overweight or obese	-7.11	-6.84	-9.44	-10.07	-10.03	-10.03
At least one overweight or obese	-7.19	-6.91	-9.56	-10.21	-10.16	-10.15
All overweight or obese	-7.22	-6.94	-9.60	-10.24	-10.19	-10.19
Socio-economic class						
Rich	-7.03	-6.76	-9.32	-9.95	-9.90	-9.91
Average	-7.20	-6.92	-9.57	-10.22	-10.17	-10.16
Poor	-7.29	-7.01	-9.71	-10.36	-10.31	-10.30
Margins (% price)	19.23	49.86	20.09	17.65	22.50	19.11