Where There's a Levy, There's a Way

Prices, recipes, and the UK Soft Drinks Industry Levy

Maxime Tranchard*

November 4, 2026

[Most recent version]

Abstract

The Soft Drinks Industry Levy (SDIL), implemented in the United Kingdom in 2018, taxes soft drinks in tiers of sugar content and was explicitly designed to provide manufacturers with incentives to reduce sugar content of their products. In this paper, I develop a tool to evaluate and design such a tax. I separate the levy's effect on sugar into a price channel and a recipe channel, and predict the response of recipes, prices and welfare to alternative schedules, including the reform of 2028. Using household scanner data, I estimate a random-coefficients demand system in which price sensitivity varies across households and each recipe carries its own fixed effect. Combined with a multiproduct pricing model, observed reformulation decisions yield bounds on product-level reformulation costs. Changes in recipes account for about a third of the levy's effect on sugar. About 15% of the recipe channel runs through consumers substituting across products in response to the new recipes. The tiered design worked as intended: products near a threshold reformulate without losing demand, and products further away still find it worth avoiding the levy. Whether higher rates would raise welfare depends on the social cost of sugar. In this application at £3 per kilogram no counterfactual schedule does, while at £4 most do.

*Toulouse School of Economics. Email: maxime.tranchard@tse.fr. Website: https://tranchardm.github.io/. This research was funded by the Agence Nationale de la Recherche (ANR) and the Deutsche Forschungsgemeinschaft (DFG) under the project PARETO ("Producer And RETailer markets Organization", ANR-23-FRAL-0010, DFG 529250214). I used generative AI tools to edit the language of this paper.

1 Introduction

Taxes on sugar-sweetened beverages have become a central policy instrument in efforts to reduce sugar consumption and address rising rates of obesity and diet-related diseases. As a growing number of countries have implemented such policies, a rapidly expanding empirical literature has studied their effects(Aguilar et al., 2021; Cawley et al., 2019; Griffith et al., 2019a; Silver et al., 2017; Capacci et al., 2019) and motivation Allcott et al. (2019). In April 2018, the United Kingdom introduced the Soft Drinks Industry Levy (SDIL), a tiered tax applied to soft drinks according to their sugar concentration. Beverages containing less than 5 grams of sugar per 100 millilitres are exempt, drinks containing between 5 and 8 grams face a lower tax rate, and products exceeding 8 grams per 100 millilitres are subject to a higher rate.

Unlike standard excise taxes that aims to operate primarily through prices, the SDIL was explicitly designed and publicized with the objective of inducing product reformulation by manufacturers. Because tax liability depends directly on the sugar concentration of beverages, firms can reduce or entirely avoid the tax by lowering the sugar content of their products. This feature places firms' product design decisions at the center of the policy.

This paper studies how manufacturers reformulated their drinks in response to the Soft Drinks Industry Levy, and how much of the levy's effect on sugar runs through new recipes rather than through prices. Using Kantar Worldpanel household scanner data, I document the changes in recipes around the implementation and the response of prices and volumes. I complement this reduced-form evidence by developing a structural framework that links consumer demand, oligopolistic pricing, and endogenous product reformulation. The demand system follows the micro-BLP procedure of Conlon and Gortmaker (2026) with the random-coefficients discrete-choice framework commonly used in differentiated-product markets (Berry et al., 2004; Nevo, 2001; Berry et al., 1995). These models allow the recovery of substitution patterns, markups, and marginal costs, and have been widely used to evaluate tax policies in imperfectly competitive markets (Dubois et al., 2020; Bonnet and Réquillart, 2013). Price sensitivity varies across households, which is crucial for evaluating taxes in soft drink markets (Etilé et al., 2021), while every product-level taste is absorbed by a fixed effect indexed by the recipe(Conlon and Gortmaker, 2026; Nevo, 2001). The demand effect of a reformulation is thus read off the data rather than imposed by a model of preferences over sugar. Because that difference is a before-and-after comparison for a single drink, it bundles the effect of the new recipe with whatever else moved its demand over the period; the effect of a reformulation is therefore identified only against the same difference computed for the drinks that changed nothing, at the same dates, and only for groups of drinks defined by the size of the cut. In that sense recipe effects are thus interpreted as the demand counterpart of the reformulation decision.

Then, the model recovers bounds on each drink's reformulation cost. Firms choose the sugar content of their products in a first stage, before competing in prices in a second stage. Changing a recipe requires paying a fixed cost, so observed reformulation decisions, and the absence of reformulation where a cut would have paid, reveal information about the magnitude of these costs. The approach follows Koujianou Goldberg and Hellerstein (2013), who recover unobserved fixed costs of price adjustment from observed equilibrium pricing. In the same spirit, reformulation costs are treated here as equilibrium objects that rationalize

the recipes observed in the market, rather than as technological parameters to be measured separately. The resulting bounds are what make the counterfactuals possible: under each alternative tax schedule, a firm keeps or drops its new recipe according to its bounds.

This paper contributes to the literature on corrective taxation of sugar-sweetened beverages and to the broader literature on taxation in markets with imperfect competition. A central motivation for soda taxes is that beverage choices generate social costs through diet-related disease risks and associated healthcare expenditures, and may also reflect internalities when consumers misperceive or underweight the health consequences of sugar consumption (Allcott et al., 2019; Griffith et al., 2018). In such environments, the effectiveness of corrective taxation depends not only on consumer responses but also on how firms adjust prices and product characteristics.

A large reduced-form literature documents that soda taxes can affect beverage prices and consumption. Evidence from Mexico shows substantial declines in purchases of taxed beverages following the introduction of a national excise tax (Colchero et al., 2017, 2016). In the United States, city-level taxes have been found to increase prices and reduce consumption of taxed beverages, although their effects may be attenuated by cross-border shopping and tax avoidance (Rogers et al., 2023; Seiler et al., 2021). While these studies provide important evidence on consumer responses, they typically abstract from supply-side adjustments in product characteristics.

The importance of reformulation has been documented in other markets (Griffith et al., 2017). Empirical evaluations of this policy show that sugar purchased from soft drinks declined after its introduction, even if overall beverage consumption did not fall proportionally (Dickson et al., 2025; Rogers et al., 2023; Bandy et al., 2020; Scarborough et al., 2020). These patterns suggest that reformulation played a central role in shaping the policy's effects. However, existing evidence does not recover the structural determinants of reformulation decisions, such as the costs firms incur when modifying product recipes or the loss of demand due to change in taste.

Most structural evaluations of beverage taxes treat product characteristics as fixed and focus on price responses and consumer substitution. Exceptions are the recent work of Barahona et al. (2023), and Boncomtpe, Javier (2026) which incorporates firms' product reformulation decisions in a structural framework. However, the literature on endogenous product reformulation in response to corrective taxes remains very limited, with only a small number of applications. This paper contributes to this emerging area by providing a structural analysis of product reformulation in the context of soda taxation and the UK Soft Drinks Industry Levy, that differs from both.

First, I measure what a reformulation does to demand. The recipe fixed effects of reformulated drinks are compared with those of drinks that changed nothing, at the same dates, so that the loss from a new recipe is not derived from a preference for sugar. Second, observed reformulation decisions bound each drink's reformulation cost, and in every counterfactual a firm keeps or drops its new recipe according to those bounds, instead of having the recipes imposed. This strucutral framework help me decompose the levy's effect on sugar into a price channel and a recipe channel, and compares the tiered schedule with a linear tax on sugar. The results reinforce the idea that the levy worked through recipes. Changes in recipes account for about a third of the levy's effect on sugar, well below the 84% estimated by Dickson et al. (2025). About 15% of the recipe channel runs through consumers

substituting across products in response to the new recipes, a margin little discussed in the literature. The tiered design nonetheless did what it was meant to do. Products close to a threshold reformulate without losing demand, and even products further away, which do lose demand with a new recipe, gain enough from avoiding the levy to reformulate. Nevertheless a linear tax with a threshold could keep this feature while strengthening the incentive for the most sugary drinks. Finally, whether the levy should be raised hinges on the social cost of sugar. At £3 per kilogram, none of the counterfactual schedules raises total welfare; at £4, most do.

The rest of the paper is organised as follows. Section 2 describes the levy, the data and the market's response around the implementation. Section 3 develops the structural model of demand, pricing and reformulation, and decomposes the levy's effect on sugar. Section 4 evaluates alternative tax schedules. Section 5 discusses the limitations and concludes.

2 The policy and the market it slashes

2.1 The policy

The Soft Drinks Industry Levy (SDIL) was announced in March 2016 and implemented on 6 April 2018. It taxes packaged soft drinks with added sugar on a tiered, avoidable schedule: nothing below 5 g of sugar per 100 ml, 18p per litre from 5 to 8 g, 24p per litre at or above 8 g. Pure fruit juice, milk-based drinks and small producers are exempt. The levy is paid by producers and importers, and VAT is charged on top of it. Unlike standard excise taxes that aims to operate primarily through prices, the SDIL was explicitly designed and publicized with the objective of inducing product reformulation by manufacturers. Because tax liability depends directly on the sugar concentration of beverages, firms can reduce or entirely avoid the tax by lowering the sugar content of their products ,and the two-year gap between announcement and implementation left time to do so. This feature places firms' product design decisions at the center of the policy.

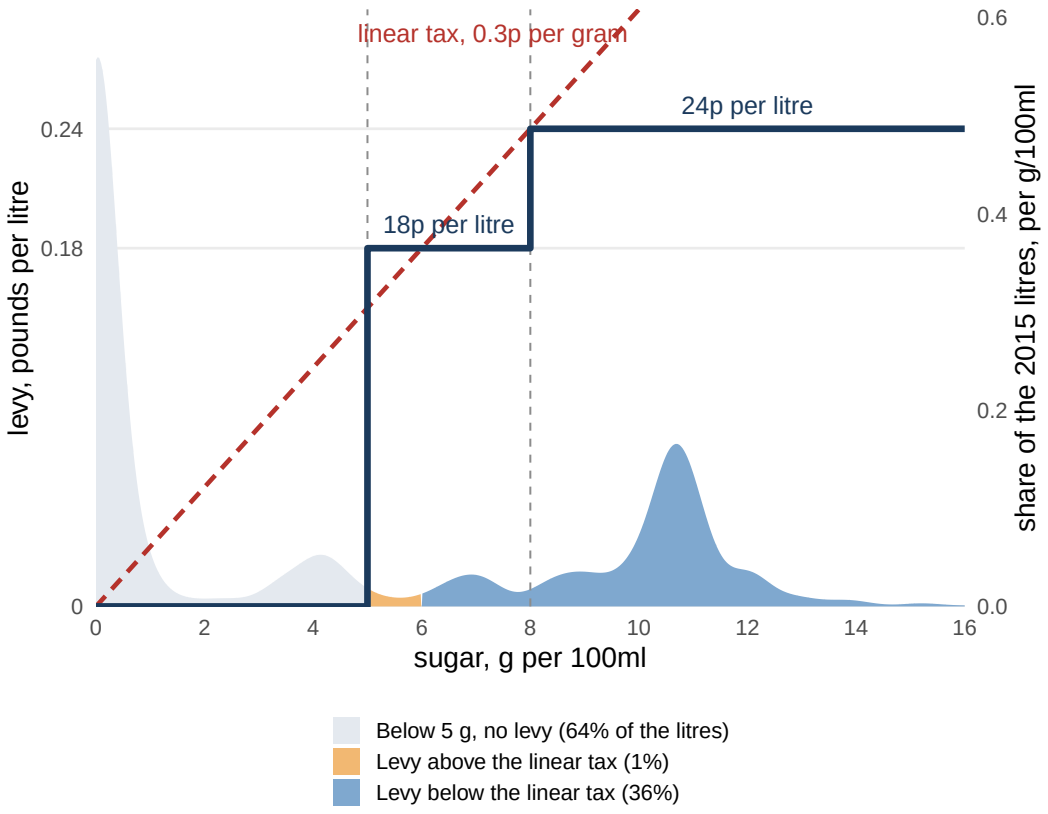


Figure 1: The levy of 2018 against the market of 2015

Figure 1 show that the levy is a step function of sugar. It is presented over the volume of 2015 by sugar content in the levy's categories, for the whole distribution on the raw data. Two masses stand out. About 64% of the volume already sat below the 5 g threshold. The rest concentrated far above the higher threshold. The dashed line is an hypothetical linear tax on sugar at 0.3 pence per gram. If we rationalize this intervention as a Pigouvian instrument, the design therefore reveals the regulator's implicit valuation of the sugar externality: at most £3 per kilogram of sugar[1].

The small area in yellow, about 1% of the volume, points to a feature of volumetric sin taxes that is well known and much criticized (Griffith et al., 2019b). The externality here runs through grams of sugar, yet the levy is charged per litre within each tier. Dividing the rate of a tier by the grams it covers, the implicit price of sugar is highest just above a threshold and falls as sugar content rises. Drinks sitting just above 5 g per 100 ml therefore pay more per gram than the linear tax, while the rest of the distribution pays less. The most sugary drinks, the ones a Pigouvian schedule would hit the hardest, face the weakest incentive per gram of sugar. The design makes more sense once read from the firm's side. The step structure enhance the incentive to reformulate for products close to the threshold, arguably less costly to reformulate, and channels the reduction in sugar through recipes rather than through consumers substituting away from taxed drinks.

[1]In that regards, this social cost of sugar is considered as a benchmark for the next parts of the article.

2.2 The consumption of soft drink in the UK

The analysis rely on household scanner data drawn from the Kantar Worldpanel. This dataset provides detailed information on grocery purchases recorded at the household level. It covers 2015, 2017 and 2018, each year split into thirteen four-week periods (39 periods). 39,712 distinct households across the window of analysis record every grocery purchase brought into the home; each record carries the household, the barcode, the brand, the spend, the volume, and the sugar and calorie densities of the product. Restricted to soft drinks[2] the dataset contains 4,409,607 purchase records on 7,847 barcodes (9.6 million litres). In order to be able to define a product and to follow it trough the dataset timeline, the analysis propose the notion of "drink". Drinks can be seen both as the barcode identity strips from pack size and volume size or by the intersection between brand, sugar level, and flavor. From the 7,847 barcodes 6,438 drinks are defined. Table 1 gives the sample by year.

Table 1: Household panel by year

				Households in the year		Households per period					
Year	Records	Barcodes	Drinks	present	buyers	present	weight	represent (m)	Litres (m)	Sugar (g/100ml)	GBP/litre
2015	1,492,337	4,826	3,927	32,092	31,175	26,543	1,008	26.8	3.4	5.17	0.77
2017	1,446,668	5,045	4,119	30,956	29,940	25,366	1,076	27.3	3.1	4.71	0.80
2018	1,470,602	5,065	4,116	30,401	29,579	25,294	1,090	27.6	3.1	4.02	0.85

Note: Households in the year: "present" are the distinct households in the panel (weight > 0) in at least one four-week period of the year, "buyers" those among them that record at least one soft-drink purchase in the year. Households per period: "present" is the number in the panel in average; "weight" being the average weight of a present household and "represent" the sum of the weights, summing to the UK household population in millions.

This dataset carries very rich household's demographics: size, number of children, income band, social class, region, urban or rural location, the main shopper's age band and lifestage, and the gender, age, height, weight and BMI of every household member. In Appendix, tables A7 and A8 give the composition of the member households on every available dimension, raw and survey-weighted, in 2015 and 2018. The weighted composition is essentially identical in 2015 and 2018 and limit the potential bias in the analysis of a drift of the panel through the policy window. The panel is deep enough to follow individuals: 23,844 households (74% of 2015 members) are observed on both sides of the reform.

[2]The data covers the packaged soft-drink category: carbonates, energy and sports drinks, juice drinks and chilled juice, flavoured milk, mixers. Two categories are excluded from the analysis. Plain bottled water has no sugar margin,keeping it would blur the measured effect of the policy while adding no sugar to the market. Dilutable drinks are excluded because their recorded sugar content has no consistent basis, as shown in Appendix B.1.

Table 2: Take-home soft-drink purchasing by household type.

	2015 (pre-announcement)					2018		
	Litres /pers/wk	Sugar g/pers/wk	Sugar g/litre	% vol. ≥ 5 g	% vol. later reformulated	Sugar g/pers/wk	Sugar g/litre	Δ sugar /pers (%)
All households	0.92	48	52	29.9	11.6	36	41	-25
By household income								
Under £20,000	0.98	53	54	32.6	13.0	40	41	-24
£20,000-39,999	0.93	48	52	29.7	11.5	37	41	-24
£40,000+	0.86	44	51	26.9	9.9	32	40	-27
Not stated	0.89	48	54	30.3	12.2	35	41	-26
By social class								
AB	0.83	44	53	26.2	10.8	33	42	-25
C1	0.93	48	52	28.4	11.1	36	41	-25
C2	0.91	47	52	31.0	11.3	35	40	-25
DE	1.02	54	52	33.5	13.1	40	40	-26
By children in household								
No children	1.01	50	50	28.1	11.6	39	39	-23
1 child	0.88	49	56	33.5	12.4	36	43	-28
2 children	0.78	44	57	32.4	11.4	31	45	-29
3+ children	0.70	40	57	33.3	10.8	28	46	-28
By mean adult BMI								
Under 25	0.76	46	60	33.1	13.0	35	49	-25
25-30	0.92	48	52	29.1	11.5	35	40	-27
30+	1.21	53	44	26.9	10.3	40	34	-24
Not recorded	0.97	50	51	30.2	11.6	36	40	-27

Note: "% vol. ≥ 5 g" is the share of the group's 2015 volume in drinks whose recipe sat at or above the exemption threshold in 2015; "% vol. later reformulated" the share in drinks that subsequently crossed a levy tier downward.

Table 2 cuts purchasing by income, social class, children and the measured BMI of the household's adults. The average member household bought 0.92 litres and 48 g of soft-drink sugar per person per week in 2015, 29.9% of the volume in would-be-liable (≥ 5 g) drinks. Households under £20,000 buy 53 g per person per week against 44 above £40,000, class DE 54 against AB 44, a fifth more sugar at the bottom, carried by more litres of essentially similar baskets (sugar per litre is flat at 51 to 54 g). Households with children buy fewer litres and less sugar per person. Adult BMI grades volume and composition in opposite directions: At 30+ households have by far the most volume (1.21 litres per person per week against 0.76 where adults are under BMI 25) and the most sugar (53 against 46 g), yet the least sugar-dense baskets (44 against 60 g/litre) and the lowest liable share (26.9% against 33.1%): their sugar comes from more litres, not stronger drinks. The share of 2015 volume in drinks that would later cross a levy tier down is highest for low-income (13.0%) and DE (13.1%) households, in contrast to 9.9 and 10.8%.

Table 3: Concentration of take-home sugar across households.

		2015 purchases			Profile (%)			Same households, 2018		
2015 sugar rank	% of hholds	Sugar g/pers/wk	% of all sugar	% vol. ≥ 5 g	With children	Class DE	Obese adults	Still present	Sugar g/pers/wk	Δ (%)
All households	100	48	100.0	29.9	27	28	22	71	36	-27
Top 10%	10	191	35.2	49.4	20	33	27	74	106	-44
Next 40%	40	60	52.7	29.7	30	27	21	72	42	-30
Bottom 50%	50	12	12.1	12.6	27	27	22	69	16	+30

Note: Households ranked by 2015 sugar per person per week (survey-weighted deciles of the 2015 member population); profile columns give each group's weighted share of households with children, in social class DE, and whose adults' mean recorded BMI is ≥ 30. The final columns follow the same households into 2018 ("still present" = share re-observed as members in 2018); because the ranking is on the 2015 outcome, these changes mix true adjustment with regression to the mean.

Ranking households by sugar per person, the top decile of the 2015 distribution buys 191 g per person per week, sixteen times the bottom half's 12, and carries 35% of all take-home soft-drink sugar; the top quintile carries 55%, the bottom half 12% (Table 3). The top decile has a distinct profile, more class DE (33% against 28%), more obese adults (27% against 22%), fewer households with children (20% against 27%), and its drinks are far more exposed to the levy (49.4% of volume in liable drinks against 29.9% overall).

2.3 Defining reformulation and recovering recipes

A carefull reader wouldn't have missed that reformulation hasn't been defined yet and that the drink unit of analysis by taking into account the sugar level would create different drinks for two state of the same drink at different recipes. Reformulation is not direclty observed here, since recorded sugar is single-valued at the barcode-period and that drink are basically agregation of barcode, it's possible to follow the barcode and matched drinks between their old and new recipie[3]. Most recorded series are already clean: a flat line, or a single step at the reformulation date. In order to deal with uncertainties, that concern a small parts of the drinks 4.6 to 5.4% of the market (Appendix Table A1), three cleaning rules are defined. Rule 1: packs of an identical recipe cannot disagree, so within a drink and period, density is the volume-dominant value across the drink's barcodes. Rule 2: recording oscillations (One product reformulated once in 2017, yet some packs' series flip back and forth) are collapsed by locking a drink's series to its final state from the first period that state is reached, symmetrically, so genuine upward changes survive. Rule 3: a recipe cannot move from exactly 0 g of sugar to at or above the exemption threshold, so series starting at exactly zero and ending ≥ 5 g/100 ml, pure-juice and mixer relabellings that the provider registered with a lag, have their initial zeros rewritten to the final state[4]. With clean series, each drink gets a tier, exempt (< 5 g), low (5 to 8 g), high (≥ 8 g), before and after, and its

[3]As the brand-flavor interraction is already discrimating a lot between products we can verify that the reformulation isn't hidden by the launch of a new barcode replacing the old ones.

[4]These drinks are now correctly non-movers, not upward crossers (6 drinks, 101 barcode-period cells carrying 0.015% of volume).

movement is classified. Table 4 shows downward tier-crossing is the dominant movement in the reformulation process, and is stronger among large drinks. Upward movement into the levy is negligible: 34 drinks ever cross up, the largest holding 0.02% of the 2015 market. And most drinks never move at all.

Table 4: Drink movement across levy tiers.

Movement (drinks)	Raw	90%	75%	60%	50%
Downward					
crossed below 5 g (into exempt)	230	96	37	17	8
crossed below 8 g (high→low)	171	35	10	2	1
within tier (no crossing)	652	138	50	20	10
Upward					
exempt → levied	11	2	0	0	0
low → high	23	3	2	0	0
within tier	181	54	17	7	1
Non-mover (stable)	5,170	599	235	94	54
Total drinks	6,438	927	351	140	74

Note: Drink movement across levy tiers (SDIL thresholds 5 and 8 g), by share of market volume covered. "Raw" is all 6,438 drinks.

A stunning fact of this movement decomposition is that the vast majority of products reformulation seems very unlikely due to the SDIL. Most of the downward movement didn't cross any tier and upward movement isn't credibly directly due do it. The natural interpetation is that nutritionnal content is strategicaly sets by firms to maximise their profits given consumers preferences, likely changing over time, and without link to the SDIL. The market shows a downward trend in sugar while upward reformulation still exist,consistent with profit maximisation.

In the same way the widely documented "bunching at the threshold"[5] is visible when looking at the whole portfolio of reformulated drinks , but figure 2 also shows a huge landing on the right-hand of the distribution. In light of table 4 this choice is likely concentrate in products with very low market shares.

[5]See Scarborough et al. (2020)

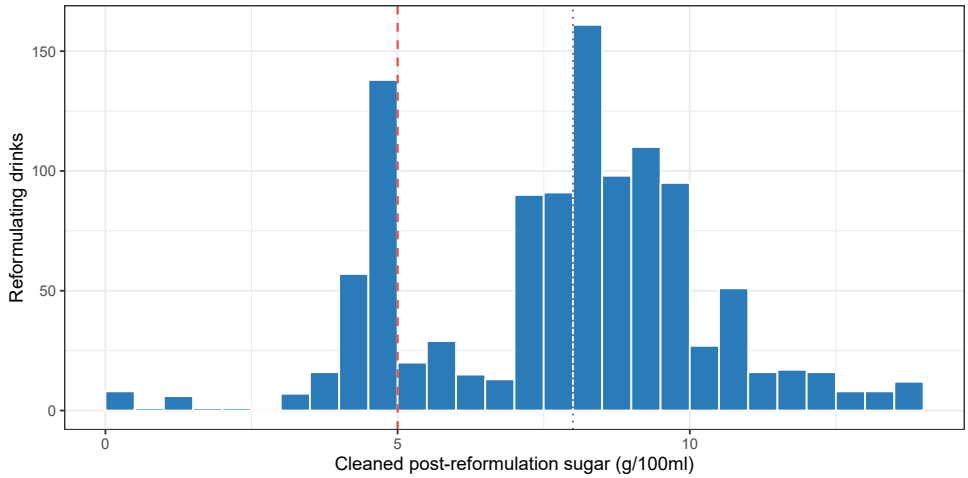


Figure 2: Bunching below the exemption threshold ?

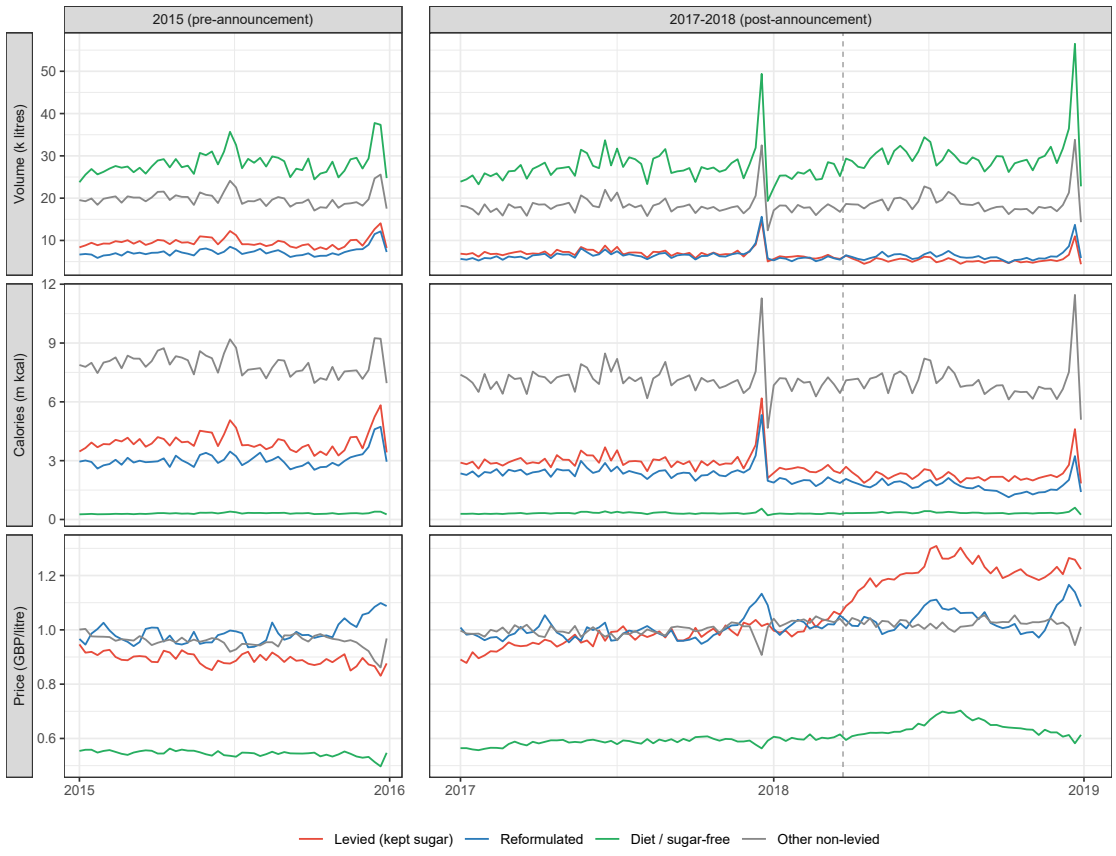


Figure 3: Volume, calories and price by category.

Note: Weekly volume, calories and price by category. Reformulated = drinks crossing a levy tier down; levied = kept ≥ 5 g; diet = near-zero sugar; other non-levied = exempt or always < 5 g. Dashed line = SDIL implementation.

The figure 3, looks at the trend in Volume, Calories and Price by category for the panel

during the time of analysis. A few trends emerges from a mostly flat figure. Regarding volume nothing major seems to happened in the market during that period. While levied products seems to decrease less in volume than levied one and appears higher in volume at the end of 2018. In calories a decrease seems to happened in the reformulatd one as soon as early 2017, but that trend seems to be follow by levied also. The price channel is the one that seems the most easily interpretable: four parralels trends than at the SDIL implementation, an increase in price and in price stability for all category a part from the products out of scope of the levy that remain stable.

With the explicit limitation of what was just shown, and in order to see if this data reproduce the facts shown in previous study, treatment will be defined in the following way. A treated drinks will be a drink that cross a levy tier downward, "reformulated to avoid or reduce the levy". In that sense the results can be compare to the study of Dickson et al. (2025).

The interaction-weighted event study of Sun and Abraham (2021) is estimated at the drink level. Let y_{it} be the log calories or the log litres sold by drink i in week t, and E_i the week in which drink i crossed a levy tier downward, its event date; the non-movers, which never cross, form the control set C and have no event date. A treated drink belongs to the cohort e of the drinks that crossed in the same week, and $\ell = t - E_i$ is its distance in weeks to that event.

$$y_{it} = \tau_t + \gamma_i + \sum_{e} \sum_{\ell \neq -1} \delta_{e,\ell} \, \mathbf{1}\{E_i = e\} \, \mathbf{1}\{t - E_i = \ell\} + \varepsilon_{it}, \tag{1}$$

with τ_t a week fixed effect, γ_i a drink fixed effect and ε_{it} the error. The coefficient $\delta_{e,\ell}$ is the effect of the reformulation on cohort e at distance ℓ, measured against the week before the event, $\ell = -1$, which is left out, and against the non-movers[6], which identify the week effects.

Table 5: Reformulation effects across the product ladder.

	Log calories ATT		Log volume ATT	
Sample	Period FE	Weekly FE	Period FE	Weekly FE
Top-100	-0.500^{***} (0.088)	-0.565^{***} (0.090)	-0.050 (0.086)	-0.119 (0.088)
Top-250	-0.492^{***} (0.080)	-0.492^{***} (0.076)	-0.038 (0.068)	-0.044 (0.069)
Top-500	-0.491^{***} (0.094)	-0.531^{***} (0.084)	0.029 (0.080)	-0.008 (0.070)
Top-1000	-0.428^{***} (0.074)	-0.475^{***} (0.062)	0.094 (0.062)	0.041 (0.052)
Top-2000	-0.391^{***} (0.057)	-0.437^{***} (0.051)	0.095^{*} (0.050)	0.048 (0.043)
Top-3000	-0.394^{***} (0.056)	-0.436^{***} (0.050)	0.086^{*} (0.049)	0.045 (0.042)
All drinks	-0.394^{***} (0.056)	-0.436^{***} (0.050)	0.086^{*} (0.049)	0.045 (0.042)

Note: IW ATT across the product ladder. Clustered by drink.

The estimation on subsample shows a very clear gradient the less product in the analysis the more the effect of reformulation in terms of calories avoid. Two instants remarks in regards to the litterature. First using the effect evaluate on the top products to estimate

[6]Results survives an extensive robustness programme that will be accessible in the online appendix in particular to the latest-cohort design of Dickson et al. (2025)

the global may lead to an overstatement of the overall effect. Second, Dickson et al. (2025) whose study covers the top-100 brands at market level, reports calorie falls above 50% from reformulating brands, this estimate is match by the upper bound of the robustness suite (-0.783, a 54% cut). Hence the household level dataset doesn't reject the results obtain in the whole market.

Another exercise that can be run, direclty inspire by Dickson et al. (2025), is to describe the levy intervention trough an interrupted time series at the fourweek period, group by group. A group g is a set of drinks fixed by their exposure at implementation: each liable subcategory splits into its levied drinks, at or above 5 g in their last period before implementation, and its never-liable diet counterparts, which never reach 5 g in any period and so exclude reformulators by construction; the diet counterparts split again into sugar-free (≤ 0.5 g) and low-sugar (0.5 to 5 g). Both sets require sales before implementation, so a level shift is the response of a fixed set of products, not a change in composition. For a group g and a period t the outcome y_{gt} is either the price of the group, a fixed-weight index in GBP per litre in which each drink's price is weighted by its pre-implementation share of the group's volume, so that changes in the mix of brands and packs do not move the series, or the group's volume in litres, panel and survey-weighted. The regression is

$$y_{gt} = \beta_0 + \beta_1\, t + \beta_2\, \mathbf{1}\{t \geq t^*\} + \beta_3\, \max(t - t^*, 0) + \beta_4\, \mathbf{1}\{t = t^*\} + \sigma_{m(t)} + \varepsilon_{gt}, \qquad (2)$$

estimated separately for each group, where t counts four-week periods in calendar time, t^* is the implementation period, and $\sigma_{m(t)}$ is a fixed effect for the position of the period in the year, which absorbs seasonality. The levy started on 6 April, in the middle of t^*, so that period is only partly treated: β_4 gives it a dummy of its own, and the level shift β_2 is identified off the fully treated periods that follow. β_1 is the trend before implementation and β_3 the change in trend after it. Table 6 reports the price shifts, the statutory levy and the pass-through and the volume shifts. These estimates are descriptive at best, as there is no clean control group at implementation as seen in figure 3.

Table 6: Price shifts at implementation and implied pass-through.

Subcategory	Level shift $\hat{\beta}_2$ (GBP/litre)	Statutory levy (GBP/litre)	Pass-through ($\hat{\beta}_2$/levy)
Levied drinks (≥ 5 g/100 ml at implementation)			
Colas	0.265*** (0.023)	0.237	112%
Lemonade	0.124*** (0.037)	0.215	58%
Mixers/tonic	0.038 (0.042)	0.212	18%
Energy/one-shot	0.077** (0.036)	0.235	33%
Other carbonates	0.054* (0.028)	0.182	30%
Diet counterparts (never liable, < 5 g throughout)			
Colas	0.052 (0.031)	–	–
sugar-free	0.052 (0.031)	–	–
low-sugar	-0.154** (0.059)	–	–
Lemonade	0.038 (0.023)	–	–
sugar-free	0.050* (0.026)	–	–
low-sugar	0.008 (0.018)	–	–
Mixers/tonic	0.042*** (0.007)	–	–
sugar-free	0.048*** (0.009)	–	–
low-sugar	0.015** (0.006)	–	–
Energy/one-shot	0.131*** (0.033)	–	–
sugar-free	0.018 (0.026)	–	–
low-sugar	0.141*** (0.034)	–	–
Other carbonates	0.085** (0.040)	–	–
sugar-free	0.114* (0.055)	–	–
low-sugar	-0.026 (0.018)	–	–
All diet	0.057** (0.026)	–	–
sugar-free	0.058* (0.029)	–	–
low-sugar	0.050*** (0.017)	–	–

Note: ITS level shift in price (GBP/litre) at implementation: levied drinks by subcategory, with the statutory levy per litre they face (fixed-weight mix of the 18p/24p 2018 rates) and the implied pass-through; below, their never-liable diet counterparts (each split sugar-free / low-sugar), which face a zero rate.

Five main findings arise from table 6. Pass-through is more than one for (at most[7]) two subcategory and very low for the rest of the market: cola prices rise £0.27 per litre against a statutory mix of £0.24 (112%). Pass-through carries the same selection gradient as the calorie effect: pooled, it is 98% among the top-100 drinks and declines monotonically to 75% market-wide (Appendix Table A11). Untaxed diet counterparts became dearer too, by ∼6p/litre when pooled. Table A10 presents in annexe the results of the equivalent exercice on volume and shows that levied volume falls modestly (−5.4 million litres per period nationally, summed over the subcategories) and diet volume rises by more +8.3 million, 64% of it sugar-free.

Table 7 combines the two channels, the event-study calorie effect of Table 5 applied to the weighted 2015 calories of every tier-crossing drink, plus the volume shifts of Table A10 The

[7]the apparent partial pass-through in lemonade is an artifact of late reformulators inside the levied-at-implementation series, and excluding them restores 124 to 130% (Appendix Table A12).

second is defined by the levied groups' lost litres valued at their own calories per litre over the year before implementation, net of the calories carried back by the diet counterparts' gains at their own densities. Two effect sizes are allowed for the reformulation effect, the baseline weekly all-drink ATT (35% cut), and an upper bound using the largest calorie ATT in the robustness suite (−0.783, a 54% cut) applied to the whole crosser base. Reformulation dominates in both columns. The levy removed 3.2 to 4.4 kcal per person per day of recorded take-home calories (1,157 to 1,605 per year); survey-weighted, 1.5 to 2.0 billion kcal per week nationally.

Table 7: Aggregate calorie change

	Baseline (−0.436, 35% cut)			Upper bound (−0.787, 54% cut)		
	m kcal	per person		m kcal	per person	
Component	/period	/day	/year	/period	/day	/year
Reformulation effect	4,040	2.3	828	6,223	3.5	1,275
Volume response	1,943	0.9	340	1,943	0.9	340
Total	5,982	3.2	1,168	8,166	4.4	1,615

Notes: Baseline: the weekly-FE all-drink ATT (−0.436, Table 5). Upper bound: the largest calorie ATT anywhere in the robustness suite: it reads "if the whole category responded like the strongest measurement". Volume response (identical in both columns): the weighted market-level ITS volume shift of each levied category × the levied segment's own calories per litre over the year before implementation, net of the calories carried back by the measured substitution into never-liable diet counterparts at those segments' densities. m kcal/period are survey-weighted national take-home quantities. Per-person figures use no population gross-up: they divide the *unweighted* panel components by the people in the panel (68,741 on average) and by the 28 days of a 4-week period. Strictly take-home purchases as recorded: no imputation for consumption outside the panel's recording scope.

This part has reproduced a lot the facts the literature already established. Recipes moved before the levy was charged and bunched just below the threshold. The calories of the reformulated drinks fell by about a third with no loss of volume. The price of the drinks that stayed liable rose by the levy and more, and the volume they lost went to their diet counterparts. Take-home sugar fell by about a quarter in every kind of household. None of these facts are really surprising in regards to the recent literature. What the literature does not discuss, and becomes really important when moving to structural estimation, is how many products one has to look at to evaluate the policy. In order to discuss that, figure 4 comes back to the Sun and Abraham (2021) estimates. Whereas it is reassuring that the effect is well identied at each sample, the confidence bands widen as the sample shrinks and moves against the gradient shown earlier.

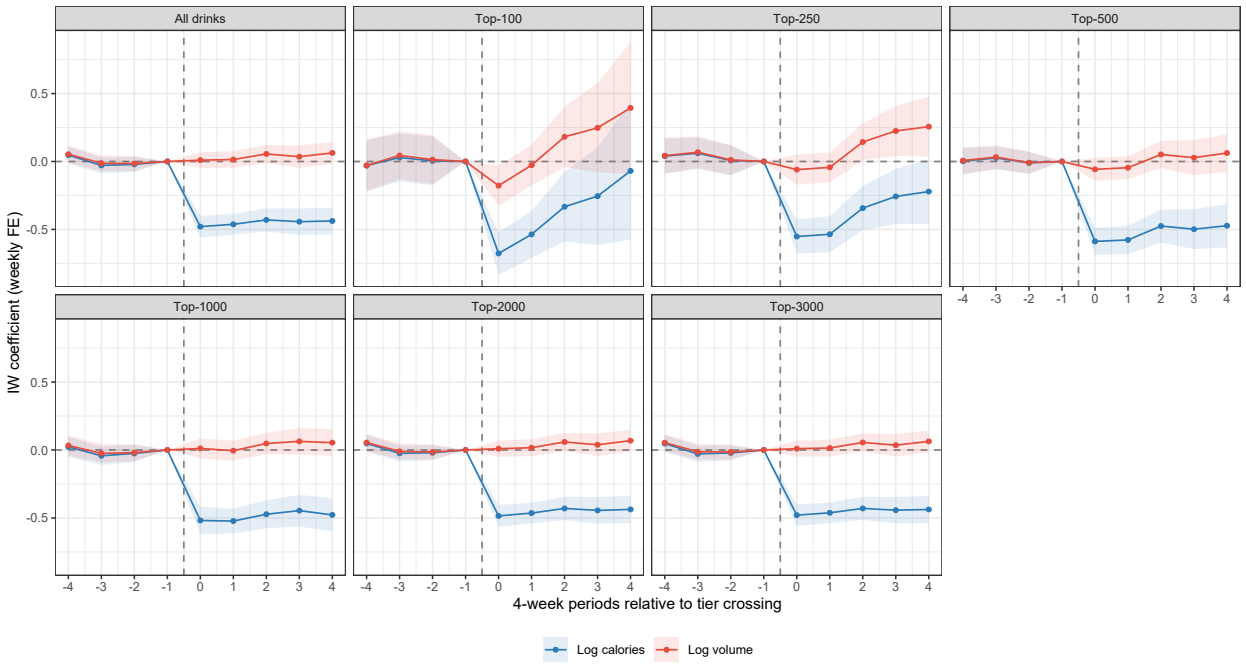


Figure 4: Event-study profiles across the product ladder.

Note: Weekly-FE event-study profiles across the product ladder (all drinks and the top-100 to top-3000 drinks). Calories (blue) drop sharply with flat pre-trends at every sample size; volume (red) is broadly flat. 95% CIs.

3 A structural model to understand the levy

The strucutral model develop here has four ingredients: a demand system for the top drinks; the effect of a reformulation on demand, read off the recipe fixed effects of that system and measured against the drinks that changed nothing ; a standard pricing model that linked observed prices to the marginal costs ; and the recipe decision, which turns the gain a firm makes from a new recipe into a bound on the cost of changing it . Then I solves the model over one year with and without the levy, and with and without the new recipes, and reads the result against the estimates of the reduce form analysis.

The data use is restricted to the two years around the implementation, 2017 and 2018: 26 four-week markets, the union over markets of each market's top 100 best-selling drinks each month (184 drinks, 223 recipes, 39 drinks that reformulate within the window), between 155 and 166 products per market, and every soft drink outside that set as the outside good, which holds from 32 to 39% of volume. The rationale behind that agregation as an outside good is partly that the SDIL only target big firms with a minimum turnover as threshold. Small market participants are then unlikely to be subject to it.

The drink and its recipe history are those previously defined. Prices are unit values in pounds per litre. Volumes are grossed up with the panel's survey weights. The micro data are the complete purchase records of the 31,303 households active in the sample with 1,394,643 purchased.

3.1 Consumer demand for soft drinks

A consumer i in market t chooses a drink j among the $\mathcal{J}_t$ inside goods or the outside good 0:

$$u_{ijt} = -\alpha_i\, p_{jt} + \lambda_{r(j,t)} + \tau_t + \xi_{jt} + \gamma' y_i + \varepsilon_{ijt}, \qquad u_{i0t} = \varepsilon_{i0t}, \tag{3}$$

with ε type-I extreme value and price sensitivity

$$\alpha_i = \exp\big(\mu_a + \pi' y_i + \sigma_a \nu_i\big), \qquad \nu_i \sim N(0,1), \tag{4}$$

the lognormal specification of Conlon and Gortmaker (2026). y_i holds the number of children, the age of the main shopper and the household's social grade (AB to E); π shifts price sensitivity and γ the taste for the inside goods as a whole.

The fixed effect $\lambda_{r(j,t)}$ is indexed by the *recipe*: a drink in a given formulation state. A drink that never reformulates has one recipe; one that reformulates has two, and $\lambda_{r_1(j)} = \lambda_{r_0(j)} + \kappa_j$, so the recipe effects are a drink fixed effect plus a drink-specific reformulation effect κ_j: the change in the drink's mean utility at its relaunch, holding price and the market fixed. κ_j carries every possible a reformulation does to demand, taste, sweetener and relaunch marketing alike, without a model of sugar preferences. τ_t is a market effect and ξ_{jt} the unobserved drink-by-market quality.

The level and dispersion of price sensitivity, (μ_a, σ_a), are identified by the aggregate panel, the demographic shifters (π, γ) by the micro data. With recipe and market effects absorbed, the identifying price variation is within recipe and within market.

The micro moments are the standard ones of Conlon and Gortmaker (2026) in the first step, for each demographic its mean among purchasers and its covariance with the price paid, and the optimal micro moments, the average scores of the micro likelihood, in the second. Estimation follows their nested fixed point algorithm.

Table 8: Price sensitivity by demographic group.

Number of children						
	0	1	2	3+		
$E[\alpha_i]$	3.79	3.84	3.67	3.60		
mean own-price elasticity	−1.81	−1.86	−1.89	−1.93		
Age of main shopper						
	24	31	39.5	49.5	59.5	70
$E[\alpha_i]$	4.12	3.91	3.74	3.73	3.69	3.57
mean own-price elasticity	−1.88	−1.87	−1.85	−1.83	−1.82	−1.81
Social grade						
	AB	C1	C2	D	E	
$E[\alpha_i]$	3.54	3.70	3.81	3.98	4.09	
mean own-price elasticity	−1.74	−1.79	−1.86	−1.92	−1.97	

Table A14 in appendix reports the estimates, whereas table 8 presents the price sensitivity by demographic group. Social grade is the main dimension of heterogeneity: each step down raises price sensitivity by +3.8% (t = 4.0), from 3.54 for AB households to 4.09 for E

households (Table 12). Age works the other way (-0.4% per year, t = -2.6). Children shift price sensitivity lower (-4.0% per child, t = -1.3) but raise the taste for the category.

The recipe effects $\hat{\lambda}_r$ are recovered now, after the estimation, by regressing the mean utilities on recipe and market dummies.

Household i buying drink j in market t has utility

$$u_{ijt} = \delta_{jt} - \alpha_i\, p_{jt} + \gamma' y_i + \varepsilon_{ijt}, \qquad \delta_{jt} = \lambda_{r(j,t)} + \tau_t + \xi_{jt}, \tag{5}$$

At the estimate, (5) is a linear regression of $\hat{\delta}_{jt}$ on recipe dummies and period dummies, with the first period as the reference, whose coefficients are $\hat{\lambda}_r$ and $\hat{\tau}_t$ and whose residual is $\hat{\xi}_{jt}$. The fixed effects are then the objects of a second step, as in Nevo (2001), who regresses the brand effects of his demand system on product characteristics to recover the tastes they absorb. Here the second step is the comparison of the recipe effects of a drink before and after its relaunch.

For a drink j that reformulates, the difference between its two fixed effects,

$$\hat{\kappa}_j = \hat{\lambda}_{r_1(j)} - \hat{\lambda}_{r_0(j)}, \tag{6}$$

is the change in its mean utility at the relaunch, holding its price and the market fixed. Written out, it is a before/after difference:

$$\hat{\kappa}_j = \frac{1}{T_j^1} \sum_{t \geq \text{relaunch}} \left(\hat{\delta}_{jt} - \hat{\tau}_t\right) \; - \; \frac{1}{T_j^0} \sum_{t < \text{relaunch}} \left(\hat{\delta}_{jt} - \hat{\tau}_t\right), \tag{7}$$

with T_j^0 and T_j^1 the numbers of markets in which the drink is sold before and after. The levels of λ are defined up to the reference period and the outside good; the difference does not depend on either.

Two things follow from (7). The period effects $\hat{\tau}_t$ are common to all drinks, and most drinks do not reformulate: what is taken out of the reformulated drink is the movement of the market. And the demand shocks average to zero within each recipe by construction, so $\hat{\kappa}_j$ takes everything that differs, on average, between the markets before the relaunch and the markets after. It bundles the taste of the new recipe, the sweetener preferences, the relaunch marketing, but also any movement in the demand for the drink that would have taken place without a new recipe.

The estimation of $\hat{\kappa}_j$ uses no assumption on how firms behave: no pricing model and no model of the recipe choice enter it. It does assume that the reformulation is not a response to the demand shocks ξ_{jt}: within a drink, and net of market effects, the date of the relaunch is unrelated to the unobserved quality of the drink in that market.

Taken together, the reformulated drinks do not differ from the others: the difference in medians is -0.07. But a small change of recipe and a large one need not move demand in the same direction, and pooling them can hide both. The reformulated drinks are therefore separated by the size of the cut in sugar, and each group is compared with the drinks that changed nothing, taken at the relaunch dates of that group (Table 9 and Figure 5).

Table 9: Before/after change in utility, by size of the cut.

		Reformulated		Not reformulated,	Difference	
	Drinks	Median	> 0	same dates: median	medians	means
All reformulated	18	+0.11	11/18	+0.18	−0.07	+0.07
Cut below 4 g	11	+0.25	11/11	+0.18	+0.06	+0.33
Cut of 4 g or more	7	−0.21	0/7	+0.20	−0.41	−0.35
Cut below 3 g	8	+0.28	8/8	+0.19	+0.09	+0.39
Cut of 3 g or more	10	−0.03	3/10	+0.20	−0.23	−0.19

Note: Before/after change in the utility of a drink, net of price and market effects, by size of the cut in sugar. National brands in the levy's scope. Reformulated drinks: $\hat{\kappa}_j$. Not reformulated: the same difference at the relaunch dates of the group, one value per drink.

The 7 national brands that cut 4 g or more lose demand: None have a positive $\hat{\kappa}_j$, the median is -0.21 against +0.20 for the drinks that changed nothing. Hence a difference of -0.41 at the median product with a mean of -0.35. The 11 that cut less than 4 g all have a positive $\hat{\kappa}_j$, with a median of +0.25 against +0.18 for the median product of the non reformulated.

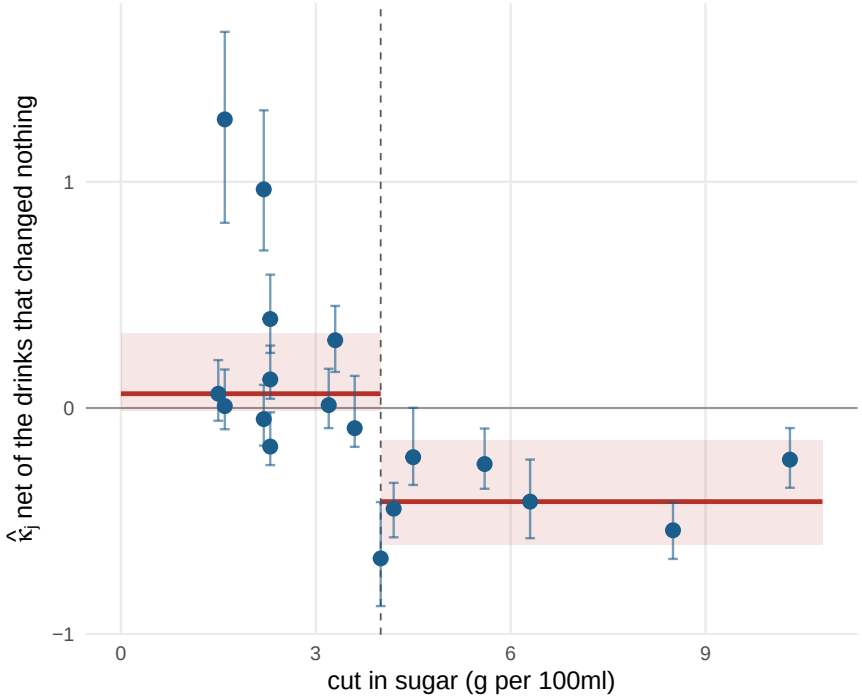


Figure 5: The effect of a reformulation.

Note: One point per national brand reformulated drink: $\hat{\kappa}_j$ less the before/after difference of the drinks that changed nothing at the relaunch dates. Dashed line: cut-off between small and large cuts. 2.5th to 97.5th percentiles obtains over 50 bootstrap replications, in which households are drawn with replacement and the demand estimated again.

3.2 Profit maximisation under taxation and strategical recipies

The profit maximisation model estimated here is defined has a two stages game. In the first, firms choose the recipes of their drinks, knowing the schedule of the levy. In the second, recipes being given, they set prices in every market.

Firms set prices in static Bertrand-Nash competition. Firm f owns the drinks $\mathcal{J}_{ft}$ and keeps, per litre, the wholesale price net of VAT, less marginal cost and the levy. With VAT at rate v charged on the levy-inclusive price, the first-order conditions stack to

$$p_t - \eta_t = (1+v)\,(c_t + \tau_t), \qquad \eta_t = -(O_t \circ G_t)^{-1} s_t, \qquad G_t(j,k) = \frac{\partial s_{kt}}{\partial p_{jt}}, \tag{8}$$

where O_t is the ownership matrix, η_t the markup in consumer prices and τ_{jt} the levy per litre at the tier of the recipe as sold, from implementation, zero for exempt drinks. Based on the demand estimates, equation (8) retrieve marginal costs from observed equilibrium prices (Berry et al., 1995, 2004; Nevo, 2001).

In the first step of the game the firm changes a recipe when the yearly profit it gains exceeds the cost of the change; the decision observed, to reformulate or to keep paying the levy, turns that gain into a bound on the cost, in the manner of Koujianou Goldberg and Hellerstein (2013). It didn't force that the observed recipes are always at the optimum. It can even rationalize that each drink has an optimal recipe, the one its owner would sell if changing a recipe cost nothing. Before the levy no firm reformulates, but that does not mean every drink is at its optimal recipe. Coming back to the estimates of κ_j, it was clear earlier that the sign of κ_j wasn't defined. For some drinks that are at or really close to the optimal sugar level any change moves them away from it and lowers their demand, $\kappa_j < 0$. For others a better recipe exists, moving to it would raise their demand, $\kappa_j > 0$, and they have not moved because the cost of the change exceeds what the better recipe would bring. The levy create incentives to reformulate for the first one while enhancing the incentive for the second one.

A recipe choice is a vector $r = (r_j)_j$ with $r_j \in \{0,1\}$: drink j sells its old recipe ($r_j = 0$) or its new one ($r_j = 1$). Given r and the levy ℓ, prices $p(r,\ell)$ are the Bertrand-Nash equilibrium of each market, and the variable profit of firm f agregated to one year is

$$\Pi_f(r,\ell) = \sum_t \sum_{k \in \mathcal{J}_f} \left(\frac{p_{kt}}{1+v} - c_{kt} - \tau_{kt} \right) M_t\, s_{kt}, \tag{9}$$

with v the VAT rate, c the marginal cost, M_t the size of market t, s_{kt} the share of drink k at the prices $p(r,\ell)$ and τ_{kt} the levy per litre at the tier of the recipe drink k sells. The recipe of drink j enters (9) in two places: the levy it pays, and its mean utility, which the new recipe shifts by the effect of its group. Both move the shares and the prices of every drink in the market.

Assumption 1 (Information) *A firm decides to reformulate knowing the cost F_j of the change and the effect $\bar{\kappa}_{g(j)}$ that a reformulation of that size has on demand, and before the demand shocks ξ_{jt} are realized.*

Under Assumption 1 the decision depends on $(\bar{\kappa}_{g(j)}, F_j)$ and not on ξ_{jt}, so the demand estimates remain valid when recipes are chosen. The part of $\hat{\kappa}_j$ that is specific to the drink is a surprise to the firm, or a drift that has nothing to do with the recipe; it does not enter the decision.

The effect of a new recipe on demand is the effect of its group:

$$\bar{\kappa}_{\text{small}} = 0, \qquad \bar{\kappa}_{\text{large}} = -0.41. \tag{10}$$

The effect of a small cut is set to zero, its estimate not being distinguishable from zero. Whether the drink was at its optimal recipe is not observed and not necessary here. A large cut lowers demand, which is what is expected of a drink moved far from any recipe it had. A small cut shows no loss, and no gain either.

The new recipe of drink j costs F_j. Firm f chooses the recipes of its drinks to maximize its profit net of these costs, given the recipes r_{-f} of the other firms:

$$\max_{(r_j)_{j\in\mathcal{J}_f}} \quad \Pi_f\big(r_f, r_{-f}, \ell\big) \; - \sum_{j\in\mathcal{J}_f} F_j\, r_j. \tag{11}$$

Assumption 2 (Recipe equilibrium) *The observed recipes r^* solve (11) for every firm, given the recipes of the others.*

If r_f^* solves (11), it does at least as well as any other choice of the firm, and in particular as the choice that differs from it by the recipe of one drink. Write $(1, r_{-j}^*)$ and $(0, r_{-j}^*)$ for the observed recipes with drink j at its new and at its old recipe, and define the gain from the new recipe of drink j,

$$G_j(\ell) = \Pi_f\big(1, r_{-j}^*, \ell\big) - \Pi_f\big(0, r_{-j}^*, \ell\big). \tag{12}$$

For a drink that reformulated, $r_j^* = 1$, and keeping the old recipe must not have been better:

$$\Pi_f\big(1, r_{-j}^*, \ell\big) - F_j \;\geq\; \Pi_f\big(0, r_{-j}^*, \ell\big) \quad\Longleftrightarrow\quad F_j \leq G_j(\ell). \tag{13}$$

For a drink that still pays the levy, $r_j^* = 0$, and the new recipe must not have been better:

$$\Pi_f\big(0, r_{-j}^*, \ell\big) \;\geq\; \Pi_f\big(1, r_{-j}^*, \ell\big) - F_j \quad\Longleftrightarrow\quad F_j \geq G_j(\ell). \tag{14}$$

The same maximization held before the levy was announced, with no levy, $\ell = 0$, and no drink reformulated then. For a drink that the levy led to reformulate, (14) holds without the levy and (13) with it. Writing $G_j^0 = G_j(0)$ and $G_j^1 = G_j(\ell)$,

$$G_j^0 \;\leq\; F_j \;\leq\; G_j^1, \tag{15}$$

a bound on both sides. For a drink that still pays the levy, the two inequalities go the same way and only the larger binds: $F_j \geq G_j^1$. The width of (15) is $G_j^1 - G_j^0$, the part of the gain that comes from the levy: the bounds are tight for a drink that avoids little levy and wide for one that avoids much.

3.3 Results of the decomposition

The levy was announced in March 2016 with its thresholds and took effect in April 2018. The firms decided in between, on the market they knew. The gain is therefore evaluated on one year, the thirteen markets of 2017, the last full year before the levy. The question the model rationalize the firms put to each drink is the following: over a year like this one, with the levy in force, does the firm earn more with the new recipe than with the old one? Everything compared is an equilibrium of the model in that year. The demand of 2017 and the marginal costs recovered from the prices of 2017 are kept; the levy is charged on every liable drink at the tier of its recipe; prices are solved again. Nothing observed after April 2018 enters the gain. G_j^1 is the gain in that year with the levy, G_j^0 the gain in the same year without it: the two differ by the levy and by nothing else. The year is also the clean baseline: the observed prices of 2017 contain no levy, so the marginal costs recovered from them are unpolluted, and the year with no levy and the old recipes is almost the year as it was.

The gain of a drink depends on the recipes of the others. Three cases are computed: first, all the other decision drinks sell their old recipe; last, all the others sell their final recipe, the recipe equilibrium of Assumption 2 and the case reported as the estimate; and 30 random orders, in which a drink sees the new recipes of the reformulated drinks placed before it and the old recipes of those placed after[8]. This test give us our first result. Between deciding first and deciding last, the gain changes by 3% at the median over the decision drinks, and by 7% at most. The sign of the gain never depends on the order.

[8]The dates of the relaunches are not used as an order: within a firm and across firms they are interleaved, and they reflect production and listing calendars as much as decisions.

Table 10: The gain from reformulating

	Sugar	Expected	Litres	Levy	Gain in a year with the levy, G_j^1					Without the levy, G_j^0		Break-even
							Random order					
Drink	(g/100ml)	effect	(m/year)	alone	first	last	min	median	max	first	last	κ_j^*
A1	10.3 → 4.7	−0.41	21.2	3,516	1,207	1,183	1,183	1,194	1,207	−2,176	−2,208	−0.71
B1	13.0 → 4.5	−0.41	19.6	4,531	1,167	1,137	1,137	1,152	1,167	−3,150	−3,210	−0.60
B2	8.7 → 4.5	−0.41	15.7	3,377	869	846	846	858	869	−2,342	−2,394	−0.60
C1	15.2 → 4.9	−0.41	7.1	1,248	364	355	355	359	363	−828	−843	−0.64
D1	9.1 → 4.6	−0.41	6.3	1,042	357	349	349	354	357	−644	−655	−0.71
E1	11.0 → 4.7	−0.41	4.2	738	202	197	197	198	202	−500	−510	−0.62
F1	10.9 → 4.8	−0.41	3.2	613	86	83	83	85	86	−488	−498	−0.50
G1	11.0 → 7.0	−0.41	9.7	275	−338	−332	−338	−335	−332	−975	−987	−0.17
H1	7.2 → 4.9	+0.00	22.3	3,048	3,113	3,048	3,048	3,088	3,113	0	0	−0.59
I1	6.9 → 4.6	+0.00	11.2	1,523	1,563	1,523	1,523	1,539	1,563	0	0	−0.59
J1	6.6 → 3.3	+0.00	8.3	1,163	1,195	1,163	1,163	1,175	1,195	0	0	−0.55
I2	6.4 → 4.8	+0.00	7.8	1,022	1,050	1,022	1,022	1,035	1,050	0	0	−0.66
I3	6.9 → 4.6	+0.00	5.4	733	753	733	733	742	753	0	0	−0.52
K1	6.9 → 4.7	+0.00	3.7	528	537	528	528	534	537	0	0	−0.33
K2	6.2 → 4.7	+0.00	2.4	319	325	319	319	321	325	0	0	−0.33
K3	6.9 → 4.7	+0.00	1.8	156	159	156	156	157	159	0	0	−0.37
K4	6.3 → 4.7	+0.00	0.9	132	134	132	132	132	134	0	0	−0.35
F2	10.3 → 7.1	+0.00	2.4	89	91	89	89	90	91	0	0	−0.12
F3	10.7 → 7.1	+0.00	2.0	75	77	75	75	76	77	0	0	−0.12

Note: The gain from reformulating over the year 2017, national brands in the levy's scope that changed their recipe, in thousand pounds per year. Upper panel: cuts of 4 g or more; lower panel: smaller cuts. Levy alone: the gain with no effect on demand. First, last: the other drinks at their old, final recipe. κ_j^*: effect on demand at which the gain with the levy is zero.

For a reformulated drink, G_j^1 is an upper bound on its cost F_j and G_j^0 a lower bound. With the levy, 18 of the 19 drinks gain from their new recipe; the median gain is 355 thousand pounds per year (Table 10). Of the 8 drinks that cut 4 g or more, 7 gain, with a median of 352 thousand pounds; the loss of demand takes most of the levy avoided, and 26% of it is left at the median. Without the levy, none of them would have gained. The 11 drinks that cut less than 4 g gain 528 thousand pounds at the median; their expected effect on demand is zero, so the gain is purely the levy avoided, and without the levy none of them would gain.

Table 11: The gain from a hypothetical reformulation

	Sugar	Expected	Litres	Levy	Gain in a year with the levy, G_j^1					Without the levy, G_j^0		Break-even
							random orders: min, median, max					
Drink	(g/100ml)	effect	(m/year)	alone	first	last				first	last	κ_j^*
L1	10.6 → 4.9	−0.41	136.1	22,262	7,722	7,456	7,478	7,623	7,722	−14,266	−14,432	−0.70
M1	11.0 → 4.9	−0.41	55.9	8,932	3,198	3,136	3,136	3,167	3,198	−5,503	−5,587	−0.73
L2	11.2 → 4.9	−0.41	8.5	1,468	459	442	443	451	458	−932	−944	−0.66
N1	10.0 → 4.9	−0.41	7.0	1,226	362	349	349	353	361	−798	−808	−0.64
N2	12.2 → 4.9	−0.41	4.3	756	221	213	213	216	221	−493	−499	−0.64
O1	10.5 → 4.9	−0.41	2.8	538	49	46	46	47	49	−449	−456	−0.46
P1	10.0 → 4.9	−0.41	2.1	440	−34	−35	−36	−35	−34	−441	−452	−0.38

Note: The gain from a hypothetical reformulation to 4.9 g/100ml over the year 2017, national brands that pay the levy and kept their recipe, in thousand pounds per year. Columns as in Table 10.

For a drink that still pays, the gain is a lower bound on its cost. With no effect on demand, all 7 would gain from leaving the levy; at the effect of a large cut, 6 of 7 still would (Table 11). The largest is drink L1, the leading cola: 22.3 million pounds per year of levy avoided, and 7.5 million at the effect of a large cut. The median break-even effect of the

drinks that still pay is −0.64. A cost common to all drinks in pounds per year is rejected: L1 gives up 7.5 million pounds a year by keeping its recipe, while the drinks that reformulated did so for 355 thousand at the median. Per litre sold, at the expected effect, the drinks that still pay would gain 0.05 pounds at the median; the drinks that made a large cut gain 0.05. This is in part by construction: they start in the same tier and are given the same effect on demand, so their gains per litre can differ only by their margins and ownership matrix.

The structural estimates available here won't help us answer to the question why did a product reformulate and why another one did not, distinguish between is not the question the model was targeting. The aim is to be able to disentagle the reaction in prices and recipes. In order to do that the following decomposition compares four worlds over one year, the thirteen markets of 2017. Each is an equilibrium of the model with the demand and the marginal costs of that year and the observed ownership:

	new recipes	old recipes
levy	S_{11}	S_{10}
no levy	S_{01}	S_{00}

$S_{\ell r}$ is the world with the levy ($\ell = 1$) or without it ($\ell = 0$) and with the new recipes ($r = 1$) or the old ones ($r = 0$). S_{00} is the year 2017 with every drink at its old recipe. It is the year as it was, except for the 8 drinks in the levy's scope that already sold their new recipe during part of it: they are put back to their old one, which raises the sugar bought from 70 thousand tonnes to 73. The levy is charged on every liable drink at the tier of the recipe it sells in that world. The drinks that change recipe between the right and the left column are the 29 drinks in the levy's scope that reformulated in the sample, 19 national brands and 10 own labels; recipe changes of exempt drinks carry no levy motive and are kept as observed. A new recipe changes three things: the sugar content of the drink, its levy tier, and its demand, by the effect (10) of a reformulation of that size[9].

[9]Marginal costs do not depend on the recipe. The observations whose first-order condition is not valid at the observed prices, the cheapest own labels, keep their observed prices.

Table 12: The levy's effect on sugar: prices versus recipes.

	Bertrand-Nash	Marginal-cost pricing
Change in sugar purchased (% of the year without the levy)	−30.4	−27.6
Levy first: the levy on the old recipes, then the new recipes		
prices ($S_{10} - S_{00}$)	−24.1	−20.1
recipes ($S_{11} - S_{10}$)	−6.3	−7.5
share through prices (%)	79	73
Recipes first: the new recipes without the levy, then the levy		
recipes ($S_{01} - S_{00}$)	−14.0	−13.9
prices ($S_{11} - S_{01}$)	−16.4	−13.7
share through prices (%)	54	50
Average of the two orders		
prices	−20.2	−16.9
recipes	−10.2	−10.7
share through prices (%)	67	61
Change in litres purchased (%)	−2.7	−2.4

Note: The levy's effect on the sugar bought in the inside goods over one year, in % of the year without the levy. Bertrand-Nash: prices solve (8). Marginal-cost pricing: prices move by the levy and VAT. Their average following the Shapley split of the total (Shorrocks, 2013)

$$\text{price} = \tfrac{1}{2}\left[(S_{10} - S_{00}) + (S_{11} - S_{01})\right], \qquad \text{recipe} = \tfrac{1}{2}\left[(S_{01} - S_{00}) + (S_{11} - S_{10})\right]$$

The levy and the new recipes lower the sugar bought in the inside goods by 30.4% (Table 12), and the litres bought by 2.7%. The levy alone, on the old recipes, lowers sugar by 24.1%. The new recipes alone, without any levy, lower it by 14.0%. Together they give 30.4%, less than the sum by 7.7 points. On the old recipes, 14% of the litres and 45% of the sugar sells would pay the levy; with the new recipes, 8% and 28%. If reformulation had no effect on demand, the recipe channel would be 8.7 points instead of 10.2, and the total 28.9%. Most of the recipe channel is therefore the sugar taken out of each litre, not the buyers lost (around 15% of the sugar reduction).

Table 13 shows the effect of reformulation on total welfare. Consumer surplus is the log-sum of the logit divided by the marginal utility of income,

$$CS_w = \sum_t M_t \sum_i w_i \frac{1}{\alpha_i} \log\left(1 + \sum_j e^{V^w_{ijt}}\right),$$

with V^w_{ijt} the utility of (3) net of ε_{ijt}, so that $CS_w - CS_{00}$ is the compensating variation of the year. Profits are those of (9), the levy and VAT taken out of the wholesale price. Total welfare adds to these the cost of the new recipes, each reformulated brand at the midpoint of its bounds (15), and the sugar avoided, in kilograms, valued at the social cost of £3 per kilogram of Section 2.1:

$$W_w = \Delta CS_w + \Delta\Pi_w + R_w + \Delta T_w - K_w + \phi\,(Q_{00} - Q_w), \qquad \phi = 3.$$

R_w is the revenue of the levy, zero in S_{00}; ΔT_w the change in VAT collected on soft drinks and K_w the cost of the new recipes.

On the old recipes the levy costs consumers 95 million pounds a year and brand manufacturers 35 million in margin, and raises 56 million. With the new recipes consumers lose 80 million, manufacturers -27 million, and the levy raises 32 million: reformulation returns 15 million pounds to consumers and 9 million to manufacturers, and takes 25 million from the revenue of the levy. The gain of the manufacturers is before the cost of changing the recipes. It is the gain of all the new recipes taken together and not the sum of the gains estimated before at product level. New recipes without the levy would lower the manufacturers' profit (by 3 million), since the large cuts lose demand and avoid nothing.

Table 13: Welfare decomposition

	Levy alone	New recipes alone	Levy and new recipes
Sugar purchased (%)	−24.1	−14.0	−30.4
Litres purchased (%)	−3.3	−0.7	−2.7
Consumer surplus (£m)	−95	−24	−80
Levy revenue (£m)	56	0	32
Variable profit, brand manufacturers (£m)	−35	−3	−27
Variable profit, retailers' own labels (£m)	+1	+1	+3
Litres paying the levy (% of litres)	13.9	0.0	7.6

Note: Accounts of the levy over one year, Bertrand-Nash pricing, against S_{00}, the year without the levy and with the old recipes. Consumer surplus, levy revenue and variable profits in million pounds per year.

Table A17 in the appendix G shows the effect by household group. In proportion to what each group buys, the reduction is the same for all at around 30% with a recipe channel of 10 %. The loss of consumer surplus is 4.7 pence per litre bought for AB households and 4.0 for E households. Households in lower grades are more sensitive to price: they move away from the taxed drinks more, and a given rise in price costs them less in pounds.

4 The take away to understand them all

In order to enhance the future design of sin taxes. We can use the current developed model to evaluate a set of different counterfactual and understand what does it tell about sin taxation in general and about effective taxes on soft drinks in particular.

Before going further we can say that the drink reformulates if $F_j \leq G_j^L$: for sure if G_j^L exceeds the upper bound on F_j, for sure not if it is below the lower bound, and otherwise the bounds do not say. Three worlds follow in the whole counterfactual analysis: the fewest reformulations, the most, and the expected outcome when F_j is uniform between its bounds (100 draws).

Every counterfactual schedule is therefore solved in four worlds, each an equilibrium of the model on the year 2017: Recipes observed: every drink at the recipe it sells at the end of the sample, so the new schedule acts through prices alone. Fewest: only the drinks whose bounds say they reformulate for sure do so. Expected: the mean over 100 draws in which each undetermined drink's cost is drawn uniform between its bounds and the drink reformulates when the draw falls below its gain. Most: every drink that the bounds do not rule out reformulates.

The counterfactual schedule taxes every liable drink at 0.3 pence per gram of sugar, with no threshold. The firm still chooses between two recipes, the old one and the one observed. In that sense it's a very restrictive counterfactual as the decision of the firm is very limited (and with limited reason in regards to the design) but the results may still be informative.

Table 14: Threshold against linear tax

	Tiers		Linear tax			
	old recipes	observed recipes	old recipes	new recipes fewest	new recipes expected	new recipes most
Sugar purchased (%)	−24.1	−30.4	−29.1	−32.3	−34.5	−35.8
Litres purchased (%)	−3.3	−2.7	−4.3	−4.5	−4.4	−4.3
Consumer surplus	−95	−80	−124	−127	−125	−122
Revenue of the tax	56	32	78	71	67	64
Change in VAT revenue	−3	−4	−4	−4	−5	−5
Variable profit, brand manufacturers	−35	−27	−46	−44	−44	−42
Variable profit, retailers' own labels	+1	+3	−8	−3	−3	−4
Cost of the new recipes (expected)	0	1	0	-1	-3	-4
Sugar avoided, at the social cost	+52	+66	+63	+70	+75	+78
Welfare	−23	−9	−40	−36	−31	−27
Social cost at which welfare is zero (pence per gram)	0.43	0.34	0.49	0.46	0.42	0.41
National brands that reformulate	0	19	0	3	11	19

Note: The linear tax is 0.3 pence per gram of sugar. Sugar avoided valued at 3 pounds per kilogram.

The linear tax is a heavier tax. At the same marginal rate it taxes the sugar below the threshold and taxes the flagships at more than 24p per litre. On the old recipes it raises 78 million against 56, lowers sugar by 29.1% against 24.1%, and costs consumers 124 million against 95.

Table 15 show us that gain from the new recipe falls for every drink but the two that moved from the high tier to the lower tier. The bounds settle few cases: 3 drinks reformulate for sure, 0 do not, and 16 are not determined. With the reformulations it induces, the linear tax lowers sugar by 34.5% in expectation, against 30.4%, but its effect on welfare is -31 million against -9, and its break-even social cost, 0.42 pence per gram, is above that of the tiers. The range over the reformulations the bounds allow, from -36 to -27 million, does not reach the tiers. Nevertheless as seen for the tier design the reformulation while enhancing the sugar effect, limit the consumer surplus loss and the total welfare loss.

Table 15: The gain from the new recipe

	Sugar	Litres	Gain from the new recipe			Probability	
Drink	(g/100ml)	(m/year)	no tax	tiers	linear tax	under the linear tax	
H1	7.2 → 4.9	22.3	0	3,056	829	0.27	not determined
B1	13.0 → 4.5	19.6	−3,218	1,142	798	0.92	not determined
J1	6.6 → 3.3	8.3	0	1,165	532	0.46	not determined
I1	6.9 → 4.6	11.2	0	1,526	430	0.28	not determined
C1	15.2 → 4.9	7.1	−845	356	340	0.99	not determined
I3	6.9 → 4.6	5.4	0	734	218	0.30	not determined
I2	6.4 → 4.8	7.8	0	1,024	195	0.19	not determined
K1	6.9 → 4.7	3.7	0	529	168	0.32	not determined
A1	10.3 → 4.7	21.2	−2,214	1,188	143	0.69	not determined
F2	10.3 → 7.1	2.4	0	89	133	1.00	reformulates
F3	10.7 → 7.1	2.0	0	75	125	1.00	reformulates
K2	6.2 → 4.7	2.4	0	320	71	0.22	not determined
K3	6.9 → 4.7	1.8	0	157	48	0.31	not determined
E1	11.0 → 4.7	4.2	−512	198	31	0.76	not determined
K4	6.3 → 4.7	0.9	0	132	31	0.23	not determined
D1	9.1 → 4.6	6.3	−657	350	−37	0.62	not determined
F1	10.9 → 4.8	3.2	−499	83	−44	0.78	not determined
G1	11.0 → 7.0	9.7	−989	−333	−113	1.00	reformulates
B2	8.7 → 4.5	15.7	−2,400	849	−440	0.60	not determined
L1	10.6 → 4.9	136.1	−14,459	7,476	910	–	does not
M1	11.0 → 4.9	55.9	−5,599	3,146	681	–	does not
L2	11.2 → 4.9	8.5	−945	443	89	–	does not
N2	12.2 → 4.9	4.3	−500	214	84	–	does not
N1	10.0 → 4.9	7.0	−809	350	−39	–	does not
O1	10.5 → 4.9	2.8	−457	46	−83	–	does not
P1	10.0 → 4.9	2.1	−453	−35	−152	–	does not

Note: The gain from the new recipe under three schedules, national brands in the levy's scope, thousand pounds per year, the other drinks at the recipes observed. Probability: that $F_j \leq G_j^L$ when F_j is uniform between its bounds.

The counterfactual where the schedule change for 2028 are tested. A rise in the amount at each threshold, the lower threshold falls from 5 to 4.5 grams of sugar per 100ml, and pre-packaged milk-based drinks enter the scope[10]. The model is built for these questions: the drinks that left the levy landed just below the old threshold, and a lower threshold asks them to decide again, while a higher rate changes what every drink gains from its recipe. The exercise takes the rate rise alone, the lower threshold alone, and the two together. Of

[10]Only one milk-based drink enter the scope in this application.

the drinks sold in 2017 and in the levy's scope, 23 sit below 5 grams and at or above 4.5 in the recipe observed at the end of the sample: 15 national brands that reformulated, 2 that never changed their recipe, and 6 own labels. The first cuts landed between 4.5 and 4.9 grams, that is 0.3 grams below the threshold at the median; a second cut is taken to land the same distance below the new threshold, at 4.2 grams.

Table 16: The reform of 2028 on the year 2017

	Levy of 2018	Rates uprated	Threshold 4.5 g, rates of 2018				Threshold 4.5 g, rates uprated				
	observed	observed	observed	fewest	expected	most	observed	fewest	expected	most	exp., milk
Sugar purchased (%)	−30.4	−31.8	−32.6	−31.2	−31.2	−31.5	−34.3	−32.7	−32.7	−33.0	−32.9
Litres purchased (%)	−2.7	−2.8	−3.6	−2.7	−2.7	−2.7	−3.9	−2.9	−2.9	−2.8	−2.9
Consumer surplus	−80	−85	−106	−81	−81	−80	−115	−87	−87	−85	−88
Revenue of the levy	32	33	53	40	40	32	57	43	43	33	44
Change in VAT revenue	−4	−4	−5	−4	−4	−4	−5	−4	−4	−4	−4
Variable profit, brand manufacturers	−27	−29	−36	−27	−27	−27	−39	−30	−30	−29	−30
Variable profit, retailers' own labels	+3	+3	−0	−4	−4	+3	−1	−6	−6	+3	−6
Sugar avoided, at the social cost	+66	+69	+71	+68	+68	+69	+75	+71	+71	+72	+72
Welfare	−9	−13	−24	−10	−9	−8	−30	−14	−14	−11	−14
Social cost at which welfare is zero (pence per gram)	0.34	0.36	0.40	0.34	0.34	0.33	0.42	0.36	0.36	0.35	0.36
Drinks that cut a second time	0	0	0	15	15	23	0	15	15	23	15

Note: The first column is the levy of 2018 with the recipes observed; the second raises its rates to 20.8 and 27.8 pence per litre, recipes unchanged. Under a threshold of 4.5 grams: the recipes observed (no second cut), then the fewest, the expected and the most second cuts the bounds allow; "exp., milk" adds the milk-based drinks to the scope. Sugar avoided valued at 3 pounds per kilogram.

At the recipes observed, the higher rates raise the revenue of the levy from 32 to 33 million and cost consumers 6 million more; sugar falls by 31.8% against 30.4%, through prices alone, and welfare moves from -9to -13 million. The rise does not change the set of drinks that pay, and all the drinks that still pay could now find a large cut worth its cost.

If no drink reacts, the threshold puts the reformulated drinks back in the lower tier: the levy raises 53 million and sugar falls by 32.6%. The gain from a second cut of a national brand runs from 136 to 3,122 thousand pounds a year, 696 at the median (Table 17): it is the levy avoided on the drink's volume, less what a lower price costs its siblings, with no direct loss of demand. The bounds settle every case: all 15 brands cut for sure, none is undetermined. This follows mostly from the structure of the problem. A drink whose first cut was small faces the same decision again, mostly the same levy avoided with no loss of demand. A drink whose first cut was large keeps the levy saving but no longer loses demand, so G_j^2 exceeds G_j^1, which bounds F_j from above. Only the product without a bound are open cases. In expectation 15 drinks cut a second time, at a cost of 0.5 million. Sugar then falls by 31.2% against 30.4% under the levy of 2018, the levy raises 40 million against 32, and welfare is the same. The lower threshold on its own removes a little more sugar at no cost to welfare, because the second cuts are cheap and lose no demand. The range over the second cuts the bounds allow runs from -10 to -8 million.

With the uprated rates the second cut is worth more: 778 thousand pounds at the median, and the same 15 drinks cut for sure. Sugar falls by 32.7% and welfare is -14 million, against 30.4% and -9 under the levy of 2018. The two changes seems additive, and 7 of the 7 drinks that still pay could now find a large cut worth its cost.

Table 17: The drinks caught by a threshold of 4.5 grams

			Bounds on F_j		4.5 g, rates of 2018		4.5 g, rates uprated	
Drink		Sugar	lower	upper	gain	cuts again	gain	cuts again
Own label 1	own label	4.5	–	–	3,269	no bound	3,799	no bound
H1	reformulated	4.9	0	3,048	3,122	yes	3,470	yes
B1	reformulated	4.5	−3,210	1,137	2,532	yes	2,839	yes
A1	reformulated	4.7	−2,208	1,183	1,979	yes	2,200	yes
B2	reformulated	4.5	−2,394	846	1,887	yes	2,117	yes
Own label 2	own label	4.9	–	–	1,608	no bound	1,870	no bound
I1	reformulated	4.6	0	1,523	1,567	yes	1,743	yes
Own label 3	own label	4.7	–	–	1,112	no bound	1,294	no bound
I2	reformulated	4.8	0	1,022	1,053	yes	1,164	yes
Own label 4	own label	4.6	–	–	1,006	no bound	1,169	no bound
Q1	never changed	4.9	–	–	951	no bound	1,072	no bound
I3	reformulated	4.6	0	733	756	yes	846	yes
C1	reformulated	4.9	−843	355	696	yes	778	yes
D1	reformulated	4.6	−655	349	586	yes	651	yes
K1	reformulated	4.7	0	528	543	yes	617	yes
Own label 5	own label	4.8	–	–	430	no bound	500	no bound
E1	reformulated	4.7	−510	197	411	yes	460	yes
Own label 6	own label	4.7	–	–	400	no bound	466	no bound
F1	reformulated	4.8	−498	83	338	yes	382	yes
K2	reformulated	4.7	0	319	329	yes	373	yes
K3	reformulated	4.7	0	156	161	yes	181	yes
K5	never changed	4.7	–	–	143	no bound	162	no bound
K4	reformulated	4.7	0	132	136	yes	154	yes

Note: The drinks caught by a threshold of 4.5 grams: liable, below 5 grams and at or above 4.5 in the recipe observed. Bounds on F_j from the first decision and the gain from a second cut, thousand pounds per year, the other drinks at the recipes observed, under two schedules.

5 Limitations and concluding remark

As shown in the first part of this article, the sample selection is an important part of the policy evaluation. Until now the structural results only comes from the sample defined by the top 100 products per period rule.

Table 18 recap the results of the same analysis on the 50,75,100,125,150 product rules. Central results of the analysis are not dependant of that choice. New recipes alone lower sugar by 12.6 to 15.9% across the five universes, and the effect of a large cut is always negative, from -0.25 to -0.53. The ranking of the tax design holds in the first 4. At the top 150 the price sensitivity is low enough for the linear tax to do better than the tiers. The same finding is also appearing with the boostrap analysis on the top 100 sample. Part of the estimates, with very low prices sensitivity, lead to a better linear tax scenario.

This is the main limitation of the estimates and results presented here. Price sensitivity falls as tail products are added, from 4.73 with the top 50 to 1.73 with the top 150. With it the price channel and the levy's total effect shrink, from 38.4% to 20.3% of sugar, and the share through prices runs from 38 to 59% with the recipes first and from 56 to 84% with the levy first. Part of this pattern is plausibly due to adding products that depart from the top sellers, but most of it reflects the loss of precision that comes with a larger choice set, where market shares plummet and the outside option shrinks.

Table 18: Changing the sample

	Drinks in each market, by volume				
	top 50	top 75	top 100 (benchmark)	top 125	top 150
Drinks in the universe	93	135	184	234	291
National brands that reformulated	11	16	19	23	26
of which large cuts	5	7	8	9	10
National brands that still pay	3	5	7	10	12
Mean price sensitivity $E[\alpha_i]$	4.73	2.02	3.78	2.85	1.73
Median own-price elasticity	-1.99	-1.30	-1.95	-1.66	-1.19
Effect of a large cut on demand	-0.53	-0.33	-0.41	-0.28	-0.25
Pass-through, Bertrand	1.52	1.27	1.53	1.46	1.20
Sugar, levy and new recipes (% fall)	38.4	27.9	30.4	27.3	20.3
levy alone, old recipes	32.2	19.1	24.1	20.7	11.4
new recipes alone	15.9	14.6	14.0	13.2	12.6
Share through prices, levy first (%)	84	69	79	76	56
Share through prices, recipes first (%)	59	48	54	52	38
Welfare, levy with the recipes observed (GBP m)	-10	-14	-9	-9	-1
Welfare, linear tax, expected (GBP m)	-28	-28	-31	-29	+11
Brands caught by a 4.5 g threshold that cut again for sure	8 of 8	12 of 12	15 of 15	18 of 18	–

Note: Each column is a full run of the chain on the drinks that rank among the N best-selling by volume in at least one market of 2017 and 2018, with the demand estimated again, the same instruments and demographics as the benchmark, and every counterfactual solved on the year 2017.

While Dickson et al. (2025) estimate that 84% of the effect comes from reformulation, the present analysis did not include that possibility in the bounds of the potential results. It shows that changes in recipes account for a third of the levy's effect on sugar. When prices move only by the levy and VAT, the marginal-cost pricing benchmark, the share of recipes

rises to 39% on average over the two orders and to 50% with the recipes counted first. At most, 62% of the effect can be attributed to reformulation. A particular lever that is, to my knowledge, not much discussed in the literature is the 15% of the reformulation impact that can be attributed to consumer substitution due to preferences in recipes.

What remains stable, in accordance with the literature, is that the levy was designed to change recipes, and it did. Agreeing with Dickson et al. (2025), it is relevant to consider a tiered tax. The estimates show that most products that are close to the threshold show strong incentives to reformulate without any fear of loss in demand. While this is not the case for the products further away from the threshold, which suffer an identified loss in utility, the gain from avoiding the levy is sufficient to incentivise reformulation even in that case. This nevertheless does not preclude considering a linear tax with a threshold that would keep the intended feature of the current one while creating more incentives for the right-hand side of the distribution.

The substantiality of the levy matters too. The rates of 2017 have proven sufficient to induce reformulation and decrease sugar. An increase in the rates would enhance these effects, but at the cost of consumer surplus and firms' profits. Whether or not such an increase is welfare-enhancing depends on the estimated social cost of sugar. At £3 per kilogram, none of the applications shown above leads to a positive total welfare. At £4, most would. If the true cost is below £3, it is difficult to rationalize this intervention, whereas if it is higher than £4, there is room for more substantial taxes. Which is the case is not a question this article can answer.

References

Aguilar, A., Gutierrez, E., and Seira, E. (2021). The effectiveness of sin food taxes: Evidence from Mexico. *Journal of Health Economics*, 77:102455.

Allcott, H., Lockwood, B. B., and Taubinsky, D. (2019). Should We Tax Sugar-Sweetened Beverages? An Overview of Theory and Evidence. *Journal of Economic Perspectives*, 33(3):202–227.

Bandy, L. K., Scarborough, P., Harrington, R. A., Rayner, M., and Jebb, S. A. (2020). Reductions in sugar sales from soft drinks in the UK from 2015 to 2018. *BMC medicine*, 18(1):20.

Barahona, N., Otero, C., and Otero, S. (2023). Equilibrium Effects of Food Labeling Policies. *Econometrica*, 91(3):839–868. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.3982/ECTA19603.

Berry, S., Levinsohn, J., and Pakes, A. (1995). Automobile Prices in Market Equilibrium. *Econometrica*, 63(4):841.

Berry, S., Levinsohn, J., and Pakes, A. (2004). Differentiated Products Demand Systems from a Combination of Micro and Macro Data: The New Car Market. *Journal of Political Economy*, 112(1):68–105.

Boncomtpe, Javier (2026). Shaping More Than Prices: Corrective Taxes with Product Reformulation.

Bonnet, C. and Réquillart, V. (2013). Tax incidence with strategic firms in the soft drink market. *Journal of Public Economics*, 106:77–88.

Capacci, S., Allais, O., Bonnet, C., and Mazzocchi, M. (2019). The impact of the French soda tax on prices and purchases. An ex post evaluation. *PLOS ONE*, 14(10):e0223196.

Cawley, J., Thow, A. M., Wen, K., and Frisvold, D. (2019). The Economics of Taxes on Sugar-Sweetened Beverages: A Review of the Effects on Prices, Sales, Cross-Border Shopping, and Consumption. *Annual Review of Nutrition*, 39(Volume 39, 2019):317–338.

Colchero, M. A., Popkin, B. M., Rivera, J. A., and Ng, S. W. (2016). Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. *BMJ*, 352:h6704.

Colchero, M. A., Rivera-Dommarco, J., Popkin, B. M., and Ng, S. W. (2017). In Mexico, Evidence Of Sustained Consumer Response Two Years After Implementing A Sugar-Sweetened Beverage Tax. *Health Affairs*, 36(3):564–571.

Conlon, C. and Gortmaker, J. (2026). Incorporating Micro Data into Differentiated Products Demand Estimation with PyBLP. *Journal of Econometrics*, 257:105926.

Dickson, A., Gehrsitz, M., and Kemp, J. (2025). Does a Spoonful of Sugar Levy Help the Calories Go Down? An Analysis of the UK Soft Drinks Industry Levy. *The Review of Economics and Statistics*, 107(6):1754–1763.

Dubois, P., Griffith, R., and O'Connell, M. (2020). How Well Targeted Are Soda Taxes? *American Economic Review*, 110(11):3661–3704.

Etilé, F., Lecocq, S., and Boizot-Szantai, C. (2021). Market heterogeneity and the distributional incidence of soft-drink taxes: evidence from France. *European Review of Agricultural Economics*, 48(4):915–939.

Griffith, R., O'Connell, M., and Smith, K. (2017). The Importance of Product Reformulation Versus Consumer Choice in Improving Diet Quality. *Economica*, 84(333):34–53. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ecca.12192.

Griffith, R., O'Connell, M., Smith, K., and Stroud, R. (2019a). *The evidence on the effects of soft drink taxes*. IFS.

Griffith, R., O'Connell, M., and Smith, K. (2018). Corrective Taxation and Internalities from Food Consumption. *CESifo Economic Studies*, 64(1):1–14.

Griffith, R., O'Connell, M., and Smith, K. (2019b). Tax design in the alcohol market. *Journal of Public Economics*, 172:20–35.

Koujianou Goldberg, P. and Hellerstein, R. (2013). A Structural Approach to Identifying the Sources of Local Currency Price Stability. *The Review of Economic Studies*, 80(1):175–210.

Nevo, A. (2001). Measuring Market Power in the Ready-to-Eat Cereal Industry. *Econometrica*, 69(2):307–342. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/1468-0262.00194.

Rogers, N. T., Pell, D., Mytton, O. T., Penney, T. L., Briggs, A., Cummins, S., Jones, C., Rayner, M., Rutter, H., Scarborough, P., Sharp, S., Smith, R., White, M., and Adams, J. (2023). Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: a controlled interrupted time series analysis. *BMJ Open*, 13(12):e077059.

Scarborough, P., Adhikari, V., Harrington, R. A., Elhussein, A., Briggs, A., Rayner, M., Adams, J., Cummins, S., Penney, T., and White, M. (2020). Impact of the announcement and implementation of the UK Soft Drinks Industry Levy on sugar content, price, product size and number of available soft drinks in the UK, 2015-19: A controlled interrupted time series analysis. *PLOS Medicine*, 17(2):e1003025.

Seiler, S., Tuchman, A., and Yao, S. (2021). The Impact of Soda Taxes: Pass-Through, Tax Avoidance, and Nutritional Effects. *Journal of Marketing Research*, 58(1):22–49.

Shorrocks, A. F. (2013). Decomposition procedures for distributional analysis: a unified framework based on the Shapley value. *The Journal of Economic Inequality*, 11(1):99–126.

Silver, L. D., Ng, S. W., Ryan-Ibarra, S., Taillie, L. S., Induni, M., Miles, D. R., Poti, J. M., and Popkin, B. M. (2017). Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. *PLOS Medicine*, 14(4):e1002283.

Sun, L. and Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *Journal of Econometrics*, 225(2):175–199.

Appendices A to C document the data. Appendices D, Appendix E, F and G some supplementary material on the ITS, the demand estimates, the supply and the decomposition results.

A The cleaning and classification algorithm

Rule 1: per drink-period, the volume-dominant sugar and calorie density across the drink's barcodes.
Rule 2: final state = volume-modal consensus over the last six periods; from the first period within 0.2 g of it, lock to the final state (symmetric in direction).
Rule 3: a series that starts at exactly 0 g and ends at or above 5 g/100 ml is a description change (pure-juice and mixer recodes), not a possible reformulation; the initial zeros are rewritten to the final state (sugar and calories), so the drink is a non-mover, not an upward crosser.
Sample selection: drinks with $\geq$ 6 positive-sale periods, plus continuous late entrants (present in every period from first appearance to the sample end, excluding drinks first seen in the final period), describe in Table A3.

Table A1: Reach of the cleaning rules.

			% of cells changed			Drinks	Market share of changed cells (%)		
Sample	Drinks	Barcodes	Rule 1	Rule 2	Rule 3	touched %	Frequency	Spend	Volume
All drinks	6,438	7,847	1.75	6.37	0.08	23.8	5.5	4.8	4.6
Top-100	227	837	4.76	3.96	0.00	37.0	5.3	4.6	4.1
Top-250	610	1,408	3.74	3.84	0.00	28.0	5.2	4.5	4.3
Top-500	1,198	2,164	3.24	4.54	0.00	26.5	5.3	4.6	4.5
Top-1000	2,415	3,567	2.45	4.92	0.08	24.6	5.3	4.7	4.6
Top-2000	5,145	6,530	1.84	6.12	0.08	24.5	5.5	4.8	4.6
Top-3000	6,438	7,847	1.75	6.37	0.08	23.8	5.5	4.8	4.6

Note: Reach of the cleaning rules, by product-selection sample. Columns: share of barcode-period cells whose value is changed by each rule; the share of drinks with at least one changed cell; and the market weight of the changed cells, the share of the sample's purchase records, spend and volume sitting in cells either rule changed. "All drinks" is the whole panel.

Table A2: Concentration across drinks.

Largest drinks (by volume)	Brands (count)	Frequency (% of records)	Spend (% of £)	Volume (% of litres)
Top-100	82	37.9	44.3	54.9
Top-250	160	54.2	58.7	69.3
Top-500	249	68.6	71.6	80.8
Top-1,000	433	82.8	83.9	90.9
Top-2,000	735	94.0	94.3	97.4
Top-3,000	1,035	97.8	97.8	99.2
All 6,438 drinks	2,095	100.0	100.0	100.0

Note: Concentration across drinks: the share of purchase frequency (records), spend and volume held by the largest drinks, ranked by volume as in the top-N rule used throughout.

Table A3: The minimum-observations floor

Floor ($\geq k$ periods)	Drinks kept	Drinks dropped (% of drinks)	Market share dropped records	spend	volume	Late entrants retained
$k = 2$	5,981	457 (7.1%)	0.03%	0.04%	0.02%	0
$k = 3$	5,644	794 (12.3%)	0.08%	0.09%	0.05%	31
$k = 4$	5,309	1,129 (17.5%)	0.19%	0.19%	0.11%	88
$k = 5$	5,017	1,421 (22.1%)	0.35%	0.34%	0.20%	115
$k = 6$	4,771	1,667 (25.9%)	0.53%	0.49%	0.31%	128

Note: The estimation-panel sample rule: drinks kept and dropped by the minimum-observations floor as it varies from ≥ 2 to the adopted ≥ 6 of the 39 periods; the dropped (intermittent) drinks' market share under the three definitions of Table A2; and the continuous late entrants that the exemption retains (final-period entrants excluded).

B Panel construction

B.1 The dilutables exclusion

Dilutable squash is the one concentrate category in these data (662 drinks on 736 barcodes, 8.9% of the unrestricted category's as-sold volume), and its recorded sugar density has no consistent basis. The statute makes the basis decisive: for dilutables the SDIL thresholds apply to the drink as prepared at the stated dilution ratio, while the data record a single density per 100 ml with no dilution-ratio field. Direct inspection shows the recording basis is mixed product by product. Some products are demonstrably recorded as sold: One squash sold as "double strength" carries exactly twice the density of the same-flavour regular version of the same brand (21 against 9.9 g orange), and a high-juice and barley tail runs 19 to 52 g/100 ml, calorie densities above any prepared drink. Others are demonstrably recorded as prepared: a leading blackcurrant squash records 10.9 g/43 kcal, its well-documented ready-to-drink value, a five-fold denser syrup as sold, and drops to 4.6 g in mid-2018, exactly its publicised reformulation to just under the threshold per 100 ml as prepared. A further 41 barcodes show one-step density drops by factors of 5 to 10 clustered around implementation: dilution-basis flips, not recipe changes. No within-data rule can assign every squash product its statutory tier under these conditions, so the category is excluded from the baseline sample.

B.2 Reformulation

Table A4: Drinks and reformulators by subcategory

Subcategory	Drinks	Tier-cross.	% cross.	Mean drop (g)	Vol. share %
Colas	160	10	6	5.0	33.2
Lemonade/other carb.	1767	209	12	3.9	29.1
Chilled juice	1430	46	3	3.3	13.7
Juice drinks	976	56	6	5.6	10.0
Energy/one-shot	1241	40	3	3.8	6.3
Mixers/tonic	295	20	7	2.5	4.9
Flavoured milk	549	17	3	1.9	2.4
Other carbonates	20	3	15	1.8	0.4

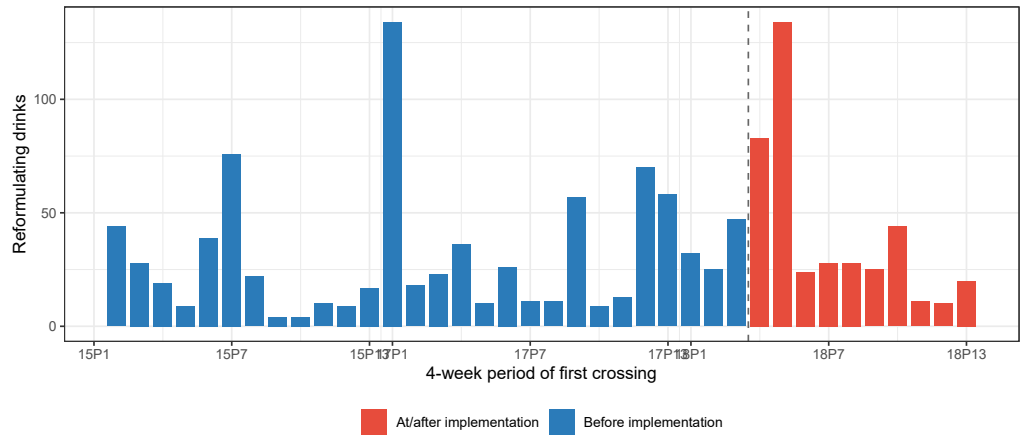


Figure A1: Timing of detected reformulation.

Note: Timing of detected reformulation (drinks), by 4-week period; dashed line = implementation; 2016 absent from the data, hence first period of 2017 agregates those reformulations.

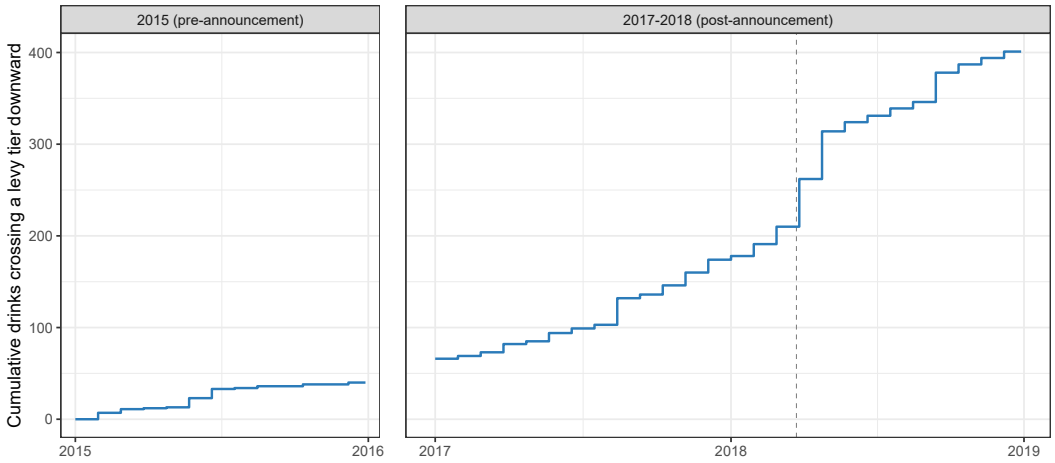


Figure A2: Cumulative reformulation by week.

Note: Reformulation timing: cumulative number of drinks that have crossed a levy tier downward, by week of crossing.

B.3 Household

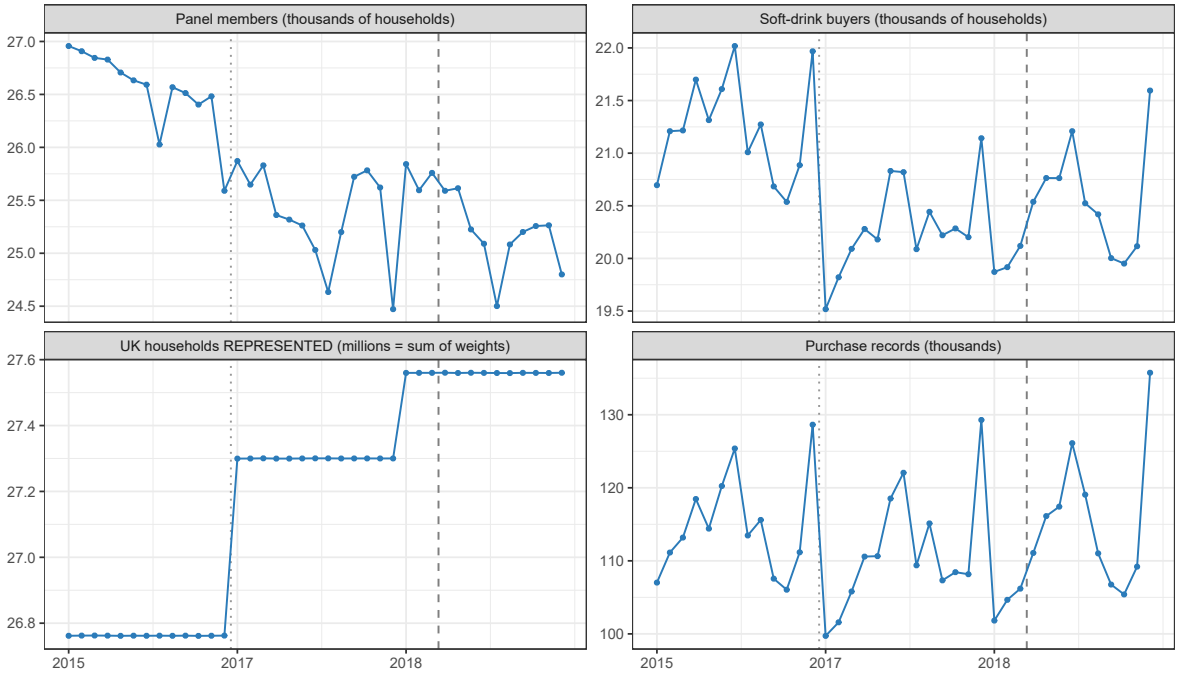


Figure A3: Panel integrity.

Note: Panel integrity, by 4-week period. Top row: households actually in the panel (thousands), members, and the subset buying soft drinks that period. Bottom left: the UK households those members represent (millions = the sum of their survey weights); a step function because the provider calibrates the weights to official annual household-population totals (26.8 → 27.3 → 27.6m). Membership drifts down ∼8% while the represented population is pinned; the mean weight per member rises correspondingly (≈1,010 → 1,090).

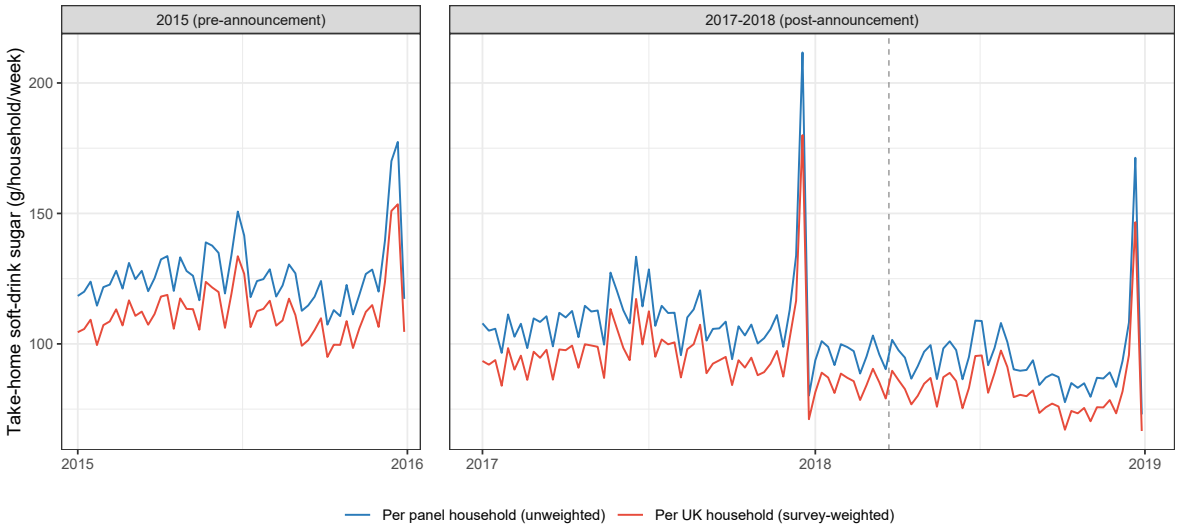


Figure A4: Take-home sugar per household per week.

Note: Take-home soft-drink sugar per household per week: panel (unweighted) and national (survey-weighted).

Table A5: Product turnover by levy tier.

Panel A: drinks already sold in 2015, by pre-period tier — shares of the 2015 market (before any exit)					
		Exit early	Share of 2015 market (%)		
	Drinks	(%)	Frequency	Spend	Volume
Exempt (< 5 g)	1,027	52.4	38.8	38.1	51.8
of which exit early	538		6.6	4.6	6.9
Standard rate (5–8 g)	399	68.7	6.3	6.8	4.8
of which exit early	274		1.8	1.5	1.1
Higher rate (≥ 8 g)	2,501	62.7	55.0	55.1	43.4
of which exit early	1,568		21.2	18.2	14.2
Panel B: drinks first seen 2017–2018 (entrants), by final tier — shares of the 2017–2018 market (once inside)					
			Share of 2017–18 market (%)		
	Drinks		Frequency	Spend	Volume
Exempt (< 5 g)	879		8.5	7.4	7.7
Standard rate (5–8 g)	461		2.1	2.2	1.1
Higher rate (≥ 8 g)	1,171		9.0	8.0	5.3

Note: Product turnover by levy tier (tiers from cleaned sugar), with market shares measured at the relevant date. Panel A: drinks already sold in 2015, by pre-period tier; "exit early" = last seen at least three periods before the window ends; the share columns give the group's weight in the 2015 market, with a second line for the exiting drinks themselves. Panel B: drinks first seen in 2017 and 2018, and their weight in the 2017 to 2018 market.

Table A6: Market weight of the estimation samples.

	Treated (tier-crossers)				Controls (non-movers)			
Sample	Drinks	Freq. %	Spend %	Vol. %	Drinks	Freq. %	Spend %	Vol. %
All drinks	377	12.90	13.20	10.70	3,588	67.87	70.65	74.16
Top-100 drinks	26	5.78	6.20	5.39	156	35.68	42.65	51.50
Top-250 drinks	68	8.23	8.60	7.39	416	48.26	53.08	62.29
Top-500 drinks	129	10.76	11.08	9.53	827	57.12	60.79	68.62
Top-1000 drinks	238	12.22	12.50	10.36	1,669	64.44	67.39	72.79
Top-2000 drinks	366	12.89	13.19	10.70	3,267	67.71	70.52	74.13
Top-3000 drinks	377	12.90	13.20	10.70	3,588	67.87	70.65	74.16

Note: Market weight of the first section estimation samples: treated (tier-crossing) and control (non-mover) drinks' share of the whole category's purchase frequency, spend and volume.

C The households in detail

Table A7: Household's characteristics (a)

	2015		2018	
Share of households (%)	Panel	Weighted	Panel	Weighted
Household size (persons)				
1	18.3	31.2	18.0	31.0
2	36.1	33.6	35.9	34.4
3	18.8	15.5	18.4	15.4
4	18.2	13.2	19.2	13.0
5+	8.6	6.5	8.5	6.2
Children in household				
No children	66.5	74.6	67.0	74.4
1 child	14.9	12.0	14.3	12.1
2 children	13.7	9.9	14.2	10.1
3+ children	4.8	3.6	4.5	3.4
Household income (per year)				
Under £20,000	27.8	32.8	23.6	29.2
£20,000-39,999	32.9	31.2	32.6	31.1
£40,000+	24.6	21.3	27.7	24.2
Not stated	14.7	14.8	16.0	15.5
Social class				
AB	21.6	25.1	21.6	25.1
C1	38.1	27.2	39.5	28.1
C2	17.9	20.3	17.4	19.5
DE	22.3	27.4	21.5	27.3

Table A8: Household's characteristics (b)

	2015		2018	
Share of households (%)	Panel	Weighted	Panel	Weighted
Main shopper age				
Under 35	14.5	19.9	11.7	19.9
35-44	22.1	17.3	21.4	16.5
45-54	22.7	19.5	24.3	19.3
55-64	19.1	16.3	19.9	16.9
65+	21.6	27.0	22.6	27.5
Region				
North	26.6	24.8	26.1	24.7
South	24.0	22.8	23.8	22.8
Midlands	17.1	16.3	17.0	16.3
London	8.7	12.0	8.8	12.1
East	10.7	9.6	10.8	9.6
Scotland	8.2	9.4	8.5	9.4
Wales	4.7	5.1	5.0	5.1
Urban / rural				
Suburban	36.1	34.7	35.7	33.7
Urban	34.7	34.1	33.4	33.4
City	13.2	16.2	14.6	17.9
Semi-rural	11.4	10.7	11.5	10.6
Rural	4.6	4.2	4.8	4.4
Lifestage				
Retired	19.8	25.6	20.7	26.0
Empty Nesters	23.4	23.1	23.7	23.2
Pre-Family	11.7	17.8	10.0	17.4
Young Family 0-4 Years	14.7	12.0	12.9	12.0
Older Dependents	11.6	8.1	12.7	7.9
Middle Family 5-9 Years	9.7	6.8	10.3	7.1
Family 10+ Years	9.0	6.6	9.8	6.5

Table A9: Take-home purchasing by household size, age, region and lifestage.

		2015 (pre-announcement)					2018		
	House-holds	Litres /pers/wk	Sugar g/pers/wk	Sugar g/litre	% vol. ≥ 5 g	% vol. later reformulated	Sugar g/pers/wk	Sugar g/litre	Δ sugar /pers (%)
All households	32,084	0.92	48	52	29.9	11.6	36	41	-25
By household size (persons)									
1	6,002	1.10	56	51	27.7	12.2	47	40	-17
2	11,649	1.02	49	48	26.3	10.7	37	38	-25
3	6,814	0.91	48	53	31.9	11.9	36	41	-26
4	6,380	0.83	46	56	32.6	11.9	33	44	-30
5+	2,997	0.72	41	57	34.8	12.7	29	45	-29
By main shopper age									
Under 35	6,054	0.78	44	57	34.1	12.3	32	46	-28
35-44	7,908	0.91	48	53	30.2	10.9	34	41	-29
45-54	7,571	1.06	56	53	31.5	12.1	40	39	-28
55-64	6,195	1.05	48	46	26.1	10.7	38	37	-20
65+	6,564	0.86	45	52	26.0	12.1	37	41	-18
By region									
East	3,421	0.93	48	52	29.5	11.9	37	42	-24
London	2,975	0.81	51	63	37.4	14.9	38	50	-26
Midlands	5,503	0.92	48	52	29.8	11.8	35	39	-27
North	8,498	0.92	45	49	27.6	10.3	33	38	-26
Scotland	2,703	1.14	59	52	31.4	14.0	42	39	-29
South	7,642	0.88	46	53	29.0	10.6	35	42	-24
Wales	1,500	1.01	49	48	28.4	10.0	37	38	-23
By lifestage									
Empty Nesters	7,511	1.17	53	45	25.9	10.5	41	35	-22
Family 10+ Years	3,303	1.03	58	57	33.8	13.0	41	44	-29
Middle Family 5-9 Years	3,728	0.81	45	56	31.9	11.3	32	44	-28
Older Dependents	3,830	0.97	51	52	31.8	12.5	37	40	-27
Pre-Family	4,571	1.05	54	52	30.5	11.8	39	41	-28
Retired	6,053	0.87	45	52	25.4	12.0	37	41	-17
Young Family 0-4 Years	5,889	0.67	38	57	33.1	11.0	28	45	-28

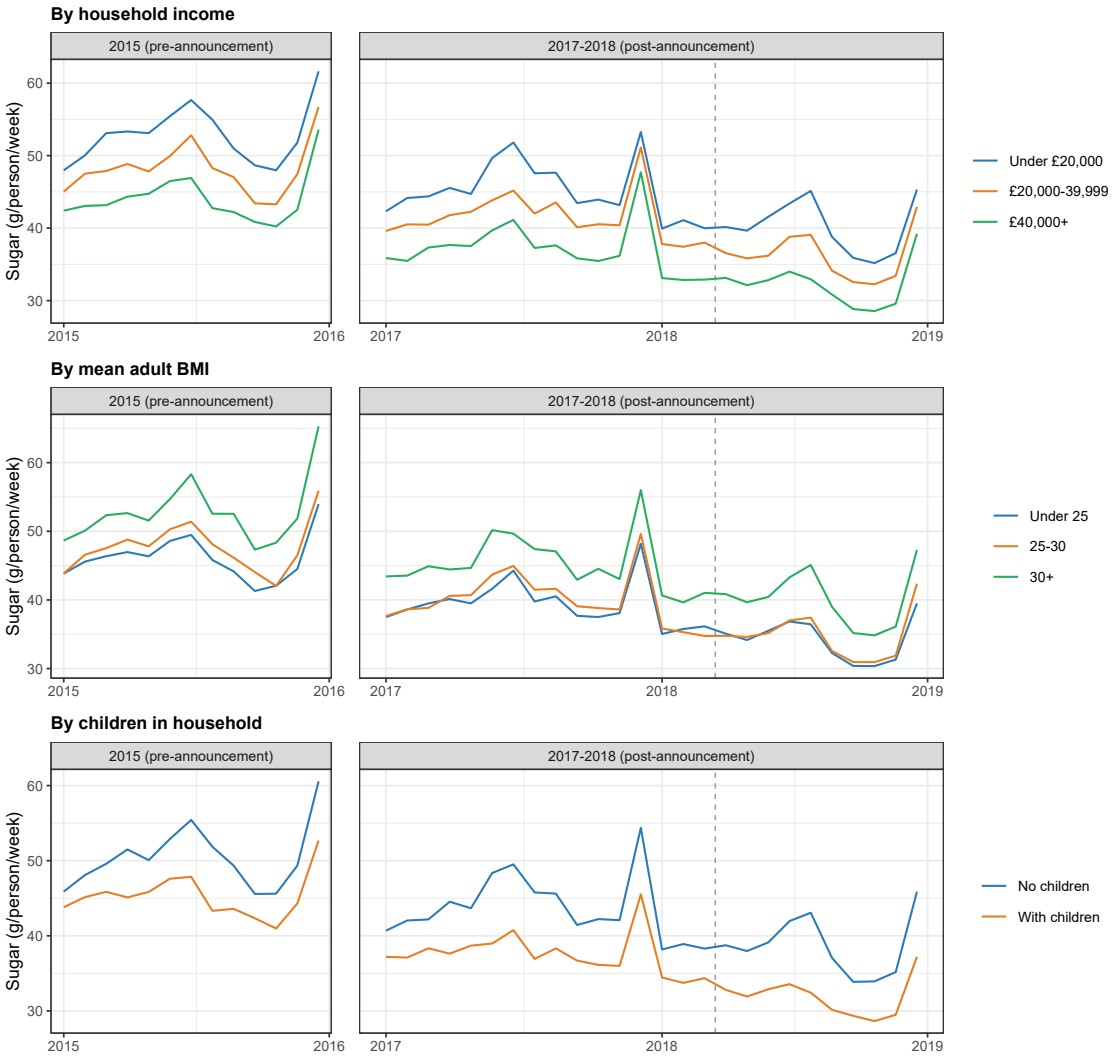


Figure A5: Take-home sugar per person by household type.

Note: Take-home soft-drink sugar per person per week by household type, 4-week periods, survey-weighted: by household income band, by mean recorded adult BMI, and by presence of children; dashed line = implementation.

D Supplementary material on ITS

Table A10: Volume shifts at implementation.

Subcategory	Panel volume (thousand litres)	National (weighted) (m litres)
Levied drinks (≥ 5 g/100 ml at implementation)		
Colas	-3.159*** (0.822)	-3.264*** (0.764)
Lemonade	-1.661*** (0.555)	-1.898*** (0.529)
Mixers/tonic	-0.085 (0.127)	-0.026 (0.119)
Energy/one-shot	-0.301 (0.520)	-0.307 (0.370)
Other carbonates	0.068** (0.030)	0.066* (0.033)
Diet counterparts (never liable, < 5 g throughout)		
Colas	2.808 (2.381)	2.699 (1.943)
sugar-free	2.766 (2.355)	2.671 (1.922)
low-sugar	0.042 (0.029)	0.028 (0.023)
Lemonade	4.862*** (1.355)	4.096*** (0.878)
sugar-free	2.146 (1.378)	1.566 (0.960)
low-sugar	2.717*** (0.381)	2.530*** (0.434)
Mixers/tonic	1.785*** (0.488)	1.607** (0.664)
sugar-free	1.259*** (0.414)	1.071* (0.572)
low-sugar	0.526*** (0.144)	0.536*** (0.160)
Energy/one-shot	-0.314 (0.539)	-0.193 (0.504)
sugar-free	-0.075* (0.040)	-0.057 (0.046)
low-sugar	-0.239 (0.539)	-0.136 (0.485)
Other carbonates	0.073 (0.078)	0.045 (0.079)
sugar-free	0.035 (0.065)	0.013 (0.069)
low-sugar	0.038 (0.044)	0.032 (0.036)
All diet	9.215*** (3.268)	8.254*** (2.191)
sugar-free	6.132* (3.290)	5.264** (2.214)
low-sugar	3.083*** (0.715)	2.990*** (0.828)

Note: The level shift β_2 of (2) with the group's volume. Panel volume is the litres recorded by the member households; national is the survey-weighted total. *, **, ***: significant at the 10%, 5% and 1% levels. The levied and diet shifts of this table, national column, are the volume response that enters Table 7.

Table A11: Volume shifts at implementation (gradient of sample)

	All levied				All diet	
Sample	Price $\hat{\beta}_2$ (GBP/litre)	Statutory levy	Pass-through	Volume, national (m litres)	Price $\hat{\beta}_2$ (GBP/litre)	Volume, national (m litres)
Top-100	0.224*** (0.029)	0.232	97%	-5.157*** (0.776)	0.056** (0.027)	6.669*** (1.575)
Top-250	0.200*** (0.025)	0.232	86%	-4.738*** (0.831)	0.058** (0.027)	7.058*** (1.978)
Top-500	0.190*** (0.023)	0.232	82%	-6.169*** (0.963)	0.057** (0.026)	7.533*** (2.016)
Top-1000	0.182*** (0.023)	0.231	79%	-6.875*** (1.104)	0.057** (0.026)	8.160*** (2.150)
Top-2000	0.175*** (0.022)	0.231	76%	-7.035*** (1.152)	0.057** (0.026)	8.267*** (2.192)
Top-3000	0.175*** (0.022)	0.231	76%	-7.052*** (1.156)	0.057** (0.026)	8.254*** (2.191)
All drinks	0.175*** (0.022)	0.231	76%	-7.052*** (1.156)	0.057** (0.026)	8.254*** (2.191)

Table A12: Volume shifts at implementation. (remove late)

Subcategory	Price $\hat{\beta}_2$ (GBP/litre)	Statutory levy	Pass-through	Volume $\hat{\beta}_2$, national (m litres)	Late reformulators dropped
Colas	0.295*** (0.023)	0.237	124%	-3.364*** (0.808)	8
Lemonade	0.294*** (0.085)	0.227	130%	-1.426*** (0.237)	143
Mixers/tonic	0.064 (0.082)	0.207	31%	-0.147 (0.131)	13
Energy/one-shot	0.072* (0.039)	0.236	30%	-0.220 (0.286)	28
Other carbonates	0.052 (0.046)	0.183	28%	0.010 (0.023)	2

Table A14: Demand estimates.

	Estimate	S.e.
Price sensitivity $\alpha_i = \exp(\mu_a + \pi' y_i + \sigma_a \nu_i)$		
μ_a (log mean)	1.157^{***}	0.220
σ_a (log dispersion)	0.582^{***}	0.106
π: number of children (per sd)	-0.035	0.027
π: age of main shopper (per sd)	-0.059^{***}	0.022
π: social grade (per sd)	$+0.051^{***}$	0.013
Taste for the inside goods $\gamma' y_i$		
γ: number of children (per sd)	$+0.701^{***}$	0.035
γ: age of main shopper (per sd)	$+0.472^{***}$	0.025
γ: social grade (per sd)	$+0.243^{***}$	0.025
Mean price sensitivity $E[\alpha_i]$	3.78	
Median own-price elasticity	-1.95	
Median diversion to the outside good	0.32	
Markets / drink×market observations	26 / 4,198	
Drinks / recipes / reformulated drinks	184 / 223 / 39	

Note: Standard errors clustered by brand; For σ_a by the delta method. $E[\alpha_i]$ is mean price sensitivity in the population. The first-step estimates are in Appendix E. *, **, ***: significant at the 10%, 5% and 1% levels.

E First-step demand estimates

Table A13: First-step demand estimates

	Estimate	S.e.
Price sensitivity $\alpha_i = \exp(\mu_a + \pi' y_i + \sigma_a \nu_i)$		
μ_a (log mean)	1.549^{***}	0.480
σ_a (log dispersion)	0.694^{***}	0.188
π: number of children (per sd)	-0.106	0.072
π: age of main shopper (per sd)	-0.095^{**}	0.048
π: social grade (per sd)	$+0.041^{**}$	0.017
Taste for the inside goods $\gamma' y_i$		
γ: number of children (per sd)	$+1.003^{***}$	0.128
γ: age of main shopper (per sd)	$+0.505^{***}$	0.050
γ: social grade (per sd)	$+0.246^{***}$	0.046
Mean price sensitivity $E[\alpha_i]$	6.03	

Note: First-step demand estimates (standard micro moments). *, **, ***: significant at the 10%, 5% and 1% levels.

F Supplementary material on supply results

Table A15: Markups and marginal costs

	Obs.	Price	Markup η_{jt} (medians [q25, q75]; £/litre)	Cost c_{jt}
All drink-markets	4,198	0.70	0.383 [0.285, 0.484]	0.248 [0.050, 0.435]
Levy-paying	164	1.20	0.535 [0.487, 0.600]	0.286 [0.197, 0.579]
Liable categories, below 5 g or pre-levy	3,071	0.47	0.349 [0.275, 0.480]	0.094 [0.050, 0.379]
Exempt categories	963	0.81	0.401 [0.365, 0.448]	0.343 [0.237, 0.522]

Note: Markups and marginal costs, net of VAT and levy, by levy status: medians over the drink-market observations of the group, with the interquartile range in brackets. Levy-paying: observations that pay the levy at the recipe sold. Liable categories: the drinks in the levy's scope that are below 5 g or observed before implementation.

Table A16: The heteregeneous targeting of the levy

Firm	Obs.	Volume (%)	Price (medians)	Markup (medians)	Levy-paying (% of post-levy vol.)	Pass-through (£/£ levy)
Manufacturer 1	672	30.1	0.97	0.533	25.9	1.17
Manufacturer 2	506	20.3	0.91	0.467	8.4	1.29
Retailer 1	799	12.7	0.40	0.316	0.3	-0.07
Retailer 2	436	12.5	0.30	0.295	2.4	-0.12
Retailer 3	423	5.4	0.27	0.271	0.0	–
Retailer 4	329	5.0	0.26	0.273	18.9	-0.17
Manufacturer 3	78	3.0	0.70	0.363	0.0	–
Manufacturer 4	156	3.0	1.08	0.442	0.0	–
Retailer 5	259	2.8	0.33	0.277	0.6	-0.14
Retailer 6	156	1.8	0.39	0.291	0.0	–
Manufacturer 5	98	1.1	1.50	0.527	0.0	–
Manufacturer 6	52	0.6	0.75	0.372	5.0	-0.29
Manufacturer 7	78	0.5	1.75	0.564	24.3	0.19
Manufacturer 8	78	0.5	1.68	0.548	85.1	-1.01
Manufacturer 9	26	0.4	0.97	0.415	60.5	0.14
Manufacturer 10	26	0.2	1.33	0.485	0.0	–
Manufacturer 11	26	0.2	1.09	0.434	9.3	1.02

Note: Levy-paying: the litres the firm sold while paying the levy, in % of the litres it sold from implementation. Pass-through is computed here as a descriptive difference-in-differences per drink, in regards to what is done in the first part. It is the change in the drink's volume-weighted price between the markets before implementation and those in which it pays the levy, net of the same change for the never-liable drinks of the sample, divided by the levy per litre the drink paid at its recipe; the firm's figure averages its drinks weighted by the litres sold while paying.

G Supplementary material on decomposition results

Table A17: The decomposition by household group

	Households	Bertrand-Nash			Marginal-cost	Consumer surplus
	(%)	total	price	recipe	total	(pence per litre)
Social grade						
AB	24.0	−30.1	−19.9	−10.3	−27.3	−4.7
C1	27.9	−30.4	−20.2	−10.2	−27.6	−4.5
C2	20.0	−30.4	−20.3	−10.1	−27.6	−4.3
D	16.1	−30.6	−20.5	−10.1	−27.7	−4.1
E	12.0	−30.6	−20.6	−10.1	−27.8	−4.0
Children in the household						
None	68.0	−30.6	−20.4	−10.2	−27.8	−4.5
One	15.0	−30.5	−20.4	−10.1	−27.7	−4.3
Two	12.2	−29.8	−19.7	−10.1	−27.1	−4.3
Three or more	4.8	−29.4	−19.2	−10.2	−26.7	−4.1

Note: The decomposition by household group, in % of each group's sugar in the year without the levy; consumer surplus with the levy and the new recipes, in pence per litre bought.