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Who pays and Who benefits? A distributional health-economic evaluation of strengthening the UK soft drinks industry levy

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Abstract

This paper examines the distributional welfare effects of strengthening the UK Soft Drinks Industry Levy (SDIL). Using individual-level dietary data from the UK National Diet and Nutrition Survey, we simulate three scenarios for strengthening the SDIL within a comparative risk assessment framework and translate policy-induced reductions in sugar intake from sugar-sweetened beverages into changes in quality-adjusted life years over a 10-year horizon. Health gains are monetised at willingness-to-pay thresholds of £20,000 and £30,000 per quality-adjusted life year, while consumer burden is expressed relative to household resources using Office for National Statistics income and expenditure benchmarks.

Results show that stronger levy designs yield greater reductions in sugar intake and body mass index, and deliver positive net monetised benefits under the two stronger scenarios. Health gains are disproportionately concentrated among more deprived groups because baseline sugar-sweetened beverage exposure is socially graded, and these groups exhibit greater price responsiveness. Health-gain ratios between the most and least deprived quintiles consistently exceed the corresponding burden ratios across all age groups. When expressed relative to income or expenditure, consumer burden shares decline monotonically from the most to the least deprived quintile, confirming financial regressivity. Weighted gradient tests show that this regressivity is a consistent structural feature across age groups rather than being concentrated in any particular life stage. Overall, a strengthened levy appears regressive in payment incidence but progressive in health terms, highlighting the importance of jointly assessing financial burdens and health benefits when evaluating corrective health taxes.

Keywords Soft Drinks Industry Levy · Sugar-sweetened beverages · Health taxation · Distributional incidence · Health equity · Quality-adjusted life years · Obesity prevention · Health-economic evaluation

JEL classification I12 · I18 · H23 · D63 · C63

Introduction

Sugar-sweetened beverages (SSBs) are a major source of free sugars and are linked to obesity, type 2 diabetes, and dental disease, imposing substantial downstream health and economic costs [1, 2]. In the United Kingdom, soft drinks remain an important contributor to sugar intake, particularly among children, thereby strengthening interest in fiscal interventions to reduce consumption and improve diet quality [3]. From a public economics perspective, SSB taxation is typically justified as a corrective instrument to address health-related externalities and encourage substitution towards lower-sugar alternatives [4]. This rationale is particularly relevant for tiered sugar-based levies such as the UK Soft Drinks Industry Levy (SDIL), which targets sugar concentration rather than beverage volume alone [5].

A growing international evidence base suggests that SSB taxes can reduce purchases and sugar intake, although the magnitude of these effects depends on policy design, the extent of tax pass-through to consumer prices, and behavioural responses [6–10]. The UK SDIL is distinctive in

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both structure and policy intent[1]. It is levied upstream on manufacturers and importers and was explicitly designed to drive reformulation alongside consumer response [7, 11]. Existing evaluations indicate that reformulation has been a central channel of impact and that the levy has generated measurable health gains and favourable cost-effectiveness outcomes [7, 12]. Complementary producer-level evidence from other European settings indicates that soda taxes can affect domestic sales and firm financial outcomes without necessarily generating employment losses, underscoring that incidence can extend beyond consumers [13]. Policy impacts may also operate partly through informational channels; announcement effects in the SDIL setting have been interpreted as consistent with a tax-as-signal mechanism [14].

For policy evaluation, however, average effects are insufficient. In the case of corrective taxation, a central question is not only whether the policy improves outcomes on average, but also how its costs and benefits are distributed across the population. This issue is particularly important for SSB taxation because consumption is socially patterned, with higher baseline exposure among more deprived groups [3, 15]. Consequently, an SSB tax may be financially regressive in terms of payment incidence, yet welfare-progressive if the resulting health gains are larger for disadvantaged populations [4, 16–20]. Although this tension is increasingly recognised in the broader literature, SDIL-focused evidence that jointly evaluates health-economic benefits and explicit distributional incidence remains limited.

These questions have become more policy-relevant following the UK government's November 2025 decision to strengthen the SDIL by lowering sugar thresholds and broadening product coverage, with implementation planned for January 2028 [21]. Against this background, this paper evaluates the distributional welfare effects of alternative SDIL-strengthening scenarios in the UK. Using nationally representative dietary microdata from the National Diet and Nutrition Survey (NDNS), we simulate three policy-strengthening scenarios and, within a comparative risk assessment health-economic framework, translate reductions in SSB sugar intake into changes in body mass index (BMI) and quality-adjusted life years (QALYs) over a 10-year horizon. We then monetise the resulting health gains and compare them with consumer burden across age groups and deprivation quintiles. The aim is therefore not only to assess whether stronger SDIL designs generate net benefits, but also to identify how those benefits and burdens are distributed across the population.

The paper addresses two related questions: whether stronger SDIL scenarios would yield net health and welfare gains in the UK, and how those gains and burdens would be distributed across the population. It makes three main contributions. First, it develops a UK-specific simulation of strengthened SDIL scenarios using nationally representative NDNS dietary data. Second, it integrates comparative risk assessment with economic valuation to translate changes in SSB sugar intake into effects on BMI, QALY gains, and monetised welfare outcomes. Third, it brings an explicitly distributional perspective to SDIL evaluation by examining how consumer burden and health benefits vary across age groups and deprivation quintiles. In doing so, the paper extends the literature beyond average policy effectiveness to the equity and welfare implications of SSB taxation.

Literature review

Economic rationale, market responses, and policy effectiveness

The economic rationale for taxing sugar-sweetened beverages rests on well-documented links between SSB intake and adverse health outcomes. The literature consistently shows that SSB consumption contributes to weight gain and incident type 2 diabetes, with weak satiety compensation for liquid calories providing a plausible behavioural mechanism [1, 2, 22, 23]. From a public economics perspective, these harms justify corrective fiscal instruments when private consumption choices do not fully internalise wider social costs [4]. Recent theory strengthens this case for tiered, sugar-density-based designs. Specifically, Eichner and Runkel [5] characterise the underlying distortion as a "missing market" for sugar content, implying that an efficient policy should target sugar concentration rather than beverage volume alone. The effects of taxation may extend further still. Barigozzi et al. [14] argue that tax announcements can serve as costly government signals about health risks, shaping behaviour even before full implementation.

How well these effects translate into welfare gains depends critically on market adjustment. Producer responses, price pass-through, and consumer substitution all mediate the relationship between a levy and its downstream impact [13]. Evidence from Mexico shows sustained reductions in SSB purchases after implementation, alongside substitution towards untaxed products [6, 24], while natural experiments in the United States report persistent declines in purchases across a range of settings [8–10]. The magnitude of these effects varies with the extent of pass-through and

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[1] HM Treasury's SDIL consultation explains the policy design and rationale for the levy, including its upstream application to producers and importers and its intended purpose to encourage reformulation by reducing the sugar content of soft drinks. See: HM Treasury (2016) *Soft Drinks Industry Levy: consultation*. London: HM Treasury. Available at: https://assets.publishing.service.gov.uk/media/5a80a0b040f0b62302694998/Soft_Drinks_Industry_Levy-consultation.pdf

with differences in price responsiveness across socioeconomic groups and consumption intensities [25–27]. For the UK SDIL, existing evaluations document substantial reductions in sugar content following the levy's announcement and implementation [7], driven primarily by reformulation rather than quantity contractions [28]. Cross-country European evidence is consistent with this, finding that tiered levies are associated with sizeable reductions in sales-weighted sugar concentration [29]. Reformulation matters for welfare because it can reduce harmful exposure while imposing a smaller utility loss than an equivalent reduction achieved solely through higher prices and lower quantities. That said, effectiveness may be attenuated if consumers substitute towards untaxed high-sugar foods, placing beverage-market effects within a wider dietary context [30].

However, observed reductions in purchases or sugar content do not, by themselves, establish welfare gains. To evaluate policy efficiency, behavioural responses must be linked to downstream health outcomes and assessed against the private costs imposed on consumers [25, 26]. For the SDIL, health-economic modelling has reported significant aggregate QALY gains and healthcare savings at the population level [12]. In addition, systematic reviews conclude that SSB taxes are often cost-effective and, in some cases, cost-saving when implementation costs are weighed against health and fiscal benefits [31]. Cross-country observational evidence sometimes shows limited immediate differences in outcomes such as diabetes prevalence [32], suggesting that measurable health returns may require longer horizons or complementary interventions. Taken together, these considerations strengthen the case for simulation frameworks that translate dietary change into downstream outcomes over explicit time horizons, as this study does.

Distributional incidence, equity, and age heterogeneity

Evidence from the UK and Europe shows that SSB consumption is higher among more deprived groups, reflecting disparities in the food environment, affordability constraints, differential marketing exposure, and broader structural determinants of diet [15, 33, 34]. These patterns imply that a given levy-induced reduction in consumption may yield larger absolute health gains for disadvantaged populations. At the same time, they raise concerns about financial regressivity if more deprived households devote a larger share of resources to taxed products [6, 18]. This tension maps directly onto the public economics distinction between payment incidence and welfare incidence. In other words, a tax may be regressive in financial terms yet welfare-progressive if the health harms it evades are disproportionately concentrated among disadvantaged groups [4, 16, 17]. Evidence on this is consistent with heterogeneous behavioural responses by socioeconomic status across settings, including UK loyalty card data and Mexican evidence that examines regressivity more directly [35, 36]. Critical perspectives continue to question both the fairness and the broader reach of such policies, arguing that substitution effects and structural drivers of diet may limit the extent to which beverage taxes can reduce wider inequalities [30, 37].

Despite this progress, many empirical studies still provide only partial accounts of incidence. Some separate financial burden from health valuation, while others estimate health effects without disaggregating results by deprivation. Distributional cost-effectiveness analysis provides a relevant methodological foundation for incorporating health inequality concerns into economic evaluation by examining how health gains are distributed across population subgroups [38]. Failure to disaggregate health effects and burden measures by deprivation can therefore limit the practical value of such evidence for policymakers [39]. This limitation becomes more consequential when stronger levy designs are considered, since changes in aggregate outcomes alone do not reveal how burdens and benefits are distributed across the socioeconomic gradient. For that reason, incidence needs to be assessed explicitly, ideally relative to household resources and in monetary terms [40]. Related extended cost–benefit approaches make a similar point by combining household budget burdens with medical cost savings and productivity channels in order to assess net distributional effects more comprehensively [41, 42].

Age adds a further dimension to this distributional picture that must be examined alongside deprivation. SSB consumption often peaks during adolescence, and reductions earlier in life may yield larger long-run returns because obesity tends to persist into adulthood and the benefits of lower exposure accumulate over a longer horizon [43]. Evidence on the SDIL across childhood age groups supports the plausibility of such heterogeneity [44], while modelling evidence from other settings suggests that distributional health gains may be amplified when intake is reduced earlier in the life course [45]. Examining age and deprivation jointly is therefore important for a complete account of distributional incidence.

Sugar-density-based tiered designs that induce reformulation and may also operate through signalling are well-founded both theoretically and empirically [5, 14, 28, 29]. However, two applied economics gaps remain important for evaluating a strengthened UK SDIL. First, although existing studies increasingly estimate aggregate QALYs and cost-effectiveness, fewer provide a clear public-finance incidence account that expresses consumer burden relative to household resources and tests whether burden shares decline systematically across the socioeconomic distribution [20, 40].

Second, while differences in baseline intake and policy responsiveness by age are increasingly recognised, SDIL-focused work rarely examines whether incidence gradients vary by age in ways that matter for equity-efficiency trade-offs [43, 44]. This study addresses both gaps using NDNS dietary microdata, a comparative risk assessment health-economic framework, and weighted regression models with robust inference.

Methodology

This study evaluates three modelled SDIL-strengthening scenarios: one moderate policy-informed scenario and two stronger intensification scenarios for the UK SDIL. The analysis integrates dietary microdata on sugar intake from SSBs with a comparative risk assessment-based health model and a public-finance incidence framework. The objective is to estimate how policy-induced reductions in SSB sugar intake translate into changes in BMI, QALYs, monetised health value, and consumer financial burden across age and socioeconomic groups.

The evaluation adopts a healthcare-system perspective on health outcomes and monetised QALY values, complemented by a household-resource perspective to assess the financial burden. The analysis is not a lifetime model; rather, it reports policy impacts over a 10-year analytic horizon consistent with the policy simulation outputs, with selected outcomes presented annually for interpretability.

Data sources and population stratification

Data were drawn from the UK NDNS rolling programme, Years 12–15 (2019–2023), a nationally representative survey of dietary intake in the UK based on 4-day estimated food diaries. Food and beverage items were coded into detailed NDNS food groups.

In the baseline specification, SSBs are defined as soft drinks with added sugar, including squash/cordial, carbonated drinks, and still soft drinks. Pure fruit juices, no-added-sugar soft drinks, fruit and vegetable juices and smoothies, and other non-levied beverages are excluded to keep the dietary measure aligned with the SDIL's targeted categories. Baseline SSB sugar intake was constructed by identifying diary entries in the NDNS food group "Soft drinks, with added sugar" and aggregating the corresponding free sugar content to obtain mean grams per day.

Individuals are grouped into four age categories (4–10, 11–18, 19–64, and 65+years) and socioeconomic position is indexed by deprivation quintile Q:

$$Q \in \{1,2,3,4,5\}$$

where $Q = 1$ represents the most deprived quintile and $Q = 5$ the least deprived.

To express financial burden relative to household resources, we use external benchmark denominators from the UK Office for National Statistics (ONS): equivalised disposable income and total household expenditure, both by income quintile. These are used as scaling denominators and are not micro-linked to NDNS individuals. Accordingly, burden-share measures should be interpreted as group-level approximations of financial burden relative to resources, rather than individual-level estimates.

Younger age groups (4–10 and 11–18 years) are included to capture observed consumption patterns and distributional effects across the population. For these groups, results primarily reflect preventive impacts and consumption behaviour rather than immediate health outcomes within the model horizon. Consumption patterns for younger age groups are based on observed NDNS dietary data and are interpreted as reflecting household-level decision-making rather than fully independent individual choice.

SDIL structure and strengthening scenarios

Current UK dietary guidelines recommend that free sugars should not exceed 5% of total daily energy intake, a threshold exceeded on average across several age groups in the population [3]. The current UK SDIL applies a two-tier charge based on sugar concentration: £0.194 per litre for drinks containing 5–8 g of sugar per 100 ml and £0.259 per litre for drinks containing more than 8 g per 100 ml (rates applicable from April 2025, following inflation uprating). Drinks containing less than 5 g per 100 ml are not subject to the levy. Since its introduction, the SDIL has already prompted substantial reformulation. Official evidence [21] indicates that, by 2019, around 65% of soft drinks that had contained more than 5 g of sugar per 100 ml had reformulated below that threshold, bringing the share of the market below 5 g per 100 ml to about 89%. Government reports also indicate an average reduction in sugar in drinks of roughly 46–47% between 2015 and 2024 [for further reading: OHID, 2022 and 2025].

Against this background, we model three progressively stronger SDIL scenarios: Scenario I (moderate strengthening), Scenario II (high strengthening), and Scenario III (very high strengthening). Rather than mapping these scenarios to exact statutory levy schedules, we parameterise them as calibrated incremental post-SDIL reductions in mean SSB free sugar intake relative to an already substantially reformulated market. This reflects the fact that, because most soft drinks are already below the current lower threshold, further tightening is more plausibly interpreted as generating additional marginal reductions rather than repeating the much larger initial reformulation shock associated with the original SDIL.

Scenario I is calibrated as a moderate marginal strengthening case, informed by the government's 2025 reform context, under which the lower threshold is reduced from 5 g to 4.5 g per 100 ml, and coverage is broadened. Official documents indicate that around 11% of soft-drink sales fall within the newly affected 4.5–4.9 g per 100 ml range, that 65% of newly in-scope sales are expected to reformulate below the new threshold, and that a drink at 4.9 g per 100 ml would require a 10.2% sugar reduction to fall below 4.5 g. A lower-bound calculation for soft drinks alone is therefore approximately $0.11 \times 0.65 \times 10.2\% \approx 0.73\%$. Allowing modestly for broader coverage and limited behavioural adjustment, we calibrate Scenario I to a 0.83% reduction in mean SSB free sugar intake.

Scenarios II and III represent stronger hypothetical intensification cases and are calibrated to reductions of 5.91% and 11.56% in mean SSB free sugar intake, respectively. These values are intended to bracket moderate and stronger incremental post-SDIL responses through further reformulation, broader coverage, pass-through, and consumer behavioural adjustment.

Behavioural responses are represented using own-price elasticities of demand for SSBs. The baseline overall elasticity is set at −1.20. To reflect heterogeneity, subgroup-specific elasticities are specified by deprivation quintile and age group: by quintile, −1.30 (Q1), −1.20 (Q2), −1.20 (Q3), −1.15 (Q4), and −1.00 (Q5); by age group, −1.00 (4–10 years), −0.95 (11–18 years), −1.30 (19–64 years), and −1.10 (65+years). Q2 and Q3 are assigned the same quintile elasticity as a mid-distribution assumption. These are calibrated modelling inputs rather than NDNS-estimated parameters and are informed by prior evidence from the SSB taxation and demand literature [12, 25, 46, 47]. For each age-by-quintile cell, a combined elasticity is defined as

$$\varepsilon_{aQ} = \varepsilon_a + \varepsilon_Q - \varepsilon_{avg}$$

where ε_{avg} is −1.20. An 85% pass-through rate is assumed. Under the baseline overall elasticity, the three calibrated scenario targets imply approximate average consumer price increases of 0.69%, 4.93%, and 9.63%, respectively. For each scenario, a common implied consumer price change is first derived from the aggregate target; cell-specific percentage reductions in intake are then calculated as $| \varepsilon_{aQ} |$ multiplied by that common price change and rescaled proportionally so that the weighted aggregate reduction matches the scenario target exactly. These subgroup-specific intake changes are then carried forward into the health and economic modelling described in Section "Health and economic outcome modelling".

Health and economic outcome modelling

Health impacts are modelled using an established comparative risk assessment / health-economic framework embedded in the simulation model. In this framework, policy-induced reductions in SSB sugar intake translate into changes in BMI via an energy-balance relationship between sugar intake and BMI. The BMI conversion coefficient applied in the simulation is 0.06716 BMI units per 1 g/day reduction in SSB free sugar intake, derived from the energy-balance parameters used in prior UK SSB modelling [46, 47]. These BMI changes are then mapped to QALY outcomes using calibrated health-economic relationships that capture the overall impact of excess weight on morbidity and mortality.

Accordingly, the model uses reduced-form QALY estimates rather than explicitly modelling individual disease pathways, consistent with prior SSB policy modelling. Age-specific parameters are applied within each age band.

For each age group a and deprivation quintile Q, the model produces (i) change in SSB sugar intake (grams/day and percentage), (ii) change in mean BMI, (iii) annual QALYs gained, and (iv) total QALYs gained over 10 years. Subgroup differences in SSB reduction reflect both differences in baseline intake and heterogeneous cell-specific percentage responses derived from the combined elasticity structure.

Future health and economic outcomes are discounted at an annual rate of 3.5%[2], consistent with standard UK health-economic evaluation guidelines [48]. For presentation, per-person QALY values are reported in milli-QALYs (mQALYs), where 1 mQALY = 0.001 QALY.

Because health outcomes are modelled as a function of both BMI change and underlying baseline risk, QALY gains may differ across age and deprivation groups for identical changes in consumption. Age- and deprivation-specific adjustment factors applied in the reduced-form QALY module, along with the rationale for their use, are reported in the Appendix (Tables 7 and 8).

Monetised health value and consumer burden

Health gains are monetised using UK willingness-to-pay thresholds, λ, of £20,000 and £30,000 per QALY:

$$V_{aQ}(\lambda) = \lambda \cdot QALY_{aQ}$$

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[2] NICE methodological guidance recommends applying an annual discount rate of 3.5% to future health and economic outcomes in UK health-economic evaluations. See: National Institute for Health and Care Excellence (NICE) (2014) *Developing NICE guidelines: The Manual*. Available at: https://www.nice.org.uk/process/pmg20

Consumer burden, B_{aQ}, reflects the additional expenditure incurred on retained post-response SSB consumption following the policy, incorporating both price effects and behavioural responses. For each age-by-quintile cell, this burden is calculated as:

$$B_{aQ} = \Delta p_s \cdot c_s \cdot S_{aQ} \cdot (1- \mid \varepsilon_{aQ} \mid \cdot \Delta p_s \cdot \phi_s)$$

where Δp_s is the common proportional consumer price increase under scenario s (0.0069, 0.0493, and 0.0963 under Scenarios I, II, and III, respectively); c_s is a scenario-specific constant that converts baseline mean daily SSB intake into annual expenditure units and incorporates the assumed 85% pass-through; S_{aQ} is baseline mean daily SSB free sugar intake for cell aQ; $\mid \varepsilon_{aQ} \mid$ is the combined absolute own-price elasticity for that cell; and ϕ_s is the proportional rescaling factor used to ensure that the population-weighted aggregate reduction matches the calibrated scenario target exactly. The term $(1- \mid \varepsilon_{aQ} \mid \cdot \Delta p_s \cdot \phi_s)$ represents the fraction of baseline intake retained after behavioural response. Accordingly, B_{aQ} captures the price-related expenditure burden on continuing consumption rather than the full difference between total post-policy and pre-policy expenditure. It should therefore not be interpreted as a statutory tax payment remitted directly by households.

Net monetised benefit (NMB) is calculated as:

$$NMB_{aQ}(\lambda) = V_{aQ}(\lambda) - B_{aQ}$$

We also report a summary consumer burden per QALY (CBQ) metric:

$$CBQ_{aQ} = \frac{B_{aQ}}{QALY_{aQ}}$$

This provides an interpretable measure of the implied private financial cost per unit of health gain.

Baseline and post-policy distributional patterns in SSB consumption

Baseline socioeconomic differences in SSB consumption are summarised using the ratio of mean intake in the most deprived quintile to the least deprived quintile:

$$I_a^S = \frac{\overline{S}_{(a,Q1)}}{\overline{S}_{(a,Q5)}}$$

where $\overline{S}_{(a,Q)}$ is the mean daily SSB sugar intake for age group a and quintile Q.

All policy impact measures (sugar reduction, BMI change, QALYs, monetised value, burden, and CBQ) are reported for each $a \times Q$ subgroup to characterise distributional incidence.

Burden as a share of household resources

Financial burden is expressed relative to household income and expenditure:

$$BS_{aQ}^{inc} = 10{,}000 \times \frac{B_{aQ}}{Y_Q} \text{and} BS_{aQ}^{exp} = 10{,}000 \times \frac{B_{aQ}}{E_Q}$$

where Y_Q and E_Q are quintile-specific income and expenditure benchmarks from ONS. The ONS benchmark denominators are Q1-Q5 = £15,186, £27,318, £36,757, £48,542, and £85,615 for equivalised disposable income, and £13,406, £15,434, £17,862, £20,072, and £26,151 for total expenditure. These measures allow comparison of the relative financial burden across socioeconomic groups. Reporting burden shares in basis points (bp) improves readability when absolute shares are small.

Statistical analysis of distributional gradients

To assess whether the policy generates financially regressive burden shares and whether this gradient varies by age, we estimate weighted linear models at the age-quintile cell level.

Let BS_{aQ} denote the burden share, measured relative to income or expenditure, for age group a and deprivation quintile Q. We estimate the following model:

$$BS_{aQ} = \alpha + \beta \widetilde{Q} + \sum_{k=2}^{K} \gamma_k D_{ak} + \sum_{k=2}^{K} \delta_k (\widetilde{Q} \times D_{ak}) + u_{aQ}$$

where $\widetilde{Q} = Q - 1$ is the zero-based deprivation-quintile rank, D_{ak} is an indicator equal to 1 if the observation belongs to age group k and 0 otherwise, and one age group is omitted as the reference category. In this specification, α is the intercept for the reference age group in the most deprived quintile, β captures the socioeconomic gradient in burden share for the reference age group, γ_k captures differences in the intercept across the other age groups, and δ_k captures how the quintile gradient differs by age group. A negative and statistically significant value of β indicates that burden shares decline as deprivation decreases in the reference age group, consistent with financial regressivity in relative terms.

Interaction terms between deprivation quintile and age group are included to test whether the socioeconomic gradient in burden shares differs across age groups. These interaction effects are formally assessed using both ANOVA tests and coefficient-level inference. Models are estimated using weighted least squares with heteroskedasticity-robust standard errors. The results report ANOVA tests for quintile effects, age effects, and quintile × age interactions. In addition, deterministic sensitivity analyses vary key parameters, including willingness-to-pay thresholds and scenario-specific intake reductions, to assess the robustness of efficiency and distributional conclusions.

This study does not constitute a formal cost-effectiveness analysis. Rather, it adopts a distributional policy-evaluation approach, jointly examining health outcomes (QALYs) and financial burden across socioeconomic groups under alternative SSB levy scenarios. While both health and economic outcomes are reported, these are not combined into cost-effectiveness ratios, and the analysis does not include a full accounting of healthcare-system or societal costs. Accordingly, the results should be interpreted as arising from a partial distributional evaluation framework focused on health gains and consumer burden.

Table 1 Baseline SSB free sugar intake by age group and deprivation quintile

Age group	Quintile	Mean SSB free sugar intake (grams per day)	95% CI
4–10	Q1	5.10	3.12—7.08
	Q2	2.43	1.53—3.33
	Q3	2.63	0.61—4.65
	Q4	1.78	0.63—2.93
	Q5	1.72	1.03—2.41
11–18	Q1	8.96	6.14—11.78
	Q2	8.38	5.17—11.59
	Q3	7.66	5.43—9.89
	Q4	6.34	4.36—8.32
	Q5	4.80	3.46—6.14
19–64	Q1	13.51	6.98—20.04
	Q2	6.79	4.10—9.48
	Q3	6.87	4.60—9.14
	Q4	5.46	3.01—7.91
	Q5	3.42	2.23—4.61
65+	Q1	3.67	−2.01—9.35
	Q2	2.13	0.74—3.52
	Q3	1.77	0.93—2.61
	Q4	0.99	0.17—1.80
	Q5	0.84	0.41—1.27

Estimates are derived from the UK NDNS Years 12–15 (2019–2023). Values represent mean daily free sugar intake from sugar-sweetened beverages (grams per day). 95% confidence intervals (CI) are survey-weighted. Confidence intervals crossing zero reflect sampling variability and small subgroup sizes

Results

This section presents empirical findings on baseline socioeconomic gradients in SSB sugar exposure, the projected effects of SDIL-strengthening scenarios, and the distributional incidence of both health gains and consumer burdens across age groups and quintiles. We first report overall population-average effects of the SDIL strengthening scenarios and then examine how these effects vary by age group and deprivation quintile.

Baseline distributional patterns in SSB consumption by deprivation quintile

Table 1 reports mean daily SSB free sugar intake by deprivation quintile and age group using NDNS data. A clear socioeconomic gradient is observed, with higher intake in more deprived groups across all age categories, although the gradient is not perfectly monotonic in all cases. Among adults aged 19–64 years, mean intake declines from 13.51 g/day in Q1 to 3.42 g/day in Q5 (ratio ≈ 3.95). Adolescents aged 11–18 years show a more moderate gradient (8.96 vs 4.80 g/day; ratio ≈ 1.87), while children aged 4–10 years also show higher intake in more deprived groups overall (5.10 vs 1.72 g/day; ratio ≈ 2.96). Among older adults aged 65+, intake is lower overall but remains socially graded (3.67 vs 0.84 g/day), although uncertainty is greater in this group due to smaller sample sizes. These results confirm a socially graded pattern of SSB sugar consumption consistent with prior evidence, with higher exposure concentrated among more deprived populations.

Aggregate policy impacts over 10 years: Net health-economic outcomes

Table 2 summarises the main population-average results for the three policy scenarios, with subsequent tables providing age- and deprivation-specific detail. Stronger SDIL scenarios yielded larger reductions in SSB sugar intake, larger mean BMI reductions, and more substantial health gains. At the same time, monetised health gains and consumer burdens also increased with policy intensity, leading to different net-benefit profiles across scenarios. Consistent with the model specification, the 10-year values reported in Table 2 are cumulative discounted totals over the model horizon.

Across all ages, Scenario I generated a modest reduction in SSB sugar intake of 0.041 g/day, with correspondingly limited health gains (0.0044 mQALYs per person annually). At £20,000 per QALY the monetised health value was £0.73 per person over 10 years, marginally below the cumulative consumer burden of £0.75, yielding a slightly negative

Table 2 Policy impacts under the strengthening scenarios

Domain	Outcome	Horizon	Scenario I	Scenario II	Scenario III
Intake effects	SSB reduction (g/day)	Annual	0.041	0.296	0.580
	SSB reduction (%)	Annual	0.83	5.91	11.56
Health effects	Mean BMI change	Annual	−0.0028	−0.0199	−0.0390
	QALYs per 1 million population	Annual	4.4	31.0	60.7
		10-year	36.6	257.8	504.8
Monetary outcomes	Monetised health value (£)	Annual	0.09	0.62	1.21
		10-year	0.73	5.16	10.10
	Consumer burden (£)	Annual	0.09	0.52	0.80
		10-year	0.75	4.32	6.65
	Net monetised benefit (£, λ=20,000/QALY)	Annual	−0.01	0.10	0.42
		10-year	−0.02	0.83	3.44
	Net monetised benefit (£, λ=30,000/QALY)	10-year	0.35	3.41	8.49
Efficiency summary	CBQ (£)	10-year	20,456	16,774	13,180

N total = 3,893. Baseline SSB intake (g/day) = 5.02. Values are reported on a per-person basis unless otherwise stated. Monetised health values are calculated using willingness-to-pay thresholds of £20,000 and £30,000 per QALY. Consumer burden represents the modelled change in SSB-related household expenditure attributable to the policy, incorporating both levy-induced price effects and behavioural responses. Ten-year values are cumulative present values over the 10-year horizon, discounted at 3.5% annually. QALYs per 1 million population are shown for interpretability. Source: Authors' calculations

net monetised benefit of −£0.02 and an implied CBQ of £20,456.

Scenario II produced a substantially larger reduction of 0.296 g/day, with annual health gains of 0.031 mQALYs per person. The 10-year monetised health value of £5.16 exceeded the consumer burden of £4.32, generating a positive net monetised benefit of £0.83 at £20,000 per QALY and a CBQ of £16,774.

Scenario III yielded the largest effects, with an intake reduction of 0.580 g/day and annual health gains of 0.0607 mQALYs per person. The 10-year monetised health value of £10.10 exceeded the consumer burden of £6.65, producing a net monetised benefit of £3.44 and a CBQ of £13,180.

Across all three scenarios, stronger levy designs yield larger health gains, lower CBQ values, and more favourable net benefit profiles. At the higher threshold of £30,000 per QALY, net monetised benefits rise to £0.35, £3.41, and £8.49 under Scenarios I, II, and III, respectively, while health gains and consumer burdens remain unchanged. The consumer burden reported in Table 2 does not represent a statutory tax paid directly by households. Rather, it reflects the modelled net change in consumer expenditure on SSBs after allowing for both levy-induced price increases and reduced consumption. Net monetised benefit is calculated as the monetised value of projected QALY gains minus this consumer burden. Because the results are reported on a per-person basis, the associated annual monetary amounts are necessarily small. Even under Scenario III, the average annual consumer burden remains below £1 per person, indicating that the direct financial effect on individuals is modest, while the cumulative health gains become more substantial under stronger levy designs.

Because Table 2 already reports the aggregate results for all three scenarios, the more detailed subgroup analysis that follows focuses only on Scenario II. This scenario is used as the principal illustrative specification for distributional analysis. The three scenarios differ mainly in the magnitude of their estimated effects rather than in the overall direction of the distributional pattern; accordingly, presenting the full disaggregation for Scenario II provides a clear and representative account of how burdens and benefits are distributed across age and deprivation groups.

Distributional incidence of Scenario II

Table 3 reports the distributional incidence of Scenario II, stratified by age group and IMD quintile. Across all age groups, absolute reductions in SSB sugar intake were consistently larger in more deprived quintiles. This gradient reflects two reinforcing mechanisms: more deprived groups have both higher baseline SSB consumption and higher own-price elasticities, so they reduce consumption more in both absolute and percentage terms following the levy-induced price change. This dual mechanism amplifies the Q1:Q5 gradient in intake reductions, BMI changes, and health gains relative to a flat reduction model, and is most pronounced among adults, where the combined age and quintile elasticity is largest.

Among adults aged 19–64 years, Q1 showed the largest behavioural response, with an SSB reduction of 0.973 g/day, the largest BMI change (−0.0654), and the highest health gain over the 10-year cumulative discounted horizon (1.248 mQALYs, or 0.001248 QALYs per person),

Table 3 Distributional incidence of Scenario II (by age × IMD quintile)

Age group	Q	*N*	SSB reduction g/day	ΔBMI	mQALY / person, annual	mQALY / person, 10-year	MHV (£), annual	MHV (£), 10-year	Consumer burden (£), annual	Consumer burden (£), 10-year	CBQ (£/QALY)
4–10	Q1	213	0.289	-0.0194	0.027	0.223	0.54	4.47	0.53	4.45	19,918
	Q2	230	0.125	-0.0084	0.010	0.080	0.19	1.60	0.26	2.13	26,640
	Q3	183	0.135	-0.0091	0.010	0.080	0.19	1.60	0.28	2.31	28,876
	Q4	233	0.087	-0.0058	0.005	0.041	0.10	0.83	0.19	1.57	37,852
	Q5	242	0.071	-0.0048	0.004	0.035	0.08	0.69	0.18	1.52	44,019
11–18	Q1	143	0.484	-0.0325	0.041	0.342	0.82	6.85	0.94	7.84	22,881
	Q2	142	0.410	-0.0275	0.030	0.248	0.60	4.96	0.89	7.37	29,741
	Q3	164	0.374	-0.0251	0.023	0.193	0.46	3.86	0.81	6.74	34,916
	Q4	140	0.294	-0.0197	0.016	0.137	0.33	2.74	0.67	5.59	40,771
	Q5	151	0.185	-0.0124	0.009	0.076	0.18	1.52	0.51	4.27	55,981
19–64	Q1	254	0.973	-0.0654	0.150	1.248	3.00	24.95	1.39	11.59	9,290
	Q2	325	0.454	-0.0305	0.060	0.499	1.20	9.99	0.70	5.86	11,733
	Q3	278	0.460	-0.0309	0.052	0.433	1.04	8.66	0.71	5.93	13,686
	Q4	315	0.351	-0.0236	0.036	0.299	0.72	5.99	0.57	4.72	15,780
	Q5	308	0.194	-0.0130	0.017	0.143	0.35	2.87	0.36	2.98	20,793
65 +	Q1	57	0.227	-0.0152	0.046	0.382	0.92	7.64	0.38	3.18	8,331
	Q2	106	0.121	-0.0081	0.021	0.175	0.42	3.50	0.22	1.86	10,612
	Q3	121	0.100	-0.0067	0.015	0.127	0.31	2.54	0.19	1.54	12,159
	Q4	148	0.053	-0.0036	0.007	0.061	0.15	1.23	0.10	0.87	14,111
	Q5	140	0.039	-0.0026	0.005	0.039	0.09	0.78	0.09	0.74	19,077

MHV Monetised health value at λ = £20,000/QALY. Annual values are modelled annual flows; 10-year values are cumulative present values discounted at 3.5%. mQALY = milli-QALY (0.001 QALY). Combined elasticities by cell: 4–10 (Q1 = 1.10, Q2/Q3 = 1.00, Q4 = 0.95, Q5 = 0.80); 11–18 (Q1 = 1.05, Q2/Q3 = 0.95, Q4 = 0.90, Q5 = 0.75); 19–64 (Q1 = 1.40, Q2/Q3 = 1.30, Q4 = 1.25, Q5 = 1.10); 65 + (Q1 = 1.20, Q2/Q3 = 1.10, Q4 = 1.05, Q5 = 0.90). Source: Authors' calculations

compared with Q5 (0.194 g/day, − 0.0130, and 0.143 mQALYs, or 0.000143 QALYs per person). This Q1:Q5 QALY ratio of 8.70 substantially exceeds the corresponding burden ratio of 3.89, reflecting both the higher baseline risk and greater elasticity of the most deprived working-age group. Among adolescents aged 11–18 years, Q1 also recorded the largest absolute reduction (0.484 g/day) compared with Q5 (0.185 g/day), though the within-group percentage differential is somewhat narrower than for adults because the age elasticity for this group (0.95) is below the population average. A similar pattern was observed among children aged 4–10 years (0.289 g/day in Q1 versus 0.071 g/day in Q5). Among those aged 65 +, absolute reductions were smaller overall but remained socially graded (0.227 g/day in Q1 versus 0.039 g/day in Q5), and the Q1:Q5 QALY ratio of 9.84 was the highest across all age groups, reflecting the disproportionately large cardiometabolic age- and deprivation-specific adjustment factors applied to older, more deprived individuals in the health module.

Consumer burdens, both annual and 10-year cumulative discounted, remained higher in absolute terms in Q1 than in Q5 across all age groups, primarily reflecting higher baseline SSB consumption in more deprived groups. However, because more deprived groups also reduce consumption by a larger percentage, their retained quantity, and therefore their expenditure burden, is partially offset relative to the scenario where a uniform percentage reduction was applied. As a result, burden ratios are modestly lower than they would be under a flat-reduction model, while QALY ratios are substantially larger, widening the gap between health progressivity and financial regressivity. When expressed as CBQ gained, values ranged from approximately £8,331 (adults aged 65 + in Q1) to £55,981 (adolescents aged 11–18 in Q5), reflecting the greater differentiation in health gains across strata. Lower CBQ values were concentrated where both baseline risk and elasticity were jointly high, particularly among adults aged 19–64 in Q1 (£9,290) and older adults aged 65 + in Q1 (£8,331).

In absolute terms, less deprived groups bore a smaller total burden due to both lower baseline consumption and lower price responsiveness, while more deprived groups bore a higher absolute burden driven by higher initial SSB intake and stronger behavioural responses to the levy-induced price change.

Summary of distributional pattern and progressivity

Table 4 summarises the distributional pattern and progressivity of the policy under Scenario II. In absolute terms, both consumer burden and health gains are concentrated in the most deprived quintile (Q1) across all age groups,

Table 4 Distributional pattern/progressivity summary

Age group	Annual burden ratio (Q1:Q5)	QALY ratio (Q1:Q5)	Financial status	Health status
4–10	2.92	6.45	More burden in Q1	Strongly higher in Q1
11–18	1.84	4.49	More burden in Q1	More gains in Q1
19–64	3.89	8.70	More burden in Q1	Strongly higher in Q1
65 +	4.30	9.84	More burden in Q1	Strongly higher in Q1

Ratios above 1 indicate concentration in Q1. Higher QALY ratios relative to burden ratios indicate progressive health effects. With heterogeneous elasticities applied, Q1:Q5 QALY ratios increase across all age groups relative to the original flat-reduction model, while burden ratios remain broadly similar, strengthening the progressivity finding. Source: Authors' calculations

reflecting higher baseline SSB free sugar intake and stronger price responsiveness among more deprived populations. However, the distribution of health gains is substantially more progressive than the distribution of financial burden, and this divergence is observed consistently across all four age groups.

The Q1:Q5 QALY ratios range from 4.49 among adolescents aged 11–18 years to 9.84 among older adults aged 65 +, compared with burden ratios of 1.84 and 4.30, respectively, for the same groups. Among adults aged 19–64, the QALY ratio of 8.70 is more than twice the corresponding burden ratio of 3.89, the widest absolute divergence observed across age groups. These patterns reflect the joint operation of two mechanisms. First, more deprived groups have higher baseline SSB consumption, so a given price-induced reduction in consumption translates into a larger absolute reduction in intake and a larger absolute health gain. Second, more deprived groups exhibit stronger own-price elasticities, meaning they reduce consumption by a larger percentage in response to the same levy-induced price change, which amplifies the Q1:Q5 gradient in intake reductions and health gains beyond what baseline consumption differences alone would produce. Because the health module additionally applies higher age- and deprivation-specific adjustment factors to more deprived and older populations, the QALY gradient is steeper than the intake gradient, particularly for older adults aged 65 + in Q1, where the combination of high deprivation, high elasticity, and elevated baseline risk yields the largest proportional health gains relative to financial burden of any group in the analysis.

The burden ratios are modestly compressed relative to the QALY ratios because higher elasticity in Q1 means more consumption is reduced, leaving less retained quantity to drive expenditure burden. This partial offset in the burden gradient, combined with the amplification of the QALY gradient through both elasticity and adjustment factor effects, means the gap between financial regressivity and health progressivity is pronounced across all age groups. Collectively, the results indicate that while the policy imposes a higher absolute financial burden on more deprived groups, it delivers disproportionately larger health benefits to those same groups, consistent with a progressive public health impact. This progressivity is driven by both structural inequality in baseline SSB exposure and greater behavioural responsiveness to price changes among more deprived populations.

To summarise these distributional incidence results, Fig. 1 offers a complementary synthesis that combines two perspectives presented separately in the preceding tables. The left panel displays CBQ for each age-by-quintile cell, colour-coded from dark green (lowest financial cost per unit of health gain) to dark red (highest). The right panel presents, for each age group, the Q1:Q5 ratios for annual consumer burden and 10-year QALY gain side by side, making the progressivity gap directly visible.

The heatmap shows a clear gradient in implied policy efficiency across age and deprivation. Within each age group, CBQ values rise from Q1 to Q5, indicating that the policy delivers greater health gain per unit of consumer burden in more deprived groups. The most favourable cells are concentrated among adults aged 19–64 and older adults in Q1, with CBQ values of £9,290 and £8,331, respectively, both below the £20,000 threshold. The least favourable cell is adolescents aged 11–18 in Q5, with a CBQ of £55,981. Most remaining cells fall between these extremes, indicating substantial variation in the implied private financial cost per unit of health gain across the deprivation distribution.

The right panel reinforces the core finding on progressivity. Across all age groups, the Q1:Q5 ratio for QALY gains exceeds the corresponding ratio for consumer burdens, indicating that health gains are more strongly concentrated in the most deprived quintile than financial burdens are. The gap is widest among adults aged 65 +, where the QALY ratio is 9.84 compared with a burden ratio of 4.30, and narrowest among adolescents aged 11–18, where the corresponding values are 4.49 and 1.84. Taken together, the two panels show that the groups bearing the highest relative financial burden also receive the largest proportional health gains and the lowest implied burden per QALY, consistent with the paper's central argument that a strengthened SDIL can be financially regressive yet welfare progressive.

Burden as a share of income and expenditure (weighted analysis)

To assess financial regressivity more directly, the annual consumer burden is presented in Table 5 as a share of

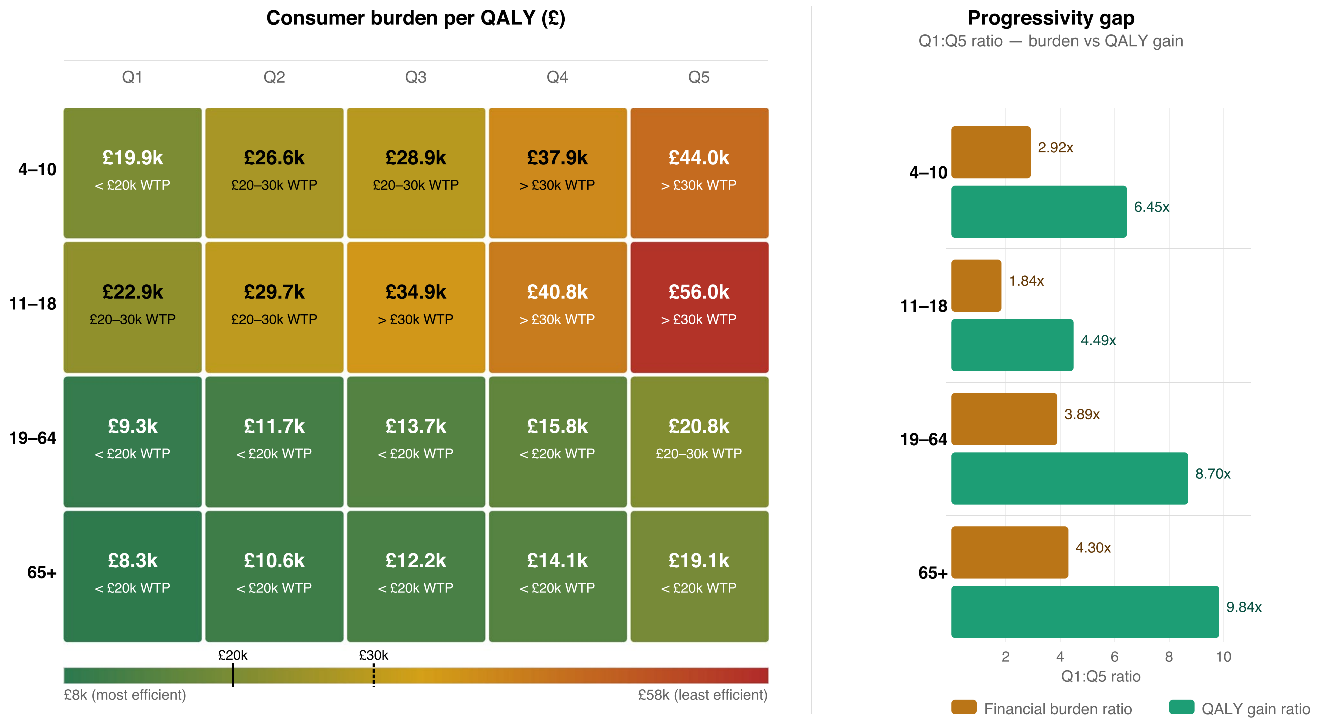

Fig. 1 CBQ gained and Q1:Q5 progressivity ratios by age group and deprivation quintile

Table 5 Annual consumer burden as a share of income and expenditure (Scenario II)

Age group	Q	B_{aQ}(annual, £)	BS^{inc}_{aQ}(bp)	BS^{exp}_{aQ}(bp)
4–10	Q1	0.53	0.3522	0.3990
	Q2	0.26	0.0938	0.1660
	Q3	0.28	0.0755	0.1553
	Q4	0.19	0.0388	0.0938
	Q5	0.18	0.0214	0.0701
11–18	Q1	0.94	0.6205	0.7029
	Q2	0.89	0.3244	0.5741
	Q3	0.81	0.2203	0.4534
	Q4	0.67	0.1385	0.3349
	Q5	0.51	0.0599	0.1962
19–64	Q1	1.39	0.9178	1.0396
	Q2	0.70	0.2578	0.4564
	Q3	0.71	0.1939	0.3990
	Q4	0.57	0.1170	0.2830
	Q5	0.36	0.0419	0.1372
65+	Q1	0.38	0.2521	0.2855
	Q2	0.22	0.0818	0.1447
	Q3	0.19	0.0505	0.1039
	Q4	0.10	0.0214	0.0519
	Q5	0.09	0.0104	0.0341

B_{aQ} is the modelled annual consumer burden for the age group a and quintile Q. Y_Q (equivalised disposable income) and E_Q (total expenditure) are the ONS benchmark denominators by quintile. 1 bp = 0.01 percentage points. Cell-specific elasticities are applied to derive percentage reductions: combined elasticities range from 0.75 (11–18 years, Q5) to 1.40 (19–64 years, Q1). Source: Authors' calculations using model estimates and ONS benchmark data

equivalised disposable income and of total household expenditure. Cell-specific burden values reflect a heterogeneous elasticity structure, in which more deprived, higher-elasticity groups reduce consumption by a larger percentage in response to the levy-induced price change, thereby modestly compressing the absolute burden gradient relative to a uniform-reduction model.

Across all age groups, burden shares declined monotonically from Q1 to Q5 under both denominators. Among adults aged 19–64 years, the income burden share was 0.918 bp in Q1 versus 0.042 bp in Q5; as a share of expenditure, the corresponding values were 1.040 bp and 0.137 bp, respectively. Adolescents aged 11–18 years showed a similar gradient (income share: 0.621 bp in Q1 versus 0.060 bp in Q5; expenditure share: 0.703 bp in Q1 versus 0.196 bp in Q5). Among children aged 4–10 years, the income share ranged from 0.352 bp in Q1 to 0.021 bp in Q5, while among older adults aged 65+, it ranged from 0.252 bp in Q1 to 0.010 bp in Q5. These patterns indicate that, when scaled by income or expenditure capacity, the consumer burden is regressive across all age groups, with more deprived groups bearing a substantially larger relative burden. The monotonic decline from Q1 to Q5 is consistent across both denominators and all four age groups, and is robust to correcting for heterogeneous elasticities, yielding only marginal changes in burden share values relative to the uniform-reduction specification.

Figure 2 compares the distributional profiles of financial burden and health-related outcomes across deprivation

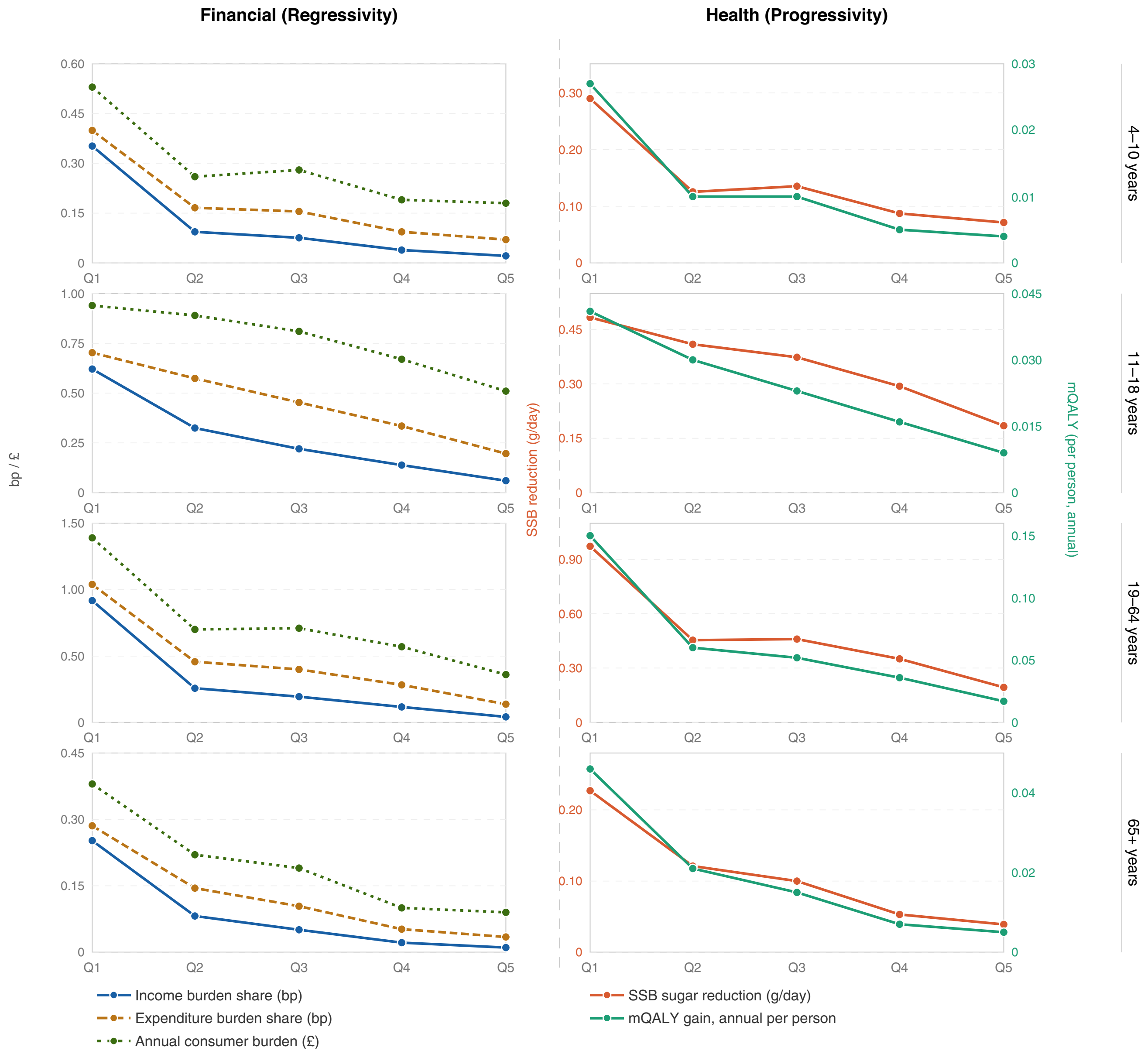

Fig. 2 Financial Regressivity and Health Progressivity Across Quintiles by Age Group

quintiles (Q1-Q5, left to right) and age groups (rows). The financial panels show annual consumer burden (£), income burden share, and expenditure burden share, while the health panels show annual SSB sugar reduction (g/day) and annual mQALY gains per person under Scenario II. Each row uses independent y-axes scaled to that age group's range, so the figure should be read primarily for the shape and steepness of the gradients; absolute values are reported in Tables 3 and 5. The figure shows that financial burden declines from Q1 to Q5 in every age group, indicating regressivity in relative terms, whereas health gains are more concentrated among more deprived groups, indicating progressive health effects. This contrast is strongest among adults aged 19–64 and older adults, where the health gradient is visibly steeper than the burden gradient.

Trend and interaction tests for burden-share gradients

Table 6 presents formal tests of whether burden shares declined monotonically from Q1 to Q5 and whether the steepness of this gradient differed by age group. In weighted linear models of burden share (Panel A) as a function of quintile rank and age group, there was substantial evidence of a negative overall gradient, indicating higher burden

Table 6 Trend and interaction tests for burden-share gradients across quintiles

Panel A. Within-age trends (slope of burden share on Q; basis points per quintile step)[1]

Outcome (BS)	Age group	Slope (bp / Q)
BS^{inc}	4–10	−7.0†
	11–18	−13.0*
	19–64	−17.9†
	65+	−4.5†
BS^{exp}	4–10	−7.2*
	11–18	−12.5***
	19–64	−19.0*
	65+	−5.3*

Panel B. Pooled ANOVA tests for gradients and age differences ($Q \times a$)[2]

Model outcome	Effect tested	df	F
BS^{inc}	Quintile gradient (Q)	1, 12	32.01***
	Age-group differences (a)	3, 12	3.98*
	Gradient differs by age ($Q\ :\ a$)	3, 12	2.42
BS^{exp}(weighted)	Quintile gradient (Q)	1, 12	54.05***
	Age-group differences (a)	3, 12	10.96***
	Gradient differs by age ($Q\ :\ a$)	3, 12	3.35†

Panel C. Weighted BS^{exp} model with robust (HC1) SEs: coefficient tests[3]

Model: $BS^{exp}_{aQ} = \alpha + \beta Q + \gamma_a + \delta_a(Q \times a) + u_{aQ}$ (WLS, weights = n; HC1 SEs)

Term	Estimate	Robust SE (HC1)	t
(Intercept)	0.32**	0.0761	4.2004
Q	−0.07*	0.0247	−2.8976
$a = 11$–18	0.38***	0.0762	5.0288
$a = 19$–64	0.51*	0.2009	2.5587
$a = 65+$	−0.09	0.0860	−1.1094
$Q \times (a = 11$–18)	−0.05†	0.0247	−2.1785
$Q \times (a = 19$–64)	−0.12†	0.0638	−1.8503
$Q \times (a = 65+)$	0.01	0.0284	0.6500

[1] Slopes estimated by weighted OLS within each age group with HC1-robust standard errors (n=5 quintile cells per group). Slopes are expressed in basis points per quintile step (negative = burden share declines as deprivation decreases)

[2] Type I sequential ANOVA from the pooled model estimated at 20 age-by-quintile cells. Q entered first, age dummies second, Q × age interactions third. Denominator df = 12 (residual from full model with 8 parameters). BS^{exp} model uses cell-size weights

[3] $\widetilde{Q} = Q - 1$(zero-based quintile rank, ranging 0 to 4). Reference age group: 4–10 years. Weights are subgroup sample sizes (n). HC1-robust standard errors adjust for heteroskedasticity

Significance: † $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Source: Authors' calculations

shares in more deprived quintiles, for both income- and expenditure-based denominators.

For burden as a share of income, the main effect of quintile rank was statistically significant (Panel B). In contrast, neither the age-group main effect nor the Q × age-group interaction reached conventional significance levels, suggesting limited evidence that the income-based gradient differed materially across age groups.

For burden as a share of expenditure, the weighted model showed a strong overall quintile gradient, alongside clear differences in burden-share levels by age group. Evidence that gradients differed by age was borderline. Robust (HC1) coefficient tests (Panel C) corroborated a negative overall gradient, with marginal evidence that the gradient was steeper for adolescents and working-age adults relative to children. In contrast, the interaction for older adults was not statistically significant.

To present distributional gradients in an interpretable way, we plotted burden shares across quintiles separately for the income- and expenditure-denominator specifications. Figure 3 displays (*i*) fitted gradients by age group and (*ii*) uncertainty bands (e.g., 95% intervals) derived from the weighted regression model. The figure emphasises the shape and steepness of the gradients rather than point estimates alone, supporting the paper's incidence narrative in an applied economics format. The left panel shows annual consumer burden as a percentage of total expenditure (shown in % in the figure; reported in bp in the tables);

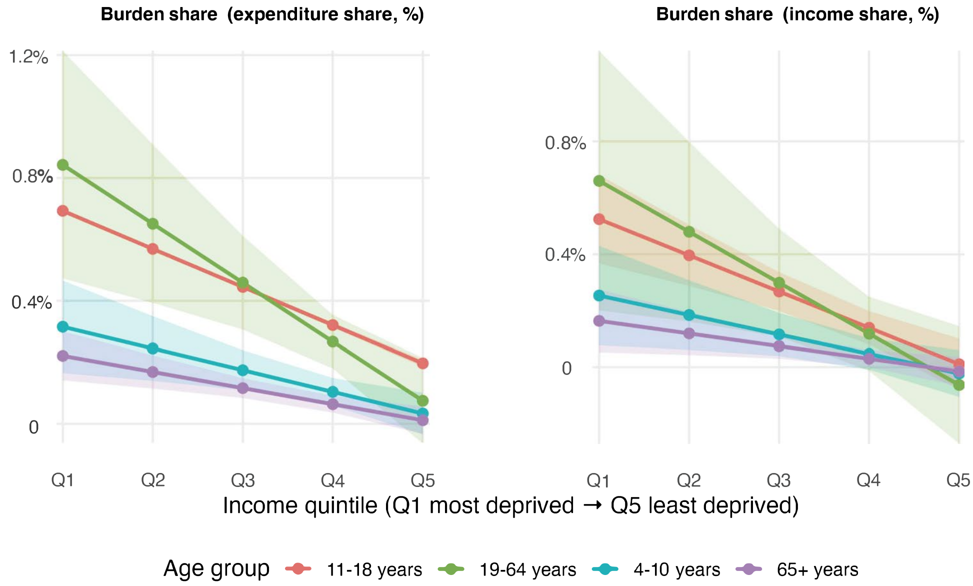

Fig. 3 Age-stratified burden share across income quintiles. Note: Burden share is defined as the modelled annual change in SSB-related household expenditure attributable to the policy, divided by total household expenditure (left panel) or equivalised disposable income (right panel). Shaded bands indicate uncertainty intervals from the weighted regression model

the right panel shows annual consumer burden as a percentage of equivalised disposable income. In both panels, burden shares decline monotonically from Q1 (most deprived) to Q5 (least deprived), indicating a regressive distribution of consumer burden when scaled by economic capacity. Shaded bands represent uncertainty intervals around the fitted values.

Discussion

This study examined the distributional welfare effects of three SDIL-strengthening scenarios, with particular attention to how the consumer financial burden and health benefits are allocated across socioeconomic groups and age categories. The results show that a corrective commodity tax may appear regressive when assessed solely by payment incidence, yet it can improve equity and welfare simultaneously when its health benefits are concentrated among populations with disproportionately high baseline risk [4, 16]. This approach aligns with extended cost-effectiveness analysis, which explicitly accounts for the financial consequences borne by different population groups alongside aggregate health gains [49, 50]. Unlike conventional cost-effectiveness analysis, in which tax payments are treated as transfer payments and netted out from a full societal perspective [51], this study adopts a distributional policy evaluation framework in which changes in consumer expenditure are treated as substantive outcomes, given their concentration across socioeconomic groups, a central policy concern. The UK SDIL is therefore best understood not only as a fiscal instrument but also as a public health investment whose distributional consequences cannot be adequately characterised by financial incidence alone [41].

The persistence of socioeconomic gradients in SSB-related sugar intake after the original SDIL was introduced aligns with a body of evidence showing that dietary risks remain socially patterned even as average consumption declines. UK and European studies suggest that these gradients reflect structural determinants (including food environments, marketing exposure, and unequal access to lower-sugar substitutes) rather than individual preferences alone [15]. The SDIL was designed primarily as an upstream reformulation instrument rather than a targeted redistributive mechanism [11]. The enduring socioeconomic gradient in baseline consumption should therefore not be interpreted as evidence of policy failure; rather, it reflects the continued operation of structural determinants of diet across deprivation strata.

Against this backdrop, the study's central finding is that strengthening the SDIL yields health gains that are distributionally progressive, even when the financial burden is more concentrated among more deprived groups. Across all four age groups, the Q1:Q5 QALY ratios consistently exceed the corresponding burden ratios, indicating that the most deprived populations receive disproportionately larger health benefits relative to their financial contribution. This pattern reflects three reinforcing mechanisms. First, socioeconomic gradients in baseline SSB sugar intake mean that, for a given proportional reduction in consumption, more deprived groups experience larger absolute decreases in sugar exposure. Second, the model applies deprivation-specific price elasticities (ranging from -1.30 in Q1 to -1.00 in Q5), so more deprived groups exhibit stronger behavioural responses to price changes, which amplifies the absolute intake reduction. Third, age- and deprivation-specific adjustment factors in the comparative risk assessment module mean that equal BMI reductions translate into larger

QALY gains in higher-risk groups. These mechanisms jointly explain why the QALY gradient is steeper than the burden gradient across all subgroups, and why the pattern is most pronounced among adults aged 19–64 and older adults. This interpretation aligns with distributional and extended cost-effectiveness frameworks, which emphasise that equity outcomes depend on the joint distribution of baseline risk, intervention reach, and behavioural response rather than on payment incidence alone [49]. It also reinforces findings from prior work, including Long et al. [51], which demonstrate that SSB taxes can be financially regressive while remaining health-progressive when harmful exposure is socially concentrated.

The age pattern of the results adds another dimension to this interpretation. Health gains are largest in absolute and relative terms among working-age adults and adolescents, consistent with evidence that SSB consumption peaks earlier in the life course and that weight trajectories established during youth and early adulthood have durable effects on later cardiometabolic risk [43]. Among children aged 4–10 years, projected health gains over the 10-year analytic horizon are more modest, reflecting the age-specific parameters embedded in the health module rather than any lack of clinical relevance of early intervention. From an applied economics perspective, these results strengthen the case for explicitly modelling heterogeneity rather than relying on a representative consumer.

A further contribution of this study is the formal statistical assessment of distributional gradients across quintiles and age groups. Weighted linear models with heteroskedasticity-robust standard errors confirm a significant negative gradient in burden shares from Q1 to Q5 under both income- and expenditure-based denominators (Table 6, Panel B), providing formal support for the inference of financial regressivity. The quintile-by-age interaction terms are at most marginally significant. This finding has a substantive implication absent from earlier SDIL evaluations: financial regressivity is a broadly consistent structural feature of the levy across age groups, rather than a phenomenon concentrated in a particular life stage. Consequently, age-targeted modifications to the levy design would be unlikely to materially alter its overall regressivity profile.

The divergence between income- and expenditure-based burden gradients warrants separate attention. Burden shares measured relative to total household expenditure show a clearer, more consistently age-differentiated gradient than those expressed as a share of equivalised disposable income. This divergence aligns with the view that annual household expenditure is a smoother proxy for permanent income and longer-run living standards, whereas current-year income is more volatile [41]. The stronger gradient under expenditure-based scaling suggests that the regressivity of consumption taxes may be somewhat underestimated when assessed against current-year income. At the same time, the weaker age interaction in the income-based model cautions against over-interpreting age variation in financial regressivity when the denominator is itself more unstable. These considerations support reporting both denominators as complementary measures of burden incidence [41].

Taken together, the findings extend the UK SDIL evidence base in several ways. Prior evaluations have focused primarily on average cost-effectiveness and aggregate health gains [7, 12]. This study complements that literature by embedding the incidence of both benefits and burdens within a unified health-economic and public-finance framework, thereby addressing two specific gaps identified in the literature: the absence of explicit burden-share measures expressed relative to household resources, and the lack of formal tests for whether incidence gradients vary by age [20, 41, 43, 44]. The results suggest that where baseline exposure is socially concentrated, strengthening an upstream reformulation-oriented levy can generate progressive health effects even when the financial burden is unequally distributed [15, 41]. This conclusion is robust to the choice of willingness-to-pay threshold: the qualitative distributional pattern, QALY ratios exceeding burden ratios, and monotonically declining burden shares from Q1 to Q5 are preserved across the £20,000 and £30,000 per QALY thresholds examined in the sensitivity analysis.

The findings have implications for policy appraisal and evaluation practice. They support the view that corrective health taxes should not be appraised solely through the lens of payment incidence, but through the joint distribution of financial burden and health benefit [4, 16, 41, 49]. For public health policy, they reinforce the value of treating the SDIL as part of a broader structural prevention strategy rather than as a stand-alone behavioural intervention. For evaluation practice, they demonstrate the importance of incorporating equity-sensitive outputs (including expenditure- and income-based burden-share measures and QALY distributions by deprivation quintile) into routine appraisal of corrective health taxes. Although this study is not a full cost-effectiveness analysis, the SDIL is an administratively straightforward instrument, with implementation costs generally considered low relative to its potential health and fiscal effects [12, 31]. The levy also generates government revenue that can be directed towards complementary public health initiatives, further strengthening its policy case. Even the modest individual-level gains projected here may therefore be policy-relevant when considered at the population scale and at low marginal cost.

Several limitations must be acknowledged. The analysis is model-based and relies on calibrated assumptions about price elasticities, tax pass-through, and the energy-balance and dose–response relationships linking sugar intake to BMI and health outcomes. These parameters are drawn from the prior literature rather than estimated directly from the NDNS data, and the results are sensitive to the assumed magnitude of behavioural response, particularly the deprivation-specific elasticity values that partly drive the observed QALY gradient (though qualitative conclusions on progressivity and net benefit direction are robust to the willingness-to-pay thresholds examined). The health model uses reduced-form QALY estimates rather than explicit disease-pathway simulation, which limits the clinical granularity of the projections and may understate long-run benefits for younger cohorts whose downstream obesity and cardiometabolic risk extend well beyond the 10-year horizon. The burden-share measures rely on external ONS income and expenditure denominators rather than on linked household resource data for the same NDNS individuals, introducing an element of approximation. In addition, the framework treats SSBs in isolation and does not capture substitution towards other high-sugar foods or beverages that fall outside the levy's scope. Finally, NDNS subgroup sample sizes, particularly for the 65 + age group and for Q1 within younger age categories, are small enough to produce wide confidence intervals, and the ANOVA findings on age interactions should therefore be interpreted with appropriate caution.

Conclusion

This study assessed the distributional welfare effects of strengthening the UK Soft Drinks Industry Levy using NDNS dietary microdata and a comparative risk assessment health-economic simulation framework. Three strengthening scenarios were evaluated across four age groups and five deprivation quintiles, with outcomes expressed as changes in SSB sugar intake, BMI, QALYs, monetised health value, and consumer financial burden. The principal finding is that a strengthened SDIL remains regressive in payment incidence but progressive in health and welfare terms. Consumer burden shares decline monotonically with deprivation under both income- and expenditure-based denominators, confirming financial regressivity in relative terms. QALY gains are more strongly concentrated among more deprived groups across all age categories, with Q1:Q5 health ratios consistently exceeding the corresponding burden ratios. Net monetised benefits are positive under Scenarios II and III at both willingness-to-pay thresholds, and the absolute per-person financial burden remains modest throughout. The formal gradient analysis yields a further substantive finding: regressivity in relative burden shares is a broadly consistent structural feature of the levy across age groups, with limited statistical evidence that the gradient differs materially by age, implying that age-stratified modifications to the levy design would be unlikely to resolve the regressivity of financial incidence.

These findings support the view that corrective health taxes should be assessed using the joint distribution of financial burden and health benefits, rather than payment incidence alone [4, 16, 41, 49]. The study shows that this approach can be operationalised in a UK policy context using publicly available data, and that, where baseline SSB exposure is socially concentrated, strengthening an upstream reformulation-oriented levy can yield progressive health effects even when the financial burden is unequally distributed.

Future research should prioritise three directions. The most important is linking NDNS dietary records with household resource data at the individual level, which would allow burden-share measures to be estimated directly rather than approximated from external quintile denominators, and would enable richer analysis of within-quintile heterogeneity in both exposure and behavioural response. Second, extending the analytic horizon beyond ten years would better capture the long-run health returns from reduced early-life SSB exposure, particularly for children and adolescents whose downstream cardiometabolic risk accumulates well beyond the modelling window used here. Third, incorporating substitution patterns across the full dietary margin, including towards untaxed high-sugar foods, and evaluating how SDIL strengthening interacts with complementary food-environment and nutrition interventions would provide a more complete account of the welfare effects of levy reform at the population level.

Appendix

Age- and deprivation-specific adjustment factors in the reduced-form QALY module

The reduced-form QALY module allows health gains to vary across age-by-deprivation cells by applying age- and deprivation-specific adjustment factors to the BMI-to-QALY mapping. The implementation is:

$$AF_{aQ} = AF_a^{age} \times AF_Q^{IMD}$$
$$QALY_{aQ} = \mid \Delta BMI_{aQ} \mid \times \beta_{QALY/BMI} \times AF_{aQ}$$

where $\beta_{QALY/BMI}$ is the base QALY-per-BMI conversion parameter (1.68), calibrated dynamically from the reference cell (19–64 years, Q3) in the simulation model. The adjustment factors AF are calibrated modelling inputs that allow QALY gains to vary across population subgroups and are intended to capture heterogeneity in BMI-attributable disease burden. They are not estimated directly from the NDNS data and should be treated as calibration assumptions subject to sensitivity analysis. Appendix Tables 7 and 8 report their values.

Sensitivity analysis examines how the Q1:Q5 QALY ratios reported in Table 4 of the main text change when the IMD adjustment factors are varied. Because AF^{age} cancels in the Q1:Q5 ratio within any age group, only the IMD factors affect this metric; age-factor variation is therefore not shown.

Each scenario scales the deviation of each AF^{IMD} value from the reference value of 1.00 by a common factor. At−50%, the Q1:Q5 AF^{IMD} ratio falls from 1.69 (base) to 1.31; at+50%, it rises to 2.18. The limiting case in which all $AF^{IMD} = 1.00$ is equivalent to a model with no deprivation-specific adjustment to the QALY gradient. Burden ratios are not affected by the adjustment factors and are shown as a fixed reference row.

Two findings emerge from the sensitivity analysis. First, the core progressivity result, that Q1:Q5 QALY ratios exceed Q1:Q5 burden ratios in every age group, is preserved across all six scenarios, including when all IMD adjustment factors are set to 1.00. In the limiting flat case, the QALY ratios remain above the corresponding burden ratios in all four age groups. This confirms that the result is not driven solely by the specific AF^{IMD} calibration. Without any adjustment for deprivation, socially graded baseline intake and heterogeneous own-price elasticities are still sufficient to generate progressive health effects.

Second, the IMD adjustment factors affect the magnitude of the QALY gradient, not its direction. For adults aged 19–64 years, the Q1:Q5 QALY ratio falls from 8.70 in the base case to 5.16 when AF^{IMD} is flat and rises to 11.23 when deviations are scaled by+50%. The qualitative conclusion, that a strengthened SDIL produces progressive health effects despite regressive payment incidence, is therefore robust to substantial variation in the calibrated IMD adjustment factors.

Table 7 IMD adjustment factors by deprivation quintile

	Q1 (most deprived)	Q2	Q3 (reference)	Q4	Q5 (least deprived)
IMD factor (AF^{IMD})	1.35	1.15	1.00	0.90	0.80

Q3 is the reference category ($AF^{IMD} = 1.00$). Values above 1.00 indicate a higher QALY conversion factor per unit BMI change relative to the reference; values below 1.00 indicate a lower conversion factor. The Q1:Q5 ratio is $1.35/0.80 = 1.69$

Table 8 Age adjustment factors by age group

	4–10 years	11–18 years	19–64 years (reference)	65+years
Age factor (AF^{age})	0.60	0.55	1.00	1.30

Adults aged 19–64 years are the reference category ($AF^{age} = 1.00$). The combined cell-level factor is $AF_{aQ} = AF_a^{age} \times AF_Q^{IMD}$

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Data availability The data used in this study are publicly available. All data sources are cited and fully described within the manuscript.

Declarations

Ethical statement This study uses publicly available secondary data and does not involve human participants or animals. Ethical approval was therefore not required.

Conflict of interest The author declares that there are no conflicts of interest.

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References

1. Malik, V. S., B. M. Popkin, G. A. Bray, J.-P. Després, W. C. Willett, and F. B. Hu. 2010. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis. *Diabetes Care* 33 (11): 2477–2483. https://doi.org/10.2337/dc10-1079.
2. Vartanian, L. R., M. B. Schwartz, and K. D. Brownell. 2007. Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis. *American Journal of Public Health* 97 (4): 667–675. https://doi.org/10.2105/AJPH.2005.083782.
3. Public Health England: *Sugar Reduction: Achieving the 20%.* Public Health England, London (2017). Available at: https://www.gov.uk/government/publications/sugar-reduction-achieving-the-20. Accessed 12 November 2025
4. Chaloupka, F. J., L. M. Powell, and K. E. Warner. 2019. The use of excise taxes to reduce tobacco, alcohol, and sugary beverage consumption. *Annual Review of Public Health* 40:187–201. https://doi.org/10.1146/annurev-publhealth-040218-043816.
5. Eichner, T., and M. Runkel. 2025. Efficient taxation of sugar-sweetened beverages and missing markets for sugar content. *The Scandinavian Journal of Economics* 127 (3): 576–612. https://doi.org/10.1111/sjoe.12585.
6. Colchero, M. A., B. M. Popkin, J. A. Rivera, and S. W. Ng. 2016. Beverage purchases from stores in Mexico under the excise

tax on sugar sweetened beverages: Observational study. *BMJ* 352:h6704. https://doi.org/10.1136/bmj.h6704.

7. Scarborough, P., V. Adhikari, R. A. Harrington, et al. 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. *PLoS Medicine* 17 (2): e1003025. https://doi.org/10.1371/journal.pmed.1003025.
8. Leider, J., and L. M. Powell. 2022. Longer-term impacts of the Oakland, California, sugar-sweetened beverage tax on prices and volume sold at two-years post-tax. *Social Science and Medicine* 292:114537. https://doi.org/10.1016/j.socscimed.2021.114537.
9. Shen, J., J. Wang, F. Yang, and R. An. 2023. Impact of soda tax on beverage price, sale, purchase, and consumption in the US: A systematic review and meta-analysis of natural experiments. *Frontiers in Public Health* 11:1126569. https://doi.org/10.3389/fpubh.2023.1126569.
10. White, J. S., S. Basu, S. Kaplan, K. A. Madsen, S. B. Villas-Boas, and D. Schillinger. 2023. Evaluation of the sugar-sweetened beverage tax in Oakland, United States, 2015–2019: A quasi-experimental and cost-effectiveness study. *PLoS Medicine* 20 (4): e1004212. https://doi.org/10.1371/journal.pmed.1004212.
11. Department of Health and Social Care (HM Government): *Soft Drinks Industry Levy: Guidance for manufacturers and importers of soft drinks*. HM Government, London (2017).
12. Cobiac, L. J., N. T. Rogers, J. Adams, S. Cummins, R. Smith, O. Mytton, M. White, and P. Scarborough. 2024. Impact of the UK soft drinks industry levy on health and health inequalities in children and adolescents in England: An interrupted time series analysis and population health modelling study. *PLoS Medicine* 21 (3): e1004371. https://doi.org/10.1371/journal.pmed.1004371.
13 Gonçalves, J., R. Merenda, and J. Pereira dos Santos. 2023. Not so sweet: Impacts of a soda tax on producers. *International Tax and Public Finance* 31 (5): 1388–1412. https://doi.org/10.1007/s10797-023-09808-7.
14. Barigozzi, Francesca, Laura Cornelsen, and Mario Mazzocchi. 2025. A tax is a signal: Theory and evidence. Working Paper DSE, Quaderni (1206). Dipartimento di Scienze Economiche, Università di Bologna.
15. Pechey, R., S. A. Jebb, M. P. Kelly, et al. 2013. Socioeconomic differences in purchases of more vs. less healthy foods and beverages: Analysis of over 25,000 British households in 2010. *Social Sciences & Medicine* 92:22–26. https://doi.org/10.1016/j.socscimed.2013.05.012.
16. Gruber, Jonathan. 2016. *Public Finance and Public Policy*, 5th edn. Worth Publishers.
17. Salgado, J. C., and S. W. Ng. 2019. Understanding heterogeneity in price changes and firm responses to a national unhealthy food tax in Mexico. *Food Policy* 89:101783. https://doi.org/10.1016/j.foodpol.2019.101783.
18. Andreyeva, T., F. J. Chaloupka, and K. D. Brownell. 2011. Estimating the potential of taxes on sugar-sweetened beverages to reduce consumption and generate revenue. *Preventive Medicine* 52 (6): 413–416. https://doi.org/10.1016/j.ypmed.2011.03.013.
19. World Bank. 2019. Using taxation to address noncommunicable diseases: Lessons from a five-year evaluation of health taxes in the Pacific and Southeast Asia. *World Bank Group*. https://doi.org/10.1596/32063.
20. Cookson, R., S. Griffin, O. F. Norheim, A. J. Culyer, and K. Chalkidou. 2021. Distributional cost-effectiveness analysis comes of age. *Value Health* 24 (1): 118–120. https://doi.org/10.1016/j.jval.2020.10.001.
21. HM Treasury: *Strengthening the Soft Drinks Industry Levy – Summary of responses*. HM Treasury/Department of Health and Social Care, London (2025). Available at: https://www.gov.uk/government/consultations/strengthening-the-soft-drinks-industry-levy/outcome/strengthening-the-soft-drinks-industry-levy-summary-of-responses. Accessed 8 Dec 2025.
22. Imamura, F., L. O'Connor, Z. Ye, J. Mursu, Y. Hayashino, S. N. Bhupathiraju, and N. G. Forouhi. 2016. Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: Systematic review, meta-analysis, and estimation of population attributable fraction. *British Journal of Sports Medicine* 50 (8): 496–504. https://doi.org/10.1136/bjsports-2016-h3576rep.
23. Malik, V. S., A. Pan, W. C. Willett, and F. B. Hu. 2013. Sugar-sweetened beverages and weight gain in children and adults: A systematic review and meta-analysis. *American Journal of Clinical Nutrition* 98 (4): 1084–1102.
24 Taillie, L. S., J. A. Rivera, B. M. Popkin, and C. Batis. 2017. Do high vs. low purchasers respond differently to a nonessential energy-dense food tax? Two-year evaluation of Mexico's 8% nonessential food tax. *Preventive Medicine* 105 (Suppl): S37–S42. https://doi.org/10.1016/j.ypmed.2017.07.009.
25. Andreyeva, T., M. W. Long, and K. D. Brownell. 2010. The impact of food prices on consumption: A systematic review of research on the price elasticity of demand for food. *American Journal of Public Health* 100 (2): 216–222. https://doi.org/10.2105/AJPH.2008.151415.
26. Etilé, F., and A. Sharma. 2015. Do high consumers of sugar-sweetened beverages respond differently to soft drink taxes? *American Journal of Agricultural Economics* 97 (2): 440–465. https://doi.org/10.1002/hec.3157.
27. Andreyeva, T., K. Marple, S. Marinello, T. E. Moore, and L. M. Powell. 2022. Outcomes following taxation of sugar-sweetened beverages: A systematic review and meta-analysis. *JAMA Network Open* 5 (6): e2215276.
28. Dickson, A., M. Gehrsitz, and J. Kemp. 2025. Does a spoonful of sugar levy help the calories go down? An analysis of the UK Soft Drinks Industry Levy. *Review of Economics and Statistics* 107 (6): 1754–1763. https://doi.org/10.1162/rest_a_01345.
29. Leibinger, A., O. Huizinga, K. Emmert-Fees, S. Pedron, M. Laxy, E. Rehfuess, J. Burns, and P. von Philipsborn. 2025. The impact of tiered soft drink taxes in Europe on mean sales-weighted sugar content of soft drinks: A quasi-experimental study. *BMC Public Health* 25 (1): 2106. https://doi.org/10.1186/s12889-025-23331-w.
30. Hoffer, Adam, and Jacob Macumber-Rosin. 2025. Soda taxes won't fix global health. Tax Foundation (2025). Available at: https://taxfoundation.org/research/all/global/sugar-tax-soda-tax-ssb/.
31. Liu, S., P. J. Veugelers, C. Liu, and A. Ohinmaa. 2022. The cost effectiveness of taxation of sugary foods and beverages: A systematic review of economic evaluations. *Applied Health Economics and Health Policy* 20 (2): 185–198. https://doi.org/10.1007/s40258-021-00685-x.
32. Wendorf, Aleksandra, and Ignacy Rogoń. 2025. Is a beverage tax really a healthy start? Worldwide analysis. Journal of Public Health. https://doi.org/10.1007/s10389-025-02528-8.
33. Drewnowski, A., and S. E. Specter. 2004. Poverty and obesity: The role of energy density and energy costs. *American Journal of Clinical Nutrition* 79 (1): 6–16. https://doi.org/10.1093/ajcn/79.1.6.
34. Larson, N. I., M. T. Story, and M. C. Nelson. 2009. Neighborhood environments: Disparities in access to healthy foods in the US. *American Journal of Preventive Medicine* 36 (1): 74–81. https://doi.org/10.1016/j.amepre.2008.09.025.
35. Fearne, A., N. Borzino, B. De La Iglesia, P. Moffatt, and M. Robbins. 2022. Using supermarket loyalty card data to measure the differential impact of the UK soft drink sugar tax on buyer behaviour. *Journal of Agricultural Economics* 73 (2): 321–337. https://doi.org/10.1111/1477-9552.12462.

36. Quiroz-Reyes, J. A., J. E. Morales-Ríos, A. Vargas-Flores, N. A. Sánchez-Ortiz, and M. A. Colchero. 2025. Are taxes to sugar-sweetened beverages and non-essential energy dense food implemented in Mexico regressive? *PLoS ONE* 20 (3): e0319922. https://doi.org/10.1371/journal.pone.0319922.
37. Young, A., K. James, and A. Hassan. 2022. The role of regressive sugar tax in the soft drink industry levy (SDIL): A Marxist analysis. *Critical Perspectives on Accounting* 88:102326. https://doi.org/10.1016/j.cpa.2021.102326.
38. Asaria, M., S. Griffin, and R. Cookson. 2016. Distributional cost-effectiveness analysis: A tutorial. *Medical Decision Making* 36 (1): 8–19. https://doi.org/10.1177/0272989X15583266.
39. Lal, A., A. M. Mantilla-Herrera, L. Veerman, K. Backholer, G. Sacks, M. Moodie, and A. Peeters. 2017. Modelled health benefits of a sugar-sweetened beverage tax across different socioeconomic groups in Australia: A cost-effectiveness and equity analysis. *PLoS Medicine* 14 (6): e1002326. https://doi.org/10.1371/journal.pmed.1002326.
40. Wagstaff, A. 2002. Inequality aversion, health inequalities and health achievement. *Journal of Health Economics* 21 (4): 627–641. https://doi.org/10.1016/S0167-6296(02)00006-1.
41. Fuchs, Alan, and Denisse Pierola. 2022. The distributional impacts of health taxes. Equitable Growth, Finance and Institutions Insight - Poverty and Equity. World Bank, Washington, DC. https://doi.org/10.1596/38409.
42. Paraje, G. R., P. Jha, W. Savedoff, and A. Fuchs. 2023. Taxation of tobacco, alcohol, and sugar-sweetened beverages: Reviewing the evidence and dispelling the myths. *BMJ Global Health* 8 (Suppl 8): e011866. https://doi.org/10.1136/bmjgh-2023-011866.
43. Simmonds, M., A. Llewellyn, C. G. Owen, and N. Woolacott. 2016. Predicting adult obesity from childhood obesity: A systematic review and meta-analysis. *Obesity Reviews* 17 (2): 95–107. https://doi.org/10.1111/obr.12334.
44. Rogers, N. T., S. Cummins, H. Forde, et al. 2023. Associations between trajectories of obesity prevalence in English primary school children and the UK soft drinks industry levy: An interrupted time series analysis of surveillance data. *PLoS Medicine* 20 (1): e1004160. https://doi.org/10.1371/journal.pmed.1004160.
45. Lee, M. M., J. L. Barrett, E. L. Kenney, et al. 2024. A sugar-sweetened beverage excise tax in California: Projected benefits for population obesity and health equity. *American Journal of Preventive Medicine* 66 (1): 94–103.
46. Briggs, A. D. M., et al. 2017. Health impact assessment of the UK soft drinks industry levy: A comparative risk assessment modelling study. *Lancet Public Health* 2:e15–e22. https://doi.org/10.1016/S2468-2667(16)30037-8.
47. Collins, B., et al. 2015. Modelling the health impact of an English sugary drinks duty at national and local levels. *PLoS ONE* 10:e0130770. https://doi.org/10.1371/journal.pone.0130770.
48. National Institute for Health and Care Excellence (NICE). Guide to the methods of technology appraisal 2013. Process and methods [PMG9], 2013, Available at: https://www.nice.org.uk/process/pmg9
49. Verguet, S., R. Laxminarayan, and D. T. Jamison. 2015. Universal public finance of tuberculosis treatment in India: An extended cost-effectiveness analysis. *Health Economics* 24:318–332. https://doi.org/10.1002/hec.3019.
50. Watkins, David A., et al. 2018. Universal health coverage and essential packages of care in *Disease Control Priorities*. 3rd ed. **9**, 3rd edn. (ed. Jamison, D. T.) (World Bank, 2018) 43–65. https://doi.org/10.1596/978-1-4648-0527-1_ch3.
51. Long, M. W., et al. 2015. Cost effectiveness of a sugar-sweetened beverage excise tax in the US. *American Journal of Preventive Medicine* 49:112–123. https://doi.org/10.1016/j.amepre.2015.03.004.

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