Fiscal and pricing policies related to food and non-alcoholic drinks

A review of the evidence

Fiscal and pricing policies related to food and non-alcoholic drinks: a review of the evidence

Publication date: April 2023

Acknowledgements

*safe*food wishes to acknowledge all those who contributed to the completion of this project:

- Prof Ciaran O'Neill (Principal Investigator), Professor Jayne Woodside, Professor Frank Kee and Professor Mike Clarke, Dr Luke Barry, School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast
- Professor John Cawley, Department of Economics, Cornell University
- Dr Edel Doherty, Dr Grainne Crealey, School of Business and Economics, University of Galway
- Professor Jim Duggan, School of Computer Science, University of Galway.

Table of contents

Executive summary

In this report we present the findings from a review of the evidence on fiscal and pricing strategies for food and non-alcoholic drinks commissioned by safefood. The review of the evidence comprised two umbrella reviews of the literature and two empirical studies. The umbrella reviews examined evidence for whether and how such fiscal and pricing policies in relation to food and non-alcoholic drinks might improve diet and prevent non-communicable diseases (NCDs). They also examined the effects of such policies with respect to equity and to the public and political acceptability of fiscal and pricing measuresintended to improve diet. In addition to this, empirical studies were undertaken to examine the relationship between the taxation of sugar-sweetened beverages (SSBs) in Northern Ireland with, on one hand, their consumption and, on the other, treatment for dental caries.

The key findings are:

- There is sufficient evidence (mainly from SSBs) to suggest that taxes affect consumption if applied appropriately (that is, at the right level and where consumers have limited opportunity to buy untaxed sugary alternatives instead).
- While there is evidence of public support for measures to address obesity/overweight, there is limited evidence of support for using taxes to achieve this. Consensus must therefore be sought as to the merits of such policies, providing credible evidence that they succeed and will mitigate any regressive effects that disadvantage lower-income groups.
- There is currently a lack of evidence on the impact of taxes and pricing policies on health outcomes. This is an important gap in itself, and also matters because of its potential to undermine arguments for the use of taxes and pricing policies in the future. While our preliminary evidence suggests they affect the use of healthcare services, further evidence of health effects is required.
- We recommend that the use of fiscal instruments be considered beyond those currently applied to SSBs, with a view to improving public health and reducing health inequalities.

Recommendations

Adopted at the correct level, fiscal measures have the potential to influence consumption, and may influence health. Hence, our work gives rise to the following recommendations to improve the effectiveness and acceptability of FIs:

- If the intention is to minimise the administrative burden, then a value-added tax may be most appropriate as this fits within the existing tax structure and automatically adjusts for inflation. However, it may drive consumers towards more unhealthy but cheaper goods.
- If the intention is to raise government revenue, then a lower (<15-25% increase in the price faced by consumers) ad-quantum tax on individual products may be most appropriate as it would provide a more consistent revenue stream. However, it may not change behaviour sufficiently to improve health.
- If the intention is to improve health (as was assumed to be the case in these reviews), then a higher (>15-25% increase in the price faced by consumers) ad-quantum tax on health-harming nutrients may be most appropriate as it would reduce leakage to cheaper alternative SSBs. Also, if announced far enough in advance of its introduction, this tax may encourage manufacturers to reformulate their products.
- To improve the acceptability of an FI, the government should:
    - Be clear about the intention and of the FI and how its design is fit for purpose
    - Provide credible evidence on how effectively FIs can achieve their goals
    - Set out measures to mitigate costs or create positive financial advantages for lower-income consumers (distributional effects)
    - Set measurable goals to assess how effectively the FI achieves its intention, and audit its progress
    - Promise to share information on progress towards the stated goals and mitigations
- In the cases of diet-related taxes specifically, government should:
    - Where feasible, target health-harming nutrients as opposed to individual products
    - Where this is not feasible, identify a list all health-harming products which may act as substitutes and may require taxation
    - Coordinate with neighbouring jurisdictions to avoid possible cross-border leakage
    - Undertake educational and promotional campaigns to highlight the potential of such instruments to improve health
    - Use revenues raised through such measures to mitigate costs to lower-income groups – for example, by subsidising fruit and vegetables – and promote these alternatives to the public
    - Audit and publicise the allocation of revenues to these initiatives.

- In addition to promoting the positive intentions and impacts of taxes, government should counter opposition narratives about how taxes can damage the economy (e.g. causing unemployment), including by fact-checking and countering industry-sponsored studies.
- Furthermore, where opposition groups publicise anti-tax narratives, government should, as part of their promotion strategy, highlight the sources of this messaging and show how it stems from the biases of these groups.

1 Introduction

Background

Non-communicable diseases (NCDs) are a leading cause of morbidity and mortality globally[1]. They present a significant avoidable burden to the health and social care system as well as the wider economy. Poor diet is a major contributor to the rise in NCDs and has been linked with the development of a range of conditions, includingtype 2 diabetes, cardiovascular disease, several cancers and overweight/obesity[2]. In Ireland, it is estimated that 60% of adults are living with overweight or obesity, with similar figures for Northern Ireland. A social patterning in prevalence is also evident. There is also evidence of excessive salt and fat consumption, with associated social patterning. Overweight and obesity in 2009 were estimated to cost €1.13 billion in Ireland and €0.51 billion in Northern Ireland[3]. Other studies have estimated the cost of diabetes, heart failure and stroke. Consistent with the socio-economic gradient in many of these conditions, lower socio-economic groups are likely to experience a disproportionate share of morbidity attributable to diet.

A body of literature has suggested that measures such as taxes and subsidies on specific nutrients including sugar, salt, fats and fibre or on categories such as energy-dense foods, fruit and vegetables may be successful in changing consumption patterns[4-8]. Compared to interventions targeted at individuals – based on public health information messages and education, for example – evidence suggests fiscal measures may be more effective and, by involving less personal agency, may also reduce inequalities[7]. The literature in this area continues to evolve as new evidence becomes available and as researchers seek to address specific gaps in our current knowledge and identify options for interventions. How transferable these findings are to the context in Ireland and Northern Ireland is unclear, given differences such as price elasticity; the coordination of pricing with other measures aimed at improving diet; the healthcare system; and broader societal issues including attitudes to inequality.[9]

Recent systematic reviews of evidence have taken place on pricing and fiscal policies and on the public and political acceptability of fiscal policies, though evidence continues to evolve[10]. With regard to evidence in Ireland, the *potential* impact of a fiscal measure has been estimated – for example, the tax on sugar-sweetened beverages (SSBs)[11]. However, the value of these estimates is open to question as they were based on a modelling exercise whose parameters did not match those of the tax that was introduced. In addition, the model could not take account of efforts by manufacturers to avoid the tax through reformulating their products. No work

appears to have been published specific to Northern Ireland on the effect of the tax or its impact on consumption by different groups.

While the upward trend in prevalence of overweight and obesity on the island of Ireland (IOI) appears to have stabilised in recent years, obesity and overweight continue to present a significant burden to the health and social care system, the economy and people's lives, as does cardiovascular disease related to salt and fat consumption[3,12]. Globally, governments and international agencies have prioritised a coordinated response among state and non-state agencies to address unhealthy diets. In concert with international agencies such as the World Health Organization, various countries have adopted a range of fiscal and pricing policies. Policy makers on the IOI can look to these policies to assess what measures others have used, to what effect, for whom, how and over what time period. They may also help shed light on barriers and facilitators (B/F) – the factors that make it politically possible or difficult to adopt such measures.

Recent systematic reviews of fiscal and pricing policies that have been adopted internationally have examined (a) their effectiveness in changing behaviours with respect to specific nutrients and food groups[4-8]; and (b) the public and political acceptability of fiscal policies aimed at changing behaviour[10]. In both areas, evidence continues to evolve but its transferability to the IOI remains unexamined. This omission makes it difficult for policy makers on the IOI to develop policy instruments.

To the best of our knowledge, no analysis based on real-world data has examined the impact of fiscal instruments (FIs) on consumption patterns on the IOI. In other jurisdictions, such studies have used real-world evidence (RWE) to examine the impact of FIs on consumption, but there is little evidence about their impact on health. We know of no studies that have examined this issue on the IOI.

In this report:

- We provide an overview and data synthesis of systematic reviews of fiscal and pricing policies directed at changing diet and reducing the risk of non-communicable disease.
- We consider how such measures affect socio-economic inequality and how far the evidence is transferable to the IOI.
- We undertake an overview and data synthesis of systematic reviews examining the public and political acceptability of fiscal and pricing strategies, and identify the key factors associated with support for such measures.

- Using data from expenditure surveys, we examine changes in consumption in Northern Ireland that coincided with the introduction of the tax on SSBs introduced in the UK in 2018. This is the first work of its type we are aware of on the IOI.
- We examine changes, coinciding with the introduction of the tax, in patterns of publicly funded treatment of caries among children, using dental claims data in Northern Ireland. This is the first work of its type we are aware of on the IOI.
- Based on our overviews of the literature and our original empirical work, we identify gaps in our knowledge and set out policy recommendations grounded in evidence relevant to the IOI.

Research methods

The work was divided across three work packages (WPs):

- WP1 comprised two overviews of systematic reviews and an assessment of their transferability to the IOI.
- WP2 comprised the analyses of secondary data on the association between taxing SSBs on the IOI, consumption of SSBs and treatment for caries.
- WP3 comprised the development of a series of policy recommendations grounded in the evidence of what works and what is politically sustainable for adoption on the IOI; as well as an assessment of threats and opportunities to the attainment of these policies.

The specific aims, methods, results and conclusions are set out in the chapters that follow.

References

1. GBD 2017 Causes of Death Collaborators. (2018). Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet*, *392*(10159), 1736-1788. doi: 10.1016/S0140-6736(18)32203-7
2. GBD 2017 Diet Collaborators. (2019). Health effects of dietary risks in 195 countries, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet*, *393*(10184), 1958-1972. doi: 10.1016/S0140-6736(19)30041-8. Epub 2019 Apr 4. PMID: 30954305; PMCID: PMC6899507
3. Dee, A., Kearns, K., O'Neill, C. et al. (2014). The direct and indirect costs of both overweight and obesity: a systematic review. *BMC Res Notes 7*, 242. https://doi.org/10.1186/1756-0500-7-242
4. Powell, L.M., Chriqui, J.F., Khan, T., Wada, R., Chaloupka, F.J. (2013) Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, demand and body weight outcomes. Obes Rev. 2013 Feb;14(2):110-28. doi: 10.1111/obr.12002. Epub 2012 Nov 23. PMID: 23174017; PMCID: PMC3556391
5. Thow, A.M., Downs, S., Jan, S. (2014). A systematic review of the effectiveness of food taxes and subsidies to improve diets: Understanding the recent evidence, *Nutrition Reviews*, *72*, 9, 1 September 2014, 551–565. https://doi.org/10.1111/nure.12123
6. Niebylski, M.L., Redburn, K.A., Duhaney, T., Campbell, N.R. (2015). Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition, 31*(6), 787-95. doi: 10.1016/j.nut.2014.12.010. Epub 2014 Dec 31. PMID: 25933484
7. McGill, R., Anwar, E., Orton, L. *et al.* Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health 15,* 457 (2015). https://doi.org/10.1186/s12889-015-1781-7
8. Wright, A., Smith, K.E. & Hellowell, M. (2017). Policy lessons from health taxes: a systematic review of empirical studies. *BMC Public Health 17*, 583. https://doi.org/10.1186/s12889-017-4497-z
9. https://www.euro.who.int/__data/assets/pdf_file/0008/273662/Using-price-policies-to-promote-healthier-diets.pdf
10. Eykelenboom, M., van Stralen, M.M., Olthof, M.R. et al. (2019). Political and public acceptability of a sugar-sweetened beverages tax: a mixed-method systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity 16*, 78. https://doi.org/10.1186/s12966-019-0843-0
11. Briggs, A.D., Mytton, O.T., Madden, D. et al. (2013). The potential impact on obesity of a 10% tax on sugar-sweetened beverages in Ireland, an effect assessment modelling study. *BMC Public Health 13*, 860. https://doi.org/10.1186/1471-2458-13-860
12. Hendriksen, M.A., van Raaij, J.M., Geleijnse, J.M., Breda, J., Boshuizen, H.C. (2015). Health gain by salt reduction in Europe: a modelling study. *PLoS One*, *10*(3). e0118873. doi:10.1371/journal.pone.0118873

2 An umbrella review of the effectiveness of fiscal and pricing policies to reduce diet-related non-communicable disease

Introduction

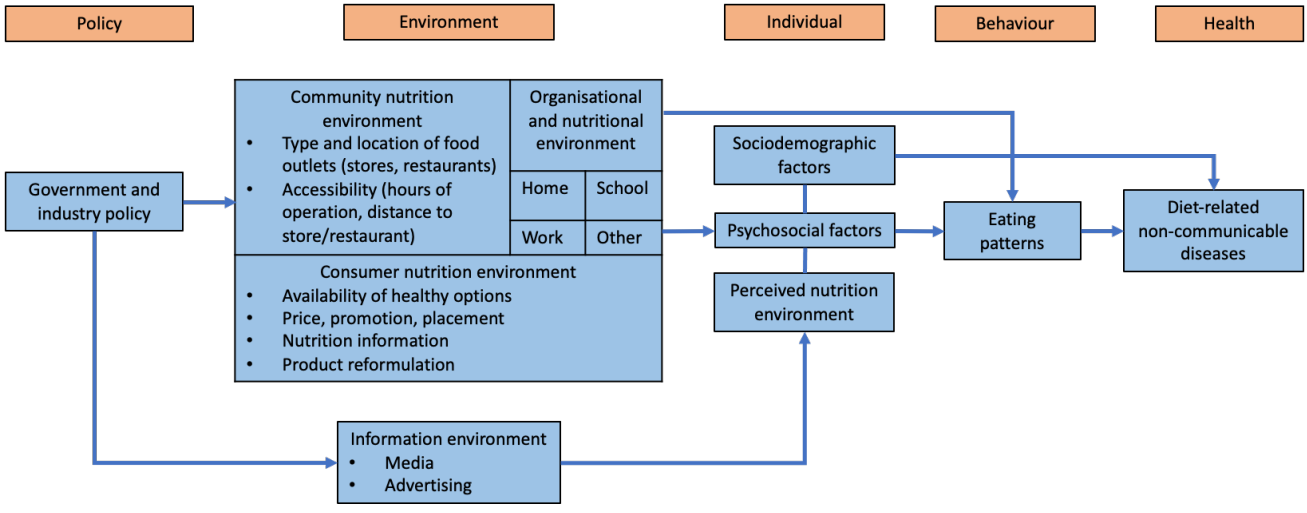
Poor-quality diets, specifically those high in salt, sugar and fat and low in fruit, vegetables, legumes and nuts, represent major risk factors for the global burden of disease[1-3]. Unhealthy eating patterns are common on the island of Ireland (IOI), as are socio-economic disparities in such eating behaviours, ultimately affecting the health of the population[4-8]. Evidence in Ireland from modelling studies indicates a potential for fiscal policies to change behaviour and reduce risks[9, 10]. The policy environment (the context in which governments make policies about food, or the policies affecting food choice, or the general availability and cost of the foods people buy) in which food choices are made on the IOI has also changed in recent years, which could limit or increase the effectiveness of fiscal and other pricing policies[11, 12]. While the upward trend in the prevalence of overweight and obesity on the IOI appears to have stabilised in recent years, these conditions continue to present a significant burden to the health and social care system and the economy, while high levels of salt and fat consumption in the obese and non-obese remain linked to rates of cardiovascular disease[13, 14]. In line with international agencies such as the World Health Organization, governments have prioritised a coordinated response involving state and non-state agencies to address current dietary intake[15]. This has sparked interest in a range of fiscal and other pricing measures that policymakers on the IOI may wish to consider as public health measures.

Fiscal and pricing policies (henceforth referred to as fiscal interventions [FI]), such as taxes or subsidies, are seen as an important tool for changing consumer behaviour – both by affecting the price of goods and by encouraging manufacturers to reformulate their products – and ultimately for improving the health of the population[16-18]. Government-level measures such as these do not remove personal choice but rely less on an individual's ability to comply, which may be linked to socioeconomic factors (e.g. health literacy or level of education)[19-21]. The distributional impacts of FIs (how the costs and benefits of the policies affect various socioeconomic groups) can be positive and negative. For instance, a tax on sugar-sweetened beverages (SSB) might impose a relatively large tax burden on low-income families but also

confer a greater health benefit[22-25]. Much of the evidence on the distributional impacts of FIs as well as their overall effect on health comes from modelling studies rather than real-world evidence (RWE)[25]. As the number of jurisdictions implementing FIs has grown, however, so too has the number of studies examining their effectiveness, as well as reviews synthesising these studies. Umbrella reviews provide an important tool for policymakers by summarising the highest level of evidence, namely systematic reviews and meta-analyses, on a research topic/question[26].

In this chapter, we present an umbrella review of the effectiveness of fiscal and pricing policies in reducing diet-related non-communicable disease (NCD). We also consider intermediate outcomes which may help to reduce NCDs, such as changing consumer behaviour or reformulating products. We use an updated framework from Bowen et al (2015) to consider FIs in the context of factors which may affect their success and are part of the current system (Figure 2.1), for example the availability and healthiness of substitutes not directly affected by the FI[27]. As disparities in diet-related NCDs are evident across socioeconomic and minority groups[28], they are critical in assessing the success of such fiscal policies. Where possible, we examine the distributional impacts of policies according to PROGRESS+ categories[29].

Figure 2.1: Framework contextualising the complex system within which fiscal and pricing policies to reduce diet-related non-communicable diseases are implemented



Adapted from Bowen et al (2015)

Methods

Search strategy

The protocol for the umbrella review was registered at the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42021249212, Appendix 2.1). A search of the following databases was conducted on 10 June 2021: MedLine, EMBASE, PsychINFO, SCI, SSCI,

Web of Science, Scopus, EconLit, the Cochrane Library, Epistemonikos, and the Campbell Library. For Google Scholar, we first completed the review on all other databases and then compared this final list to the returns from the first five pages (50 studies) returned to see if any additional studies merited inclusion.

We used a range of search terms (Appendix 2.2) classified under three themes: study type, intervention and outcome. Search terms for 'study type' focused on systematic reviews or meta-analyses. Terms for 'intervention' and 'outcomes' focused on the policy variables, behaviour and health categories outlined in Figure 2.1. 'Intervention' terms included those related to government fiscal and pricing policies. 'Outcome' terms included intermediate outcomes, such as consumer behaviour or product reformulation, and tertiary outcomes, namely bodyweight or diet-related NCDs. Within each theme "or" operators were used to combine terms, and across each theme "and" operators were used. Searches were tailored according to the functionality of each database. Where possible, we used MeSH terms (MedLine, EMBASE, PsychInfo) which corresponded to the thematic areas (Appendix 2.2). Where a database provided tools to further limit the search strategy, we restricted it to studies of 'humans' (MedLine, EMBASE, PsychInfo) and applied a database tool designed to achieve the best balance between sensitivity and specificity of searches for systematic reviews (MedLine)[30].

To further ensure the specificity of our search, we identified four systematic reviews from the outset[22, 24, 31, 32], which we had expected to include based on the inclusion/exclusion criteria used. These were used to test the search strategy but not to design it. We validated our search strategy across search engines, based on whether or not they returned these articles. No restrictions were placed on language. We followed the Peer Review of Electronic Search Strategies (PRESS) guidelines in designing our search strategy, though it was not peer reviewed[33].

Screening

One reviewer (LB) executed the search strategy, collated the results and removed the duplicates in EndNote 20 software[34]. Two reviewers (CON and LB) independently screened article titles first to remove redundancies, and compared results before finalising a list of articles for abstract screening. Disagreements were discussed until consensus was reached or input was sought from a third reviewer (FK), though ultimately this was not required. Next, abstracts were screened using the same process followed by a full-text screening. We searched reference lists, contacted authors and sought expert opinion to identify relevant studies or acquire full texts. For any articles that required translation into English, we initially used online translation software to identify any clear reasons for exclusion and otherwise used a professional translation service.

Inclusion/exclusion criteria

We included all systematic reviews examining the effectiveness of fiscal and pricing policies implemented by governments to improve diet at population level. Eligible reviews for inclusion were those that:

- Conducted a systematic review with or without meta-analysis
- Examined at least one government-enacted fiscal intervention (FI)
- Used real-world evidence (RWE), i.e. not simulated models of expected effectiveness
- Examined policies that targeted the consumption of food and non-alcoholic beverages, i.e. not agricultural policies with unintended impacts upon consumption
- Examined impact upon tertiary outcomes, i.e. diet-related NCDs, or upon intermediate outcomes, e.g. consumer behaviour or product reformulation
- Examined policies that applied to the entire population of its jurisdiction, e.g. we excluded experiments with price discounts in supermarkets or subsidies provided to selected groups

Criteria for qualification as a systematic review were taken from the Cochrane Handbook for Systematic Reviews of Interventions[35]. Reviews were therefore excluded if they did not provide all of the following:

1. A clearly stated set of objectives with pre-defined eligibility criteria for studies
2. An explicit, reproducible methodology
3. A systematic search that attempted to identify all studies that would meet our eligibility criteria
4. An assessment of the validity of the findings of the included studies
5. A systematic presentation and synthesis of the characteristics and findings of the included studies

We also excluded reviews if the authors stated explicitly that they had not conducted a systematic review.

We excluded reviews of modelling/simulation studies (i.e. those that simulate a result) and theoretical studies. If a review included studies which satisfied the inclusion criteria (i.e. RWE examining an implemented fiscal policy applied across an entire population of its jurisdiction) as well as studies which did not (e.g. a modelling study of the same intervention), and if it presented these different types separately, we included the review and reported results only relating to the relevant studies. If the original reviewers had combined the findings of modelling or theoretical studies with those examining RWE, we used the combined results while noting reviews that included a mix of results in our synthesis. The same process was followed where a

review examined price changes in relation to an FI as well as variations in prices for other reasons, e.g. supermarket promotions. We excluded reviews evaluating interventions that applied only within a limited setting such as supermarkets, airports or schools; reviews that only involved price variation unrelated to an implemented government policy; and reviews that targeted only a specific group, such as low-income groups, children or pregnant women. Where a review reported on FIs targeted at a specific group of the population as well as ones applied to an entire population, we reported on both.

Data extraction

Data extraction was carried out using an online form that included questions on: aims; methods; eligibility criteria and search strategy; funding sources; setting; participants; intervention (and comparator where available); outcomes measured; research design; any sub-group analyses related to specific groups of participants; any distributional impacts on outcomes or the tax burden; and criteria relevant to our quality appraisal (see below), for example whether any conflicts of interest were reported. Distributional impacts of the tax burden or NCD outcomes were examined using axes of differentiation according to PROGRESS-Plus[29], given that inequalities may arise across groups differentiated in ways other than by socio-economic status[36, 37].

The extraction form was trialled by two reviewers (LB and CON), each using three systematic reviews before finalising the form[38]. As part of the original protocol, we intended to conduct data extraction and quality appraisal in duplicate. However, due to time constraints, extraction was performed in duplicate (LB and CON) on 25% of articles. These results were compared and guidelines developed on how best to extract information from the remaining studies in a consistent manner, and this task was completed by one reviewer (LB). For example, it was decided 'research design' should be documented according to whether the systematic review included studies that were: randomised-controlled trials (RCTs); non-random studies of interventions (NRSIs) (e.g. controlled before-and-after, cohort, longitudinal or cross-sectional studies); modelling studies (which simulated results); or other reviews[39].

Quality appraisal

We assessed the methodological quality of 25% of the systematic reviews included for final review in duplicate (LB and CON) using the AMSTAR2 tool[40]. Disagreements were resolved by discussion and where necessary by reference to a third reviewer (FK), though this was not required. The rest of the reviews were appraised by one reviewer (LB) and results discussed with an independent expert advisory panel (EAP) established to advise on the conduct of the overview. The EAP comprised researchers with international reputations in the areas of public

health and economics for work in this area. Details of the EAP are shown in Appendix 2.3. The AMSTAR2 tool allows a broad indication of whether the quality of a study is high, moderate, low or critically low. Studies which received a critically low score were excluded from the final review but were listed for transparency. The quality rating applied to studies in this systematic review does not necessarily reflect the overall quality of the study but rather reflects how well it addresses the aim of our umbrella review. For example, a review may have included information which merited inclusion as part of our review criteria even where this information may not have been the focus of the original study.

Synthesis

Relatively few of the heterogeneous reviews we looked at met our eligibility criteria, including only one meta-analysis. Having excluded some studies through quality appraisal, we made a narrative synthesis of those systematic reviews we chose to include. A summary of each review is presented in Table 2.1.

Table 2.2 provides an overview of the evidence on the use of FI in affecting outcomes. We structure the table according to evidence related to the intermediate and tertiary outcomes that each study examined (Figure 2.1). Thus a review article may be named more than once within Table 2.2. Results are documented according to whether there is evidence or a lack of evidence for the effectiveness of FIs according to the review authors' qualitative assessment. Where quantitative results were provided as part of a meta-analysis, these are reported in Table 2.2, as are any distributional or subgroup impacts.

Robustness check

Reviews which have more than one critical flaw, according to the AMSTAR2 rating, received a critically low score. As a robustness check, we examined characteristics and results from reviews which had only two critical flaws (i.e. those studies which, given one change in score, would have been included in our final review). We compared results from our main synthesis with the results from these lower-rated reviews to check whether including them would have led us to different conclusions.

While umbrella reviews summarise high-level evidence from systematic reviews, they are not fully up to date as they can only summarise primary studies published up to the most recent systematic review search date. While our search covered work published up to June 2021, the most recent systematic review search date was October 2019. As countries have continued to implement FIs, we conducted a literature review of primary studies published between January 2020 and November 2021 to examine whether these supported or conflicted with the results of our umbrella review. This literature review used the search strategy from the umbrella review.

However, it was applied only to EMBASE and updated to focus only on English-language journal articles whose titles referenced tax or subsidies and excluded references to alcohol or tobacco (Appendix 2.4). The literature review search was more restricted than the umbrella review (e.g. by language), was conducted at a high level by only one reviewer (LB) and did not involve any quality assessment. It provides a useful overview of primary studies after 2019 on the intermediate and tertiary (including distributional) impacts of taxes and subsidies to compare with our umbrella review results.

Results

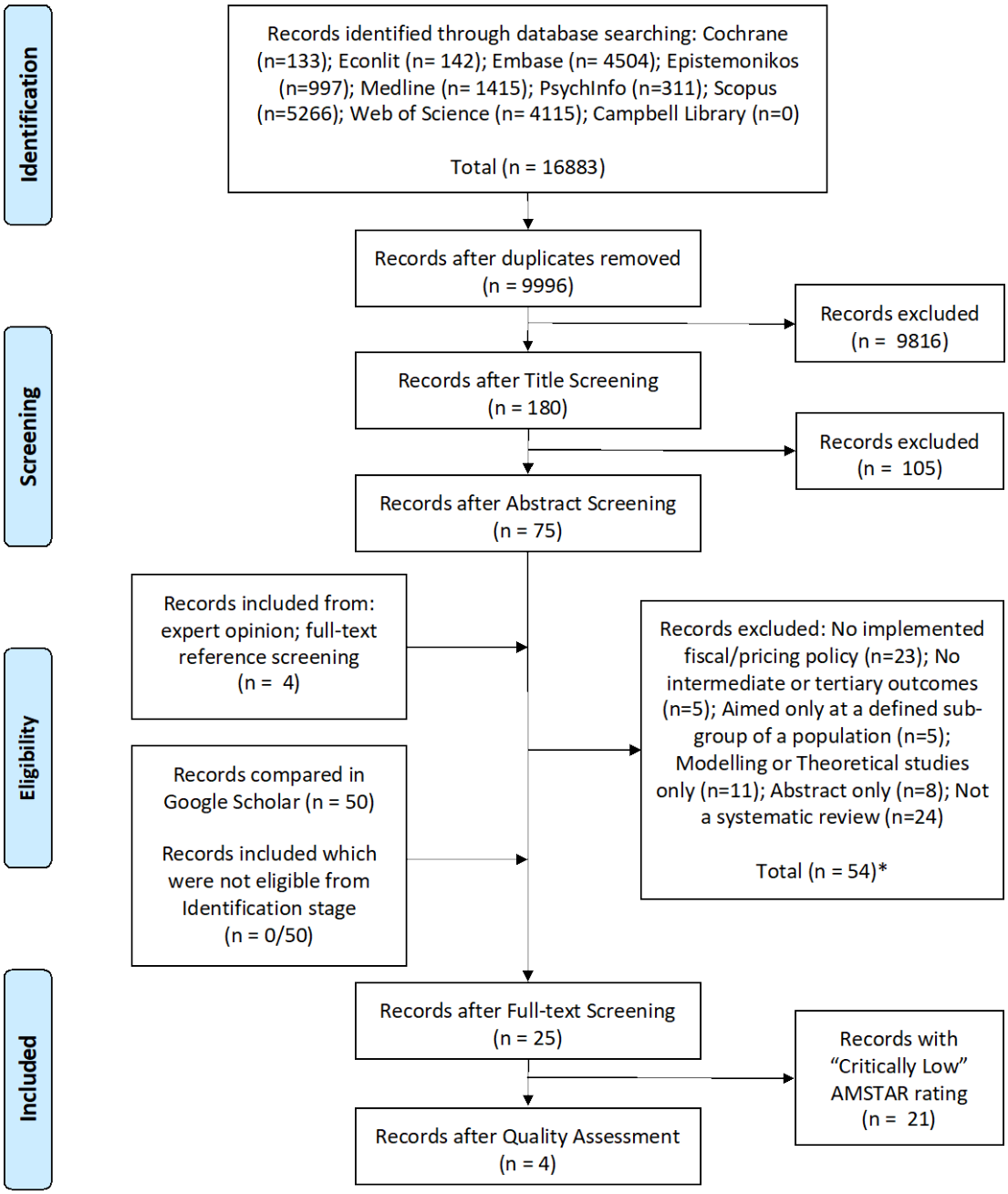
Screening

A total of 16,883 records were identified through database searches, resulting in 9,996 unique records once duplicates were removed (Figure 2.2). After abstract screening this was reduced to 75 records, with an additional four records included following recommendations from experts in the field and searches of reference lists, though these four were excluded in subsequent screening. The Google Scholar search found no new records to include which had not already been identified in the original database search. One study in Russian was translated online for full-text screening and all others were in English. Following full-text screening, a further 54 records were excluded (the Russian paper was excluded as it did not qualify as a systematic review), leaving 25 potentially relevant records for data extraction. All 25 are listed in Appendix 2.5 along with a summary of the databases in which they were indexed. 100% (25/25) of reviews were indexed across only two databases (EMBASE for 96% [24/25] and Web of Science for 84% [21/25]).

Quality appraisal

Following quality appraisal, only four systematic reviews/meta-analyses were included as part of our synthesis. Two reviews were rated as 'high'[41, 42] and two as 'low'[43, 44]; while the rest received a 'critically low' AMSTAR2 rating. Six reviews received a marginal 'critically low' rating and were therefore included in sensitivity analysis (below). Not including a list of potentially relevant but excluded studies (n=6/6) and not justifying publication restrictions (n=4/6) were the main reasons for these ratings (Appendix 2.6). Where a review restricted inclusion to studies of humans only, no justification was necessary and thus no penalty was incurred in the AMSTAR2 rating. All the included reviews either reported no conflicts of interest or, where conflicts of interest were reported, described how these were managed so as not to influence results.

Figure 2.2: PRISMA flow diagram for systematic identification of umbrella review literature



*Counts for individual exclusions do not sum to total as reviews may have been excluded based on one or more criteria

Characteristics of included reviews

Table 2.1 provides an overview of each of the included reviews. These were published between 2017 and 2020, had no publication restrictions (except humans) and had few restrictions on the populations they analysed. One review focused broadly on changes to healthy/unhealthy eating resulting from FIs as well as other non-FI interventions such as menu labelling[44]. Two reviews focused more specifically on taxes on sugar and sugary food and beverages[41, 43] and one on taxed

fat[42]. None of these reviews included results from modelling studies as they all examined NRSIs using RWE on the implementation of FIs. Two of these were conducted as Cochrane reviews[41, 42], which were also the reviews that received a 'high' quality rating. They included a combined total of only four studies, suggesting the Cochrane systematic review evidence base had meagre data for the effectiveness of taxes on the sugar, fat or other nutrient content of foods in changing behaviour or health.

Table 2.1: Characteristics of reviews included in the narrative synthesis

	Lhachimi et al 2020	Pfinder et al 2020 [41]	Sisnowski et al 2017 [44]	Teng et al 2019 [43]
Research designs	NRSI	NRSI	NRSI	NRSI
Synthesis method	Narrative synthesis	Narrative synthesis	Narrative synthesis	Meta analysis
Population	Healthy population, any age, any setting, any country	Healthy population, any age, any setting, any country	General population, any age, any setting, any country	Any population, any age, any country, distinct local or central government setting (e.g., city, region, or nation)
Intervention	FI (taxes) on the fat content in foods	FI (taxes) on unprocessed sugar or sugar-added foods	FI (taxes and subsidies) and other non-FI interventions (e.g. labelling) to reduce the consumption of energy-dense foods and beverages and increase consumption of healthy foods	FI (taxes) on sugar-sweetened beverages
No. of databases	20	29	16	4
Search period	Earliest date up to September/October 2019	Earliest date up to September/October 2019	2005 to 31 October 2015	Earliest date up to June 2018
Search restrictions	Humans	Humans	Humans	None
No. of included studies	3	1	36	15

NRSI - non-random studies of interventions; FI – fiscal intervention

Note: We have described the populations as they were described by the review authors. Where the population inclusion criteria were not described in the review, we have assumed that 'any' population, age, setting or country could be included.

Table 2.2: Effects of intervention strategies synthesised by included systematic reviews on intermediate and tertiary outcomes

Author/year	Intervention	Outcome	Narrative synthesis results	Meta-analysis results	Distributional effects	Quality rating
Intermediate outcomes: direct effects						
Lhachimi et al, 2020	FI (taxes) on the fat content in foods	Total fat consumption	Evidence to support effectiveness of taxes in reducing fat consumption – "Very uncertain evidence that taxing the fat content of foods reduces estimated total fat consumption by 41.8 grams per week, per person in a household (P < 0.001)."	No meta-analysis conducted	No subgroup analysis conducted	High
		Total saturated fat consumption	Evidence to support effectiveness of taxes in reducing saturated fat consumption – "There is very uncertain evidence that taxing the fat content of foods reduces the estimated saturated fat content of sales by 4.2% for minced beef and by 5.8% for cream, and increases the estimated saturated fat content of sales by 0.5% for sour cream. (No measure of statistical			

			precision was reported for any of these results.)"			
Pfinder et al, 2020	FI (taxes) on unprocessed sugar or sugar-added foods	Taxed sugar-added food consumption /purchasing	Evidence to support effectiveness of taxes in reducing sugar-added food consumption – "There was a decrease in the mean consumption of taxed sugar-added foods by 4.0% (SMD −0.040, 95% CI −0.07 to −0.01) after implementation of the Hungarian public health product tax intervention. The effect is based on very low-certainty evidence."	No meta-analysis conducted	No subgroup analysis conducted	High
		Taxed sugar-added food expenditure	Evidence to support effectiveness of taxes in reducing taxed sugar-added food expenditure – "There was an effect of the intervention on the mean expenditure of taxed sugar-added foods. Data show that the mean expenditure decreased after the implementation of the intervention. slightly by 0.6% (SMD −0.006, 95% CI			

			−0.03 to 0.02). The effect is based on very low certainty evidence."			
Sisnowski et al, 2017	FI (taxes and subsidies) and other non-FI interventions (e.g. menu labelling) to reduce the consumption of energy-dense foods and beverages and increase consumption of healthy foods (fruit and vegetables)	Taxed unhealthy food and beverage consumption and subsidised healthy food consumption	Evidence to support effectiveness of taxes & subsidies in reducing consumption/purchasing of unhealthy foods and increasing consumption/purchasing of healthy foods "...recent studies at national level and in hotspots of obesity prevention activities such as New York City have found both a shift in the attitudes of consumers towards sugary drinks and an actual reduction in average soft drink consumption."	No meta-analysis conducted	No subgroup analysis conducted	Low
Teng et al, 2019	FI (taxes) on SSBs	Taxed SSB consumption /purchasing	Evidence to support effectiveness of taxes in reducing consumption/purchasing of SSBs – "This examination of real-world SSB tax evaluations through meta-analysis presents compelling evidence that SSB taxes are associated with decreased sales,	Each 10% increase in the price (of SSBs) is associated with a 10.2% (-5.0 to -14.7; n=17 studies/6 jurisdictions) decrease in	Estimate of own-price elasticity (1.02) was not significantly different for adults (0.64)	Low

			purchasing, and dietary intake of taxed beverages."	consumption/purchasing of SSBs. The random effects model was justified given the high level of heterogeneity between jurisdictions (I-squared = 97%)	vs children (0.77), p = 0.91.	
Intermediate outcomes: indirect effects						
Lhachimi et al, 2020	FI (taxes) on the fat content in foods	Taxed medium/low-fat foods	Evidence to support effectiveness of taxes in switching consumers from high-fat to medium/low-fat foods consumption – "Jensen 2015 reported the changes in the distribution of sales as a consequence of the tax for all three included food products, i.e. from a high-fat variety to a medium- or low-fat variety, based on supermarket sales data. The authors, however, did not report confidence intervals, significance levels (i.e. p-values),	No meta-analysis conducted	No subgroup analysis conducted	Low

			or any other measure about the statistical precision of their effect estimates."			
Pfinder et al, 2020	FI (taxes) on unprocessed sugar or sugar-added foods	Untaxed sugar-added food consumption /purchasing	Lack of evidence to support effectiveness of taxes in increasing untaxed sugar-added food consumption – "There was no direct substitution effect. The mean consumption of untaxed sugar-added foods even decreased after the implementation of the tax by 1.3% (SMD −0.013, 95% CI −0.05 to 0.02). The effect is based on very low certainty evidence." HOWEVER "The mean consumption of taxed sugar-added foods differed from the mean consumption of untaxed sugar-added foods after the implementation of the intervention by 2.8% (SMD −0.028, 95% CI −0.07 to 0.02). The effect is based on very low-certainty evidence."	No meta-analysis conducted	No subgroup analysis conducted	High

		Untaxed sugar-added food expenditure	Evidence to support effectiveness of taxes in increasing untaxed sugar-added food expenditure – "The mean expenditure on untaxed sugar-added foods increased after the implementation of the intervention by 3.0% (SMD 0.03, 95% CI −0.01 to 0.07). The effect is based on very low-certainty evidence." AND "The mean expenditure on taxed sugar-added foods differed from the mean expenditure on untaxed sugar-added foods after the implementation of the intervention by 3.7% (SMD −0.037, 95% CI −0.08 to 0.01). The effect is based on very low-certainty evidence."			
Teng et al, 2019	FI (taxes) on SSBs	Untaxed beverage consumption /purchasing (e.g. milk, water, juice, or diet/zero	Lack of evidence to support effectiveness of SSB tax in increasing untaxed beverage consumption (e.g. milk, water, juice, or diet/zero and light beverages) – “There was no statistical evidence of an increase in total untaxed beverage	Each 10% increase in the price (of SSBs) is associated with a 1.9% (-2.1 to 6.1; n=6 studies/4 jurisdictions) increase in untaxed beverage	No subgroup analysis conducted	Low

		and light beverages)	consumption nor for water, juice, milk, or diet/zero and light beverage volumes." HOWEVER "… there were significant increases in untaxed beverage consumption in three of the four jurisdictions (Berkeley, Mexico, and other United States), with only the combined Chile studies showing a non-significant decrease."	consumption. Each 10% increase in the price (of SSBs) is associated with a 2.9% (-6.2 to 12.7; n=6/4) increase in water consumption. Each 10% increase in the price (of SSBs) is associated with a 2% (-10.5 to 7.2; n=3 studies) decrease in juice consumption. Each 10% increase in the price (of SSBs) is associated with a 47.4% (-35.5 to 237.1; n=2 studies) increase in milk consumption. Each 10% increase in the price (of SSBs) is associated with a 4.5% (-12.7 to 25.1; n=2		

				studies) increase in diet/zero and light beverage consumption.		
Tertiary outcomes						
Sisnowski et al, 2017	FI (taxes and subsidies) and other non-FI interventions (e.g. menu labelling) to reduce the consumption of energy-dense foods and beverages and increase consumption of healthy foods (fruit and vegetables)	Overweight, obesity, and diet-related non-communicable disease	Lack of evidence to support effectiveness of taxes and subsidies in improving health – "...the interventions assessed here fail to achieve an effect on consumption that could plausibly be considered as clinically significant, i.e. as having an effect on individuals' nutritional intake to the extent that it would reduce the incidence of overweight, obesity, and related chronic diseases."	No meta-analysis conducted	No subgroup analysis conducted	Low

FI – fiscal intervention; SMD – standardised mean difference; SSB – sugar-sweetened beverage

Effectiveness of fiscal interventions

Intermediate outcomes – direct effects

All four of the included reviews provided information on the effectiveness of FIs, namely taxes, in changing consumption or purchasing of the targeted food or non-alcoholic beverage(s). The reviews covered 55 primary studies with some overlap of included studies between reviews, while Sisnowski et al (2017) also included studies of non-FIs, e.g. menu labelling[44]. The evidence across reviews consistently supported the effectiveness of taxes on unhealthy foods or non-alcoholic beverages – in particular SSBs – in reducing their consumption, often proxied by purchasing behaviour. Those reviews with the highest quality rating included the fewest studies[41, 42] but also focused on more specific nutrients in foods; see Table 2.1.

Estimates of own-price elasticity (how the quantity demanded changes according to the price of the product) were only identified for SSBs, with one review conducting a meta-analysis that examined the effect of taxes on SSBs from studies conducted up to June 2018[43]. The authors present strong evidence that taxes on SSBs are associated with reduced purchases by using a two-step approach to adjust for both jurisdiction (n=6) and study-level heterogeneity (n=17) while also conducting a range of sensitivity analyses. The authors estimated an own-price elasticity of -1.00 (95% confidence interval [CI]: 0.57 to 1.47), noting that higher taxes tended to have a larger impact on consumption. No statistically significant differences ($p < 0.05$) were observed across study designs (interrupted time-series, before-after or cross-sectional); tax types (*ad valorem*[1], volumetric or threshold values); study quality (high or medium/low); consumption measure (self-report or purchasing/sales data); peer-review (Y/N); funding source (NGO/public, other/unclear or industry); or when comparing adults to children.

Pfinder et al (2020) reviewed studies conducted up to September/October 2019 examining the effect of taxes on sugar and sugar-added foods. They judged only one study from Hungary as having sufficient quality and relevance to be included (the Hungarian Public Health Product tax on foods with a specific sugar content as well as certain beverages and foods high in sugar or caffeine). Lhachimi et al (2020) reviewed studies examining taxes on the fat content of food (an excise tax approximately equivalent to USD$2.70/kg on certain food types such as meat and full-fat dairy, while exempting those with a saturated fat content of 2.3% or less) up to the same date; they included two primary studies conducted in Denmark and one supporting study noted as relevant but having a high risk of bias. Though the evidence from these reviews

[1] Duty levied as a percentage of value of the services or goods being imported, rather than on their weight or the number of units. Ad valorem duty | Access2Markets (europa.eu)

supported the idea that taxes could change consumer behaviour, the review authors noted a high level of uncertainty as to these results, given the relatively few studies included. Sisnowski et al (2017) also included these Danish and Hungarian studies, along with studies examining other FIs that aim to encourage healthy diet more generally. They reported that FIs have the potential to change behaviour, especially when combined with other types of interventions, such as menu labelling, that aim to change consumer attitudes towards nutrition. A number of studies commented on the failure of adopted policies to implement taxes at a level thought to change behaviour – a threshold around 15-25% on the price faced by the consumer[45-47]. Sisnowski et al also noted that studies of subsidies, although not applied to an entire population within a jurisdiction, often noted increased purchasing of subsidised goods, e.g. fruit and vegetables.

Intermediate outcomes – indirect effects

Three out of the four reviews reported on indirect effects: namely, substitution to different food products as a result of a tax. Significantly, no reviews reported on product reformulation, despite its potential to influence consumption. Lhachimi et al (2020) noted some substitution from high-fat to medium/low-fat foods following the introduction in October 2011 of a tax in Denmark on the fat content of food (this tax being eventually repealed and removed in December 2012). Pfinder et al (2020) reported mixed evidence of the effects of substitution following the introduction in Hungary of a tax on the sugar content of foods in September 2011. The consumption and purchasing of both taxed and untaxed sugar-added food (measured in units of kg) dropped after the tax was implementedt, while average expenditure on untaxed sugar-added foods increased, though not significantly ($p > 0.05$). They noted that both mean expenditure and consumption/purchasing of untaxed sugar-added foods differed from that of taxed sugar-added foods after the tax was introduced, though not significantly ($p > 0.05$).

Finally Teng et al (2019), in their meta-analysis of taxes on SSBs, found no statistically significant ($p > 0.05$) differences in the consumption of untaxed beverages[43]. Compared to their meta-analysis of direct effects, fewer studies ($n = 6$) across fewer jurisdictions ($n = 4$) were available for this analysis, and the authors also noted that this non-significant result was driven by results in one jurisdiction (Chile). Low-sugar or no-sugar items with a lower tax rate were included in the "taxed" category in Chile, which may complicate this analysis. When Chile was excluded from the meta-analysis, a significant increase in the use of untaxed beverages was observed in the remaining jurisdictions (Berkeley, Mexico and the US).

Tertiary outcomes

Only one review examined RWE of tertiary outcomes; that is, whether the tax altered nutrient or energy intake at population level enough to affect health. Sisnowski et al (2017) found little

evidence that, at the levels of tax used, taxes or subsidies to encourage healthy eating would have a strong enough impact to affect overweight or obesity and related NCDs. They caution, however, that such policies may still be able to affect tertiary outcomes. The design of such policies is critical in establishing such evidence and in properly analysing real-world policies in action (where substitution can be taken into account) rather than modelling studies. Two reviews included tertiary outcomes (overweight, obesity, health-related quality of life, mortality and other diet-related NCDs such as type 2 diabetes or cardiovascular disease) as part of their search strategy[41, 42]. However, they found no evidence on the effectiveness of FIs in relation to these outcomes.

Robustness check

Review characteristics and results were extracted for reviews (n=6) which had only two critical flaws in the AMSTAR2 quality rating[22, 48-52] and therefore received a marginal critically low rating (Appendices 2.7 and 2.8). When considering the results of these reviews, the key messages from our narrative synthesis were unchanged:

1. There is evidence to support the use of taxes and subsidies in changing the consumption or purchasing of taxed/subsidised goods.
2. There is some evidence of substitution, i.e. consuming or purchasing untaxed goods or crossing borders to buy them in jurisdictions where they are not taxed.
3. There is a lack of RWE to show that FIs are effective in changing health outcomes.

Many of these additional reviews included modelling studies, which were more likely to indicate that FIs would affect tertiary outcomes (e.g. BMI or diet-related NCDs).

Finally, three of the reviews examined the distributional impacts of FIs[22, 49, 52]. They found some evidence that FIs which apply to entire populations either improved inequalities or at least did not make them worse with respect to outcome and only to a small degree have made inequality with respect to taxation worse (i.e. increased the tax burden on the poor). However, most of this evidence came from modelling studies, and the selection of primary studies using RWE found that taxes had a neutral impact on health conditions among different socioeconomic groups.

Our literature review identified 24 primary studies, published between January 2020 and November 2021, which presented RWE of the effectiveness of taxes and subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related NCDs (Appendices 2.9 and 2.10). These covered FIs implemented in India[53], Spain[54], France and Hungary[55], Denmark[56], South Africa[57, 58], Cook Islands[59], Tonga[60], Saudi Arabia[61-63], Thailand[64], Mexico[65, 66], and various jurisdictions within the US[67-76]. The majority of these (n = 23) examined taxes on non-alcoholic

beverages, namely SSBs. The other study, conducted on the Navajo Nation, examined the effect of subsidies on healthy food and found that the availability of fruits and vegetables increased by comparison to neighbouring unsubsidised jurisdictions[67].

Twenty studies found evidence that taxes were effective in reducing consumption of taxed items[54-60, 62-66, 68-76]. Two of these showed that reformulation was part of the mechanism underlying reduced sugar intake[58, 69]. Three studies showed that when a tax was reduced or repealed there was a subsequent increase in the consumption of taxed or previously taxed beverages[56, 59, 70]. Many studies found evidence of substitution, whereby consumers switched to untaxed alternatives within stores or shopped in untaxed jurisdictions. In some cases substitution was implied rather than explicit, either because people were consuming as much sugar as before despite buying fewer taxed items, or because effects were negligible at a population level[54, 55, 57, 58, 60, 65, 69, 71-74]. Only one study examined tertiary outcomes, and it found no evidence that an SSB tax in South Africa (known as the Health Promotion Levy) reduced BMI at the tax levels implemented[57].

Finally, a selection of studies (n = 5) examined the distributional impacts of the taxes. These focused on inequalities in outcomes rather than on the tax burden. All except one study consistently found evidence that the tax was most effective in reducing consumption among lower-income, lower-educated or unemployed individuals/households, and among those with high baseline intake[57, 60, 64, 68]. The study that found greater reduction in SSB consumption among higher-educated individuals was from a distinct sample of employees from a healthcare provider[66]. One study conducted among a sample of high-consuming and low-income individuals found large reductions in taxed beverage intake[58]. We did not conduct a quality assessment of these studies, but results were consistent with those described above when we restricted the sample of included studies to those which analysed both a pre- and post-tax implementation period as well as figures from untaxed jurisdictions[54, 67-71, 73-75].

Discussion

We conducted an umbrella review to summarise the highest-level evidence of the effects of FIs on food and non-alcoholic beverages in improving diet and preventing diet-related NCDs. We considered four systematic reviews, one including a meta-analysis, in our final sample[41-44]. We found evidence to support the effectiveness of FIs (taxes and subsidies) in changing the consumption of taxed/subsidised goods, and some evidence of taxes leading consumers to substitute untaxed products or those with a lower tax rate. However, there was a lack of RWE to show that FIs effectively improved population health. There was little evidence from the included reviews as to the distributional impacts of FIs. Teng et al (2019) found no difference

between adults and children in their meta-analytic estimate of elasticity (change in demand) due to taxes on SSB consumption[43].

Relatively few of the reviews that we identified as being potentially relevant (n=25) were included in our final sample (Appendix 2.5). As a robustness check, we examined those studies which were closest to being included (<=2 critical-domain flaws in their AMSTAR2 rating). These reviews showed FIs to be effective in changing consumer behaviour[48-51], improving population health[49, 51], and reducing disparities in health[22, 49] or at least not increasing disparities[52]. They also found that taxes are likely to be regressive (paid by everyone regardless of income, therefore a greater burden on low-income groups) though not substantially so[49]. This is supported by other reviews which showed that taxes reduce health inequalities and, while they may be regressive, are often more cost-effective for lower rather than higher socioeconomic groups in terms of leading to better health and less expenditure on healthcare[22, 23, 77].

Much of this evidence came from modelling studies (which often fail to account for substitution effects), highlighting the relative lack of detailed real-world analyses on the impact of FIs and consequently a readiness to resort to modelling studies. Although modelling studies have a greater risk of bias, they can also model higher tax rates than those actually implemented by governments, given these usually meet opposition from affected groups such as manufacturers[44]. Teng et al (2019) in analysing RWE found that higher taxes had larger impacts on consumption. It remains important to treat the results of modelling studies with caution, given their dependence on assumptions – for example, the assumption that there would be the political will to adopt FIs at higher, more effective levels.

The two reviews which received a high quality AMSTAR2 rating were conducted as Cochrane reviews (which follow a standard and internationally respected methodology to limit bias and error). This supports the validity of our quality assessment while demonstrating the importance of Cochrane reviews as part of a rigorous examination of the highest-quality evidence on health interventions. These were the two most recent reviews, published in 2020, and they provide a relatively up-to-date assessment of the current body of evidence showing that FIs effectively improve population health by targeting the sugar and fat content of foods. They found that taxes are likely to change consumption of these nutrients but report low certainty in this result, given that the two reviews covered only four primary studies in total. Further Cochrane reviews, such as the upcoming review by Heise et al on SSB taxes[78], are needed to assess the effectiveness of FIs in relation to other nutrients or products and also to assess the certainty of such evidence.

A general limitation of umbrella reviews can be their timeliness. As they are reviews of reviews of primary studies, they may lag behind emerging evidence. The estimate of own-price elasticity

of demand (how demand responds to the changing price of a particular product) resulting from SSB taxation (-1.00 [95% CI: -1.47 to -0.57]) in Teng et al (2019) was consistent with another meta-analysis published too late for our search. This study calculated the elasticity of demand due to SSB taxes to be -1.47 (95% CI -2.11 to -0.83) across 26 estimates from 19 studies[79]. When accounting for cross-border shopping in the subset of studies which examined substitution (n = 5), this elasticity was reduced to -1.05 (95% CI: -1.54 to -0.57). A systematic review examining the effectiveness of taxes on SSBs to reduce overweight and obesity was also published after the closure of our search window[80]. It found that an SSB tax could be effective in reducing consumption of SSBs and the prevalence of overweight/obesity. It also noted a dose-response effect, with higher taxes leading to lower energy intake. However, much of this evidence came from modelling studies, and the three real-world studies examining health outcomes reported no significant effects of taxes on BMI. The authors call for more longitudinal studies of implemented taxes, repeating observations over a longer timespan, to better assess their effect on health.

We also conducted a literature review of primary studies published between January 2020 and November 2021, which examined the effectiveness of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related NCDs. We found further evidence that taxes on unhealthy nutrients or products reduced the amount consumed, along with even more evidence showing a substitution effect – which often negated the impact of the tax. In the case of SSBs for example (which accounted for c.95% of the primary studies identified), consumers switched to other untaxed sugary products or shopped in neighnouring jurisdictions where no tax applied, with little to no net decline in sugar intake. This helps explain the lack of evidence we found regarding the effectiveness of taxes in affecting tertiary health outcomes such as BMI. However, there were examples of individuals switching to healthier beverages such as water or reducing their net sugar consumption in spite of substitution[60, 69]. Furthermore, the greatest reductions in consumption of unhealthy products took place among lower socioeconomic groups or those with high baseline intake[57, 60, 64, 68]. This suggests that the tax is likely to benefit those most at risk of the harms of unhealthy diets, highlighting the importance of tax design in improving public health.

FIs have the potential to correct market failures such as externalities, where the consumption of harmful goods imposes a cost to society, such as on the health system. They can also correct internalities[2], where consumers take actions that are not in their own best interest[81]. In the case

[2] a long-term benefit or cost to an individual that they do not consider when making the decision to consume a good or service

of SSB taxes, Allcott et al (2019) present a number of principles which help guide measures to reduce diet-related NCDs in general[82]. They argue that:

1. Taxes are an important tool for counteracting these market failures while still allowing individual agency (as opposed to bans, for example).
2. Internalities and externalities are concentrated among different groups, e.g. differing by socioeconomic status (SES), and tax policies should account for this as well as their potential regressivity (disproportionate burden on different groups).
3. The quantity of the health-harming ingredients should be taxed, which for SSBs would mean taxing the amount of sugar in grammes rather than the volume or value.
4. Taxation policy address the potential for substitution within and across tax jurisdictions to attain maximum effect.

In relation to these principles, we found the following:

- Excise taxes on the sugar or fat content of foods and non-alcoholic beverages were likely to reduce their consumption. This suggests that they are normal goods (where demand increases in line with an increase in consumers' income) – since Teng et al (2019) show that demand for SSBs goes down when the price rises (negative own-price elasticity of demand). It also shows that excise taxes are to some extent passed through to consumers (i.e., prices rise to reflect some of the tax) despite the availability of substitutes. A meta-analysis by Powell et al (2021) estimated that SSB excise taxes in the US have a pass-through rate of 65% (95% CI: 50-79%)[83]. However, many of the reviews included here found that taxes often did not increase the price of a good by enough to change behaviour (for example a 15-25% increase in retail price)[44, 45, 47, 84].
- Where there are distributive concerns, Allcott, Lockwood and Taubinsky (2019) show that internalities resulting from SSB consumption in the US, such as inattention, are concentrated among lower SES groups, and a tax on SSBs would particularly benefit these groups by reducing these unforeseen consequences[84]. In Ireland, poor diet is concentrated among lower SES groups[85], which suggests this principle may be transferable, as evidenced from primary studies outside of the US showing that taxes reduce consumption more among those in lower SES groups[57, 60, 64] and are likely more cost-effective for these groups[82]. Farhi and Gabaix (2019) show that where externalities (wider consequences to society) and internalities apply across all SES groups, subsidies alongside taxes may be more effective than taxes alone in correcting market failure[86],

for example a 10% reduction in the price of fruits and vegetables[15]. FIs are still unlikely to be a silver bullet, and we found evidence that to improve public health they may be more effective when implemented alongside other measures[44]. These could include public information programmes around food content and health. They could also include labelling or interventions to promote lifestyle change, such as more physical activity, given the links between other lifestyle behaviours and NCDs[87] as well as the correlation in Ireland between unhealthy diet and sedentary behaviour[88].

- An ad valorem tax, such as a sales tax based on the value of the goods being sold, increases the price in percentage terms. However, it is likely to push consumers towards cheaper but not necessarily healthier options[45]. In countries like the US where the shelf price often does not include the sales tax, it may be even less effective. Ad quantum taxes on the quantity of the health-harming nutrient, such as sugar, are preferable. Excise taxes on suppliers allow for this but are effective only when manufacturers pass through enough of the tax to the consumer to change behaviour. The more own-price elasticity there is in the demand for the product (which depends on how many substitutes are available), the less likely a producer is to pass through the cost to the consumer. However, as described in (1), a substantial proportion of a tax is often passed through. Although this makes for a more complex intervention, such ad quantum taxes – targeting the helath-harming nutrient – are more effective[82]. Denmark provides an important example of taxing a nutrient – fat. However, this tax has been repealed[42], which suggests that the acceptability of FIs to both policymakers and the public merits further research.
- These principles generally assume a paternalistic government intending to correct market failure in relation to health. However, different tax designs may serve different aims. For example, an ad valorem tax may be the least burdensome administratively, or ad quantum taxes on products rather than nutrients may generate more revenue[89]. In Mexico, an added-sugar and calorie-dense tax appears so far to have failed to correct such externalities due to substitution[65], but has been maintained and has become more acceptable due to yielding government revenue that is earmarked for improved drinking water[15, 90].
- Only one meta-analysis – taxes on SSBs – was included in our final sample. Its estimate of cross-price elasticity was insignificant but likely underpowered[43] as we found many other examples of substitution to untaxed products as a result of a tax. Where substitution occurs, then too high a tax may lead to loss of welfare as people switch to untaxed products or shop in untaxed jurisdictions[91]. In this case, other health-harming

substitutes should also be taxed – but with caution where such substitutes also provide micronutrients; e.g. fruit juices contain vitamins as well as sugar[82, 92].

- The design of FIs should consider the complex setting/environment in which they are implemented (Figure 2.1) and neighbouring jurisdictions should coordinate their policies to avoid leakage. In the case of the IOI, cross-border shopping is likely between the north and south and may negate the purpose of a tax, especially in border counties, if adopted without coordination with the neighbouring jurisdiction.
- Analyses are warranted of the direct and indirect effects of the SSB tax implemented by the UK and Ireland in April/May 2018. This involved taxing the sugar content of drinks through a two-tier system, which can both encourage substitution towards lower-sugar drinks and encourage manufacturers to reformulate their products to avoid the higher tax rate[16]. This observation is borne out elsewhere[58, 69], though we should consider the healthiness of the substituted ingredients. Our observations on substitution effects explain the lack of evidence regarding FIs on health outcomes, though more high-quality longitudinal studies are needed.

Limitations

Our study's limitations point to directions for future research.

Firstly, we restricted our review to policies which applied across an entire population within a jurisdiction. This was because we intended to avoid FIs implemented in controlled settings, such as experiments in supermarkets. Instead we aimed to examine how FIs affected different social groupings in different ways. [36], For example, although there are no US government programmes to support increased fruit and vegetable consumption nationally for the whole population[93], a number of reviews focused on the US Supplemental Nutrition Assistance Program (SNAP), which subsidises healthy eating for low-income households. However, these reviews were subsequently excluded (unless reviewed alongside eligible FIs). Additional research is required to examine policies such as these, which aim to encourage healthy eating among targeted subgroups of the population, as they provide a figurative (and potentially literal) carrot alongside the stick of taxation to encourage consumption of important micronutrients and macronutrients[92].

Missing also from this review were efforts by governments to control promotional offers by private enterprises, such as bans on buy-one-get-one-free, or minimum pricing laws such as those related to alcohol in Ireland, which may be effective in the case of other health-harming goods[94]. Synergies may also exist with policies related to climate change or environmental sustainability[95, 96], as many of the foods consumed on the island of Ireland which are nutrient

dense, such as fruits, vegetables and nuts, also have a lower environmental impact than unhealthy processed foods[8].

We found mixed evidence on how far the effect of taxes waned over time[53, 69, 75] and therefore cannot draw any conclusions on the long-term impact of FIs. The length of follow-up when analysing the effect of taxes is generally short, as most examples and analyses of FIs were less than five years old, and more research is needed.

As noted above, our umbrella review was restricted to evidence within the search windows of our selected systematic reviews, which can mean the research may be out of date. We thus discussed systematic reviews and meta-analyses conducted after our search date, examined reviews which were narrowly excluded in our quality assessment, and conducted a brief literature review of more recent studies examining the effectiveness of taxes and subsidies to reduce NCDs. We consistently found there is:

1. Evidence to support the use of taxes and subsidies in changing consumption or purchasing of taxed/subsidised goods
2. Evidence that FIs encourage substitution in terms of consuming or purchasing untaxed goods or goods in untaxed jurisdictions
3. A lack of RWE to support the effectiveness of FIs in changing health outcomes

We also found that when taxes were repealed or cut, consumption of unhealthy products returned to previous levels and potentially even higher. This highlights the importance of further research to understand the political and public acceptability of such interventions.

Conclusion

We find that taxes and to some extent subsidies are effective in changing the levels of consumption of taxed/subsidised items. However, substitution is likely to occur. Therefore, FIs present an important policy tool for improving public health but their design is critical. The fact that substitution can negate the effect of the FI undermines its goals and may also undermine public confidence. This could reduce support for such policies or lead to their repeal, further undermining the success of FIs globally. The lack of evidence we identify regarding the impact of FIs on health outcomes is therefore a concern, and more high-quality RWE longitudinal studies are needed. The implementation of an FI to improve diet and reduce diet-related NCDs can act as a signal to the public as to the importance (both negative and positive) of the taxed products or nutrients in relation to diet. The revenues from taxes in particular can also make FIs more acceptable to the public. However, further research is needed to better understand whether FIs can be implemented and optimised In a politically acceptable manner so as to achieve their aims.

References

1. Global Panel on Agriculture and Food Systems for Nutrition. (2016).*Food systems and diets: Facing the challenges of the 21st century*.
2. Branca, F., Lartey, A., Oenema, S., et al. (2019). Transforming the food system to fight non-communicable diseases. *BMJ*, *364*, l296. doi:10.1136/bmj.l296
3. World Cancer Research Fund. (2018). *Diet, nutrition, physical activity and cancer: A global perspective*. (2018). *Continuous update project expert report 2018*. https://www.wcrf.org/wp-content/uploads/2021/02/Summary-of-Third-Expert-Report-2018.pdf
4. Ward, M., McGee, H., Morgan, K., et al. (2009). SLÁN 2007: survey of lifestyle, attitudes and nutrition in Ireland. 'One Island – One Lifestyle?' Health and lifestyles in the Republic of Ireland and Northern Ireland: Comparing the population surveys SLÁN 2007 and NIHSWS 2005.
5. Purdy, J., McFarlane, G., Harvey, H., Rugkasa, J., Willis, K. (2007). *Food Poverty Fact or Fiction?* https://www.safefood.net/getattachment/e5003878-8e01-414e-903b-89cad89dc39d/PHA2007_FoodPovertyFactorFiction.pdf?lang=en-IE
6. Harrington, K.E., McGowan, M.J., Kiely, M., et al. (2001). Macronutrient intakes and food sources in Irish adults: Findings of the North/South Ireland Food Consumption Survey. *Public Health Nutrition.*, (5a), 1051-60. doi:10.1079/phn2001186
7. Purdy, J., Armstrong, G., McIlveen, H. (2002). The influence of socio-economic status on salt consumption in Northern Ireland. *International Journal of Consumer Studies.*, *26*(1), 71-80.
8. Williams, M., Ianetta, P., Styles, D. (2020). *A Combined Environmental and Nutri-Economic Assessment of Diets*. *Transition paths to sustainable legume-based systems in Europe (TRUE)*.
9. Madden, D. (2015). The poverty effects of a 'fat-tax' in Ireland. *Health Economics.*, *24*(1), 104-21. doi:10.1002/hec.3006
10. Briggs, A. D.,M., Mytton, O.,T., Madden, D., O'Shea, D., Rayner, M., Scarborough, P. (2013). The potential impact on obesity of a 10% tax on sugar-sweetened beverages in Ireland, an effect assessment modelling study. *BMC Public Health*, *13*(1), 860. doi:10.1186/1471-2458-13-860
11. Department of Health. (2016). *A Healthy Weight for Ireland: Obesity Policy and Action Plan: 2016-2025*. 1406429260.
12. Department of Health, Social Services and Public Safety. (2012). *Obesity Prevention Framework for Northern Ireland*. *A Fitter Future for All*.
13. Dee, A., Kearns, K., O'Neill, C., et al. (2014). The direct and indirect costs of both overweight and obesity: A systematic review. *BMC research notes*, *7*, 242.
14. Hendriksen, M. A. H., van Raaij, J. M. A., Geleijnse, J. M., Breda, J., Boshuizen, H. C. (2015). Health gain by salt reduction in Europe: A modelling study. *PLOS ONE*, *10*(3). e0118873. doi:10.1371/journal.pone.0118873
15. Thow, A. M., Downs, S. M., Mayes, C., Trevena, H., Waqanivalu, T., Cawley, J. (2018). Fiscal policy to improve diets and prevent noncommunicable diseases: From recommendations to action. *Bull World Health Organization*, *96*(3), 201-210. doi:10.2471/BLT.17.195982
16. Cawley, J., Thow, A. M., Wen, K., 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*, 317-338. doi:10.1146/annurev-nutr-082018-124603
17. Task Force on Fiscal Policy for Health. (2019). *Health Taxes to Save Lives: Employing Effective Excise Taxes on Tobacco, Alcohol, and Sugary Beverages*. Bloomberg Philanthropies.
18. Beaglehole, R., Bonita, R., Horton, R., et al. (2011). Priority actions for the non-communicable disease crisis. *The Lancet*, *377*(9775), 1438-1447. doi:https://doi.org/10.1016/S0140-6736(11)60393-0
19. Frieden, T. R. A framework for public health action: The health impact pyramid. (2010). *American Journal of Public Health*, *100*(4), 590-595. doi:10.2105/AJPH.2009.185652
20. Whitehead, M. (2007). A typology of actions to tackle social inequalities in health. *Journal of Epidemiology and Community Health*, *61*(6), 473-478. doi:10.1136/jech.2005.037242

21. Capewell, S., Capewell, A. (2017). An effectiveness hierarchy of preventive interventions: Neglected paradigm or self-evident truth? *Journal of Public Health*, *40*(2), 350-358. doi:10.1093/pubmed/fdx055
22. McGill, R., Anwar, E., Orton, L., et al. (2015). Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. Review. *BMC Public Health*, *15*, 457.
23. Jain, V., Crosby, L., Baker, P., Chalkidou, K. (2020). Distributional equity as a consideration in economic and modelling evaluations of health taxes: A systematic review. *Health Policy*,*124*(9), 919-931.
24. Niebylski, M. L., Redburn, K. A., Duhaney, T., Campbell, N. R. (2015). Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition*,*31*(6), 787-95. doi:10.1016/j.nut.2014.12.010
25. World Bank. (2020). *Taxes on Sugar-Sweetened Beverages: International Evidence and Experiences*.
26. Aromataris, E., Fernandez, R., Godfrey, C. M., Holly, C., Khalil, H., Tungpunkom, P. (2015). Summarizing systematic reviews: Methodological development, conduct and reporting of an umbrella review approach. *International Journal of Evidence-Based Healthcare*, *13*(3), 132-40. doi:10.1097/xeb.0000000000000055
27. Bowen, D. J., Barrington, W. E., Beresford, S. A. A. (2015). *Identifying the effects of environmental and policy change interventions on healthy eating*. Annual Reviews Inc. 25785891. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84925244218&doi=10.1146%2fannurev-publhealth-032013-182516&partnerID=40&md5=068146fb11f1d197f83d67324c7f5f78
28. Story, M., Kaphingst, K. M., Robinson-O'Brien, R., Glanz, K. (2008). Creating healthy food and eating environments: Policy and environmental approaches. *Annual Review of Public Health*, *29*, 253-72. doi:10.1146/annurev.publhealth.29.020907.090926
29. O'Neill, J., Tabish, H., Welch, V., et al. (2014). Applying an equity lens to interventions: Using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. *Journal of Clinical Epidemiology*, *67*(1), 56-64. doi:10.1016/j.jclinepi.2013.08.005
30. Wilczynski, N. L., Haynes, R.,B. (2007). EMBASE search strategies achieved high sensitivity and specificity for retrieving methodologically sound systematic reviews. *Journal of Clinical Epidemiology*, *60*(1), 29-33. doi:10.1016/j.jclinepi.2006.04.001
31. Powell, L. M., Chriqui, J. F., Khan, T., Wada, R., Chaloupka, F. J. (2013). Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: A systematic review of prices, demand and body weight outcomes. *Obesity Reviews*, *14*(2), 110-128.
32. Thow, A. M., Downs, S., Jan, S. (2014). A systematic review of the effectiveness of food taxes and subsidies to improve diets: Understanding the recent evidence. *Nutrition Reviews*, *72*(9), 551-65. doi:10.1111/nure.12123
33. McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., Lefebvre, C. (2016). PRESS Peer Review of Electronic Search Strategies: 2015 Guideline Statement. *Journal of Clinical Epidemiology*, *75*, 40-46. doi:10.1016/j.jclinepi.2016.01.021
34. *EndNote*. (2013). Version EndNote 20. Clarivate.
35. Higgins, J., Thomas, J., Chandler, J., et al. (2021). *Cochrane Handbook for Systematic Reviews of Interventions* 6.2 (updated February 2021) (Cochrane, Ed.)
36. Tugwell, P., Petticrew, M., Kristjansson, E., et al. (2010). Assessing equity in systematic reviews: Realising the recommendations of the Commission on Social Determinants of Health. *BMJ*, *341*, c4739. doi:10.1136/bmj.c4739
37. Welch, V., Petticrew, M., Petkovic, J., et al. (2016). Extending the PRISMA statement to equity-focused systematic reviews (PRISMA-E 2012): Explanation and elaboration. *Journal of Clinical Epidemiology*, *70*, 68-89. doi:10.1016/j.jclinepi.2015.09.001
38. Büchter, R. B., Weise, A., Pieper, D. (2020). Development, testing and use of data extraction forms in systematic reviews: A review of methodological guidance. *BMC Medical Research Methodology*, *20*(1), 259. doi:10.1186/s12874-020-01143-3

39. The Cochrane Collaboration. (n. d.) Non-randomised controlled study (NRS) designs. The Cochrane Collaboration. Accessed August 15th, 2021. https://childhoodcancer.cochrane.org/non-randomised-controlled-study-nrs-designs
40. Shea, B. J., Reeves, B. C., Wells, G., et al. (2017). AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*, *358*, j4008. doi:10.1136/bmj.j4008
41. Pfinder, M., Heise, T. L., Boon, M. H., et al. (2020). Taxation of unprocessed sugar or sugar-added foods for reducing their consumption and preventing obesity or other adverse health outcomes. Review. *Cochrane Database of Systematic Reviews* (4), 74. Cd012333. doi:10.1002/14651858.CD012333.pub2
42. Lhachimi, S. K., Pega, F., Heise, T. L., et al. (2020). Taxation of the fat content of foods for reducing their consumption and preventing obesity or other adverse health outcomes. *Cochrane Database of Systematic Reviews* (9). doi:10.1002/14651858.CD012415.pub2
43. Teng, A. M., Jones, A. C., Mizdrak, A., Signal, L., Genc, M., Wilson, N. (2019). Impact of sugar-sweetened beverage taxes on purchases and dietary intake: Systematic review and meta-analysis. Review. *Obesity Reviews*, *20*(9), 1187-1204.
44. Sisnowski, J., Street, J. M., Merlin, T. (2017). Improving food environments and tackling obesity: A realist systematic review of the policy success of regulatory interventions targeting population nutrition. *PLoS ONE*, *12*(8). e0182581.
45. Brownell, K. D., Farley, T., Willett, W. C., et al. (2009). The public health and economic benefits of taxing sugar-sweetened beverages. *The New England Journal of Medicine*, *361*(16), 1599-1605. doi:10.1056/NEJMhpr0905723
46. Powell, L. M., Chaloupka, F. J. (2009). Food prices and obesity: Evidence and policy implications for taxes and subsidies. *Milbank Quarterly*, *87*(1), 229-257.
47. Mytton, O. T., Clarke, D., Rayner, M. (2012). Taxing unhealthy food and drinks to improve health. *BMJ 344*, e2931. doi:10.1136/bmj.e2931
48. Bandy, L., Adhikari, V., Jebb, S., Rayner, M. (2019). The use of commercial food purchase data for public health nutrition research: A systematic review. Review. *PLoS ONE*, *14*(1), e0210192.
49. Backholer, K., Sarink, D., Beauchamp, A., et al. (2016). The impact of a tax on sugar-sweetened beverages according to socio-economic position: A systematic review of the evidence. Review. *Public Health Nutrition*, *19*(17), 3070-3084.
50. Dodd, R., Santos, J.A., Tan, M., et al. (2020). Effectiveness and feasibility of taxing salt and foods high in sodium: A systematic review of the evidence. Review. *Advances in Nutrition*, *11*(6), 1616-1630. doi:10.1093/advances/nmaa067
51. Miracolo, A., Sophiea, M., Mills ,M., Kanavos, P. (2021). Sin taxes and their effect on consumption, revenue generation and health improvement: A systematic literature review in Latin America. *Health Policy and Planning*, *22*.
52. Olstad, D.L., Teychenne, M., Minaker, L. M., et al. (2016). Can policy ameliorate socioeconomic inequities in obesity and obesity-related behaviours? A systematic review of the impact of universal policies on adults and children. Systematic Review. *Obesity Reviews*, *17*(12), 1198-1217. doi:https://dx.doi.org/10.1111/obr.12457
53. Law, C., Brown, K. A., Green, R., et al. (2021). Changes in take-home aerated soft drink purchases in urban India after the implementation of Goods and Services Tax (GST): An interrupted time series analysis. *SSM - Population Health*, *14* (no pagination) 100794. doi:http://dx.doi.org/10.1016/j.ssmph.2021.100794
54. Fichera, E., Mora, T., Lopez-Valcarcel, B. G., Roche, D. How do consumers respond to "sin taxes"? New evidence from a tax on sugary drinks. (2021). *Social Science and Medicine*, *274* (no pagination) 113799. doi:http://dx.doi.org/10.1016/j.socscimed.2021.113799
55. Kurz, C. F., Konig, A. N. (2021). The causal impact of sugar taxes on soft drink sales: Evidence from France and Hungary. *European Journal of Health Economics*, *22*(6), 905-915. doi:http://dx.doi.org/10.1007/s10198-021-01297-x
56. Schmacker, R., Smed, S. (2020). Do prices and purchases respond similarly to soft drink tax increases and cuts? *Economics and Human Biology*, *37* (no pagination)100864. doi:http://dx.doi.org/10.1016/j.ehb.2020.100864

57. Wrottesley, S. V., Stacey, N., Mukoma, G., Hofman, K. J., Norris, S. A. (2021). Assessing sugar-sweetened beverage intakes, added sugar intakes and BMI before and after the implementation of a sugar-sweetened beverage tax in South Africa. *Public Health Nutrition*, *24*(10), 2900-2910. doi:http://dx.doi.org/10.1017/S1368980020005078
58. Essman, M., Taillie, L. S., Frank, T., Ng, S. W., Popkin, B. M., Swart, E. C. (2021). Taxed and untaxed beverage intake by South African young adults after a national sugar-sweetened beverage tax: A before-and-after study. *PLoS Medicine*, *18*(5), (no pagination)1003574. doi:http://dx.doi.org/10.1371/journal.pmed.1003574
59. Teng, A. M., Genc, M., Herman, J., Signal, L., Areai, D., Wilson, N. (2021). Impact of sugar-sweetened beverage taxes on price, import and sale volumes in an island: Interrupted time series analysis. *Public Health Nutrition*, *24*(7), 1828-1835. doi:http://dx.doi.org/10.1017/S1368980021000185
60. Teng, A., Buffiere, B., Genc, M., et al. (2021). Equity of expenditure changes associated with a sweetened-beverage tax in Tonga: Repeated cross-sectional household surveys. *BMC Public Health*, *21*(1), 149. doi:http://dx.doi.org/10.1186/s12889-020-10139-z
61. Alhareky, M., Bedi, S., AlMulhim, A., El Tantawi, M., Farooqi, F.A., AlHumaid, J. (2021). Impact of sugar tax on sugar-sweetened beverage consumption among Saudi schoolchildren. *Oral Health & Preventive Dentistry*, *19*(1), 189-194. doi:http://dx.doi.org/10.3290/j.ohpd.b1075081
62. Megally, R., Al-Jawaldeh, A. (2021). Impact of sin taxes on consumption volumes of sweetened beverages and soft drinks in Saudi Arabia. *F1000Research*, *9* (no pagination) 1117. doi:http://dx.doi.org/10.12688/f1000research.25853.2
63. Alsukait, R., Wilde, P., Bleich, S. N., Singh, G., Folta, S. C. (2020). Evaluating Saudi Arabia's 50% carbonated drink excise tax: Changes in prices and volume sales. *Economics and Human Biology*, *38* (no pagination) 100868. doi:http://dx.doi.org/10.1016/j.ehb.2020.100868
64. Phulkerd, S., Thongcharoenchupong, N., Chamratrithirong, A., Soottipong Gray, R., Prasertsom, P. (2020). Changes in population-level consumption of taxed and non-taxed sugar-sweetened beverages (Ssb) after implementation of ssb excise tax in Thailand: A prospective cohort study. *Nutrients*, *12*(11), 1-15. doi:http://dx.doi.org/10.3390/nu12113294
65. Aguilar, A., Gutierrez, E., Seira, E. (2021). The effectiveness of sin food taxes: Evidence from Mexico. *Journal of Health Economics*, *77*, 102455. doi:https://doi.org/10.1016/j.jhealeco.2021.102455
66. Sánchez-Romero, L. M., Canto-Osorio, F., González-Morales, R., et al. (2020). Association between tax on sugar sweetened beverages and soft drink consumption in adults in Mexico: Open cohort longitudinal analysis of Health Workers Cohort Study. *BMJ*, *369*, m1311. doi:10.1136/bmj.m1311
67. George, C., Bancroft, C., Salt, S. K., et al. (2021). Changes in food pricing and availability on the Navajo Nation following a 2% tax on unhealthy foods: The Healthy Dine Nation Act of 2014. *PLoS ONE*, *16*(9 September), (no pagination)e0256683. doi:http://dx.doi.org/10.1371/journal.pone.0256683
68. Bleich, S. N., Dunn, C. G., Soto, M. J., et al. (2021). Association of a sweetened beverage tax with purchases of beverages and high-sugar foods at independent stores in Philadelphia. *JAMA Network Open*. doi:http://dx.doi.org/10.1001/jamanetworkopen.2021.13527
69. Powell, L. M., Leider, J., Oddo, V. M. (2021). Evaluation of changes in grams of sugar sold after the implementation of the Seattle sweetened beverage tax. *JAMA Network Open*,*4*(11), (no pagination) e2132271. doi:http://dx.doi.org/10.1001/jamanetworkopen.2021.32271
70. Powell, L.M., Leider, J. (2020). Evaluation of changes in beverage prices and volume sold following the implementation and repeal of a sweetened beverage tax in Cook County, Illinois. *JAMA Network Open*, *3*(12). doi:http://dx.doi.org/10.1001/jamanetworkopen.2020.31083
71. Zhong, Y., Auchincloss, A. H., Lee, B. K., McKenna, R. M., Langellier, B. A. (2020). Sugar-sweetened and diet beverage consumption in Philadelphia one year after the beverage tax. *International Journal of Environmental Research and Public Health*, *17*(4), (no pagination), 1336. doi:http://dx.doi.org/10.3390/ijerph17041336

72. Restrepo, B. J., Cantor, J.H. (2020). The effects of soda taxes on adolescent sugar intake and blood sugar. *Health Economics (United Kingdom)*, *29*(11), 1422-1434. doi:http://dx.doi.org/10.1002/hec.4142
73. Cawley, J., Frisvold, D., Hill, A., Jones, D. (2020). Oakland's sugar-sweetened beverage tax: Impacts on prices, purchases and consumption by adults and children. *Economics and Human Biology*, *37*, (no pagination), 100865. doi:http://dx.doi.org/10.1016/j.ehb.2020.100865
74. Powell, L. M., Leider, J., Leger, P. T. (2020). The impact of a sweetened beverage tax on beverage volume sold in Cook County, Illinois, and its border area. *Annals of Internal Medicine*, *172*(6), 390-397. doi:http://dx.doi.org/10.7326/M19-2961
75. Lawman, H. G., Bleich, S. N., Yan, J., et al. (2020). One-year changes in sugar-sweetened beverage consumers' purchases following implementation of a beverage tax: A longitudinal quasi-experiment. *American Journal of Clinical Nutrition*, *112*(3), 644-651. doi:http://dx.doi.org/10.1093/ajcn/nqaa158
76. Cawley J., Frisvold D., Jones, D. (2020). The impact of sugar-sweetened beverage taxes on purchases: Evidence from four city-level taxes in the United States. *Health Economics*, *29*(10), 1289-1306. doi:https://doi.org/10.1002/hec.4141
77. Vidaña-Pérez, D., Braverman-Bronstein, A., Zepeda-Tello, R., et al. (2022). Equitability of individual and population interventions to reduce obesity: A modeling study in Mexico. *American Journal of Preventive Medicine*, *62*(1) , 105-113. doi:https://doi.org/10.1016/j.amepre.2021.05.033
78. Heise, T. L., Katikireddi, S.V ., Pega, F., et al. (2016). Taxation of sugar-sweetened beverages for reducing their consumption and preventing obesity or other adverse health outcomes: A protocol. *Cochrane Database of Systematic Reviews*. .
79. Powell, L. M., Marinello, S., Leider, J., Andreyeva, T. (2021). *A review and meta-analysis of the impact of local US sugar-sweetened beverage taxes on demand.* Chicago, IL: Policy, Practice and Prevention Research Center: University of of Illinois Chicago.
80. Itria, A., Borges, S. S., Rinaldi, A. E. M., Nucci, L. B., Enes, C. C. (2021). Taxing sugar-sweetened beverages as a policy to reduce overweight and obesity in countries of different income classifications: A systematic review. *Public Health Nutrition*, 1-11. doi:10.1017/S1368980021002901
81. Allcott, H., Sunstein, C. R. (2015). Regulating internalities. *Journal of Policy Analysis and Management*, *34*(3):698-705. doi:https://doi.org/10.1002/pam.21843,
82. Allcott, H., Lockwood, B. B., Taubinsky, D. (2019). Should we tax sugar-sweetened beverages? An overview of theory and evidence. *Journal of Economic Perspectives*, *33*(3):202-27. doi:10.1257/jep.33.3.202
83. Powell, L. M., Marinello, S., Leider, J. (2021). *A review and meta-analysis of tax passthrough of local sugar-sweetened beverage taxes in the United States.* Chicago, IL: Policy, Practice and Prevention Research Center: University of of Illinois Chicago.
84. Allcott, H., Lockwood, B. B., Taubinsky, D. (2019). Regressive sin taxes, with an application to the optimal soda tax*. *The Quarterly Journal of Economics*, *134*(3), 1557-1626. doi:10.1093/qje/qjz017
85. Harrington, J., Fitzgerald, A. P., Layte, R., Lutomski, J., Molcho, M., Perry, I.J. (2011). Sociodemographic, health and lifestyle predictors of poor diets. *Public Health Nutrition*, *14*(12), 2166-75. doi:10.1017/s136898001100098x
86. Farhi, E., Gabaix, X. (2020). Optimal taxation with behavioral agents. *American Economic Review*, *110*(1), 298-336.
87. Heron, L., O'Neill, C., McAneney, H., Kee, F., Tully, M. A. (2019). Direct healthcare costs of sedentary behaviour in the UK. *Journal of Epidemiology and Community Health*, *73*(7), 625-629. doi:10.1136/jech-2018-211758
88. Harrington, J. M., Perry, C., Keane, E., Perry, I. J. (2020). Sugar-sweetened beverage consumption and association with weight status in Irish children: A cross-sectional study prior to the introduction of a government tax on sugar-sweetened beverages. *Public Health Nutrition*, *23*(12), 2234-2244. doi:10.1017/S1368980020000014

89. World Health Organization. (2015). *Using price policies to promote healthier diets*. WHO Regional Office for Europe.
90. Eykelenboom, M., van Stralen, M. M., Olthof, M. R., Schoonmade, L. J., Steenhuis, I. H., Renders, C. M. (2019). Political and public acceptability of a sugar-sweetened beverages tax: A mixed-method systematic review and meta-analysis. Literature review; systematic review; meta analysis. *The International Journal of Behavioral Nutrition and Physical Activity 16,* ArtID 78. 16doi:http://dx.doi.org/10.1186/s12966-019-0843-0
91. Arnabal, L. R. (2021). Optimal design of sin taxes in the presence of nontaxable sin goods. *Health Economics*, *30*(7), 1580-1599. doi:https://doi.org/10.1002/hec.4269
92. Finaret, A. B., Masters, W. A.(2019). Beyond calories: The new economics of nutrition. *Annual Review of Resource Economics*, *11*(1). 237-259. doi:10.1146/annurev-resource-100518-094053
93. Pomeranz, J. L., Huang. Y., Mozaffarian, D., Micha, R. (2020). Legal feasibility and implementation of federal strategies for a national retail-based fruit and vegetable subsidy program in the United States. *Milbank Quarterly*, *98*(3), 775-801. doi:http://dx.doi.org/10.1111/1468-0009.12461
94. Health Service Executive. (2021, May 25). *Minimum Unit Pricing on Alcohol – what is it and what will it mean for me?* https://www2.hse.ie/healthy-you/alcohol-blogs/minimum-unit-pricing-on-alcohol-what-is-it-and-what-will-it-mean-for-me-.html
95. Jensen, H. T., Keogh-Brown, M. R., Shankar, B., et al. (2019). International trade, dietary change, and cardiovascular disease health outcomes: Import tariff reform using an integrated macroeconomic, environmental and health modelling framework for Thailand. *SSM - Population Health*, *9*, 100435. doi:https://doi.org/10.1016/j.ssmph.2019.100435
96. de Andrade, M. A. U. J., Watson, J. E. M., Maxwell, S. L. (2020). Unveiling the environmental benefits of reducing sugar. *The Lancet Planetary Health*, *4*(11), e497-e498. doi:10.1016/S2542-5196(20)30226-6
97. Afshin, A., Peñalvo, J. L., Del Gobbo, L., et al. (2017). The prospective impact of food pricing on improving dietary consumption: A systematic review and meta-analysis. *PloS One*, *12*(3), e0172277. doi:10.1371/journal.pone.0172277
98. Alagiyawanna, A., Townsend, N., Mytton, O., Scarborough, P., Roberts, N., Rayner, M. (2015). Studying the consumption and health outcomes of fiscal interventions (taxes and subsidies) on food and beverages in countries of different income classifications: A systematic review. *BMC Public Health*, *15*, 887.
99. Cabrera Escobar, M. A., Veerman, J. L., Tollman, S. M., Bertram, M. Y., Hofman, K. J. (2013). Evidence that a tax on sugar sweetened beverages reduces the obesity rate: A meta-analysis. *BMC Public Health*, *13*, 1072.
100. Gittelsohn, J., Trude, A. C. B., Kim, H. (2017). Pricing strategies to encourage availability, purchase, and consumption of healthy foods and beverages: A systematic review. Review. *Preventing Chronic Disease*, *14*, E107.
101. Maniadakis, N., Kapaki, V., Damianidi, L., Kourlaba, G. (2013). A systematic review of the effectiveness of taxes on nonalcoholic beverages and high-in-fat foods as a means to prevent obesity trends. *ClinicoEconomics and Outcomes Research*, *5*(1), 519-543.
102. McGill R, Anwar E, Orton L, Bromley H, Lloyd-Williams F, O'Flaherty M, Taylor-Robinson D, Guzman-Castillo M, Gillespie D, Moreira P, Allen K, Hyseni L, Calder N, Petticrew M, White M, Whitehead M, Capewell S. Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health*. 2015 May 2;15:457. doi: 10.1186/s12889-015-1781-7. Erratum in: *BMC Public Health*. 2015;15:894. PMID: 25934496; PMCID: PMC4423493.
103. Moran, A.J., Gu, Y., Clynes, S., Goheer, A., Roberto, C. A., Palmer, A. (2020). Associations between governmental policies to improve the nutritional quality of supermarket purchases and individual, retailer, and community health outcomes: An integrative review. Review. *International Journal of Environmental Research and Public Health*, *17*(20), 1-23.

104. Nakhimovsky, S. S., Feigl, A. B., Avila, C., O'Sullivan, G., MacGregor-Skinner, E., Spranca, M. (2016). Taxes on sugar-sweetened beverages to reduce overweight and obesity in middle-income countries: A systematic review. Review. *PLoS One*, *11*(9), e0163358.
105. Redondo, M., Hernandez-Aguado, I., Lumbreras, B. (2018). The impact of the tax on sweetened beverages: a systematic review. Systematic review. *American Journal of Clinical Nutrition*, *108*(3), 548-563. doi:https://dx.doi.org/10.1093/ajcn/nqy135
106. Sobhani, S., Babashahi, M. (2019). Taxation for reducing purchase and consumption of sugar-sweetened beverages: A systematic review. Review. *International Archives of Health Sciences*, *6*(2), 65-72. doi:10.4103/iahs.iahs_62_18
107. Thow, A. M., Jan, S., Leeder, S., Swinburn, B. (2010). The effect of fiscal policy on diet, obesity and chronic disease: A systematic review. [Spanish]. Efecto de la politica fiscal en la dieta, la obesidad y las enfermedades cronicas: Revision sistematica. *Bull World Health Organization*, *88*(8), 609-614.
108. Wright, A., Smith, K. E., Hellowell, M. (2017). Policy lessons from health taxes: A systematic review of empirical studies. *BMC Public Health*, *17*(1), 1-14.

Appendices

Appendix 2.1: PROSPERO umbrella review protocol (CRD42021249212)

Review Title

A systematic review of systematic reviews on the effects of fiscal and pricing policies for food and non-alcoholic drinks on improving diet and preventing non-communicable disease (NCD).

Anticipated Start date

16 April 2021

Anticipated completion date

31 July 2021

Stage of review at time of PROSPERO submission

Not yet started

Named Contact

Dr. Luke Barry, l.barry@qub.ac.uk

Organisational Affiliation of the review

Centre for Public Health, Queen's University Belfast, University Rd., Belfast BT7 1NN, Northern Ireland.

Review Team members and their organisational affiliations

- Prof. Ciaran O'Neill, Queen's University Belfast
- Prof. Jayne Woodside, Queen's University Belfast
- Prof. John Cawley, Cornell University
- Prof. Mike Clarke, Queen's University Belfast
- Prof. Frank Kee, Queen's University Belfast

Funding Sources

The Food Safety Promotion Board (Safefood) [Project Ref: 02A-2020].

Conflicts of Interest

The reviewers declare that they have no known conflict of interest

Collaborators

- Dr. Edel Doherty, National University of Ireland, Galway
- Prof. Jim Duggan, National University of Ireland, Galway

Review Question

Primary Review Question

What is the evidence that fiscal and other pricing strategies relating to food and non-alcoholic drinks: improve diet, reduce non-communicable diseases (NCDs), and induce behaviour change in anticipation of the adoption of a policy?

Secondary Review Question

What is the evidence of the impact of these fiscal and other pricing policies on inequalities, according to PROGRESS-Plus (1, 2), with respect to the outcomes of interest?

Searches

We will search for eligible systematic reviews published between January 1990 and February 2021. The resources searched will include PubMed, MedLine, Web of Science, Scopus, Psycinfo, SCI, SSCI, Google Scholar, EconLit and EMBASE. We will also search repositories of reviews (epistemonikos for published reviews and PROSPERO for registered reviews) and the Cochrane and Campbell Libraries. We will contact relevant individuals working in this field (including those in academia, policy and government), and authors of relevant reports and publications to ask for information on potentially eligible published or unpublished reviews, reports or contacts that might support the overview. Included studies must be conducted as systematic reviews and can be published or unpublished. This will be documented in our review and quality/risk of bias will be assessed and reported using the AMSTAR 2 tool.

Search strategy

We will use already identified reviews (3-6) to build a list of topic-related search terms, which will be used alongside terms and filters for systematic reviews and meta-analyses.

Condition or domain being studied

This overview will focus on health impacts related to poor diet. This covers excessive or imbalanced intake of nutrients leading to diet-related NCDs (e.g. Type 2 diabetes, cancer, dental caries and cardiovascular disease), overweight and obesity (7). We will also consider intermediate impacts such as expenditure on, or consumption of, specific nutrients (including sugar, fats, fibre and salt) and energy-dense foods and non-alcoholic drinks, as well as product reformulation by manufacturers. A final consideration will be the impact of these fiscal and other pricing policies on inequalities, according to PROGRESS-Plus (1, 2), with respect to the outcomes of interest.

Participants/Population

All populations will be eligible for inclusion. The population examined as part of each systematic review will be documented as part of data extraction. Any population subgroups and outcomes for these subgroups will also be examined.

Intervention/Exposure

National, regional or local fiscal or pricing policies, such as taxes or subsidies, which target the intermediate or tertiary outcomes described above. Our analyses will consider the scalability of regional and local policies to the national level and transferability to the Island of Ireland.

Comparator/Control

As this is a study of fiscal and pricing policies targeting diet or risk of NCD at a population level it is unlikely that randomised trials will have been conducted and included in the eligible systematic reviews. Therefore, we will extract information on the availability and strength of any comparators but reviews will not be excluded because of a lack of comparator.

Type of studies to be included

We will include systematic reviews of randomised or non-randomised design studies that assessed fiscal and pricing policies targeting the conditions/domains described. Where reviews focus solely on modelling or theoretical studies, these will be excluded as they do not analyse original data. Where modelling or theoretical studies were included as part of a review including experimental or observational studies, we will include those findings relating to the experimental or observational studies but if the original reviewers have combined the findings of modelling or theoretical studies with those of experimental or observational studies we will use the combined results. Search methods will be developed to include only systematic reviews, this will involve restriction of searches to include “systematic review” or “meta-analysis” in the title, abstract or keywords, as well as using specific features of some search engines to focus only on systematic reviews while optimising balance between sensitivity and specificity (8-10).

Context

No restrictions will be placed on the context of the research provided the review includes the relevant Population (P), Intervention (I), Comparators (C) (where available) and Outcomes (O). Our analysis will consider the scalability of identified policies as well as transferability in the context of implementation on the Island of Ireland.

Main outcome(s)

Non-communicable disease (e.g. Type 2 diabetes)

Obesity

Overweight

Weight change

Nutrient intake

Nutrient balance

Food and non-alcoholic drink consumption

Food and non-alcoholic drink sales (quantity)

Food and non-alcoholic drink expenditure (price * quantity)

Additional Outcome(s)

Distributional impacts of policies

Product reformulation by manufacturers

Data extraction (selection and coding)

Study Selection

Titles identified in our searches will be screened independently by two reviewers (LB & CON), and the abstracts of those judged to be potentially eligible will be checked by the same two reviewers. Where disagreements exist, these will be resolved by discussion and if necessary following reference to a third reviewer (FK/MC). All articles deemed potentially eligible will be retrieved for full text review. Full text articles will be screened independently by two reviewers (LB & CON). Disagreements will be resolved by discussion and if necessary, by reference to a third reviewer (FK/MC). References will be collated, duplicates removed, and titles and abstracts screened using EndNote 20 software.

Data Extraction

Data will be extracted independently by two reviewers (LB & CON) and will include design features: aims, methods, eligibility criteria and search strategy, funding sources, setting, participants, intervention (and comparator where available), outcomes measured, length of follow-up, outcomes reported, any sub-group analyses related to specific groups of participants, and any distributional impacts on outcomes or the tax burden. A Google Form will be developed based on the list of data to be extracted. Once complete, the meta-data will be used to generate separate spreadsheets of extracted data for each reviewer, which will be compared and any disagreements resolved by a third reviewer (FK/MC).

Risk of Bias

The methodological quality of each systematic review will be independently assessed by two reviewers (LB & CON) using the AMSTAR2 tool (8). Furthermore, how the quality of any estimates were assessed within reviews will be documented, for example use of the Phillips checklist (9). Disagreements will be resolved by discussion and where necessary by reference to a third reviewer (FK/MC). Care will be taken when assessing evidence to avoid collider stratification bias

that could arise when stratifying results by quality through sensitivity analyses on thresholds. Studies which receive a critically low score according to AMSTAR 2 will be excluded from the final review but will be listed for transparency.

Strategy for data synthesis

A narrative synthesis is planned given the complexities involved in attempting meta-analyses of systematic reviews. Data will be extracted from the included studies into a Microsoft Excel spreadsheet and an examination of the data for narrative synthesis will be conducted, for example to produce summary tables of the scope of included reviews and their results or graphical analysis using harvest plots. If more advanced analyses are feasible, for example unpicking individual treatment effects from studies to remove overlap and conduct a meta-analysis, we will use Stata (for example the metan command).

As fiscal and other pricing measures may have been adopted as part of more complex interventions, the assessment of reviews will explicitly address the approaches used for data synthesis of complex interventions. This will include an examination of stated purpose of the synthesis, heterogeneity in the studies from which data were synthesised, level of detail available from the studies included in the reviews, nature of the results reported and the resources available to the research team engaged in the review. The intervention will be detailed in terms of the nature and magnitude of tax or subsidy, minimum price etc.; what this is levied on, when it was announced and when it was introduced. Any effect on inequalities in outcomes or tax burden attributed to the intervention will be noted, as will any evidence regarding indirect effects, transaction costs and deadweight loss. Inequalities will be examined using axes of differentiation according to PROGRESS-Plus (1), given the potential for inequalities to arise across groups differentiated in ways other than socio-economic status (10).

Analysis of Subgroups

In line with the planned examination of inequalities in relation to study outcomes and/or policy tool/mechanism, any reporting of results according to subgroups captured under PROGRESS-Plus will be reported. If, as expected, we need to present this overview as a narrative synthesis, these will be reported discursively.

Type and method of review

Type of review

Intervention

Narrative Synthesis

Review of reviews

Systematic review

Health area of review

Cardiovascular

Child health

Endocrine and metabolic disorders

Health inequalities/health equity

Public Health

Language

English

Country

United Kingdom – Northern Ireland

References

1. O'Neill J, Tabish H, Welch V, Petticrew M, Pottie K, Clarke M, et al. Applying an equity lens to interventions: using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. Journal of Clinical Epidemiology. 2014;67(1):56-64.
2. Oliver S, Kavanagh J, Caird J, Lorenc T, Oliver K, Harden A, et al. Health promotion, inequalities and young people's health: a systematic review of research. 2008.
3. Powell LM, Chriqui JF, Khan T, Wada R, Chaloupka FJ. Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, demand and body weight outcomes. Obesity reviews. 2013;14(2):110-28.
4. Thow AM, Downs S, Jan S. A systematic review of the effectiveness of food taxes and subsidies to improve diets: understanding the recent evidence. Nutrition reviews. 2014;72(9):551-65.
5. Niebylski ML, Redburn KA, Duhaney T, Campbell NR. Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. Nutrition. 2015;31(6):787-95.
6. McGill R, Anwar E, Orton L, Bromley H, Lloyd-Williams F, O'Flaherty M, et al. Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. BMC Public Health. 2015;15(1):1-15.
7. Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R, et al. Transforming the food system to fight non-communicable diseases. BMJ. 2019;364:l296.
8. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358:j4008.
9. Philips Z, Ginnelly L, Sculpher M, Claxton K, Golder S, Riemsma R, et al. Review of guidelines for good practice in decision-analytic modelling in health technology assessment. Health Technol Assess. 2004;8(36):iii-iv, ix-xi, 1-158.
10. Tugwell P, Petticrew M, Kristjansson E, Welch V, Ueffing E, Waters E, et al. Assessing equity in systematic reviews: realising the recommendations of the Commission on Social Determinants of Health. BMJ. 2010;341:c4739.

Appendix 2.2: Search used across databases according to key themes

Study type	AND	Intervention	AND	Outcome	
Systematic review*		**Tax***		**Nutrient***	**obesity**
Meta-analys?s		Subsid*		nutrition	overweight
		Levy		energy	Diet*
		Levies		Food*	BMI
		Price		healthy eating	body mass
		demand		Vegetable*	body weight
		Elastic*		Fruit*	non-alcoholic
		fiscal		non-communicable disease*	Drink*
		pricing		Cancer*	Calori*
		supply		cardiovascular disease*	Sweeten*
				Isch?emic heart disease*	caries
				Hypertensi*	DMFT
				Diabet*	DMFS
				Sugar*	carious surface
				fat*	Expen*
				Sodium	Consum*
				Salt*	Purchas*
				SSB	Reformulate*
				Beverage*	

Note: ‘*’ represents truncation as part of the search strategy; ‘?’ represents a wildcard for word spellings. Different terms were used depending on the search engine.

Appendix 2.3: Expert Advisory Panel Members

Name	Affiliation
Michael Donaldson	Health and Social Care Board, Northern Ireland (HSCNI)
David Frisvold	University of Iowa
Susan Jebb	Oxford University
Mark Petticrew	London School of Hygiene and Tropical Medicine

Appendix 2.4: EMBASE search strategy for identification of primary studies examining the effectiveness of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease, conducted between January 2020 and November 2021

1	Systematic Review/
2	systematic review$.ab,kw,ti.
3	Meta-Analysis/
4	meta-analys?s.ab,kw,ti.
5	(tax$ or subsid$ or levy or levies or price or pricing or demand or supply or elastic$ or fiscal).ab,kw,ti.
6	(nutrient$ or energy or food$ or "healthy eating" or vegetable$ or "fruit$" or "non-communicable disease$" or cancer$ or "cardiovascular disease$" or "isch?emic heart disease$" or hypertensi$ or diabet$ or sugar$ or fat$ or sodium or salt$ or SSB or beverage$ or obesity or overweight or diet$ or BMI or "body mass" or "body weight" or "non-alcoholic" or drink$ or calori$ or sweeten$ or caries or DMFT or DMFS or "carious surface" or expen$ or consum$ or purchas$ or reformulat$).ab,kw,ti.
7	Taxes/
8	Fiscal Policy/
9	Nutrients/
10	Energy Drinks/ or Energy Intake/
11	Food/ or "Diet, Food, and Nutrition"/ or Food, Formulated/
12	Diet, Healthy/
13	Vegetables/
14	Fruit/
15	Noncommunicable Diseases/
16	Neoplasms/
17	Cardiovascular Diseases/
18	Coronary Disease/ or Heart Failure/ or Myocardial Ischemia/
19	Hypertension/
20	Diabetes Mellitus, Type 2/ or Diabetes Mellitus/
21	Sugars/
22	Dietary Fats, Unsaturated/ or Dietary Fats/ or Fats, Unsaturated/ or Fats/
23	Sodium/ or Sodium Chloride/ or Sodium, Dietary/ or Sodium Chloride, Dietary/
24	Salts/
25	Sweetening Agents/ or Beverages/ or Dietary Sucrose/ or Sugar-Sweetened Beverages/

26	Obesity/
27	Overweight/ or Adipose Tissue/ or Body Weight/
28	Diet/
29	Body Mass Index/
30	Sucrose/ or Sweetening Agents/ or Dietary Carbohydrates/
31	Dental Caries Susceptibility/ or Dental Caries/
32	DMF Index/ or Oral Health/
33	Economics/
34	Consumer Behavior/
35	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 34
36	6 or 35
37	5 or 7 or 8 or 33
38	1 or 2 or 3 or 4
39	36 and 37
40	39 not 38
41	("tax" or "taxing" or "taxation" or "taxes").m_titl.
42	("subsidy" or "subsidi#ation" or "subsidi#e" or "subsidi#ed" or "subsidies").m_titl.
43	41 or 42
44	40 and 43
45	limit 44 to human
46	limit 45 to yr="2020 -Current"
47	limit 46 to ((article or article in press) and journal)
48	tobacco consumption/ or tobacco smoke/ or "tobacco use"/ or tobacco/ or tobacco snuff/ or smokeless tobacco/ or tobacco dependence/ or chewing tobacco/ or tobacco.mp. or dipping tobacco/ or tobacco industry/
49	47 not 48
50	alcohol psychosis/ or alcohol blood level/ or alcohol intoxication/ or alcohol liver disease/ or alcohol abuse/ or alcohol tolerance/ or alcohol liver cirrhosis/ or alcohol consumption/ or alcohol abstinence/ or alcohol/ or alcohol.mp.
51	49 not 50
52	limit 51 to english language

Appendix 2.5: Matrix of databases searched and which of these indexed the 25 potentially relevant systematic reviews identified following screening

Reference	MedLine	EMBASE	PsychInfo	Web of Science	Scopus	EconLit	Cochrane Library	Epistemonikos	Campbell Library	Google Scholar
Afshin et al, 2017 [97]	X	X		X	X			X		X
Alagiyawanna et al 2015 [98]	X	X		X	X			X		X
Backholer et al 2016 [49]	X	X		X	X			X		X
Bandy et al 2019 [48]	X	X		X	X					X
Dodd et al 2020 [50]	X	X		X	X			X		X
Escobar et al 2013 [99]	X	X		X	X			X		
Gittelsohn et al 2017 [100]	X	X		X	X			X		X
Lhachimi et al 2020 [42]	X	X		X	X		X			
Maniadakis et al 2013 [101]		X			X			X		X
McGill et al 2015 [102]	X	X		X	X			X		
Miracolo et al 2021 [51]		X								
Moran et al 2020 [103]		X			X					
Nakhimovsky et al 2016 [104]		X		X	X			X		X
Niebylski et al 2015 [24]	X	X		X	X			X		X
Olstad et al 2016 [52]	X	X		X	X			X		
Pfinder et al 2020 [41]	X	X		X	X		X			
Powell et al 2009 [46]		X			X					
Powell et al 2013 [31]	X	X		X	X			X		X

Reference	MedLine	EMBASE	PsychInfo	Web of Science	Scopus	EconLit	Cochrane Library	Epistemonikos	Campbell Library	Google Scholar
Redondo et al 2018 [105]	X	X		X	X			X		
Sisnowski et al 2017 [44]	X	X		X	X			X		
Sobhani et al 2019 [106]				X						
Teng et al 2019 [43]	X	X		X	X			X		
Thow et al 2014 [32]	X	X		X	X			X		X
Thow et al 2010 [107]	X	X		X	X			X		X
Wright et al 2017 [108]	X	X		X	X			X		X
No. referenced	**19**	**24**	**0**	**21**	**23**	**0**	**2**	**18**	**0**	**13**
% referenced	**76%**	**96%**	**0%**	**84%**	**92%**	**0%**	**8%**	**72%**	**0%**	**52%**

Note: Indexed reviews are marked with an 'X'.

Appendix 2.6: Quality rating using AMSTAR2 checklist (studies with two or more critical domain flaws receive a critically low rating)

	CRITICAL DOMAINS								NON-CRITICAL DOMAINS										
Author	Item 2	Item 4	Item 7	Item 9	Item 11	Item 13	Item 15	No. "N" for critical domains	Item 1	Item 3	Item 5	Item 6	Item 8	Item 10	Item 12	Item 14	Item 16	No. "N" for non-critical domains	Quality Rating
Afshin et al	N	PY	N	N	N	Y	Y	4	Y	Y	N	Y	N	N	Y	Y	Y	3	CL
Alagiyawanna et al	N	N	N	Y	N/A	Y	N/A	3	N	Y	N	Y	PY	N	N/A	Y	Y	3	CL
Backholer et al	PY	Y	N	N	N/A	Y	N/A	2	N	N	Y	Y	PY	N	N/A	Y	Y	3	CL
Bandy et al	PY	N	N	Y	N/A	Y	N/A	2	N	N	Y	Y	PY	N	N/A	Y	Y	3	CL
Dodd et al	PY	Y	N	PY	N/A	N	N/A	2	N	Y	Y	Y	N	N	N/A	Y	Y	3	CL
Escobar et al	N	N	N	N	N	N	Y	6	N	Y	N	N	N	N	N	Y	Y	6	CL
Gittelsohn et al	N	N	N	N	N/A	Y	N/A	4	N	N	Y	Y	PY	N	N/A	Y	Y	3	CL
Lhachimi et al	Y	Y	Y	Y	N/A	Y	N/A	0	Y	Y	Y	Y	Y	Y	N/A	Y	Y	0	H
Mandiakis et al	N	N	N	N	N/A	N	N/A	5	N	N	Y	Y	N	N	N/A	N	Y	5	CL
McGill et al	PY	N	N	PY	N/A	Y	N/A	2	Y	Y	N	N	PY	N	N/A	Y	Y	3	CL
Miracolo et al	PY	N	N	Y	N/A	Y	N/A	2	Y	Y	N	N	PY	Y	N/A	Y	Y	2	CL
Moran et al	N	N	N	N	N/A	N	N/A	5	N	Y	Y	Y	PY	N	N/A	Y	Y	2	CL
Nakhimovsky et al	PY	N	N	N	N/A	Y	N/A	3	N	Y	N	Y	PY	N	N/A	Y	Y	3	CL
Niebylski et al	N	N	N	PY	N/A	Y	N/A	3	N	Y	N	N	N	N	N/A	Y	N	6	CL
Pfinder et al	Y	Y	Y	Y	N/A	Y	N/A	0	Y	Y	Y	Y	Y	Y	N/A	Y	Y	0	H

	CRITICAL DOMAINS								NON-CRITICAL DOMAINS										
Author	**Item 2**	**Item 4**	**Item 7**	**Item 9**	**Item 11**	**Item 13**	**Item 15**	**No. "N" for critical domains**	**Item 1**	**Item 3**	**Item 5**	**Item 6**	**Item 8**	**Item 10**	**Item 12**	**Item 14**	**Item 16**	**No. "N" for non-critical domains**	**Quality Rating**
Olstad et al	Y	N	N	Y	N/A	Y	N/A	2	Y	Y	Y	Y	PY	N	N/A	Y	Y	1	CL
Powell et al	N	N	N	PY	N/A	Y	N/A	3	N	Y	Y	N	N	N	N/A	Y	N	5	CL
Powell et al	N	N	N	N	N/A	Y	N	5	N	Y	N	N	N	N	Y	Y	Y	5	CL
Redondo et al	N	N	N	Y	N	Y	N/A	4	N	Y	Y	Y	Y	Y	Y	Y	Y	1	CL
Sisnowski et al	PY	PY	N	Y	N/A	Y	N/A	1	Y	Y	N	N	PY	N	N/A	Y	Y	3	L
Sobhani et al	N	N	N	N	N/A	N	N/A	5	N	Y	Y	N	PY	N	N/A	N	Y	4	CL
Teng et al	Y	PY	PY	Y	N	Y	Y	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	L
Thow et al	N	N	N	N	N/A	Y	N/A	4	N	N	N	N	N	N	N/A	Y	Y	6	CL
Thow et al	N	N	N	N	N/A	N	N/A	5	N	Y	N	N	PY	N	N/A	Y	Y	4	CL
Wright et al	N	N	N	N	N/A	N	N/A	5	N	Y	Y	Y	N	N	N/A	Y	Y	3	CL

Y - Yes; PY - Partial Yes; N – No; N/A – Not Applicable; H - High; M - Moderate; L - Low; CL - Critically Low

Appendix 2.7: Characteristics of reviews outlined in sensitivity as having a marginal AMSTAR2 critically low quality rating

	Review eligibility criteria				Search strategy			
Author/year	**Research design**	**Synthesis method**	**Population**	**Intervention**	**No. of databases**	**Search period**	**Search restrictions**	**No of included studies**
Backholer et al, 2016	NRSI; models	Narrative synthesis	Any population, any age, any setting, High-income countries	FI (taxes) on SSB's	5	Earliest date up to June 2015	None	11
Bandy et al, 2019	NRSI; models	Narrative synthesis	Any population, any age, any setting, any country	FI (taxes and subsidies) on unhealthy foods and beverages and other applications of commercial purchase data for public health nutrition research	5	Earliest date up to March 2018	English language	69

	Review eligibility criteria				Search strategy			
Author/year	**Research design**	**Synthesis method**	**Population**	**Intervention**	**No. of databases**	**Search period**	**Search restrictions**	**No of included studies**
Dodd et al, 2020	NRSI; models; experiments	Narrative synthesis	Any population, any age, any setting, any country	FI (taxes) on salt and foods high in salt	12	January 2000 to October 2019	None	18
McGill et al, 2015	RCT; NRSI; models	Narrative and graphical (harvest plot) synthesis	Healthy population, any age, any setting, any country	FI (taxes and subsidies) and other non-FI interventions (e.g. labelling) to promote healthy diet	9	1980 to NR (publication date: May 2015)	English language	36
Miracolo et al 2021	NRSI; models; reviews	Narrative synthesis	Any population, any age, any setting, Latin American countries	FI (taxes) on 'harmful' goods (alcohol, sugar, salt, junk food (i.e. calorie-dense foods)	11	1 January 2000 to 31 December 2018	English and Spanish language	34

	Review eligibility criteria				Search strategy			
Author/year	**Research design**	**Synthesis method**	**Population**	**Intervention**	**No. of databases**	**Search period**	**Search restrictions**	**No of included studies**
				and/or tobacco products)				
Olstad et al 2016	RCT; NRSI	Narrative and graphical (harvest plot) synthesis	Healthy population, any age, any setting, any country	FI (taxes and subsidies) and other non-FI interventions (e.g. labelling) to reduce obesity and obesity-related behaviours	3	January 2004 to August 2015	English language, Humans	36

Appendix 2.8: Effects of intervention strategies on intermediate and tertiary outcomes synthesised by reviews outlined in sensitivity as having a marginal AMSTAR2 critically low quality rating

Author/year	Intervention	Outcome	Narrative synthesis results	Meta-analysis results	Distributional effects	Quality rating
Intermediate Outcomes: Direct Effects						
Backholer et al, 2016	FI (taxes) on SSB's	Taxed SSB consumption	Some evidence (mainly modelling studies) to support effectiveness of taxes in reducing SSB consumption – "Current evidence suggests that a tax on SSB is likely to be an effective policy to reduce SSB consumption"	No meta-analysis conducted	Evidence (mainly modelling studies) that an SSB tax would be regressive but only to a small degree – "An SSB tax would be regressive, but with small differences between higher- and lower-income households (0·10–1·0% and 0·03%–0·60% of annual household income paid in SSB	Critically low

					tax for low- and high-income households, respectively)."	
Bandy et al, 2019	FI (taxes and subsidies) on unhealthy foods and beverages and other applications of commercial purchase data for public health nutrition research	Taxed unhealthy food and beverage consumption and subsidised healthy food consumption	Evidence to support effectiveness of taxes and subsidies in encouraging healthy food consumption and discouraging unhealthy food and beverage consumption	No meta-analysis conducted	No subgroup analysis conducted	Critically low
Dodd et al, 2020	FI (taxes) on salt and foods high in salt	Taxed salt and salty food consumption	Evidence (mainly modelling studies) to support effectiveness of taxes in reducing taxed salt consumption – "Although there is some evidence on the potential	No meta-analysis conducted	No subgroup analysis conducted	Critically low

			effectiveness and cost-effectiveness of salt taxation, especially from modelling studies, uptake of salt taxation is limited in practice."			
McGill et al, 2015	FI (taxes and subsidies) and other non-FI interventions (e.g. labelling) to promote healthy diet	Taxed unhealthy food and beverage consumption and subsidised healthy food consumption	Review examined distributional impacts of interventions and did not provide results on the overall effectiveness of interventions	No meta-analysis conducted	Lack of evidence (except modelling studies which accounted for 17/18 interventions) to support effectiveness of taxes and subsidies in reducing inequalities in healthy eating according to SEP – "ten of the eighteen "Price" interventions were likely to reduce inequalities by	Critically Low

					preferentially improving healthy eating outcomes in lower SEPs. All six studies reporting interventions which consisted of a combination of taxes and subsidies consistently had a greater impact on lower SEP."	
					Results did not differ comparing distributional impacts across ethnicity	
Miracolo et al, 2021	FI (taxes) on 'harmful' goods (alcohol, sugar, salt, junk food (i.e. calorie-dense	Taxed energy-dense food and beverage consumption	Evidence to support effectiveness of tax in reducing consumption/purchasing of harmful goods (mainly SSB's) -	No meta-analysis conducted	No subgroup analysis conducted	Critically low

	foods) and/or tobacco products)		"The majority of studies reported that implementation of sin taxes in Latin America resulted in reductions in harmful goods consumption"			
Olstad et al, 2016	FI (taxes and subsidies) and other non-FI interventions (e.g. labelling) to reduce obesity and obesity-related behaviours	Taxed unhealthy food and beverage consumption and subsidised healthy food consumption	Review examined distributional impacts of interventions and did not provide results on the overall effectiveness of interventions	No meta-analysis conducted	Evidence to support taxes and subsidies in having a neutral effect on inequalities in outcomes according to SEP – "The majority of agento-structural policies (including taxes and subsidies) had a neutral (68%) or positive (18%) impact on inequities in behavioural or anthropometric	Critically low

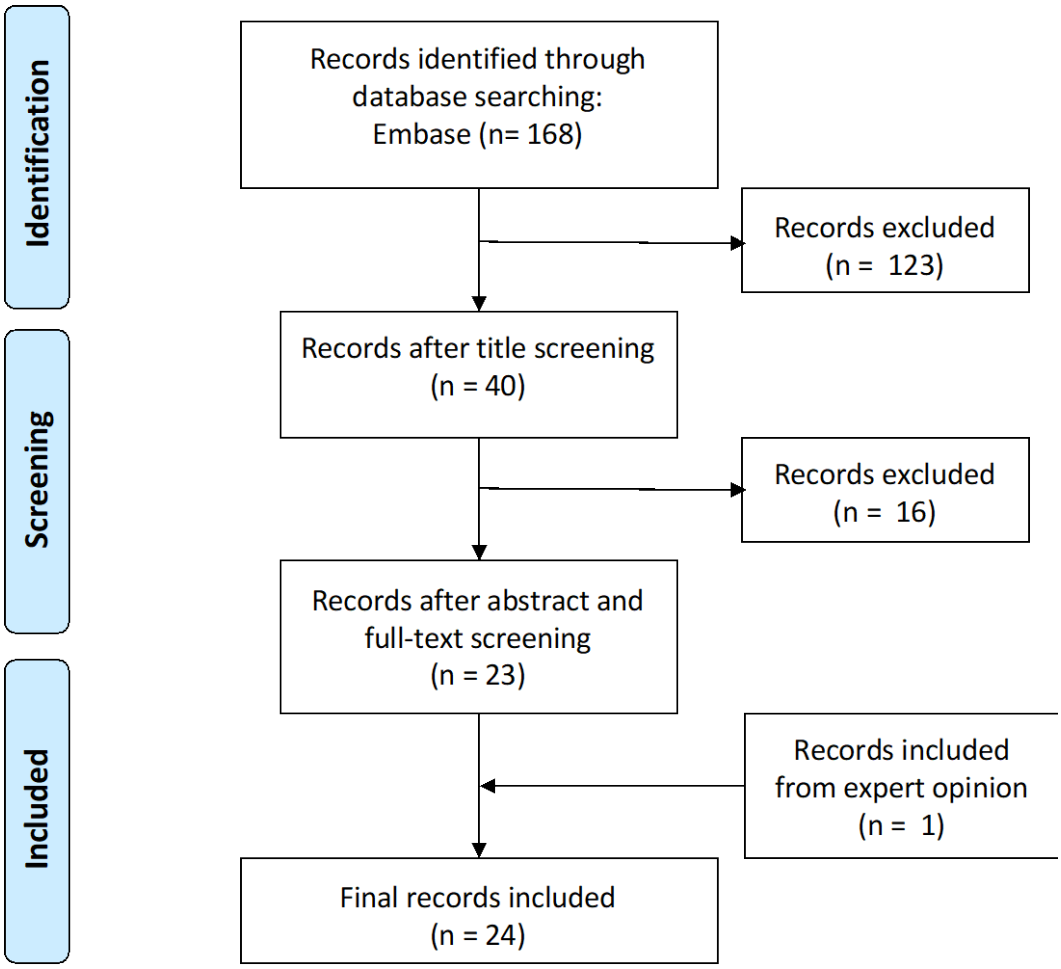
					outcomes (negative [14%])" Results did not differ comparing distributional impacts in adults vs children separately	
Intermediate outcomes: indirect effects						
Dodd et al, 2020	FI (taxes) on salt and foods high in salt	Untaxed salt and salty food consumption	Evidence (mainly modelling studies) to support effectiveness of taxes in increasing untaxed salt consumption – "Indeed, as in the modeling studies, there is some evidence that product substitution could have unintended negative effects on salt consumption: Tonga found that taxes on fatty meats (turkey tails, mutton flaps) led to substitution with salted beef and corned beef,	No meta-analysis conducted	No subgroup analysis conducted	Critically low

			which were exempt from taxation."			
Tertiary outcomes						
Backholer et al, 2016	FI (taxes) on SSB's	BMI and other weight outcomes	Lack of evidence (except modelling studies) to support the effectiveness of taxes on SSB's in clinically improving weight outcomes at the population level – "Powell et al.(27) reported no relationship between variation in SSB taxes and adolescents' BMI for any parental education group" AND "In the study by Sturm et al.(28) associations between variations in existing SSB tax rates and SSB consumption and BMI were examined for the entire population and for children from low-income households. For the	No meta-analysis conducted	Evidence (mainly modelling studies) that an SSB tax would improve weight outcomes for individuals in lower SEP – "a tax on SSB will deliver similar population weight benefits across socio-economic strata or greater benefits for lower SEP groups."	Critically Low

			whole population, no association was observed between SSB taxes and overall SSB consumption or mean BMI change" AND "Fletcher et al.(29) reported a stronger relationship between variation in SSB taxes and weight outcomes for adults with lower (compared with higher) income and for those with a higher (compared with a lower) education level. Between 1990 and 2006, a 1 percentage point increase in existing SSB tax rates was associated with a significant 0·015 kg/m2 reduction in BMI for low-income adults and a 0·008 kg/m2 decrease in BMI for high-income adults."				

Miracolo et al, 2021	FI (taxes) on 'harmful' goods (alcohol, sugar, salt, junk food (i.e. calorie-dense foods) and/or tobacco products)	Diabetes, stroke, heart attack, death	Lack of evidence (except modelling studies) to support effectiveness of tax in improving health outcomes – "Since the majority of our included 'Price' interventions were modelling studies, there is an urgent need to investigate the feasibility and impact of such taxes and subsidies using additional research methods."	No meta-analysis conducted	No subgroup analysis conducted	Critically low

Appendix 2.9: PRISMA flow diagram for identification of primary studies examining the effectiveness of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease which were indexed in EMBASE and conducted between January 2020 and November 2021



Appendix 2.10: Literature review results of primary studies examining the effectiveness of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease which were indexed in EMBASE and conducted between January 2020 and November 2021

Title	Year	Population	Intervention	Comparator	Outcome	Timeframe	Setting	Design	Effect category	Evidence summary	Distributional evidence
Changes in take-home aerated soft drink purchases in urban India after the implementation of Goods and Services Tax (GST): An interrupted	2021	General population (as measured by state-level monthly take-home purchases)	Goods and Service Tax (GST) change on carbonated drinks	Pre- and post-implementation	Purchases of carbonated drinks	January 2013 to June 2018	Urban India	NRSI: interrupted time series (ITS) analysis	Intermediate: Direct	Lack of evidence to support effectiveness of tax in reducing carbonated drinks purchases	

time series analysis											
How do consumers respond to "sin taxes"? New evidence from a tax on sugary drinks	2021	Loyalty card data of monthly purchases by 884,843 households	SSB tax	Pre- and post-implementation and Catalonia vs rest of Spain (no tax)	Purchased quantity of beverages and sugar	May 2016 to April 2018	Catalonia	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct and indirect	Evidence to support effectiveness taxes in reducing taxed beverage consumption; evidence to support effectiveness of taxes in	

										increasing untaxed beverage consumption	
Assessing sugar-sweetened beverage intakes, added sugar intakes and BMI before and after the implementation of a sugar-sweetened beverage tax in	2021	Adolescents, young adults and middle-aged adults (n = 617)	April 2018, SSB tax (Health Promotion Levy)	1 year pre- and 1 year post-implementation	SSB and added sugar intakes, as well as BMI	May 2017 to May 2019	Soweto, Johannesburg, South Africa	NRSI: Longitudinal analysis	Intermediate: direct and indirect; Tertiary: BMI	Evidence to support effectiveness of taxes in decreasing SSB consumption; lack of evidence to support effectiveness of taxes in	Greatest reduction in SSB consumption for those with high baseline intake

South Africa										reducing total energy consumption from added sugar; lack of evidence to support effectiveness of taxes in reducing BMI	
Impact of sugar-sweetened beverage taxes on price,	2021	General population	Import tariffs on sweetened beverages	Pre- and post-implementation and sugary	Quarterly price of an indicator beverage, monthly beverage	2001-2017	Cook Islands	NRSI: interrupted time series (ITS)	Intermediate: direct	Evidence to support effectiveness of taxes in	

import and sale volumes in an island: interrupted time series analysis				snacks control	import volumes (both 2001-2017) and quarterly sales volumes (2012-2017)			analysis		decreasing soft drink import volumes, and in increasing import volumes when the tax was decreased	
The impact of sugar-sweetened beverage taxes on purchases: evidence from four city-level taxes in	2020	1477 households in the US	SSB tax	Adjacent areas and matched households nationally	Monthly household purchases of beverages	6 months pre-tax and 6 months post-tax implementation (exact dates	Philadelphia, PA; San Francisco, CA; Seattle, WA; and Oakland, CA	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support he effectiveness of taxes in reducing consump	This decline in purchasing was concentrated in only 1 out of the 4 cities (Philadelphia)

the United States						varied by city)				tion of SSBs	
Changes in food pricing and availability on the Navajo Nation following a 2% tax on unhealthy foods: The Healthy Dine Nation Act of 2014	2021	71 stores (51 in the Navajo Nation and 20 in border towns) - measured using Nutrition Environment Measurement Survey-Stores (NEMS-S) adapted for	The Healthy Dine Nation Act of 2014 - 2% tax on foods of 'minimal-to-no-nutritional value' and waiver of 5% sales tax on healthy foods	Pre- and post-implementation and Navajo nation stores vs border towns (no tax)	Changes in pricing and food availability in stores on the Navajo Nation	2013 and 2019	Navajo Nation	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support effectiveness of subsidies in increasing availability of fruits and vegetables in	

		the Navajo Nation								affected stores	
Taxed and untaxed beverage intake by South African young adults after a national sugar-sweetened beverage tax: A before-	2021	adults aged 18-39 years (pre-tax, n = 2,459; post-tax, n = 2,489)	April 2018, SSB tax (Health Promotion Levy)	Pre- and post-implementation and taxed and untaxed beverages	Food composition tables (FCTs) for South African beverages before and after the tax, linked with the diet recalls	Feb/Mar 2018 - Feb/Mar 2019	Langa, South Africa.	NRSI: repeated cross-sectional analysis	Intermediate: direct and indirect	Evidence to support effectiveness of taxes in reducing taxed beverage consumption and total sugar intake via reduced consump	Sample of low-income and high-intake users

and-after study											tion and reformulation; Evidence to support effectiveness of taxes in increasing untaxed beverage consumption (offsetting some of the effect)	

Impact of Sugar Tax on Sugar-sweetened Beverage Consumption among Saudi Schoolchildren	2021	Schoolchildren aged 12-14 years (pre-tax, n = 453; post-tax, n = 2,334)	A 2017 120% tax on energy drinks and a 50% tax on soft drinks	Pre- and post-implementation	SSB consumption	Pre-tax data were collected in May 2017 and post-tax data in April 2018	Tri-city metropolitan area of Dammam-Khobar-Dhahran, Eastern Province, Saudi Arabia	NRSI: repeated cross-sectional analysis	Intermediate: direct	Lack of evidence to support effectiveness of taxes in reducing consumption of energy and soft drinks	Children only
Changes in population-level consumption of taxed and non-taxed sugar-sweetened	2020	General population (n = 5594)	A 2017 SSB tax	Pre- and post-implementation and taxed and untaxed SSBs	Taxed and non-taxed SSB consumption	2018 and 2019	Thailand	NRSI: prospective cohort analysis	Intermediate: direct	Evidence to support effectiveness of taxes in reducing SSB	Greatest reductions among male, older, lower income and unemployed individuals

beverages (Ssb) after implementation of ssb excise tax in Thailand: A prospective cohort study										consumption	
The effectiveness of sin food taxes: Evidence from Mexico	2021	General population (8,130 households) - measured using scanner data containing weekly purchases of 47,973 barcodes	2014 tax reform on sugar-added drinks and caloric-dense food	Pre- and post-implementation	Taxed and untaxed foods and beverages	2013 and 2014	Mexico	NRSI: regression discontinuity	Intermediate: direct and indirect	Evidence to support effectiveness of taxes in reducing consumption of taxed food and beverages	

										; evidence to support effectiveness of taxes in increasing consumption of untaxed food and beverages	
Association of a Sweetened Beverage Tax with Purchases of Beverages and High-	2021	116 independent stores and 4738 customer purchases	1.5 cent-per-fluid-ounce excise tax on sugar- and artificially sweetened beverages	Independent stores in Philadelphia and Baltimore, Maryland (a nontaxed control) before and 2	Changes in mean price (measured in cents per fluid ounce) of taxed and nontaxed	2017-2019	Philadelphia, Pennsylvania	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support effectiveness of taxes in increasing prices and	Greatest reductions in low-income neighbourhoods and among individuals with lower reductions levels

Sugar Foods at Independent Stores in Philadelphia				years after tax implementation	beverages, mean fluid ounces purchased of taxed and nontaxed beverages, and mean total calories purchased from beverages and high-sugar foods					decreasing purchasing of SSBs	
Evaluation of Changes in Grams of Sugar Sold after	2021	General population (Nielsen scanner data from	Sweetened Beverage Tax (SBT) on January 1, 2018.	Taxed and untaxed products in Seattle compared	Changes in grams of sugar sold from taxed beverages,	Pre-tax period (January 8-December 30, 2017)	Seattle, Washington and Portland, Oregan	NRSI: Difference in Difference	Intermediate: direct and indirect	Evidence to support effectiveness of	

the Implementation of the Seattle Sweetened Beverage Tax		supermarkets and mass merchandise as well as grocery, drug, convenience, and dollar stores on unit sales and measurements for beverage and food product universal product codes (UPCs).		with Portland, Oregon, at year 1 and year 2 post tax	untaxed beverages, sweets, and stand-alone sugar	and the corresponding weeks in year 1 post tax (2018) and in year 2 post tax (2019).		(DiD) analysis		taxes in reducing sugar purchases via reduced taxed beverage purchases and reformulation; evidence to support effectiveness of taxes in increasing untaxed sugar consumption	

Evaluation of Changes in Beverage Prices and Volume Sold following the Implementation and Repeal of a Sweetened Beverage Tax in Cook County, Illinois,	2020	General population (Nielsen food store scanner data were obtained for weekly volume and dollar amount sold of non-alcoholic beverage universal product codes (UPCs) for each site in supermarkets and mass merchandise, grocery, drug,	Implementation and repeal of the Cook County, Illinois, Sweetened Beverage Tax (SBT)	St Louis County and city, Missouri, which did not impose a tax	Changes in taxed and untaxed beverage prices and volume sold	16 510 UPCs for volume and 2141 UPCs (balanced sample) for prices for 122 pre-tax weeks, 16 tax weeks, and 35 post repeal weeks	Cook county, Illinois and St Louis County and city, Missouri	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support effectiveness of taxes in increasing prices and decreasing volumes sold of taxed beverages, and in increasing prices and volumes sold when tax	

		convenience, and dollar stores)								is repealed	
Sugar-sweetened and diet beverage consumption in Philadelphia one year after the beverage tax	2020	General population (random-digit-dialling phone survey was administered to a population-based cohort (N = 515))	A 2017 excise tax ($ 0.015/ounce) on sugar-sweetened and diet beverages in Philadelphia (Pennsylvania)	Nearby comparison cities (Trenton, New Jersey; Camden, New Jersey; and Wilmington, Delaware)	Changes in 30-day consumption frequency and ounces of sugar-sweetened and diet beverages (and a substitution beverage, bottled water) in the	Baseline (December 2016-January 2017) vs. 12-month follow-up (December 2017-February 2018).	Philadelphia; Trenton, New Jersey; Camden, New Jersey; and Wilmington, Delaware	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support effectiveness of taxes in reducing SSB consumption	

					analytic sample						
The effects of soda taxes on adolescent sugar intake and blood sugar	2020	Adolescents aged 12-19 years - measured using a restricted-use version of the 1999-2014 National Health and Nutrition Examination Survey (NHANES)	Soda sales taxes	Within-state variation in soda sales tax rates over time	Total daily sugar intake and blood sugar	1999-2014	US	NRSI: longitudinal analysis	Intermediate: direct and indirect	Evidence to support effectiveness of taxes in reducing calories consumed from taxed soft drinks; evidence to support effectiveness of tax in increasing calorie	

										intake from untaxed beverages	
Impact of sin taxes on consumption volumes of sweetened beverages and soft drinks in Saudi Arabia	2021	General population	Excise tax on sugar-sweetened beverages in Saudi Arabia, 2017	Pre- and post-implementation	Consumption level of SSB's	2010-2020	Saudi Arabia	NRSI: time-series analysis	Intermediate: direct	Evidence to support effectiveness of taxes in reducing sales volumes of soft drinks	
The causal impact of sugar taxes on soft drink sales: evidence	2021	General population (Euromonitor International)	Sugar tax	Pre- and post-implementation	SSB sales	2004-2018	France and Hungary	NRSI: Synthetic control	Intermediate: Direct and Indirect	Evidence to support effectiveness of tax in	

from France and Hungary								analysis		reducing SSB sales; Lack of evidence to support effectiveness of taxes in reducing overall soft drink sales	
Do prices and purchases respond similarly to soft drink tax increases and cuts?	2020	General population (longitudinal scanner data of 1,282 Danish households)	Increases and cuts of the soft drink tax in Denmark	Pre- and post-implementation	Within-product changes in prices and within-household changes in purchase quantity	2012-2014	Denmark	NRSI: longitudinal analysis	Intermediate: direct	Evidence to support effectiveness of taxes in decreasing soft drink	

										consumption, and in increasing consumption when tax is repealed; lack of evidence to show repeal of tax is associated with a decrease in untaxed beverages (greater net	

										calorie intake)	
Oakland's sugar-sweetened beverage tax: Impacts on prices, purchases and consumption by adults and children	2020	Oakland stores and their customers and a matched group of stores in surrounding counties and their customers	A July 1, 2017, tax of one cent per ounce on SSBs	Pre- and post-implementation and Oakland and stores outside of the city	(1) Prices, (2) purchase information from customers exiting the stores, and (3) a follow-up household survey of adults and child beverage purchases and consumption	2017-2018 (months prior to the implementation of the tax and again a year later on)	Oakland, California	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct and Indirect	Evidence to support effectiveness of tax in reducing SSB consumption in stores in taxed jurisdiction; evidence to support effectiveness of tax in	

										increasing SSB consumption in stores in bordering untaxed jurisdictions	
Evaluating Saudi Arabia's 50% carbonated drink excise tax: Changes in prices and volume sales,	2020	General population (Saudi Arabia's General Authority of Statistics (GASTAT) survey of average prices of goods and services and	50 % excise tax on carbonated drinks in June 2017	Pre- and post-implementation	Changes in taxed carbonated drinks' monthly prices and annual volume sales (litres per capita). volume sales of	2012-2018	Saudi Arabia	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct	Evidence to support effectiveness of taxes in increasing prices and decreasing volumes sold of	

		Euromonitor's passport database for volume sales)			untaxed beverages (water and juice)					taxed beverages	
Association between tax on sugar sweetened beverages and soft drink consumption in adults in Mexico: Open cohort longitudinal analysis of Health	2020	1770 employees from a healthcare provider aged 19 years or older from three waves of the Health Workers Cohort Study	SSB tax	Pre- and post-implementation	Change in probability of belonging to one of four categories of soft drinks consumption (non, low, medium, high) after the tax was	2004-2018	Mexico	NRSI: longitudinal analysis	Intermediate: direct	Evidence to support effectiveness of tax in reducing SSB consumption among employees of healthcare providers	Within this distinct population, higher education was associated with a greater reduction in SSB consumption

Workers Cohort Study					implemented						
Equity of expenditure changes associated with a sweetened-beverage tax in Tonga: repeated cross-sectional household surveys	2021	General population (the Household Income and Expenditure Surveys in 2009 (n = 1982) and 2015/16 (n = 1800))	T$0.50/L sweetened-beverage (SB) excise in Tonga 2013	Pre- and post-implementation	Changes in soft drink (taxed), bottled water, and milk (both untaxed) expenditure were examined namely: (i) prevalence of households purchasing the beverage; (ii) average	2009-2016	Tonga	NRSI: repeated cross-sectional analysis	Intermediate: direct and indirect	Evidence to support effectiveness of taxes in reducing soft drink purchases; evidence to support effectiveness of taxes in increasing untaxed beverage (water)	Low-income households appeared to have slightly greater declines in soft drink expenditure

					expenditure per person (inflation-adjusted); (iii) expenditure as a proportion of household food budget; and (iv) expenditure per person as a proportion of equivalised income.					expenditure	

The impact of a sweetened beverage tax on beverage volume sold in cook county, Illinois, and its border area	2020	General population (universal product code-level store scanner data from supermarkets and grocery, convenience, drug, mass merchandise, and dollar stores)	2017 Cook County, Illinois, Sweetened Beverage Tax (SBT)	Pre- and post-implementation and Cook county, Illinois and St. Louis City, Missouri	Beverage volume sold of taxed and untaxed beverages, across product categories and sizes	2016-2017	Illinois and Missouri, USA	NRSI: Difference in Difference (DiD) analysis	Intermediate: direct and indirect	Evidence to support effectiveness of taxes in reducing volumes sold of taxed beverages in taxed jurisdictions and overall; evidence to support effectiveness of tax in increasing	

										volumes sold of same beverages in untaxed jurisdictions; lack of evidence to support effectives of taxes in increasing volumes sold of untaxed beverages in taxed and untaxed	

										jurisdictions	
One-year changes in sugar-sweetened beverage consumers' purchases following implementation of a beverage tax: A longitudinal quasi-experiment	2020	Adult sugar-sweetened beverage (SSB) consumers in Philadelphia (n = 306) and Baltimore (n = 297; a nontaxed comparison city)	Philadelphia beverage tax on sugar-sweetened and artificially sweetened beverages	Baltimore (a nontaxed comparison city)	Changes in objectively measured beverage purchases	From 2016 to 2017 participants submitted all food and beverage receipts during a 2-wk period at: baseline (pre-tax) and 3, 6, and 12 mo post tax (91.0% retention; data	Philadelphia, Pennsylvania	NRSI: Difference in Difference (DiD) analysis	Intermediate: Direct	Evidence to support effectiveness of taxes in reducing taxed beverage purchases	

						analysed in 2019)					

3 An umbrella review of the acceptability of fiscal and pricing policies to reduce diet-related non-communicable disease

Introduction

As noted in the previous chapter poor quality diets (specifically those high in salt, sugar and fat and low in fruit, vegetables, legumes and nuts) represent major risk factors affecting the global burden of disease[1-3]. Unhealthy eating patterns are common on the island of Ireland (IoI), as are socio-economic disparities in such eating behaviours, ultimately impacting on the health of the population[4-8]. A number of policy actions have been promoted to help counter the rise in diet-related non-communicable disease (NCD), including fiscal and pricing policies, henceforth *fiscal interventions* (FIs)[9-11]. Preventive policies such as these, rely only partly on an individual's ability to engage with the intervention, which may be linked to socio-economic factors[12-14]. While they may be more effective than downstream (personal-level) interventions, they can also be more complex to implement[14-17].

There is evidence in Ireland from modelling studies that FIs can be used to change behaviour and reduce health risks[18, 19]. However, the use of research evidence in public health policymaking bears little resemblance to the systematic and hierarchical process of decision-making in evidence-based medicine[20, 21]. Rather than a linear sequence covering all stages in a hierarchy of evidence from identifying a problem to treatment evaluation, policymaking usually occurs in a complex and non-linear fashion requiring a range of evidence of varying types depending on the problem[21, 22]. This multi-stranded approach can help to identify barriers and facilitators (B/F) affecting the acceptability of FIs, so highlighting the various points of influence on policymaking[17, 23]. Recent examples from outside the IoI of FIs which have been implemented but then repealed, with their effects reversed[24, 25], highlight the need to consider acceptability and not just effectiveness in measuring the success of a health policy.

Several political process theories have been developed in recognition of this complex policymaking endeavour[17, 26]. Kingdon's Multiple Streams Framework (MSF) for agenda setting outlines three separate but complementary streams: *problem*, *policy* and *politics*[27]. When these streams are aligned it creates a window of opportunity for successful policy implementation. This theory has been widely used to address agenda setting as well as policy adoption and

implementation, especially for diet-related FIs[17, 26, 28-30]. The *problem* of diet-related NCDs is widely acknowledged, and here we focus on a specific type of *policy:* diet-related FIs. The parallel umbrella review reported in the preceding chapter has examined their effectiveness and distributional effects (CRD42021249212).

In this chapter, we focus on *politics* by conducting an umbrella review of the acceptability of FIs applied to food and non-alcoholic beverages to improve diet and reduce diet-related NCDs. As the topic of acceptability of FIs has grown, so too have the number of studies and systematic reviews examining it[31-36]. Umbrella reviews provide an important tool for policymakers by summarising the highest level of evidence, namely systematic reviews and meta-analyses, in relation to a research topic or question[37].

Methods

Acceptability is defined as the degree to which individuals' or groups' experience of barriers/facilitators (B/F) is linked to the implementation or proposed implementation of such policies[33]. We group B/F according to the criteria in the WHO-INTEGRATE framework, which is used to guide the process from collecting evidence to making decisions for complex health interventions, according to WHO norms and values [23]. Our other review (CRD42021249212) sought to explain the criteria relating to:

- *'Balance of health and benefits'* – the scale and types of health benefit gained from intervention
- *'Health equity, equality and non-discrimination'* – an effort to improve health and reduce structural differences (relating, for example, to socioeconomic or educational status) in health across populations

This review includes the above criteria along with:

- *'Human rights and sociocultural acceptability'* – an intervention's impact on human rights, and how far people understand or feel it to be appropriate
- *'Societal implications'* – an intervention's wider economic, social and environmental associations
- *'Financial and economic considerations'* – the economic impact on the health system, government and society
- *'Feasibility and health system considerations'* – how an intervention fits into the framework of legislation and governance, the structure of the health system, other programmes, human resources and infrastructure

- *'Quality of evidence'*, which is considered across these criteria and is described in the *'Quality appraisal'* section

Search strategy

The review protocol for this study was registered at the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42021274454, Appendix 3.1). We searched MedLine, EMBASE, PsychInfo, SCI, SSCI, Web of Science, Scopus, EconLit, the Cochrane Library, Epistemonikos and the Campbell Library for eligible systematic reviews published from 1 January 1990 up to June 2021. A range of search terms were used to cover three themes for relevant reviews. Specifically we required that:

1. The study type must be a systematic review (defined according to the Cochrane Handbook for Systematic Reviews of Interventions[38]) with or without meta-analysis.
2. It must focus on fiscal or pricing policies, such as taxes or subsidies [referred to here as fiscal interventions (FIs)].
3. The intent must be to change diet with a view to improving health.

We identified a list of search terms across these three themes using Boolean 'or' operators for terms within each theme and 'and' operators between each theme (Appendix 3.2). Where a database provided tools to further limit our search strategy, we restricted to studies of 'humans' (MedLine, EMBASE, PsychInfo) and applied a database tool designed to achieve a balance between sensitivity and specificity of searches for systematic reviews (MedLine)[39]. We followed the Peer Review of Electronic Search Strategies (PRESS) guidelines in designing our search strategy, though it was not peer reviewed[40]. To help validate our search strategy, we identified two systematic reviews which we expected from the outset to be relevant to our umbrella review[33, 34], and used these to test our strategy but not to design it; i.e. if a search database indexed our validation reviews then our search was required to include it. For Google Scholar, we first completed the review on all other databases and then compared this final list to the first five pages (50 studies) returned to see if any additional studies merited inclusion.

Screening

One reviewer (LB) carried out the search, collated the results and removed the duplicates in EndNote 20 software[41]. Two reviewers (CON and LB) independently screened article titles first to remove redundancies and compared results before finalising a list of articles for abstract screening. Disagreements were discussed until consensus was reached or input was sought from a third reviewer (FK), though ultimately the latter was not required. Next, abstracts were screened using the same process followed by a full-text screening. We searched reference lists,

contacted authors and sought expert opinion to identify any additional relevant studies and acquire full texts where necessary. For any articles that required translation into English, we initially used online translation software to identify any clear reasons for exclusion and otherwise used a professional translation service.

Inclusion/exclusion criteria

We included all systematic reviews examining B/Fs related to FIs that had been implemented by governments to improve diet quality across the population. Eligible reviews for inclusion:

- Were conducted as a systematic review with or without meta-analysis
- Examined acceptability in relation to an implemented or proposed government policy that targeted the price of a good
- Used real-world evidence (RWE), i.e. not simulated models
- Examined policies that targeted the consumption of food and non-alcoholic beverages, i.e. not agricultural policies with unintended impacts upon consumption
- Examined real or perceived B/F experienced by the public or political groups, e.g. a real or perceived reduction in local employment resulting from a food tax, as well as actions taken in relation to such B/F, e.g. lobbying
- Examined policies that applied to the entire population of a government's jurisdiction, e.g. not experiments on price discounts in supermarkets or subsidies on selected samples

Criteria for qualification as a systematic review were taken from the Cochrane Handbook for Systematic Reviews of Interventions[38]. Reviews were therefore excluded if they did not provide:

1. A clearly stated set of objectives with pre-defined eligibility criteria for studies
2. An explicit, reproducible methodology
3. A systematic search that attempted to identify all studies that would meet the eligibility criteria
4. An assessment of the validity of the findings of the included studies
5. A systematic presentation and synthesis of the characteristics and findings of the included studies

We excluded reviews of modelling/simulation studies (i.e. those that simulated a result) or theoretical studies. Some reviews included studies which satisfied the inclusion criteria (i.e. RWE examining a fiscal policy that had been applied across the entire population under its jurisdiction) as well as studies which did not satisfy the criteria (e.g. a modelling study of the same intervention). In these cases, we included the review and reported results only relating to the relevant studies, provided these results were presented separately. If the original reviewers

had combined the findings of modelling or theoretical studies with those examining RWE, we used the combined results while noting that they included a mix of results in our synthesis. Reviews noting the existence of a policy but not discussing the B/F it involved were not included.

Quality appraisal

As part of the original protocol, it was intended that quality appraisal and data extraction would be conducted in duplicate. However, due to time constraints, we assessed the methodological quality of 25% of the systematic reviews included for final review in duplicate (LB and CON) using the AMSTAR2 tool[42]. Disagreements were resolved by discussion and where necessary by reference to a third reviewer (FK), though in the event this was not required. The rest of the reviews were appraised by one reviewer (LB). The AMSTAR2 tool allows a broad indication of whether the quality of a review is high, moderate, low or critically low by counting the number of critical and non-critical domain flaws present. Given some reviews included qualitative studies, such as focus group discussions, these AMSTAR2 criteria were adapted. We did not require the reviews to explicitly specify a comparator (where one could be inferred, for example) and, where no quantitative analysis was conducted, reviews were not graded on related criteria. We planned to exclude all those reviews which had more than one critical domain flaw, but decided to relax this criterion as all the potentially included reviews (Appendix 3.3) had two or more critical domain flaws. As such, we have based our synthesis on those reviews with only two or three critical domain flaws. The quality rating applied to reviews in this systematic review does not necessarily reflect the overall quality of the review but rather reflects how well it addressed our umbrella review question.

Data extraction

Data extraction was carried out using an online form to document review features: aims; methods; eligibility criteria and search strategy; funding sources; setting; participants; intervention (and comparator where available); outcomes measured; research design; length of follow-up; outcomes reported; any sub-group analyses related to specific groups of participants; and any distributional impacts on groups defined according to PROGRESS-Plus [43] (bearing in mind that inequalities could arise across other types of groups as well as socio-economic [44]). The extraction form was trialled by two reviewers (LB and CON), each using three systematic reviews, before being finalised[45]. As with the quality appraisal, extraction was performed in duplicate (LB and CON) on 25% of articles. These results were compared between reviewers, and guidelines were developed on how best to extract information from the remaining studies in a consistent manner. This extraction was completed by one reviewer (LB).

Synthesis

Given the heterogeneity across studies, a narrative synthesis of the included systematic reviews was conducted[46] following extraction and final exclusions based on our quality appraisal. Data were grouped using thematic analysis according to the nature of results being reported. This analysis involved categorising review results into sub-themes using an inductive approach (or by relying on themes identified by the review authors). Having extracted review results according to sub-themes, we further grouped them according to WHO-INTEGRATE criteria[23]. Because these criteria were designed to guide the evidence-to-decision-making process for complex health interventions, such as FIs to improve diet, they were suitable for structuring our results. They also improved transparency in defining themes, which can be an issue when using an inductive approach[46] i.e. starting from observations. The number of results (relating to sub-themes) which appear under each WHO criterion provided a useful way of identifying information gaps when considering the acceptability of FIs to improve diet. It also identified which criteria were more important to consumers and other groupsin the prioritisation of B/F. While we acknowledge that some sub-themes could be classified under multiple criteria, to allow for interpretation and prioritisation of the results we have selected the single criterion judged to be the most relevant to each sub-theme.

A summary of each review is presented in Table 3.1. Table 3.2 provides an overview of the evidence regarding the documented B/F in relation to FIs, reported according to sub-themes and grouped according to WHO-INTEGRATE criteria[23]. Where quantitative results were provided as part of a meta-analysis, these are reported in Table 3.2, as are any distributional/subgroup results.

Robustness check

While umbrella reviews summarise high-level evidence from systematic reviews, they are restricted in their timescale as they can only deal with primary studies published up to the most recent systematic review search date. While our search covered the period up to June 2021, the most recent systematic review search date was October 2019. As countries have continued to implement FIs, we conducted a literature review of primary studies published between January 2020 and November 2021 to examine whether these supported or conflicted with the results of our umbrella review. This literature review used the search strategy from the umbrella review. The strategy applied only to EMBASE but was updated to focus on journal articles in English only, with titles referring to tax or subsidies but not alcohol or tobacco (Appendix 3.4). Although the search was more restrictive (e.g. limited to articles in English), was conducted at a high level by only one reviewer (LB) and did not involve any quality assessment, the resulting review

provides a useful overview – to compare with our umbrella review results – of primary studies after 2019 on the acceptability of taxes and subsidies.

Results

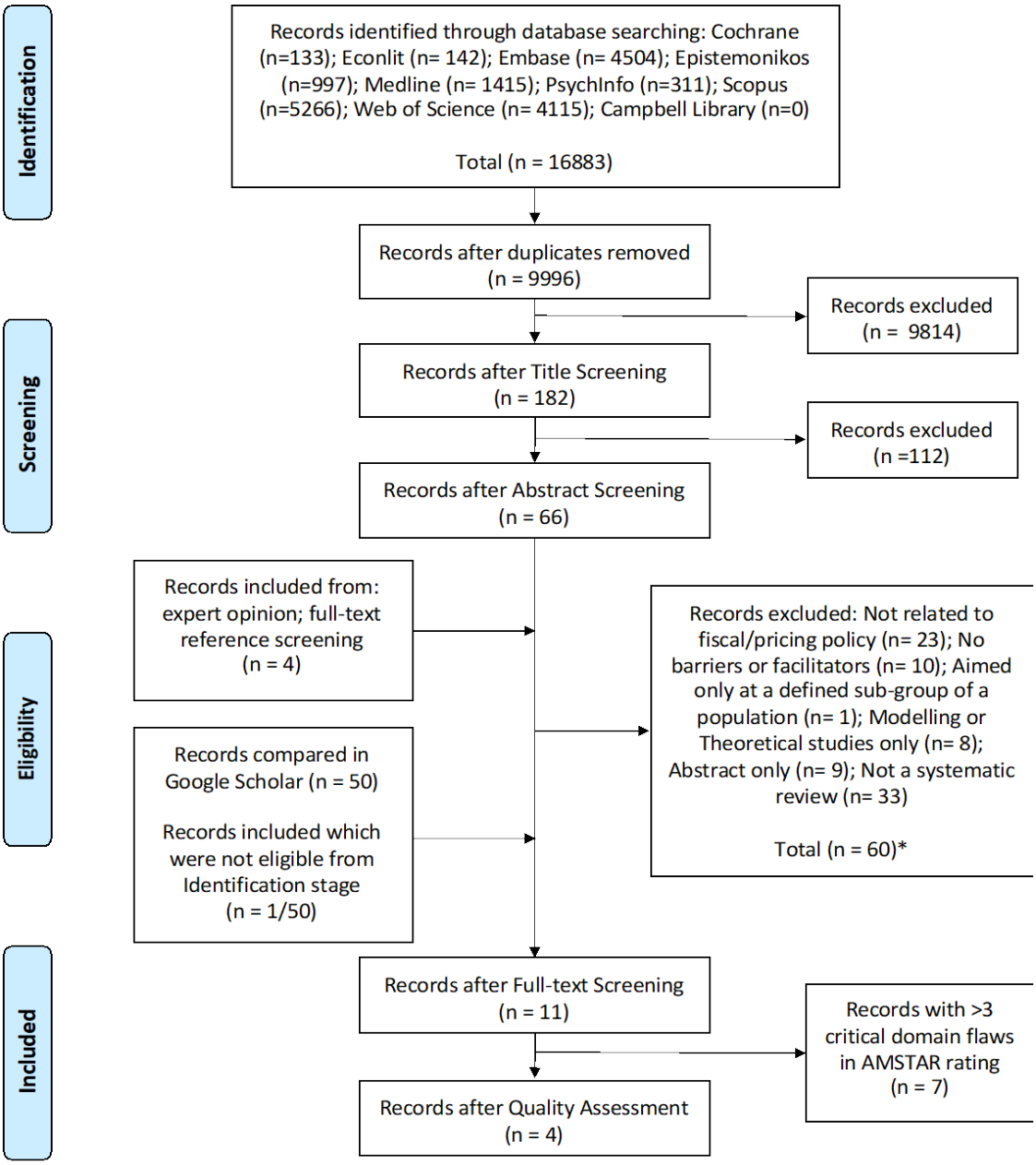
Screening

A total of 16,883 records were identified through database searches, resulting in 9,996 unique records once duplicates were removed (Figure 3.1). After abstract screening this was reduced to 66 records, with four additional records included based on recommendations from experts in the field and searches of reference lists. The Google Scholar search added one new record which had not been identified in the original database search. One study in Dutch was translated online for full-text screening and the rest were in English. Following full-text screening, a further 60 records were excluded (the Dutch paper was excluded as it did not qualify as a systematic review), leaving 11 potentially relevant records for data extraction. The list of all 11 potentially relevant reviews are detailed in Appendix 3.5 along with a summary of the databases in which they were indexed. Two of these reviews were identified after screening by searching Google Scholar and reference lists[47, 48]. Of the remaining nine reviews, 100% of these were indexed across two databases (MedLine = 8/9; EMBASE or Scopus = 7/9).

Quality appraisal

Following quality appraisal, *all* reviews were assessed to have two or more critical flaws and thus received a 'critically low' AMSTAR2 rating. As such, we have based our synthesis on the four reviews containing only two or three critical domain flaws. Not including a list of potentially relevant but excluded studies (n=4/4) and not justifying publication restrictions (n=3/4) were the main reasons for these ratings (Appendix 3.3). Where a review restricted inclusion to studies of humans only, no justification was necessary and thus no penalty was incurred in the AMSTAR2 rating. All but one of the included reviews[49] reported either no conflicts of interest or, where conflicts of interest were reported, they described how these were managed so as not to influence results (see item 16 in Appendix 3.3).

Figure 3.1: PRISMA flow diagram for systematic identification of umbrella review literature



*Counts for individual exclusions do not sum to total as reviews may have been excluded based on one or more criteria

Characteristics of included reviews

Table 3.1 provides an overview of each of the four included reviews. Three reviews focused solely on taxation with one focusing on SSBs only[33]; another on SSBs and energy-dense foods[50]; and one on salt and salty foods[51]. The last review included both taxes and subsidies to promote healthy diet more generally[49]. The studies were published between 2015 and 2020. Three of them had search strategies that were restricted to English language only but did not explain why. The types of research design and populations covered in the reviews varied widely, with three

reviews including modelling studies[49-51]. One review included qualitative and mixed-methods data, which were used to assess real or perceived B/F for the public and policymakers globally, alongside quantitative data. This was part of a meta-analysis to estimate support both for SSB taxation and for arguments used to justify support or opposition to SSB taxation[33]. Two reviews focused on general populations[49, 51], though Niebylski et al (2015) restricted their sample to Western Europe, Canada, United States, Australia and New Zealand. Finally, one review looked at the macro-economic impacts of SSB and energy-dense food taxation for different national economies: Brazil, Mexico, South Africa, UK and USA[50].

Acceptability of fiscal interventions

Financial and economic considerations

Three of the four reviews included sub-themes relating to *'financial and economic considerations'*[33, 49, 50]. These sub-themes included macro-economic impacts in general as well as more specific impacts such as those on GDP, government revenue, employment and industry sales. Eykelenboom et al (2019) examined public and policymakers' beliefs about these economic impacts. They found that both the public and policymakers had concerns that SSB taxation could lead to job losses and business closures but thought it might also provide a means of raising revenue that could be used to support social and health initiatives. In a meta-analysis (n=2) of perceptions regarding the potential of SSB taxation to raise revenue for health programmes, the authors found that only 39% (95% CI: 0.36-41) of the public believed this would be the case.

Both Niebylski et al (2015) and Mounsey et al (2020) identified empirical evidence that taxes on food and non-alcoholic beverages are likely to be revenue raising[49, 50] and found support for allocating revenue towards NCD prevention programmes or healthy food subsidies[49]. Mounsey et al (2020) estimated that revenue from SSB taxation would range from US$1.05 to US$43.39 per head of the population in the jurisdiction applying the tax. However, the length of follow-up varied across estimates. Much of this data came from modelling studies, which also estimated a negative impact on industry sales, GDP and local sales tax revenue from cross-border shopping[50]. Mounsey et al (2020) highlighted the limitations of these estimates as being very dependent on modelling assumptions – which often failed to account for important factors such as substitution by consumers – and noted that the studies were mostly industry-funded. They found no evidence, except from industry-funded modelling studies, that diet-related taxes resulted in net unemployment. The two peer-reviewed (and non-industry-funded) studies which used interrupted time series analysis (i.e. the result was not simulated) found no net change in either employment or unemployment following the implementation of soft drink and SSB taxes in the USA and Mexico.

Human rights and sociocultural acceptability

Three reviews included sub-themes addressing *'human rights and sociocultural acceptability'*[33, 49, 51]. These related to:

- The appropriateness of and support for taxation as an intervention strategy
- Whether food and non-alcoholic beverages, specifically SSBs in this instance, are a good target for FIs
- Whether industry and government stakeholders can be trusted in policymaking

Although some doubt was reported as to whether SSBs contribute to obesity, there was a general consensus that they do, with Eykelenboom et al (2019) finding that, across five studies from the US, UK and Mexico, 68% (0.48–0.85) of the public believed SSBs were an appropriate target for intervention. There was much less support for taxation as means to reduce consumption of unhealthy products or nutrients, in particular SSBs and salt[33, 49, 51]. In a random-effects meta-analysis of studies from the UK, the US, Australia and France, only 42% (0.38-0.47; n=9) of the public supported SSB taxation, with similar results when it was framed as a strategy to reduce obesity (39% [0.29-0.50]; n=10)[33]. Support rose to 66% (0.6-0.72; n=4) where it was indicated that SSB tax revenue would be used "appropriately". [This term varied from study to study but generally indicated the use of revenues to fund health initiatives, such as healthy food subsidisation.] The difference between these estimates suggests a level of mistrust among the public as to the current use of tax revenues – as indicated by taking pooled proportions (weighted averages) from three studies in the UK and US, which showed that 61% (0.56-0.67) of the public mistrusted the government. Mistrust of industry was also reported[33, 51], while support for salt taxation was higher among those who believed that food manufacturers have a responsibility to reduce salt consumption[51].

Balance of health benefits and harms

Pooling across two studies from the US and Australia, 92% (91%-93%) of the responding public believed that obesity was a public health issue[33], while adults in Great Britain believed that improving awareness of this issue would increase support for policies to tackle obesity[49]. While there were reports that policymakers and the public believed that SSB taxes would reduce their consumption and be cost-effective, pooled proportions indicated a degree of scepticism. Across seven studies from the UK, the US, Mexico and France, 39% (0.26-0.54) of the public believed an SSB tax would reduce consumption; across five studies from France, the UK and the US, 40% (0.29-0.54) believed it would improve health-related outcomes. In addition to looking at what people thought about the direct effect of FIs on consumption and health, Eykelenboom et al (2019) noted concerns among the public as to whether healthy alternatives would be available if

there were incentives to substitute. Their concerns included, for example, beliefs that an SSB tax could increase consumption of artificial sweeteners, and are discussed further under *'Societal implications'*.

Health equity, equality and non-discrimination

Equity was examined with respect to both the distribution of tax burden and health effects. Distributional issues which relate to *'health equity, equality and non-discrimination'* of FIs were raised in two reviews[33, 49]. Both identified concerns among the public and policymakers that taxes can be regressive, placing a larger burden on those with less income. Eykelenboom et al (2019) found that some policymakers believed that SSB taxation could improve health equity. However, the public seemed less aware of this potential or at least did not perceive it as a facilitator. Concerns were raised as to whether the tax would reduce consumption among those who are not price sensitive (e.g. high-income individuals), or addicted to SSBs or with high levels of obesity. Some respondents also viewed the tax as unfair to 'healthy' individuals who consumed SSBs responsibly [33]. From two studies in France and the UK, 50% (0.48-0.52) of the public believed SSB taxation made socioeconomic inequality worse, while the same study from the UK found that only 36% believed it made the situation more equal. Finally, Niebylski et al (2015) noted that, while this regressivity may make taxes less acceptable, it could be countered by clearly promoting the tax as helping key groups such as children.

Societal implications

Sub-themes around the availability of healthy alternatives, industry efforts to reformulate foods and changing prices were grouped under *'societal implications'*. In Mexico, for example, inadequate investment in clean drinking water infrastructure made an SSB tax less acceptable, but using revenues from the tax to improve water supply was seen as a facilitator that enabled the government to continue levying the tax. In Australia, it was suggested that the price of packaged water should be reduced while SSB taxation increased. In the UK, people were concerned about an increased consumption of artificial sweeteners[33]. By contrast, both the public and policymakers expressed doubts that an SSB tax would raise prices sufficiently to change behaviour, suggesting they perceived the policymaking process to lack vigour. This was thought to be a result of industry interference – pressuring the government to keep the tax rate lower than recommended. However, where manufacturers opted to reformulate their products so as to avoid the tax, this was seen as a positive by the public[33].

Feasibility and health system considerations

A number of barriers were also identified in Eykelenboom et al (2019) as impacting upon *'feasibility and health system considerations'*. One barrier was seen to be the long and complex

political/administrative process involved in implementing an SSB tax, with competing views across stakeholders, especially resistance from the SSB industry. Another perceived barrier was the development of shadow economies, for example in home-made or black market goods[33]. While Dodd et al (2020) did not report on studies addressing this criteria, they discussed the added complexities of taxing a nutrient such as salt as opposed to a single product such as an SSB, as nutrients are more pervasive across the food supply[51]. This can create a negative cycle whereby evidence grows on the effectiveness of easier-to-implement product-based taxes and so makes it easier to introduce more of them. On the other hand, nutrient-based taxes, although potentially more efficient[52], face the barrier of a lack of RWE, meaning governments are less likely to implement them.

Robustness check

Our literature review identified 31 studies published between January 2020 and November 2021 which examined B/F as part of the process of implementing taxes or subsidies on food and non-alcoholic beverages to improve diet and prevent diet-related NCDs (Appendices 3.4, 3.6 and 3.7). These covered FIs – implemented or proposed – in Barbados[53], Botswana[36, 54, 55], Chile[56, 57], Colombia[57], Kenya[36, 54, 55], Mexico[29, 56, 57], Namibia[36, 54, 55, 58], the Netherlands[31, 32], Rwanda[36, 54, 55, 59], South Africa[28, 60-62], Tanzania[36, 54, 55], Uganda[35, 36, 54, 55], the UK[63, 64], various jurisdictions within the US[65-77], and Zambia[36, 54, 55]. Two studies examined the feasibility of fruit and vegetable subsidisation programmes in the UK[63] and the US[70]. They found that communities often engaged in these programmes and that existing government structures in the US could facilitate them, but a voluntary opt-in approach for local jurisdictions would be more feasible than a mandatory one. One study examined revenues raised from a tax on unhealthy foods within the Navajo Nation, finding an increase in revenues which declined over time[68]. The remaining 28 studies related to taxes on non-alcoholic beverages, namely SSBs. The majority of studies presented evidence which related to *'financial and economic considerations'* (n=20), followed by *'human rights and sociocultural acceptability'* (n=19), *'feasibility and health system considerations'* (n=17), *'balance of health benefits and harms'* (n=12), *'health equity, equality and non-discrimination'* (n=8), and *'societal implications'* (n=8).

A number of studies examined the political process of implementing FIs (almost entirely SSB taxes). They found that a key barrier to this process related to industry-promoted anti-tax arguments that FIs would lead to economic harm[28, 31, 35, 36, 57, 58, 62, 75, 77], such as unemployment or reduced sales revenues, with these concerns echoed by retailers[65]. Studies which examined the economic impact of SSB taxation found a lack of RWE that taxes reduce employment within affected industries and in general[69, 73], or that they adversely affect retailers. In the US, retailers were in favour of implementing nationwide SSB taxation[66].

Support for taxation among the public was often low, owing to concerns about its effectiveness and doubts about how equitable it might prove[32, 53, 60, 65, 71, 72, 77] as well as mistrust in the government's use of revenues or a lack of transparency in the implementation[32, 60, 65, 71]. Support for taxation and beliefs about its benefit tended to be lower among those who consumed large quantities of SSBs, were overweight, or were less educated[32, 71, 72]. Eykelenboom et al (2021) independently associated these three factors with the acceptability of an SSB tax in the Netherlands[32]. A key facilitator in implementation related to how diet-related taxes were framed as revenue raising[28, 29, 31, 68] or health improving[35, 36, 58, 64], or whether revenues were allocated towards social programmessuch as early-childhood education and to health initiatives such as subsidising healthy food[28, 32, 54, 64, 67, 76, 77]. Media campaigns were found to be effective in promoting such messages and were seen as a facilitator in implementation, alongside strong advocacy and networking among people in favour of the tax[28, 29, 36, 54, 56-58, 61, 75-77]. In general, the results here supported the results from our umbrella review and are discussed in further detail in the next section.

Table 3.1: Characteristics of reviews included in the narrative synthesis

Author/Yeary	Research design	Synthesis method	Population	Intervention	No. of databases	Search period	Search restrictions	No. of included studies	AMSTAR2 rating
Eykelenboom et al, 2019	NRSI; RCT; Mixed-methods studies; qualitative studies	Thematic synthesis and meta-analysis	Any individuals involved in the decision-making process (e.g. policy-makers, politicians and officials of ministries) or any individuals potentially affected by an SSB tax (i.e. the public)	FI (taxes) on SSBs	4	Earliest date up to November 2018	English language	37	CL
Mounsey et al, 2020	NRSI; models	Narrative synthesis	National economies	FI (taxes) on SSBs and energy-dense foods	7	Earliest date up to November 2018 (one article from 2019 included after search date)	English language	11	CL
Dodd et al, 2020	NRSI; models; experiments	Narrative synthesis	Any population, any age, any setting, any country	FI (taxes) on salt and foods high in salt	12	January 2000 to October 2019	None	18	CL

Author/Yeary	Research design	Synthesis method	Population	Intervention	No. of databases	Search period	Search restrictions	No. of included studies	AMSTAR2 rating
Niebylski et al, 2015	NRSI; RCT; models; reviews; experiments	Narrative synthesis	Adults and children, any setting, in Western Europe, Canada, United States, Australia and New Zealand	FI (taxes and subsidies) to promote healthy diet	4	June 2003 to November 2013 (Google Scholar – June and November 2013)	Peer-reviewed; English language	78	CL

NRSI – Non-Random Studies of Interventions; RCT – Randomised Controlled Trials; FI – Fiscal Intervention; SSB – Sugar-Sweetened Beverages; CL – Critically Low

Note: We have described the population as they were described by the review authors. Where the population inclusion criteria were not described in the review, we have assumed that 'any' population, age, setting or country had the potential to be included.

Table 3.2: Acceptability of intervention strategies synthesised by included systematic reviews

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
Financial and economic considerations					
Eykelenboom et al 2019	FI (taxes) on SSBs	Macroeconomic impacts	Beliefs that an SSB tax may have negative macroeconomic impacts - "Concerns about the negative impact of an SSBs tax on the economy were reported in four studies on political [n=2] and public acceptability [n=3], such as concerns about a reduction in jobs and closing of SSB companies as a result of the tax."	-	-
		Revenue generation	Beliefs that SSB taxes would be effective in raising revenue for social, health and general budgets - "the potential to raise revenue for societal health programs (e.g. for prevention funds, sport fields and recreational activities) was perceived as a positive consequence of implementation" AND "The potential of an SSBs tax to raise revenue for health care (e.g. for the National Health Service) was identified in three studies on political and	"Pooled proportions indicated that of the public ...39% (0.36–0.41) believed that an SSBs tax has the potential to raise revenue for societal health programs"	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			public acceptability." AND "Four studies on political acceptability reported that an SSBs tax was viewed as a potential to raise revenue for the general budget"		
Mounsey et al 2020	FI (taxes) on SSBs and energy-dense foods	Employment	Lack of evidence (except from modelling studies) that diet-related taxes result in net unemployment - "the three non-industry supported peer-reviewed academic studies found none of the significant job losses industry reports suggested, but found instead, no significant net decline in employment and job creation."	-	-
		Gross domestic product	Evidence (from modelling studies) that SSB taxation would reduce GDP contributions however these were industry-funded and dependant on modelling assumptions - "the projections for reductions of approximately US$173 million and US $1 billion to GDP contributions from UK and South Africa analyses, respectively, were likely overestimated because of failure to incorporate	-	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			milk and other substitutions across sectors, and for South Africa, the over-shifting of the pass-through rate. It was also clear from the studies reviewed that the PE selected for modelling had a significant impact on the potential GDP effects of a tax."		
		Industry sales	Evidence (from modelling studies) that SSB taxation would reduce sales revenue generation however these were industry-funded and dependant on modelling assumptions - "Three reported the dollar value of sales revenue reductions (between $US13.3 and $US779 million), but not the total revenue prior to the tax, and one reported the percentage reduction in total revenue (23.5 %)" BUT "assumptions regarding the products taxed, wage fixing, the pass-through rate and substitution availability varied between papers, which have significant implications for the outcome of the models."	-	

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
		Revenue generation	Evidence (including modelling studies) that SSB taxation would increase government revenue - "Estimates ranged from between US$31 million to US$940 million, translating to per capita values of between US$1.05 to US$43.39. The most significant impacts on the magnitude of revenue were the tax levels imposed and onto what products, price-elasticity and substitution estimates."	-	"One study reported the cross-border shopping impact of the Philadelphia SSB tax on both beverages and non-beverage items and showed a gross loss from the local sales tax revenue that should have been collected"
Niebylski et al, 2015	FI (taxes and subsidies) to promote healthy diet	Revenue generation	Evidence (from modelling studies) that SSB taxation would increase government revenue and support for the allocation of revenue towards health initiatives - "In 2008, the CBO estimated that a federal excise tax of $0.03 per 12 ounces of SSB would generate an estimated $24 billion over 2009–13 and $50 billion over 2009–2018." AND "Using tax revenue to fund NCD prevention	-	

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			programs and/or subsidize healthy foods was further recommended"		
Human rights and sociocultural acceptability					
Dodd et al, 2020	FI (taxes) on salt and foods high in salt	Taxation as an intervention strategy	Lack of support for the introduction of tax to reduce salt consumption - "In Tonga, focus group discussions revealed food taxes to be unpopular with consumers, due to the cost for consumers" AND "In Ireland, salt tax was the least popular of proposed salt reduction initiatives" BUT "Support for salt taxation was highest amongst those who saw food manufacturers as responsible for reducing salt consumption, suggesting knowledge of the food production process could be key to winning public support"	-	-
Eykelenboom et al, 2019	FI (taxes) on SSBs	Mistrust	Beliefs that some stakeholders cannot be trusted as part of SSB tax policy process - "Mistrust of the industry was identified in five studies on public acceptability of an SSBs tax [n=5]" AND "Public	"Pooled proportions indicated that of the public … 49% (0.32–0.66) mistrusted the	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			doubts were reported about [government's] use of raised revenue in four studies on public acceptability of an SSBs tax [n=4]" AND "Mistrust of public health experts was expressed in one study on public acceptability"	industry, and 61% (0.56–0.67) mistrusted the government"	
		Public support for SSB taxation	-	Quantitative estimates on public support for SSB taxation were pooled using a random-effects meta-analysis finding that - "42% of the public (95% CI = 0.38–0.47) supports an SSBs tax, 39% of the public (0.29–0.50) supports an SSBs tax as a strategy to	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
				reduce obesity, and 66% of the public (0.60– 0.72) supports an SSBs tax if revenue is appropriately used."	
		SSBs as an intervention target	Mixed beliefs as to whether SSBs are a good target for taxation as they provide pleasure but may also contribute to obesity - "Those supportive of an SSB tax believed that SSBs are a major contributor to obesity [n=6], while opponents indicated a lack of personal evidence that SSBs can cause obesity and referred to the many other determinants of obesity [n=4]."	"Pooled proportions indicated that of the public … 68% (0.48–0.85) believed that SSBs are an appropriate intervention target"	-
		Taxation as an intervention strategy	Mixed beliefs about whether taxation is an appropriate intervention strategy to reduce SSB consumption - "Taxation was viewed as an appropriate intervention strategy in the majority of studies on political acceptability. Taxation was also		-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			considered necessary in two studies on public acceptability. However, in other studies on political and public acceptability taxation was viewed as government intrusion."		
Niebylski et al, 2015	FI (taxes and subsidies) to promote healthy diet	Taxation as an intervention strategy	Lack of support for taxation as a mean to improve diet - "A public opinion survey to examine attitudes on pro- and anti-food & SSB tax arguments … determined that more people agreed with antitax vs. pro-tax arguments." AND "Policy support was highest for healthy lifestyle campaigns and food labelling but lowest for taxing unhealthy foods."	-	-
Balance of health benefits and harms					
Eykelenboom et al, 2019	FI (taxes) on SSBs	Cost-effectiveness	Beliefs that an SSB tax would be cost-effective - "An SSB tax was seen as a cost-effective intervention for improving public health nutrition and obesity prevention across six studies on political [n=3] and public acceptability [n=3]"	-	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
		Effectiveness	Beliefs that taxes would be effective in reducing SSB consumption - "The belief that an SSBs tax would be effective in reducing purchases and consumption of SSBs was reported in studies on political … and public acceptability."	"Pooled proportions indicated that of the public 39% (95% CI = 0.26–0.54) believed that an SSBs tax has impact on SSB purchases and consumption"	Belief that taxes would be ineffective in reducing SSB consumption among certain groups - "an SSBs tax was perceived to be ineffective in those addicted to SSBs, in those who lacked awareness of SSB prices, in those with obesity, and in rich and stubborn people."
		Health-related outcomes	Mixed beliefs that an SSB tax would be effective in improving health - "While some studies among the public reported the belief that an SSB tax could improve population health [n = 5], others indicated that such a policy does not cure anything [n = 3]."	"Pooled proportions indicated that of the public … 40% (0.29–0.54) believed that an SSBs tax has impact on health-	Beliefs that taxes would be unfair for certain groups - "SSB tax [perceived] as unfair to 'healthy' individuals who

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
				related outcomes" WHILE "92% (0.91–0.93) believed that obesity is a problem"	consume SSBs responsibly"
Niebylski et al, 2015	FI (taxes and subsidies) to promote healthy diet	Health-related outcomes	Support for policy action to reduce obesity prevalence - "Improving awareness of the multiple causes of obesity could facilitate acceptance of policy action to reduce obesity prevalence."	-	-
Health equity, equality and non-discrimination					
Eykelenboom et al, 2019	FI (taxes) on SSBs	Socioeconomic inequality	-	"Pooled proportions indicated that of the public … 50% (0.48–0.52) believed that an SSBs tax has a negative impact on socioeconomic equality"	Mixed beliefs on the effect of SSB taxation on inequality - "In three studies on political acceptability, an SSBs tax was believed to have a positive impact on equality in health"

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
					HOWEVER "concerns primarily arose from the belief that an SSB tax is regressive [n=7]; low-income individuals have to spend relatively more of their income and consume greater quantities of SSBs [n=2]."
Niebylski et al, 2015	FI (taxes and subsidies) to promote healthy diet	Helping key groups	-	-	Support for policies to help children - "small taxes with the clear purpose of promoting the health of key groups, e.g. children, are more likely to receive public support."

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
		Tax regressivity	-	-	Beliefs that taxes to reduce SSB consumption would be regressive - "that low SES [groups] may carry more of the fiscal burden … may limit feasibility of SSB fiscal policy implementation "
Societal implications					
Eykelenboom et al 2019	FI (taxes) on SSBs	Healthy substitutes	Beliefs that a lack of healthy alternatives would lead consumers to consume unhealthy alternatives - "Three studies on public acceptability reported concerns about an increase in the consumption of artificial sweeteners as a result of an SSB tax"	-	-
		Reformulation	Beliefs that an SSB tax would encourage manufacturers to reformulate SSB contents - "UK	-	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			news website commentators indicated that manufacturers would reduce the amount of sugar as a consequence of the tax, which was viewed as a potential facilitator in the effectiveness of an SSBs tax."		
		SSB prices	Beliefs that tax may not be passed through to consumers - "Studies among Australian citizen jurors and students from Michigan, UK, indicated that a tax rate of 50 to 100% may be large enough to change consumer behaviour."	-	-
Feasibility and health system considerations					
Eykelenboom et al, 2019	FI (taxes) on SSBs	Feasibility	Beliefs that SSB taxes could be feasible but many barriers exist - "Examples of barriers are a long law-making process in Mexico and the UK, competing national agendas in Mexico, the difficulty of defining products that should be taxed in Israel and the UK, the difficulty of regulating 'home-made, unlabelled products' in Mexico, the development of	-	-

Author/year	Intervention	Sub-theme	Narrative synthesis results	Meta-analysis results	Distributional results
			a black market in Israel, a high administrative load in New Zealand, and political costs of taxation in European countries." AND "resistance from the SSB industry was described to complicate policy adoption and implementation"		

FI – Fiscal Intervention; SES – Socioeconomic Status; GDP – Gross Domestic Product; SSB – Sugar-Sweetened Beverage

Discussion

We conducted an umbrella review to assess the highest-level evidence of the acceptability of FIs on food and non-alcoholic beverages in improving diet and preventing diet-related NCDs. We included four systematic reviews – one including a meta-analysis – in our final sample. While we allowed for a broader scope covering FIs in general, the majority of evidence concerned diet-related taxes, in particular for SSBs [33, 49-51]. Barriers and facilitators that could influence acceptability were grouped according to WHO-INTEGRATE framework criteria for guiding complex public health interventions[23].

We found evidence that public and political acceptability is influenced by beliefs about financial and economic aspects of FIs. While both the public and policymakers believed that taxation would raise revenue, they were also concerned about the potential for job losses or business closures[33]. Two reviews found evidence that diet-related taxation was revenue raising[49, 50] with one also finding increases in unemployment, reduced industry sales and lower GDP[50]. The review authors raised concerns as to the reliance on modelling studies and a lack of RWE regarding these impacts[49-51]. Mounsey et al (2020) in particular found that while all 11 of their included studies showed increased government revenue from diet-related taxation, only the modelling studies which were funded by industry stakeholders found reductions in employment[50]. The three non-industry-funded studies, including the two that used RWE, found no significant reduction in employment. Unsurprisingly, the authors therefore questioned the influence of industry in the research process. Eykelenboom et al (2019) found that the public and policymakers believed industry resistance to be a barrier to the implementation of diet-related FIs, and were concerned about lobbying and relationships between industry representatives and politicians[33]. In meta-analysis, they also found that a majority of the UK and US public mistrusted the government (61% [95% CI: 0.56-0.67]). Facilitators in the implementation of FIs included a credible evidence base showing the potential of FIs to raise revenue and not to adversely affect macro-economic variables such as unemployment. Barriers included a lack of trust in government and well-organised opposition from industry.

Although the public in the US and Australia believed that obesity was an issue[33], concerns were raised about the use of FIs to tackle it[33, 49, 51]. These included: doubts about the effectiveness of FIs in changing behaviour or improving health; a general lack of support for taxation; beliefs that taxes are regressive or could worsen socioeconomic inequality; and a lack of healthy alternatives to replace goods affected by diet-related taxes. The majority of the evidence we uncovered related to SSB taxes. This may be due to the greater feasibility of taxing a single product rather than a nutrient, the lack of nutritional value from SSBs, and a growing body of evidence on the effectiveness of SSB taxes[51]. Why other products, for example breakfast cereals,

do not appear to have received the same degree of scrutiny is unclear. Dodd et al (2020) noted that even when their studies focused on salt taxation, most examples related to salty products rather than taxes on salt in the food supply. We found little evidence to compare the acceptability of different tax designs, for example excise vs value-added taxes, or subsidisation in general. However, we did find indirect evidence for the acceptability of subsidisation, as support for taxes was highest among the public when revenues were earmarked for health initiatives such as subsidies on healthy food[33]. This may suggest that the public support initiatives, running alongside taxation, which attempt to counter the signs of regressiveness in the taxes. While there was some evidence that policymakers believed SSB taxes would improve health equity, the public did not appear to share this belief, as they were concerned that taxes would be ineffective for those who were overweight or addicted to SSBs while being unfair to those who consumed them responsibly[33].

Therefore, facilitators include credible evidence that diet can affect health; that FIs can address this issue; and that FIs are not harmfully regressive. Barriers include a lack of trust in government to use the revenue raised to benefit the public, in particular those whose taxes pay for these revenues; and a lack of transparency around the use of funds.

A general limitation of umbrella reviews can be their timeliness. As they are reviews of reviews of primary studies, they can lag behind emerging evidence. We therefore conducted a literature review of primary studies, published between January 2020 and November 2021, examining the acceptability of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related NCD. These results support those of our umbrella review finding, as follows:

1. The majority of studies (>90%) focus on SSB taxation.
2. Policymaking is inhibited by industry influence, which focuses on the economic drawbacks of diet-related taxation[28, 31, 35, 36, 57, 58, 62, 75, 77], even though the two studies we found using RWE to examine this claim found that SSB taxes had no significant impact on employment[69, 73].
3. Policymaking is facilitated when diet-related taxes are framed as revenue raising[28, 29, 31, 68] and when revenues are allocated towards social programmes such as early-childhood education, and health initiatives such as healthy food subsidisation[28, 32, 54, 64, 67, 76, 77].

We also found that support for SSB taxation was lower among less-educated individuals, those who are overweight or have high SSB consumption[32, 71, 72]. We found that policymaking is influenced by media campaigns and facilitated by strong advocacy and networking among those in favour of the tax[28, 29, 36, 54, 56-58, 61, 75-77].

There is growing recognition that, for nutritional policy to change, understanding the costs and benefits of an intervention is necessary but not sufficient[78]. Rather, policy change demands political will, underpinned by public will, and this is in turn influenced by the real or perceived B/F associated with that policy. Two recommendations emerge from our review which highlight the drivers and leverage points (the goals and the most effective ways to achieve them) in policymaking: counter misleading anti-tax narratives, and provide clear evidence-based pro-tax narratives instead.

Counter misleading anti-tax narratives

Public opinion may sometimes direct government *to do something* but more often restricts government *from doing something*[27]. In the US, industry-funded informational campaigns focusing on the negative economic effects of SSB taxes were successful in blocking municipalities from enacting beverage taxes[79, 80]. While negative economic effects were a concern to both the public and policymakers[33], there was a lack of evidence – except from industry-funded modelling studies – that these drawbacks materialised in practice. Modelling studies may provide useful evidence as part of the policymaking process. For example, they can model higher tax rates than those actually implemented by governments, given that these taxes usually meet industry opposition[81]. However, the contrast that we noted between industry-funded modelled results and non-industry-funded results, which included models and RWE, highlights their limitations and risk of bias.

This was reaffirmed in our literature review[69, 73], and also in a number of studies examining the political process of SSB taxation across different jurisdictions, which noted that industry narratives and influence were a major barrier to implementation[28, 31, 35, 36, 57, 58, 62, 75, 77]. Support among the public was higher for salt taxes among those who believed manufacturers bore responsibility for poor diet[51]. Blaming the SSB industry for anti-SSB-tax messaging was seen as a facilitator in implementing SSB taxes in the US[75]. Policymakers who seek to implement diet-related taxes should confront false narratives from whatever source and with whatever intent where evidence exists to contradict them. Their efforts may need to include pointing out the role and interests of industry in studies that propagate misleading narratives[82, 83], as well as explaining the role and interests of advocacy groups that may lean in the opposite direction.

Provide clear evidence-based pro-tax narratives

It may not be enough to push back on misleading narratives. Rather, the vacuum needs to be filled by a clear message in favour of implementing diet-related FIs. Eykelenboom et al (2019) found that while 92% of the public believed obesity was a problem and 68% believed SSBs were an appropriate target, less than 40% supported SSB taxation to reduce obesity; or believed

taxes would change consumption or health-related outcomes; or believed the resulting revenues would be used to fund social programmes[33]. However, they found evidence that both the public and policymakers believed FIs could raise revenues for social and health programmes. Support among the public increased to 66% when the tax policy was explained in terms of the 'appropriate' use of revenues from FIs, i.e. use of revenues for health initiatives such as subsidising healthy foods, rather than in terms of their effect on obesity; an observation supported elsewhere[34]. In Eykelenboom et al (2019), findings varied across the included studies and countries on support for SSB taxation in general (n=9), or to tackle obesity (n=10), or if revenue is used 'appropriately' (n=4). This variety was evidenced by their high I^2 statistics (>95%), which measure heterogeneity across study effects. However, only in the studies assessing support for taxation if revenues were used 'appropriately' was support consistently greater than 50%, though this group did include the fewest studies.

We found evidence to support the revenue-raising potential of diet-related taxes in our umbrella review[49, 50] and our literature review uncovered examples of raised revenues being used as intended by government to fund social programmes such as early-childhood education, and health initiatives such as healthy food subsidisation[28, 32, 54, 64, 67, 76, 77].

While there is strong evidence that FIs can change consumption of targeted goods, there is a lack of evidence – except from modelling studies – that they can improve health. In part this lack of evidence is owing to issues in the design of the studies, for example when modelling lower tax rates than recommended, or not accounting for leakage as consumers shop in untaxed jurisdictions or buy untaxed substitutes[81, 84-88]. Where untaxed substitutes are unhealthy they should be taxed, but governments should be cautious about taxing substitutes that also provide micronutrients (e.g. fruit juices contain sugar but also vitamins[52, 89]) or where there is concern about a lack of access to healthy alternatives [33]. This lack of RWE as to the health effects of substitute foods creates a negative loop enabling opponents to use misleading or inadequate information to undermine tax implementation (either blocking implementation altogether or reducing the suggested tax rate of a 15-25% increase in the price faced by consumers[81, 90-92]) – which makes it yet more difficult to produce RWE on the effects of taxation.

We also found evidence that the public and policymakers believed SSB taxes to be regressive, though some policymakers acknowledged their potential to reduce health inequalities[33]. Studies elsewhere suggest that they are likely to be minimally regressive and, overall, help to counter socioeconomic inequality[93-95]. In our literature review, we found that strong advocacy and clear messaging on the part of pro-tax stakeholders was a key facilitator in policymaking[28, 29, 36, 54, 56-58, 61, 75-77]. Policymakers seeking to implement diet-related taxes, who have had to counter

misleading narratives regarding the impacts of the taxes on the economy and inequality, should also promote:

- The harm to health fromthe targeted nutrient/product
- The effectiveness of taxes in changing consumption
- Their revenue-raising potential
- The earmarking of revenues to fund programmes which can further reduce inequality and improve health, especially for children

Further considerations

While the use of evidence to counteract anti-tax or promote pro-tax narratives is important, a number of other issues arose which can affect the acceptability of diet-related FIs. Our umbrella review identified major barriers as mistrust in a government's use of revenues, and lack of transparency in how it implemented taxes or allocated tax revenue[32, 33, 60, 65, 71].

While taxes may reduce consumption of harmful products and nutrients, they also restrict autonomy and will inevitably meet opposition from some members of the public. Public support for taxation in general is low, but increases when funds are earmarked for health initiatives[33, 34]. Where taxes do change behaviour, they bring in less revenue as consumers buy less of the taxed good or producers reformulate to avoid taxation. It may be unclear whether the primary goal of the FI is to generate revenue or change behaviour/health, and this lack of clarity may undermine public confidence in the policy[34]. Given the importance of trust in government in predicting public health outcomes, for example as related to COVID-19 preparedness[96], policymakers need to work hard to justify the restriction of autonomy by carefully designing policies based on clear intentions. To succeed, they must implement the policies alongside a commitment to transparency in the policymaking process, especially when revenues are to be allocated to social and health initiatives, as has been demonstrated in the US.[67].

Another issue raised was the lack of healthy substitutes available to consumers who face increased taxes on unhealthy food or non-alcoholic beverages[33]. This may be even more of an issue where cross-border shopping is possible. It can make FIs less effective and reduce revenue for local government [50, 97, 98]. In Mexico, an added-sugar and calorie-dense tax appears so far to have failed to correct negative externalities (unintended consequences affecting third parties, such as overburdened dental services) as consumers buy cheaper substitutes[87]. However, the tax has been maintained and has become more acceptable as it raises revenue earmarked for improving drinking water[33, 99]. Policymakers could capitalise on the barrier of substitution and could make taxes more acceptable by earmarking tax revenues to subsidise healthy food, for example with a 10% reduction in the price of fruit and vegetables[99]. This would be expected to

be more effective in correcting externalities and internalities (consequences of SSB consumption for both society at large and individual consumers) than taxation alone[100]. Evidence suggests that the public would support subsidies for healthy food, especially in Ireland[63, 101], and subsidies paired with taxation could even increase public support for taxation[33].

Limitations

Our review's limitations point to directions for future research. The paucity of evidence as to the acceptability of non-SSB taxes or subsidies in general means it is difficult to draw firm conclusions. While we believe the recommendations we provide around taxation could be extended to products and nutrients beyond SSBs, there are important differences. For example, it may be less feasible to tax a nutrient such as sugar, which features at every stage across the supply chain, than to tax a single product[51]. Further research is required to understand the acceptability of other diet-related FIs, such as taxes on nutrients such as sugar or subsidies on healthy foods – though we did find that acceptability for diet-related taxation was high (66%) when revenues were allocated to initiatives such as healthy food subsidisation.

A final over-arching criterion from the WHO-INTEGRATE criteria is the *'quality of evidence'*[23]. While our included reviews scored the highest in relative terms, they all received a critically low AMSTAR2 rating (>1 critical domain flaws). Additionally, the supplementary literature review was undertaken as a high-level summary of studies conducted in the last two years to compare against our umbrella review results, and did not undergo quality appraisal. It is reassuring that the results of our umbrella and literature reviews were similar, but there is still a high risk of bias. Further high-quality systematic reviews (for example, Cochrane reviews) would help to improve certainty in this evidence base.

Finally, when considering the issue of complexity, the setting in which an FI is proposed is likely to vary across populations, economic cycles and jurisdictions and to affect both effectiveness and acceptability. For example, different behaviours or properties may emerge from proposing or implementing different diet-related FIs[102]. While we have provided general recommendations based on evidence from multiple jurisdictions, context-specific research is necessary to gauge acceptability depending on the population/jurisdiction being affected.

Conclusion

Acceptability of diet-related FIs will vary depending on stakeholders' interests and beliefs. Media campaigns can influence consumers' beliefs, so policymakers could increase acceptability by promoting the benefits of intervention – given supporting evidence – as well as the revenue-raising potential of taxes in particular. Earmarking revenues for health and social programmes from the outset, while auditing and promoting the use of revenue for such

programmes, may further increase acceptability for current and future FIs provided these results are made known to the public.

Where evidence does not support criticisms of taxation, this should also be shared. For example, we found a lack of unbiased evidence that diet-related taxes result in unemployment despite industry's claims to the contrary. As part of FI promotion, misleading narratives put forward by opposing stakeholders, such as industry, should be explicitly ascribed to the biases of those stakeholders.

A lack of RWE as to the health benefits of diet-related FIs is a barrier to acceptability which can inhibit the implementation or design of proposed FIs, further inhibiting the gathering of RWE and creating a negative cycle. Beyond evidence regarding the effect of FIs on health, we also highlight facilitators that policymakers could use to help break this cycle.

References

1. Global Panel on Agriculture and Food Systems for Nutrition. (2016). *Food systems and diets: Facing the challenges of the 21st century*.
2. Branca, F., Lartey, A., Oenema, S., et al. (2019). Transforming the food system to fight non-communicable diseases. *BMJ*, *364*, l296. doi:10.1136/bmj.l296
3. World Cancer Research Fund. (2018). *Diet, nutrition, physical activity and cancer: A global perspective*. *Continuous update project expert report 2018*. https://www.wcrf.org/wp-content/uploads/2021/02/Summary-of-Third-Expert-Report-2018.pdf
4. Ward, M., McGee, H., Morgan, K., et al. (2009). SLÁN 2007: Survey of lifestyle, attitudes and nutrition in Ireland. 'One Island–one lifestyle?' Health and lifestyles in the Republic of Ireland and Northern Ireland: Comparing the population surveys SLÁN 2007 and NIHSWS 2005.
5. Purdy, J., McFarlane, G., Harvey, H., Rugkasa, J., Willis, K. (2007). *Food poverty fact or fiction?* https://www.safefood.net/getattachment/e5003878-8e01-414e-903b-89cad89dc39d/PHA2007_FoodPovertyFactorFiction.pdf?lang=en-IE
6. Harrington, K. E., McGowan, M. J., Kiely, M., et al. (2001). Macronutrient intakes and food sources in Irish adults: Findings of the North/South Ireland Food Consumption Survey. *Public Health Nutrition*. *4* (5a), 1051-60. doi:10.1079/phn2001186
7. Purdy, J., Armstrong, G., McIlveen, H. (2002). The influence of socio-economic status on salt consumption in Northern Ireland. *Int J Consum Stud.*, *26*(1), 71-80.
8. Williams, M., Ianetta, P., Styles., D. (2020). *A combined environmental and nutri-economic assessment of diets*. *Transition paths to sustainable legume-based systems in Europe (TRUE)*.
9. World Health Organization. (2013). *Global action plan for the prevention and control of noncommunicable diseases 2013-2020*. World Health Organization.
10. Beaglehole, R., Bonita, R., Horton, R., et al. (2011). Priority actions for the non-communicable disease crisis. *The Lancet*, *377*(9775), 1438-1447. doi:https://doi.org/10.1016/S0140-6736(11)60393-0
11. Task Force on Fiscal Policy for Health. (2019). Health taxes to save lives: Employing effective excise taxes on tobacco, alcohol, and sugary beverages. Bloomberg Philanthropies.
12. Frieden, T. R. (2010). A framework for public health action: The health impact pyramid. *American Journal of Public Health*, *100*(4), 590-595. doi:10.2105/AJPH.2009.185652
13. Whitehead, M. (2007). A typology of actions to tackle social inequalities in health. *Journal of Epidemiology and Community Health*, *61*(6), 473-478. doi:10.1136/jech.2005.037242
14. Capewell, S., Capewell, A. (2017). An effectiveness hierarchy of preventive interventions: Neglected paradigm or self-evident truth? *Journal of Public Health*,*40*(2), 350-358. doi:10.1093/pubmed/fdx055
15. Afshin, A., Penalvo, J., Del Gobbo, L., et al. (2015). CVD prevention through policy: A review of mass media, food/menu labeling, taxation/subsidies, built environment, school procurement, worksite wellness, and marketing standards to improve diet. *Current Cardiology Reports*, *17*(11), 98. doi:10.1007/s11886-015-0658-9
16. Briggs, A. (2019). "Sin taxes"— the language is wrong, but the evidence is clear. *BMJ*, *366*, l4616. doi:10.1136/bmj.l4616
17. Cullerton, K., Donnet, T., Lee, A., Gallegos, D. (2016). Using political science to progress public health nutrition: A systematic review. Review
Systematic Review. *Public Health Nutrition*, *19*(11), 2070-8. doi:https://dx.doi.org/10.1017/S1368980015002712
18. Madden, D. (2015). The poverty effects of a 'fat-tax' in Ireland. *Health Econ.*, *24*(1), 104-21. doi:10.1002/hec.3006
19. Briggs, A. D. M., Mytton, O. T., Madden, D., O'Shea, D., Rayner, M., Scarborough, P. (2013). The potential impact on obesity of a 10% tax on sugar-sweetened beverages in Ireland, an effect assessment modelling study. *BMC Public Health*, *13*(1), 860. doi:10.1186/1471-2458-13-860

20. Yanovitzky, I., Weber, M. (2020). Analysing use of evidence in public policymaking processes: A theory-grounded content analysis methodology. *Evidence & Policy: A Journal of Research, Debate and Practice,.16*(1), 65-82.
21. Parkhurst, J. O., Abeysinghe, S. (2016). What constitutes "good" evidence for public health and social policy-making? From hierarchies to appropriateness. *Social Epistemology*, *30*(5-6), 665-679. doi:10.1080/02691728.2016.1172365
22. Campos, P. A., Reich, M. R. (2019). Political analysis for health policy implementation. *Health Systems & Reform*,*5*(3), 224-235. doi:10.1080/23288604.2019.1625251
23. Rehfuess, E. A., Stratil, J. M., Scheel, I. B., Portela, A., Norris, S. L., Baltussen, R. (2019). The WHO-INTEGRATE evidence to decision framework version 1.0: Integrating WHO norms and values and a complexity perspective. *BMJ Global Health*, *4*(Suppl 1), e000844. doi:10.1136/bmjgh-2018-000844
24. Powell, L. M., Leider, J. (2020). Evaluation of changes in beverage prices and volume sold following the implementation and repeal of a sweetened beverage tax in Cook County, Illinois. *JAMA Network Open*, *3*(12). doi:http://dx.doi.org/10.1001/jamanetworkopen.2020.31083
25. Schmacker, R., Smed, S. (2020). Do prices and purchases respond similarly to soft drink tax increases and cuts? *Economics and Human Biology*,*37* (no pagination)100864. doi:http://dx.doi.org/10.1016/j.ehb.2020.100864
26. Moloughney B. (2012). *The use of policy frameworks to understand public health-related public policy processes: A literature review*.
27. Kingdon, J. W., Stano, E. (1984). *Agendas, alternatives, and public policies*. (Vol 45). Little, Brown.
28. Kruger, P., Abdool Karim, S., Tugendhaft, A., Goldstein, S. (2021). An analysis of the adoption and implementation of a sugar-sweetened beverage tax in South Africa: A multiple streams approach. *Health Systems and Reform*, *7*(1) , e1969721. doi:http://dx.doi.org/10.1080/23288604.2021.1969721
29. James, E., Lajous, M., Reich, M. R. (2020). The politics of taxes for health: An analysis of the passage of the sugar-sweetened beverage tax in Mexico. *Health Systems and Reform*, *6*(1), e1669122. doi:http://dx.doi.org/10.1080/23288604.2019.1669122
30. Mosier, S. L. (2013). Cookies, candy, and coke: Examining state sugar-sweetened-beverage tax policy from a multiple streams approach. *International Review of Public Administration*,*18*(1), 93-120. doi:10.1080/12294659.2013.10805242
31. Eykelenboom, M., Djojosoeparto, S. K., van Stralen, M.,M., et al. (2021). Stakeholder views on taxation of sugar-sweetened beverages and its adoption in the Netherlands. *Health Promotion International*. 01doi:http://dx.doi.org/10.1093/heapro/daab114
32. Eykelenboom, M., van Stralen, M.,M., Olthof, M. R., Renders, C. M., Steenhuis, I. H. (2021). Public acceptability of a sugar-sweetened beverage tax and its associated factors in the Netherlands. *Public Health Nutrition*, *24*(8), 2354-2364. doi:http://dx.doi.org/10.1017/S1368980020001500
33. Eykelenboom, M., van Stralen, M. M., Olthof, M. R., Schoonmade, L. J., Steenhuis, I. H., Renders, C. M. (2019). Political and public acceptability of a sugar-sweetened beverages tax: A mixed-method systematic review and meta-analysis. Literature review; systematic review; meta-analysis. *The International Journal of Behavioral Nutrition and Physical Activity 16* (ArtID 78). 16doi:http://dx.doi.org/10.1186/s12966-019-0843-0
34. Wright, A., Smith, K. E., Hellowell, M. (2017). Policy lessons from health taxes: A systematic review of empirical studies. *BMC Public Health*, *17*(1), 1-14.
35. Ahaibwe, G., Abdool Karim, S., Thow, A. M., Erzse, A., Hofman, K. (2021). Barriers to, and facilitators of, the adoption of a sugar sweetened beverage tax to prevent non-communicable diseases in Uganda: A policy landscape analysis. *Global Health Action*, *14*(1), 1892307. doi:10.1080/16549716.2021.1892307
36. Thow, A. M., Abdool Karim, S., Mukanu, M. M., et al. (2021). The political economy of sugar-sweetened beverage taxation: An analysis from seven countries in sub-Saharan Africa. *Global Health Action*, *14*(1), 1909267. doi:http://dx.doi.org/10.1080/16549716.2021.1909267

37. Aromataris, E., Fernandez, R., Godfrey, C. M., Holly, C., Khalil, H., Tungpunkom, P. (2015). Summarizing systematic reviews: Methodological development, conduct and reporting of an umbrella review approach. *International Journal of Evidence-Based Healthcare*, *13*(3), 132-40. doi:10.1097/xeb.0000000000000055
38. Higgins, J., Thomas, J., Chandler, J., et al. (2021). *Cochrane Handbook for Systematic Reviews of Interventions 6.2* (updated February 2021) ed. Cochrane.
39. Wilczynski, N. L., Haynes, R. B. (2007). EMBASE search strategies achieved high sensitivity and specificity for retrieving methodologically sound systematic reviews. *Journal of Clinical Epidemiology*, *60*(1), 29-33. doi:10.1016/j.jclinepi.2006.04.001
40. McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., Lefebvre, C. (2016). PRESS peer review of electronic search strategies: 2015 guideline statement. *Journal of Clinical Epidemiology*, *75*, 40-46. doi:10.1016/j.jclinepi.2016.01.021
41. *EndNote*. (2013). Version EndNote 20. Clarivate.
42. Shea, B. J., Reeves, B. C., Wells, G., et al. (2017). AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*,*358*, j4008. doi:10.1136/bmj.j4008
43. O'Neill, J., Tabish, H., Welch, V., et al. (2014). Applying an equity lens to interventions: Using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. *Journal of Clinical Epidemiology*, *67*(1), 56-64. doi:10.1016/j.jclinepi.2013.08.005
44. Tugwell, P., Petticrew, M., Kristjansson, E., et al. (2010). Assessing equity in systematic reviews: Realising the recommendations of the Commission on Social Determinants of Health. *BMJ*, *341*, c4739. doi:10.1136/bmj.c4739
45. Büchter, R. B., Weise, A., Pieper, D. (2020). Development, testing and use of data extraction forms in systematic reviews: A review of methodological guidance. *BMC Medical Research Methodology*, *20*(1), 259. doi:10.1186/s12874-020-01143-3
46. Popay, J., Roberts, H., Sowden, A., et al. (2006). Guidance on the conduct of narrative synthesis in systematic reviews. *A product from the ESRC methods programme version*, *1*, b92.
47. Diepeveen, S., Ling, T., Suhrcke, M., Roland, M., Marteau, T.M. (2013). Public acceptability of government intervention to change health-related behaviours: A systematic review and narrative synthesis. *BMC Public Health*,*13*(1), 756. doi:10.1186/1471-2458-13-756
48. Clarke, B., Swinburn, B., Sacks, G. (2016). The application of theories of the policy process to obesity prevention: A systematic review and meta-synthesis. *BMC Public Health*, *16*(1), 1084. doi:10.1186/s12889-016-3639-z
49. Niebylski, M. L., Redburn, K. A., Duhaney, T., Campbell, N. R. (2015). Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition*, *31*(6), 787-95. doi:10.1016/j.nut.2014.12.010
50. Mounsey, S., Veerman, L., Jan, S., Thow, A. M. (2020). The macroeconomic impacts of diet-related fiscal policy for NCD prevention: A systematic review. *Economics & Human Biology*, *37*, 100854. doi:https://doi.org/10.1016/j.ehb.2020.100854
51. Dodd, R., Santos, J. A., Tan, M., et al. (2020). Effectiveness and feasibility of taxing salt and foods high in sodium: A systematic review of the rvidence. Review. *Advances in Nutrition*, *11*(6), 1616-1630. doi:10.1093/advances/nmaa067
52. Allcott, H., Lockwood, B. B., Taubinsky, D. (2019). Should we tax sugar-sweetened beverages? An overview of theory and evidence. *Journal of Economic Perspectives*, *33*(3) , 202-27. doi:10.1257/jep.33.3.202
53. Mangera, K. A. S., Adams, O. P. (2021). Knowledge, attitudes and practices with regard to sugar sweetened beverages and taxation among people with type 2 diabetes mellitus in the Caribbean island of Barbados - A cross sectional survey in primary care. *Primary Care Diabetes*, *15*(1), 69-73. doi:http://dx.doi.org/10.1016/j.pcd.2020.04.002
54. Erzse, A., Abdool Karim, S., Thow, A.M., et al. (2021). The data availability landscape in seven sub-Saharan African countries and its role in strengthening sugar-sweetened beverage taxation. *Global Health Action*, *14*(1) , 1871189. doi:http://dx.doi.org/10.1080/16549716.2020.1871189

55. Abdool Karim S., Erzse A. , Thow A.M., et al. The legal feasibility of adopting a sugar-sweetened beverage tax in seven sub-Saharan African countries. *Global Health Action*. 01 Jan 2021;14(1):1884358. doi:http://dx.doi.org/10.1080/16549716.2021.1884358
56. Fuster, M., Burrowes, S., Cuadrado, C., et al. (2021). Understanding policy change for obesity prevention: Learning from sugar-sweetened beverages taxes in Mexico and Chile. *Health Promotion International*. *36*(1), 155-164. doi:http://dx.doi.org/10.1093/heapro/daaa045
57. Carriedo, A., Koon, A. D., Encarnacion, L. M., Lee, K., Smith, R., Walls, H. (2021). The political economy of sugar-sweetened beverage taxation in Latin America: Lessons from Mexico, Chile and Colombia. *Globalization and Health*,*17*(1), (no pagination)5. doi:http://dx.doi.org/10.1186/s12992-020-00656-2
58. Amukugo, H.J., Abdool Karim S., Thow, A. M., et al. (2021). Barriers to, and facilitators of, the adoption of a sugar sweetened beverage tax to prevent non-communicable diseases in Namibia: A policy landscape analysis. *Global Health Action*, *14*(1), 1903213. doi:10.1080/16549716.2021.1903213
59. Ruhara, C. M., Abdool Karim, S., Erzse, A., Thow, A. M., Ntirampeba, S., Hofman, K. J. ((2021). Strengthening prevention of nutrition-related non-communicable diseases through sugar-sweetened beverages tax in Rwanda: A policy landscape analysis. *Global Health Action*, *14*(1), 1883911. doi:http://dx.doi.org/10.1080/16549716.2021.1883911
60. Bosire, E. N., Stacey, N., Mukoma, G., Tugendhaft, A., Hofman, K., Norris, S. A. (2020). Attitudes and perceptions among urban South Africans towards sugar-sweetened beverages and taxation. *Public Health Nutrition*, 374-383. doi:http://dx.doi.org/10.1017/S1368980019001356
61. Murukutla, N., Cotter, T., Wang, S., et al. (2020). Results of a mass media campaign in South Africa to promote a sugary drinks tax. *Nutrients*, *12*(6), 1-18. doi:http://dx.doi.org/10.3390/nu12061878
62. Abdool Karim, S., Kruger, P., Hofman, K. (2020). Industry strategies in the parliamentary process of adopting a sugar-sweetened beverage tax in South Africa: A systematic mapping. *Globalization and Health*, *16*(1), (no pagination)116. doi:http://dx.doi.org/10.1186/s12992-020-00647-3
63. Relton, C., Crowder, M., Blake, M., Strong, M. (2020). Fresh street: The development and feasibility of a place-based subsidy for fresh fruit and vegetables. *Journal of Public Health*, *09*. doi:http://dx.doi.org/10.1093/pubmed/fdaa190
64. Cornelsen, L., Quaife, M., Lagarde, M., Smith, R. D. (2020). Framing and signalling effects of taxes on sugary drinks: A discrete choice experiment among households in Great Britain. *Health Economics (United Kingdom)*, *29*(10), 1132-1147. doi:http://dx.doi.org/10.1002/hec.4123
65. Hua, S. V., Uzwiak, B., Hudgins, A., et al. (2021). A qualitative study on retailer experiences with Philadelphia's sweetened beverage tax. *Translational Behavioral Medicine*, *04*. doi:http://dx.doi.org/10.1093/tbm/ibab111
66. Ponce, J., Yuan, H., Schillinger, D., et al. (2020). Retailer perspectives on sugar-sweetened beverage taxes in the California Bay area. *Preventive Medicine Reports*, *19* (no pagination)101129. doi:http://dx.doi.org/10.1016/j.pmedr.2020.101129
67. Krieger, J., Magee, K., Hennings, T., Schoof, J., Madsen, K. A. (2021). How sugar-sweetened beverage tax revenues are being used in the United States. *Preventive Medicine Reports*, *23* (no pagination)101388. doi:http://dx.doi.org/10.1016/j.pmedr.2021.101388
68. Yazzie, D., Tallis, K., Curley, C., et al. (2020). The Navajo Nation healthy dine nation act: A two percent tax on foods of minimal-to-no nutritious value, 2015-2019. *Preventing Chronic Disease*, *17*, E100. doi:http://dx.doi.org/10.5888/pcd17.200038
69. Marinello, S., Leider, J., Powell, L. M. (2021). Employment impacts of the San Francisco sugar-sweetened beverage tax 2 years after implementation. *PLoS ONE*, *16*(6 June), (no pagination) e0252094. doi:http://dx.doi.org/10.1371/journal.pone.0252094
70. Pomeranz, J. L., Huang, Y., Mozaffarian, D., Micha, R. (2020). Legal feasibility and implementation of federal strategies for a national retail-based fruit and vegetable subsidy program in the United States. *Milbank Quarterly*, *98*(3), 775-801. doi:http://dx.doi.org/10.1111/1468-0009.12461

71. Bombak, A. E., Colotti, T. E., Raji, D., Riediger, N. D. (2021). Exploring attitudes toward taxation of sugar-sweetened beverages in rural Michigan. *Journal of Health, Population, and Nutrition*, *40*(1), 36. doi:http://dx.doi.org/10.1186/s41043-021-00259-6
72. Altman, E. A., Madsen, K. A., Schmidt, L. A. (2021). Missed opportunities: The need to promote public knowledge and awareness of sugar-sweetened beverage taxes. *International Journal of Environmental Research and Public Health*,*18*(9), (no pagination) 4607. doi:http://dx.doi.org/10.3390/ijerph18094607
73. Marinello, S., Leider, J., Pugach, O., Powell, L. M. (2021). The impact of the Philadelphia beverage tax on employment: A synthetic control analysis. *Economics and Human Biology*, *40* (no pagination) 100939. doi:http://dx.doi.org/10.1016/j.ehb.2020.100939
74. Knox, M. A., Oddo, V. M., Walkinshaw, L. P., Jones-Smith, J. (2020). Is the public sweet on sugary beverages? Social desirability bias and sweetened beverage taxes. *Economics and Human Biology*, *38* (no pagination) 100886. doi:http://dx.doi.org/10.1016/j.ehb.2020.100886
75. Marriott, R. W., Dillard, J. P. (2021). Sweet talk for voters: A survey of persuasive messaging in ten U. S. sugar-sweetened beverage tax referendums. *Critical Public Health*, *31*(4), 477-486. doi:http://dx.doi.org/10.1080/09581596.2020.1724263
76. Falbe, J., Grummon, A. H., Rojas, N., Ryan-Ibarra, S., Silver, L. D., Madsen, K. A. (2020). Implementation of the first US sugar-sweetened beverage tax in Berkeley, CA, 2015-2019. *American Journal of Public Health*, *110*(9), 1429-1437. doi:http://dx.doi.org/10.2105/AJPH.2020.305795
77. Elstein, J. G., Lowery, C. M., Sangoi, P., et al.(2021). Analysis of public testimony about Philadelphia's sweetened beverage tax. *American Journal of Preventive Medicine*. doi:http://dx.doi.org/10.1016/j.amepre.2021.08.023
78. Cullerton, K., Donnet, T., Lee, A., Gallegos, D. (2016). Playing the policy game: A review of the barriers to and enablers of nutrition policy change. *Public Health Nutrition*, *19*(14), 2643-53. doi:10.1017/s1368980016000677
79. Daniels, J. (n.d.). *California soda tax bill shelved, in reprieve for beverage industry*. cnbc.com. Accessed January 8, 2022. https://www.cnbc.com/2019/04/22/california-soda-tax-bill-shelved-in-reprieve-for-beverage-industry.html
80. White, J. B. (n.d.). *Is big soda winning the soft drink wars?* Politico.com. Accessed January 8, 2022. https://www.politico.com/agenda/story/2019/08/13/soda-tax-california-public-health-000940/
81. Sisnowski, J., Street, J. M., Merlin, T. (2017). Improving food environments and tackling obesity: A realist systematic review of the policy success of regulatory interventions targeting population nutrition. *PLoS ONE*, *12*(8), e0182581.
82. Moodie, A. R. What public health practitioners need to know about unhealthy industry tactics. (2017). *American Journal of Public Health*, *107*(7), 1047-1049. doi:10.2105/AJPH.2017.303861
83. McKee, M., Stuckler, D. (2018). Revisiting the corporate and commercial determinants of health. *American Journal of Public Health*, *108*(9), 1167-1170. doi:10.2105/ajph.2018.304510
84. Pfinder, M., Heise, T. L., Boon, M. H., et al. (2020). Taxation of unprocessed sugar or sugar-added foods for reducing their consumption and preventing obesity or other adverse health outcomes. Review. *Cochrane Database of Systematic Reviews*. *2020*(4), 74. Cd012333. doi:10.1002/14651858.CD012333.pub2
85. Lhachimi, S.K., Pega, F., Heise, T. L., et al. (2020). Taxation of the fat content of foods for reducing their consumption and preventing obesity or other adverse health outcomes. *Cochrane Database of Systematic Reviews*, *2020*(9). doi:10.1002/14651858.CD012415.pub2
86. Teng, A. M., Genc, M., Herman, J., Signal, L., Areai, D., Wilson, N. (2021). Impact of sugar-sweetened beverage taxes on price, import and sale volumes in an island: Interrupted time series analysis. *Public Health Nutrition*, *24*(7), 1828-1835. doi:http://dx.doi.org/10.1017/S1368980021000185
87. Aguilar, A., Gutierrez, E., Seira, E. (2021). The effectiveness of sin food taxes: Evidence from Mexico. *Journal of Health Economics*, *77*, 102455. doi:https://doi.org/10.1016/j.jhealeco.2021.102455

88. World Bank. (2020). *Taxes on sugar-sweetened beverages: International evidence and experiences*.
89. Finaret, A. B., Masters, W. A. (2019). Beyond calories: The new economics of nutrition. *Annual Review of Resource Economics*, *11*(1), 237-259. doi:10.1146/annurev-resource-100518-094053
90. Brownell, K. D., Farley, T., Willett, W. C., et al. (2009). The public health and economic benefits of taxing sugar-sweetened beverages. *The New England Journal of Medicine*, *361*(16), 1599-1605. doi:10.1056/NEJMhpr0905723
91. Powell, L. M., Chaloupka, F. J. (2009). Food prices and obesity: Evidence and policy implications for taxes and subsidies. *Milbank Quarterly*, *87*(1), 229-257.
92. Mytton, O. T., Clarke, D., Rayner, M. (2012). Taxing unhealthy food and drinks to improve health. *BMJ : British Medical Journal*, *344*, e2931. doi:10.1136/bmj.e2931
93. Falbe, J. (2020). The ethics of excise taxes on sugar-sweetened beverages. *Physiology and Behavior*, *225* (no pagination) 113105. doi:http://dx.doi.org/10.1016/j.physbeh.2020.113105
94. McGill, R., Anwar, E., Orton, L., et al. (2015). Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. Review. *BMC Public Health*, *15*, 457.
95. Jain, V., Crosby, L., Baker, P., Chalkidou, K. (2020). Distributional equity as a consideration in economic and modelling evaluations of health taxes: A systematic review. *Health Policy*, *124*(9), 919-931.
96. Bollyky, T.J., Hulland, E. N., Barber, R. M., et al. (2021). Pandemic preparedness and COVID-19: An exploratory analysis of infection and fatality rates, and contextual factors associated with preparedness in 177 countries, from Jan 1, 2020, to Sept 30, 2021. *The Lancet*. doi:10.1016/S0140-6736(22)00172-6
97. Cawley, J., Frisvold, D., Hill, A., Jones, D. (2020). Oakland's sugar-sweetened beverage tax: Impacts on prices, purchases and consumption by adults and children. *Economics and Human Biology*, *37* (no pagination) 100865. doi:http://dx.doi.org/10.1016/j.ehb.2020.100865
98. Powell, L. M., Leider, J., Leger, P. T. (2020). The impact of a sweetened beverage tax on beverage volume sold in Cook County, Illinois, and its border area. *Annals of Internal Medicine*, *172*(6), 390-397. doi:http://dx.doi.org/10.7326/M19-2961
99. Thow, A. M., Downs, S. M., Mayes, C., Trevena, H., Waqanivalu, T., Cawley, J. (2018). Fiscal policy to improve diets and prevent noncommunicable diseases: From recommendations to action. *Bull World Health Organization*, *96*(3), 201-210. doi:10.2471/BLT.17.195982
100. Farhi, E., Gabaix, X. (2020). Optimal taxation with behavioral agents. *American Economic Review*, *110*(1), 298-336.
101. Heery, E., Delaney, M., Kelleher, C., Wall, P., McCarthy, M. (2014). *Attitudes of the Irish public towards policies to address obesity*. https://www.safefood.net/research-reports/public-attitude-obesity-policies
102. Petticrew, M., Knai, C., Thomas, J., et al. (2019). Implications of a complexity perspective for systematic reviews and guideline development in health decision making. *BMJ Global Health.*, *4*(Suppl 1).
103. Moran, A. J., Gu, Y., Clynes, S., Goheer, A., Roberto, C. A., Palmer, A. (2020). Associations between governmental policies to improve the nutritional quality of supermarket purchases and individual, retailer, and community health outcomes: An integrative review. Review. *International Journal of Environmental Research and Public Health*, *17*(20), 1-23.
104. Gittelsohn, J., Trude, A. C. B., Kim, H. (2017). Pricing strategies to encourage availability, purchase, and consumption of healthy foods and beverages: A systematic review. Review. *Preventing Chronic Disease*, *14*, E107.
105. Phulkerd, S., Lawrence, M., Vandevijvere, S., Sacks, G., Worsley, A., Tangcharoensathien, V. (2016). A review of methods and tools to assess the implementation of government policies to create healthy food environments for preventing obesity and diet-related non-communicable diseases. Review. Systematic review. *Implementation Science*, *11*, 15. doi:https://dx.doi.org/10.1186/s13012-016-0379-5

106. Caraher, M., Cowburn, G. (2005). Taxing food: Implications for public health nutrition. Meta-analysis review. *Public Health Nutrition*, *8*(8)1242-9.

Appendices

Appendix 3.1: PROSPERO umbrella review protocol (CRD42021274454)

Review Title

A systematic review (overview) of systematic reviews of the evidence of public and political acceptability of fiscal and pricing measures applied to food and non-alcoholic beverages intended to improve diet.

Anticipated Start date

01 June 2021

Anticipated completion date

31 October 2021

Stage of review at time of PROSPERO submission

Started

Named Contact

Dr. Luke Barry, l.barry@qub.ac.uk

Organisational Affiliation of the review

Centre for Public Health, Queen's University Belfast, University Rd., Belfast BT7 1NN, Northern Ireland.

Review Team members and their organisational affiliations

- Prof. Ciaran O'Neill, Queen's University Belfast
- Prof. Jayne Woodside, Queen's University Belfast
- Prof. John Cawley, Cornell University
- Prof. Mike Clarke, Queen's University Belfast
- Prof. Frank Kee, Queen's University Belfast

Funding Sources

The Food Safety Promotion Board (*safe*food) [Project Ref: 02A-2020].

Conflicts of Interest

The reviewers declare that they have no known conflict of interest

Collaborators

- Dr. Edel Doherty, National University of Ireland, Galway
- Prof. Jim Duggan, National University of Ireland, Galway
- Dr. Grainne Crealey, National University of Ireland, Galway

Review Question

What is the evidence of public and political acceptability of fiscal and pricing measures applied to food and non-alcoholic beverages intended to improve diet?

Searches

We will search for eligible systematic reviews published since 1 January 1990. The resources searched will include PubMed, MedLine, Web of Science, Scopus, Psycinfo, SCI, SSCI, Google Scholar, EconLit and EMBASE. We will also search repositories of reviews (epistemonikos for published reviews and PROSPERO for registered reviews) and the Cochrane and Campbell Libraries. We will contact relevant individuals working in this field (including those in academia, policy and government), and authors of relevant reports and publications to ask for information on potentially eligible reviews, reports or contacts that might support the overview. Search methods will be developed to include only systematic reviews, this will involve restriction of searches to include "systematic review" or "meta-analysis" in the title, abstract or keywords, as well as using specific features of some search engines to focus only on systematic reviews while optimising balance between sensitivity and specificity (8-10). The full search strategy will be documented in our review.

Search strategy

We will use already identified reviews (1, 2) and expert opinion to build a list of topic-related search terms, which we will use alongside terms and filters for systematic reviews and meta-analyses, as applicable to the resource being searched.

Condition or domain being studied

This overview will focus on the public and political acceptability of fiscal and other pricing policies applied to food and non-alcoholic beverages intended to improve diet and reduce diet-related NCDs. The health outcomes cover those linked to excessive or imbalanced intake of nutrients leading to diet-related NCDs (e.g. Type 2 diabetes, cancer, dental caries and cardiovascular disease), excess weight, or pregnancy-related outcomes, such as gestational diabetes or macrosomia (3). We will also consider intermediate impacts such as expenditure on, or consumption of, specific nutrients (including sugar, fats, fibre and salt) and energy-dense foods and non-alcoholic drinks, as well as product reformulation by manufacturers. Included reviews do not have to examine the effect of such policies but must give consideration to the public and/or political acceptability of such policies according to the inclusion/exclusion criteria outlined below and informed by the WHO-INTEGRATE framework (4).

Participants/Population

All populations will be eligible for inclusion. The population examined as part of each systematic review will be documented as part of data extraction. Any population subgroups, which are reported in the review according to PROGRESS-Plus characteristics (5, 6), and outcomes for these subgroups will also be examined.

Intervention/Exposure

National, regional or local fiscal or pricing policies, such as taxes or subsidies, which target the intermediate, e.g. reformulation or consumer behaviour, or tertiary outcomes, e.g. diet-related NCD's, described above.

Comparator/Control

As this is a study of fiscal and pricing policies targeting diet or risk of NCD at a population level there may be few randomised controlled trials included in the eligible systematic reviews. Selected reviews are likely to include such studies of populations which lack a comparator however no exclusions will be made on this basis.

Type of studies to be included

'Systematic reviews of studies that examined the public and political acceptability, for example lobbying activity or legislative amendments or repeals by politicians, of fiscal and pricing policies targeting the conditions/domains described above. We will include those findings relating to experimental or observational studies, both quantitative and qualitative, which examine acceptability in relation to an implemented government policy or one proposed by government which targets the price of a good.

An overview is underway (CRD42021249212) to assess the effectiveness of such policies as well as their potential distributional impacts. The overview described in this entry will focus on the other WHO-INTEGRATE framework criteria (4) by including studies which address 'human rights and sociocultural acceptability', 'societal implications', 'financial and economic considerations' and 'feasability and health system considerations' of such interventions as well as considering the 'quality of evidence' and 'health equity, equality and non-discrimination' in relation to such criteria.'

Context

No restrictions will be placed on the context of the research provided the review includes the relevant Population (P), Intervention (I), Comparators (C) (where available) and Outcomes (O) or domains described above.

Main outcome(s)

- Human rights and sociocultural acceptability (e.g. Impacts on autonomy of stakeholders reflected in opinion polls, lobbying activity, overturning of a policy or legislative amendments)
- Societal implications (e.g. Environmental impacts from changes in the demand for food)
- Financial and economic considerations (e.g. Employment impacts from the introduction of a tax)
- Feasibility and health system considerations (e.g. Impacts on the healthcare sector from a reduction in the prevalence of diet-related NCD's)
- Health equity, equality and non-discrimination (This may intersect with any of the above criteria, e.g. the distribution of employment generation or the impact on hospitals in communities which see disproportionate changes in the prevalence of diet-related NCDs)

Data extraction (selection and coding)

Study Selection

Titles identified in our searches will be screened independently by two reviewers (LB & CON), and the abstracts of those judged to be potentially eligible will be checked by the same two reviewers. Where disagreements exist, these will be resolved by discussion and if necessary following reference to a third reviewer (FK or MC). All articles deemed potentially eligible will be retrieved for full text assessment. Full text articles will be screened independently by two reviewers (LB & CON). Disagreements will be resolved by discussion and if necessary, by reference to a third reviewer (FK or MC). References will be collated, duplicates removed, and titles and abstracts screened using EndNote 20 software.

Data Extraction

Data will be extracted independently by two reviewers (LB & CON) and will include design features: aims, methods, eligibility criteria and search strategy, date, funding sources, setting, participants, intervention (and comparator where available), outcomes examined and reported (according to 'main outcome(s)' above), and any sub-group analyses related to specific groups of participants. A Google Form will be developed based on the list of data to be extracted. Once complete, the meta-data will be used to generate separate spreadsheets of extracted data for each reviewer, which will be compared and any disagreements will resolved by discussion and where necessary by reference to a third reviewer (FK or MC).

Risk of Bias

The methodological quality of each systematic review will be independently assessed by two reviewers (LB & CON) using the AMSTAR 2 tool (7). Disagreements will be resolved by discussion

and where necessary by reference to a third reviewer (FK or MC) . Studies which receive a critically low score according to AMSTAR 2 will be excluded from the final review but will be listed for transparency.

Strategy for data synthesis

A narrative synthesis is planned which will assess the potential contribution of fiscal and pricing policies targeting diet-related NCDs according to the WHO-INTEGRATE criteria listed under 'main outcome(s)'. Data will be extracted from the included reviews into a Microsoft Excel spreadsheet and an examination of the data for narrative synthesis will be conducted (8, 9), for example to produce summary tables of the scope of included reviews and their results or graphical analysis using harvest plots.

As fiscal and other pricing measures may have been adopted as part of more complex interventions, the assessment of reviews will explicitly address the approaches used for data synthesis of complex interventions. This will include an examination of stated purpose of the synthesis, heterogeneity in the studies from which data were synthesised, level of detail about a study provided in the review, nature of the results reported and the resources available to the research team engaged in the review. The intervention will be detailed in terms of the nature of tax or subsidy, minimum price etc.; what this is levied on, and, using the main outcomes above, the extent to which this intervention contributed to each or any of these.

Analysis of Subgroups

Any reporting of effects relating to the main outcomes according to subgroups will also be documented. If, as expected, we need to present this overview as a narrative synthesis, these will be reported discursively.

Type and method of review

Type of review

Intervention

Narrative Synthesis

Review of reviews

Systematic review

Health area of review

Public Health

Language

English

Country

United Kingdom – Northern Ireland

References

1. Wright A, Smith KE, Hellowell M. Policy lessons from health taxes: a systematic review of empirical studies. BMC Public Health. 2017;17(1):1-14.
2. Eykelenboom M, van Stralen MM, Olthof MR, Schoonmade LJ, Steenhuis IH, Renders CM. Political and public acceptability of a sugar-sweetened beverages tax: A mixed-method systematic review and meta-analysis. The International Journal of Behavioral Nutrition and Physical Activity Vol 16 2019, ArtID 78. 2019;16.
3. Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R, et al. Transforming the food system to fight non-communicable diseases. BMJ. 2019;364:l296.
4. Rehfuess EA, Stratil JM, Scheel IB, Portela A, Norris SL, Baltussen R. The WHO-INTEGRATE evidence to decision framework version 1.0: integrating WHO norms and values and a complexity perspective. BMJ Global Health. 2019;4(Suppl 1):e000844.
5. O'Neill J, Tabish H, Welch V, Petticrew M, Pottie K, Clarke M, et al. Applying an equity lens to interventions: using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. Journal of Clinical Epidemiology. 2014;67(1):56-64.
6. Oliver S, Kavanagh J, Caird J, Lorenc T, Oliver K, Harden A, et al. Health promotion, inequalities and young people's health: a systematic review of research. 2008.
7. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358:j4008.
8. Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, et al. Guidance on the conduct of narrative synthesis in systematic reviews. A product from the ESRC methods programme Version. 2006;1:b92.
9. Wong G, Greenhalgh T, Westhorp G, Buckingham J, Pawson R. RAMESES publication standards: meta-narrative reviews. BMC Medicine. 2013;11(1):20.

Appendix 3.2: Search used across databases according to key themes

Study type	AND	Intervention	AND		Outcome
Systematic review*		Tax*		Nutrient*	obesity
Meta-analys?s		Subsid*		Nutrition	overweight
		Levy		Energy	Diet*
		Levies		Food*	BMI
		Price		healthy eating	body mass
		demand		Vegetable*	body weight
		Elastic*		Fruit*	non-alcoholic
		fiscal		non-communicable disease*	Drink*
		pricing		Cancer*	Calori*
		supply		cardiovascular disease*	Sweeten*
				Isch?emic heart disease*	caries
				Hypertensi*	DMFT
				Diabet*	DMFS
				Sugar*	carious surface
				fat*	Expen*
				Sodium	Consum*
				Salt*	Purchas*
				SSB	Reformulate*
				Beverage*	

Note: ‘*’ represents truncation as part of the search strategy; ‘?’ represents a wildcard for word spellings. Different terms were used depending on the search engine.

Appendix 3.3: Quality rating using AMSTAR2 checklist (Studies with two or more critical domain flaws receive a critically low rating)

	CRITICAL DOMAINS ITEMS								NON-CRITICAL DOMAINS ITEMS										
Author and publication year	Item 2	4	7	9	11	13	15	No. "N" for critical domains	Item 1	3	5	6	8	10	12	14	16	No. "N" for non-critical domains	Quality rating
Clarke et al 2016	N	N	N	N	N/A	Y	N/A	4	PY	N	N	N	PY	N	N/A	Y	Y	4	CL
Eykelenboom et al 2019	Y	N	N	PY	Y	Y	N	3	PY	N	Y	Y	PY	N	Y	Y	Y	2	CL
Mounsey et al 2020	PY	N	N	PY	N/A	Y	N/A	2	PY	N	Y	Y	PY	Y	N/A	Y	Y	1	CL
Dodd et al 2020	PY	Y	N	PY	N/A	N	N/A	2	N	Y	Y	Y	N	N	N/A	Y	Y	3	CL
Gittelsohn et al 2020	N	N	N	N	N/A	Y	N/A	4	Y	N	Y	Y	PY	N	N/A	Y	Y	2	CL
Moran et al 2020	N	N	N	N	N/A	N	N/A	5	PY	Y	Y	Y	PY	N	N/A	Y	Y	1	CL
Niebylski et al 2015	N	N	N	PY	N/A	Y	N/A	3	PY	Y	N	N	N	N	N/A	Y	N	5	CL
Wright et al 2017	N	N	N	N	N/A	N	N/A	5	N	Y	Y	Y	N	N	N/A	Y	Y	3	CL

Phulkerd et al 2016	N	N	N	N	N/A	Y	N/A	4	PY	N	N	N	PY	N	N/A	Y	Y	4	CL
Diepeveen et al 2013	N	N	N	N	N/A	Y	N/A	4	PY	N	N	N	PY	Y	N/A	Y	Y	3	CL
Caraher et al 2005	N	N	N	N	N/A	Y	N/A	4	N	N	N	N	N	N	N/A	Y	Y	6	CL
	8	10	11	7	0	3	1		3	7	5	5	4	9	0	0	1		

Highlighted reviews are those that had 2-3 critical domain flaws and were included in our review.

Appendix 3.4: EMBASE search strategy for identification of primary studies examining the acceptability of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease, conducted between January 2020 and November 2021

1	Systematic Review/
2	systematic review$.ab,kw,ti.
3	Meta-Analysis/
4	meta-analys?s.ab,kw,ti.
5	(tax$ or subsid$ or levy or levies or price or pricing or demand or supply or elastic$ or fiscal).ab,kw,ti.
6	(nutrient$ or energy or food$ or "healthy eating" or vegetable$ or "fruit$" or "non-communicable disease$" or cancer$ or "cardiovascular disease$" or "isch?emic heart disease$" or hypertensi$ or diabet$ or sugar$ or fat$ or sodium or salt$ or SSB or beverage$ or obesity or overweight or diet$ or BMI or "body mass" or "body weight" or "non-alcoholic" or drink$ or calori$ or sweeten$ or caries or DMFT or DMFS or "carious surface" or expen$ or consum$ or purchas$ or reformulat$).ab,kw,ti.
7	Taxes/
8	Fiscal Policy/
9	Nutrients/
10	Energy Drinks/ or Energy Intake/
11	Food/ or "Diet, Food, and Nutrition"/ or Food, Formulated/
12	Diet, Healthy/
13	Vegetables/
14	Fruit/
15	Noncommunicable Diseases/
16	Neoplasms/
17	Cardiovascular Diseases/
18	Coronary Disease/ or Heart Failure/ or Myocardial Ischemia/
19	Hypertension/
20	Diabetes Mellitus, Type 2/ or Diabetes Mellitus/
21	Sugars/
22	Dietary Fats, Unsaturated/ or Dietary Fats/ or Fats, Unsaturated/ or Fats/
23	Sodium/ or Sodium Chloride/ or Sodium, Dietary/ or Sodium Chloride, Dietary/
24	Salts/
25	Sweetening Agents/ or Beverages/ or Dietary Sucrose/ or Sugar-Sweetened Beverages/

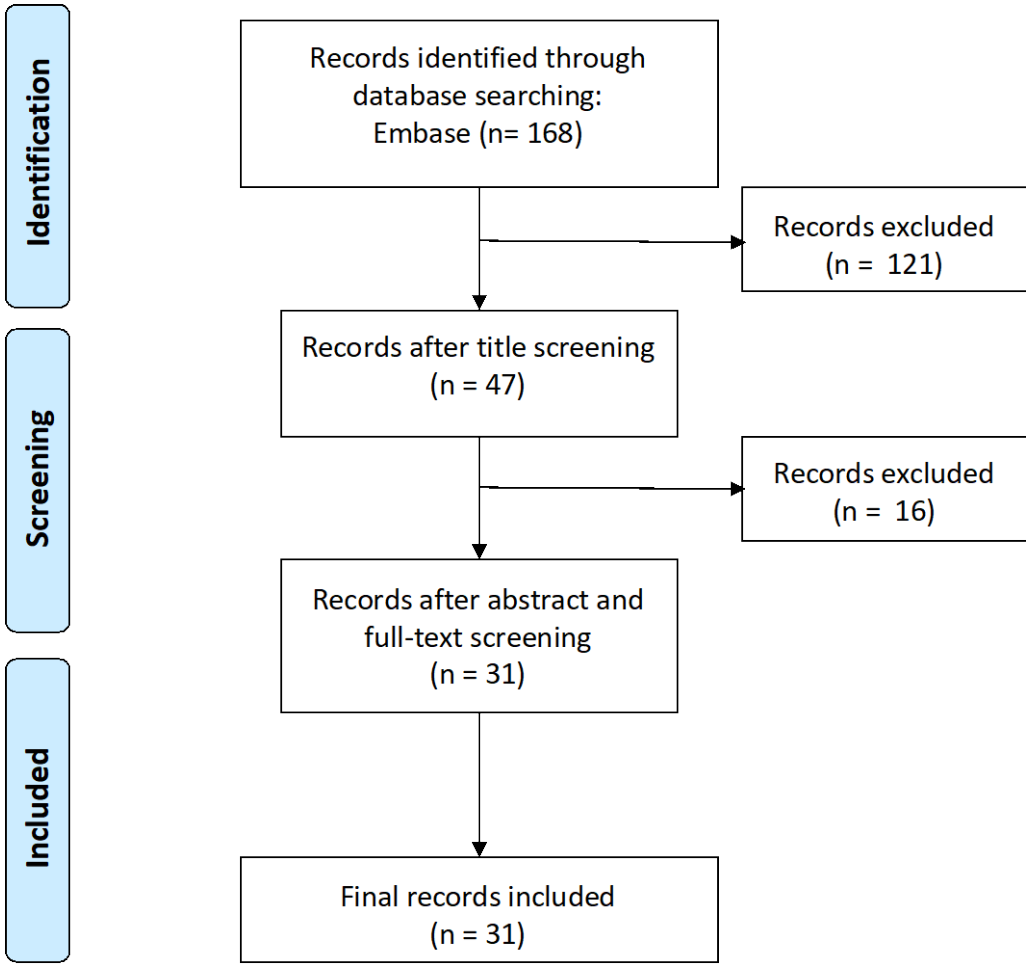
26	Obesity/
27	Overweight/ or Adipose Tissue/ or Body Weight/
28	Diet/
29	Body Mass Index/
30	Sucrose/ or Sweetening Agents/ or Dietary Carbohydrates/
31	Dental Caries Susceptibility/ or Dental Caries/
32	DMF Index/ or Oral Health/
33	Economics/
34	Consumer Behavior/
35	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 34
36	6 or 35
37	5 or 7 or 8 or 33
38	1 or 2 or 3 or 4
39	36 and 37
40	39 not 38
41	("tax" or "taxing" or "taxation" or "taxes").m_titl.
42	("subsidy" or "subsidi#ation" or "subsidi#e" or "subsidi#ed" or "subsidies").m_titl.
43	41 or 42
44	40 and 43
45	limit 44 to human
46	limit 45 to yr="2020 -Current"
47	limit 46 to ((article or article in press) and journal)
48	tobacco consumption/ or tobacco smoke/ or "tobacco use"/ or tobacco/ or tobacco snuff/ or smokeless tobacco/ or tobacco dependence/ or chewing tobacco/ or tobacco.mp. or dipping tobacco/ or tobacco industry/
49	47 not 48
50	alcohol psychosis/ or alcohol blood level/ or alcohol intoxication/ or alcohol liver disease/ or alcohol abuse/ or alcohol tolerance/ or alcohol liver cirrhosis/ or alcohol consumption/ or alcohol abstinence/ or alcohol/ or alcohol.mp.
51	49 not 50
52	limit 51 to english language

Appendix 3.5: Matrix of databases searched and which of these indexed the 25 potentially relevant systematic reviews identified following screening

Author/year	MedLine	EMBASE	PsychInfo	Web of Science	Scopus	EconLit	Cochrane Library	Epistemonikos	Campbell Library	Google Scholar	Reference list search
Moran et al, 2020 [103]	-	X	-	-	X	-	-	-	-	-	-
Niebylski et al, 2015 [49]	X	X	-	X	X	-	-	X	-	-	-
Mounsey et al, 2020 [50]	X	X	-	X	X	-	-	X	-	-	-
Wright et al, 2017 [34]	X	X	-	X	X	-	-	X	-	-	-
Eykelenboom et al, 2019 [33]	X	X	X	X	X	-	-	X	-	X	-
Gittelsohn et al, 2017 [104]	X	X	-	X	X	-	-	X	-	-	-
Phulkerd et al, 2016 [105]	X	-	-	-	-	-	-	-	-	X	-
Caraher et al, 2005 [106]	X	-	-	-	-	-	-	-	-	X	-
Dodd et al, 2020 [51]	X	X	-	X	X	-	-	X	-	-	-
Diepeveen et al, 2013 [47]	-	-	-	-	-	-	-	-	-	-	X
Clarke et al, 2016 [48]	-	-	-	-	-	-	-	-	-	X	-
No. referenced	8	7	1	6	7	0	0	6	0	4	1
% referenced	73%	64%	9%	55%	64%	0%	0%	55%	0%	36%	9%

Note: Indexed reviews are marked with an 'X'

Appendix 3.6: PRISMA flow diagram for identification of primary studies examining the acceptability of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease which were indexed in EMBASE and conducted between January 2020 and November 2021



Appendix 3.7: Literature review results of primary studies examining the acceptability of taxes or subsidies on food and non-alcoholic beverages in improving diet and preventing diet-related non-communicable disease; these studies were indexed in EMBASE and conducted between January 2020 and November 2021

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
A qualitative study on retailer experiences with Philadelphia's sweetened beverage tax	2021	Retailers in Philadelphia interviewed before (n=15) and after (n=11) the tax was implemented	Tax on sugar- and artificially-sweetened beverages	Retailers' reactions to beverage taxes	Philadelphia, PA	Semi-structured interviews with retailers before and after introduction of the tax (implemented on January 1, 2017)	Beliefs that: transparency regarding the allocation of tax revenues is lacking; a tax would affect business negatively; it would be confusing to implement; and it would be regressive	Human rights and sociocultural acceptability; health equity, equality and non-discrimination; feasibility and health system considerations; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Public acceptability of a sugar-sweetened beverage tax and its associated factors in the Netherlands	2021	Dutch adults aged >=18 years representative of the Dutch population for age, sex, education level and location (n=500)	SSB tax	Acceptability of an SSB tax	The Netherlands	Online self-administered questionnaire	Lack of support (40% supported vs 43% opposed) for an SSB tax in general however there was support for an SSB tax when revenue is allocated towards health initiatives (55% supported vs 32% opposed). Effectiveness, appropriateness, socioeconomic and economic benefit, implementation and trust were all significant factors affecting acceptability of an SSB tax. Additionally support decreased among households with adolescents and individuals who had less education, were high/moderate consumers of SSBs or were overweight.	Human rights and sociocultural acceptability; health equity, equality and non-discrimination; feasibility and health system considerations; balance of health benefits and harms; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Attitudes and perceptions among urban South Africans towards sugar-sweetened beverages and taxation	2020	Adults aged 18 years or above living in Soweto (n=57)	SSB tax (known as the Health Promotion Levy)	Perceptions and attitudes on South Africa's use of a tax to reduce SSB consumption	Soweto, Johannesburg, South Africa	Six focus group discussions using a semi-structured guide conducted 3 months before South Africa's SSB tax was implemented	Mixed beliefs as to whether an SSB tax would change SSB consumption and also mistrust as to governments' stated intention of improving health. These beliefs did not vary across age, sex or obesity status.	Human rights and sociocultural acceptability; balance of health benefits and harms
Knowledge, attitudes and practices with regard to sugar-sweetened	2021	People with type 2 diabetes (T2D) attending public sector primary care clinics	SSB tax	Knowledge, attitudes and practices towards SSB	Barbados	A survey, including the Beverage Intake Questionnaire (BEVQ-15), and waist circumference measurement	Lack of support for an SSB tax (44.7% favoured the current 10% tax and 29.7% favoured a 20% tax). These responses did not vary by neighbourhood income.	Human rights and sociocultural acceptability

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
beverages and taxation among people with type 2 diabetes mellitus in the Caribbean island of Barbados - A cross sectional survey in primary care				consumption and taxation				

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Retailer perspectives on sugar-sweetened beverage taxes in the California Bay Area	2020	103 randomly selected retailers (50 corner and liquor stores; 28 chain convenience, drug, and mass-merchandise stores; 18 chain supermarkets and discount supermarkets; and 7 independent supermarkets)	SSB tax	Retailers' perceptions of SSB	Berkeley, Oakland, and San Francisco	Semi-structured interviews (including open- and closed-ended questions) occurred in 2018 and 2019 (approximately 3 years, 1 year and 6 months post tax-implementation, respectively).	Lack of evidence that an SSB tax affects retailers negatively and support (53%) for an expansion of an SSB tax nationwide	Human rights and sociocultural acceptability; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
How sugar-sweetened beverage tax revenues are being used in the United States	2021	General population from seven US cities with SSB taxes	SSB tax	Tax revenue and allocation	Albany, Berkeley, Boulder, Oakland, Philadelphia, San Francisco and Seattle	Information collected from public documents and key informants about allocations in the most recent fiscal year (2018-2021)	Evidence that the allocation of revenues raised from SSB taxation was consistent with government intentions, such as supporting health and equality initiatives.	Human rights and sociocultural acceptability; health equity, equality and non-discrimination; feasibility and health system considerations; financial and economic considerations
The Navajo Nation Healthy Dine Nation	2020	General population from a sovereign	2% tax on foods of minimal	Tax revenue and allocation	The Navajo Nation	Summarisation of tax revenue and disbursements from 2015-2019 from the	Evidence that taxes on unhealthy foods are revenue raising with decreases in revenue over-time	Financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Act: A Two Percent Tax on Foods of Minimal-to-No Nutritious Value, 2015-2019		tribal nation in the US	-to-no nutritional value (junk food tax)			Navajo Nation Healthy Dine Nation Act of 2014		
Employment impacts of the San Francisco sugar-sweetened beverage tax 2 years after implementation	2021	San Francisco overall economy, private sector, supermarkets and other grocery stores, convenience stores, limited service restaurants,	SSB tax	Employment	San Francisco, CA	A synthetic control analysis using monthly employment counts from the Bureau of Labour Statistics to analyse employment levels 5 years before (January 2013) and leading up to 2 years after (December 2019) tax implementation on	Lack of evidence that an SSB tax has a negative effect on employment in SSB-related industries and in general	Societal implications; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
		and beverage manufacturing				1 January 2018 for San Francisco vs synthetic controls (i.e., estimated counterfactuals) taken from a pool of urban control counties using pre-tax labour market-related characteristics		
Results of a mass media campaign in South Africa to promote a sugary drinks tax	2020	Adults ages 18 to 56 years old interviewed before (n-1000) and after (n=1000) the campaign	Mass media campaign to promote a sugary drinks tax	Knowledge and attitudes around sugary drinks and on public support for a proposed	South Africa	A representative cross-sectional survey of households interviewed just prior to the launch of the campaign (October 7-10, 2016) and immediately following its conclusion (July 12-21, 2017)	Evidence that media campaigns can be effective in generating support for sugary drink taxation by educating the public on the health harms of sugary drink consumption	Human rights and sociocultural acceptability; Balance of health benefits and harms

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
				tax on sugary drinks				
Legal feasibility and implementation of federal strategies for a national retail-based fruit and vegetable subsidy program in	2020	Existing federal, state, local and non-governmental organization (NGO) policies and programs that subsidise F&Vs	A national retail-based F&V subsidy program	Mechanisms to effectuate a national retail-based F&V subsidy program	USA	A legal and policy research using LexisNexis, the UConn Rudd Center Legislation Database, the Centers for Disease Control and Prevention Chronic Disease State Policy Tracking System, the US Department of Agriculture's website, Congress.gov, grey	Evidence that national F&V subsidisation would be feasible within current legal structures and would be most feasible as a voluntary program for states	Feasibility and health system considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
the United States						literature, and government reports		
Fresh street: the development and feasibility of a place-based, subsidy for fresh fruit and vegetables	2020	Area of socioeconomic deprivation	Vouchers available to every household, regardless of income or household type, and	Feasibility of the scheme	Northern England	The feasibility of the scheme was assessed in four streets using rapid ethnographic assessment and voucher redemption information.	Support for local F&V subsidisation schemes	Human rights and sociocultural acceptability; health equity, equality and non-discrimination

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
			redeemable with local suppliers of fresh FV (not supermarkets)					
Exploring attitudes toward taxation of sugar-sweetened beverages in rural Michigan	2021	Adult Michiganders	SSB tax	Attitudes and beliefs about sugar-sweetened beverages being taxed	Rural Michigan	25 semi-structured, audio-recorded interviews analysed using critical policy analysis	Lack of support for SSB taxation by members of the public in part due to concerns about its effectiveness and equitability as well as a mistrust in government. Beliefs that the tax would be particularly ineffective among regular consumers, who were frequently perceived as mostly	Human rights and sociocultural acceptability; health equity, equality and non-discrimination; balance of health

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
							low income and/or of higher weight	benefits and harms
Missed opportunities: The need to promote public knowledge and awareness of sugar-sweetened beverage taxes	2021	General population (n = 2715)	SSB tax	Awareness and perceptions of SSB taxes and whether tax awareness and perceptions differ based on sociodemographic	Berkeley, Oakland, San Francisco and Richmond	Serial cross-sectional study intercept surveys in demographically diverse neighbourhoods conducted between 2015 and 2017	Beliefs that the benefits of SSB taxes to the community and to children's health were moderate, and varied by educational attainment.	Health equity, equality and non-discrimination; balance of health benefits and harms

Title	Year	Population	Intervention	Outcome characteristics	Setting	Design	Summary	WHO-INTEGRATE criteria
An analysis of the adoption and implementation of a sugar-sweetened beverage tax in South Africa: A multiple streams approach	2021	Institutional documents, such as policy proposals and parliamentary debate records, stakeholder submissions to Parliament and media reports	SSB tax (known as the Health Promotion Levy)	Adoption and implementation of the sugar-sweetened beverage tax in South Africa	South Africa	Qualitative data extraction and analysis of institutional documents, such as policy proposals and parliamentary debate records, stakeholder submissions to Parliament and media reports, were guided by the Kingdon Multiple Streams Theory	Evidence that the SSB tax policy process was facilitated by: strong networks and consistent messaging across stakeholders; continuity of key policymakers; and framing of taxes as revenue-raising though uncertainty regarding the purpose of the tax negatively impacted public attitudes towards it. Evidence that the SSB tax policy process was inhibited by: industry arguments related to employment impacts; and	Feasibility and health system considerations; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
							regulatory action by sectors outside of finance and health	
The politics of taxes for health: An analysis of the passage of the sugar-sweetened beverage tax in Mexico	2020	Documents from government, international organizations, and civil society groups; media articles; and key informant interviews	SSB tax	Passage of the sugar-sweetened beverage (SSB) tax in Mexico	Mexico	Primary data collection and interviews with a broad range of stakeholders	Evidence that the SSB tax policy process was facilitated by: strong networks across stakeholders and a good understanding of how to manage the political and economic context; framing of taxes as revenue-raising; and early public relations campaigns to shape public perceptions	Human rights and sociocultural acceptability; societal implications; feasibility and health system considerations; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Stakeholder views on taxation of sugar-sweetened beverages and its adoption in the Netherlands	2021	27 stakeholders from health and consumer organizations, health professional associations, trade associations, academia, advisory bodies, ministries and parliamentary parties	SSB tax	Stakeholder views on taxation of SSB and perceived barriers and facilitators to its adoption	The Netherlands	Semi-structured interviews conducted in 2019 were analysed using a thematic content approach	Mixed beliefs about the effectiveness, appropriateness and (socio)economic effects of an SSB tax. Perceived barriers were an unfavourable political context, limited advocacy for an SSB tax, a strong lobby against an SSB tax, perceived public opposition, administrative load and difficulties in defining SSB. Perceived facilitators were increasing prevalence of overweight, disappointing results from voluntary industry actions, a change of government, state budget deficits, a shift in public opinion, international recommendations and a solid legal basis.	Human rights and sociocultural acceptability; Societal implications; Feasibility and health system considerations ; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Understanding policy change for obesity prevention: learning from sugar-sweetened beverages taxes in Mexico and Chile	2021	24 key informant interviews (16 researchers, 5 civil society representatives and 3 food/beverage industry representatives)	SSB tax	The policy change process resulting in SSB taxes in Mexico and Chile	Mexico and Chile	Qualitative study design using the Kaleidoscope Model for Policy Change, a framework developed for nutrition and food policy change analysis	Evidence that the SSB tax policy process was facilitated by: strong networks across stakeholders and good communication; flexible framing of taxes; and taking advantage of windows of opportunity	Human rights and sociocultural acceptability; feasibility and health system considerations
Framing and signalling effects of taxes on sugary drinks: A discrete	2020	A randomly selected group of households (n = 603) with children in Great Britain (GB) who	SSB tax	Demand for SSBs	Great Britain	Discrete choice experiment (DCE) administered online	Evidence that an increase in the price of SSBs may be more effective in reducing consumption when it is signalled as a tax and framed as a health-related and earmarked policy	Human rights and sociocultural acceptability; feasibility and health system considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
choice experiment among households in Great Britain		regularly purchase SSBs						; balance of health benefits and harms
The political economy of sugar-sweetened beverage taxation in Latin America: lessons from Mexico, Chile and Colombia	2021	Coalitions of stakeholders including participants of civil society organizations and transnational corporations	SSB tax	The interests, goals and operations of the coalitions	Mexico, Chile and Colombia	Qualitative synthesis of existing empirical evidence. Key stakeholders involved in the policy process were identified, along with their interests and how they influenced adoption and implementation of the tax.	Evidence that the SSB tax policy process was facilitated by: strong networks and support across government stakeholders Evidence that the SSB tax policy process was inhibited by transnational industry influence and a lack of transparency during agenda setting	Feasibility and health system considerations ; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Industry strategies in the parliamentary process of adopting a sugar-sweetened beverage tax in South Africa: a systematic mapping	2020	Beverage and related industries during the public consultation phase of the process to adopt the South African SSB tax	SSB tax (known as the Health Promotion Levy)	Arguments and strategies utilised by industry during policymaking processes to oppose regulatory actions in LMIC	South Africa	To describe and analyse the arguments and strategies utilised by industry during policymaking processes to oppose regulatory actions in LMIC	Evidence that the SSB tax policy process was inhibited by: industry arguments that the tax would lead to employment losses and other economic harms; industry discussed self-regulation and voluntary measures as a form of policy substitution; misused or disputed evidence to undermine the perceived efficacy of the tax; anti-competition arguments in relation to small business vs multi-national corporations	Financial and economic considerations
The political economy of sugar-sweetened beverage taxation: an	2021	Policy content, stakeholders and corporate political activity from	SSB tax	Politico-economic factors relevant to nutrition-related	Kenya, Tanzania, Botswana, Rwanda,	A political economy framework, focusing on ideas, institutions, interests and power, and a 'bricolage' approach was	Evidence that the SSB tax policy process was facilitated by: framing of taxes as health-improving; developing positive public opinion; linking with agricultural sectors; and	Human rights and sociocultural acceptability; societal implications;

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
analysis from seven countries in sub-Saharan Africa		seven countries in east and southern Africa augmented by qualitative interviews in Botswana, Namibia, Kenya and Zambia, and stakeholder consultations in Rwanda, Tanzania and Uganda		fiscal policies, and lessons regarding strategies to strengthen sugar-sweetened beverages taxation	Namibia, Zambia, Uganda	employed to identify strategies for future action	leadership by a central government agency. Evidence that the SSB tax policy process was inhibited by industry arguments that the tax would lead to economic harm.	feasibility and health system considerations ; balance of health benefits and harms; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Strengthening prevention of nutrition-related non-communicable diseases through sugar-sweetened beverages tax in Rwanda: a policy landscape analysis	2021	Policy content and stakeholders	SSB tax	Facilitators of and barriers to strengthening taxation on SSBs	Rwanda	A desk-based policy analysis to assess the facilitators of and barriers to strengthening sugary beverage taxation policy. Eight stakeholders were consulted to validate the findings of the desk review	Evidence that the SSB tax policy process was facilitated by: the existence of excise taxes on sugar. Evidence that the SSB tax policy process was inhibited by economic reliance on the sugar industry	Feasibility and health system considerations ; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
The data availability landscape in seven sub-Saharan African countries and its role in strengthening sugar-sweetened beverage taxation	2021	The SSB taxation-related data landscape in seven sub-Saharan African countries	SSB tax	The potential role of available data in strengthening SSB taxation	Kenya, Tanzania, Botswana, Rwanda, Namibia, Zambia, Uganda	Mixed-methods approach involving a secondary data analysis of publicly available documents, and a qualitative exploration of the data needs of policy makers' using primary data	Evidence that the SSB tax policy process was inhibited by a paucity of SSB taxation-related data. Evidence that the SSB tax policy process was facilitated by timely, easily understood, concise, and locally relevant evidence with collaboration across multiple sectors	Feasibility and health system considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Barriers to, and facilitators of, the adoption of a sugar sweetened beverage tax to prevent non-communicable diseases in Namibia: a policy landscape analysis	2021	Policy content and stakeholders	SSB tax	The readiness of the Government to adopt sugar-sweetened beverage taxation policies for public health	Namibia	Government policy documents relating to nutrition-related non-communicable diseases were analysed, utilising predetermined variables based on policy theory. Thirteen key informant interviews were conducted with stakeholders from Government, non-governmental organisations and academic institutions. Data sets were analysed utilising	Evidence that the SSB tax policy process was inhibited by: a paucity of SSB taxation-related data; industry narratives and influence; or apprehensions that emanate from other sources. Evidence that the SSB tax policy process was facilitated by: strong pro-tax advocacy and messaging to support the adoption of the tax and generate public support for the intervention; education on the contribution of SSB's diet-related NCDs.	Human rights and sociocultural acceptability; feasibility and health system considerations; balance of health benefits and harms; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
						Kingdon's analytical theory for agenda setting.		
Barriers to, and facilitators of, the adoption of a sugar-sweetened beverage tax to prevent	2021	Policy content and stakeholders	SSB tax	Barriers to and facilitators of the adoption of sugar-sweetened beverage taxation	Uganda	A desk-based policy analysis of policies related to nutrition-related non-communicable diseases and sugar-sweetened beverage taxation and four key informant consultations. Analysis	Evidence that the SSB tax policy process was inhibited by: industry narratives and influence. Evidence that the SSB tax policy process was facilitated by education on the contribution of SSB's diet-related NCDs	Balance of health benefits and harms; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
non-communicable diseases in Uganda: a policy landscape analysis						was framed by Kingdon's theory of agenda setting and policy change		
The legal feasibility of adopting a sugar-sweetened beverage tax in seven sub-Saharan African countries	2021	Existing laws, laws related to impacted sectors, legal infrastructure, and processes involved in adopting laws	SSB tax	The legal feasibility of introducing or strengthening taxation laws related to	Kenya, Tanzania, Botswana, Rwanda, Namibia, Zambia, Uganda	The legal feasibility of adopting four types of sugar-sweetened beverage tax formulations in each of the seven countries was assessed using the novel FELIP framework along with a desk-based review of the	Evidence that the SSB tax policy process was facilitated by existing tax structures and nutrition labelling laws as these made it easier to adopt taxes linked to sugar content	Feasibility and health system considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
				sugar-sweetened beverages		legal system related to sugar-sweetened beverage taxation.		
The impact of the Philadelphia beverage tax on employment: A synthetic control analysis	2021	Key industries that sell sweetened beverages and the overall Philadelphia economy	SSB tax	Employment	Philadelphia, PA	A synthetic control analysis of total, private sector, limited-service restaurant, and convenience store employment drawing on monthly employment count data from the Bureau of Labor Statistics from January 2012 through June 2019	Lack of evidence that the SSB tax resulted in job losses up to two and a half years after the tax was implemented	Societal implications; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Is the public sweet on sugary beverages? Social desirability bias and sweetened beverage taxes	2020	1704 adults	SSB tax	Social desirability bias	Seattle, Minneapolis, and the D.C. metro area	A mixed-mode opinion survey of phone and web-based respondents	Support for SSB tax was 58% across phone and web-respondents. Beliefs that an SSB tax would lead to positive health and economic impacts overall which was partially influenced by social desirability bias.	human rights and sociocultural acceptability; Societal implications; balance of health benefits and harms; financial and economic considerations
Sweet talk for voters: a survey of persuasive messaging in ten U. S.	2021	Pro- and anti-tax messaging (campaign materials and local press) from all US	SSB tax referendums	Tactics used to address the public on the subject of	USA	This study gathered and analysed pro- and anti-tax messaging from all US SSB tax referendums from 2012 through 2018. The	Evidence that the SSB tax policy process was inhibited by: overt politicisation of tax debates; and anti-tax messaging which frames an SSB tax as a 'grocery tax'. Evidence that the SSB tax policy	Human rights and sociocultural acceptability; feasibility and health system

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
sugar-sweetened beverage tax referendums		SSB tax referendums		SSB taxes, and the persuasive setting of voter referendums as a whole		methods and strategies used in each campaign were identified. Common themes and arguments are distinguished and a set of decisions that appeared to heavily influence referendum outcomes are discussed.	process was facilitated by: a cohesive justification of a new tax; and associating anti-tax messaging with the SSB industry	considerations; financial and economic considerations
Implementation of the first US sugar-sweetened beverage tax in	2020	City stakeholders and SSB distributors and retailers (n=48)	SSB tax	Lessons learned from implementation of the nation's	Berkeley, CA	Semi-structured interviews were carried out from June 2015 to April 2017 with city staff, its tax administrator, SSB distributors, Berkeley	Evidence that SSB taxes are revenue raising especially for public health, nutrition, and health equity. Lack of evidence that an SSB tax functions as a 'grocery tax' as no retailers reported raising food prices.	Human rights and sociocultural acceptability; health equity, equality and non-

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Berkeley, CA, 2015-2019				first sugar-sweetened beverage (SSB) excise tax in 2015 in Berkeley, California		retailers, and SSBPPE commissioners followed by deductive and inductive analysis and coding to identify common themes was conducted in January 2019.	Evidence that the SSB tax policy process was facilitated by: thorough and timely communications with distributors and retailers; adequate lead time for implementation; advisory commissions for revenue allocations; funding of staff, communications, and evaluation before tax collection begins	discrimination ; feasibility and health system considerations ; balance of health benefits and harms; financial and economic considerations

Title	Year	Population	Intervention	Outcome	Setting	Design	Summary	WHO-INTEGRATE criteria
Analysis of public testimony about Philadelphia's sweetened beverage tax	2021	Public testimony about the beverage tax presented to the Philadelphia City Council in 2016	SSB tax	How public testimony for and against the tax was framed in a city that ultimately passed the policy	Philadelphia, PA	A content analysis of all public testimony about the beverage tax presented to the Philadelphia City Council in 2016 was conducted. Testimonies were coded for policy stance (pro-tax or anti-tax), speaker type, and specific pro-tax or antitax arguments. Quantitative data were analysed in 2018-2019 using chi-square tests.	Support for SSB taxation was 58% across testimonies. Arguments for taxation highlighted the revenue benefits for early childhood education and community infrastructure rather than the tax's potential to reduce sweetened beverage consumption and improve health. Arguments against taxation highlighted the unfairness of targeting a single industry, potential negative economic impacts, and the perceived lack of evidence that the tax would influence consumer behaviour.	Human rights and sociocultural acceptability; societal implications; health equity, equality and non-discrimination; financial and economic considerations

4 The impact of the Soft Drinks Industry Levy (SDIL) on consumption of soft drinks in the United Kingdom: a difference-in-differences (DiD) analysis

Introduction

In the UK, consumption of free sugars is more than double the guideline intake for adults and close to triple for children aged 4–10 and 11–18 years (PHE). Soft drinks have been a major source of free sugars for many years (Ng et al., 2012) and currently account for 21% (57g/day) and 33% (67g/day) of the total free sugar intake in adults and children, respectively (PHE). This is of particular concern currently as obesity is associated with a wide range of chronic diseases including cardiovascular disease, heart attack, stroke, and cancer as well as increased risk of severe illness from COVID-19[1-2] .

High consumption of SSBs is associated with obesity, and with type 2 diabetes and cardiovascular disease independent of its association with obesity.[3-5] Reasons cited for high consumption include their low price relative to healthier alternatives, high availability and aggressive marketing.[6-8]

Concerns regarding the effects on health have led to recommendations to tax SSBs in order to curb demand,[9] with sweetened beverage taxes (i.e., taxes on SSBs which may also apply to artificially sweetened beverages) currently implemented in more than 40 countries worldwide and seven US cities.[10]

The impact of sweetened beverage taxes on prices faced by consumers, and hence the incentive for consumers to decrease their purchases and consumption of these beverages, depends on the extent to which taxes are passed through to prices and hence consumers. As noted in previous chapters, international studies of country-level sweetened beverage taxes are limited by the fact that they have generally lacked a geographic comparison site.[11-32]

In October 2015, in response to the Health Select Committee Inquiry on Childhood Obesity,[33] Public Health England (PHE) published a report listing recommendations for reducing sugar consumption in children, including a tax on SSBs.[34] In March 2016, it announced a tiered levy on sugar-sweetened soft drinks, which was implemented in April 2018 and is the first soft drink tax in the world to have multiple tiers designed to drive reformulation. Products containing more than 8g sugar per 100 ml are now taxed at 24 pence per litre and products containing 5–8g/100 ml are taxed at 18 pence per litre. Products with less than 5g sugar per 100 ml are not subject to the tax.[35] Pure, unsweetened fruit juice and flavoured milk drinks (amongst other smaller categories) are excluded from the levy. The soft drinks industry levy (SDIL), as it is known, is levied directly on manufacturers, importers and bottlers rather than consumers.

The announcement of the SDIL two years prior to its implementation was undertaken to encourage the food and drinks industry to reformulate their products. Therefore, this tax differs from other SSB taxes in that the aim was not to increase the price to consumers per se, but rather to reduce consumption of sugars and thus achieve health gains. The introduction of the tax was accompanied by a large public awareness campaign, particularly as part of an initiative called Change4Life (https://www. Nhs.uk/change4life#)[36] and through increased attention to sugar-related harm in the mass media.[37] The tax was introduced into law in the UK on 6 April 2018 (corresponding to the start of the UK financial year) and took effect immediately. A similar tax was adopted in Ireland at the same time.[38]

In this chapter, we evaluate the impact of the SDIL on the consumption of sugar-sweetened soft drinks at one year after implementation, using repeated cross-sectional data from the National Diet and Nutrition Survey (NDNS). We use a difference-in-differences (DiD) estimation approach (comparing outcomes for different groups exposed to different policies) and focus on the experience in Northern Ireland.

Methods

This repeated cross-sectional study (which included follow-ups on the same groups of respondents) uses data on the consumption of sugar-sweetened beverages in the UK obtained from the National Diet and Nutrition Survey (NDNS). Full methodological details of the NDNS have been described elsewhere.[39] In short, the survey aims to collect data from a UK representative core sample of 1,000 people per year: 500 adults (aged 19 years and over)

and 500 children (aged 1.5 years to 18 years). Data are collected over 12 months to account for seasonal variation, and samples are stratified by country, ensuring proportional representation from England, Scotland, Wales and Northern Ireland. Food and drink consumption data are collected using four-day unweighted food diaries (completed on four consecutive days, including one weekend day). A series of weighting factors are available with the data to remove any bias in the observed results where the bias may arise because some people are more likely than others to be selected to take part. The weighting factors alsoattempt to reduce non-response bias (where people opt out of a survey because they have intrinsically different traits from those who choose to take part). The sample design adjusts the numbers of respondents from Wales and Northern Ireland so that they reflect the correct population proportions of the four UK countries.

Pell and colleagues[40] explored changes in soft drink purchases related to SDIL by households in Britain. They adopted a controlled interrupted time series (CITS) approach, sales data based on periodic reports from a panel of households. However, sales data do not capture out-of-home consumption (e.g. restaurants, vending machines, friends' homes) and typically represent only larger-format retail establishments. Additionally, sales data do not account for wastage (buying extra but not consuming it) nor time factors in consumption (where consumers may stockpile when offers are available from large retailers). As a result, questions could be raised about using sales figures in a study of consumption.

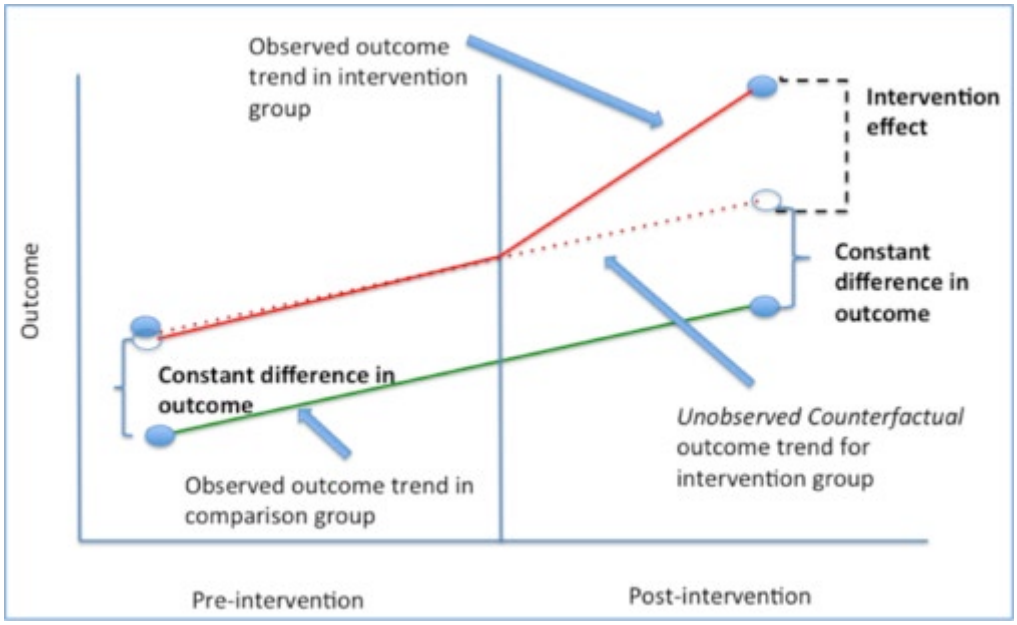
In the NDNS survey, the variable of interest was 'SOFTDRINKSNOTLOWCALORIE', which was a continuous variable indicating the amount of drink consumed by the individual (in grams/day) as recorded in a four-day food diary. No information was available on the sugar content of the drinks (i.e. whether the drink contained over 8g, 5-8g or less than 5g of sugar, as per the tiered SDIL structure). Socio-demographic information was collected on all participants by a trained interviewer.

Given the available data, we used a quasi-experimental design appropriate for use with repeated cross-sectional data. A difference-in-differences (DiD) approach uses data from treatment and control groups to show what happens without intervention (the counterfactual) and thus to assume that the intervention has a causal effect. This approach has been used to estimate the effect of a specific intervention or treatment (such as a passage of law, enactment of policy, or implementation of a large-scale programme) by

comparing the changes in outcomes over time between a group which is subject to a tax and a group which is not.

The DiD model relies upon the parallel trends assumption – the assumption that, in the absence of the treatment, the time trend in the outcome (pattern of change over time) for the treated (taxed) group would be the same as that of the untreated comparison (untaxed) group. That is, if no tax had been imposed on anyone, all the consumers involved in the survey would have experienced the same outcomes. As seen in the graph below (Figure 1), when this assumption holds, it allows researchers to estimate the effect of treatment in terms of how the outcome changed for the treated group relative to what was expected to happen without treatment, (i.e., what actually happened for the comparison group). It is impossible to verify whether the time trend would have been the same for the treatment and control groups in the absence of the treatment (because the treatment did in fact occur), but researchers often check the plausibility of the parallel trends assumption by checking whether the time trend in the outcome was similar for the treatment and control groups prior to the treatment.

Figure 1. Difference-in-difference estimation, graphical explanation[41]



The DiD approach has been used to estimate the impact of the SSB tax introduction in Philadelphia[16,42-43] and Seattle, Washington.[44] In these studies, a geographical counterfactual series was used (for example, the untaxed suburbs serving as the geographic comparison

group for the taxed city). As the SDIL was implemented on a population-wide basis in the UK, it was not possible to compare changes in consumption with an unaffected jurisdiction. Hence, in this paper, the counterfactual was provided by an alternative category of household purchases, which were exempt from the levy but exhibited similar trends in consumption before the levy applied.

Our choice of counterfactual was informed by studies of the impact of the announcement and subsequent introduction of the SDIL in the UK, using data from supermarket sales.[40,45] Fruit juices and milk-based drinks were the SDIL-exempt products which those studies assumed would serve as comparable items for a DiD analysis exploring the *announcement* of the tax (i.e. items showing parallel trends in consumption between the SDIL-exempt and SDIL-liable groups before the tax was introduced). An additional series (of household toiletries) were used when examining the impact of the *implementation* of the SDIL.[40]

In our study, we hypothesised that consumers may substitute sugar-sweetened soft drinks with other low-calorie soft drinks, fruit drinks or water. Rather than simply follow Pell and Scarborough, however, we explored a variety of potential counterfactual series of products to identify a comparator series which could satisfy the parallel trend assumption. A series constructed from milk products (1% milk, semi-skimmed milk and whole milk) exhibited a similar trend to SDIL-eligible drinks prior to the introduction of the tax, although varying somewhat with seasonal demand.

DiD is usually used to express the interaction between time and the treatment group's dummy variables in a regression model (a statistical model showing the relationship between variables). Here, Y is our consumption variable (of either the SDIL-exempt or SDIL-liable good) measured in grammes of sugar-sweetened soft drinks per day; $\beta 0$ is the baseline average; $\beta 1$ is the time trend in the control group; $\beta 2$ is the difference between the two groups pre-intervention; $\beta 3$ is our parameter of interest – the difference-in-differences (DiD) estimator; and βk is a series of covariates.

$$Y= \beta 0 + \beta 1*[Time] + \beta 2*[Treatment] + \beta 3*[Time*Treatment] + \beta k*[Covariates]+\varepsilon$$

Data on consumption (for both sugar-sweetened soft drinks and the counterfactual series) were continuous, non-negative (positive but unquantified) and over-dispersed (more variable than expected). To account for this, the regression approach adopted was a generalised linear model (GLM – a model that relates several concurrent variables to each other) with a gamma

family, log link and robust standard errors. Covariates included the following variables: age, gender, race/ethnicity, general health, and household income. A dummy variable for existence of the tax in time was included. All results are estimated using survey weights at the individual level to account for the sample design, over-sampling and non-response and to enable comparisons between jurisdictions – as we focus on experience in Northern Ireland, which was not studied separately by Pell and colleagues.[40]

Data were analysed for 12 months before the SDIL was implemented (2017/2018) and for 12 months after (2018/19), and involved 2,305 individuals. A variable indicating the month in which the data was collected was used to construct a dataset spanning 24 months (12 months before and 12 months after the introduction of the SDIL). Before undertaking the DiD, we used data from 2015/16, 2016/17 and 2018/19 to determine if trends were sufficiently parallel to progress the analysis, i.e. to explore trends in potential counterfactuals. As the tax may affect consumption in different ways, the estimates of the average impact of the SDIL may obscure important differences across key baseline characteristics. Therefore, we explored the impact of the tax differentially for children and adults and, as noted, for individuals from Northern Ireland compared with those in Britain.

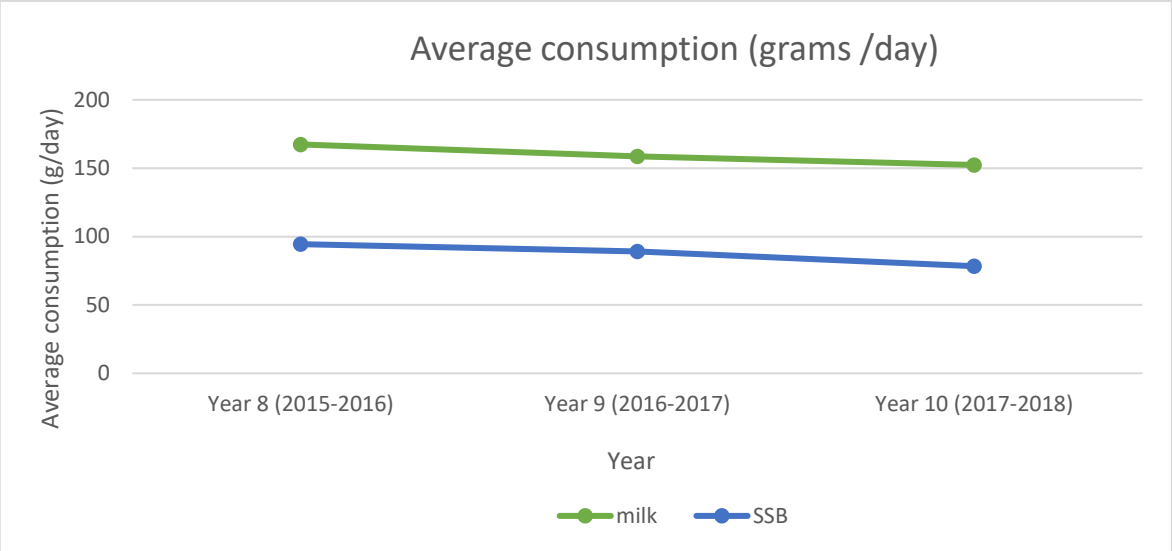
All statistical analyses were performed in Stata v 17 (StataCorp 2021, College Station, TX). This study is reported in accordance with the guidelines on strengthening the reporting of observational studies in epidemiology (STROBE).[46]

Results

Summary statistics for respondents from Northern Ireland and the rest of the UK are presented in Tables 1a and 1b. A slightly higher proportion of respondents were female in Northern Ireland compared to the rest of the UK (55.6% compared to 52.9%) and reported their general health as being 'very good' or 'good' (89.6% compared to 85.5%). A higher proportion of respondents in Northern Ireland were white (96.5%) compared to the rest of the UK (86.9%), and were in the lowest income tertile (44.3%) compared with respondents from the rest of the UK. Similar patterns of consumption of sugar-sweetened drinks were observed for the period 2016-2019: in Northern Ireland mean consumption was 22g/day in those aged 1.5-3 years, 147g/day in 11-18 year olds and 112g/day in adults; in the rest of the UK these figures were 19g/day, 142g/day and 89g/day respectively. The Northern Ireland and 'rest of the UK' regression samples contained 318 and 1,663 respondents respectively. The overall

response rate for individuals completing three or four diary recording days (upon which consumption data was based) was 45% in Year 10 of the study (2017 to 2018) and 47% in Year 11 (2018 to 2019).[47] For the DiD analysis, the sample was restricted to 12 months before and 12 months after the introduction of the SDIL. A graphical illustration to support the parallel trend assumption is presented in Figure 2.

Figure 2. Graphical illustration of the parallel trend assumption



In Tables 2 and 3 the results of the generalised linear regression models are reported for Northern Ireland and Britain respectively. The coefficient of interest relates to the interaction term between the dummy variables indicating introduction of the SDIL and treatment group – the variable labelled difference in differences in the Tables. This captures the impact of the soft drinks industry levy as discussed in Figure 1.

Table 1a Northern Ireland mean estimation. Number of observations=318

	Mean	Std. err.	[95% conf.	
Post period	0.4560	0.0198	0.4172	0.4948
Treatment indicator	0.5000	0.0198	0.4610	0.5390
Age				
1.5-3 years	0.1195	0.0129	0.0942	0.1448
4-10 years	0.2201	0.0164	0.1878	0.2524
11-18 years	0.2201	0.0164	0.1878	0.2524
19-64 years	0.3428	0.0188	0.3058	0.3798

	Mean	Std. err.	[95% conf.	
65+ years	0.0975	0.0118	0.0744	0.1206
Gender				
Male	0.4434	0.0197	0.4047	0.4821
Female	0.5566	0.0197	0.5179	0.5953
Ethnic group				
White	0.9654	0.0073	0.9512	0.9796
Mixed ethnic group	0.0031	0.0022	-0.0012	0.0075
Black or Black British	0.0126	0.0044	0.0039	0.0213
Asian or Asian British	0.0189	0.0054	0.0083	0.0295
Self-assessed general health				
Very good	0.5943	0.0195	0.5561	0.6326
Good	0.3019	0.0182	0.2661	0.3377
Fair	0.0755	0.0105	0.0549	0.0961
Bad	0.0189	0.0054	0.0083	0.0295
Very bad	0.0094	0.0038	0.0019	0.0170
Income				
Lowest tertile	0.4434	0.0197	0.4047	0.4821
Middle tertile	0.3019	0.0182	0.2661	0.3377
Highest tertile	0.2547	0.0173	0.2208	0.2887
Time	23.4874	0.2662	22.9647	24.0101

Table 1b: Rest of UK mean estimation. Number of observations=1663

	Mean	Std. err.	[95% conf.	interval]
Post period	0.4817	0.0087	0.4647	0.4986
Treatment indicator	0.5000	0.0087	0.4830	0.5170
Age				
1.5-3 years	0.0830	0.0048	0.0736	0.0924
4-10 years	0.2044	0.0070	0.1907	0.2182
11-18 years	0.1894	0.0068	0.1761	0.2027
19-64 years	0.4119	0.0085	0.3952	0.4286
65+ years	0.1112	0.0055	0.1006	0.1219
Gender				
Male	0.4714	0.0087	0.4545	0.4884
Female	0.5286	0.0087	0.5116	0.5455
Ethnic group				
White	0.8689	0.0059	0.8574	0.8804
Mixed ethnic group	0.0241	0.0027	0.0188	0.0293
Black or Black British	0.0349	0.0032	0.0286	0.0411
Asian or Asian British	0.0553	0.0040	0.0475	0.0631
Any other group	0.0168	0.0022	0.0125	0.0212
Self-assessed general health				
Very good	0.4853	0.0087	0.4683	0.5023
Good	0.3728	0.0084	0.3564	0.3893
Fair	0.1185	0.0056	0.1075	0.1294
Bad	0.0198	0.0024	0.0151	0.0246
Very bad	0.0036	0.0010	0.0016	0.0056
Income				
Lowest tertile	0.3175	0.0081	0.3017	0.3333
Middle tertile	0.3373	0.0082	0.3213	0.3534
Highest tertile	0.3452	0.0082	0.3290	0.3613
Time	24.1696	0.1192	23.9359	24.4032

Table 2: GLM results for Northern Ireland

	Coefficient	Robust std. err.	z	P>z	[95% conf.	interval]
Post period	-0.3597	0.3199	-1.12	0.261	-0.9867	0.2673
Treatment indicator	-1.0453	0.2716	-3.85	0.000	-1.5777	-0.5130
Difference-in-differences	-0.3912	0.3837	-1.02	0.308	-1.1432	0.3608
Age						
1.5-3 years	-0.9555	0.2463	-3.88	0.000	-1.4383	-0.4727
4-10 years	-0.6160	0.2139	-2.88	0.004	-1.0352	-0.1969
19-64 years	-0.4725	0.2379	-1.99	0.047	-0.9387	-0.0063
65+ years	-1.3743	0.3078	-4.46	0.000	-1.9776	-0.7710
Gender						
Female	-0.4320	0.1942	-2.22	0.026	-0.8126	-0.0514
Ethnic group						
Mixed ethnic group	-2.0533	0.7426	-2.77	0.006	-3.5088	-0.5978
Black or Black British	-0.2782	0.7373	-0.38	0.706	-1.7233	1.1669
Asian or Asian British	0.4020	0.7999	0.50	0.615	-1.1658	1.9698
Self-reported general health						
Good	-0.2467	0.2370	-1.04	0.298	-0.7112	0.2178
Fair	0.1814	0.3450	0.53	0.599	-0.4948	0.8575
Bad	0.1328	0.6360	0.21	0.835	-1.1137	1.3792
Very bad	-0.8280	0.7038	-1.18	0.239	-2.2074	0.5515
Income						
Middle tertile	0.1189	0.2140	0.56	0.578	-0.3004	0.5383
Highest tertile	0.0707	0.2417	0.29	0.770	-0.4031	0.5445
Time	0.0299	0.0241	1.24	0.216	-0.0175	0.0772
Constant	5.3800	0.5019	10.72	0.000	4.3963	6.3636

Table 3: GLM results for rest of UK

	Coefficient	Robust std. err.	z	P>z	[95% conf.	interval]
Post period	-0.2197	0.1556	-1.41	0.158	-0.5246	0.0852
Treatment indicator	-0.4691	0.1209	-3.88	0.000	-0.7060	0.2322
Difference-in-differences	-0.2419	0.1623	-1.49	0.136	-0.5599	0.0762
Age						
1.5-3 years	-0.2462	0.1229	-2.00	0.045	-0.4871	-0.0054
4-10 years	-0.3686	0.0965	-3.82	0.000	-0.5577	-0.1795
19-64 years	-0.2311	0.0955	-2.42	0.016	-0.4183	-0.0439
65+ years	-0.5855	0.1215	-4.82	0.000	-0.8237	-0.3473
Gender						
Female	-0.2398	0.0779	-3.08	0.002	-0.3926	0.0870
Ethnic group						
Mixed ethnic group	0.0181	0.2357	0.08	0.939	-0.4438	0.4800
Black or Black British	0.2266	0.2944	0.77	0.442	-0.3504	0.8036
Asian or Asian British	-0.1902	0.1374	-1.38	0.166	-0.4595	0.0791
Any other group	-0.3668	0.2685	-1.37	0.172	-0.8932	0.1595
Self-assessed general health						
Good	-0.1216	0.0922	-1.32	0.187	-0.3024	0.0592
Fair	-0.1594	0.1245	-1.28	0.200	-0.4034	0.0845
Bad	-0.0873	0.2015	-0.43	0.665	-0.4822	0.3075
Very bad	1.1966	0.5480	2.18	0.029	0.1226	2.2706
Income						
Middle tertile	-0.0745	0.1011	-0.74	0.461	-0.2726	0.1236
Highest tertile	-0.3368	0.1013	-3.32	0.001	-0.5353	-0.1382

	Coefficient	Robust std. err.	z	P>z	[95% conf.	interval]
Time	0.0164	0.0115	1.42	0.155	-0.0062	0.0390
_cons	5.1780	0.2405	21.53	0.000	4.7067	5.6493

The regression-adjusted DiD estimates of the change in consumption between the SDIL-liable and SDIL-exempt drinks was negative .i.e. a reduction and not statistically significant for either Northern Ireland (-0.391, p=0.308) or Britain (-0.242, p=0.136). Similar patterns in consumption were observed in both jurisdictions with respect to age and gender (i.e. statistically significant reductions in consumption for all age groups compared to those aged 11-18 years and females compared to males). In Britain, there was a statistically significant decline in consumption for those in the highest income tertile (-0.34, p=0.001), which was not observed in Northern Ireland.

While not the primary aim of the study, when consumption was explored separately for adults and children (where adults were defined as those aged over 18 years), there was a significant reduction in consumption of sugar-sweetened soft drinks after the introduction of the SDIL for those aged 18 years and under in Northern Ireland (-0.7708, p=0.017) (Table 4). This was not the case in Britain. This result suggests a reduction of 77 grams of sugar-sweetened soft drinks per day, which equates to approximately one fewer drink every five days. As a sensitivity analysis, this regression used data from two years prior to the introduction of the SDIL, compared to data from one year after, and this finding remained (-0.70, p=0.005).

Table 4: GLM results for Northern Ireland (children only)

	Coefficient	Robust std. err.	z	P>z	[95% conf.	interval]
Post period	-0.0792	0.3190	-0.25	0.804	-0.7043	0.5460
Treatment indicator	-0.4862	0.2553	-1.90	0.057	-0.9865	0.0140
Difference-in-differences	-0.7708	0.3225	-2.39	0.017	-1.4028	-0.1388
Gender						
Female	-0.2476	0.1647	-1.50	0.133	-0.5705	0.0753

	Coefficient	Robust std. err.	z	P>z	[95% conf.	interval]
Ethnic group						
Mixed ethnic group	-2.0035	0.7389	-2.71	0.007	-3.4517	-0.5554
Black or Black British	-0.4145	0.6146	-0.67	0.500	-1.6192	0.7902
Asian or Asian British	-1.1716	0.5742	-2.04	0.041	-2.2970	-0.0462
Self-assessed general health						
Good	-0.1599	0.1731	-0.92	0.356	-0.4992	0.1794
Fair	0.1599	0.2935	0.54	0.586	-0.4154	0.7353
Income						
Middle tertile	0.0868	0.1742	0.50	0.618	-0.2547	0.4282
Highest tertile	-0.1421	0.1879	-0.76	0.450	-0.5104	0.2263
Time	0.0157	0.0217	0.72	0.470	-0.0269	0.0582
_cons	4.9833	0.4146	12.02	0.000	4.1707	5.7960

N=356

Discussion

Using the NDNS data, we found no statistically significant differences in consumption of sugar-sweetened soft drinks before and afer the introduction of SDIL in Britain or Northern Ireland or these combined using a difference in difference methodology. This finding is in line with the conclusions reported by Pell and colleagues[40] employing a controlled interrupted time series (CITS) analysis of the implementation of the SDIL in the UK using household purchases (Kantar World Panel data). Before exploring the impact of the implementation of the SDIL, Scarborough and colleagues[45] used a CITS design to explore the impact of the announcement of the SDIL on sugar content, price, product size and number of available soft drinks in the UK (from 2015 to 2019). They concluded that the SDIL incentivised manufacturers to reduce sugar in soft drinks, whilst maintaining the volume of sales and not increasing prices to consumers. The analysis by Pell and colleagues, however, found that the introduction of the tax was associated with a significant reduction in sugar consumption arising from substitution between drinks of higher and lower sugar content[40]. Our data did not allow us to look at substitution within high and lower-tier SSBs, though there is no

reason to assume that behaviours on substitution would be any different within our data. A number of studies, which have explored the impact of more conventional SSB taxes on quantity of purchases, have reported pass-through rates (passing on price increases to consumers) of between 25% and 81% depending on the data source and methodology employed, and reported varying reductions in quantity, with significant reductions being observed in younger consumers.[14-20,31]

In Northern Ireland, we did observe a statistically significant reduction in consumption among children under 18, coinciding with the introduction of the tax. This is *in addition* to any reduction in sugar achieved where the SDIL has encouraged reformulation – assuming the behaviours reported by Pell and colleagues extend to our data[40].

This reduction among children is significant for two reasons. First, relative to adults they consume more SSBs. Therefore, consistent with a dose-response relationship (the more they drink, the greater the effect), consuming less should result in greater health gains than would, other things being equal, be experienced by adults. Second, compared to adults, children are less likely to have currently accumulated obesity-related morbidity (relating to type 2 diabetes, hypertension, coronary health disease, obesity-related cancers, or conditions exacerbated by obesity). That is, reducing SSB intake at this stage is more likely to help prevent future ill health by setting them on a different path to health than they wouldotherwise follow.

Thus, the combined effect of reduced overall consumption and reduced sugar consumption through reformulation is arguably particularly significant in this age group in terms of potential health effects and healthcare costs. For example, over a decade ago, the direct and indirect costs of obesity-related illness on the IoI were estimated at £107-£186 million (Northern Ireland) and €420-749 million (Ireland), a figure which has no doubt increased, suggesting that even a modest reduction in obesity-related morbidity could provide cost savings.[48]

In Northern Ireland, mean consumption of sugar-sweetened soft drinks for 11-18 year-olds was 147g/day (with previous research suggesting that estimates from manufacturer data can be three to four times as much).[49] Before reformulation, this equated to between 50 and 170 kcal per day respectively. In our study, for children in Northern Ireland (taking into account the counterfactual series) the reduction observed equated to approximately 50g of sugar-

sweetened soft drinks per day. Depending on whether the drink was categorised as high (8g/100g) or low tier (5g/100g), this could equate to a reduction of 10 to 15 kilocalories daily.

Collins and colleagues, using NDNS data, concluded that an average net reduction of 20 kcal per person per day could translate to 179,000 fewer cases of diabetes; 122,000 fewer cases of stroke and coronary heart disease; 32,000 fewer obesity-related cancers, and a gain of over 3 million quality-adjusted life years (QALYs) for local authorities in England[50]. A similar calculation for Northern Ireland (based on population size and hypothesised reduction in calories) could see a gain of over 100,000 QALYs. However, such *ad hoc* comparisons should be viewed with caution in the absence of local data. Although the proportion of obese and overweight individuals in both jurisdictions is similar, differences are unclear in key assumptions regarding how price changes and sociodemographic variables affect demand for SSBs. Further research is warranted. Similarly, the reduction in calories is based on the difference in consumption predicated on the counterfactual series (milk products). The quasi-experimental (not strictly randomised) approach used was determined by the available data, and it is possible that there may be more appropriate controls. However, the use of a control is better than an uncontrolled before-and-after estimate.

As outlined in a recent review of the worldwide experience of evaluating beverage tax policies[51], there are real and practical challenges in evaluating the impact of SSB taxes. This is even more apparent when measures which would usually be considered markers of success (such as reduced consumption) are not the primary focus of the tax, as has been the case with the implementation of the SDIL. Nonetheless, in the absence of prospectively designed (longitudinal) studies, natural experiments and quasi-experimental methods have been used in a variety of jurisdictions to explore outcomes at individual and population level, and a substantial literature exists on the various approaches which allow us to infer causation with more confidence.[52-55]

A range of quasi-experimental methods have been used to assess the impact of SSB taxes. The most frequently used approaches include DiD models (using a control group or propensity score matching); interrupted time series (ITS) (with synthetic controls or correlated random effects); controlled interrupted time series (CITS); and regression discontinuity models (RD).[16,42,56-59] In most cases, the choice of experimental design is determined by the research question, the cost of generating empirical data, and the type of data available (whether repeated cross-sectional or panel data). National diet and nutrition

surveys are important sources of information that are representative of the target population.

However, these surveys often use complex sample designs for efficient data collection, including sampling weightings, multistage sampling and stratification. The statistical analysis of dietary intake data collected using such complex survey designs is inherently challenging, and many statistical issues remain unresolved. The distribution pattern of intake can be highly skewed due to the presence of apparently abnormal observations and a large proportion of zero observations; day-to-day variation in food and drink consumption need to be accounted for in estimating correct inferences; and the estimation needs to take account of the complex sample design to allow us to extrapolate results to the target population.[60] As in the studies exploring the impact of the SDIL in the UK,[40,45] the DiD coefficients represent the impact of the SDIL tax alongside the advertising and social media campaigns on consumption, and it is not possible to disentangle their separate impact.

Despite these challenges, a key strength of the current study is that conclusions are drawn from a large nationally representative sample by employing face-to-face interviewing techniques and long-term data collection on food and drink consumption. Additionally, conclusions drawn regarding Northern Ireland will have benefited from the sample being 'boosted' to ensure that the number sampled in Northern Ireland is comparable with that from other jurisdictions in the UK. Further analysis, however, is warranted and could perhaps explore the impact of the SDIL using a survey-weighted two-part model to account for decision to consume, and then how much to consume. Additional work should also determine whether the reductions reported here are sustained and are large enough to affect population health in the manner suggested.

References

1. Centers for Disease Control and Prevention. (2021). https://www.cdc.gov/obesity/index.html (accessed 28 March 2022)
2. *Clinical guidelines in the identification, evaluation and treatment of overweight and obesity in adults: The evidence report*. (n.d.). https://www.nhlbi.nih.gov/files/docs/guidelines/ob_gdlns.pdf
3. Imamura, F., O'Connor, L., Ye, Z., Mursu, J., Hayashino, Y., Bhupathiraju, S. N., Forouhi, N. G. (2015). 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. *BMJ*, *351*, h3576. doi: 10.1136/bmj.h3576. PMID: 26199070; PMCID: PMC4510779
4. Malik, V. S., Hu, F. B. (2022). The role of sugar-sweetened beverages in the global epidemics of obesity and chronic diseases. *Nature Reviews Endocrinology, 18*(4), 205-218. doi: 10.1038/s41574-021-00627-6. Epub 2022 Jan 21. PMID: 35064240; PMCID: PMC8778490
5. Narain, A., Kwok, C. S., Mamas, M. A. (2016). Soft drinks and sweetened beverages and the risk of cardiovascular disease and mortality: A systematic review and meta-analysis. *International Journal of Clinical Practice. 70*(10). 791-805. doi: 10.1111/ijcp.12841. Epub 2016 Jul 25. PMID: 27456347
6. Harris, J. L.; Kalnova, S. S. (2018). Food and beverage TV advertising to young children: Measuring exposure and potential impact. *Appetite 123*, 49–55.
7. Kern, D. M., Auchincloss, A. H., Ballester, L. S., Robinson, L. F. (2016). Neighbourhood variation in the price of soda relative to milk and its association with neighbourhood socio-economic status and race. *Public Health Nutrition. 19*(18), 3386-3396. doi: 10.1017/S1368980016001579. Epub 2016 Jun 30. PMID: 27357494
8. Blecher, E., Liber, A. C., Drope, J. M., Nguyen, B., Stoklosa, M. (2017). Global trends in the affordability of sugar-sweetened beverages, 1990–2016. *Preventing Chronic Disease, 14*, E37.
9. World Health Organization. (2016). Fiscal policies for diet and prevention of noncommunicable diseases: Technical meeting report 5-6 May 2015. World Health Organization. https://apps.who.int/iris/bitstream/handle/1 0665/250131/9789241511247-eng.pdf?sequence=1 (Accessed 28 March 2022).
10. World Bank. (2020). *Taxes on sugar-sweetened beverages: International evidence and experiences.* https://openknowledge.worldbank.org /handle/10986/33969 (Accessed 28 March 2022).
11. Cawley, J., Thow, A. M., Wen, K., 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*, 317–338. https://doi.org/10.1146/annurevnutr-082018-124603
12. Bleich, S. N., Lawman, H. G., LeVasseur, M. T., Yan, J., Mitra, N., Lowery, C. M., Peterhans, A., Hua, S., Gibson, L. A., Roberto, C. A. (2020). The association of a sweetened beverage tax with changes in beverage prices and purchases at

independent stores. *Health Affairs (Millwood), 39*(7), 1130-1139. doi: 10.1377/hlthaff.2019.01058. PMID: 32634353

13. Bleich, S. N., Dunn, C. G., Soto, M. J., Yan, J., Gibson, L. A., Lawman, H. G., Mitra, N., Lowery, C. M., Peterhans, A., Hua, S. V., Roberto, C. A. (2021). Association of a sweetened beverage tax with purchases of beverages and high-sugar foods at independent stores in Philadelphia. *JAMA Network Open, 4*(6), e2113527. doi: 10.1001/jamanetworkopen.2021.13527. PMID: 34129022; PMCID: PMC8207239
14. Cawley, J., Frisvold, D. (2017). The pass-through of taxes on sugar-sweetened beverages to retail prices: The case of Berkeley, California. *Journal of Policy Analysis and Management, 36* (2017), 303-326. 10.1002/pam.21960
15. Cawley J., Willage B., Frisvold D. (2018). Pass-through of a tax on sugar-sweetened beverages at the Philadelphia international airport *Journal of the American Medical Association, 319* (2018), 305-306. 10.1001/jama.2017.16903
16. Cawley, J., Frisvold, D., Hill, A., Jones, D. (2020a). The impact of the Philadelphia beverage tax on prices and product availability. *Journal of Policy Analysis and Management, 39*, 605-628. 10.1002/pam.22201
17. Cawley, J., Frisvold, D., Hill, A., Jones, D.. (2020b). Oakland's sugar-sweetened beverage tax: impacts on prices, purchases and consumption by adults and children. *Economics and Human Biology, 37* ,100865, 10.1016/j.ehb.2020.100865
18. Cawley, J., DFrisvold, D., Jones, D., Lensing, C.. (2021). The pass-through of a tax on sugar-sweetened beverages in Boulder, Colorado. *American Journal of Agricultural Economics, 103*, 987-1005, 10.1111/ajae.12191
19. Falbe, J., Rojas, N., Grummon, A. H., Madsen, K. A. (2015). Higher retail prices of sugar-sweetened beverages 3 months after implementation of an excise tax in Berkeley, California. *American Journal of Public Health, 105*(11), 2194-201. doi: 10.2105/AJPH.2015.302881. Epub 2015 Oct 7. PMID: 26444622; PMCID: PMC4605188
20. Falbe, J., Lee, M. M., Kaplan S., Rojas, N. A., Ortega Hinojosa, A. M., Madsen, K. A. (2020). Higher sugar-sweetened beverage retail prices after excise taxes in Oakland and San Francisco. *American Journal of Public Health, 110*(7), 1017-1023. doi: 10.2105/AJPH.2020.305602. Epub 2020 May 21. PMID: 32437271; PMCID: PMC7287565
21. Jones-Smith, J. C., Pinero Walkinshaw, L., Oddo, V. M., Knox, M., Neuhouser M. L., Hurvitz, P. M., Saelens, B. E., Chan, N. (2020). Impact of a sweetened beverage tax on beverage prices in Seattle, WA. *Economics and Human Biology, 39*, 100917. doi: 10.1016/j.ehb.2020.100917. Epub 2020 Jul 23. PMID: 32801099
22. Léger, P. T., Powell, L. M. (2021). The impact of the Oakland SSB tax on prices and volume sold: A study of intended and unintended consequences. *Health Economics, 30*(8), 1745-1771. doi: 10.1002/hec.4267. Epub 2021 Apr 30. PMID: 33931915
23. Leider, J., Pipito , L., Powell, M. (2018). The impact of the Cook County, Illinois, sweetened beverage tax on prices, 2017. Illinois Prevention Research Center, University of Illinois at Chicago. https://p3rc.uic.edu/wp-content/uploads/sites/561/2019/12/Tax-Pass-Through_Cook-County-IL-Illinois-PRC-Brief-No.-105-Sept-2018-5.pdf

24. Leider, J., Li, Y., Powell, L. M. (2021). Pass-through of the Oakland, California, sugar-sweetened beverage tax in food stores two years post-implementation: A difference-in-differences study. *PLoS One, 16*(1), e0244884. doi: 10.1371/journal.pone.0244884. PMID: 33395444; PMCID: PMC7781485
25. Marinello, S., Pipito, A. A., Leider, J., Pugach, O., Powell, L. M. (2019). The impact of the Oakland sugar-sweetened beverage tax on bottled soda and fountain drink prices in fast-food restaurants. *Preventive Medicine Reports, 17*, 101034. doi: 10.1016/j.pmedr.2019.101034. PMID: 32089991; PMCID: PMC7026275
26. Marinello, S., Pipito, A. A., Leider, J., Pugach, O., Powell, L. M. (2021). Longer-term impacts of sugar-sweetened beverage taxes on fast-food beverage prices: Evidence from Oakland, California, 2-year post-tax. *Public Health Nutrition 24*(11), 3571-3575. doi: 10.1017/S1368980020005212. Epub 2020 Dec 22. PMID: 33349292
27. Powell, L. M., Leider, J. (2020). Evaluation of changes in beverage prices and volume sold following the implementation and repeal of a sweetened beverage tax in Cook County, Illinois. *JAMA Network Open, 3*(12), e2031083. doi: 10.1001/jamanetworkopen.2020.31083. PMID: 33369659; PMCID: PMC7770557
28. Powell, L. M., Leider, J. (2020). The impact of Seattle's sweetened beverage tax on beverage prices and volume sold. *Economics and Human Biology, 37*, 100856. doi: 10.1016/j.ehb.2020.100856. Epub 2020 Jan 21. PMID: 32070906
29. Roberto, C. A., Lawman, H. G., LeVasseur, M. T., Mitra, N., Peterhans, A., Herring, B., Bleich, S. N. (2019). Association of a beverage tax on sugar-sweetened and artificially sweetened beverages with changes in beverage prices and sales at chain retailers in a large urban setting. *JAMA, 321*(18), 1799-1810. doi: 10.1001/jama.2019.4249. PMID: 32930704
30. Seiler, S., Tuchman, A., Yao, S. (2021). **T**he impact of soda taxes: Pass-through, tax avoidance, and nutritional effects. *Journal of Marketing Research, 58* , 22-49, 10.1177/0022243720969401
31. Silver, L. D., Ng, S. W., Ryan-Ibarra, S., Taillie, L. S., Induni, M., Miles, D. R., Poti, J. M., 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. doi: 10.1371/journal.pmed.1002283. PMID: 28419108; PMCID: PMC5395172
32. Taylor, R. L. C., Kaplan, S., Villas-Boas, S. B., Jung, K. (2019). Soda wars: The effect of a soda tax election on university beverage sales. *Economic Inquiry, 57*, 1480-1496. 10.1111/ecin.12776
33. Health Select Committee. (2015). *Childhood obesity – brave and bold action*. House of Commons..
34. Public Health England. (2015). *Sugar reduction: the evidence for action*. Public Health England.
35. HM Revenue & Customs. (2016). *Soft drinks industry levy – consultations.* GOV.UK. Available from: https://www.gov.uk/government/ publications/soft-drinks-industry-levy/soft-drinks-industry-levy

36. NHS. *Home | Change4Life*. (n. d.). [cited 2019 Sep 19]. Available from: https://www.nhs.uk/change4life#
37. Elliott-Green, A., Hyseni, L., Lloyd-Williams, F., Bromley, H., Capewell, S. (2016). Sugarsweetened beverages coverage in the British media: An analysis of public health advocacy versus pro-industry messaging. *BMJ Open, 6*, e011295. https://doi.org/10.1136/bmjopen-2016-011295
38. *A tax on sugar sweetened drinks: An overview.* (2016). https://data.oireachtas.ie/ie/oireachtas/libraryResearch/2016/2016-10-05_l-rs-note-tax-on-sugar-sweetened-drinks_en.pdf
39. Gov.uk. https://www.gov.uk/government/collections/national-diet-and-nutrition-survey (accessed 28 March 2022)
40. Pell, D., Mytton, O., Penney, T. L., Briggs, A., Cummins, S., Penn-Jones, C., Rayner, M., Rutter, H., Scarborough, P., Sharp, S. J., Smith, R. D., White, M., Adams, J. (2021). Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: Controlled interrupted time series analysis. *BMJ, 372*, n254. doi: 10.1136/bmj.n254. PMID: 33692200; PMCID: PMC7944367
41. Population Health Methods. (n. d.). Difference-in-Difference Estimation | Columbia Public Health
42. Zhong, Y., Auchincloss, A. H., Lee, B. K., Kanter, G. P. (2018). The short-term impacts of the Philadelphia beverage tax on beverage consumption. *American Journal of Preventive Medicine, 55*(1), 26-34. doi: 10.1016/j.amepre.2018.02.017. Epub 2018 Apr 12. PMID: 29656917
43. Zhong, Y., Auchincloss, A. H., Lee, B. K., McKenna, R. M., Langellier, B. A. (2020). Sugar-sweetened and diet beverage consumption in Philadelphia one year after the beverage tax. *International Journal of Environmental Research and Public Health, 17*(4), 1336. doi: 10.3390/ijerph17041336. PMID: 32092982; PMCID: PMC7068482
44. Powell, L. M., Leider, J. (2021). Impact of a sugar-sweetened beverage tax two-year post-tax implementation in Seattle, Washington, United States. *Journal of Public Health Policy, 42*(4), 574-588. doi: 10.1057/s41271-021-00308-8. Epub 2021 Nov 3. PMID: 34732842
45. Scarborough, P., Adhikari, V., Harrington, R. A., Elhussein, A., Briggs, A., Rayner, M., Adams, J., Cummins, S., Penney, T., 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. doi: 10.1371/journal.pmed.1003025. PMID: 32045418; PMCID: PMC7012398
46. von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., Vandenbroucke, J. P.. (2008). STROBE initiative. Strengthening the reporting of observational studies in epidemiology (STROBE)statement: Guidelines for reporting observational studies. J Clin Epidemiol. 2008 Apr;61(4), 344-9. PMID: 18313558
47. Public Health England. (n. d.). *NDNS: Rolling programme years 9 to 11 (2016/17 to 2018/19)* (accessed 28 March 2022) Available from:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943114/NDNS_UK_Y9-11_report.pdf

48. Perry, I. J., Dee, A., O'Neill, C. et al. (2012). The cost of overweight and obesity on the Island of Ireland. *Journal of Epidemiology and Community Health, 67*, (Suppl 1). DOI: 10.1136/jech-2013-203126.144
49. British Soft Drinks Association. (2016). *The economic impact of the soft drinks levy.* https://www.britishsoftdrinks.com/write/MediaUploads/Publications/The_Economic_Impact_of_the_Soft_Drinks_Levy.pdf
50. Collins, B., Capewell, S., O'Flaherty, M., Timpson, H., Razzaq, A., Cheater, S., Ireland, R., Bromley, H. (2015). Modelling the health impact of an English sugary drinks duty at national and local levels. *PLoS One, 10*(6), e0130770. doi: 10.1371/journal.pone.0130770. PMID: 26121677; PMCID: PMC4486083
51. Ng, S. W., Ni Mhurchu, C., Jebb, S. A., Popkin, B. M. (2012). Patterns and trends of beverage consumption among children and adults in Great Britain, 1986-2009. *British Journal of Nutrition, 108*(3), 536 –51.
52. Craig, P., Katikireddi, S. V., Leyland, A., Popham, F. (2017). Natural experiments: An overview of methods, approaches, and contributions to public health intervention research. *Annual Review of Public Health, 38*(1), 39–56. https://doi.org/10.1146/annurev-publhealth-031816-044327
53. Basu, S., Meghani, A., Siddiqi, A. (2017). Evaluating the health impact of large-scale public policy changes: Classical and novel approaches. *Annual Review of Public Health, 38*(1), 351–70. https://doi.org/10.1146/annurev-publhealth-03181 6-044208
54. Leatherdale, S. T. (2019). Natural experiment methodology for research: A review of how different methods can support real-world research. *International Journal of Social Research Methodology, 22*(1), 19–35. https://doi.org/10.1080/13645579.2018.1488449
55. Snell, A., Reeves, A., Rieger, M., Galea, G., Mauer-Stender, K., Mikkelsen, B., et al. (2018). WHO Regional Office for Europe's natural experiment studies project: An introduction to the series. *European Journal of Public Health, 28*(suppl_2), 1–3.
56. Colchero, M. A., Rivera-Dommarco, J., Popkin, B. M., Ng, S. W. (2017). In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. *Health Affairs, 36*(3), 564–71. https://doi.org/10.1377/hlthaff.2016.1231
57. Grogger, J. (2017). Soda taxes and the prices of sodas and other drinks: Evidence from Mexico. *American Journal of Agricultural Economics, 99*(2), 481–98. https://doi.org/10.1093/a jae/aax024
58. Caro, J. C., Corvalán, C., Reyes, M., Silva, A., Popkin, B., Taillie, L. S. (2018). Chile's 2014 sugar-sweetened beverage tax and changes in prices and purchases of sugar-sweetened beverages: An observational study in an urban environment. *PLoS Medicine, 15*(7), e1002597. https://doi.org/10.1371/journal.pmed.1002597
59. Schmacker, R., Smed, S. (2020). Do prices and purchases respond similarly to soft drink tax increases and cuts? *Economics and Human Biology, 37*, 100864. https://doi.org/10.1016/j.ehb.2020.100864

60. Pell, D. A. (2019). *Statistical models for estimating the intake of nutrients and foods from complex survey data* [Doctoral thesis]. https://doi.org/10.17863/CAM.33644

5 The association between adoption of the tax on SSB and publicly funded treated caries among children in Northern Ireland

Introduction

As noted in Chapter 2, there is little evidence regarding the impact of fiscal or other pricing instruments on health outcomes. This is an important gap in our current knowledge base and, as noted in Chapter 3, it contributes to uncertainty around the value of measures such as a tax on sugar-sweetened beverages (SSBs) or other nutrients in policy debate and public discourse.This uncertainty can undermine efforts to introduce such measures or to introduce them at levels that might be effective in changing behaviours.

On 16 March 2016, the UK Chancellor of the Exchequer announced plans to introduce a tax on SSBs in the UK[1]. The tax, which was subsequently adopted in April 2018, operated in tiers. At the higher tier, drinks with more than 8g of sugar per 100ml were taxed at £0.24 per litre; at the lower tier, drinks with more than 5g but less than 8g of sugar per 100ml were taxed at £0.18 per litre. Drinks with less than 5g of sugar per 100ml were not taxed[2]. The adoption of the tax was in part influenced by arguments as to the relationship between high consumption of SSBs, obesity[3], type 2 diabetes[4], cardiovascular disease[5] and dental caries[6]. Northern Ireland, which was covered by the tax, was reported to have the highest consumption of SSBs of any UK region prior to the introduction of the tax[6] and is known to have a high prevalence of obesity, cardiovascular disease and the worst oral health of any UK region for children[7]. It also exhibits sharp inequalities, related to socio-economic status, in oral health care among children and adolescents[8,9].

The SSB tax introduced in the UK was coordinated with the adoption of a tax in Ireland which mirrored the tiered structure in the UK[10]. This made it less likely that the effect of the tax would be dissipated through substitution of products between the two parts of the island. The tax was explicitly designed to encourage manufacturers of SSBs to reduce the sugar

content of their products. Thus, the tax was announced two years before its adoption to give manufacturers time to reformulate their products. It was levied on manufacturers or importers of SSBs rather than consumers – supposedly directly targeting the behaviour of manufacturers and importers and indirectly the behaviour of consumers. The tax was tiered to sharpen the penalty in line with increasing sugar content. A number of reviews, including those referenced in Chapter 2, suggest that taxes on foods with harmful content in general (including SSBs in particular) are associated with a decrease in sales, purchasing and consumption[11]. More recent findings support this conclusion[12-16]. Although price is one important mediator of these changes, other potential mechanisms include reformulation of products to reduce sugar concentration. "Guilt by association" also affects consumption, in the sense that SSBs (or others with harmful content) are linked with products such as tobacco and alcohol that are similarly taxed because of their harmful effects on health[17].

With specific regard to SSBs, the change in consumption as well as substitution within the SSB range in favour of beverages with less sugar should, logically, produce changes across various aspects of health, including obesity, type 2 diabetes, cardiovascular disease and dental caries. Recent evidence indeed points to a reduction in sugar consumption, as distinct to SSB consumption, within one year of the tax's adoption in Great Britain[2]. The study by Pell et al[2] based on sales data suggests that, compared with estimates of sugar consumption based on pre-announcement trends, the purchased volume of drinks in the high levy tier decreased by 155ml (95% confidence interval 240.5 to 69.5ml) per household per week, equivalent to 44.3% (95% confidence interval 59.9% to 28.7%), and sugar purchased in these drinks decreased by 18.0g (95% confidence interval 32.3 to 3.6g), or 45.9% (68.8% to 22.9%). Purchases of low-tier drinks decreased by 177.3ml (225.3 to 129.3ml) per household per week, or 85.9% (95.1% to 76.7%), with a 12.5g (15.4 to 9.5g) reduction in sugar in these drinks, equivalent to 86.2% (94.2% to 78.1%). Logically, such reductions should translate into effects on health. As noted with respect to tertiary outcomes in Chapter 2, however, real-world evidence (RWE) here is not strong[18-20]. As noted, Sisnowski et al (2017)[20] found little evidence that taxes impacted on health, findings echoed in more recent reviews by Lhachimi et al[18] and Pfinder et al[19]. Evidence of a health effect thus remains elusive. (It is noteworthy, moreover, that the study by Pell et al[2] did not identify changes in Northern Ireland separately.)

The limited evidence of health effects from SSB taxes, however, likely relates in part at least to the difficulty of linking taxes explicitly to changes in health. As noted, a price increase due

to a new tax is only one of a number of ways by which a tax on sugar might affect consumption. Others include the success or otherwise of reformulating products, or the moral pressure around suggesting SSBs may be harmful. Moral arguments may be raised in public discourse around the role of SSBs in a healthy diet before a tax is announced, as well as in public information at the time it is announced and then introduced. It therefore becomes difficult to identify an appropriate time to test for a change in purchase or consumption of SSBs.

Even allowing for the potential of a tax to affect consumption, however, further factors may mediate the impact of consumption on health. While increased consumption of sugar may increase the risks of obesity, type 2 diabetes, cardiovascular disease and dental caries, these effects will take time to emerge (or recede) and a variety of factors, including other dietary and lifestyle habits, may increase or mitigate any risk. Dental caries may demonstrate a more direct link between sugar and health compared, for example, to cardiovascular disease or type 2 diabetes, in part because caries may develop more quickly. In consequence, dental caries may offer a better marker of health effects. Indeed, there is evidence directly linking dental caries to consumption of SSBs, and disease increases in line with rising consumption (dose response)[21]. Modelling studies have also suggested that a tax on SSBs may reduce the prevalence of caries[22-24] .

However, it takes some time as well as sugar and bacteria to develop caries, and this makes it difficult to isolate the role of sugar in the emergence of the disease. By extension, it is also difficult to tell how far changes in the prevalence of dental caries are attributable to changes in consumption of SSBs in the wake of a tax. It may be more practical to collect evidence on dental treatment as a surrogate measure of health, rather than assess actual health. However, valid and easily measurable outcomes in dentistry are scarce because they are mediated by variable factors such as diet and personal oral hygiene. These have bedevilled efforts to set up an effective system of reimbursement in dentistry[25,26]. While treatment patterns may provide a useful surrogate measure of health for assessing the effect of a tax, the mediating variables continue to apply. For example, if better oral health means less income for dentists, they may respond by lowering the threshold at which they choose to treat carious teeth. This change could mask the effect of a tax as measured by treatment patterns on caries[27,28]. In short, gathering evidence for the impact of a tax on health is not

straightforward. While it may be easier to obtain evidence from caries than from other conditions, significant challenges remain.

The aim of this study was to examine changes in the provision of restorative care (treatment of caries) in Northern Ireland when the tax on SSBs was adopted. Dental care as opposed to other aspects of health or oral health was chosen for practical reasons. We contend that the impact of any change in consumption on other aspects of health would take longer to emerge and involve more variability than is the case for caries. Oral health care was chosen rather than oral health because no oral health surveys coincided with the introduction of the tax and could not therefore be used to investigate its effect. The study was confined to Northern Ireland as no comparable data was available in Ireland or across Britain to support such an analysis.

Materials and methods

Materials

Data were taken from the Northern Ireland Regional Maternity system (NIMATs)[29] and linked with data from the dental reimbursement system in Northern Ireland. NIMATs contains a range of demographic and clinical information on mothers and infants. It captures data relating to the current complete maternity process and contains details about the mother's past medical and obstetric history, including gestational diabetes. It is a key source for data on birth numbers, interventions, maternal risk factors, birth weights, gestational age, maternal smoking, BMI, and breastfeeding on discharge. Data were taken from NIMATs to identify children born before and after the adoption of the tax on SSBs, as well as socio-demographic characteristics of their mothers that may affect subsequent use of dental care. By focusing on young children, we expected to gain more clarity on the possible effect of the tax, as the cumulative effects of lifestyle would be less developed than in adults or older children.

In Northern Ireland, dental care is provided primarily through a system of independently employed general dental practitioners (GDPs)[30]. This is supported by the community dental service, which provides care to special needs groups, and the Royal Dental Hospital, which houses the Dental Education Centre and provides specialist services on a referral basis and services to at-risk groups who would not normally be treated by GDPs. All normally resident children are entitled to a range of services provided free at the point of care, usually without

restrictions on frequency. In this respect, the service could be described as demand led, although access to orthodontic care is conditional on meeting a particular level of need. GDPs are reimbursed by a combination of fee-for-service payments, capitation-based payments and grants. Compared to England and Wales, the dental fee system in Northern Ireland is graded in much more detail. The Statement of Dental Remuneration (SDR)[31] identifies precisely the nature of the care provided – for example, specific codes covering types of fillings. As dentists submit claims for remuneration on a monthly basis, and presumably without delay, we can identify changes in the type of care they provide from month to month, and relate these changes to the timing of the tax.

Data on children born from 2012 up to 2017, as gathered from NIMATs via their mother's health and care number, were linked to the child's subsequent health and care number (when registered with a GP) and on to their subsequent use (if any) of dental care. Dental care data covered the period from January 2015 up to September 2021, including the period in which the tax was adopted. Children in NIMATs whose records were not included in the dental utilisation data were assumed not to have used dental services. The starting point of 2012 was chosen based on the accuracy of maternal electronic records from 2012 onwards.

Data were obtained through the Northern Ireland Honest Broker Service[32] – a service that allows researchers to access linked administrative healthcare data that has been anonymised. Mothers are linked to children through their respective health and care numbers at birth and can be treated as dyads for analytical purposes.

Methods

Dental restorative care was identified using SDR codes and the month in which claims were made for these. (See Appendix 5.1 for details of the codes used.) By using these codes it was possible to identify restorations (fillings) for cavities/caries.

NIMATs data were extracted on the mother's:

- Age at the birth (in years)
- Smoking status (smoker or non-smoker at child's birth)
- Marital status (married versus not married)
- Ethnic group (White versus other)
- Lone-parent status (whether the mother was a lone parent or not)

- Multiple deprivation index[33] (an area-based measure of deprivation based on the mother's address at the time of delivery, categorised in deciles and subsequently reduced to quintiles, 1 indicating the most deprived area)
- Employment status at the time of birth (i.e., employed or not)

To this was added the child's gestational age (the number of weeks gestation at which birth occurred) and age in months as measured at September 2021.

An emerging literature has demonstrated an association between gestational diabetes, developmental defects in dental enamel[34] and subsequent use of dental services[35]. These studies have been supported by others linking a range of birth outcomes to gestational diabetes mellitus (GDM), including macrosomia and caries[36]. While the studies remain tentative, being based on relatively small samples, they nevertheless highlight the existence of clinically plausible relationships that may be important to control for when examining figures on oral health or, as is the case here, use of dental treatments. Maternal GDM status was therefore also extracted for analysis (mother diagnosed with GDM, yes or no).

Three separate analyses were undertake, which we hoped would give us a clearer picture of the relationship between the tax on SSBs and dental care.

First, using the introduction of the tax as a discrete event, children were separated into two groups. We identified children aged two at April 2016)24 months before the tax's adoption_ – and calculated the number of instances when restorative care was claimed for them (and assumed to have taken place) in the succeeding 24 months. These data were compared with those of a group of children aged two at April 2018, for whom we calculated claims for restorative services up to the end of March 2020. March 2020 was chosen as a termination point to allow comparison across 24 months and because we were mindful of the possible effects on services of the lockdown arising from the COVID-19 pandemic, which came into effect at the end of March 2020. Age two was chosen somewhat arbitrarily but as approximately the age by which the first and possibly second molars will have erupted[37] and the risk of developing caries will have increased. By comparing the number of restorative claims in each group after age two, we hoped to identify a group of individuals who were as yet free of caries and were exposed to conditions before and after SSB taxation. Other things being equal, we expected the impact of the tax on sugar exposure to translate into differing needs for dental restoration treatment among these children.

Our hypothesis is: *those who were aged two in April 2018 would experiencefewer dental restorations than those aged 2 in April 2016.*

Comparison in this analysis was limited to those aged exactly two at these time points to sharpen focus on the impact of the tax as an event.

Second, to expand the number of children involved in the analysis while still treating the introduction of the tax as a discrete event, children in the sample groups were categorised as being aged two or over or as being aged under two (as distinct from exactly two) at the time point the tax was adopted (i.e. aged under 65 months in September 2021 or equal to or over 65 months in September 2021). The total number of claims for publicly funded restoration work (which was assumed to have taken place) in these two groups was calculated for each individual up to March 2020. Given a large number of zeros – children for whom no claim was made– both a zero-inflated Poisson model and zero-inflated negative binomial model were considered likely to be appropriate for a regression analysis examining the relationship between the imposition of the tax and the count of claims for restorative services. The imposition of the tax was the point at which there would be reduced need for dental care, that is, by potentially changing the sugar environment to which the child was exposed, the point at which the tax on SSBs was imposed was treated as the basis for the generation of structural zeros, i.e. the variable giving rise to the inflated number of zeros. The zero-inflated negative binomial may be a more accurate model than a zero-inflated Poisson model which, in addition to structural zeros, must also take account of over-dispersed claims. These occur where, for example, a few individuals have very many restorative claims. In explaining variation in the number of claims for restoration, the model also controlled for the child's age (measured in months at September 2021) whether the child was White, whether the child's mother was White, the mother's age, GDM status, lone-parent status, marital status, employment status, smoking status, multiple deprivation status (in quintiles) and the child's gestational age.

Our hypothesis is: *the dummy variable categorising children as aged younger than two at the introduction of the tax in April 2018 would be more likely to exhibit a structural zero and have fewer restoration claims than those who were aged two or over at the introduction of the tax.*

While not the primary focus of this analysis, we further hypothesised that the child's age, being White and their gestational age would correlate to a higher number of restoration

claims. This is because older children would, other things being equal, be exposed for longer to sugar; White children may be less likely to exhibit a 'healthy migrant effect'; and being born pre-term has been linked to higher rates of dental caries[38]. We hypothesised that maternal smoking, lone parenting and GDM status would also be positively related to dental caries. This is because smoking is related to lower levels of health literacy; lone-parent status is likely to mean the parent has less time to supervise tooth brushing; and GDM as noted is associated with defects in enamel[34]. We hypothesised that being an older mother, married, White, employed and in a more affluent area would all be associated with a lower number of restorations, whether through access to greater family support or greater health literacy.

Third, we partitioned the sample based on those who were aged under 65 months in September 2021 (that is, aged under two when the tax was introduced in April 2018) and those who were aged 65 months or older in September 2021 (2 or older when the tax was introduced). We considered age two to be the time from which teeth were exposed to sugar and therefore at risk of caries. Separately for the two groups, we examined the time to first restoration using a Cox proportional hazards model. The termination date was the date of the child's first dental treatment – or March 2020 where no earlier treatment had been noted. March 2020 was chosen because that was when the COVID-19 lockdown started, bringing a potential change in subsequent behaviour. The same covariates used in the count model – deprivation and maternal and child characteristics – were used in the survival models.

Our hypothesis is: age will shorten the time before the first dental restoration treatment among those whose teeth were exposed to more sugar – i.e. aged two or over when the tax was introduced – compared to those who were solely exposed to lower levels of sugar under the SSB tax. That is, the coefficient on age will be greater than one and higher in the model for those aged two or over at the introduction of the tax than in the model for those aged under two.

Again, while not the focus of our analyses, our hypotheses with respect to the role of other covariates is consistent with that detailed in the count model: maternal GDM, smoking, lone-parenting, deprivation status and the child's gestational age tend to shorten the time to the first restoration by extending the time exposed to sugar (the gestational age weakening the enamel). Other variables are explained again by health literacy (e.g. maternal age) or having too little time to supervise tooth brushing (e.g. due to marital status).

Results

Table 1 presents descriptive statistics for the sample. As can be seen, the mean age at September 2021 was approximately 82 months (i.e. almost seven years old), the average age of mothers was 30, almost 15% of mothers were smokers, almost 85% were White, approximately 51% were married, 75% were employed and 5% were lone-parents. Approximately 71% of children were White and the mean gestational age was almost 39 weeks.

Table 1

				Mean	Std. Err.	[95% conf. Interval]	
No of restoration claims to March 2020				0.510464	0.005089	0.500489	0.520439
Child's age in months at sept 21				82.186	0.055099	82.07801	82.294
Mother's smoking status		(yes)		0.149196	0.000956	0.147322	0.151069
Child's ethnicity White				0.71456	0.001212	0.712185	0.716935
Mother's ethnicity White				0.846852	0.000966	0.844958	0.848746
Mother married				0.507649	0.001341	0.50502	0.510278
Mother's age at child's birth				30.0066	0.014916	29.97737	30.03584
Mother a lone parent				0.050905	0.00059	0.049749	0.052061
Child's gestational age (weeks)				38.99716	0.005402	38.98657	39.00774
Multiple deprivation quintile							
1	(lowest)			0.228372	0.001126	0.226164	0.23058
2				0.217537	0.001107	0.215368	0.219707
3				0.2067528	0.001087	0.204623	0.208883
4				0.193082	0.001059	0.191006	0.195157
5	(highest)			0.154257	0.000969	0.152357	0.156156

Mother had gestational diabetes				0.052612	0.000599	0.051437	0.053786
Mother employed				0.747504	0.001166	0.745219	0.749788
Time period after the tax				0.251431	0.001164	0.249149	0.253712

Number of observations = 138,905

Table 2 reports the mean number of claims for children aged two in April 2016 in the subsequent 24 months, together with those for children aged two in April 2018. As can be seen, while the mean is lower in the group aged two in 2018 the confidence intervals overlap, indicating that the difference is not statistically significant. (The lower number involved in the analyses is because the analyses relate to live births in a particular month of two particular years, not those over the entire study period.)

Table 2 Mean number of restoration claims for children aged two in April 2016 in subsequent 24 months

Number of obs	2, 037				
		Mean	Std. Err.		
Number of restoration claims 1		0.047619	. 0102105	0.027595	0.067643
Mean number of restoration claims for children aged two in April 2018 in subsequent 24 months					
Number of obs	2, 034				
		Mean	Std. Err.	095* conf. Interval]	
Number of restoration claims		0.034907	. 007563	0.020075	0.049739

Table 3 reports the results of the zero-inflated negative binomial regression. While controlling for other things (including age as a continuous variable), it shows that children aged under two at the time the tax was adopted had fewer claims for restorative care. That is, being exposed to the post-tax environment was protective. other things being controlled for in terms of restorations. While not the primary focus of this study, it is noted that having an

older, employed, White and less deprived mother were also protective factors. Having a mother who was a smoker was disadvantageous, as was the child being White, having a longer gestation and being older.

Tables 4a and 4b present the results of the survival analysis. Comparing across models, the higher value attached to the coefficient on age in the model for those aged two or over when the tax was introduced suggests length of exposure is significant here but is not significant in the model for those aged under two when the tax was introduced. While not the focus of attention here, the role of other variables is broadly in line with expectations in the case of older children. Affluence and having an older and White mother are all protective. With respect to younger children, it appears to be a disadvantage to have a lone-parent and White mother, the latter in contrast to the result for older children.

Table 3 Zero inflated negative binomial regression

No of restoration claims to March 2020	Coef .	Std. Err .		P> l z l	[95* conf. Interval]	
Child' s age in months at Sept 21	0.0664131	0.0011509	57.71	0.00	0.0641574	0.0686688
Mother's smoking status (yes)	0.2199937	0.0281066	7.83	0.00	0.1649057	0.2750817
Child's ethnicity White	0.269171	0.0348003	7.73	0.00	0.2009636	0.3373784
Mother's ethnicity White	0.106796	0.0303902	-3.51	0.00	0.1663597	0.0472323
Mother married	0.1036919	0.0222489	-4.66	0.00	0.147299	0.0600848
Mother's age at child's birth	0.007117	0.0019839	-3.59	0.00	0.0110053	0.0032286
Mother a lone parent	0.0368767	0.0419593	0.88	0.379	0.045362	0.1191154
Child's gestational age (weeks)	0.0362158	0.0054481	6.65	0.00	0.0255377	0.0468939
Multiple deprivation quintile						
NIMDMx						
2	0.196945	0.0295474	-6.67	0.00	-0.2548569	-0.1390331
3	0.1397475	0.0301951	-4.63	0.00	-0.1989289	-0.0805662
4	0.243712	0.0312364	-7.8	0.00	-0.3049341	-0.1824898
5 (highest)	0.6149067	0.034959	-17.59	0.00	-0.683425	-0.5463884

Mother had gestational diabetes	0.0344874	0.0494559	0.7	0.486	-0.0624444	0.1314192
Mother employed	0.2406642	0.0235093	-10.24	0.00	-0.2867416	-0.1945867
cons	-7.548625	0.2728303	-27.67	0.00	-8.083362	-7.013887
inflate Time period after the tax	3.725997	0.3414049	10.91	0.00	3.056856	4.395138
cons	-1.593328	0.4201627	-3.79	0.00	-2.416832	-0.7698243
/ Inalpha	1.828656	0.0934593	19.57	0.00	1.645479	2.011833
alpha	6.225513	0.5818322			5.183492	7.477008

Number of observations = 138,905 LR chi²(14) = 6850.91 Prob>chi² = 0.000

Number of non-zero observations = 18,472 Log Likelihood = -86623.6

Table 4a Time to first restoration for those aged less than 2 when the tax was introduced

Cox regression model

					Robust	z			
				Ha z. Ratio	Std. Err.		P> l z l	[95% conf. Interval]	
Multiple deprivation quintile									
N IMDMX									
2				2.038669	1.602149	0.91	0.365	0.436923	9.512376
3				1.637602	1.34462	0.6	0.548	0.327563	8.186949
4				1.16697	1.018972	0.18	0.86	0.210771	6.461152
5				1.408271	1.280657	0.38	0.707	0.236929	8.37055
Child's age in months at sept 21				1.039259	0.05884	0.68	0.496	0.930104	1.161225
Mother's smoking status	(yes)			2.852533	1.601044	1.87	0.062	0.949458	8.57009
Child's ethnicity White				0.184537	0.203953	-1.53	0.126	.0.211505	1.61007
Mother's ethnicity White				1.86+15	1.22+16	5.34	0	4.60+09	7.50+20
Mother a lone parent				1.09E-16	4.91E-17	-81.75	0	4.52E-17	2.63E-16
Mother married				0.887162	0.457656	-0.23	0.816	0.322773	2.438416
Mother's age at child's birth				1.055062	0.043859	1.29	0.197	0.972508	1.144623

Mother had gestational diabetes				1.598651	1.773539	0.42	0.672	0.181733	14.06289
Mother employed				1.62848	1.031323	0.77	0.441	0.470666	5.634452
Child's gestational age (weeks)				1.588155	0.40209	1.83	0.068	0.966908	2.60856

Number of observations = 34,925, Number of subjects = 34,925, Number of failures = 13

Wald chi^2 = 19230.76, Prob>chi^2 = 0.00

Table 4b Time to first restoration for those aged 2 or more when the tax was introduced

Cox regression

					Robust	z			
				Haz. Ratio	Std. Err.		P> z	[95% Conf . Interval]	
Multiple deprivation quintile									
		NIMDMX							
		2		0.8188408	0.0460228	-3.56	0	0.7334285	0.9141999
		3		0.8466921	0.0488956	-2.88	0.004	0.7560831	0.9481597
		4		0.7932188	0.0478672	-3.84	0	0.7047365	0.8928105
		5		0.6794926	0.0471404	-5.57	0	0.5931055	0.7784622
Child's age in months at Sept 21				1.084696	0.0030279	29.12	0	1.078777	1.090646
Mother's smoking status	(yes)			1.039412	0.0557988	0.72	0.471	0.9356053	1.154736
Child' s ethnicity White				1.161241	0.0944613	1.84	0.066	0.9901054	1.361958
Mother's ethnicity White				0.8748523	0.0400832	-2.92	0.004	0.7997148	0.9570494
Mother a lone parent				0.9897323	0.0721106	-0.14	0.887	0.8580259	1.141656
Mother married				0.9946906	0.0446017	-0.12	0.905	0.9110041	1.086065
Mother's age at child' s birth				0.9864175	0.0039945	-3.38	0.001	0.9786194	0.9942777
Mother had gestational diabetes				0.872462	0.106788	-1.11	0.265	0.6863739	1.109002

Mother employed				0.9536573	0.0447811	-1.01	0.312	0.8698058	1.045592
Child's gestational age (weeks)				1.050008	0.0096669	5.3	0	1.031231	1.069127

Number of observations = 103,980, Number of subjects = 103,980, Number of failures = 2,645

Wald chi^2 = 2685.31, Prob>chi^2 = 0.00

Discussion

A body of work suggests that taxes on SSBs reduce the amount purchased, as would be expected. As noted, however, data relating such taxes to tertiary outcomes (e.g., effect on bodyweight or NCDs) are scarce. Sisnowski et al (2017)[20] found little evidence that taxes impact on health and these findings were echoed in more recent reviews by Lhachimi et al[19] and Pfinder et al[18]. Evidence of a health effect thus remains elusive. As noted in Chapter 3, this may have important implications for seeking public support and countering the narratives promoted by industry about taxes. The evidence presented here suggests that taxes on SSBs in Northern Ireland may have had a beneficial effect on health, measured in terms of dental claims for restorations among children. In looking at the time elapsing before a child's first dental fillings, several variables are consistent with the argument that this age-group needed less treatment for dental caries after the taxation of SSBs: the comparison of means, the count of restorative claims and the changing role of age. This is in turn consistent with the argument that a child's exposure to sugar reduced in the wake of the tax. Dental treatment may thus provide a sentinel indicator of other future health effects. This is consistent with studies that have demonstrated a dose response – the more SSBs are consumed, the more cases of and treatment for dental caries are counted[21] – and with existing evidence indicating less consumption of SSBs in the wake of a tax.

Our findings with respect to the role of other variables are interesting but are beyond the scope of this analysis.

The evidence presented here must, however, be handled with care and treated as tentative. Oral health has improved in Northern Ireland over time and the trends reported here may therefore fit as part of an overall trend independent of the tax. For example, the percentage of children who were registered with a dentist and received a filling was static between 2017/18 and 2018/19 at 22.1% before falling in 2019/20 to 21.0%. However, a downward trend had

preceded the 2017 figures, where the percentage fell from 26.1% in 2013 to 23.1% in 2017[39]. The stability in the period immediately preceding the tax may lend support to the argument for a 'tax effect'. But it must be remembered that caries needs time to develop, in addition to bacteria and sugar, and we should bear in mind the possible time lag before it shows up, as well as the time involved in reformulating products and seeing results. It is important also to consider restorations within a context of other dental care children may receive as well as demand based around needs. For example, we did not control for use of preventive dental services prior to restorative treatments for caries in our analysis. These could well have affected the risk of dental caries, independent of exposure to sugar. Trends with respect to these preventive services may have changed over time. Similarly, we cannot discount broader trends, such as a demand from private patients that may impact on the opportunity cost of treating public patients and with it the number of treatments provided to public patients. That is, dentists may offer fewer publicly funded treatments because these take up time they could otherwise spend on better-paid private work. Clearly, the COVID-19 pandemic has limited our research also by restricting the period of follow-up available for children, in particular younger children who are more likely to have benefited from the tax on SSBs. Before firmer conclusions can be drawn, further work is needed, in particular controlling for previous exposure to preventive care.

Further research may adopt a different approach to that used here. For example, it could be based on matching (ensuring the same variables apply to all the groups under investigation), which may provide more robust evidence as to the impact (if any) of SSBs on treated caries.

Conclusions

Our analysis suggests the tax on SSBs was associated with a decline in treated caries when controlling for other variables in Northern Ireland. Further research is needed, however, that takes into account the role of prevention and the potential for pre-existing trends to impact on the treatment of caries, before firmer conclusions can be drawn.

Acknowledgements

The authors would like to acknowledge the help provided by the staff of the Honest Broker Service (HBS) within the Business Services Organisation Northern Ireland (BSO). The HBS is funded by the BSO and the Department of Health (DoH). The authors alone are responsible for

the interpretation of the data, and any views or opinions presented are solely those of the authors and do not necessarily represent those of the BSO.

References

1. Jones, C. The UK sugar tax – a healthy start? (2016). *British Dental Journal, 221,* 59–60. https://doi.org/10.1038/sj.bdj.2016.522

2. Pell, D., Mytton, O., Penney, T. L., Briggs, A., Cummins, S., Penn-Jones, C. et al. (2021). Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: Controlled interrupted time series analysis. *BMJ, 372*, n254. doi:10.1136/bmj.n254

3. http://apps.who.int/iris/bitstream/handle/10665/260253/WHO-NMH-PND-16.5Rev.1-eng.pdf Accessed March 2022.

4. Imamura, F., O'Connor, L., Ye, Z., et al. (2015). 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. *BMJ, 351*, h3576. doi:10.1136/bmj.h3576

5. Xi, B., Huang, Y., Reilly, K. H., et al. (2015). Sugar-sweetened beverages and risk of hypertension and CVD: A dose-response meta-analysis. *British Journal of Nutrition, 113*, 709-17. doi:10.1017/S0007114514004383

6. Moynihan, P. J., Kelly, S. A. M. (2014). Effect on caries of restricting sugars intake: Systematic review to inform WHO guidelines. *Journal of Dental Research, 93,* 8-18. doi:10.1177/0022034513508954

7. Briefing-Child-oral-health-Northern-Ireland-March-2018.pdf (bda.org) Date of access - March 2022

8. Telford, C. and O'Neill, C. (2012). Changes in dental healthcare registration across the adolescent years: Northern Ireland longitudinal study. *British Dental Journal, 212*(9), 1-6.

9. Telford, C., Murray, L., Donaldson, M., O'Neill, C. (2012). An analysis examining socio-economic variations in the provision of NHS general dental practitioner care under a fee for service contract among adolescents: Northern Ireland longitudinal study. *Community Dentistry and Oral Epidemiology, 40*(1), 70-9.

10. https://www.revenue.ie/en/companies-and-charities/excise-and-licences/sugar-sweetened-drinks-tax/index.aspx Accessed March 2022

11. Teng, A. M., Jones, A. C., Mizdrak, A., Signal, L., Genç, M., Wilson, N. (2019). Impact of sugar-sweetened beverage taxes on purchases and dietary intake: Systematic review and meta-analysis. *Obesity Reviews, 20*, 1187-204. doi:10.1111/obr.12868

12. Alvarado, M., Unwin, N., Sharp, S. J., et al. (2019). Assessing the impact of the Barbados sugar-sweetened beverage tax on beverage sales: An observational study. *International Journal of Behavioral Nutrition and Physical Activity, 16*, 13. doi:10.1186/s12966-019-0776-7

13. Roberto, C. A., Lawman, H. G., LeVasseur, M. T., et al. (2019). Association of a beverage tax on sugar-sweetened and artificially sweetened beverages with changes in beverage prices and sales at chain retailers in a large urban setting. *JAMA, 321.* 1799-810. doi:10.1001/jama.2019.4249

14. Royo-Bordonada, M.A., Fernández-Escobar, C., Simón, L., SanzBarbero, B., Padilla, J. (2019). Impact of an excise tax on the consumption of sugar-sweetened beverages in young people living in poorer neighbourhoods of Catalonia, Spain: A difference in differences study. *BMC Public Health, 19*, 1553. doi:10.1186/s12889-019- 7908-5

15. Cawley, J., Frisvold, D., Hill, A., Jones, D. (2019). The impact of the Philadelphia beverage tax on purchases and consumption by adults and children. *Journal of Health Economics, 67*, 102225. doi:10.1016/j. jhealeco.2019.102225

16. Lee, M. M., Falbe, J., Schillinger, D., Basu, S., McCulloch, C. E., Madsen, K. A. (2019). Sugar-sweetened beverage consumption 3 years after the Berkeley, California, sugar-sweetened beverage tax. *American Journal of Public Health, 109*, 637-9. doi:10.2105/AJPH.2019.304971

17. Penney, T., Adams, J., Briggs, A., et al. (2017). Theorising how the UK Soft Drinks Industry Levy could impact population level diet and health: Development of a multi-sectoral systems map. *International Society for Behavioural Nutrition and Physical Activity*.

18. Pfinder, M., et al. (2020). *Taxation of unprocessed sugar or sugar-added foods for reducing their consumption and preventing obesity or other adverse health outcomes.* Cochrane Database of Systematic Reviews, 2020(4), 74.

19. Lhachimi, S. K., et al. (2020). *Taxation of the fat content of foods for reducing their consumption and preventing obesity or other adverse health outcomes.* Cochrane Database of Systematic Reviews, 2020(9).

20. Sisnowski, J., Street, J. M., and Merlin, T. (2017). *Improving food environments and tackling obesity: A realist systematic review of the policy success of regulatory interventions targeting population nutrition. PLoS ONE, 12*(8).

21. Valenzuela, M. J., Waterhouse, B., Aggarwal, V. R., Bloor, K., Doran, T. (2021). Effect of sugar-sweetened beverages on oral health: A systematic review and meta-analysis. *European Journal of Public Health*, *31*, (1), 122–129. https://doi.org/10.1093/eurpub/ckaa147

22. Urwannachotima, N., Hanvoravongchai, P., Ansah, J.P., et al. (2020). Impact of sugar-sweetened beverage tax on dental caries: A simulation analysis. *BMC Oral Health, 20*(76). https://doi.org/10.1186/s12903-020-1061-5

23. Jevdjevic, M., Trescher, A. L., Rovers, M., Listl, S. (2019). The caries-related cost and effects of a tax on sugar-sweetened beverages. *Public Health, 169*, 125-132. doi: 10.1016/j.puhe.2019.02.010. Epub 2019 Mar 16. PMID: 30884363.

24. Schwendicke, F., Thomson, W. M., Broadbent, J. M., Stolpe, M. (2016). Effects of taxing sugar-sweetened beverages on caries and treatment costs. *Journal of Dental Research, 95*(12), 1327-1332. doi: 10.1177/0022034516660278. Epub 2016 Oct 1. PMID: 27671690.

25. Grytten, J. (2017). Payment systems and incentives in dentistry. *Community Dentistry and Oral Epidemiology, 45*, 1-11.

26. Tickle, M., McDonald, R., Franklin, J., Aggarwal, V., Milsom, K. and Reeves, D. (2011). Paying for the wrong kind of performance? Financial incentives and behaviour changes in National Health Service dentistry 1992-2009. *Community Dentistry and Oral Epidemiology, 39*, 465-473.

27. Birch, S. (1988). The identification of supplier-inducement in a fixed price system of health care provision. The case of dentistry in the United Kingdom. *Journal of Health Economics, 7*(2), 129-50. doi: 10.1016/0167-6296(88)90012-4. PMID: 10288955

28. Gottschalk, F, Mimra, W., and Waibel, C. (2019). *Health services as credence goods: A field experiment* (October 2019). Available at SSRN: https://ssrn.com/abstract=3036573 or http://dx.doi.org/10.2139/ssrn.3036573

29. https://web.www.healthdatagateway.org/dataset/89d76819-32cb-48ad-9337-880f324a6ec0 Accessed March 2022

30. https://www.euro.who.int/__data/assets/pdf_file/0020/178040/E96724.pdf Accessed March 2022

31. https://hscbusiness.hscni.net/pdf/SDR_2020-21.pdf Accessed March 2022

32. https://hscbusiness.hscni.net/services/2454.htm Accessed March 2022

33. https://www.nisra.gov.uk/statistics/deprivation/northern-ireland-multiple-deprivation-measure-2017-nimdm2017 Accessed March 2022

34. Pascon, T., Barbosa, A. M. P., Cordeiro, R. C. L., Bussaneli, D. G., Prudencio, C. B., Nunes, S. K., et al. (2019) Prenatal exposure to gestational diabetes mellitus increases developmental defects in the enamel of offspring. *PLoS ONE 14*(2), e0211771. https://doi.org/10.1371/journal.pone.0211771

35. Ghapanchi, J., Kamali, F., Siavash, Z., Ebrahimi, H., Pourshahidi, S., Ranjbar, Z. The Relationship between Gestational Diabetes, Enamel Hypoplasia and DMFT in Children: A Clinical Study in Southern Iran *British Journal of Medicine & Medical Research 10(9): 1-6, 2015, Article no.BJMMR.19574 ISSN: 2231-061.*

36. Yokomichi, H., Tanaka, T., Suzuki, K., Akiyama, T.; Okinawa Child Health Study Group, Yamagata, Z. (2015). Macrosomic neonates carry increased risk of dental caries in early childhood: Findings from a cohort study, the Okinawa child health study, Japan. *PLoS One, 10*(7), e0133872. doi: 10.1371/journal.pone.0133872. eCollection 2015

37. https://www.mouthhealthy.org/en/az-topics/e/eruption-charts Accessed March 2022

38. Tanaka, K., Miyake, Y. (2014). Low birth weight, preterm birth or small-for-gestational-age are not associated with dental caries in young Japanese children. *BMC Oral Health 14*(38). https://doi.org/10.1186/1472-6831-14-38

39. https://hscbusiness.hscni.net/pdf/General%20Dental%20Statistics%20Publication%202001920%20-%20Revised.pdf Accessed March 2022

Appendices

Appendix 5.1

Statement of Dental Remuneration codes

Restoration

SDRcodes: 1401, 1405, 1406, 1407, 1421, 1422, 1423, 1424, 1426, 1411, 4401, 4402, 1402, 1403, 1404, 1408, 1425, 1431, 1441, 1461, 1471, 3611, 5001, 5815, 5816, 5817, 5821, 5822, 5823, 5826, 6001, 6301, 5041

Extraction

SDRcodes: 2101, 2121, 2201, 2203, 2221, 5201, 5206

6 Summary of key findings

Summative discussion

Poor diet is a major contributor to the rise in non-communicable diseases (NCDs) and has been causally implicated in the development of a range of conditions that include type 2 diabetes, cardiovascular disease and several cancers as well as overweight/obesity. Across the island of Ireland the prevalence of overweight and obesity is high, as are the costs associated with them in terms of healthcare and avoidable morbidity and mortality. A growing body of evidence points to the ability of taxes either used alone or with other measures to influence consumption. Our two umbrella reviews summarise the highest quality systematic review evidence currently available on 1) the effectiveness and 2) the acceptability of fiscal and pricing policies to improve diet and reduce diet-related NCDs. Our empirical studies contribute to the evidence base on the use of such instruments on the island of Ireland.

Our umbrella reviews focused on real-world examples of implemented policies so as to better understand their impact on diet, health and equity. We deliberately eschewed modelling studies, as their validity may be open to question – as might the motivation of the authors on occasion. We identified barriers and facilitators to policymaking, where these arose from industry or public opinion on the use of fiscal policies. While much of the real-world evidence concerns taxes on sugar-sweetened beverages (SSBs), we also found examples of taxes and subsidies on nutrients (i.e. nutrients in the supply chain rather than a single product such as SSBs).

A simple logic underpins fiscal and pricing measures to effect changes to diet and thereby health. Taxes that target harmful content (such as the tiered tax on sugar in SSBs) can change costs to manufacturers and encourage them to reformulate their products. The effectiveness of such taxes can be increased by allowing enough lead time for manufacturers to reformulate their products and offer consumers a new range of choices, thereby indirectly altering consumption patterns. Taxes such as sugar taxes, as well as those such as value-added taxes that target a product or class of product, can directly impact consumer choice by increasing the cost to consumers. This is because, depending on the price elasticity of demand (how demand changes in relation to price), manufacturers pass on some portion of

the tax in the form of price increases to consumers. As detailed in our first umbrella review, it is estimated that in the US, excise taxes on SSBs have a pass-through rate of 65% (95% CI: 50-79%) with significant *potential* to directly affect purchases. That said, many of the reviews we included in that umbrella review found that taxes often did not increase the price of a good to a sufficient degree to change behaviour. Studies have suggested that to be effective in changing consumption patterns, a tax should change the price of the good to consumers by 15-25%, a level that was not always achieved in practice.

Understandably perhaps, there is no real-world evidence that directly compared the effectiveness of value-added versus excise taxes within a single jurisdiction in terms of their impact on consumption behaviours. Sisnowski et al (2017) found that the tax changed the price of the good was more important than from whom the tax was collected or how. Logically, however, excise taxes should be more effective where people have only limited opportunities for cross-border shopping and therefore less opportunity to switch to lower-priced but equally unhealthy substitutes. The highest-quality reviews we found – the Cochrane reviews, which included a combined total of just four studies – suggest there is meagre evidence for the effectiveness of taxes on the sugar, fat or other nutrient content of foods in changing behaviour or health. On balance, however, there is sufficient existing and emerging evidence, including that from Pell et al on the tax adopted in the UK on SSBs, to suggest they can be effective in changing behaviour. Our own empirical work, while equivocal, supports this with respect to the effect of the tax on SSBs in Northern Ireland.

Our reviews suggest that, to be effective, fiscal interventions require a coordinated approach to limit the possibility for untaxed substitutes or non-taxed items from other jurisdictions to blunt the effect of a policy. The tax adopted by the UK and Ireland which targeted the harmful component – albeit within a single product – operated in a tiered fashion at a rate of 15-25%, which is considered effective. There was a gap between announcement and enactment to allow reformulation. This case appears to combine the beneficial elements of a policy and provide an exemplar for future actions. To convince the public as to the value of such a measure (and face down industry efforts to stifle it) it is essential to bolster the credibility of claims that the measure will be effective and that distributional effects on different socio-economic groups can be mitigated. As noted with respect to the intermediate effect on SSB consumption, there is credible real-world evidence as to the potential of such taxes. The

findings from our own empirical study suggest that consumption of SSBs in Northern Ireland have likely declined, though further work here is required.

While the argument that taxes or other pricing instruments can affect consumption goes deeper than a first impression, there is little direct evidence directly linking fiscal and pricing measures to health outcomes. Despite our predictions about consumption for the island of Ireland, our review found little direct real-world evidence of a positive impact on health arising from fiscal and pricing policies. The reviews of Sisnowski et al (2017), echoed in more recent reviews by Lhachimi et al (2020) and Pfinder et al (2020), underscore an important gap in the current evidence base. Our empirical work on the treatment of dental caries in Northern Ireland adds to the literature but as noted should be treated with caution. Further work is needed on this specific example, along with evidence on other health outcomes, though we recognise the challenges in producing it. For now, a combination of three factors suggests that fiscal and pricing policies can affect health: logic; evidence of the intermediate effects of policies on consumption; and evidence from our own empirical study on dental treatment as a surrogate for health effects. The distributional effects of a tax or pricing policy are an important dimension of the role of fiscal instruments. Distributional effects here relate to how outcomes as well as tax burdens are distributed. Our umbrella review found that diet-related taxes are regressive in that they impose a higher burden as a percentage of income on those with lower incomes – often those whose consumption of the products in question is highest.

However, the review suggests that this income-related inequity must be balanced against the health-related benefits which favour those on lower incomes. The potential to mitigate negative income effects by re-directing tax revenues to programmes that target lower income groups is also worth noting. While it may not be practicable to earmark the revenue from a tax for transfer payments (such as government benefit payments) or subsidies of healthier foods, for example, it may be feasible to track that revenue and invest funds to the same value in particular ways. As noted in our second umbrella review, such investments may be important in forging a consensus for further measures – beyond the current target of sugar in SSBs – and in countering narratives that may (as in the case of the fat tax in Denmark) see a fiscal measure withdrawn.

Along with concerns about the effectiveness and equity of diet-related fiscal and pricing measures, our second overview identified a number of other barriers and facilitators to their

acceptability. Facilitators include credible evidence on broader macro-economic variables such as unemployment. As noted, in the US industry-funded informational campaigns focusing on the costs of SSB taxes to the economy were successful in blocking municipalities from introducing beverage taxes and were a concern to both the public and policymakers. We found no compelling evidence – except from industry-funded modelling studies – that such concerns were warranted. Literature in the second umbrella review raised concerns that government actions may be motivated by the wish to increase taxable income. To succeed, a taxation policy must be implemented alongside a commitment to transparency in policymaking, especially when revenues are to be allocated to social and health initiatives, as has been demonstrated in the US.

Recommendations

Adopted at the correct level, fiscal measures have the potential to influence consumption, and may influence health. Hence, our work gives rise to the following recommendations to improve the effectiveness and acceptability of FIs:

- If the intention is to minimise the administrative burden, then a value-added tax may be most appropriate as this fits within the existing tax structure and automatically adjusts for inflation. However, it may drive consumers towards more unhealthy but cheaper goods.
- If the intention is to raise government revenue, then a lower (<15-25% increase in the price faced by consumers) ad-quantum tax on individual products may be most appropriate as it would provide a more consistent revenue stream. However, it may not change behaviour sufficiently to improve health.
- If the intention is to improve health (as was assumed to be the case in these reviews), then a higher (>15-25% increase in the price faced by consumers) ad-quantum tax on health-harming nutrients may be most appropriate as it would reduce leakage to cheaper alternative SSBs. Also, if announced far enough in advance of its introduction, this tax may encourage manufacturers to reformulate their products.
- To improve the acceptability of an FI, the government should:
    - Be clear about the intention and of the FI and how its design is fit for purpose
    - Provide credible evidence on how effectively FIs can achieve their goals
    - Set out measures to mitigate costs or create positive financial advantages for lower-income consumers (distributional effects)
    - Set measurable goals to assess how effectively the FI achieves its intention, and audit its progress
    - Promise to share information on progress towards the stated goals and mitigations
- In the cases of diet-related taxes specifically, government should:
    - Where feasible, target health-harming nutrients as opposed to individual products

    - Where this is not feasible, identify a list all health-harming products which may act as substitutes and may require taxation
    - Coordinate with neighbouring jurisdictions to avoid possible cross-border leakage
    - Undertake educational and promotional campaigns to highlight the potential of such instruments to improve health
    - Use revenues raised through such measures to mitigate costs to lower-income groups – for example, by subsidising fruit and vegetables – and promote these alternatives to the public
    - Audit and publicise the allocation of revenues to these initiatives
- In addition to promoting the positive intentions and impacts of taxes, government should counter opposition narratives about how taxes can damage the economy (e.g. causing unemployment), including by fact-checking and countering industry-sponsored studies.
- Furthermore, where opposition groups publicise anti-tax narratives, government should, as part of their promotion strategy, highlight the sources of this messaging and show how it stems from the biases of these groups.

safefood, 7 Eastgate Avenue,
Eastgate, Little Island,
Co. Cork, T45 RX01

safefood, Ascaill an Gheata Thoir,
An tOileán Beag,
Co. Chorcaí, T45 RX01

safefood, Aistyett Avenue,
Aistyett, Wee Isle,
Co. Cork, T45 RX01