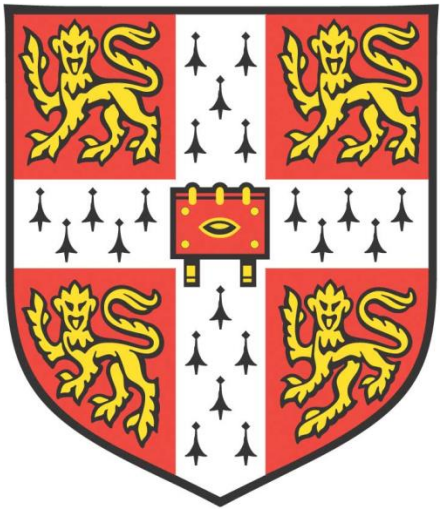
EVALUATING THE BARBADOS SSB TAX: A MIXED-METHOD NATURAL EXPERIMENTAL STUDY



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DECLARATION

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ABSTRACT

Evaluating the Barbados SSB tax:

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Consuming sugar-sweetened beverages (SSBs) has been associated with increased rates of obesity and type 2 diabetes, making SSBs an increasingly popular target for policy interventions such as taxation. SSB taxes are intended to reduce SSB consumption, and several national evaluations have suggested that they may be effective. However, SSB taxes have been implemented in diverse settings (e.g. in terms of baseline SSB consumption) and designed in a variety of ways (e.g. in terms of tax structure), with important implications for effectiveness.

The Government of Barbados introduced a 10% excise tax on SSBs in 2015. In this thesis, I evaluated the Barbados SSB tax with the aims of 1) evaluating the impact of Barbados SSB tax on price and sales change and 2) contributing to the development of broader SSB taxation theory. My research objectives were to assess 1) price change, 2) sales change, 3) how the tax design compared with pre-tax SSB consumption patterns, and 4) whether the introduction of the tax conveyed information about the health risks of SSBs (i.e. through a risk signalling effect). I used a mixed methods approach and analysed data from a major grocery store chain, a nationally representative cross-sectional survey, interviews with members of the public and archived media data.

My findings suggest that the tax was associated with an increase in the price of SSBs and a decrease in SSB sales, after controlling for pre-existing time trends, seasonality and other time-varying confounders. Prices of non-SSBs did not change and sales of non-SSBs were estimated to have increased. However, the Barbados SSB tax only addressed around 60% of SSB-related free sugars and did not clearly differentiate between high- and low-sugar SSBs. Finally, the Barbados SSB tax may have conveyed additional information about the health risks of sodas but not sugar-sweetened juice drinks.

In terms of theoretical contributions, I proposed three criteria to improve the design of SSB taxes using pre-existing nutritional survey data and operationalised legal theory

around an SSB taxation risk signaling effect. In addition, I found suggestive evidence that the introduction of an SSB tax may encourage industry to 1) increase SSB advertising (diminishing any potential risk signal) and/or 2) introduce low-cost SSBs (diminishing any potential price effect).

Overall, I suggest that the Barbados SSB tax may have reduced consumption of taxed SSBs but had several unexpected effects, with important implications from a health perspective. After considering these findings in the context of the broader SSB taxation evidence base, I identify a number of implications for policymakers, civil society organisations and future SSB tax evaluation teams. Finally, I suggest that evaluations of SSB taxes and other population-level health interventions may benefit from the integration of multiple types of evidence, a focus on eliminating alternative explanations and an emphasis on contributing to theory development.

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List of Abbreviations and Acronyms

$	US Dollar
%	Percentage
*	Indicates significance ($p<0.05$)
**	Indicates significance ($p<0.01$)
***	Indicates significance ($p<0.001$)
£	Great Britain Pound
<	Less than
>	Greater than
≤	Less than or equal to
≥	Greater than or equal to
Δ	Change in
Ad	Advertisement
ADA	Americans with Disabilities Act
ASB	Artificial sweetened beverages
AVE	Ad valorem equivalent
BMI	Body Mass Index
CARPHA	Caribbean Public Health Agency
CBC	Caribbean Broadcast Corporation
CHD	Coronary heart disease
CI	Confidence interval
CPI	Consumer price index
DALY	Disability adjusted life year
E.g.	Exempli gratia or 'for example'

Etc.	Et cetera or ‘and so forth’
EMIM	Monthly survey of manufacturing industry
FAO	Food and Agriculture Organisation
GBD	Global Burden of Disease
GDP	Gross domestic product
GST	Goods and service taxes
HANCI	Hunger and Nutrition Commitment Index
HS	Harmonised system
HCC	Healthy Caribbean Coalition
HotN	Health of the Nation
I.e.	Id est or ‘That is’
ITS	Interrupted time series
MAD	Moroccan dirham
MRC	Medical Research Council
N	Number (used to indicate number of participants in a study)
NCDs	Non-communicable diseases
Non-SSB	Non-sugar-sweetened beverage
p	P-value
PA	Physical activity
PAHO	Pan-American Health Organisation
PHI	Population-level health interventions
PPP	Purchasing power parity
PT	Process tracing
RCT	Randomised controlled trial
SD	Standard deviation
SDG	Sustainable Development Goal

SEP	Socio-economic position
SIDS	Small Island Developing State
SSB	Sugar-sweetened beverage
STROBE-nut	Strengthening the Reporting of Observational studies in Epidemiology (nutritional epidemiology extension)
UK	United Kingdom
UK SDIL	UK Soft Drinks Industry Levy
UNICEF	United Nations Children's Fund
US	United States of America
VAT	Value added tax
WHO	World Health Organisation
WCRF	World Cancer Research Fund
YLL	Years of life lost
ZAR	South African rand

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1 BACKGROUND

1.1 Global Burden of Non-Communicable Diseases

1.1.1 Global levels and trends of non-communicable diseases

In 2016, over 15 million people died between the ages of 30 and 70 from non-communicable diseases (NCDs).[1] Four major NCDs accounted for 80% of total NCD deaths: cardiovascular diseases, cancers, chronic respiratory diseases and diabetes.[1] In most countries (including many low- and middle-income countries), the likelihood of dying before the age of 70 due to an NCD is higher than the likelihood of dying due to communicable, maternal, perinatal and nutritional conditions combined.[1] Given population growth and ageing trends, the absolute number of people living with an NCD will continue to rise.[2] NCDs are projected to account for an increasing proportion of years of life lost (YLLs), from 51.7% in 2016 to 67.3% by 2040.[3] The economic burden due to NCDs is also projected to increase, nearly doubling from 2010 to 2030.[2]

1.1.2 Global levels and trends of obesity and overweight

High body mass index (BMI) is one of the major risk factors associated with NCDs, accounting for 4.7 million deaths worldwide in 2017.[4] High BMI has been defined as overweight (BMI≥25 kg/m^2 and <30 kg/m^2) and obesity (BMI≥30 kg/m^2) combined. A five kg/m^2 higher BMI has been associated with the risk of developing diabetes,[5]

ischemic heart disease,[5] hypertensive heart disease,[5] some cancers[6,7] and other NCDs.[5] In an analysis by Stanaway et al., rates of high BMI increased more between 1990 and 2017 than almost any other risk factor considered,[4] with especially rapid increases amongst populations in low- and middle-income countries.[8,9]

1.1.3 Commitments and progress around NCD prevention

There have been numerous commitments around NCD prevention.[8,10–13] For example, following the 2011 Political Declaration of the High-level Meeting of the General Assembly on the Prevention and Control of Non-communicable Diseases, the World Health Assembly committed to reducing premature mortality attributable to cardiovascular disease, cancer, diabetes and chronic respiratory disease by 25% between 2010 and 2025.[14] The Sustainable Development Goals (SDGs) included a target to "reduce by one third premature mortality from non-communicable diseases through prevention and treatment" (SDG 3.4).[15]

However, the World Health Organisation (WHO) Independent High-Level Commission on NCDs has suggested that without a dramatic change in approach, SDG 3.4 will not be met.[8,11] Based on population growth and ageing trends in many countries,[16] increased rates of diabetes[17] and the lack of significant progress in addressing NCD-related risk factors,[4] NCDs are projected to account for an increasingly high absolute and economic burden in many countries.[2,3,18]

1.1.4 Contribution of sub-optimal diet to NCD risk

Sub-optimal diet has been identified as one important cluster of NCD-related risk factors. Afshin et al. estimated that high intake of sodium, low intake of whole grains and low intake of fruits were associated with the greatest attributable disease burden amongst a range of dietary factors considered.[19] In comparison, high consumption of SSBs was found to rank much lower in terms of attributable global disease burden. However, policies targeting 1) sugar and 2) fat have received considerable attention in recent years and have been the target of a number of policy interventions. To further assess the health risks associated with sugar and SSBs in particular, I summarise the evidence base in more detail below.

1.2 Free sugar consumption as a dietary health risk

In 2015 the WHO published guidelines on sugar intake, suggesting that both adults and children should limit free sugar consumption to 10% of total caloric intake, with further benefits from restriction to 5%.[20] Free sugars were defined as "monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates."[20] For a 2000 kcal/day diet, this 10% threshold is equivalent to 50 grams of free sugar/day (i.e. a 500mL bottle of regular soda). This guidance was based on evidence of associations between free sugar consumption and two health outcomes (body weight and dental caries), drawing heavily on two WHO-commissioned systematic reviews based on prospective cohort studies, experimental studies and repeated cross-sectional studies (summarised in Appendix 1).[21,22]

In the first commissioned review, Morenga et al. assessed the association between free sugar intake and body weight and suggested that there was consistent evidence of an association, most likely driven by increases in total energy intake.[21] In the second review, Moynihan et al. assessed the association between free sugar intake and dental caries and suggested that there was consistent evidence of an association, with some evidence to support the 10% and 5% free sugar thresholds.[22]

Much of the evidence around free sugars is focused on SSBs, which account for the greatest single source of free sugar consumption in some settings (e.g. the US,[23] Mexico).[24] In the next section, I summarise several recent systematic reviews around the health risks associated with SSB consumption in particular.

1.3 SSB consumption as a dietary health risk

Systematic reviews and meta-analyses of prospective cohort studies and experimental studies have found greater SSB consumption is associated with increased risk of high bodyweight, type 2 diabetes, hypertension and coronary heart disease (as summarised in Appendix 2).[25–30] For example, Malik et al. assessed the association between SSB consumption and bodyweight and found evidence of an association amongst both children and adults.[30] Luger et al. conducted a recent update to Malik et al.'s review, corroborating these results.[31] Imamura et al. found that consuming one serving of SSBs per day was associated with an 18% increase in incidence of type 2 diabetes (13%

increase after controlling for body weight).[28] Xi et al. assessed the association between SSB consumption and incident hypertension, coronary heart disease (CHD) and stroke and found evidence of a higher risk of incident hypertension and CHD for every additional serving of SSBs consumed per day (but no association with stroke).[29] These findings are broadly consistent with previous reviews.[25,27,32,33]

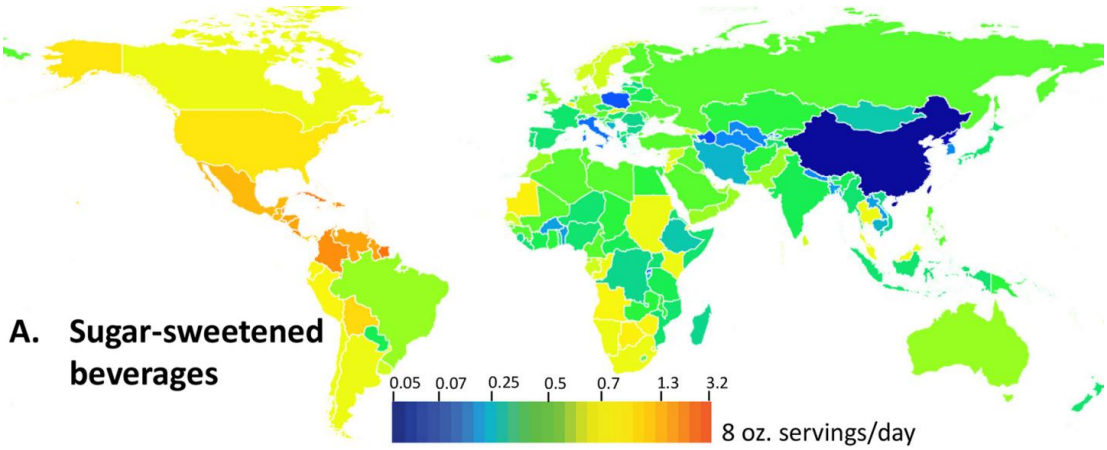
However, these reviews faced some common limitations. First, the majority of studies were from the US and did not include settings with varied (and potentially much higher) levels of SSB consumption.

Second, all of these reviews defined SSB exposure based on volume consumed, which does not take into account variation in sugar concentration across different types of SSBs. If sugar concentration of commonly consumed SSBs varies substantially (either across study populations or between sub-groups within a study population),[34] this may underestimate the relationship between SSB intake and the health outcomes. Finally, if assessment methods tend to underestimate SSB intake, estimates of associations would be underestimated as well. Despite these limitations, there is compelling evidence that SSBs are a risk factor for several NCDs. In the next section, I summarise current evidence about global levels of SSB consumption to characterise exposure to this risk factor.

1.4 Global levels of SSB consumption

As part of the broader Global Burden of Disease (GBD) 2010 study, Singh et al. estimated that global SSB consumption was 0.58 eight oz. servings/person/day amongst adults aged 20 and older [95% CI 0.37, 0.90]. Consumption levels varied greatly, from an estimated 1.9 servings/day in the Caribbean to 0.2 servings/day in East Asia.[35] Average SSB consumption in Latin America and the Caribbean was almost twice the global average (1.1 daily servings/person, compared to 0.58 servings/person).[35] Geographical variation in SSB consumption levels are summarised in Figure 1, reproduced from Singh et al.[35] Overall, younger age groups consumed a greater volume of SSBs, although this analysis was limited to adults 20 years and older. Singh et al. modelled country/age/sex-specific SSB consumption based on survey data, with the majority of surveys from Europe and a limited number from Latin America or the Caribbean. Overall, survey data were only available from 27% of countries considered, highlighting the scarcity of data on SSB consumption.

Figure 1: Levels of sugar-sweetened beverage (SSB) consumption[35]



Note: Reproduced from Singh et al.

To assess adolescent soda consumption, Yang et al. analysed data from the Global School-based Student Health Surveys (2009 to 2013) across 53 low- and middle-income countries.[36] They found that on average, adolescents aged 12 to 15 years reported consuming sodas 1.4 times per day, with considerable variation by region. The highest mean frequency of soda consumption was estimated in Central and South America (1.7 times per day), compared to the lowest estimate in Southeast Asia (0.9 times per day).[36] No data were available on volume consumed or on other types of SSBs (e.g. sugar-sweetened juice drinks, energy or sports drinks, etc.).

Overall, SSB consumption varied greatly amongst both adults and adolescents, with some of the highest levels observed in Central America and the Caribbean (see Appendix 3 for a more detailed summary of these studies).

1.5 Burden of disease attributable to SSB consumption

Mean estimates of annual deaths attributable to SSB consumption range from 137,000 to 184,000 (compared to 54.7 million total deaths) and mean estimates of disability adjusted life years (DALYs) attributable to SSBs range from 4.5 million to 8.5 million (compared to 2.5 billion total DALYs in 2017).[19,37–39] A number of methodological differences may account for differences in study estimates, including variation in estimates of SSB consumption levels and differences in the attribution of risk (see Appendix 4). These studies share some common limitations, such as the scarcity of

survey data on SSB consumption and reliance on estimates of disease risk primarily based on studies from the US. In addition, both studies estimated reductions in SSB intake holding all else constant, whereas in real-world settings, reductions in SSB intake may be associated with substitution towards other products, changing the net effect on health. Overall, both studies suggest that the disease burden attributable to SSBs worldwide is relatively small (i.e. less than half of one percent). This implied that targeting SSB consumption worldwide may have limited potential to reduce overall disease burden. However, given the heterogeneity observed in SSB consumption levels, targeting SSB consumption may still be an important public health strategy in some settings.

In the next chapter, I summarise the evidence base around SSB taxation as a policy tool designed to reduce consumption.

2 OVERVIEW OF SSB TAXES AS A POLICY TOOL

In this chapter, I review and assess the existing evidence base around SSB taxation and identify gaps in the literature.

2.1 Overview of SSB taxation

I begin with an overview of SSB taxation, including the rationale for taxation, theory around SSB taxation, variation in SSB tax design, and a brief summary of existing SSB taxes.

2.1.1 Rationale for SSB taxation

There has been increasing support for SSB taxation from a number of health organisations, including the WHO,[40] the Task Force on Fiscal Policy for Health,[41] the World Cancer Research Fund,[42,43] United Nations Children's Fund (UNICEF),[44] the Healthy Caribbean Coalition,[45] the American Cancer Society,[46] the American Heart Association,[47,48] the American Academy of Pediatrics,[49] and the American Public Health Association.[50]

Proponents of SSB taxation argue that these taxes should be used to correct the negative externalities and internalities arising from over-consumption of SSBs.[51,52] Individuals often do not fully take into account social and healthcare costs (externalities) or individual future costs from health risks (internalities) of present day behaviours, and taxation is one tool that governments can use to address these unaccounted costs.[51,53,54] Allcott et al. demonstrate that an optimal tax rate can be estimated by assessing both social and individual costs.[51,55] However, in addition to correcting for market failures, SSB taxation has been described as a "triple win" for governments because it has the potential to 1) improve population health,[56] 2) reduce long-term healthcare costs[52,57,58] and 3) generate revenue.[41,56] I briefly expand on each of these points below.

First, simulation studies have suggested that SSB taxes may reduce the prevalence of overweight and obesity by 1-2% (absolute percentage points).[59–61] Since most SSBs provide limited nutritive value (i.e. because the majority of calories come from added sugars)[53] and healthier alternatives are usually readily available (e.g. tap water), SSBs provide a particularly attractive target for taxation in comparison to other dietary risks.[37,53,62] For example, while products high in sodium may account for a greater proportion of disease burden,[19] they may also be harder to identify and target from a policy perspective.

Second, cost-effectiveness studies have demonstrated that these improvements in health would reduce future healthcare costs.[63] Given the large and growing healthcare bill associated with NCDs,[2,8,52,64] identifying opportunities to reduce these costs will be increasingly important.[65]

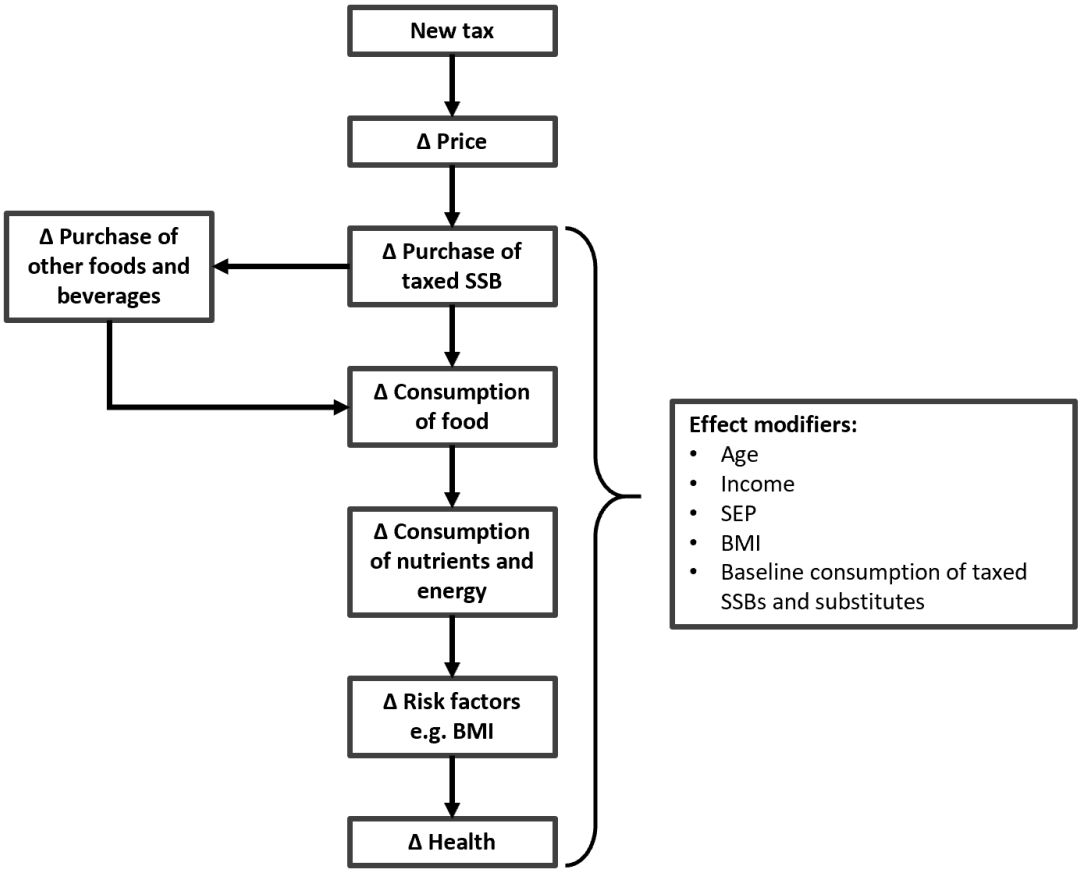
Third, taxes offer an additional source of revenue for governments. Some organisations have suggested that SSB taxation may contribute to innovative financing for universal health coverage.[65] Taxing dietary risks to reduce consumption may be more politically feasible than using subsidies to promote consumption of under-consumed foods (e.g. whole grains, fruit), given the additional cost to government such subsidies would represent. However, the revenue potential of SSB taxes may be lower than has been observed amongst other relatively price insensitive products (e.g. tobacco).[41,66]

In the next section, I focus on how SSB taxes are thought to operate.

2.1.2 Theory around SSB taxation

There is an increasing recognition that SSB taxes operate within complex adaptive systems and may have unexpected effects, produce feedback loops, and/or operate through multiple mechanisms.[67,68] However, much of the research around SSB taxation to date has relied on a simple theoretical framework, as summarised by Mytton et al. and reproduced in Figure 2.[67] SSB taxes are frequently hypothesised to lead to a price

Figure 2: Mytton et al.'s framework on how food taxes may influence health[67]



Note: Reproduced from Mytton et al.

change which in turn dampens purchases of taxed products, shifts purchases of other foods and beverages, and leads to a change in the total composition of foods and beverages consumed. This change in the total composition of nutrients and calories in the diet is then hypothesised to change important risk factors, such as BMI, which then may lead to changes in health outcomes. The impact that a new tax may have on purchases of foods, consumption, risk factors and health outcomes may be modified by age, measures of SES, BMI and baseline SSB/non-SSB consumption.[67]

However, as Mytton et al. emphasise, this framework faces several limitations. First, it does not take into account potential supply-side responses to the introduction of a new tax (e.g. reformulation or changes in advertising). Second, the introduction of a tax has been hypothesised to shift social norms around SSB consumption, which is not reflected in this framework.[69] Third, SSB taxes may vary considerably, and aspects of SSB tax design may moderate each step in this framework (e.g. a tiered tax may incentivise reformulation more than a uniform (single rate) tax). Finally, additional contextual factors may be important which are not captured here (e.g. acceptability of different SSB substitutes, SSB affordability, etc.).[70,71]

Nevertheless, this framework (Figure 2) provides a useful structure for assessing the evidence base.

In the next sections, I provide a brief overview of various SSB tax structures, describe existing SSB taxes and appraise the evidence around SSB taxation.

2.1.3 SSB tax structures

There are a variety of potential SSB tax structures[72–74] (summarised in Table 1), including excise taxes, sales taxes, value added taxes (VAT) (which are also known as good and services taxes, or GST) and import taxes. Broadly, excise taxes are applied on selected goods and are usually collected directly from manufacturers or distributors. In comparison, sales taxes and VAT are usually paid directly by consumers and tend to include a broader base of goods. Sales taxes (as distinct from VAT) are not incorporated into shelf prices, potentially dampening their salience to consumers.[75] Finally, import taxes can be applied on selected goods, but are only collected on imported goods. From a health perspective, excise taxes are the most appropriate type of tax because they enable policymakers to target selected products efficiently.[73]

Excise taxes may be *specific* (e.g. based on volume or sugar content) or *ad valorem* (e.g. based on a percentage of the value of the good).[76] Overall, the WHO recommends specific excise taxes rather than ad valorem excise taxes. This is in part because it has been suggested (but not shown) that ad valorem SSB taxes may encourage brand down-switching, i.e. the consumer strategy of substituting to cheaper brands.[74,77] However, ad valorem taxes do not need to be adjusted for inflation, unlike specific taxes which require regular adjustment to account for inflation. Also, ad valorem taxes may be somewhat

easier to implement administratively, since they do not require additional data collection or monitoring of volume or sugar content levels.

An additional consideration for ad valorem taxes is how to define the *value* of a good, since this may be assessed at different levels of the production/distribution chain (e.g. based on the producer price, the VAT-exclusive retail price, etc.).[76] When producer price is used as the basis for an ad valorem tax, the tax rate is effectively applied on a smaller tax base, diminishing the impact of the tax on final prices. In addition, companies may be able to manipulate reported producer prices in order to pay taxes on an even smaller base.[76]

Finally, SSB taxes may be uniform (e.g. single rate) or tiered (e.g. multi-rate), with tiers defined by sugar content, product type, etc. In addition to these differences in tax structure, SSB taxes may vary widely in terms of 1) the definition of products subject to the tax, and 2) tax rates.

In terms of defining taxable products, the WHO has highlighted the need for additional nutrient profiling models to classify foods and beverages according to their nutrient content.[74] However, there is no internationally accepted definition of SSBs, and countries have defined taxable products in a wide variety of ways (e.g. carbonated SSBs – sodas, carbonated SSBs and non-SSBs – sodas and diet sodas, carbonated and non-carbonated SSBs – sodas and juice drinks, etc).

In terms of tax rate, if the primary goal of an SSB tax is to correct for externalities and internalities, optimal SSB taxes should be based on marginal unaccounted costs (both to society and future individual costs).[53,55] However, from a health perspective it has been suggested that SSB taxes should be set at a sufficiently high level to result in a meaningful change in SSB consumption.[53] On this basis, the WHO suggests that taxes should be designed to produce a 20% price increase,[74] which is thought to produce a meaningful change in consumption as I review later in this chapter.

In the next section, I review existing SSB taxes and classify them according to some of the aspects of tax structure discussed above.

2.1.4 Existing taxes

SSB taxes have been introduced in every major region around the world.[43,78] In Figure 3, I summarise the landscape of SSB taxes (reproduced from The Global Food Research Program at the University of North Carolina, Chapel Hill). [79]

Table 1: Advantages and disadvantages of different sugar-sweetened beverage (SSB) tax structures

Tax Type	Definition	Examples	Advantages	Disadvantages
Value Added Tax (VAT)	A percentage of value paid at every stage of production/distribution and ultimately paid by the consumer at point of purchase.	Morocco (MAD 0.15-6.00/litre)	• Usually reflected in shelf price (unlike most sales taxes)	• Tends to be applied generally across a broad base of products • Challenging or potentially inefficient to vary VAT rates by product type
Import Tax	Only applied on imported goods.	Bermuda (75%)	• Less pushback from domestic companies	• High risk of violating international trade agreements
Sales Tax	A percentage of the product's value paid by consumers at point of purchase.	US States (e.g. California, 6.25%[80])	• May be less politically challenging to introduce	• Less likely to be reflected in shelf price and therefore less likely to impact consumer behaviour (lower salience)
Excise Tax	Applied on selected goods and usually collected directly from manufacturers or distributors.	Mexico (1 peso/litre) UK (£0.18-0.24/litre), South Africa (ZAR 2.1 cents/g of sugar) Barbados (10%)	• Reflected in shelf price • Ease of administration (fewer companies to collect tax from, which may also reduce tax evasion) • Designed to target specific products	• May be more politically challenging to implement

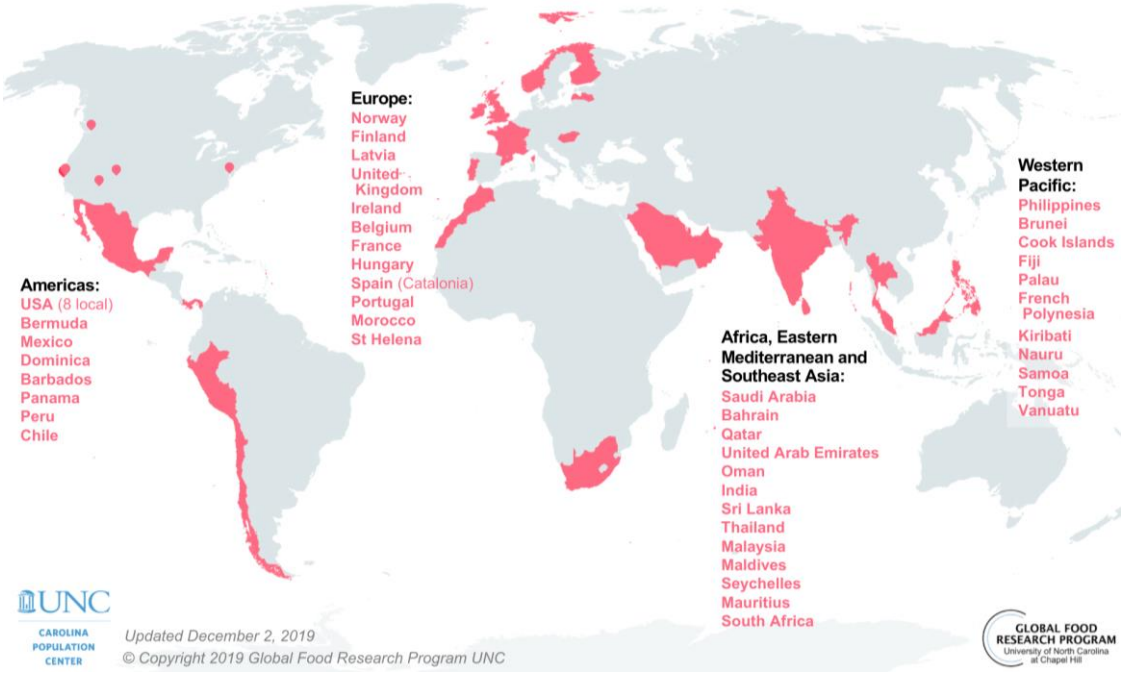
Tax Type	Definition	Examples	Advantages	Disadvantages
		Chile (10-18%) Saudi Arabia (SSBs: 50%; Energy drinks: 100%)		
Excise Taxes may be:				
Specific Excise Tax	Based on volume or sugar content	Mexico (1 peso/litre) UK (£0.18-0.24/litre) South Africa (ZAR 2.1 cents/gram of sugar)	• Reduces price dispersion (i.e. range of prices); • Produces more stable revenue	• Smaller impact on prices of most expensive SSBs (e.g. energy drinks) • May erode in relative value over time due to inflation
Volume-based specific excise tax	Based on volume	Mexico (1 peso/litre) UK (£0.18-0.24/litre)	• Ease of administration (volume of sales data readily available)	• Does not differentiate between high- and low-sugar SSBs
Sugar-based specific excise tax	Based on sugar content	South Africa (ZAR 2.1 cents/gram of sugar)	• Differentiates between high- and low-sugar SSBs • May incentivise consumers to substitute to lower-sugar SSBs	• More challenging administratively (sugar content data not readily available) • Requires additional monitoring

Tax Type	Definition	Examples	Advantages	Disadvantages
			• May incentivise companies to reformulate	
Ad valorem Excise Tax	Based on a percentage of the value of the good	Barbados (10%) Chile (10-18%) Saudi Arabia (50-100%)	• Does not require adjustment for inflation • Leads to proportionate price changes in most expensive types of products (e.g. energy drinks)	• May incentivise brand down-switching • May produce less stable revenue • Industry may evade tax by strategically reporting lower producer costs
Excise Taxes (both specific and ad valorem) may also be:				
Uniform	Same rate applied across products	Barbados (10%) Mexico (1 peso/litre)	• Administrative ease • Consistent with trend towards simplified tax systems	• Does not differentiate between high- and low-sugar SSBs (except when based on sugar content) • Does not incentivise consumers to substitute to lower-sugar SSBs • Does not incentivise companies to reformulate
Tiered (by sugar content)	Various rates applied based on sugar concentration	UK (T1: £0.18/litre; T2: £0.24/litre) Chile (T1: 10%; T2: 18%)	• Differentiates between high- and low-sugar SSBs • May incentivise consumers to substitute to lower-sugar SSBs	• More challenging administratively (sugar content data not readily available) • Requires monitoring and audits

Tax Type	Definition	Examples	Advantages	Disadvantages
			• May incentivise companies to reformulate	• Incentivises reformulation to just under thresholds
Tiered (by product type)	Various rates applied based on product types	Saudi Arabia (SSBs: 50%; Energy drinks: 100%)	• May address price variation between product types • May gain political support if some SSBs are perceived as more threatening	• Does not differentiate between high- and low-sugar SSBs within product categories • Does not incentivise companies to reformulate

Note: Unless otherwise indicated, SSB tax examples are from the World Cancer Research Fund's NOURISHING database.[43]

Figure 3: Map of sugar-sweetened beverage (SSB) taxes (as of December 2019)[79]



Note: Reproduced from The Global Food Research Program at the University of North Carolina, Chapel Hill.

To further describe existing national SSB taxes, I reviewed the World Cancer Research Fund's (WCRF) NOURISHING database (updated as of May 2019) and extracted data on various tax structures (summarised in Table 2).[43] While additional national SSB taxes may exist (e.g. El Salvador,[81] Nicaragua,[82] etc.), these were often introduced without a health rationale and were not included in the WCRF's NOURISHING database or UNC's global SSB tax map (unpublished analysis I conducted with PAHO).

Table 2: Overview of sugar-sweetened beverage (SSB) taxes[43]

Type	Country	Year Introduced (Amended)	Tax Structure	Uniform or Tiered
VAT	India	2017	Ad valorem	Uniform
	Morocco	2019	Specific	Tiered by product type
Import	Bermuda	2018 (2019)	Ad valorem	Uniform
	Palau	2003	Specific	Uniform
Excise	Fiji	2011 (2017)	Both	Tiered by import/local
	Ecuador	2016	Both	Tiered by sugar content
	Thailand	2017	Both	Tiered by product type

Type	Country	Year Introduced (Amended)	Tax Structure	Uniform or Tiered
Excise (continued)	Bahrain	2017	Ad valorem	Tiered by product type
	Qatar	2019	Ad valorem	Tiered by product type
	Saudi Arabia	2017	Ad valorem	Tiered by product type
	UAE	2017	Ad valorem	Tiered by product type
	Chile	2015	Ad valorem	Tiered by sugar content
	Bangladesh	2014	Ad valorem	Uniform
	Barbados	2015	Ad valorem	Uniform
	Dominica	2015	Ad valorem	Uniform
	Kiribati	2014	Ad valorem	Uniform
	Peru	2018	Ad valorem	Uniform
	Hungary	2011	Specific	Tiered by product type
	Norway	1981 (2017)	Specific	Tiered by product type
	Philippines	2018	Specific	Tiered by product type
	France	2012 (2018)	Specific	Tiered by sugar and product
	Finland	1940 (2014)	Specific	Tiered by sugar content
	Ireland	2018	Specific	Tiered by sugar content
	Portugal	2017	Specific	Tiered by sugar content
	UK	2018	Specific	Tiered by sugar content
	French Polynesia	2002	Specific	Tiered by import/local
	Belgium	2016	Specific	Uniform
	Brunei	2017	Specific	Uniform
	Latvia	2004 (2016)	Specific	Uniform
	Mexico	2014	Specific	Uniform
	Samoa	1984 (2008)	Specific	Uniform
	St. Helena	2014	Specific	Uniform
	Tonga	2013	Specific	Uniform
	Vanuatu	2015	Specific	Uniform
	Mauritius	2016	Specific by sugar	Uniform
	South Africa	2018	Specific by sugar	Uniform

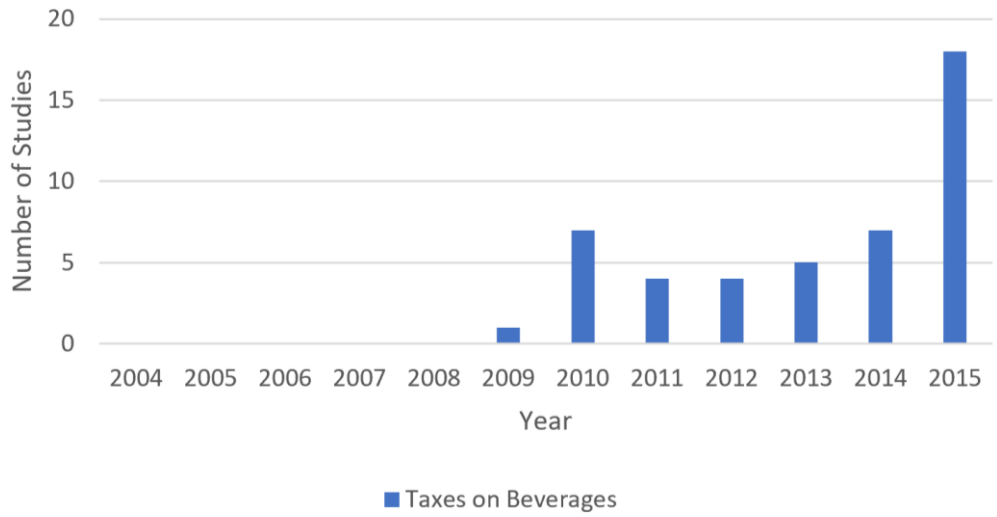
[a] *Date tax last amended in parentheses*

Although many countries have introduced SSB taxes, relatively few of these taxes have been formally evaluated. In the next section, I summarise and appraise the current evidence base around SSB taxation.

2.2 Overall evidence base around SSB taxation

The volume of research on SSB taxes has increased over the last few years, as demonstrated in Wright et al.'s review of health tax-related research in which they searched scientific and grey-literature databases (reproduced in Figure 4).[83]

Figure 4: Number of studies on beverage taxation published by year[83]



Note: Reproduced from Wright et al.

To summarise this literature, I identified key systematic reviews around the health impacts of SSB taxation through targeted Google Scholar and PubMed searches published up until October 2019, followed by a systematic check of the cited articles. I also reviewed resources shared at international SSB tax meetings (e.g. the PAHO July 2018 "Meeting to Develop a Standardised Tax Share Indicator for Alcoholic and Sugar-Sweetened Beverages" and the Radcliffe Institute May 2019 meeting on "Leveraging the impact of sugary beverage tax evaluations"). I summarise review objectives, inclusion criteria and findings and provide a brief assessment of each review in Table 3 (ordered by year of publication).

Review objectives and included studies have changed substantially from 2010-2019, from an earlier focus on price elasticity of SSBs to subsequent assessment of a broad range of fiscal policies for health, and most recently, to a narrower focus on SSB taxation

in particular. In the next sections, I briefly describe included reviews and summarise overall findings and limitations.

2.2.1 Early reviews focused on SSB price elasticity

Earlier reviews (2010 - 2013) were focused on the price elasticity of SSBs[84–88] and taken together, suggest that there is consistent evidence that as prices of SSBs increase, demand decreases. However, specific estimates of the change in demand varied considerably, with estimated price elasticities ranging from -0.5 to -1.6.[84–88] Price elasticity summarises how responsive demand is to changes in price, with a price elasticity of -1 implying that for every 10% increase in price, demand decreases by 10%. An elasticity estimate of zero implies that price increases have no effect on demand, and estimates between zero and -1 imply relatively inelastic demand. Elasticity estimates below -1 imply relatively elastic demand. Thus, this range of estimates suggest that SSBs may be either relatively price elastic (estimates>-1) or relatively price inelastic (estimates<-1). This variation is likely due to differences in setting, the definition of SSBs used, study methods and assumptions about potential substitutions.

There are several overall limitations of included price elasticity studies. First, they tend to assume a linear relationship between price change and demand, although large price changes may be associated with non-linear impacts on demand. Second, these studies often do not account for brand down-switching, in which consumers respond to price increases by substituting towards lower-quality SSBs.[89] Andalón and Gibson suggest that after adjusting for this substitution, SSB elasticity is lower than often reported.[90] Third, price elasticity studies tend to assume that all else is held constant, although they may inadvertently capture the impact of other changes that occur concurrent with a price change (e.g. shifting social norms, industry reformulation, changes in marketing, etc.). Finally, as Cornelsen et al. highlight, aggregating estimates of price elasticity based on varied methods may be misleading, as methodological differences significantly impact elasticity estimates.[91]

2.2.2 Reviews focused on fiscal policies for health

Subsequent reviews (2013 - 2017) focused on broad fiscal instruments (e.g. taxes, subsidies)[92–97] across a wide range of potential behaviours (e.g. diet and physical activity,

a number of food and beverage products, etc.).[83,92–97] These reviews often assessed purchases, consumption and bodyweight as key outcomes. Taken together, they suggest that fiscal interventions can influence purchases of targeted products, but that associations with bodyweight are less clear.

These reviews also faced some challenges. The majority of studies in many of these reviews were modelling studies, which did not take into account possible industry actions or shifting social norms in response to the introduction of fiscal interventions. Most reviews focused on high-income countries (Nakhimovsky et al.'s review on middle-income countries[98] is a notable exception). Of those reviews that did include studies on real-world food and beverage taxes, many were focused on small (<5%) sales taxes in US states. Included studies also typically assumed 100% pass-through rates, meaning that taxes were assumed to be fully passed on to consumers rather than partially absorbed by industry. Few reviews conducted formal risk of bias assessments, and it was unclear in many cases how exposures and outcomes were assessed. For example, based on available information it was difficult to evaluate whether assessments of food and beverage consumption included on-the-go purchases (i.e. products purchased for out-of-home consumption without being brought home first) or whether weight outcomes were self-reported or based on objective measures.

2.2.3 Reviews focused on SSB taxation specifically

Finally, more recent reviews (2016-2019) focused specifically on SSB taxation,[78,98–101] and included more national-level evaluations of real-world SSB taxes.[96,99] These reviews suggest that SSB taxes are associated with a decrease in SSB sales and/or intake.

However, these reviews also faced some challenges. Some combined empirical evaluations and experimental studies, leading to heterogeneity between exposures considered. Few included studies included an assessment of potential substitution effects. National and sub-national taxes were considered in the same reviews, although impacts may vary depending on the scale at which a tax is implemented (i.e. industry response may vary, cross-border shopping is a greater concern in city-specific tax evaluations, etc.). Teng et al. produced one of the most recent reviews of real-world SSB tax,[99] which I summarise in more detail below.

Table 3: Summary of key systematic reviews around sugar-sweetened beverage (SSB) taxation from 2010-2019

Review objective	Inclusion criteria	Findings	Assessment
Andreyeva et al. (2010). Am J Public Health.[84] *The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food.* **Objective:** To systematically review evidence around the price elasticity of different food/beverage groups from the US.	**Design:** Longitudinal studies, household surveys, retail scanner data. **Exposure:** Changes in price of food/beverage groups. **Outcomes:** Changes in demand of food/beverage groups (price elasticity).	**Studies included:** 160 studies (14 of which included soft drinks). **Main effect:** Price elasticity of - 0.79 for soft drinks.	• Limited to US-based studies. • Different definitions of SSBs used across studies. • Used a mean estimation rather than a meta-analysis (not able to take into account uncertainty in estimates)
Shemilt et al. (2013). PLoS One.[92] *Economic instruments for population diet and physical activity behaviour change: a systematic scoping review.* **Objective:** To systematically assess empirical studies around economic	**Design:** Empirical primary studies and reviews of any design. **Exposure:** Interventions around or changes in price or variation in price/income.	**Studies included:** 880 studies (192 intervention studies, 768 on price/income as correlates of outcomes) 18 studies and 12 reviews were focused on SSB taxes. **Main effect:**	• Few studies assessed responses to real-world interventions. • Focused on in-depth analysis of high-income country evidence in particular. • Very heterogeneous set of modelled outcomes following tax simulation studies, hard to compare.

Review objective	Inclusion criteria	Findings	Assessment
instruments for healthy diet/physical activity (PA) promotion.	**Outcomes:** Diet and PA-related behaviours (purchases, related behaviours, proximal and distal health outcomes).	Taxes may reduce purchases of taxed products, with small or no effect on body weight.	• Few studies assessed industry responses (e.g. reformulation). • Modelled tax rates were small.
Escobar et al (2013). BMC Public Health.[85] *Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis.* **Objective:** To systematically review evidence around SSB taxes/price increases and associations with SSB consumption and bodweight measures.	**Design:** Repeated cross-sectional studies, longitudinal studies. **Exposure:** SSB taxes or price changes. **Outcomes:** SSB and non-SSB consumption, obesity, overweight, BMI.	**Studies included:** 9 studies (6 from the US, 1 each from France, Mexico, Brazil). **Main effect:** Pooled own price-elasticity of −1.29 for SSBs. Suggestive evidence that higher SSB prices could reduce BMI.	• Majority of studies from the US. • Heterogeneity in data sources and populations considered (i.e. adults and children). • Longitudinal datasets (e.g. Nielsen homescan panel) often did not include on-the-go purchases.[102] • May not include substitution to other types of drinks. • Unclear how weight outcomes were ascertained.
Green et al. (2013). BMJ.[86] *The effect of rising food prices on food consumption: systematic review with meta-regression.*	**Design:** Cross-sectional, cohort, experimental, and quasi-experimental studies.	**Studies included:** 136 studies (82 included estimates of sweets, confectionery and SSB category). **Main effect:**	• Sweets, confectionery and SSBs were combined in one category. • 162 countries were included.

Review objective	Inclusion criteria	Findings	Assessment
Objective: To systematically review food/beverage prices and association with demand, accounting for income (national, household).	**Exposure:** Food/beverage price. **Outcomes:** Food/beverage demand.	Price elasticity of sweets, confectionery and SSBs combined was –0.74 in low-income countries, –0.68 in middle income countries and –0.56 in high income countries	• Focused on price elasticity estimates that used more complex methods (heightened comparability and internal validity). • Assumed a linear relationship between price and demand.
Powell et al. (2013). Obesity Reviews.[87] *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.* **Objective:** To systematically review US studies around the price elasticity of SSBs, and associations of prices and/or taxes with BMI.	**Design:** Cross-sectional studies, longitudinal, demand system and almost ideal demand system studies. **Exposure:** Price changes, SSB taxes. **Outcomes:** Consumer demand, BMI.	**Studies included:** 21 studies on price, 20 studies on BMI. **Main effect:** Price elasticity of SSBs of -1.21. Limited association between soda taxes and BMI.	• Limited to US-based studies. • Some estimates of price elasticity were for SSBs and artificially sweetened beverages (ASBs) combined (n=4). • Based on existing US state-level taxes, many of which are 1) low (e.g. <6%) and 2) structured as sales taxes, which may not effect consumer demand as strongly as taxes which are included in the shelf price. • Unclear how weight outcomes were ascertained.
Maniadakis et al. (2013). ClinicoEconomics and Outcomes Research.[88]	**Design:**	**Studies included:** 55 studies (28 were focused on SSBs, 37 on unhealthy foods/beverages).	• Few studies assessed associations with weight outcomes. • Most studies from the US (n=40).

Review objective	Inclusion criteria	Findings	Assessment
A systematic review of the effectiveness of taxes on nonalcoholic beverages and high-in-fat foods as a means to prevent obesity trends. **Objective:** To systematically review the impact of price increases of foods/beverages on consumption, caloric intake and/or weight outcomes.	Cross-sectional, longitudinal, experimental studies, modelling. **Exposure:** Price increase/tax on SSBs/unhealthy foods. **Outcomes:** Consumption, caloric intake and/or weight outcomes.	**Main effect:** Price elasticity of SSBs between -0.5 to -1.6. Price increases are association with a reduction in targeted food/beverage, but association with caloric intake and weight outcomes may be small.	• Different definitions of SSBs used across studies. • Unclear how weight outcomes were ascertained. • Weight outcomes were often modelled, with different modelling assumptions (e.g. static vs. dynamic models)
Thow et al. (2014). Nutr Res.[93] *A systematic review of the effectiveness of food taxes and subsidies to improve diets: understanding the recent evidence.* **Objective:** To systematically review evidence published between Jan 2009 and March 2012 on food/beverage taxes and subsidies and associations with dietary intake.	**Design:** Randomised controlled trials (RCTs), repeated cross-sectional studies, modelling studies, stated preference surveys. **Exposure:** Nutrient or product-specific tax/subsidy. **Outcomes:** Consumption.	**Studies included:** 43 reports covering 38 studies (16 studies assessed SSB taxes, ranging from 5%-30%). **Main effect:** Taxes seem to be associated with decreased consumption of taxed nutrient/product.	• Majority of studies were modelling studies (n=31). • Limited number of real-world policy evaluations (n=2), of small SSB taxes. • Variation in tax intervention considered.

Review objective	Inclusion criteria	Findings	Assessment
Niebylski et al. (2015). Nutrition.[94] *Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence.* **Objective:** To systematically review the evidence around effects of subsidies/taxes on food/beverages in high income countries.	**Design:** Experimental, quasi-experimental evaluation studies, modelling studies, reviews. **Exposure:** Subsidies and taxes. **Outcomes:** Purchases, consumption, bodyweight and related health indicators.	**Studies included:** 78 studies (33 modelling studies, 13 empirical studies, 10 experimental studies, 3 cost-effectiveness reviews and 19 miscellaneous). **Main effect:** Taxes and subsidies are likely to influence dietary behaviours.	• Limited number of evaluations of real-world policies. • Focused on high income countries. • Large number of modelling studies (n=33) with noted limitations. • Unclear how weight outcomes were ascertained. • Unclear if effects of tax/subsidies vary by targeted food/beverage.
Alagiyawanna et al. (2015). BMC Public Health.[95] *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.*	**Design:** Controlled and non-controlled trials, interrupted time series (ITS) analysis, cross sectional, cohort and case control studies. **Exposure:** Real-world fiscal interventions (taxes or subsidies on food/beverages).	**Studies included:** 18 studies (9 on taxes, 9 on subsidies; 9 cross-sectional comparison studies, 3 ITS/natural experimental studies, 3 before/after studies, 2 longitudinal, 1 ecological). **Main effect:** Taxes can dampen demand for taxes foods and beverages.	• The majority came from high-income countries, with all studies on taxes from high-income countries. • Assessed real-world fiscal interventions. • Diet intake was based on self-report, with known limitations. • Unclear how weight outcomes were ascertained.

Review objective	Inclusion criteria	Findings	Assessment
Objective: To systematically assess behaviour and health outcomes following fiscal interventions targeting food and beverages.	**Outcomes:** BMI, nutrient intake, diet-related health outcomes, low birth weight.		• Many studies relied on cross-sectional designs (n=9). • Many studies did not control for potential confounders.
Nakhimovsky et al. (2016). PLoS One.[98] *Taxes on sugar-sweetened beverages to reduce overweight and obesity in middle-income countries: a systematic review.* **Objective:** To review evidence on post-tax changes in 1) SSB prices, 2) SSB demand, and 3) BMI, overall and by socio-economic position (SEP) in middle-income countries.	**Design:** Quasi-experimental and non-experimental, observational and modelling studies in middle income countries. **Exposure:** Increase in SSB prices, introduction of an SSB tax. **Outcomes:** Price elasticity, change in SSB caloric intake, BMI.	**Studies included:** 9 studies (3 quasi-experimental observational studies, 6 non-experimental observational/simulation studies). **Main effect:** SSB own-price elasticity of -0.6 to -1.2. Estimated 5 to 39 SSB kilocalorie (kcal) decrease per capita/day following a 10% price increase. Three studies suggested a decrease in BMI.	• Assumed linear relationship between change in price and change in demand, by standardising to 10% price increases. • Included price changes as a result of both SSB taxes and other factors (impact may be different depending on cause of price change). • Majority of studies (n=7) not based on a real-world tax.
Bes-Rastrollo et al. (2016). Obesity.[101]	**Design:** Modelling studies, cross-sectional or cohort studies.	**Studies included:** 24 studies (18 simulation studies, 6 cross-sectional or cohort studies).	• Primarily relied on simulations. • Observational studies assessed very small taxes (<5%) and were often

Review objective	Inclusion criteria	Findings	Assessment
Impact of sugars and sugar taxation on body weight control: a comprehensive literature review. **Objective:** To systematically review and assess the association between SSB taxation and weight control.	**Exposure:** Introduction of SSB taxes. **Outcomes:** BMI.	**Main effect:** Simulation studies suggested inverse relationship between taxes and BMI and small magnitude of effect. Observational studies suggested no relationship between taxes and BMI.	cross-sectional (with limited ability to assess potential confounders between taxes/untaxed groups). • Large sample size would be required to identify a change in bodyweight following an SSB tax.
Backholer et al. (2016). Public Health Nutrition.[78] *The impact of a tax on sugar-sweetened beverages according to socio-economic position: a systematic review of the evidence.* **Objective:** To systematically review the impact of SSB taxes on purchases, consumption, weight outcomes, and SSB tax paid by socio-economic position (SEP) within high-income countries.	**Design:** Any study type that assessed differences in SSB price and outcomes of interest by SEP. **Exposure:** SSB taxes or price changes. **Outcomes:** Purchases, consumption, weight outcomes and amount paid in taxes stratified by SEP.	**Studies included:** 11 studies (7 price elasticity modelling studies, 3 cross-sectional evaluation studies, 1 price elasticity applied study) **Main effect:** Weight reductions were similar and sometimes greater amongst lower SEP groups. Lower SEP groups paid a slightly higher amount in SSB taxes.	• Focused on high income countries. • Majority of studies (n=7) were modelling studies. • Taxes considered in real-world settings were all from the US and were very small (<5%) and assessed in cross-sectional studies. • Modelling studies did not assess industry responses (e.g. reformulation), social norms change, or other unexpected consequences. • Limited testing of statistical significance between SEP groups.

Review objective	Inclusion criteria	Findings	Assessment
Gittelsohn et al. (2017). Prev Chronic Dis.[96] *Pricing strategies to encourage availability, purchase, and consumption of healthy foods and beverages: a systematic review.* **Objective:** To systematically assess price interventions on the purchase and consumption of healthy foods/beverages.	**Design:** Quasi-experimental studies, RCTs, population studies. **Exposure:** Pricing interventions (e.g. financial incentives, subsidies, excise taxes). **Outcomes:** Food and beverage stocking, sales, purchases, consumption.	**Studies included:** 65 studies covering 30 site-specific pricing interventions (27 health-promoting interventions, 3 interventions to limit unhealthy products) **Main effect:** Health-promoting pricing interventions increased stocking, sales, purchases and consumption of healthy foods/beverages. Pricing strategies targeted at unhealthy foods were generally associated with decreased sales of targeted products.	• Most studies focused on encouraging healthy foods/beverages (n=27), with 20 studies focused on fruit and vegetable promotion. • Many studies targeted specific populations (e.g. worksite, hospital), which may not produce results that are generalisable to the whole population. • Few studies assessed substitution or longer time frames. • Majority of studies conducted in the US. • Two studies were of national policies (the Danish saturated fat tax and the Mexican SSB tax). • Outcomes and details of pricing interventions varied considerably.
Afshin et al. (2017). PLoS One.[97] *The prospective impact of food pricing on improving dietary*	**Design:** Intervention trials and prospective cohort studies	**Studies included:** 30 studies (23 interventional studies and 7 prospective cohorts); 5 total studies on	• Sales/purchase of SSBs used as a proxy for consumption.

Review objective	Inclusion criteria	Findings	Assessment
consumption: A systematic review and meta-analysis. **Objective:** To review the published literature on the prospective effect of food price changes on consumption.	**Exposure:** Change in price of foods/beverages **Outcomes:** Change in consumption, change in bodyweight/BMI (secondary outcome).	SSBs (3 intervention and 2 prospective cohort). **Main effect:** A 10% price increase was associated with a 7% decrease in SSB intake. No effect on BMI.	• Some trials included additional changes (e.g. information, labelling, etc.) and may have captured non-price effects. • 25/30 studies from the US (including all studies of price increases). • Ascertainment of exposure and outcomes varied considerably, with different limitations and potential biases. • Relationship between SSB prices and BMI assessed in two studies.
Wright et al. (2017). BMC Public Health.[83] *Policy lessons from health taxes: a systematic review of empirical studies.* **Objective:** To review research on health taxes to inform policymakers around 1)	**Design:** All study types of health taxes, excluding studies of tobacco and alcohol taxation (no exclusions based on study quality). **Exposures:** Health taxes. **Outcomes:**	**Studies included:** 102 studies (54 modelling studies, 16 evaluations, 10 experiments, 9 public opinion surveys, 11 qualitative studies, 2 mixed method studies). **Main effect:** 11 of 16 studies on SSB taxes identified a positive impact on health, with 8 out of 8	• SSB tax results primarily based on modelling studies. • Primarily based on US-based studies (n=50) and high-income settings (n=93). • No uniform critical appraisal method applied or exclusions based on study quality.

Review objective	Inclusion criteria	Findings	Assessment
changes in consumption, 2) revenue usage and 3) political sustainability.	Change in consumption/health outcomes, industry behaviours, revenue, public support.	studies of SSB taxes ≥20% finding a positive impact. One study suggested that manufacturers may reformulate in response to a health tax on a single nutrient. Most studies on revenue suggested that health taxes increase revenue, although with variation based on tax structure. Four studies suggested public support for health taxes was low, although ear-marking revenue for health increased support.	
Redondo et al. (2018). The American Journal of Clinical Nutrition.[100] *The impact of the tax on sweetened beverages: a systematic review.* **Objective:** To review and synthesise existing evidence on the impact of SSB taxes on SSB sales, purchases or consumption.	**Design:** Natural experimental studies or intervention trials. **Exposure:** Real-world SSB tax or intervention. **Outcomes:** Sales, purchase or consumption of SSBs, or purchasing intent.	**Studies included:** 17 studies (5 of real-world SSB taxes, 12 in experimental/virtual intervention settings). **Main effect:** Four out of five natural experimental studies found a decrease in SSBs and an increase in non-SSBs. 2 RCTs found evidence of a decrease in intention to select or selection of SSBs.	• Heterogeneity between included studies and exposures considered. • Intention to purchase may not measure change in actual purchases. • Online and virtual environments may not reflect real-world decision-making or conditions. • Sub-national interventions may not capture wider unexpected effects (e.g.

Review objective	Inclusion criteria	Findings	Assessment
		Three out of four before/after studies in specific settings (e.g. restaurants, convenience stores) found a decrease in SSB sales associated with price increases. Five out of six virtual experimental studies found a tax was associated with decreased intention to purchase SSBs.	industry response) or consumer substitution to other outlets.
Teng et al. (2019). Obesity Reviews.[99] *Impact of sugar-sweetened beverage taxes on purchases and dietary intake: Systematic review and meta-analysis.* **Objective:** To review the published literature on real-world SSB tax evaluations and assess impact on purchases and consumption by meta-analysis.	**Design:** Pre/post tax comparison (before/after study, ITS) or tax/untaxed geographic comparison (cross-sectional). **Exposure:** Real-world SSB tax (standardised to 10% ad valorem equivalent across studies). **Outcomes:** SSB and non-SSB purchases, sales and consumption.	**Studies included:** 17 studies (11 pre/post, 6 tax/untaxed localities) across 6 jurisdictions. **Main effect:** A 10% tax was associated with a 10% decrease in SSB consumption and 1.9% increase in non-SSB consumption.	• Outcome measure aggregated results across different measures (e.g. sales, purchases and consumption all considered "consumption"). • Considerable heterogeneity between study sites. • Did not account for real-world pass-through rates (less proximal exposure). • Assumed linear relationship between change in price and change in demand by standardising to 10% ad valorem equivalent. • Majority of study sites were high-income.

Teng et al. included all evaluations of real-world SSB taxes (up to June 2018) which assessed changes in sales, purchases or consumption.[99] Based on a meta-analysis of 17 studies, they suggest that a 10% SSB tax is associated with a 10% decline in SSB consumption (implying a price elasticity of -1). Significant heterogeneity was found between settings, and the authors suggest that differences in concurrent interventions (e.g. additional health taxes, communication campaigns, etc.), variations in the definition of taxed beverages used, consumer preferences, baseline SSB consumption and non-price mechanisms may explain some of these differences. Teng et al.'s review benefited from an inclusive approach (i.e. the authors did not exclude studies based on design) and a focus on empirical studies only (i.e. they did not include modelling studies).

However, this review also faces some limitations. First, to enable comparisons between different tax structures (e.g. *specific* vs. *ad valorem* taxes), the authors produce a harmonised ad valorem equivalent (AVE) estimate for each tax. For *specific* taxes, the AVE is defined as the applicable tax per litre divided by the pre-tax mean cost per litre, estimated using import values from the UN Comtrade database (an international trade statistics database). However these import/export values may not reflect retail prices (e.g. because of import duties, importer and/or retailer mark-ups, and differences in prices of locally manufactured SSBs). For *ad valorem* taxes, the AVE is assumed to be equivalent to the tax rate. However, the AVE does not take into account possible variation in the ad valorem tax base (e.g. producer price versus retail price), which would produce different levels of price change (see Section 4.7.3).

Second, after estimating the AVE, the authors report a risk ratio scaled to a 10% AVE tax. This assumes a linear effect, which may not be the case particularly for higher tax rates (e.g. tax rates of 100%).

Third, the outcome of interest is broadly defined (i.e. Teng et al. do not distinguish between reported changes in sales, purchases and consumption). The underlying concepts that these outcomes measure may vary (e.g. purchase and consumption may vary due to wastage), and methods of ascertainment for each outcome may face different systematic limitations (e.g. potential exclusion of on-the-go purchases in consumer panel data versus potential recall bias in dietary surveys).

Despite these limitations, this review provides early empirical evidence around the effectiveness of SSB taxes across a variety of settings. These empirical evaluations may be more valid than modelling studies alone, as discussed below.

2.2.4 Rationale for focusing on empirical evaluations of SSB taxes in particular

Shemilt et al. suggest that policymakers interpret simulation studies of food and beverage taxes with caution, advocating instead for the importance of empirical evaluations.[68] This may be in part because empirical evaluations can capture changes that occur following the introduction of real-world taxes, such as non-price mechanisms (e.g. signalling, or the additional information about health risks that may be conveyed by a new tax) or unexpected industry reactions (e.g. reformulation, advertising). Mytton et al. emphasise the importance of empirical evaluations of real-world taxes:

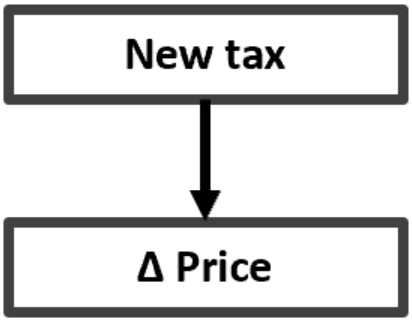
> *We believe rigorous evaluation of the introduction of health-related food taxes in practice is crucial to gaining a better understanding of their effects on health, both good and bad, and providing "real world" evidence with greater external validity to support policymaking.*[67]

Guided by these calls, I focus on empirical evaluations in the following sections and provide a more detailed assessment of real-world SSB tax evaluations. I use Mytton et al.'s theory around SSB taxation (Figure 2) to organise the following sections, beginning with the association between the introduction of a new SSB tax and a change in prices of SSBs.

2.3 Evidence base around SSB taxes and price change

I first summarise the empirical evidence around SSB taxes and price change (the component of Mytton et al.'s theory highlighted in Figure 5).

Figure 5: Theoretical link between tax and price change[67]



Note: Reproduced from Mytton et al.

To identify price change evaluations, I reviewed the Teng et al.'s study and the WCRF NOURISHING database.[43] I excluded studies of sub-national SSB taxes which may operate differently to national taxes (e.g. due to the scale of intervention, ease of cross-border shopping, etc.). I also excluded evaluations of sales taxes since these are not reflected in shelf prices and may operate differently than excise taxes.[75] I summarise all included studies in Table 4.

Taken together, these studies suggest that the introduction of a national SSB tax increases the price of taxed SSBs.[103–105] Amongst studies that reported price change in terms of pass-through, rates varied substantially (from 39%[106] to 152%).[107] All studies that stratified by package size found that smaller beverages were associated with larger relative price increases. Pass-through rates and/or price increases varied by beverage type, with different patterns across countries. For example, pass-through rates were higher amongst carbonated SSBs compared to non-carbonated SSBs in Mexico,[108,109] while prices of noncarbonated SSBs increased by more than prices of carbonated drinks in Chile.[110] Amongst studies that included sub-national stratification, there was evidence of substantial heterogeneity in pass-through rates and/or price changes, suggesting an uneven within-country impact of SSB taxes on prices.[106]

Of the studies that assessed untaxed products, most found no price increase. In Mexico, one study suggested that prices of ASBs increased (despite not being included in the definition of taxable products).[108] One study in South Africa demonstrated that prices increased even amongst SSB products which were low-sugar (and therefore, eligible for

a low or zero-tax rate), suggesting that manufacturers may strategically spread costs across taxed and untaxed products.[111]

These studies shared some common limitations. First, most studies used data from urban areas only and were not able to assess price changes in rural areas. Second, many studies excluded products with missing observations pre/post tax. As a result, products which were introduced or discontinued during the study period were not included.

Some studies faced additional challenges due to the type of data used. For example, studies based on household purchase data did not have data on the price of products which were not purchased (i.e. if a particular drink became too expensive, households may have stopped purchasing it and the new, higher price would not be captured).

Other studies faced methodological limitations due to study design. For example, several studies employed a difference-in-difference approach, using untaxed beverages as a control group.[106,107,112] This approach assumes that SSB and non-SSB prices are independent. However, if manufacturers produce both taxed and untaxed beverages, they may spread costs between beverages making the use of non-SSBs as a control group an inappropriate choice.

While these studies suggest that SSB taxes tend to be associated with changes in prices of taxed products, challenges remain around 1) understanding sources of heterogeneity, 2) addressing limitations of available data, and 3) capturing the impact of newly introduced/discontinued SSBs.

Table 4: Summary of key sugar-sweetened beverage (SSB) price change evaluations

Study	Data, Outcome and Methods	Findings	Assessment
Mexico (Specific Excise Tax, Uniform: 1 peso/litre)			
Colchero et al. (2015).[109]	**Data:** Monthly price data from the National Institute of Statistics and Geography (2011 – 2014), prices collected from different types of vendors across 46 cities with population≥ 20,000. **Outcome**: Real prices of a specific category. **Methods**: Pre/post quasi-experimental approach with fixed effects models, adjusting for each post-tax month, linear time trends, seasonality, population, and gross domestic product (GDP), stratified by product category and package size.	Prices of all SSBs increased, with average increase of 0.9-1.05 pesos (90-105% pass-through). Amongst carbonated SSBs, prices of smaller packages sizes increased more (1.5 pesos) compared to larger sizes (1.08 pesos). Prices of non-carbonated SSBs (e.g. juice drinks) increased by 0.36-0.75 pesos, varying by package size.	• Price data not collected from rural areas, although tax pass-through may vary systematically. • Data differentiated by package size allowed additional analyses. • Weighted estimates used Nielsen data, which likely does not capture on-the-go purchases and may substantially underestimate consumption of some types of SSBs (e.g. small package sizes of carbonated SSBs).
Grogger. (2015).[108]	**Data**: Monthly price data from the National Institute of Statistics and Geography (Jan 2011 – March 2015), prices collected from different types of vendors across 46 cities with population≥ 20,000. **Outcome**: Real prices of a specific category.	Prices of carbonated SSBs increased by more than tax (1.32 pesos). Prices of non-carbonated SSBs increased by less than the tax (0.63 pesos).	• Price data not collected from rural areas, although tax pass-through may vary systematically. • Used 15 months post-tax data (more than previous analyses)

Study	Data, Outcome and Methods	Findings	Assessment
	Methods: Pre-post quasi-experimental approach with fixed effects models, adjusting for each post-tax month, package size, container type, brand and city.	Prices of non-SSBs did not change substantially (with the exception of ASBs, which did increase).	• Assessed price changes in non-beverage products (e.g. butter, cheese, chicken, dried beans, and rice) as control products.
Aguilar et al. (2018).[113]	**Data**: Kantar Worldpanel weekly scanner panel dataset with 9,953 households (Jan 2013-Dec 2014). **Outcome**: Prices data collected from household receipts, tax pass-through rate. **Methods**: Uncontrolled ITS with household-week fixed effects and adjusted for seasonality. Sales-weighted price analysis (aggregated and barcode-specific sensitivity analysis) based on pre-tax purchase patterns.	100% pass-through for SSBs (equivalent to a 14% price increase for SSBs).	• Price data not collected from rural areas, although tax pass-through may vary systematically. • Price data derived from purchased products (i.e. prices not observed for products that were not purchased). • Did not differentiate between SSB sub-categories or package size, and did not report price change in pesos/litre.
Arteaga et al. (2017).[114]	**Data**: Monthly surveys of the Manufacturing Industry (EMIM) (Jan 2007 - Mar 2017). **Outcome**: Comparisons of the monthly soft drink price index from Dec 2013 to Jan 2014. **Methods**: Simple comparison pre/post tax.	12.8% increase in SSB price index.	• 'SSB' category included untaxed ASBs and non-SSBs. • Real (inflation-adjusted) price of SSBs remained unchanged for several years before the tax (inclusion of a longer time series helped to demonstrate this). • Did not differentiate between SSB sub-categories or package size, and did not report price change in pesos/litre.

Study	Data, Outcome and Methods	Findings	Assessment
Chile (Ad valorem Excise Tax, Tiered by sugar content: 10% and 18%)			
Caro et al. (2018).[110]	**Data**: Kantar Worldpanel Chile, longitudinal data (Jan, 2013-Dec 2015), 2,000 households in cities with population≥20,000. **Outcome**: Mean monthly prices of purchased SSBs/non-SSBs with each geographic and SES-specific 'market.' **Methods**: Uncontrolled ITS, adjusted for time trends, seasonality, and regional economic covariates. Additional analysis of interactions between post-tax indicator, SEP and package size.	2.0% increase in carbonated high-sugar SSBs (H-SSB) prices. 3.9% increase in noncarbonated H-SSB prices. 1.5% increase in prices of low-sugar SSBs (L-SSBs). 1.8% increase in prices of untaxed beverages.	• Price data derived from purchased products (i.e. prices not observed for products that were not purchased). • Used 'market'-specific mean prices to try and capture geographic and SES-based variation in prices. • Did not include products that were not sold both pre/post-tax (i.e. products that may have been introduced or discontinued due to the tax)
Nakamura et al. (2018).[115]	**Data:** Kantar Worldpanel Chile, longitudinal data (Jan 2011-Dec 2015) 2,836 households in cities with population≥20,000. **Outcome**: Weekly prices of purchased SSBs/non-SSBs. **Methods**: Uncontrolled ITS, with product-specific fixed effects and time trends.	1.9% increase in H-SSB prices post-announcement (no change post-implementation). 1.7% decrease in L-SSB prices post-implementation.	• Unclear whether prices changed in response to announcement of the tax rather than implementation (with consequences for subsequent purchase models). • Price data derived from purchased products (i.e. prices not observed for products that were not purchased).

Study	Data, Outcome and Methods	Findings	Assessment
France (Specific Excise Tax, Uniform: EUR 0.0755/litre)[a]			
Capacci et al. (2016).[116]	**Data**: Kantar Worldpanel France and GfK Italy, household purchase data drawn from homescan consumer data from two French regions, and two neighboring Italian regions (2,928 French households, 400 Italian households, Jan 2011 - Dec 2012). **Outcome**: Average weekly prices paid by consumers. **Methods**: Controlled ITS, adjusted for household fixed effects.	0.035 euro/litre increase in SSB prices overall. No change in soda price. 0.19 euro/litre increase in price of sugar-sweetened juice drinks. 0.16 euro/litre increase in price of ASBs.	• Appropriate classification of SSBs/non-SSBs. • Price data derived from purchased products (i.e. prices not observed for products that were not purchased). • Used region-specific mean prices to assess geographic variation in prices. • Used a control group with no SSB tax.
Berardi et al. (2012).[112]	**Data**: Beverage price records from price tracking mobile app. **Outcome**: Most frequently observed daily price per month, for each product. **Methods**: Difference-in-difference analysis using different combinations of untaxed non-SSBs as controls (selected based on pre-tax price change trends).	After 6 months of tax implementation, 100% pass-through for sodas and almost 100% for juice drinks, with large heterogeneity by brand.	• Did not include products that were not sold both pre/post-tax (i.e. products that may have been introduced or discontinued due to the tax) • Prices weighted by market share • Assessed sub-categories of SSBs/non-SSBs (e.g. bottled water, fruit drink and soda)

Study	Data, Outcome and Methods	Findings	Assessment
			• Used prices of non-SSBs as controls, although these prices could be affected by the tax as well. • Not representative of all store types. • Compared pre-tax prices with prices after six months of tax implementation without taking seasonality into account.
Etilé et al. (2018).[106]	**Data**: Kantar Worldpanel homescan data, Jan 2008-Dec 2013. **Outcome**: Exact Price Indices based on monthly mean unit price by living zone (local market). **Methods**: Before/after study and difference-in-difference design with water, adjusted for seasonality.	4% increase in SSB prices (39% pass-through) Higher pass-through rates observed in low-income and smaller markets	• Appropriate classification of SSBs/non-SSBs. • Assessed differences in pass-through across local markets. • Used prices of water as controls, although these prices could be affected by the tax as well. • Used seasonal controls. • Did not include products that were not sold both pre/post-tax (i.e. products that may have been introduced or discontinued due to the tax).

Study	Data, Outcome and Methods	Findings	Assessment
Finland (Specific Excise Tax, Tiered by sugar content: EUR 0.11-0.22/litre)			
Heinonen et al. (2018).[107]	**Data**: Grocery store data from four stores in Helsinki (2013-2014). **Outcome**: Daily price records. **Methods**: Difference-in-difference method, adjusted for seasonality and product-specific fixed effects and price promotions.	0.17 and 0.19 euros per litre increase in prices of SSBs. (pass-through of 136-152%).	• The market share that these four stores represent is unclear. • Evaluation limited to one city • Used prices of non-SSBs as controls, although these prices could be affected by the tax as well.
South Africa (Specific Excie by sugar content, Uniform: ZAR 0.021/gram of sugar)			
Stacey et al. (2019).[111]	**Data:** Statistics South Africa's Consumer Price Index data, which were collected through in-store observations (Jan 2013 - Mar 2019). **Outcome**: Real VAT-exclusive monthly price (2016 ZAR) per litre. **Methods**: Pre/post design, further stratified by reformulation, adjusted for seasonality, package size, brand, province, time trends and tax liability based on product-specific sugar content.	1.006 ZAR increase in price per litre of carbonated SSBs. No increase in price of non-carbonated SSBs (higher price increase in smaller sizes, no difference in price increase by high/low sugar status amongst carbonated SSBs, or by reformulation status). Pass-through of 68%, higher for smaller sizes.	• Appropriate classification of SSBs/non-SSBs. • Price data not collected from rural areas, although tax pass-through may vary systematically.

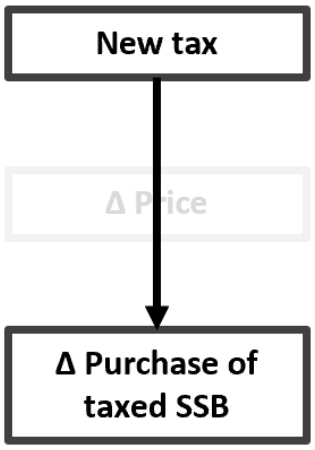
Study	Data, Outcome and Methods	Findings	Assessment
		No price increase amongst untaxed drinks.	

[a] *In 2018, France's SSB tax was modified from a uniform design to a tiered design.*

2.4 Evidence base around SSB taxes and changes in sales and consumption

In this section, I summarise evidence on the introduction of an SSB tax and subsequent changes in purchases of SSBs (the component of SSB taxation theory highlighted in Figure 6).

Figure 6: Theoretical link between tax and change in purchases[67]



Note: Reproduced with modifications from Mytton et al.

As indicated by the arrow in Figure 6, empirical SSB tax evaluations tend to assess whether the *introduction* of a tax was associated with a change in sales, purchases or consumption of SSBs, rather than formally assessing whether this change was mediated through price changes. Studies which assess the relationship between changes in price and changes in sales, purchases or consumption directly tend to be price elasticity studies, and may be based on non-tax-related price changes as well (as summarised in Section 2.2.1).

I used a similar approach to identify studies as described above in Section 2.3, and included studies with any measure of sales, purchase or consumption of SSBs.[97,99,100] I summarise evaluations of SSB taxes conducted in Mexico,[90,113,114,117–121] Chile,[110,115] France[116] and Finland[107] in Table 5. In comparison to the studies included in Teng et al., I included three additional studies (two conducted in Mexico[114,121] and one in Finland[107]), two of which were published after Teng et al.'s cut-off date (June 2018).

Taken together, these evaluations suggest that SSB taxes are associated with reductions in sales or household purchases of SSBs. However, these studies also demonstrate a variety of substitution effects. First, some studies found evidence of substitution to smaller package sizes.[113] Second, most studies that assessed substitution to untaxed non-SSBs (e.g. bottled water) found that non-SSB sales increased.[113,116–120] However, one study in Chile found a decrease in sales of untaxed non-SSBs and an increase in sales of low-sugar SSBs, suggesting substitution from non-SSBs to low-sugar SSBs.[110] A second evaluation in Chile found no significant change in volume sold of low-sugar SSBs or untaxed non-SSBs.[115] One evaluation in France found an increase in artificially-sweetened beverage (ASB) purchases even though ASBs were taxed and their prices increased, suggesting that the tax may have operated (at least in part) through non-price mechanisms.

A subset of these evaluations considered distributional impacts, with mixed findings. Evaluations of the Mexico SSB tax found that SSB taxes were associated with the largest reductions in SSB purchases among lower SEP groups,[117,119,120] while evaluations of the Chile tax found the largest reductions amongst higher SEP groups.[110,115] In addition, a study in Mexico assessed change by baseline SSB consumption and found that the largest effects were associated with high SSB consumers.[121]

These studies faced some common limitations. First, many relied on longitudinal consumer panel data,[110,113,115–117,119,121] which often do no capture on-the-go purchases. This may be especially problematic in settings in which a substantial proportion of SSBs are consumed on-the-go (e.g. such as Mexico, where 20% of SSBs have been estimated to be on-the-go purchases).[113] Two studies from Mexico relied on monthly manufacturing data,[114,118] which do not face the same limitations around on-the-go purchases. However, these data are not disaggregated by SSBs/non-SSBs, obscuring potential substitution from taxed SSBs to untaxed non-SSBs. Second, most studies relied on data that do not capture home-prepared SSBs or tap water, a concern as it is likely that consumers may have substituted towards these beverages as well.

Despite challenges, these evaluations present some of the first assessments of real-world SSB taxes, and seem to suggest that SSB taxes are associated with reductions in SSB sales. These evaluations also highlight the strengths and limitations of various sources of data that are available to conduct SSB tax evaluations.

Table 5: Summary of key sugar-sweetened beverage (SSB) sales/purchases/consumption evaluations

Study	Data, Outcome, Methods	Findings	Assessment
Mexico (Specific Excise Tax, Uniform: 1 peso/litre)			
Colchero et al. (2016). BMJ.[117]	**Data:** Nielsen Mexico's Consumer Panel Services, 6,253 households in large cities (Jan 2012- Dec 2014). **Outcome:** Monthly purchases (mL/capita/day). **Methods**: Uncontrolled ITS with fixed effects by household, adjusted for household composition, SEP, inflation and seasonality.	6% decrease in SSBs (9% decrease among low SEP group) 4% increase in non-SSBs	• Did not include SSBs/non-SSBs consumed on-the-go or at restaurants. • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Appropriate classification of SSBs/non-SSBs, household-level data enabled analysis by SEP.
Ng et al. (2018). Public Health Nutrition.[121]	**Data:** Nielsen Mexico's Consumer Panel Services, 6,645 households in in cities with population≥20,000 (Jan 2012- Dec 2015). **Outcome:** Monthly purchases (mL/capita/day) across four types of household: 1) low-SSB/high-non-SSB-consumers, 2) low-SSB/low-non-SSB consumers, 3) high-SSB/low-non-SSB consumers and 4) high-SSB/high-non-SSB consumers.	12% decrease in SSBs among high-SSB consumers.	• Did not include SSBs/non-SSBs consumed on-the-go or at restaurants. • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Household-level data enabled assessment by baseline SSB consumption levels and SEP, but may have obscured differences in consumption between individuals within a household, with implications for high/low-consumer assignment.

Study	Data, Outcome, Methods	Findings	Assessment
	Methods: Uncontrolled ITS with fixed effects by household, adjusted for household composition, SEP, inflation and seasonality.		
Colchero et al. (2017). Health Affairs.[119]	**Data:** Nielsen Mexico's Consumer Panel Services, 6,645 households in cities with population≥20,000 (Jan 2012- Dec 2015). **Outcome:** Monthly purchases (mL/capita/day). **Methods**: Uncontrolled ITS with fixed effects by household, adjusted for household composition, SEP, inflation and seasonality.	7.6% decrease in SSBs (5.5% in 2014 and 9.7% in 2015, with an 11.7% decrease among lowest SEP group) 2.1% increase in non-SSBs	• Did not include SSBs/non-SSBs consumed on-the-go or at restaurants. • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Appropriate classification of SSBs/non-SSBs, household-level data enabled analysis by SEP.
Aguilar et al. (2018). The Latin American and Caribbean Economic Association.[113]	**Data:** Kantar Worldpanel weekly scanner panel dataset with 9,953 households (Jan 2013 - Dec 2014). **Outcome:** Purchases (measured in litres, sugar content, total calories) and BMI, pass-through. **Methods**: Uncontrolled ITS with household-week fixed effects, adjusted for seasonality.	6% decrease in SSBs by volume. 6% decrease in SSBs by total kilocalories. Evidence that consumers substituted towards untaxed non-SSBs and smaller package sizes of SSBs.	• Did not include SSBs/non-SSBs consumed on-the-go or at restaurants. • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Weekly data provides fine-grained time trends. • The authors collected nutrient content data to estimate changes in overall nutrient intake. • BMI is only measured once per year using self-report.

Study	Data, Outcome, Methods	Findings	Assessment
Colchero et al. (2017). The Journal of Nutrition.[120]	**Data:** National Income and Expenditure Surveys (2008, 2010, 2012, 2014, Aug - Nov); range of households/year: 10,062- 35,146. **Outcome:** Purchases (7-day household expenditure diaries, supplemented with individual purchase data; weekly purchases of SSBs/water in litres/capita/week) **Methods:** Before and after study, adjusted for household characteristics, place of residence, and lagged GDP/capita.	6.3% decrease in SSBs (larger effect among low SEP group). 16.2% increase in water.	• 'SSB' category included untaxed ASBs • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Repeated cross-sectional design did not allow for household-level controls over time.
Colchero et a. (2016) PLoS One.[118]	**Data:** Surveys of the Manufacturing Industry (EMIM) (Jan 2007 - Dec 2015, top 80% of manufacturers). **Outcome:** Monthly sales (litres/capita). **Methods**: Uncontrolled ITS, adjusted for seasonality and monthly indicator of economic activity.	7.3% decline in SSBs. 5.2% increase in water.	• 'SSB' category included untaxed ASBs and non-SSBs. • Does not include all sources of bottled water production (potentially large proportion missing). • Data routinely reported and less likely to be biased by social desirability bias. • Includes production for on-the-go consumption.
Arteaga et al. (2017). MPRA Paper.[114]	**Data**: Surveys of the Manufacturing Industry (EMIM) (Jan 2007 - Mar 2017, top 80% of manufacturers). **Outcome:** Monthly sales (litres/capita).	3.8% decrease in SSBs	• 'SSB' category included untaxed ASBs and non-SSBs. • Does not include all sources of plain bottled water production (potentially large proportion missing).

Study	Data, Outcome, Methods	Findings	Assessment
	Methods: Uncontrolled ITS adjusted for seasonality.		• Data routinely reported and less likely to be biased by social desirability bias. • Includes production for on-the-go consumption. • Uses a structural break and a longer time series than previous analysis of the same data.
Chile (Ad valorem Excise Tax, Tiered by sugar content: 10% and 18%)			
Caro et al. (2018). PLoS Medicine.[110]	**Data:** Kantar Worldpanel Chile, longitudinal data (Jan, 2013 - Dec 2015); 2,000 households in cities with population≥20,000. **Outcome:** Weekly purchases of SSB/non-SSB (prices, volume purchased in mL/capita/day and calories purchased in kilocalories/capita/day). **Methods**: Uncontrolled ITS, adjusted for time-varying household characteristics macroeconomic measures, seasonality, and national and regional trends.	3.4% decrease in H-SSBs volume purchased. 4.0% decrease in H-SSB calories purchased; (greatest effect in high SEP groups). 10.7% increase in L-SSB volume purchased. 3.1% decrease in untaxed beverage volume purchased. 5.3% decrease in untaxed calories.	• Nutrient intake was not collected at multiple time points during the study period and does not capture reformulation that may have occurred because of the tax (changing total kilocalorie intake). • Did not include SSBs/non-SSBs consumed on-the-go or at restaurants. • Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). •
Nakamura et al. (2018)	**Data**: Kantar WorldPanel Chile, longitudinal data (Jan 2011 -	21.6% decrease in H-SSBs volume purchased (greatest effect in high SEP groups).	• Did not include SSBs/non-SSBs consumed on-the-go or at restaurants.

Study	Data, Outcome, Methods	Findings	Assessment
PLoS Medicine.	Dec 2015) 2,836 households in cities with population≥20,000 **Outcome:** Purchased volume (mL/capita/month), sugar (grams/capita/month). **Methods**: Uncontrolled ITS, adjusted for seasonality, time trend, temperature, macroeconomic indicators and household characteristics (using a fixed effects approach).	15.1% decrease in total sugar purchased.	• Did not assess SSBs/non-SSBs not purchased in-stores (e.g. tap water, homemade SSBs). • Nutrient intake was not collected at multiple time points during the study period and do not capture reformulation that may have occurred because of the tax (changing total calorie intake). • Assessed shopping patterns to assess promotion-seeking behaviour.
France (Specific Excise Tax, Uniform: EUR 0.0755/litre)[a]			
Capacci et al. (2016). Draft report.[116]	**Data:** Kantar WorldPanel France and GfK Italy, household purchase data drawn from homescan consumer data from two French regions, and two neighbouring Italian regions (2,928 French households, 400 Italian households, Jan 2011 -Dec 2012). **Outcome:** Average weekly prices paid by consumers and purchased quantities (mL/week). **Methods:** Controlled ITS, adjusted for household fixed effects.	83mL/household/week decrease in sodas purchases. 40 mL/houshold/week decrease in juice drinks purchases. Increase in ASB purchases.	• Appropriate classification of SSBs/non-SSBs. • Used a control group with no SSB tax. • Did not include SSBs/non-SSBs consumed on-the-go or at restaurants.

Study	Data, Outcome, Methods	Findings	Assessment
Finland (Specific Excise Tax, Tiered by sugar content: EUR 0.11-0.22/litre)			
Heinonen et al. (2018). Masters' thesis.[107]	**Data:** Grocery store data from four stores in Helsinki (2013 - 2014). **Outcome**: Daily price and sales records. **Methods**: Instrumental variable regression to estimate price elasticity (with tax as instrument).	6.5 - 7.3% decrease in SSBs.	• Not clear what market share these four stores represented. • Evaluation limited to one city. • Did not capture other sources of SSBs or home-prepared SSBs/non-SSBs. • Not possible to evaluate SEP.

[a] *In 2018, France's SSB tax was modified from a uniform design to a tiered design.*

In the next sections, I summarise gaps in the current SSB taxation evidence base.

2.5 Gaps in the existing SSB taxation evidence base

A number of countries have introduced SSB taxes, at least in part for health reasons, and the evidence base around SSB taxation is growing. However much is still unknown, such as the role of context, the impact of SSB tax design on effectiveness and the potential role of non-price mechanisms and co-interventions.

2.5.1 Role of Context

First, although SSB taxes have been implemented in diverse settings, the extent to which contextual factors may impact tax effectiveness is unknown. Jou & Techakehakij hypothesise that there are at least three contextual factors that may modify the effectiveness of an SSB tax: baseline SSB consumption, baseline prevalence of overweight and obesity, and the existing tax environment.[122] There is marked variation across these factors amongst the 40+ countries which have introduced SSB taxes.[35,43] Additional contextual factors are likely also important, such as availability of potable water, availability and acceptability of SSB-substitutes, market structure, and the affordability of SSBs relative to average income.[70,71]

2.5.2 Impact of SSB tax design on effectiveness

Second, few aspects of SSB tax design have been empirically evaluated in real-world settings.[83,123] For example, as of May 2019 there were at least 14 national ad valorem taxes worldwide, but only one has been evaluated (the SSB tax in Chile).[110,115] There is limited empirical evidence about the impact of various SSB tax designs on effectiveness.

2.5.3 Role of non-price mechanisms

Third, there is a lack of evidence around potential non-price mechanisms, such as the ability of a tax to signal information about health risks to consumers, or industry responses to the introduction of a tax. Current guidance around SSB taxation focuses on how to optimise the price change mechanism, but less is known about the potential

impact of additional mechanisms in potentially amplifying or dampening the impact of an SSB tax.

2.6 Gaps in the existing SSB tax evaluation approaches

The methods used to evaluate SSB taxes are also evolving as an increasing number of evaluation teams assess these policies worldwide. However, it is still unclear how to integrate various kinds of evidence within an evaluation and how to best build on existing SSB taxation theory.

2.6.1 Integration of multiple types of evidence

SSB tax evaluations have drawn on a variety of data sources, from regularly collected consumer price index data to longitudinal household purchase data. Each of these data sources is associated with various strengths and limitations. However, few evaluations have attempted to combine multiple datasets to test related hypotheses (an exception is the evaluation by Nakamura et al., which incorporated a descriptive analysis of Google Trends data to assess their hypothesis that higher SEP households may have had greater access to information about the Chilean SSB tax).[115] SSB evaluations overall may benefit from the use of multiple datasets to test assumptions and evolving hypotheses.

2.6.2 Importance of developing more general SSB taxation theory

While Mytton et al. summarise the implicit theory behind many SSB evaluations, they emphasise that this is an over-simplification. The development of a more complex theory, including aspects of tax design, context and additional mechanisms, would help to guide additional research. As Mytton et al. suggest, efforts to synthesise SSB tax evidence should examine "different aspects of a more general theory about how taxes 'work' using a variety of research methods…"[67]

Guided by this recommendation, I summarise my overall approach to the Barbados SSB tax evaluation in the next chapter, beginning with a brief discussion of natural experimental evaluations in general.

3 AIMS AND OVERVIEW OF THE BARBADOS SSB TAX EVALUATION

In this chapter, I briefly summarise the Barbados SSB tax, discuss my approach to this natural experimental opportunity and provide an overview of my research objectives. I begin with a summary of my overall aims.

3.1 Overall Aims

The aims of this thesis were 1) to evaluate the impact of Barbados SSB tax on price and sales change and 2) to contribute to the development of broader SSB taxation theory. I expand on these in Sections 3.4.3 and 3.4.4, after introducing the study setting and policy intervention.

3.2 Study setting

Barbados is a small island in the Eastern Caribbean (as shown in Figure 7 and Figure 8).

Figure 7: Map of the Caribbean and Central American regions

Note: Image courtesy of https://publicdomainvectors.org/en/free-clipart/Barbados-location-map/67838.html

Barbados is the most densely populated country in the Eastern Caribbean, with a population of 293,131 (2018 estimate).[124] The population of Barbados is primarily of African descent (92.4%). The population structure is summarised in the population pyramid reproduced in Figure 9.[124] Approximately a third of the population lives in urban areas, although urban/rural distinctions may be less meaningful given the small size of Barbados (430 square kilometres). Almost the entire adult population (99.6%) is literate.[124]

Figure 8: Map of Barbados

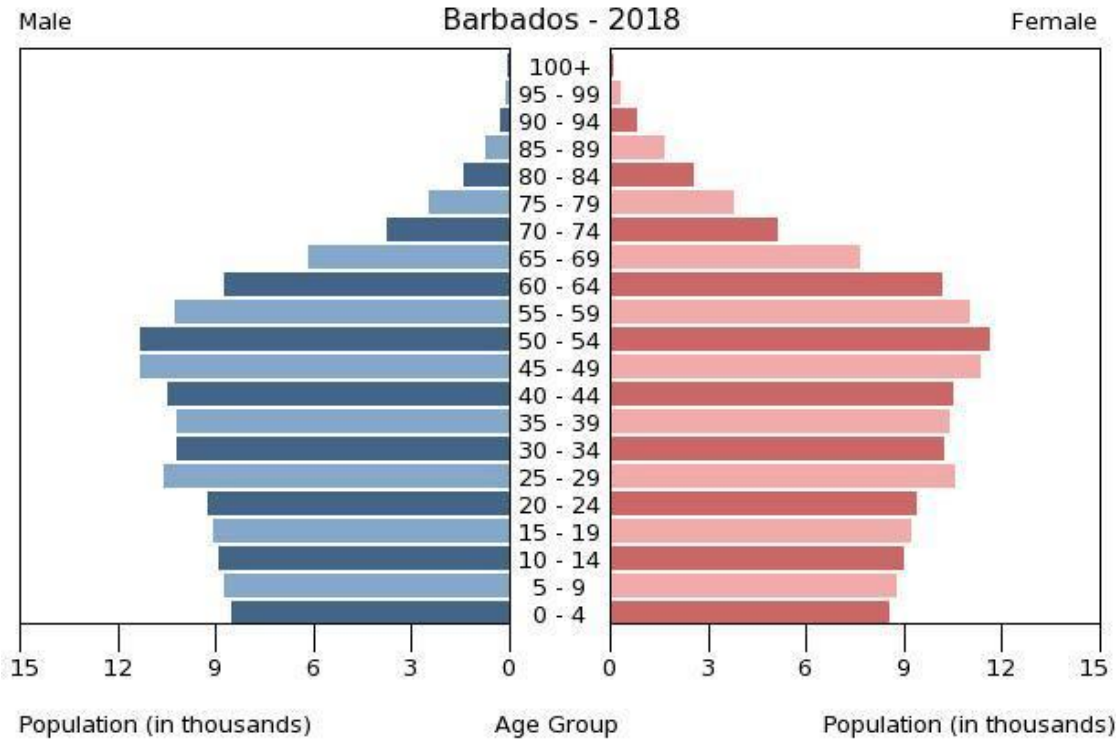
Note: Image courtesy of https://commons.wikimedia.org/wiki/File:Barbados_region_map.png

Per capita GDP in Barbados was estimated to be $18,600 in 2017 (on a purchasing power parity (PPP) basis, 2017 dollars), compared to $44,300 in the UK.[124] The economy is primarily driven by tourism, as well as sugar production and light manufacturing. Barbados is a net importer, with imports totalling $1.52 billion compared to $485.4 million in exports in 2017.[124] Imported products primarily originated from the US, Trinidad and Tobago, China and the UK. In 2017, Barbados had the third highest level of public debt (a measure of net government borrowing) worldwide, after only Japan and Greece.

Life expectancy has been estimated to be 75.7 years at birth in 2018 (ranking 103rd in the world from highest to lowest).[124] NCDs have been estimated to account for over 75% of the total disease burden in Barbados in 2017, with cardiovascular (20.4%), cancer (12.7%), type 2 diabetes (6.2%) and chronic respiratory diseases (2.4%) accounting for a substantial proportion of total disease burden (measured in DALYs).[38]

Based on a nationally representative survey conducted between 2012-2013, adult (≥25 years) rates of overweight and obesity were estimated to be 74.2% and 43.4% (respectively) for women, and 66.2% and 23.4% for men.[125] Based on the same study, rates of diabetes were estimated to be 18.7%,[125] compared to an estimated global rate of 9.3% in 2019.[126]

Figure 9: Population age pyramid, Barbados 2018



Note: Image courtesy of CIA World Factbook 2019.

Finally, in terms of SSB consumption, the GBD 2010 study extrapolated across regional data to estimate an average SSB consumption of between 2.0 to 2.4 servings/day in Barbados, compared to a global estimate of 0.6 servings/day.[35]

3.3 The Barbados SSB tax

In June 2015, the Minister of Finance introduced a 10% tax on SSBs, making Barbados one of the first two countries in the Caribbean to implement such a policy (the other

country being Dominica). The tax was framed as a response to the rising NCD burden in Barbados, with a focus on the established links between diabetes and SSB consumption:

> *It is now an indisputable reality that Barbados is on the verge of a national crisis with regards to persistent health problems associated with the escalating level of Non-Communicable Diseases (NCDs) […] One of the major afflictions in this category of illness that has escalated in the past few decades is that of diabetes mellitus, which is now a major cause of sickness, amputation and morbidity on the island. […] In Barbados, as is also the case in many other jurisdictions where diabetes is a major challenge, one of the products which is known to be heavily used by unsuspecting populations is sweetened beverages.*[127]

Tariff headings (developed to categorise imported goods) were used as the basis for defining taxable products. In particular, the tax was defined as applying to "those [products] which fall under tariff headings 20.09 and 22.02 on the import side, and similar products of like standing produced within Barbados."[127] This included sodas, sugar-sweetened juices, and sugar-sweetened sports and energy drinks, but not 100% juices, sugar-free (diet) sodas, or sugar-free flavoured waters.[128] The tax was also not levied on powdered drink mixes or syrups regardless of sugar content.

The Barbados SSB tax is applied to the value of the product when it is 1) imported by a distributor or 2) sold by the manufacturer, making it similar in structure to SSB taxes introduced in Bahrain, Bermuda, Dominica, India, Kiribati, Saudi Arabia, and the United Arab Emirates.[43]

3.4 Evaluation Principles

3.4.1 Importance of natural experimental evaluations

Although there are several definitions of a natural experimental evaluation,[129,130] I follow the Medical Research Council (MRC) guidance and define a natural experiment broadly as a study in which "exposure to the event or intervention of interest has not been manipulated by the researcher,"[130] and in which the researcher uses "naturally occurring variation in exposure to identify the impact of the event on some outcome of

interest."[131] A number of public health experts have adopted a similar perspective.[131–133]

Ogilvie et al. highlighted the importance of natural experiments in real-world evaluations in a recent commentary.[133] They began by emphasising the importance of population-level health interventions (PHIs) for NCD prevention, echoing calls from others.[131,133–135] PHIs vary widely (e.g. new transportation infrastructure, marketing restrictions around less healthy foods and beverages, etc.), but they tend to be large in scale (e.g. national policy). As a result, they are often not amenable to evaluation using approaches commonly used in the biomedical sciences (e.g. randomised control trials), and instead may be more appropriately evaluated through natural experimental evaluation.[136] Natural experimental evaluations can be used to assess real-world policies and to take into account factors which may be challenging to simulate or predict.[133]

Ogilvie et al. also highlighted some of the challenges around natural experimental evaluations.[133] For example, PHIs are often introduced quickly, limiting the feasibility of collecting pre-intervention data. Natural experimental evaluations often rely on routine sources of data and may aim to address data-related limitations by triangulating across various different data sources.

3.4.2 Two aims of natural experimental evaluations

As Ogilvie et al. and Mytton et al. emphasise, there may be two aims for these types of evaluations. First, they may produce context-specific effect size estimates, which are useful for monitoring local policy implementation. Second, they may contribute to broader PHI theory development and validation.[67,133] This kind of evaluative evidence can therefore be used to inform both 1) further policy amendment and 2) policy development elsewhere.[133,135] Given the level of interest in SSB taxation worldwide, it will be important for evaluations to address both of these aims to best inform the amendment of existing SSB taxes and to inform the optimal design of new ones.

In the next section, I focus on how the Barbados evaluation may contribute to both aims.

3.4.3 Aim 1: Producing context-specific estimates of effect sizes

To address my first goal, I focus on the whether the introduction of a new SSB tax was associated with changes in prices and purchases (solid lines in Figure 10). I also use data from a population-based nutrition survey to assess the proportion of SSBs covered by the tax. The Barbados SSB tax evaluation is the first evaluation of an SSB tax in the Caribbean region, and there is substantial interest from policymakers in Barbados and neighbouring countries in developing region-specific evidence around the effectiveness of SSB taxation. In Sections 3.8 and 3.9 I describe the ways in which I have engaged key stakeholders.

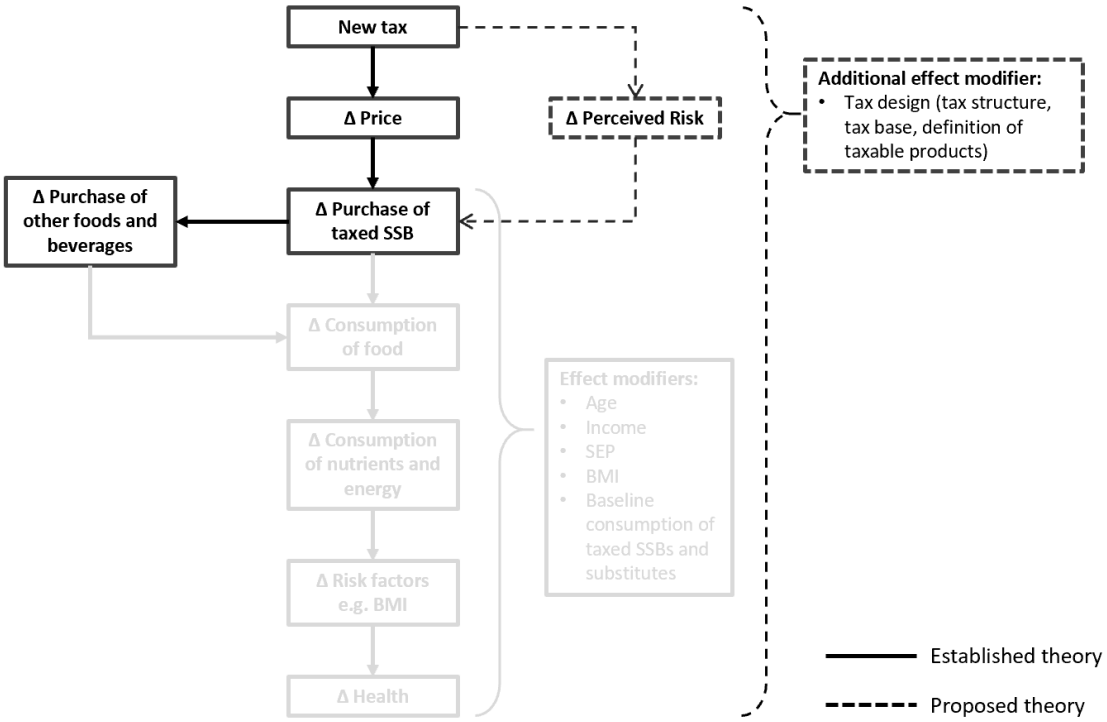
Ogilvie et al. emphasise the need to focus on areas of evaluation with the greatest uncertainty, highlighting that it is not always necessary (nor feasible) to include a health outcome in natural experimental evaluations.[133] As I summarised in Chapter 1, there is considerable evidence linking SSB consumption to NCD-related risk factors and health outcomes. However, as described in Chapter 2, SSB taxes have only been evaluated recently. As Mytton et al. suggest that "initial evaluation of any novel intervention should focus on more proximal steps in the causal pathway." [67] Guided by this advice, I focus on proximal outcomes (e.g. price and sales change).[67]

3.4.4 Aim 2: Contributing to broader SSB taxation theory

To address my second goal, I propose several additional theoretical propositions that I will assess in the context of the Barbados SSB tax (dashed lines in Figure 10). First, I hypothesise that tax design (e.g. tax structure, tax base and the definition of taxable products) moderates the impact of taxation (including price change). I assess hypotheses related to tax design and propose three criteria to improve the design of SSB taxes. Second, I hypothesise that a new tax may change the perceived risk around SSBs, leading to a change in purchases of taxed foods. I propose and test theory around this hypothesised mechanism.

In the next section, I describe the data available for this evaluation and summarise my specific research questions.

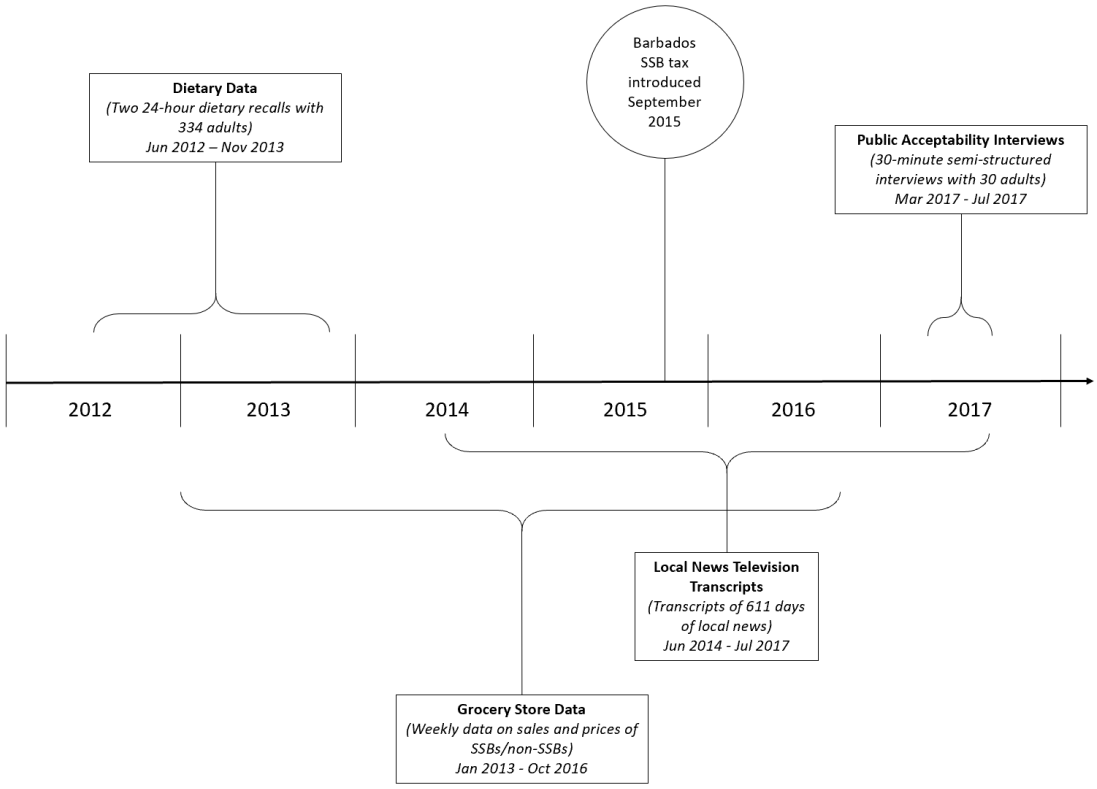
Figure 10: Initial logic model to guide the Barbados sugar-sweetened beverage (SSB) tax evaluation



3.5 Summary of data used to evaluate the Barbados SSB tax

As with many other natural experimental evaluations, I was unable to collect pre-intervention data because the Barbados SSB tax was implemented very quickly after it was announced. Instead, I rely on routine sources of data and pre-existing data, supplemented by a limited amount of post-tax data collection. I summarise the different types of data I used in Figure 11. Each of these data sources is associated with various strengths and limitations which I discuss in the relevant empirical chapter(s).

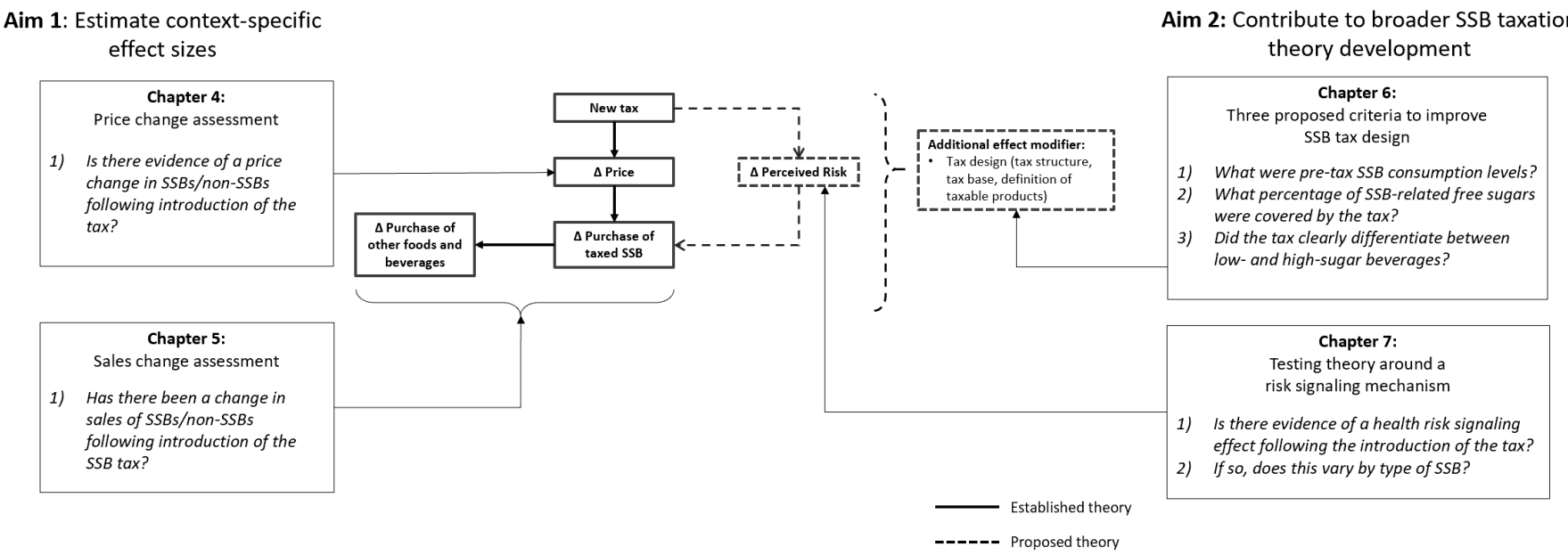
Figure 11: Summary of data used to evaluate the Barbados sugar-sweetened beverage (SSB) tax



3.6 Research objectives

My research objectives are summarised in Figure 12. My first objective was to evaluate whether the Barbados SSB tax led to a change in SSB prices as an early indicator of whether the tax operated as expected (Chapter 4). My second objective was to assess the impact of the Barbados SSB tax on SSB and non-SSB sales (Chapter 5). My third objective was to assess three proposed criteria to improve SSB tax design in the context of Barbados (Chapter 6). My fourth objective was to develop risk signalling theory and assess whether there was evidence of a risk signalling effect following the introduction of the Barbados SSB tax (Chapter 7).

Figure 12: Summary of research questions



The first two objectives broadly contribute to my first aim, of estimating context-specific effect sizes following the introduction of the Barbados SSB tax, while the third and fourth objectives broadly contribute to my second aim of contributing to broader SSB taxation theory development.

3.7 Summary of empirical chapters

The analyses presented in Chapters 4-7 are reproductions of papers that have been published, are under review or will be shortly submitted. As a result, there is some duplication in terms of background content. Study-specific discussions are included within each chapter and I highlight my contributions and those of all co-authors at the end of each chapter. Below, I briefly summarise each empirical chapter (Chapters 4-7) and my approach to the final chapter (Chapter 8), the overall discussion.

3.7.1 Assessing changes in price (Chapter 4)

First, I conducted a descriptive analysis of initial price changes following implementation of the SSB tax, using data provided by a major grocery store chain in Barbados. I summarised trends in price before and after the tax using year-on-year mean change in price per litre for SSBs and non-SSBs. This simple analysis was used to warrant the evaluation of a more distal outcome (change in sales, Chapter 5).[67] I revisit this price change analysis and conduct a more sophisticated assessment of longer-term price change in Chapter 7.

3.7.2 Assessing changes in SSB sales (Chapter 5)

I used an ITS analysis to assess what impact, if any, the introduction of the Barbados SSB tax had on sales of SSBs and non-SSBs. I used data from the same grocery store chain as above. In addition to estimating an effect size for the tax in Barbados, I include an assessment of whether there is evidence of substitution from high- to low-cost SSBs (e.g. brand down-switching), as has been predicted following the introduction of an ad valorem tax.

3.7.3 Baseline SSB consumption levels and patterns (Chapter 6)

A variety of contextual and tax design factors may be associated with the likelihood that an SSB tax will have a positive impact on health outcomes. I proposed three criteria that

may improve SSB tax design, and assessed these criteria in the context of the Barbados SSB tax using pre-tax nutritional survey data.

3.7.4 Role of a risk signalling mechanism (Chapter 7)

Several SSB tax evaluations have referred to a signalling mechanism, in which the introduction of an SSB tax conveys information to consumers leading to dampened consumption.[69,116] I used legal theory to operationalise a risk signalling mechanism, and assessed whether there was evidence of this mechanism following the introduction of the Barbados SSB tax. I used theory-testing process tracing (PT) which uses a structured framework to seek confirmatory/disconfirmatory evidence of a theory through a series of empirical tests.[137,138] I assessed the alternative explanation that price change alone fully explains the observed changes in sales trends by conducting a more in-depth price change analysis.

3.7.5 Overall discussion

In my overall discussion (Chapter 8), I revisit the theory from Figure 10 and consider my findings in the context of the SSB taxation evidence base, commenting on implications for policymakers and areas for future research.

3.8 Role of the Barbados Sugar-Sweetened Beverage (SSB) Tax Evaluation Steering Group

This evaluation was supported by the Barbados SSB Tax Evaluation Steering Group, which met three times per year from 2015-2019. The group consisted of senior representatives from both the Ministry of Health and Ministry of Finance, and key civil society, international and academic organisations. The full list of core members is summarised in Table 6.

Table 6: Summary of the Barbados SSB Tax Evaluation Steering Group

Name	Organisation
Sir Trevor Hassell	National NCD Commission of Barbados, Healthy Caribbean Coalition
Dr. Kenneth George	Ministry of Health
Dr. Arthur Phillips	Ministry of Health
Mr. Cyril Gill	Ministry of Finance and Economic Affairs
Dr. Godfrey Xuereb	PAHO
Ms. Maisha Hutton	Healthy Caribbean Coalition
Prof. Winston Moore	The University of the West Indies
Prof. Alafia Samuels	George Alleyne Chronic Disease Research Centre, Caribbean Institute for Health Research, The University of the West Indies
Prof. Nigel Unwin	
Prof. Ian Hambleton	
Dr. Madhuvanti Murphy	

The Steering Group provided assistance with the following: identifying funding sources, identifying potential data sources, reviewing and providing feedback on methods and emerging results, developing dissemination plans and engaging with policymakers and the media.

3.9 Engagement with key stakeholders

Throughout this evaluation, I presented results to senior Ministry of Health officials annually. I was invited to participate in a two-day workshop hosted by PAHO (the "Meeting to Develop a Standardised Tax Share Indicator for Alcoholic and Sugar-Sweetened Beverages,") and went on to contribute to the development of an SSB tax indicator as an intern under Rosa Sandoval, (Regional Advisor on Tobacco Control and Coordinator on Economics of NCDs). I was also invited to give a keynote presentation in the Bahamas on the Barbados SSB tax, to share overall evaluation results with policymakers in Barbados at an event hosted by the Barbados Heart and Stroke Foundation ("Exploring Enhanced Approaches to Increased Taxation on Sugar-sweetened Beverages in Barbados,") and to participate in a conference on "Accelerating Nutrition Policies in the Caribbean" hosted by the Healthy Caribbean Coalition. In

addition, I was invited to participate in the Harvard Radcliffe Institute meeting on "Leveraging the impact of sugary beverage tax evaluations," which brought together a number of leading SSB tax evaluation experts to discuss evaluation methods.

3.10 Ethics

All components of this study involving human participants (Chapter 6, Chapter 7) were approved by the Research Ethics Committee of the University of the West Indies and Barbados Ministry of Health (data for these analyses were collected through the Sir George Alleyne Chronic Disease Research Centre, University of the West Indies, Cavehill Campus). On the advice of the Research Ethics Committee, approval was not applicable for Chapter 4 and Chapter 5 since no individual human data were collected or used in these analyses.

In the next chapter, I begin with a descriptive analysis of short term price change following the introduction of the Barbados SSB tax.

4 PRICE CHANGE ASSESSMENT

This manuscript has been published:

Alvarado M, Kostova D, Suhrcke M, Hambleton I, Hassell T, Samuels TA, Adams J, Unwin N. Trends in beverage prices following the introduction of a tax on sugar-sweetened beverages in Barbados. Preventive Medicine. 2017 Dec;105S:S23–5.

I present the original publication and an extended discussion as an addendum.

Based on this analysis I was invited to present a paper titled “The Barbados tax on sugar-sweetened beverages: An overview of the evaluation and preliminary results” at the Caribbean Public Health Agency (CARPHA) conference in Georgetown, Guyana, 2017.

4.1 Abstract

A 10% excise tax on sugar-sweetened beverages (SSBs) was implemented in Barbados in September 2015. A national evaluation has been established to assess the impact of the tax. We present a descriptive analysis of initial price changes following implementation of the SSB tax using price data provided by a major supermarket chain in Barbados over the period 2014-2016. We summarise trends in price change before and after the tax using year-on-year mean price per litre change between SSBs and non-SSBs. We find that prior to the tax, year-on-year price growth of SSBs and non-SSBs was very similar (approximately 1%). During the quarter in which the tax was implemented, the trends diverged, with SSB prices growing by almost 3% while prices of non-SSBs decreased slightly. The growth of SSB prices outpaced non-SSBs prices in each quarter thereafter, reaching 5.9% growth compared to <1% for non- SSBs. Future analyses will assess the trends in prices of SSBs and non-SSBs over a longer period and will integrate price data from additional sources to assess heterogeneity of post-tax price changes. A continued examination of the impact of the SSB tax in Barbados will expand the evidence base available to policymakers worldwide in considering SSB taxes as a lever for reducing the consumption of added sugars at the population level.

4.2 Introduction

Caribbean populations suffer from the highest burden of non-communicable diseases (NCDs) in the Americas.[139] Barbados, an island in the Eastern Caribbean, faces a serious problem with overweight, obesity and related diseases. In 2012, the adult rates of overweight and obesity were 74.2% and 43.4%, respectively, for women, and 66.2% and 23.4%, respectively, for men.[125]

In June 2015, the Government of Barbados announced the introduction of a 10% ad valorem tax on sugar-sweetened beverages (SSBs). The tax is applied to sodas, sugar-sweetened juices, and sugar-sweetened sports and energy drinks, but not 100% juices, sugar-free (diet) sodas, or sugar-free flavoured waters.[128] The tax was implemented in September 2015, making Barbados one of the first two countries in the Caribbean with this measure.[128]

There is considerable evidence linking increased consumption of SSBs with weight gain in adults and children, and increased incidence of type 2 diabetes independent of

adiposity.[28,30] Reduced consumption of beverages with added sugar can have population-level health benefits.[67,74,77] A tax on SSBs can lead to an increase in the prices of SSBs relative to other beverages, creating an incentive for reducing the demand for SSBs. Prices of SSBs have been shown to increase relative to prices of non-SSBs following implementation of SSB taxes in Mexico and Berkeley, California.[105,108,109] An ongoing evaluation of the effect of the 2015 SSB tax on beverage prices and sales in Barbados is presently being conducted at the University of West Indies, on behalf of the Barbados SSB Tax Evaluation Steering Committee. This brief manuscript highlights the motivation for further analytic assessment of SSB tax effects in Barbados by comparing the pace of growth in SSB and non-SSB prices leading up to and immediately following the tax implementation.

4.3 Methods

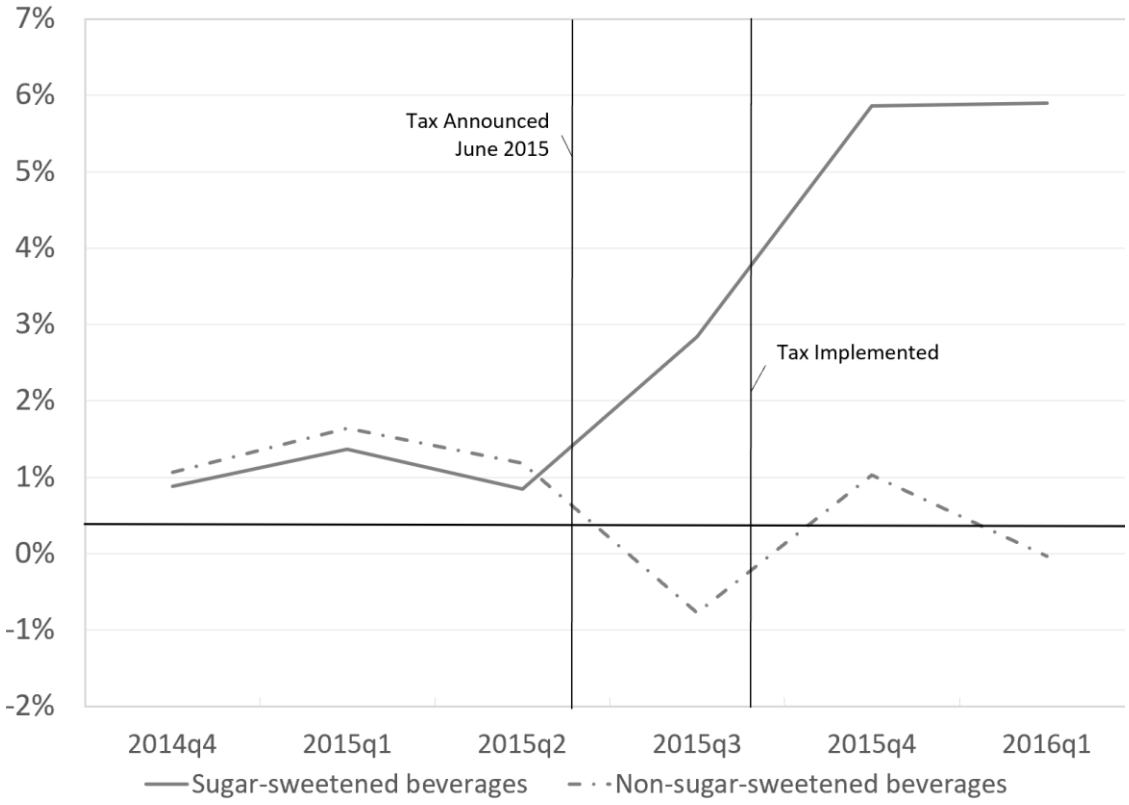
We used retail sales data from a large supermarket chain in Barbados from the last quarter of 2013 through the first quarter of 2016. We assessed trends in price across the 224 unique products which were non-missing in every quarter. Prices per litre were calculated by dividing total beverage sales in Barbados dollars by sales volume. We classified sodas, sugar-sweetened juices, and sugar-sweetened sports and energy drinks as SSBs, and no-added-sugar juices, sugar-free (diet) sodas/energy drinks/sports drinks and bottled waters as non-SSBs. We then calculated average quarterly prices and estimated the year-over-year percentage change in quarterly prices for each category. Prices in each quarter were assessed relative to the same quarter of the previous year to account for within-year seasonality.

4.4 Results

The resulting price growth estimates were compared across categories (Figure 13). In the three quarters prior to the introduction of the tax, SSBs and non-SSBs experienced very similar year-over-year price growth of approximately 1% for both beverage categories, and had parallel patterns of fluctuation. During the third quarter of 2015, at the end of which the SSB tax took effect, the trends diverged. At that time, the growth in SSB prices approached 3% while the growth in non-SSB prices decreased; thereafter, the change in SSB prices outpaced that of non-SSBs. In the two quarters after the tax

took effect, the growth in average SSB prices compared to the previous year reached 5.9% while staying mostly flat, between 0 and 1%, for non-SSBs. The two vertical lines in Figure 13 correspond to June 2015, when the tax was first announced and to September 2015, when the tax was first implemented. It is possible that manufacturers or retailers may have increased prices following the announcement of the tax, in anticipation of the actual implementation date.

Figure 13: Year-over-year percentage change in the average quarterly price per litre of sugar-sweetened and non-sugar-sweetened beverages, Barbados, 2014-2016[1]



[1] The first vertical line corresponds to June 2015 when the tax was first announced, and the second line corresponds to September 2015, when the tax was first implemented

4.5 Discussion

This is a preliminary descriptive analysis using retail data from a major grocery store chain following the Barbados SSB tax. For this descriptive analysis, unadjusted prices were used. As inflation would likely lead to similar proportional price changes among SSBs and non-SSBs, using unadjusted prices still allows a comparison of price change trends following the implementation of the tax.

The slight dip in non-SSB prices may have been part of an industry response to the introduction of the SSB tax, or may reflect other unknown factors. Bottled water and other diet beverages are produced/imported by some of the same manufacturers and distributors that supply SSBs. Future analyses will assess the trends in prices of SSBs and non-SSBs over a longer period to further explore these diverging trends (see Section 7.4.10). In addition, these price data represent prices in one major retail chain, and may not be representative of price changes across all stores. As a sensitivity analysis, we will assess price data from additional sources to assess heterogeneity of post-tax price changes (see Section 4.7.1).

4.6 Conclusion

In summary, we have shown a divergence in the growth trends of SSB prices relative to non-SSB prices following the introduction of the tax. This evidence is foundational to the forthcoming evaluation of the tax as a factor in raising SSB prices in Barbados. Presently, the number of countries that have implemented SSB taxes is limited. An examination of the impact of SSB taxes in Barbados will expand the evidence base available to policymakers worldwide in considering SSB taxes as a lever for reducing the consumption of added sugars at the population level.

4.7 Addendum

I present a sensitivity analysis and an extended discussion (including a more in-depth assessment of the strengths and limitations of the data used and a reflection on the results in relation to other studies).

4.7.1 Sensitivity analysis: Price variation in other store types

As discussed previously, a limitation of the price analysis presented above is that it relies on data from one large grocery store chain. It is not clear to what extent trends in this grocery store chain may be representative of trends in other grocery store chains or other types of stores (e.g. gas stations, convenience stores, etc.). I attempted but was unable to access electronic point of sale data from additional stores. Instead, I present a simple assessment based on a single-day survey of SSB and non-SSB prices across a range of grocery store chains and other store types.

On February 7, 2018 (2.5 years after the introduction of the tax), I visited nine different stores, including the grocery store chain included in this analysis and four additional grocery store chains, two warehouse club stores and two convenience stores. I selected these stores to maximise geographic and store type diversity.

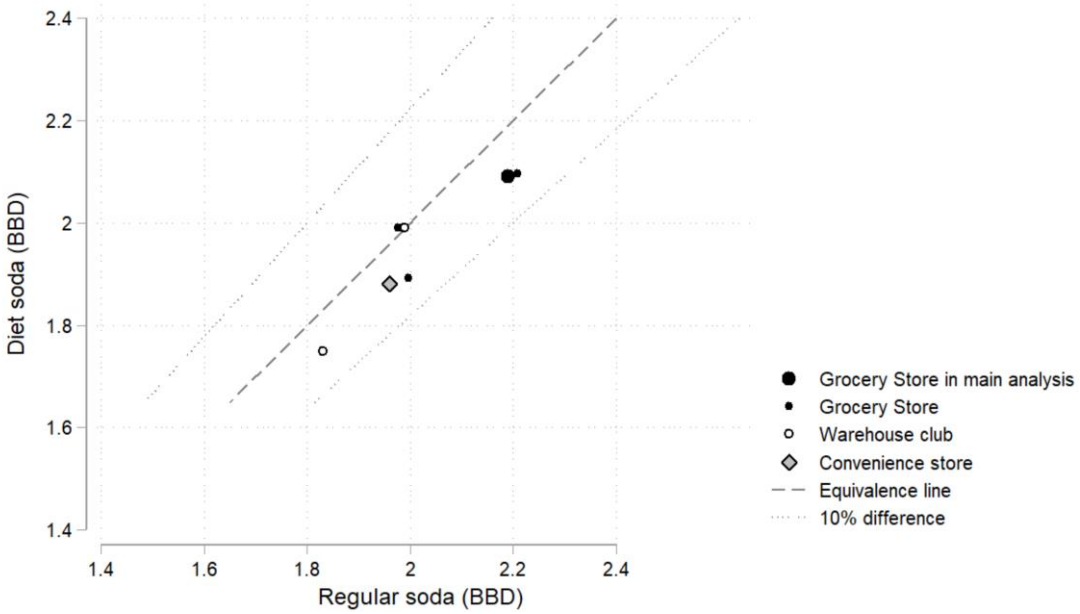
I selected two popular SSBs and identified the most similar non-SSB counterparts (Coke/Sprite and Diet Coke/Coke Zero/Sprite Zero; Pinehill Dairy sweetened and unsweetened orange juice). I then visited each store and recorded prices of these products (500mL bottles for SSB and non-SSB soda; 1L cartons for SSB and non-SSB juice). I assumed that pre-tax prices of these SSB/non-SSB pairs were the same, and further assumed that any price difference between SSBs and their non-SSB counterparts may be attributable to the tax. These are both substantial assumptions, and results should be interpreted with caution.

I present prices of sugar-sweetened and non-sugar-sweetened soda in Figure 14 and prices of sugar-sweetened and non-sugar-sweetened juice in Figure 15, including a line of equivalency and a +/- 10% line for reference. In five stores, prices of some beverages were not clearly labeled (e.g. SSBs sold in chiller cases). In these cases, I attempted to clarify prices with store employees. Two stores did not sell diet soda and were not included in Figure 14.

Overall, SSB prices were higher than prices of their non-SSB counterparts in the majority of stores. Within-store variation between sodas and diet sodas ranged from zero to 5%, with two stores (one grocery store and one convenience store) charging the same price for SSB and non-SSB soda. Within-store variation between SSB and non-SSB juice ranged from zero to 12%, with three stores (one warehouse club and two convenience stores) charging the same price for SSB and non-SSB juice. No stores charged more for non-SSBs than for corresponding SSBs.

Notably, the price variation *across* store types was greater than the variation between SSB and non-SSB pairs *within* any given store. The most expensive store charged 12% more for the same soda and 27% more for the same juice drink than the cheapest store. Finally, the grocery store which provided data for the overall Barbados SSB tax evaluation was associated with relatively higher prices than other store types, as shown in Figure 14 and Figure 15.

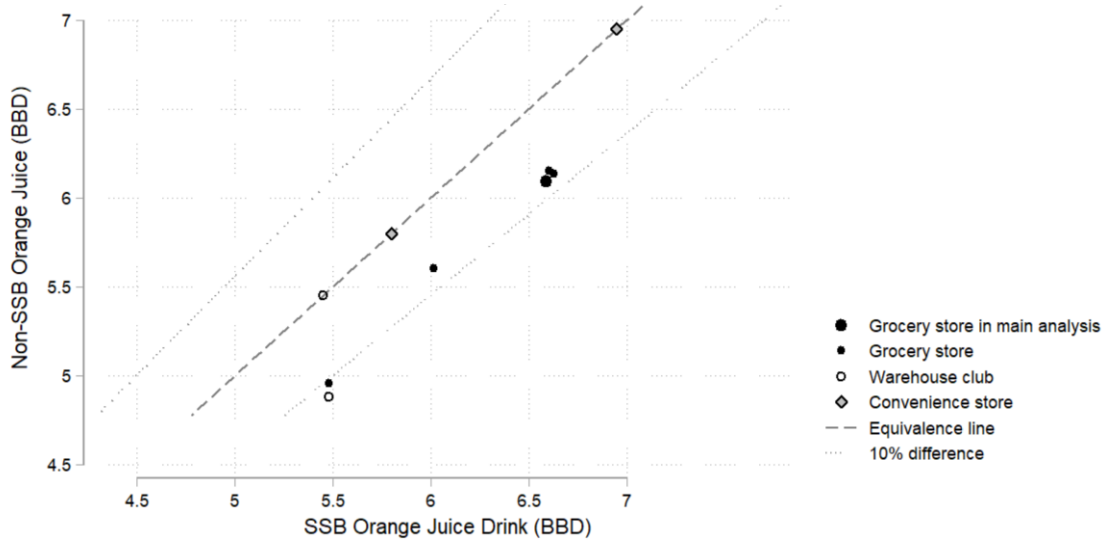
Figure 14: Cost of regular vs. diet soda (500mL) across 7 stores in Barbados, in Barbados dollars (BBD), 2018



Note: Data have been slightly jittered to show otherwise overlapping data points.

While subject to important limitations, this brief sensitivity analysis suggests that there was a price differential between popular SSBs and their untaxed non-SSB counterparts in the majority of stores considered. However, this analysis also highlighted the substantial variation in SSB prices across store types, creating the opportunity for consumers to substitute towards lower-priced stores in response to the introduction of a tax. In addition, if prices are not clearly displayed in some stores (as indicated in this analysis), tax-induced price changes may be less salient to consumers, potentially diminishing the price change effect on sales.

Figure 15: Cost of sweetened vs. unsweetened Pinehill Dairy orange juice (1L) across 9 stores in Barbados in Barbados dollars (BBD), 2018



4.7.2 Strengths and limitations

The electronic point of sale data used in the main price change analysis (and subsequent analyses in Chapters 5 and 7) have some important limitations. First, I did not have access to many of the types of data that have been used in previous SSB tax evaluations (e.g. household purchase panels, manufacturing industrial surveys, price tracking mobile applications, *de novo* pre-tax data collection). This is for a number of reasons: 1) commercial household purchase panel data are not available in Barbados, 2) the Barbados Statistical Service is only permitted to share manufacturing industrial surveys aggregated across several industries (due to the small size of the Barbados manufacturing industry), 3) price tracking mobile applications are relatively new in Barbados and app manufacturers were unresponsive to queries, and 4) the Barbados SSB tax was implemented just three months after it was first announced, precluding the possibility of collecting *de novo* pre-tax data.[104] Instead, I negotiated access to data from one major national grocery store chain (as has been done in SSB tax evaluations in Berkeley, California and Finland),[104,107] enabling the analyses presented here and in Chapter 5. However, a limitation of this type of data is that selected stores may not be representative of overall price and sales trends. The grocery store chain presented above was estimated to have a grocery market share of 34% (personal communication), and the sensitivity analysis presented above suggests their prices may have been somewhat

higher than in other grocery store chains or store types. However, the overall pattern of price differences between SSBs and non-SSBs seemed relatively consistent across stores, increasing our confidence that the price changes observed in the main analysis may have occurred across other stores as well.

Second, as has been discussed in previous SSB tax evaluations,[110,115] I did not have access to entire market price data, i.e. the data used only come from products which were sold in any given week. I was unable to distinguish whether missing data were due to zero purchases or to stock-outs, which occasionally occur in Barbados. However, it is unlikely that sales would drop to zero across all locations of this grocery store chain for regularly consumed products, reducing this concern.

Third, I only assessed products with data in every quarter, effectively excluding any products which may have been discontinued or introduced over the study period. However, in a longer-term price change analysis (see Section 7.4.10) I conduct a sensitivity analysis to assess the impact of different approaches to products with missing price observations.

Despite these limitations, the data used in the main analysis also have some important strengths. First, these data include very detailed product information, enabling appropriate classification in to SSB and non-SSB categories. Second, I was able to assess changes in non-SSB prices, in line with recommendations that SSB tax evaluations should also assess changes in non-SSB consumption.[99] Finally, data collection is automated (through an electronic point of sale system) and will therefore not be susceptible to recall biases nor is it likely to be influenced by changes in data collection methods over time.

In this short-term price change assessment, I present a descriptive summary of price change over time. This simple approach has the advantage of being straightforward to communicate. I considered using a more sophisticated model-based approach (e.g. following Grogger's post-tax monthly indicator method).[108] However, my primary objective was to assess whether there was a strong rationale for conducting a longer-term evaluation of the Barbados SSB tax and a simple analysis was sufficient to address this question, especially given the existing evidence base around SSB taxation and price

change. I revisit this price change analysis in Section 7.4.10 using a more sophisticated approach.

4.7.3 In relation to other studies

In evaluations of price change following *specific* SSB taxes (i.e. volume- or sugar-based taxes), it is feasible to assess the pass-through rate. For example, several studies assessed whether the Mexican 1 peso/litre SSB tax increased SSB prices by a full peso per litre and estimated corresponding pass-through rates between 90-105%.[108,109,113]

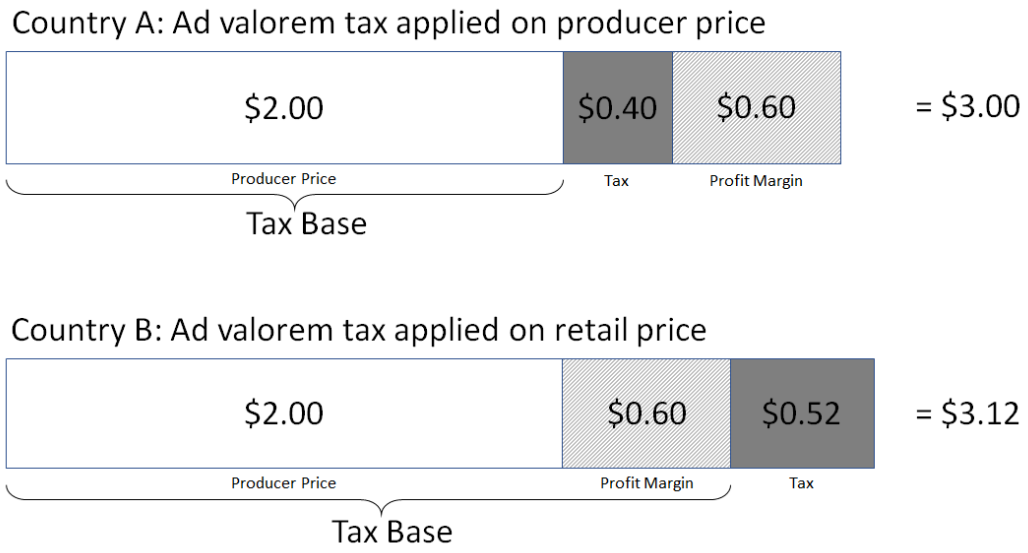
However, as previously discussed the Barbados SSB tax is applied to a tax base that we do not observe (the *producer price*). The producer price has been defined as the amount "that a manufacturer or producer of the goods would reasonably be expected to fetch for the goods on a sale in the open market to a purchaser who is not connected to the manufacturer or producer."[140] Additional data would be required (i.e. the producer price, which is almost always unobserved, or product-specific tax revenue, which is rarely disaggregated enough for use) to estimate the true pass-through rate. Some ad valorem excise taxes are applied on a different tax base, such as on retail price (e.g. Chile), while others are similar to the Barbados tax structure (e.g. Dominica).

While we were not able to estimate the pass-through rate, we provided an estimate of the observed change in SSB prices (a 5.9% increase). The ratio of this price change percentage and the tax rate (10%) provides a lower bound for the likely pass-through rate (59%). We highlight that the choice of tax base determines the potential impact of a tax on final prices, as demonstrated in Table 7 (based on a table from the WHO Report on Global Tobacco Control, 2017) and further illustrated in Figure 16.[76]

Table 7: Impact of different tax structures on price following a 20% ad valorem tax[76]

Components and summary measures of price	Country	
	A	B
[1] Producer price (same in both countries)	2.00	2.00
[2] Country A: Ad valorem tax on producer price (20%) = 20% x [1]	0.40	-
[3] Retailer's and wholesaler's profit margin (same in both countries)	0.60	0.60
[4] Country B: Ad valorem tax on retail price (20%) = 20% x ([1]+[3])	-	0.52
[5] Final Price	3.00	3.12
[6] Pass-through rate	100%	100%
[7] Price change (%)	15%	20%

Figure 16: Impact of different tax structure on price following a 20% ad valorem tax



As illustrated, even with a pass-through rate of 100%, an ad valorem tax applied to producer price will result in a price change that is lower than the tax rate.

4.7.4 Future research

There are a number of areas for future research. First, the most price sensitive consumers may have shifted to cheaper stores when confronted by tax-induced price increases (potentially shifting away from the store which provided data for the overall evaluation, given its relatively higher prices). In the next Chapter, I include several sensitivity analyses (5.4.2) to test this hypothesis. I also assess trends in sales in non-

SSBs, which should remain stable or decrease if consumers do substitute to buying SSBs from cheaper store types, rather than to non-SSBs from their original store.

Second, I will consider the impact of the Barbados SSB tax on prices using a longer time series and adjusting for inflation, stratified by major SSB product types (see Section 7.4.10).

Third, in order to synthesise SSB tax evidence, SSB taxes have to be harmonised using a summary exposure measure.[99] However, the harmonisation method should take account of differences in tax structure (i.e. different tax bases for ad valorem taxes). Assuming that an ad valorem tax applied on producer price is equivalent to the tax rate would overestimate the summary exposure measure. An alternative approach may be to use observed price change as the summary exposure measure instead, and consider which tax designs lead to greater price changes separately.

4.8 Contributions

I conceptualised the study design together with Nigel Unwin, Jean Adams, Ian Hambleton, Alafia Samuels, Madhuvanti Murphy, Deliana Kostova and the Barbados SSB Tax Evaluation Steering Group. I negotiated a data sharing agreement with the grocery store chain, cleaned the data, categorised soft drinks according to product category and taxed/untaxed status, analysed the data, generated the figures and drafted the manuscript. Deliana Kostova, Jean Adams and Nigel Unwin contributed to study design. All authors contributed to interpretation of results, provided feedback on multiple versions of the manuscript and approved the final version. I collected the data for the sensitivity analysis and wrote the addendum, with input from Jean Adams and Nigel Unwin.

I gratefully acknowledge contribution to the study design and support of the broader Barbados SSB tax Evaluation Steering Group, as well as the technical advisory committee: Deliana Kostova (US Centre for Disease Control and Prevention) and Marc Suhrcke (University of York).

5 SALES CHANGE ASSESSMENT

This manuscript has been published:

Alvarado M, Unwin N, Sharp SJ, Hambleton I, Murphy MM, Samuels TA, Suhrcke M, Adams J. Assessing the impact of the Barbados sugar-sweetened beverage tax on beverage sales: an observational study. International Journal of Behavioural Nutrition and Physical Activity. 2019 Jan 30;16(1):13.

I present the original publication with minor changes for clarity. Based on this analysis I was invited to deliver a keynote presentation on a paper titled “Assessing the impact of the Barbados sugar-sweetened beverage tax: A mixed method evaluation” at the University of the West Indies in Nassau, Bahamas, 2019.

I also presented related papers, as summarised in Appendix 5.

5.1 Abstract

Background

The World Health Organisation has advocated for sugar-sweetened beverage (SSB) taxes as part of a broader non-communicable disease prevention strategy, and these taxes have been recently introduced in a wide range of settings. However, much is still unknown about how SSB taxes operate 1) in various contexts and 2) as a result of different tax designs. In 2015, the Government of Barbados implemented a 10% ad valorem (value-based) tax on SSBs. It has been hypothesised that this tax structure may inadvertently encourage consumers to switch to cheaper sugary drinks. We aimed to assess whether, and to what extent, there has been a change in sales of SSBs following implementation of the SSB tax.

Methods

We used electronic point of sale data from a major grocery store chain and applied an interrupted time series (ITS) design to assess grocery store SSB and non-SSB sales from January 2013 to October 2016. We controlled for the underlying time trend, seasonality, inflation, tourism and holidays. We conducted sensitivity analyses using a cross-country control (Trinidad & Tobago) and a within-country control (vinegar). We included a post-hoc stratification by price tertile to assess the extent to which consumers may switch to cheaper sugary drinks.

Results

We found that average weekly sales of SSBs decreased by 4.3% [95% CI 3.6 to 4.9] compared to expected sales without a tax, primarily driven by a decrease in carbonated SSBs sales of 3.6% [95% CI 2.9 to 4.4]. Sales of non-SSBs increased by 5.2% [95% CI 4.5 to 5.9], with bottled water sales increasing by an average of 7.5% [95% CI 6.5 to 8.3]. The sensitivity analyses were consistent with the uncontrolled results. After stratifying by price, we found evidence of substitution to cheaper SSBs.

Conclusions

This study suggests that the Barbados SSB tax was associated with decreased sales of SSBs in a major grocery store chain after controlling for underlying trends. This finding was robust to sensitivity analyses. We found evidence to suggest that consumers may

have changed their behaviour in response to the tax by purchasing cheaper sugary drinks, in addition to substituting to untaxed products. This has important implications for the design of future SSB taxes.

5.2 Introduction

In 2015, fifteen million people died between the ages of 30 and 70 from non-communicable diseases (NCDs).[8] Despite the establishment of a target to reduce premature mortality from NCDs by one third, the World Health Organisation (WHO) Independent High-Level Commission on NCDs has suggested that without a dramatic change in approach, this target will not be met.[8] A greater focus on population-level efforts to prevent NCDs is urgently needed.[10]

The WHO identified 88 "Best Buys" to address the burden of NCDs.[141] One recommendation is to "reduce sugar consumption through effective taxation on sugar-sweetened beverages."[141] Consumption of SSBs is associated with higher incidence of type 2 diabetes, overweight and obesity, cardiovascular risk factors, and dental caries.[25,28] Several countries have implemented or amended SSB taxes recently (see Table 2), and the number of countries and localities implementing SSB taxes with a health focus has more than tripled since 2011.[142]

SSB taxes are hypothesised to increase the prices of SSBs, dampening demand and resulting in population-level improvements in health.[67] Evaluations of SSB taxes are beginning to emerge and provide some empirical evidence around these theoretical links. Prices of SSBs have been shown to increase following the implementation of an SSB tax.[103,104,109,143] Purchases of SSBs have been shown to decrease following the implementation of SSB taxes in Mexico, several U.S. cities and an amended SSB tax in Chile.[104,110,115,117,144] Long-term health impacts have been estimated through modelling studies and have shown potential benefits.[145,146]

However, much is still unknown. Jou & Techakehakij hypothesise that three contextual factors may modify the effectiveness of an SSB tax: baseline SSB consumption, baseline prevalence of overweight and obesity, and the existing tax environment.[122] Additional contextual factors are likely also important, such as availability of potable water, availability and perception of SSB-substitutes and income level and distribution. Finally, although it has been hypothesised that SSB taxes influence behaviour primarily through

price change, other mechanisms may also be important.[67] Many other activities may coincide with implementation, such as political lobbying, media advocacy, health education campaigns, changes in SSB marketing, price promotions, reformulation, and changes to product availability. The impact of these additional mechanisms is unknown.

In addition, SSB taxes can be designed in several ways, which may also impact tax effectiveness. Taxes can be structured as either specific, volume-based taxes (i.e. 1 peso/litre), or sugar-content based taxes; or as ad valorem, value-based taxes (i.e. 10% of the producer's price, see earlier Section 2.1.3). It has been suggested (but not shown) that *ad valorem* taxes may encourage brand down-switching, the consumer strategy of substituting to cheaper brands, since taxing drinks proportionate to their value may create a steeper price gradient across products.[74,77] The definition of taxable products varies (i.e. based on sugar content or applied to all drinks with added sugar), as do rates of taxation.[142]

5.2.1 The Barbados SSB tax

In June 2015, the Government of Barbados announced the introduction of a 10% *ad valorem* tax on SSBs.[127] Taxable products included "sweetened beverages such as carbonated soft drinks, juice drinks, sports drinks, fruit juices […] that contain added high calorie sweeteners."[127] Bottled waters, 100% juices, coconut water, unsweetened milk and powdered drinks were exempt. Initial analyses of price changes following the Barbados tax suggest that SSB prices increased by 5.9%, while prices of non-SSBs remained constant.[143]

We aimed to assess whether and to what extent there was a change in sales of SSBs following implementation of the Barbados SSB tax.

5.3 Methods

We used electronic point of sale data from a major grocery store chain. We utilised an interrupted time series (ITS) design, controlling for seasonality, autocorrelation, and other time-varying factors such as tourism and inflation.[147] To address concerns around time-varying confounding, we conducted sensitivity analyses with two control groups. We included a post-hoc stratification by price tertile to assess the extent to which consumers engage in brand down-switching.

5.3.1 Data

Electronic point-of-sale data were available from a major grocery chain in Barbados. Data were provided aggregated across all individual stores. The primary outcome was sales (measured in volume) of SSBs and non-SSBs. Sub-category analyses were conducted on carbonated SSBs, other SSBs, waters and other non-SSBs. All products were categorised according to the definitions in Chapter 5: Appendix Table 1. Products with no available size data were excluded from the analysis (39 products, accounting for 1.7% of total products sold). Data were available from January 1, 2013 - October 31, 2016, with dollar and unit sales aggregated by week (covering 1,161 unique, size-specific beverage products). This study period included 141 weeks of pre-intervention data and 59 weeks post-tax.

5.3.2 Analysis

We used an ITS design (uncontrolled and controlled) to assess trends in sales of SSBs, non-SSBs and beverage sub-categories. To address some of the major threats to validity associated with ITS designs, we were guided by Ramsay's Quality Criteria for ITS Designs checklist[148] (see Chapter 5: Appendix Box 1).

5.3.2.1 Overall change in sales

We calculated the weekly volume in millilitres sold per capita for SSBs and non-SSBs, as well as for carbonated-SSBs, other SSBs, water and other non-SSBs. We used ordinary least squares regression assuming a normally distributed outcome, and built our models using an ITS design to estimate change in sales following tax implementation. We included both an intercept effect (an indicator denoting the post-tax period) and a trend effect (zero in the pre-tax period and 1 in the week the tax was implemented, 2 for the second week of taxation and so on). Previous analyses of SSB sales following tax implementation have found both immediate step changes and changes in trend, so we allowed for both.[104,117] We also included an overall linear trend effect (1 to 200) to account for the pre-tax linear trend in beverage sales.

We included monthly indicators to allow the seasonal effect to be modelled with maximum flexibility. To account for other underlying trends, we included two time-varying covariates: monthly tourist arrivals (to control for changing demand driven by tourism) and monthly consumer price index (to control for inflation). We present the

absolute and relative difference from the counterfactual (setting the variables for the post-tax period and post-tax trend to zero). See Chapter 5: Appendix Text 1 for further details.

To assess model goodness of fit, we examined the model residuals to assess whether they were normally distributed, and whether they were randomly distributed over time. We tested for autocorrelation using the Cumby-Huizinga test[149] and included a single lag of the residual which adequately addressed autocorrelation.

5.3.2.2 Sensitivity analyses

To address potential concerns related to time-varying confounding, we conducted two sensitivity analyses. The first sensitivity analysis was an assessment of the same outcome (drink sales) in a setting without an SSB tax (Trinidad & Tobago), and the second was an assessment of a different outcome (vinegar sales) in Barbados. Further details are provided in Chapter 5: Appendix Text 2.

5.3.2.3 Change in sales by price tertile

We divided each beverage category into three price levels (low- mid- and high-cost) based on the average price observed across the study period, and repeated the main analysis by price tertile (see Chapter 5: Appendix Text 3).

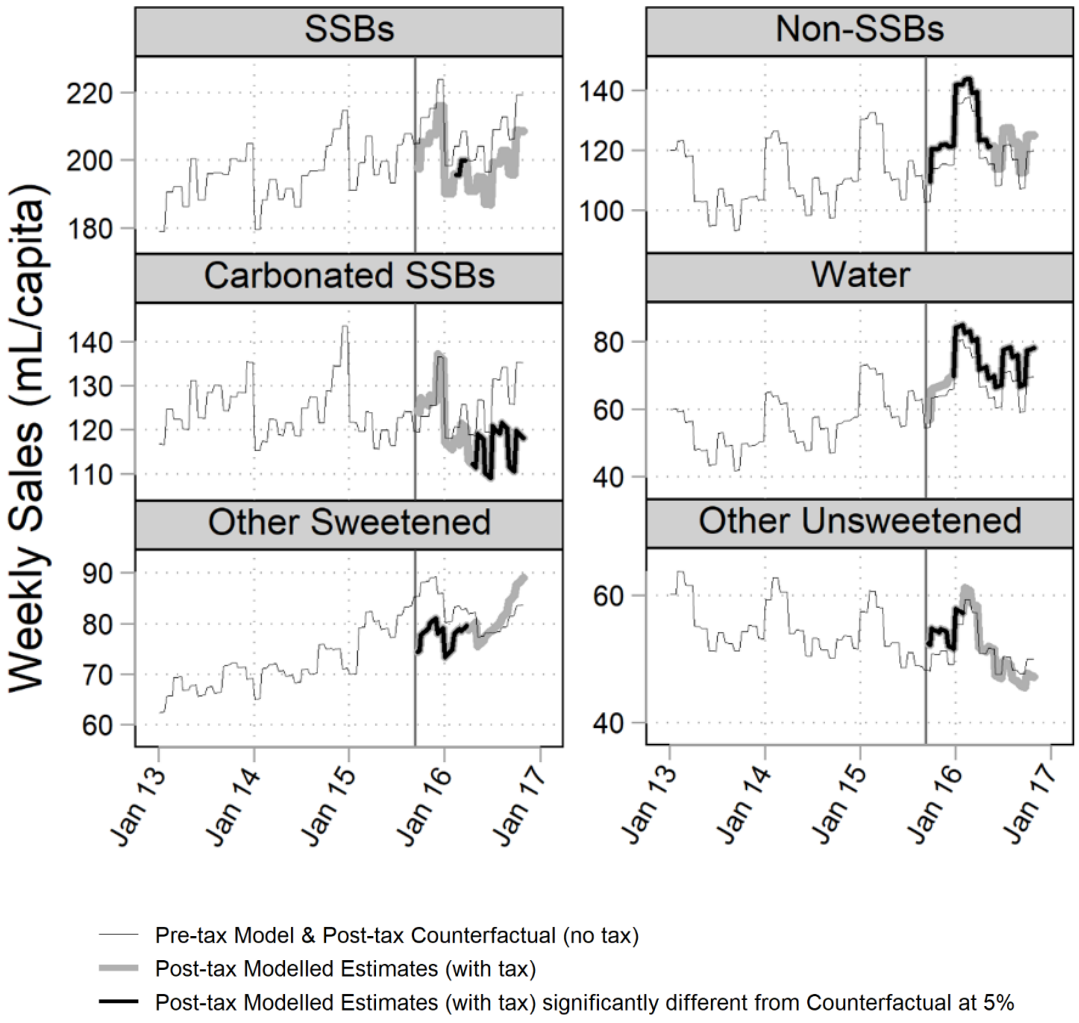
All analyses were conducted using STATA v14.0.[150]

5.4 Results

5.4.1 Overall change in sales

Sales of SSBs were lower than predicted over the 59-week post-tax period. On average, sales changed by -8.6 mL/capita/week [95% CI -10.0 to -7.3] per week compared to the counterfactual, equivalent to a -4.3% [95% CI -4.9 to -3.6] change relative to the counterfactual. Sales of carbonated SSBs decreased, both overall and at the end of the study period. Sales of other SSBs decreased overall, although at the end of the study period there was no evidence of a statistically significant difference.

Figure 17: Grocery Store Sales (mL/capita/week), January 2013-October 2016



Sales of non-SSBs were higher in the post-tax period than predicted, with an average increase of 6.1 mL/capita/week [95% CI 5.3 to 6.8], equivalent to a 5.2% [95% CI 4.5 to 5.9] relative change. Sales of bottled water increased, both overall and at the end of the study period. Sales of other non-SSBs increased overall, although at the end of the study period there was no evidence of a difference. The residuals across all models did not indicate any violation of the model assumptions.

See Figure 17, Table 8 and Chapter 5: Appendix Table 3 for detailed results.

Table 8: Mean post-tax absolute and relative effects, overall and in the final study week

	Mean Overall				Final Week of Study			
	Absolute (mL/capita/week)		Relative (%)		Absolute (mL/capita/week)		Relative (%)	
	Est	95% CI	Est	95% CI	Est	95% CI	Est	95% CI
SSBs	-8.6	-10.0, -7.3	-4.3	-4.9, -3.6	-10.4	-26.8, 6.0	-5.9	-15.5, 3.7
Carbonated SSBs	-4.5	-5.4, -3.6	-3.6	-4.4, -2.9	-15.6	-26.8, -4.5	-15.5	-27.4, -3.7
Other SSBs	-4.1	-4.6, -3.6	-5.1	-5.8, -4.5	4.1	-2.2, 10.5	5.1	-2.6, 12.8
Non-SSBs	6.1	5.3, 6.8	5.2	4.5, 5.9	5.4	-3.8, 14.6	3.8	-2.7, 10.2
Water	4.9	4.3, 5.5	7.5	6.5, 8.3	8.1	1.1, 15.0	9.1	1.5, 16.8
Other non-SSBs	1.3	1.0, 1.6	2.4	1.9, 3.1	-2.3	-5.9, 1.3	-4.3	-11.1, 2.5

5.4.2 Sensitivity analyses

The overall pattern of results was robust to both sensitivity analyses (see Chapter 5: Appendix Tables 4-5).

5.4.3 Change in sales by price tertile

Table 9, Figure 18 and Figure 19 summarise the results of the post-hoc price tertile stratification. Sales of low-cost SSBs decreased immediately following the tax, before returning to predicted levels. Sales of mid-cost SSBs increased, while sales of high-cost SSBs decreased across the whole study period. The differences in trends between low- ,mid- and high-cost tertiles were statistically significant at the 5% level (see Chapter 5: Appendix Table 7).

Low-cost non-SSBs increased across the whole study period, while there was no sustained evidence of a change in sales of mid-cost non-SSBs. Sales of high-cost non-SSBs increased immediately after the tax and decreased below predicted levels by the end of the study period. The difference in trends between cost tertiles were all statistically significant.

The product sub-category analysis showed a similar overall pattern of results. Sales of high-cost carbonated-SSBs decreased, and sales of low-cost other SSBs increased while mid-cost other SSBs sales decreased. Mid-cost bottled water sales increased, and mid-cost other non-SSBs increased immediately before decreasing by the end of the study period. Sales of high-cost other non-SSBs decreased. See Figure 18 and Figure 19, Table 9 and Chapter 5: Appendix Tables 6-7 for detailed results.

5.5 Discussion

In this first analysis of the impact of an SSB tax in a small island developing state (SIDS), we found that the implementation of a 10% ad valorem tax was associated with a 4.3% [95% CI 3.6 to 4.9%] decrease in grocery store sales of SSBs and 5.2% [95% CI 4.5 to 5.9%] increase in sales of non-SSBs. Sensitivity analyses using a cross-country control (Trinidad and Tobago) and a within-country control (vinegar) led to a similar pattern of results.

We stratified by price tertile and found evidence of brand down-switching, with sales of expensive SSBs decreasing by 7.2% [95% CI 6.5 to 7.8%] and sales of mid-cost SSBs increasing by 6.5% [95% CI 4.2 to 8.6%]. To our knowledge, this is the first evaluation of a newly introduced ad valorem tax, and the first evaluation to explicitly test for differential effects by baseline price category.

5.5.1 Strengths and weaknesses of the study

We used data from a major grocery store chain. These data may not be representative of all SSB sales and the findings from these data are limited to purchasing behaviours amongst the subset of people who shop at this chain. It is possible that consumers may have shifted to another store following the tax, which could mean our estimate of effect may be exaggerated. However, we assessed both non-SSB sales and vinegar sales and found no evidence of a decrease in these untaxed products, supporting the hypothesis that the tax did not lead consumers to change stores. We did not assess dairy, powdered drinks, concentrates or syrups used to make drinks, nor did we evaluate substitution to other non-beverage products. Unlike analyses using household purchase data,[117,151,152] we relied on aggregated weekly sales data and thus were not able to conduct sub-group analyses that would have allowed stratification by SEP. Because we used sales (rather than purchase data) we were not able to estimate absolute changes in mL purchased per person/household, as has been done elsewhere.[110,115,117]

Despite limitations, these data were the most detailed source available in this setting. Similar data have been used in other SSB evaluations in the US.[104] There is no commercial purchase panel available in Barbados, and this is likely to be the case in many other SIDS. In addition, commercial purchase panel data are prohibitively costly, and alternative data sources may be important for conducting policy evaluations in a range of contexts. Commercial panel data rely on accurate reporting by participants and often focus on

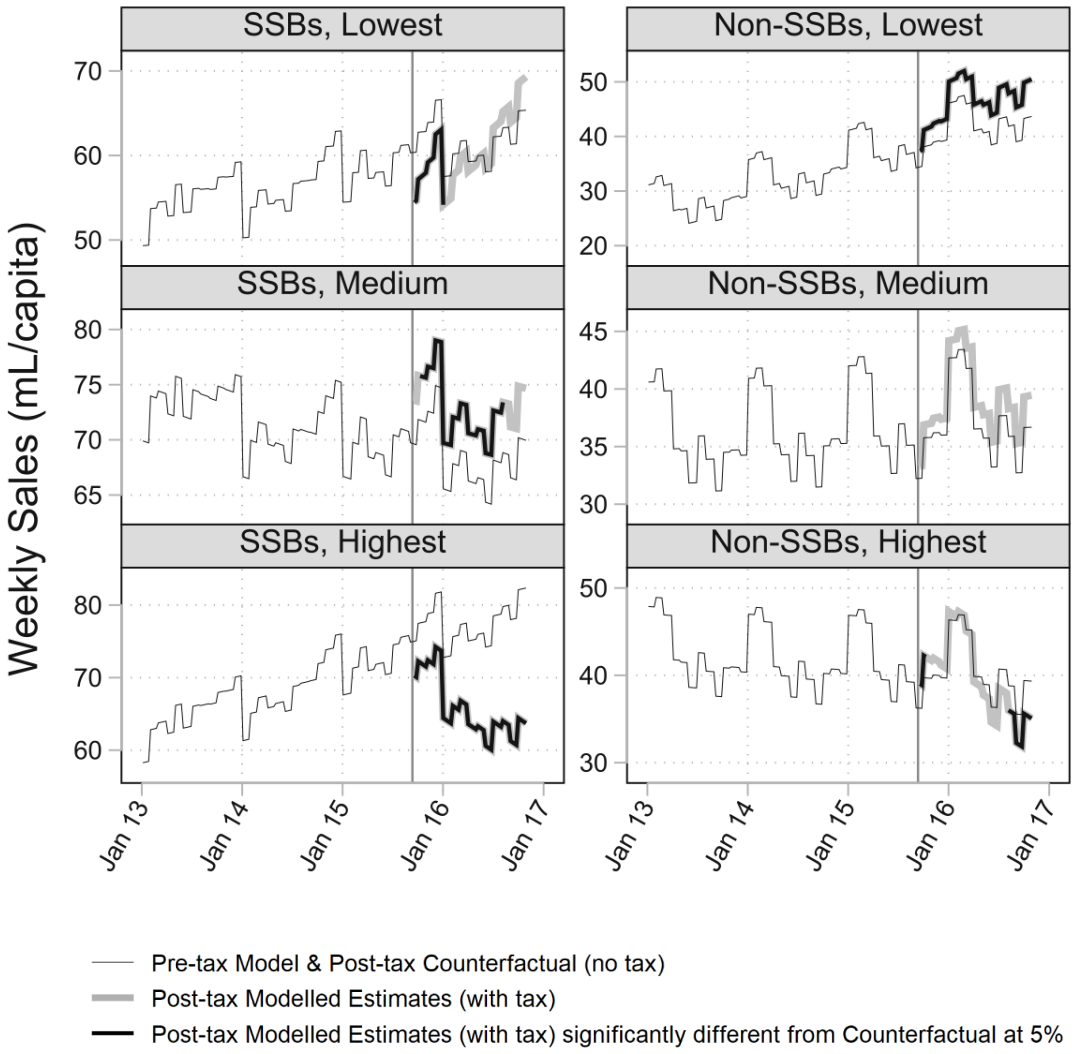
urban households and purchases made for in-home consumption (potentially missing on-the-go purchases). Repeated cross-sectional surveys have also been used in SSB tax evaluations, although these surveys 1) require pre-tax data collection and 2) may be subject to self-report biases (e.g. social desirability bias).[104,151]

In contrast, electronic point of sale data do not rely on individual reporting and can provide a detailed and consistently measured time series. With 141 pre-tax observations and 59 post-tax observations for the grocery store analysis, we had a long time series (which has been shown to add strength to the ITS design).[153] Since Barbados is a relatively isolated island, the risk of cross-border shopping was virtually zero, in contrast to some of the U.S. evaluations of city-specific SSB taxes.[104,154]

Table 9: Mean post-tax absolute and relative effects by price tertile, Barbados grocery store chain data, Jan 2013-Oct 2016

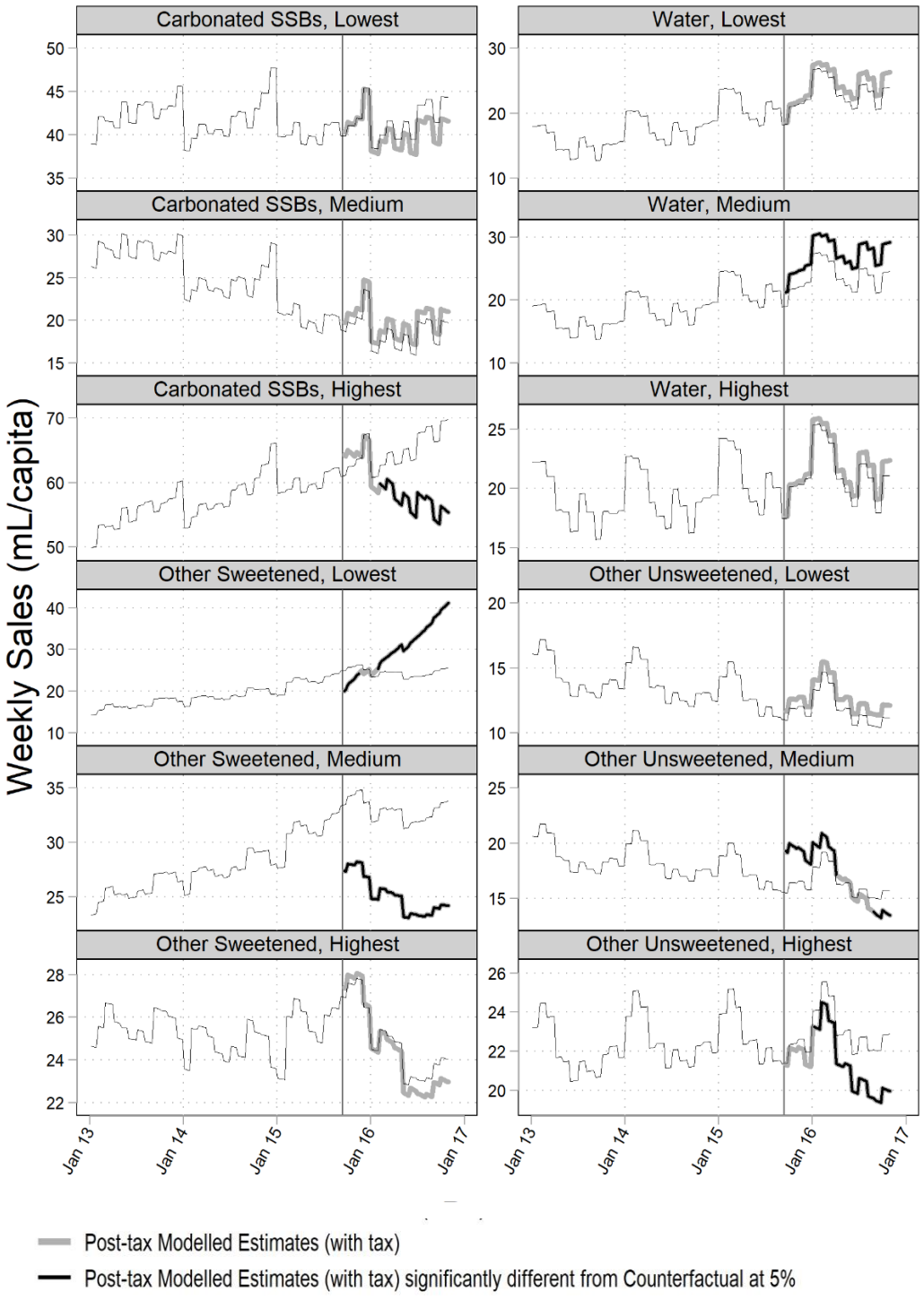
		Mean Overall				Final Week of Study			
		Absolute (mL/capita)		Relative (%)		Absolute (mL/capita/week)		Relative (%)	
	Cost level	Est	CI	Est	CI	Est	CI	Est	CI
SSBs	Low	-1.5	-2.0, -1.0	-2.6	-3.4, -1.7	3.3	-2.0, 8.5	5.5	-3.2, 14.1
	Mid	4.3	3.8, 4.8	6.4	5.6, 7.2	4.7	-0.6, 9.9	7.1	-0.7, 14.8
	High	-10.9	-11.4, -10.4	-14.4	-15.1, -13.8	-17.7	-23.0, -12.4	-31.8	-42.7, -21.0
Carbonated SSBs	Low	-0.9	-1.3, -0.6	-2.3	-3.3, -1.4	-2.5	-6.7, 1.7	-7.1	-19.2, 5.1
	Mid	1.2	0.8, 1.6	6.5	4.2, 8.6	1.3	-2.9, 5.5	8.6	-18.3, 35.6
	High	-4.6	-5.0, -4.2	-7.2	-7.8, -6.5	-13.2	-17.4, -9.0	-26.3	-35.7, -17.0
Other SSBs	Low	4.2	3.9, 4.4	17.6	16.4, 18.6	14.2	11.6, 16.8	33.0	27.6, 38.4
	Mid	-7.6	-7.9, -7.4	-23.7	-24.5, -22.9	-9.4	-12.0, -6.8	-33.7	-44.5, -22.9
	High	-0.2	-0.5, 0.0	-0.9	-2.0, 0.1	-1.0	-3.6, 1.6	-3.6	-13.6, 6.3
Non-SSBs	Low	4.7	4.4, 5.0	11.3	10.6, 12.1	6.6	3.3, 9.8	11.9	6.3, 17.4
	Mid	1.8	1.5, 2.1	4.9	4.1, 5.8	2.7	-0.5, 5.9	5.9	-1.1, 13.0
	High	-0.3	-0.6, -0.0	-0.9	-1.6, -0.1	-3.8	-7.0, -0.6	-9.2	-17.4, -1.1
Water	Low	1.1	0.9, 1.4	5.1	4.1, 6.2	2.2	-0.3, 4.7	7.5	-0.8, 15.9
	Mid	3.3	3.1, 3.5	14.5	13.5, 15.5	4.5	2.0, 7.0	14.1	6.6, 21.5
	High	0.6	0.4, 0.9	3.1	1.8, 4.2	1.2	-1.3, 3.7	4.7	-5.1, 14.4
Other non-SSBs	Low	0.8	0.7, 0.9	6.6	5.6, 7.7	0.9	-0.4, 2.3	6.5	-2.5, 15.4
	Mid	1.1	1.0, 1.2	6.7	5.9, 7.5	-1.8	-3.2, -0.5	-11.0	-19.6, -2.4
	High	-1.3	-1.4, -1.2	-5.7	-6.3, -5.2	-2.7	-4.1, -1.4	-12.0	-18.3, -5.8

Figure 18: Volume of sugar-sweetened and non-sugar-sweetened beverages sold in Barbados by price tertile, Barbados grocery store chain data, Jan 2013-Oct 2016



One major challenge with the ITS design is the potential for time-varying confounding (i.e. the possibility that other events or policies occurred concurrently with the intervention, which may influence the outcome). To address this, we used a control group in the same population (vinegar), and a control group using the same outcome in a population without an SSB tax (Trinidad & Tobago) to increase the internal validity of the study.[151,155] While it is a major challenge to find the 'perfect' country comparator, Barbados and Trinidad & Tobago have been estimated to have similar levels of SSB consumption and share demographic and cultural characteristics (as summarised in Chapter 5: Appendix Table 2).

Figure 19: Volume of product sub-categories sold in Barbados by price tertile, Barbados grocery store chain data Jan 2013-Oct 2016



Although it is not possible to make causal claims following this type of observational study, we find compelling evidence that the Barbados SSB tax was associated with changes in sales of SSBs and non-SSBs, after controlling for time-varying factors and underlying trends. Our previous finding that prices of SSBs increased following

implementation of the tax also strengthens the hypothesis that the tax was associated with these observed changes in sales.

5.5.2 In relation to other studies

This study shows a decrease in grocery store SSB sales (4.3%) following the Barbados SSB tax. An evaluation of the Mexico SSB tax (a specific tax of 1 peso/litre) found a 6.0% decrease in SSB purchases in the first year following the tax.[117] This effect was driven by a large reduction in purchases of non-carbonated SSBs (17%), alongside a much smaller reduction in purchases of carbonated SSBs (1.2%).[117] In contrast, we found that the reduction in SSB sales in Barbados was driven by a persistent reduction in carbonated SSBs, with a 15.5% reduction in carbonated SSB sales by the end of the study period. These differences may be explained by variations in the beverage market, tax structure, price changes and other changes concurrent with tax implementation. A greater proportion of the the Mexico SSB tax was passed on than the Barbados tax, consistent with the variation in the respective tax structures. The implementation of the Mexico tax was associated with 1) intense industry marketing and promotions, 2) health campaigns about SSBs and 3) a larger government-led focus on obesity control and prevention.[117,156] These concurrent changes may have contributed to shifting norms around SSBs, independent of the price effect of the tax. There was no coordinated health campaign around SSBs in Barbados, and the extent to which the tax influenced news media representations of SSBs is assessed in Chapter 7.

Evaluations of the amended SSB tax in Chile (an *ad valorem* tax modified from a single rate for all SSBs to include two tiers: 10% for low-sugar SSBS and 18% for high-sugar SSBs) found mixed evidence. One evaluation estimated a 3.4% reduction in purchases of high-sugar SSBs and a 10.7% increase in low-sugar SSBs.[110] Amongst the high-sugar SSBs, the reduction was driven by non-carbonated SSBs (8.2%), with no statistically significant overall change observed amongst carbonated SSBs. This pattern was similar to findings from Mexico, but contrasted with our findings around reductions in carbonated SSBs. Another evaluation found a 21.6% reduction in purchases of high-sugar SSBs and no statistically significant change in low-sugar drinks.[115]

Several evaluations have been conducted in U.S. cities following the implementation of SSB taxes. An evaluation of the Berkeley, California SSB tax (a specific tax of 1 cent/oz.)

used electronic point of sale data, as we did, and included data from stores in untaxed locations. They found a decrease of 9.6% in SSB sales concurrent with a 6.9% increase in sales in untaxed locations, suggesting that consumers may have engaged in cross-border shopping and that the estimated decrease may have been exaggerated. We found a 4.3% decrease in SSB sales in Barbados, and no change in untaxed locations (Trinidad & Tobago), consistent with the hypothesis that cross-border shopping would be negligible in a small island context.

We found a 5.2% increase in sales of non-SSBs, driven primarily by an increase in sales of bottled waters (7.5%), consistent with other studies. An evaluation of the Mexico tax found an increase in non-SSB purchases of 4.0% in the first year, primarily driven by increases in bottled water purchases.[117] Sales of non-SSBs increased by 3.5% in Berkeley, driven primarily by increased in bottled water sales (15.6%). Household purchases of non-SSBs in Chile were found to either decrease (3.1%) or remain unchanged following the tax modification, perhaps due to an increase in the relative price of untaxed beverages following the amended tax.[110]

We found evidence of brand down-switching amongst both carbonated and non-carbonated SSBs. None of the existing SSB tax evaluations assessed potential brand down-switching.

5.5.3 Meaning of the study

This study suggests that the Barbados SSB tax was effective at reducing sales of SSBs and increasing sales of non-SSBs in a major grocery store chain. An exploratory analysis suggests that brand down-switching may have led to an increase in sales of cheaper SSBs. Brand down-switching has been observed following tobacco taxation and is thought to be of particular concern with *ad valorem* taxes.[74,151,157] This evaluation provides initial evidence that brand down-switching may also occur following SSB taxation, with important consequences from a health perspective (perhaps especially around ad valorem SSB taxes). An increasing number of countries have implemented ad valorem SSB taxes, including the Philippines (10%), the United Arab Emirates (50%) and Chile (18%).[142] However, if ad valorem taxes incentivise brand down-switching more than specific taxes, they may undermine some of the intended health impact of these policies.

5.5.4 Future research

Sugar-sweetened beverage taxes are a relatively new policy instrument, and there is much to be learned about how these taxes function. First, it will be helpful to develop a better understanding of consumer knowledge and attitudes towards different types of SSBs and non-SSBs. Second, it will be important to measure the extent to which consumers substitute to cheaper alternatives (rather than to non-SSBs) following SSB taxation in other settings. If SSB taxation encourages consumers to substitute towards cheaper SSBs, it will be important to assess the sugar content of these cheaper SSBs and assess net impact on sugar consumption. Third, it will be important to assess the extent to which changes in sales vary by SEP, gender and age.

Finally, it will be important to continue to elaborate on and build a unified theory around how SSB taxes operate. Currently most evaluations test the implicit hypothesis that price change drives change in SSB consumption.[67] However, SSB taxes exist in complex and adaptive systems, and it is likely that they (like tobacco taxes) may operate in more complex ways.[151] SSB taxes have been implemented in a diverse range of settings (i.e. low vs. high baseline SSB consumption),[35,43] among populations with differing levels of disposable income[70] and at different levels (national, local). Additional evaluations are needed to help illustrate the potential mediating effect that these contextual factors may have on tax effectiveness, and to help guide the generalisability of these evaluation studies.

5.6 Conclusions

We find evidence that the Barbados SSB tax was associated with a reduction in sales of SSBs, after controlling for underlying trends. This finding was robust to sensitivity analyses using a within-country control and a cross-country control. Brand down-switching may have led to an increase in the sales of some low- and mid-cost SSBs. A continued assessment of the Barbados SSB tax will be helpful, in particular to assess the potential for substitution effects given the tax design (Chapter 6) and to further develop theory around SSB tax mechanisms (Chapter 7).

5.7 Contributions

I conceptualised the study design together with Nigel Unwin, Jean Adams, Ian Hambleton, Alafia Samuels, Madhuvanti Murphy and the Barbados SSB Tax Evaluation Steering Group. I negotiated a data sharing agreement with the grocery store chain, cleaned the data, categorised soft drinks according to product category and taxed/untaxed status, analysed the data, generated figures and tables, and drafted the manuscript. Jean Adams reviewed and further developed the analysis plan and suggested the post-hoc analysis by price tertile, and assisted with study interpretation and manuscript editing. Nigel Unwin reviewed and contributed to the analysis plan, and led the initial funding acquisition. Stephen Sharp and Ian Hambleton provided statistical expertise and provided feedback on the analysis plan. All authors provided feedback on multiple versions of the manuscript and approved the final version.

I gratefully acknowledge contribution to the study design and support of the broader Barbados SSB tax Evaluation Steering Group, as well as the technical advisory committee: Deliana Kostova (US Center for Disease Control and Prevention) and Marc Suhrcke (University of York).

5.8 Appendix to Chapter 5

5.8.1 Appendix Table 1: Beverage Categories

Overall Categories	**Sub-categories**	**Detailed Product Categories**
SSBs (taxed)	Carbonated SSBs	Sodas, sport drinks, energy drinks
	Other SSBs	Sweetened juice drinks, malt beverages, sweetened flavoured waters, other sweetened drinks
Non-SSBs (untaxed)	Water	Bottled waters
	Other non-SSBs	Unsweetened juices, drinks with only artificial sweeteners (diet soda, diet energy and sports drinks), unsweetened flavoured waters, other unsweetened drinks

Note: We did not consider alcoholic beverages, dairy, seasoning juices (i.e. lemon or lime juice), concentrates, syrups, or powders used to make drinks in this analysis.

5.8.2 Appendix Table 2: Summary of demographic data, Barbados and Trinidad & Tobago

Indicator	**Barbados**	**Trinidad**
Population (2016)[1]	284,996	1,364,962
Percent Population ages 0-14[2]	19.7%	20.6%
Percent Population ages 15-64[2]	67.3%	70.5%
Percent Population ages 65+[2]	13.0%	9.0%
GDP per capita, PPP (current international $, 2016)[1,3]	18,065	32,855
Land area (sq. km)	430	5,130
Annual tourism arrivals, 2016[1]	632,000	410,000
Improved water source (% of population with access, 2015)[1]	99.7%	95.1%
Premature mortality from CVD, cancer, diabetes or CRD (% of total, 2015[1,4]	16%	26%
Estimated mean SSB intake, 8 oz. servings/day (Females, ages 25-34), 2010[5]	4.4	4.7
Estimated mean SSB, 8 oz. servings/day (Males, ages 25-34), 2010[5]	4.8	5.1
Estimated prevalence of overweight and obesity (Females, 2013)[6]	69.9%	66.1%
Estimated prevalence of overweight and obesity (Males, 2013)[6]	57.5%	55.5%

[1]Data from World Bank
[2]Data from 2012 Revision of the World Population Prospects
[3]GDP= Gross Domestic Product, PPP= Purchasing Power Parity
[4] CVD=cardiovascular disease, CRD Chronic respiratory disease
[5]Data from Singh et al. [35]
[6]Data from Ng et al. [9]

5.8.3 Appendix Table 3: Absolute and Relative Weekly Effect Estimates at specific time points (first full month post-tax, 6- and 12-months thereafter)

		Absolute (mL/capita)		Relative (%)	
Category	**Date**	**Est**	**CI**	**Est**	**CI**
SSBs	Oct-15	-7.3	-18.7 to 4.1	-4.2	-11.1 to 2.6
	Apr-16	-8.9	-17.8 to 0.1	-5.2	-10.6 to 0.3
	Oct-16	-10.4	-26.8 to 6.0	-5.9	-15.5 to 3.7
Carbonated SSBs	Oct-15	4.0	-3.7 to 11.8	3.7	-3.3 to 10.8
	Apr-16	-5.8	-11.8 to 0.3	-5.8	-12.2 to 0.6
	Oct-16	-15.6	-26.8 to -4.5	-15.5	-27.4 to -3.7
Other SSBs	Oct-15	-10.4	-14.9 to -6.0	-13.8	-20.3 to -7.4
	Apr-16	-3.1	-6.6 to 0.3	-4.6	-9.8 to 0.6
	Oct-16	4.1	-2.2 to 10.5	5.1	-2.6 to 12.8
Non-SSBs	Oct-15	6.6	0.2 to 13.0	4.8	0.3 to 9.3
	Apr-16	6.0	1.0 to 11.0	4.4	0.8 to 7.9
	Oct-16	5.4	-3.8 to 14.6	3.8	-2.7 to 10.2
Water	Oct-15	2.5	-2.3 to 7.3	3.2	-3.0 to 9.4
	Apr-16	5.3	1.5 to 9.1	6.5	2.0 to 11.0
	Oct-16	8.1	1.1 to 15.0	9.1	1.5 to 16.8
Other non-SSBs	Oct-15	4.0	1.5 to 6.5	6.5	2.6 to 10.4
	Apr-16	0.8	-1.1 to 2.8	1.5	-1.9 to 4.9
	Oct-16	-2.3	-5.9 to 1.3	-4.3	-11.1 to 2.5

5.8.4 Appendix Table 4: Mean post-tax absolute and relative effects, controlled with Trinidad and Tobago

	Barbados				Trinidad & Tobago			
	Absolute (mL/capita)		Relative (%)		Absolute (mL/capita)		Relative (%)	
	Est	CI	Est	CI	Est	CI	Est	CI
SSBs	-8.2	-9.5 to -7.0	-4.1	-4.7 to -3.4	-0.4	-1.8 to 0.9	-0.4	-1.7 to 0.9
Soda	-3.1	-3.9 to -2.2	-2.6	-3.2 to -1.8	2.9	2.0 to 3.8	5.9	3.8 to 7.6
Other SSBs	-5.1	-5.6 to -4.6	-6.2	-6.8 to -5.5	-3.4	-4.0 to -2.8	-6.0	-7.1 to -5.0
Non-SSBs	7.4	6.2 to 8.7	6.3	5.2 to 7.3	-6.9	-8.2 to -5.5	-3.7	-4.4 to -3.0
Water	5.6	4.7 to 6.5	8.0	6.7 to 9.2	2.6	1.6 to 3.6	2.1	1.3 to 2.9
Other non-SSBs	1.9	1.4 to 2.3	3.9	2.9 to 4.8	-9.4	-9.9 to -8.9	-15.9	-16.6 to -15.2

5.8.5 Appendix Table 5: Mean post-tax absolute and relative effects, controlled with vinegar

	Beverages				Vinegar			
	Absolute (mL/capita)		Relative (%)		Absolute (mL/capita)		Relative (%)	
	Est	CI	Est	CI	Est	CI	Est	CI
SSBs	-8.0	-9.2 to -6.8	-3.9	-4.5 to -3.3	2.6	1.4 to 3.8	4.8	3.0 to 6.6
Carbonated SSBs	-3.3	-4.1 to -2.4	-2.6	-3.4 to -1.9	1.9	1.0 to 2.8	2.8	1.4 to 4.0
Other SSBs	-4.8	-5.4 to -4.2	-5.8	-6.5 to -5.1	4.2	3.7 to 4.8	5.8	5.0 to 6.6
Non-SSBs	5.8	5.1 to 6.4	4.9	4.3 to 5.4	3.5	2.9 to 4.2	5.1	4.2 to 6.0
Water	4.9	4.4 to 5.5	7.4	6.5 to 8.2	3.4	2.9 to 4.0	4.8	3.9 to 5.5
Other non-SSBs	0.8	0.3 to 1.2	1.5	0.5 to 2.5	3.6	3.2 to 4.1	5.0	4.4 to 5.6

5.8.6 Appendix Table 6: Absolute and Relative Weekly Effect Estimates at specific time points, by price tertile

		Low-cost Tertile				Mid-cost Tertile				High-cost Tertile			
		Absolute		Relative		Absolute		Relative		Absolute		Relative	
Category	**Date**	**Est**	**CI**	**Est**	**CI**	**Est**	**CI**	**Est**	**CI**	**Est**	**CI**	**Est**	**CI**
SSBs	Oct-15	-5.6	-9.6 to -1.5	-11.4	-20.3 to -2.5	4	-0.0 to 8.0	-2.2	-8.7 to 4.3	-5.2	-9.3 to -1.2	5.5	-3.2 to 14.1
	Apr-16	-1.1	-4.5 to 2.2	5.9	0.1 to 11.7	4.3	1.0 to 7.7	6.7	1.6 to 11.8	-11.5	-14.8 to -8.1	7.1	-0.7 to 14.8
	Oct-16	3.3	-2.0 to 8.5	-8.2	-14.9 to -1.5	4.7	-0.6 to 9.9	-19.9	-26.4 to -13.5	-17.7	-23.0 to -12.4	-31.8	-42.7 to -21.0
Carbonated SSBs	Oct-15	0.4	-2.8 to 3.6	1.1	-8.0 to 10.1	1.1	-2.2 to 4.3	-3.1	-10.7 to 4.6	2.6	-0.6 to 5.8	-7.1	-19.2 to 5.1
	Apr-16	-1.1	-3.7 to 1.6	7.2	-13.9 to 28.3	1.2	-1.5 to 3.8	8.1	-9.7 to 25.9	-5.3	-8.0 to -2.6	8.6	-18.3 to 35.6
	Oct-16	-2.5	-6.7 to 1.7	4.5	-0.9 to 9.8	1.3	-2.9 to 5.5	-9.8	-14.9 to -4.6	-13.2	-17.4 to -9.0	-26.3	-35.7 to -17.0
Other Sweetened	Oct-15	-4.2	-6.2 to -2.2	-14.8	-22.4 to -7.1	-6.2	-8.2 to -4.2	21.3	14.6 to 28.0	0.4	-1.6 to 2.4	33	27.6 to 38.4
	Apr-16	5	3.3 to 6.6	-17.6	-24.0 to -11.3	-7.8	-9.4 to -6.1	-40.8	-51.7 to -29.9	-0.3	-1.9 to 1.4	-33.7	-44.5 to -22.9
	Oct-16	14.2	11.6 to 16.8	1.1	-4.5 to 6.8	-9.4	-12.0 to -6.8	-1.6	-10.6 to 7.4	-1	-3.6 to 1.6	-3.6	-13.6 to 6.3
Non-SSBs	Oct-15	3.1	0.6 to 5.5	6.4	1.5 to 11.3	1.1	-1.3 to 3.6	9.6	5.6 to 13.5	2.5	0.1 to 5.0	11.9	6.3 to 17.4
	Apr-16	4.8	2.8 to 6.8	2.5	-3.0 to 8.0	1.9	-0.1 to 3.9	4.4	-0.3 to 9.1	-0.6	-2.7 to 1.4	5.9	-1.1 to 13.0
	Oct-16	6.6	3.3 to 9.8	5.1	0.3 to 10.0	2.7	-0.5 to 5.9	-1.4	-6.1 to 3.3	-3.8	-7.0 to -0.6	-9.2	-17.4 to -1.1
Water	Oct-15	0.3	-1.6 to 2.2	1	-6.3 to 8.3	2.3	0.4 to 4.2	4.5	-1.2 to 10.2	0.2	-1.8 to 2.1	7.5	-0.8 to 15.9
	Apr-16	1.2	-0.4 to 2.8	8.1	1.8 to 14.4	3.4	1.8 to 5.0	11.3	6.2 to 16.4	0.7	-0.9 to 2.3	14.1	6.6 to 21.5
	Oct-16	2.2	-0.3 to 4.7	0.6	-7.0 to 8.3	4.5	2.0 to 7.0	2.7	-3.6 to 9.0	1.2	-1.3 to 3.7	4.7	-5.1 to 14.4
Other Unsweetened	Oct-15	0.7	-0.3 to 1.7	4.7	-2.2 to 11.7	3.6	2.5 to 4.6	16.3	12.0 to 20.6	-0.2	-1.2 to 0.9	-0.6	-5.0 to 3.7
	Apr-16	0.8	-0.0 to 1.7	5.7	-0.1 to 11.6	0.9	0.0 to 1.7	4.6	0.2 to 9.1	-1.4	-2.3 to -0.6	-6.2	-10.0 to -2.4
	Oct-16	0.9	-0.4 to 2.3	6.5	-2.5 to 15.4	-1.8	-3.2 to -0.5	-11	-19.6 to -2.4	-2.7	-4.1 to -1.4	-12	-18.3 to -5.8

5.8.7 Appendix Table 7: Post-tax trend estimates by price tertile, test for significance between tertile trends at 5%

	Tertile-specific Trends				Test for Tertile Interaction		
	Level	**Est**	**CI**		**Difference**	**Est**	**CI**
SSBs	Low	0.19	0.07 to 0.31		Low-Mid	0.24	0.10 to 0.37
	Mid	-0.05	-0.17 to 0.07		Mid-High	0.13	0.00 to 0.27
	High	-0.18	-0.30 to -0.06		Low-High	0.37	0.23 to 0.50
Carbonated SSBS	Low	-0.07	-0.16 to 0.02		Low-Mid	0.00	-0.11 to 0.11
	Mid	-0.07	-0.17 to 0.02		Mid-High	0.18	0.01 to 0.28
	High	-0.25	-0.34 to -0.15		Low-High	0.18	0.07 to 0.28
Other SSBs	Low	0.40	0.34 to 0.45		Low-Mid	0.42	0.35 to 0.49
	Mid	-0.02	-0.08 to 0.04		Mid-High	0.02	-0.04 to 0.09
	High	-0.04	-0.10 to 0.01		Low-High	0.44	0.37 to 0.51
Non-SSBs	Low	0.16	0.08 to 0.23		Low-Mid	0.12	0.04 to 0.20
	Mid	0.04	-0.04 to 0.11		Mid-High	0.17	0.09 to 0.26
	High	-0.14	-0.21 to -0.07		Low-High	0.29	0.21 to 0.38
Water	Low	0.08	0.03 to 0.14		Low-Mid	0.00	-0.07 to 0.6
	Mid	0.08	0.03 to 0.14		Mid-High	0.05	0.00 to 0.12
	High	0.03	-0.03 to 0.09		Low-High	0.05	0.01 to 0.12
Other non-SSBs	Low	-0.01	-0.04 to 0.02		Low-Mid	0.11	0.07 to 0.14
	Mid	-0.12	-0.15 to -0.09		Mid-High	-0.08	-0.11 to -0.04
	High	-0.01	-0.04 to 0.02		Low-High	0.03	0.00 to 0.07

5.8.8 Appendix Text 1: Sales change analysis

Other SSB tax evaluations have relied on commercial household purchase panels, but these data are not available in Barbados. Given that the tax was implemented just three months after announcement, there was little opportunity to collect primary pre-tax data. Instead, we rely on electronic point of sale data from a major grocery store chain. According to a report by McKinsey & Company, this grocery store chain has 32% grocery store market share in Barbados [personal communication].

Data on the number of tourist arrivals per month were extracted from Trading Economics for Barbados and from the Tourism Statistics Office for Trinidad and Tobago. The monthly Consumer Price Index (CPI) was extracted from the International Monetary Fund (IMF) World Economic Outlook database. Additional descriptive data about Barbados and Trinidad and Tobago were extracted from the World Bank Open Data online database for the most recent year available, and from relevant SSB and obesity studies.

We used an ordinary least squares regression model, assuming a normally distributed outcome, separately for SSBs and non-SSBs:

$$\begin{aligned}\mathrm{mL/capita}_{wy} \sim & \beta_M M_M + \beta_M Tourism_M + \beta_{Mc} Inflation_M + \beta_w Holidays_w \\ & + \beta_{wy} Trend_{wy} + \beta_w yTax_{wy} + \beta_{wy} TaxTrend_{wy} \\ & + \beta_{w-1,y} Residual_{w-1,y} + \varepsilon_{wy}\end{aligned}$$

where *M* denotes the vector of month indicators (1-11), *Tourism* denotes country-month specific tourism arrivals, *Inflation* denotes the country-month specific consumer price index (CPI), *Holidays* denotes the vector of indicators for Crop Over, Easter, and Christmas, *Trend* denotes the overall week-year linear trend, *Tax* denotes an indicator for the period after tax implementation, and *TaxTrend* denotes the linear week-year trend after tax implementation. Residual denotes the 1-week lag of the residual, included to address potential autocorrelation, and ε represents the error term.

We tested additional specifications for seasonality, including a linear trend and two cosine and sine fourier functions, and used the Aikake Information Criterion (AIC) to assess model fit. On this basis, monthly indicators were selected as appropriate given model fit and flexibility, and because of the relatively large time series (200 observations).

To estimate average post-tax effects with uncertainty, we used the following steps:

1. Calculated the absolute difference between the estimated and counterfactual scenarios for each post-tax week
2. Estimated the average absolute difference between the estimated and counterfactual scenarios taking into account uncertainty in each estimate (using metan command in STATA)
3. Estimated the counterfactual estimate for each post-tax week
4. Estimated the average counterfactual estimate taking into account uncertainty in each estimate (using metan command in STATA)
5. Simulated 1000 estimates of the average absolute difference between the estimate and the counterfactual and of the average counterfactual, and took the ratio of each of these combinations (average absolute difference_1/average absolute counterfactual_1, average absolute difference_2/average absolute counterfactual_2… average absolute $\text{difference}_{1,000}$/average absolute $\text{counterfactual}_{1,000}$)
6. Ordered the ratios by size and took the 25^{th}, 500^{th} and 975^{th} observations for the estimate and 95% CI to estimate relative change (presented in % by multiplying by 100)

5.8.9 Appendix Text 2: Sensitivity analyses with Trinidad & Tobago and vinegar as controls

First, we used data from the same grocery store chain in Trinidad &Tobago, a neighbouring country where an SSB tax has not been implemented. While it would be ideal to select a comparison group with high exchangeability with the intervention group, at the country level it is inherently difficult to find a fully exchangeable comparison country[158]. In Chapter 5: Appendix Table 2 we present key country-specific summary measures, providing reassurance that comparisons between Barbados and Trinidad & Tobago are justified, particularly in terms of similar population demographics, SSB consumption and obesity levels.

The data from Trinidad & Tobago represent the same outcomes (SSB and non-SSB sales in the same grocery store chain) in a population without the intervention [155]. This allows us to partially assess the extent to which exogenous factors, which may have coincided with the implementation of the Barbados SSB tax, possibly influenced sales of SSBs or non-SSBs. To offset differences in sales driven by differences in underlying population, we standardised the outcome of interest to millilitre sold per capita per week (recognizing that this does not adjust for the relative market share that this grocery store chain has in Trinidad & Tobago compared to in Barbados, as these data were not available). We included country-specific consumer price indices to control for inflation.

As a second sensitivity analysis, we used a non-beverage product (vinegar) to assess a different outcome in the same population and test whether there may have been some factor that influenced sales at this grocery store chain. The introduction of the SSB tax coincided with the removal of roughly 50% of items that were previously exempt from value added tax (VAT) (vinegar was already subject to VAT).[159] The Minister of Health announced that removed items had been reviewed and identified as "more sophisticated things than would have been described as basic," but that "for every item that has been taken out, a nutritious equivalent substitute remains in the basket."[159] Items that were removed from the basket were subjected to the standard 17.5% VAT rate. We attempted to address this concern by assessing whether there was a change in sales of a product that should not have been affected by the SSB tax but could have been affected by changing overall prices (and therefore, changing disposable income.)

The decision to use vinegar was pragmatic (based on data availability), although it is possible that vinegar may be somewhat less responsive to immediate changes in price due to a longer lag between purchases. Other planned evaluations intend to use personal toiletries as a similar type of control product.[160]

We used an ordinary least squares model, assuming a normally distributed outcome, separately for SSBs and non-SSBs:

$$\begin{aligned}\text{mL/capita}_{wyc} \sim & \beta_m M_m + \beta_{mc} M * Control_{mc} + \beta_{myc} Tourism_{myc} \\ & + \beta_{myc} Inflation_{myc} + \beta_{wyc} Holidays_{wyc} + \beta_{wy} Trend_{wy} \\ & + \beta_{wy} Tax_{wy} + \beta_{wy} TaxTrend_{wy} \\ & + \beta_c Control_c + \beta_{wyc} Trend * Control_{wyc} + \beta_{wyc} Tax * Control_{wyc} \\ & + \beta_{wyc} TaxTrend * Control_{wyc} + \beta_{w-1,yc} Residual_{w-1,yc} + \varepsilon_{wyc}\end{aligned}$$

where *M* denotes the vector of month indicators (1-11), *M*Control* denotes the control-specific vector of month indicators, *Tourism* denotes tourism arrivals, *Inflation* denotes the consumer price index (CPI) and *Holidays* denotes the vector of indicators for Crop Over (Barbados only), Carnival (Trinidad & Tobago only) Easter and Christmas. The subscript *w* corresponds to week-specific variables (1-52), *m* corresponds to month-specific variables (1-12), *y* corresponds to year-specific variables (2013-2016), *wy* corresponds to week-year specific variables (1-200), *my* corresponds to month-year specific variables (1-50) and *c* corresponds to control-specific variables. *Trend* denotes the overall week-year linear trend, *Tax* denotes an indicator for the period after tax implementation, and *TaxTrend* denotes the linear week-year trend after tax implementation. *Control* denotes the indicator for the control (either country or vinegar), *TrendControl* denotes the interaction between the control and the overall week-year linear trend, *TaxControl* denotes the interaction between the control and the tax indicator, and *TaxTrendControl* denotes the interaction between the control and the post-tax linear trend. *Residual* denotes the 1-week lag of the residual, included to address potential autocorrelation, and ε represents the error term.

5.8.10 Appendix Text 3: Price-tertile analysis

We defined price tertile accordingly:

1. Within each country-category, we estimated the mean price of each product over the whole period (to capture products that were introduced after the tax)
2. We took the total litres sold per week of each product over the whole period
3. We sorted products (within their country-category) by mean price, and then identified price tertile cut-off points at 33% and 66% of the total litres sold within that country-category.

We then used an ordinary least squares model, assuming a normally distributed outcome, separately for SSBs and non-SSBs:

$$\begin{aligned}\mathrm{mL/capita}_{wy} \sim & \beta_M M_m + \beta_{my} Tourism_{my} + \beta_{my} Inflation_{my} + \beta_w Holidays_w \\ & + \beta_{wy} Trend_{wy} + \beta_w yTax_{wy} + \beta_{wy} TaxTrend_{wy} + \beta_{wy} Tertile_{wy} \\ & + \beta_{wy} TrendTertile_{wy} + \beta_w yTaxTertile_{wy} \\ & + \beta_{wy} TaxTrendTertile_{wy} + \beta_{w-1,y} Residual_{w-1,y} + \varepsilon_{wy}\end{aligned}$$

where *M* denotes the vector of month indicators (1-11), *Tourism* denotes country-month specific tourism arrivals, *Inflation* denotes the country-month specific consumer price index (CPI) and *Holidays* denotes the vector of indicators for Crop Over, Easter and Christmas. The subscript *w* corresponds to week-specific variables (1-52), *m* corresponds to month-specific variables (1-12), *y* corresponds to year-specific variables (2013-2016), *wy* corresponds to week-year specific variables (1-200) and *my* corresponds to month-year specific variables (1-50). *Trend* denotes the overall week-year linear trend, *Tax* denotes an indicator for the period after tax implementation, and *TaxTrend* denotes the linear week-year trend after tax implementation. Residual denotes the 1-week lag of the residual, included to address potential autocorrelation, and ε represents the error term.

Tertile denotes an indicator for each tertile (with the first tertile set as the reference category), *TrendTertile* denotes the interaction between the tertile indicators and the overall week-year linear trend, *TaxTertile* denotes the interaction between the tertile indicators and the tax indicator, and *TaxTrendTertile* denotes the interaction between the tertile indicators and the linear week-year trend after tax implementation.

As a sensitivity analysis, we categorised drinks using only pre-tax prices, but this did not substantially change the pattern of results.

5.8.11 Appendix Box 1: Quality Criteria for ITS Designs

(from Ramsay et al. 2003)[148]

1. Intervention occurred independently of other changes over time

The intervention occurred at the same time as the change in VAT-exempt products was implemented. However, this was tested as a potential time-varying confounder by controlling the grocery store analysis with a non-beverage product (vinegar).

2. Intervention was unlikely to affect data collection

The intervention itself was unlikely to affect data collection because we used routine data sources that were used for different purposes and did not change following the intervention.

3. The primary outcome was assessed blindly or was measured objectively

The primary outcome variables (sales of SSBs and non-SSBs) were recorded objectively as part of an electronic point of sale system and a national import/export ledger.

4. The primary outcome was reliable or was measured objectively

As above.

5. The composition of the data set at each time point covered at least 80% of the total number of

participants in the study

The grocery store dataset covered 100% of sales made over the study period at this grocery store chain. We acknowledge that the grocery store chain has been estimated to account for 32% of the total grocery store market share in Barbados [personal communication].

6. The shape of the intervention effect was prespecified

We pre-specified a slope and intercept change following implementation of the tax, based on results from other SSB tax evaluation studies.

7. A rationale for the number and spacing of data points was described

We used all available data from January 2013 on. Data were aggregated by week, so it was not possible to conduct an analysis at the daily level. Since a competitor opened a

new store in Barbados in November 2016, we limited our analysis of the grocery store chain data to the period ending on October 31, 2016. With 141 pre-tax observations and 59 post-tax observations for the grocery store analysis we had a long and balanced time series which has been shown to add strength to the ITS design [153].

8. The study was analysed appropriately using time series techniques

We used segmented time series regression models to analyse the data and serial correlation was adjusted for using a lagged residual.

6 THREE PROPOSED CRITERIA TO IMPROVE SSB TAX DESIGN

This manuscript is under peer review:

Alvarado M, Rachel Harris, Angela Rose, Nigel Unwin, Ian Hambleton, Fumiaki Imamura, Jean Adams. "Using nutritional survey data to inform the design of sugar-sweetened beverage taxes in low-resource contexts: a cross-sectional analysis based on data from an adult Caribbean population."

Based on this analysis I was invited to present a paper titled "Using nutritional survey data to inform the design of sugar-sweetened beverage taxes in low-resource contexts**:** A cross-sectional analysis based on data from an adult Caribbean population" at the Faculty of Medical Sciences PhD Symposium, University of the West Indies in Cavehill, Barbados January 2019.

6.1 Study Abstract

Objective

Sugar-sweetened beverage (SSB) taxes have been implemented widely. We propose three criteria that can be used to improve SSB tax design with the goal of reducing free sugar consumption: 1) high baseline consumption of SSBs and SSB-derived free sugars, 2) high percentage of SSB-derived free sugars covered by the tax, and 3) consistent differentiation between high- and low-sugar SSBs. We aimed to evaluate these criteria using pre-existing nutritional survey data in a developing economy setting.

Methods

We used data from a nationally representative cross-sectional survey in Barbados (2012-2013, prior to SSB tax implementation). Data were available on 334 adults (25-64 years) who completed two non-consecutive 24-hour dietary recalls. We estimated the prevalence of SSB consumption and its contribution to total energy intake, overall and stratified by taxable status. We assessed the percentage of SSB-derived free sugars subject to the tax and identified the consumption-weighted sugar concentration of SSBs, stratified by taxable status.

Findings

Accounting for sampling probability, 88.8% of adults [95% CI 85.1 to 92.5] reported SSB consumption, with a geometric mean of 2.4 servings/day [±1.96×standard deviation, 0.6, 9.2] among SSB consumers. Sixty percent [95% CI 54.6 to 65.4] of SSB-derived free sugars would have been subject to the Barbados SSB tax. The tax did not clearly differentiate between high- and low-sugar beverages.

Conclusion

Given high SSB consumption, targeting SSBs was a sensible strategy in this setting. A substantial percentage of free sugars from SSBs were not covered by the tax, reducing possible health benefits. The criteria proposed here may help policymakers to design more effective SSB taxes.

6.2 Background & Setting

6.2.1 Background

The WHO has recommended limiting free sugar consumption to less than 10% of total energy intake (TEI).[20] Free sugars are defined as "monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates."[20] Sugar-sweetened beverages (SSBs) are a major source of free sugars, and consumption of SSBs in particular has been associated with higher risk of diabetes, certain cancers and obesity.[28,33,161–167] Given these health risks, the WHO and others have recommended taxing SSBs to reduce consumption.[40,41,56,74,141]

A number of countries (including many small island developing states (SIDS) and low- and middle-income countries) have introduced SSB taxes,[74,127,142,168,169] at least in part for health reasons. However, these taxes vary widely in design.[142] In some settings, products liable for the tax have been narrowly defined, whereas elsewhere they have been defined to include all soft drinks (even those containing no or small amounts of free sugars).[43,142] These differences are likely to have important health implications.[170]

We propose three criteria, drawing on current guidance, that can be used to improve the design of SSB taxes with the goal of reducing free sugar consumption.[42,74,170]

First, SSB taxes are more likely to be effective in places where SSB consumption levels are high and where SSB-derived free sugars represent a high proportion of total free sugar consumption and total energy intake.[122] As Singh et al. have demonstrated, there is great heterogeneity in SSB consumption levels worldwide.[35] In terms of reducing current free sugar consumption, SSB taxes have the greatest potential in settings with high baseline consumption.

Second, SSB taxes should cover a high proportion of regularly consumed SSBs, reducing substitution incentives.[74] If taxes are applied on a limited proportion of the total SSBs consumed in a given population, the potential impact on health will be necessarily limited. If consumers substitute towards untaxed SSBs, health goals will be further undermined.

Finally, SSB taxes should consistently differentiate between high- and low-sugar products.[171,172] If SSB taxes are not consistently applied on all high-sugar SSBs, health goals will be further undermined, especially if consumers substitute towards high-sugar untaxed SSBs. Box 1 summarises these criteria.

Box 1: Proposed criteria to help inform the design of sugar-sweetened beverage (SSB) taxes from a health perspective

1. High baseline levels of SSB consumption and high contribution of SSB-derived free sugar to total energy intake
2. High percentage of SSB consumption covered by SSB tax
3. Clear distinction made by SSB tax between high- and low-sugar SSBs

The assessment of these criteria should be informed by local consumption patterns as much as possible. Commercial purchase data (such as Nielsen and Kantar consumer panels) have been used to assess SSB consumption patterns in the US and the UK, but these data are costly and unavailable in some settings.[172,173] In lower-resource settings in particular, it may be pragmatic to use pre-existing nutritional survey data to help inform context-specific policy design.[174,175] A recent review demonstrated that individual level dietary surveys have been conducted in at least 116 countries, representing 88.7% of the global 2010 adult population.[174,175] These nutritional survey data may provide a feasible way to evaluate our proposed criteria more widely.

6.2.2 Case Study: The Barbados SSB Tax

The Government of Barbados implemented a 10% SSB tax in 2015.[127] Taxable products (both imported and locally manufactured) were defined according to the Harmonized System (HS) tariff classifications and included soda, juice drinks, energy and sports drinks.[127,176] Some SSBs were not included in the tax definition, such as sugar-sweetened drink mixes (e.g. powdered juice and powdered hot chocolate) and sugar-sweetened syrups (e.g. mauby syrups, which are reconstituted to make a popular Barbadian SSB).[127]

A nationally representative nutritional survey was conducted in 2012-2013, well in advance of the introduction of the Barbados SSB tax in 2015. We revisited these data to

assess the tax according to our proposed criteria. We established three research questions: 1) what were pre-tax SSB consumption levels (in terms of volume and contribution to TEI)? 2) what percentage of SSB-related free sugars were covered by the tax? and 3) did the tax clearly differentiate between low- and high-sugar beverages? We aimed to assess whether it was feasible to evaluate these criteria in a low-resource setting using existing nutritional survey data.

6.3 Methods

6.3.1 Study Design & Population

We used nutritional survey data from Barbados, a country with a population of 293,131 (2018 estimate) and $18,600 GDP/capita (2017 estimate).[124] Barbados is likely to share characteristics with other small island developing settings (SIDS), such as a limited resources to regularly monitor sugar content of SSBs (precluding some tax designs) and a definition of taxable products based on tariff codes.

The data used in this study were from the Health of the Nation study, which was conducted between June 2012 and November 2013 and achieved a response rate of 54% and final sample size of 1,234. Details of the overall sampling design, study recruitment and study procedures have been summarised elsewhere.[125] A sub-sample of 441 participants aged 25 to 64 were randomly selected to complete two non-consecutive in-person 24-hour dietary recalls.[177] Three hundred and sixty-eight participants (83%) consented to participate (for a combined response rate of 45%).

Each dietary recall was collected at home by a trained interviewer, using a standard multi-pass probing method, three-dimensional standardised food models and familiar measuring units.[178] Recalls were evenly distributed across calendar quarters, with the exception of July-September when fewer recalls were conducted. The average time between the first and second recall was six days, and recalls were evenly distributed by day of the week. Data were processed using Nutribase Pro software.[179] Survey weights were used to reflect the clustered sampling design, to take into account the combined non-response rate and to match the age and sex distribution of the Barbados population as captured in the Barbados 2010 census.[177]

We excluded participants with reported caloric intake less than 500 kcal/day or greater than 5000 kcal/day (n=5), those with missing covariate data (n=21), those with only one recall (n=1), and those with missing survey weights (n=7), leaving a total of 334 participants.

Ethics approval was given by the University of the West Indies Cavehill Institutional Review Board.

6.3.2 Measures of SSB Consumption

We estimated the prevalence of SSB consumption, defined as individuals with any reported SSB consumption on at least one day. Next, we estimated average volume consumed (mean SSB servings/day) amongst SSB consumers (excluding those who did not report any SSB consumption). A serving was defined as 250 mL, consistent with the definition used by Imamura et al. to assess associations between SSB consumption and incident type 2 diabetes.[28] We reviewed each dietary recall and extracted detailed product information for all reported SSBs (e.g. brand, flavour, etc.)

All non-alcoholic beverages (i.e. “soft drinks”) were categorised based on whether they contained added sugars and whether they were subject to the Barbados SSB tax. Taxed SSBs included regular soda, juice drinks, energy/sports/malt drinks and other taxed SSBs (as defined in Chapter 6: Appendix Table 1); untaxed SSBs included sugar-sweetened powders, sugar-sweetened syrups, sweetened tea/coffee, sweetened condensed milk and other untaxed SSBs; and untaxed non-SSBs included water, no added sugar (NAS) fruit juice, milk, entirely artificially-sweetened beverages (ASBs) and other non-SSBs.

We identified the nutrient content for every beverage at the most detailed level possible (e.g. brand, flavour). We relied on Nutribase nutrient content for international brands (and cross-checked these with the local nutrient information panels for consistency). For brands not included in Nutribase, we collected nutrient information directly from product packaging and manufacturer websites (see Chapter 6: Appendix Text 1).

6.3.3 Covariates

Demographic information and highest education completed were collected at the first visit. We dichotomised age (25-44 years old, 45-64 years old) and education (no or

secondary education compared to tertiary education, which included undergraduate, postgraduate and technical/vocational training).

6.3.4 Statistical Methods

6.3.4.1 Levels of SSB consumption

We estimated the prevalence of SSB consumption, and provide descriptive statistics (mean ± 1.96×standard deviation (SD)) of levels of SSB consumption among consumers and the percentage of TEI from SSB-derived free sugars, stratified by covariates. Since SSB consumption was right-skewed (see Chapter 6: Appendix Figures 1 and 2), we report volume and percentage of TEI using geometric means and SD. Global estimates were reported somewhat differently (e.g. using the arithmetic mean, including non-consumers and in 8 oz. (237mL) servings).[35] To enable direct comparison, we re-estimated our overall SSB intake estimate accordingly.

6.3.4.2 Percentage of SSB-derived free sugars captured by tax

We further estimated the prevalence of SSB consumption and percentage of TEI attributable to SSB-derived free sugars separately for taxed and untaxed SSBs. Then we calculated the percentage of total SSB-derived free sugars subject to the tax (excluding free sugars from non-SSBs (such as NAS juice), even though these are considered free sugars according to WHO guidelines).[20]

6.3.4.3 Free-sugar concentration

We estimated mean free-sugar concentration by SSB sub-category (i.e. separately for sodas, SSB juice drinks, etc.), by using the amount of sugar in the product multiplied by the volume consumed. We then used estimates of free sugar concentration weighted for consumption within the survey to reflect consumption patterns (compared to reflecting the distribution of available free sugars available in the market). To illustrate how nutritional survey data may be used to assess potential SSB tax tiers, we report mean per-person daily volume consumed by grams of free sugar per 100mL.

All analyses were weighted by sampling probability and conducted using Stata 14.0.[150]

This study is reported according to the Strengthening Reporting of Observational Studies in Epidemiology Extension for Nutritional Epidemiology (STROBE-nut) checklist (see Appendix 6).[180]

6.4 Results

6.4.1 Levels of SSB consumption

Eighty-eight percent of participants reported consuming SSBs at least once over the two days (Table 10). Prevalence of SSB consumption did not differ significantly between sub-groups. Amongst those who reported any consumption, mean per-person daily SSB intake was 2.4 servings [mean± 1.96 x SD, 0.6, 9.2]. To enable comparison with published estimates, we also report mean per-person daily SSB intake in 8 oz. servings across the whole study population, equivalent to 2.7 eight oz. servings [95% CI 2.5 to 2.9]. Men and those with less education reported consuming a higher volume of SSBs than their counterparts (survey-weighted bivariate generalised linear regression test for difference associated with p-values of <0.001 and 0.004 respectively). TEI from SSB-related free sugars was 9.2% [mean± 1.96 × SD, 2.1, 41.3], with a similar patterning of results by sub-groups as seen in Table 10.

6.4.2 Percentage captured by tax

Seventy five percent of participants consumed taxed SSBs, and a similar percentage (74.5%) consumed untaxed SSBs (Table 11). A higher percentage (79.8%) of men consumed taxed SSBs as compared to women (69.7%) (p=0.035). TEI attributable to taxed SSBs was 6.7% (mean±2SD 1.7, 26.5), and TEI attributable to untaxed SSBs was 3.5% (mean±2SD 0.4, 27.3). Those who reached a lower education level consumed a higher percentage of TEI from taxed SSBs (7.2%%) than those with higher education (5.7%) (p=0.01). Sixty-one percent of SSB-derived free sugars were taxed [95% CI 55.7, 66.5], with no significant differences by sub-group.

6.4.3 Free-sugar concentration

We estimated mean consumption-weighted free sugar concentration for each product category. As summarised in Figure 20, mauby, juice drinks, and sodas were associated with the highest average free sugar concentrations. Four of the nine beverage types with

more than 6.25 grams free sugar/100 mL (Chile's SSB tax threshold) were untaxed. We also report mean per-person free sugar consumed (taking into account sugar concentration and consumption levels) by product type (see Chapter 6: Appendix Figure 3).

Table 10: Consumption of sugar-sweetened beverages (SSBs) amongst adults aged 25-64 years by demographic characteristics, Barbados 2012-2013: Barbados Salt Intake Study (n=334)

		Distribution (n=334)	**Prevalence of any SSB consumption[1] (n=334)**		**Volume (servings/day), given SSB consumption[2,3] (n=300)**		**TEI from SSB free sugars, given SSB consumption[2,5] (n=300)**	
		%	%	95% CI	Mean	Mean ± 1.96 SD[4]	%	Mean ± 1.96 SD[4]
Overall	*Total*		88.8	85.1, 92.5	2.4	0.6, 9.2	9.2	2.1, 41.3
Age	*25-44*	51.1	89.1	83.7, 94.6	2.7	0.9, 8.3	10.3	3.0, 35.6
	45-64	48.9	88.4	82.1, 94.7	2.2	0.5, 9.8	8.2	1.5, 46.6
Sex	*Males*	48.8	89.7	83.7, 95.7	2.8*	0.9, 9.1	10.5*	2.7, 41.3
	Females	51.2	87.9	83.0, 92.9	2.1*	0.5, 8.6	8.2*	1.7, 39.6
Education	*<Tertiary*	62.9	90.9	85.7, 96.2	2.7*	0.8, 9.2	10.0*	2.4, 41.3
	Tertiary+	37.1	85.1	78.1, 92.2	2.0*	0.5, 8.4	8.0*	1.6, 39.6

** Significant difference between sub-groups at p-value <0.05 in survey-weighted bivariate logistic regression (prevalence of any SSB consumption models) or survey-weighted bivariate generalised linear regression with log-link function (volume, TEI models)*

[1] Defined as >0 mL of any SSB across two 24-hour recalls

[2] Geometric means

[3] Defined as the mean volume (250 mL servings/day) from SSBs, amongst all SSB-consumers. For estimates of 8 oz per serving, each value is to be multiplied by 0.91.

[4] Geometric mean±1.96 SD derived from the log-transformed variable to reflect the sample distribution

[5]Defined as the percentage of total energy intake (TEI) from SSB-derived free sugars, amongst all SSB-consumers

Table 11: Prevalence of consumption and total energy intake (TEI) (%) from sugar-sweetened beverage (SSB)-derived free sugars among adults aged 25 to 64 years, stratified by subsequent taxable status, Barbados 2012-2013: Barbados Salt Intake Study (n=334)[1]

		Prevalence of any SSB Consumption[2]				**TEI from SSB-derived free sugars, given any SSB consumption[3,4]**				**SSB-derived free sugars from taxed SSBs[6]**	
		Taxed SSBs (n=334)		Untaxed SSBs (n=334)		Taxed SSBs (n=239)		Untaxed SSBs (n=249)		Percentage Taxed (n=300)	
		%	95% CI	%	95% CI	%	Mean± 1.96 SD	%	Mean± 1.96	%	95% CI
Overall	*Total*	74.6	69.8, 79.5	74.5	69.8, 79.2	6.7	1.7, 26.5	3.5	0.4, 27.3	61.1	55.7, 66.5
Age	*25-44*	80.8	73.7, 87.9	75.0	67.5, 82.6	7.0	1.9, 25.7	3.6	0.6, 22.6	64.2	58.3, 70.1
	45-64	68.1	59.5, 76.8	74.0	65.5, 82.4	6.3	1.4, 27.3	3.4	0.3, 33.3	57.0	47.5, 66.5
Sex	*Males*	79.8*	72.8, 86.8	70.8	62.3, 79.3	7.2	1.9, 27.9	3.9	0.5, 30.4	62.1	56.0, 68.2
	Females	69.7*	63.1, 76.3	78.0	72.9, 83.2	6.1	1.5, 24.6	3.2	0.4, 24.1	59.6	51.5, 67.7
Education	*<tertiary*	77.4	70.5, 84.3	76.8	70.2, 83.5	7.2*	1.8, 28.6	3.5	0.5, 26.9	63.2	57.7, 68.7
	Tertiary+	69.9	61.8, 78.0	70.6	63.5, 77.7	5.7*	1.5, 21.8	3.4	0.4, 28.0	56.7	48.1, 65.3

** Significant at p-value<0.05 in survey-weighted bivariate logistic regression (prevalence of any SSB consumption models) or bivariate generalised linear regression with log-link function (TEI)*

[1] The tax was introduced in 2015, so we retrospectively apply the definition of taxable goods to consumption data reported from 2012-2013

[2]Defined as >0 mL of taxed/untaxed SSBs across two 24-hour recalls

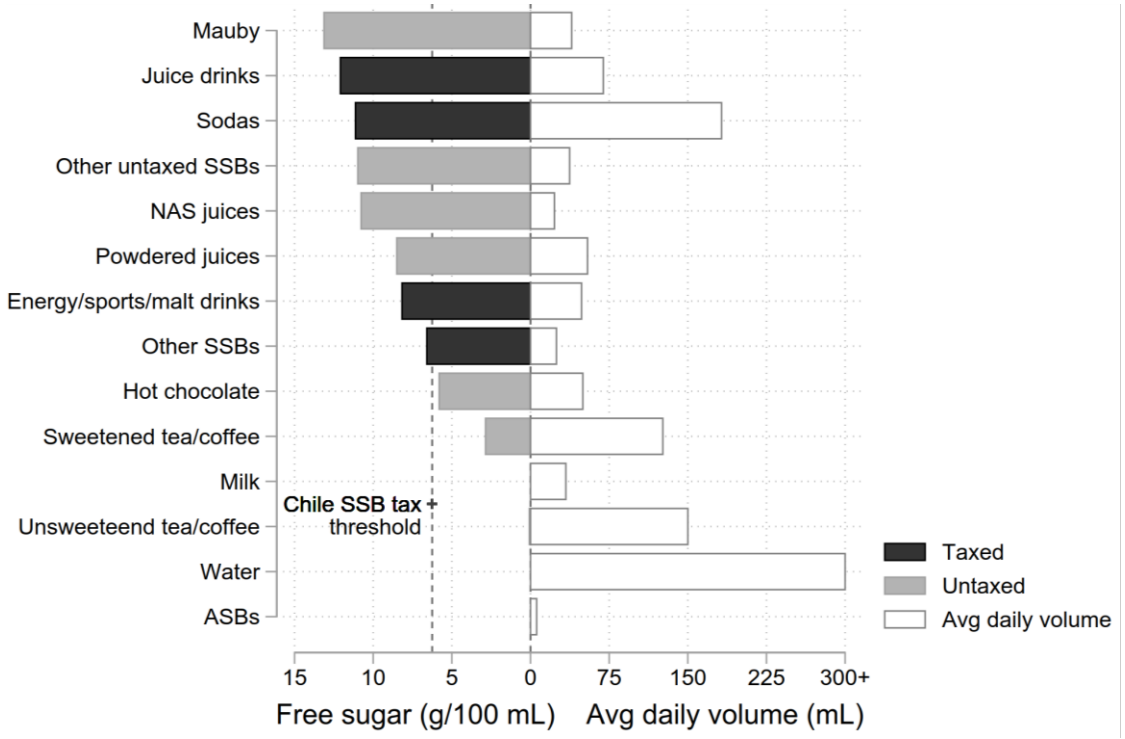
[3] Geometric means

[4] Defined as the mean TEI from SSB-derived free sugars divided by TEI, amongst all taxed and untaxed SSB-consumers separately

[5] 95% confidence interval defined as mean±1.96 SD to reflect the sample distribution

[6] Defined as the percentage of SSB-derived free sugars that were included in the original Barbados SSB tax definition of taxable products, amongst all SSB-consumers

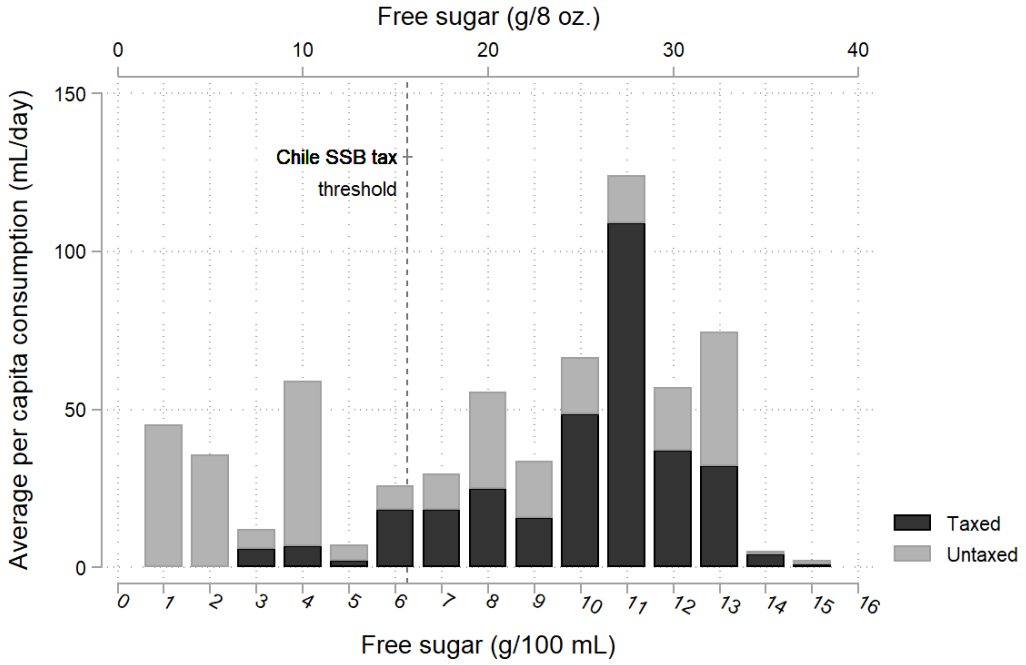
Figure 20: Mean consumption-weighted free sugar concentration by product type (g/100mL) stratified by subsequent taxable status, and mean per-person daily volume consumed (mL) in Barbados 2012-2013: the Barbados Salt Intake Study (n=334)[1, 2]



[1] The dashed line represents the SSB tax threshold used in Chile (6.25 gr sugar/100mL).[20,110]
[2] The tax was introduced in 2015, so we retrospectively apply the definition of taxable goods to consumption data reported from 2012-2013.

We assessed the mean per-person daily consumption of soft drinks (excluding those with free sugar <1 g/100mL, and including home-prepared SSBs and no added sugar juice) by free sugar concentration (Figure 21), stratified by taxed/untaxed SSBs. Nearly half of the drinks consumed with the highest free sugar levels (12+g/100mL) were not subject to the tax (see Chapter 6: Appendix Table 3 and Appendix Text 2 for examples of the products in each category by free sugar concentration).

Figure 21: Mean per-person daily volume consumed (mL) by free sugar concentration (g/100mL and g/8 oz.), stratified by subsequent taxable status in Barbados 2012-2013: the Barbados Salt Intake Study (n=334)



[1] The dashed line represents the SSB tax threshold used in Chile (6.25 gr sugar/100mL).[20,110]
[2] The tax was introduced in 2015, so we retrospectively apply the definition of taxable goods to consumption data reported from 2012-2013

6.5 Discussion

6.5.1 Overall Discussion

We proposed three criteria for evaluating the design of SSB taxes and demonstrated that pre-existing nutritional survey data may be used to address these criteria with important implications for tax design.

SSB consumption levels amongst adults aged 25-64 years in Barbados were very high (2.7 8-oz. servings/day, 95% CI 2.5, 2.9) compared to global estimates (0.58 8-oz. servings/day, 95% CI 0.37, 0.83).[35] SSB-derived free sugar accounted for 9.2% of TEI (mean± 1.96 SD 2.1, 41.3), and nearly half of the population exceeded the WHO's recommendation for *total* free sugar (10%, including sweets, jams, confectionery, etc.) from SSB consumption alone.[20]

The Barbados SSB tax captured a moderate percentage of SSB-derived free sugars (61.1%, 95% CI 55.7, 66.5), possibly incentivizing substitution to untaxed SSBs and dampening the potential health impact of the tax.

The Barbados SSB tax did not clearly differentiate between consumption-weighted high- and low-sugar products, which may further incentivise substitution to high-sugar untaxed alternatives in particular.

6.5.2 Strengths and Limitations

The proposed criteria reflect some aspects of SSB tax design, but additional context-specific factors need to be considered (e.g. public acceptability, market structure, etc.). However, applying these criteria illustrated important aspects of context-specific consumption patterns and may provide useful information to policymakers.

Given the data available, we were not able to assess SSB consumption patterns amongst children, young adults or adults over 65 years of age. The combined response rate was 45%, (comparable to that of a similar national dietary survey in the United Kingdom (47%)),[181] and survey weights were used to take the population representativeness into account and to match the age and sex distribution of the Barbados population. There was a dip in recalls conducted between July-September, suggesting that recall data may be slightly seasonally biased. July-September represent the hottest months in Barbados and SSB consumption may increase during these months, which would imply that we may have underestimated consumption.[182] Underestimation could have also occurred because of the subjectivity in the two 24-hour recall data,[183] which may have been partially mitigated by the energy density approach (% of TEI).

6.5.3 In relation to other studies

The Global Burden of Disease (GBD) 2010 study estimated that SSB consumption in Barbados was between 2.0 to 2.4 eight oz. servings/day, lower than our comparable estimate of 2.7 servings/day.[35] This difference may reflect that the GBD estimate for Barbados was modelled based on a study conducted in Jamaica between 1993-1995[184] and an unpublished analysis.[35]

In comparison to national measures of SSB consumption from other settings, our estimates were relatively high (criterion 1). Han & Powell estimated the two-day

prevalence of SSB consumption amongst US adults was 50%, lower than our comparable estimate of 89% amongst adults in Barbados.[185] A study of Dutch adults found that SSBs and non-SSBs accounted for 5.1% of TEI and a study of Australian children estimated an SSB contribution of 4.4%, much lower than our 9.2% estimate.[161,186,187]

This is the first study that we are aware of to quantify the percentage of SSB-derived free sugars covered by an SSB tax (criteria 2,3). Given the heterogeneous SSB consumption worldwide, it would be valuable to repeat this approach in different settings to assess both the potential (in general) of an SSB tax to target sources of SSB-derived free sugar, as well as to evaluate the specific definition of proposed future taxes. Powell et al. have assessed the distribution of sugar concentration by consumption of ready-to-drink SSBs (excluding home-prepared SSBs) in the US, and identified two clusters of highly-consumed concentration levels.[34] They recommended that SSB tax thresholds should be set at 5 g/8 oz. (i.e. 2.1g/100mL) below these highly-consumed clusters to encourage meaningful reformulation.[34] This guidance would imply a threshold of around 8g/100mL given the distribution we observed in Barbados, somewhat higher than the threshold used in Chile (6.25g/100mL).[110] More empirical work is needed to understand how companies respond to these thresholds in practice, and to assess how home-prepared SSBs compare in terms of sugar concentration levels in other settings.

6.5.4 Meaning of the study

6.5.4.1 Implications for Barbados

Adult SSB consumption levels were high before the introduction of the Barbados SSB tax. However, the definition of taxable products suggests that the tax was only likely to cover a moderate proportion of SSB-related free sugar consumption. Although the Barbados tax was amended in 2017 to include store-bought mauby syrup,[188] this analysis was based on the original legislation and it was not possible to identify what proportion of mauby was store-bought versus homemade. However, homemade mauby and other homemade SSBs remain difficult to address through a tax.[188] To maximise health benefits, the tax could be further amended to cover a higher proportion of SSB-derived free sugars, such as powdered juice drinks and powdered hot chocolate.

Some untaxed products (e.g. NAS juices and powdered juices) contain higher levels of free sugars than taxed products, suggesting that substitution to untaxed beverages could

have the unintended consequence of increasing free sugar consumption. Recent dietary guidelines in Barbados suggest limiting no added sugar juice intake to 250 mL/day, and similar guidelines in the UK recommend a threshold of less than 150mL/day. Excluding NAS juices from the definition of taxable products may convey that message that these are healthy alternatives, in which case it may be important to convey these recommendations clearly.[189–191]

6.5.4.2 Implications for other settings

We found that these proposed criteria were simple to assess and generated useful insight around the definition of taxable products following one particular SSB tax.[74]

Using tariff codes to identify which products should be taxed seems to be common practice and has been observed elsewhere (e.g. in St. Kitts and Nevis, Bolivia and South Africa).[192–194] When SSB taxes are defined by these tariff codes, care should be taken that all high-sugar products are taxed to limit incentives for substitution.

A potential limitation of SSB taxes in general is that they do not cover home-prepared SSBs. In contexts where a high absolute volume of SSBs are home-prepared, an SSB tax has less potential to impact health irrespective of the definition of taxable products. Complementary mass media or education campaigns that target untaxed sources of SSB-derived free sugars may be helpful in addressing free sugar consumption overall, given the limitations of any tax to capture all of these beverages.

It was feasible to assess our proposed criteria using existing nutritional survey data. Nutritional survey data can provide insight around homemade and on-the-go SSB consumption, although they may be limited by small sample sizes (which may preclude sub-group analyses) and infrequent administration. Nevertheless, standard nutritional surveys, when combined with detailed nutrient content data, can provide an opportunity to assess consumption patterns and highlight opportunities to design tailored, context-informed SSB taxes.

6.1 Conclusion

We used nutritional survey data to demonstrate high levels of SSB consumption (both in volume and as a percentage of total energy intake) amongst adults in Barbados prior to the introduction of the Barbados SSB tax. The Barbados SSB tax could be further

amended to apply to additional SSB products, potentially increasing possible health benefits. SSB taxes do not address consumption of home-prepared SSBs, and additional interventions may be needed to address these sources of free-sugars. Evaluating the criteria we propose here (baseline SSB consumption levels, the percentage of all SSBs that would be taxed, and the ability of a tax to differentiate between high- and low-sugar soft drinks) in other settings may help to improve SSB tax design and increase potential positive health impacts.

6.2 Contributions

I designed the study and developed the statistical analysis plan alongside Jean Adams and Nigel Unwin. Rachel Harris led the original Barbados Salt Intake Study which was based at the Sir George Alleyne Chronic Disease Research Centre, at the University of the West Indies, Cavehill Campus. Together with Rachel Harris, I reviewed each paper 24-hour recall record (668 records) and conducted quality assurance checks using Nutribase Pro software. I extracted additional data from the paper records (e.g. SSB/non-SSB brand name and flavour where available), and collected nutrient content data (calories/serving, sugar/serving (grams), serving size (mL, oz., etc.) for reported soft drinks. I conducted all of the statistical analyses, interpreted the results and wrote and revised the manuscript. Angie Rose developed code that was used to clean the original dietary data. Fumiaki Imamura provided feedback on the statistical analysis plan and Ian Hambleton provided feedback on the statistical analysis plan and data visualisations. All authors read several versions of the manuscript, provided feedback and approved the final draft.

I gratefully acknowledge contribution to the study design and support of the broader Barbados SSB tax Evaluation Steering Group, as well as the technical advisory committee: Deliana Kostova (US Center for Disease Control and Prevention) and Marc Suhrcke (University of York).

6.3 Appendix to Chapter 6

6.3.1 Appendix Table 1: Soft drink beverage category definitions

Main Categories	Taxable status	Level I Category	Level II Categories	Examples of frequently consumed drinks
SSBs	Taxed SSBs	Soda	Carbonated sugar-sweetened drinks (without added caffeine, etc.)	Coca Cola, Frutee, Fanta, Sprite, Pepsi
		Juice Drinks	Non-carbonated sugar-sweetened drinks with some amount of fruit or vegetable juice	Pinehill Dairy Juice drinks, Fruta
		Energy/Sports/Malt Drinks	Energy drinks (Sugar-sweetened drinks (carbonated or non-carbonated) with added caffiene or other stimulant)	Redbull, Monster
			Sports Drinks	Gatorade, Lucozade
			Malt Drinks	VitaMalt
		Other taxed SSBs	Flavoured SSB water	Cranwater
			Flavoured Dairy	Indulgence Milk
			Other taxed SSBs	Store-bought iced tea, Seamoss
	Untaxed SSBs	Mauby*	Mauby*	Mauby*
		Powdered Juice Drinks	Powdered Juice Drinks	Tang, Turbo, Koolaid
		Hot Chocolate	Powdered hot chocolate	Milo, Nestle
		Sweetened tea/coffee	Homemade sweetened tea/coffee	Coffee, tea or iced tea with added sugar or sweetened condensed milk
		Sweetened condensed milk	Sweetened condensed milk	Sweetened condensed milk consumed with cereal or cream of wheat as a milk substitute

Main Categories	Taxable status	Level I Category	Level II Categories	Examples of frequently consumed drinks
		Other untaxed SSBs	Homemade SSBs juice drinks	Sugar-sweetened homemade smoothies
				Sugar-sweetened homemade juices
			Other untaxed SSBs	Snowcone, milkshake, purchased sweetened coffee drinks (lattes, mochas etc)
Non-SSBs	Untaxed non-SSBs	Water	Water	Tap water, bottled water, soda water
		NAS juice (no added sugar)	NAS Juice	NAS Pinehill Dairy, Dewlands, Ceres
			Homemade non-SSBs	No-added sugar homemade juices
				No-sugar added homemade smoothies
		Other non-SSB	No added sugar coffee/tea	Coffee/tea with no added sugar
		Milk	Milk	Milk
		ASB	Diet Soda	Diet Coke

**Although mauby could be considered a homemade drink it can also be purchased as a syrup or a ready-made drink, and as such we report it as a separate category under SSBs.*

6.3.2 Appendix Table 2: Products by taxable status and free sugar concentration levels (with specific brands as exemplars)

Free sugar concentration (g/100mL)	**Taxable status**	**Products**
1-2.9	Taxed	NA
	Untaxed	Sugar-sweetened coffee & tea, soymilk
3-4.9	Taxed	Flavoured water (Cranwater)
	Untaxed	Hot chocolate, soy milk, sugar-sweetened coffee & tea, powdered juice (Mak-C)
5-6.9	Taxed	Sports drinks (Powerade), soda (Frutee - ginger ale flavour), flavoured milk
	Untaxed	Powdered juice (Tang), sugar-sweetened coffee & tea, powdered milk
7-.8.9	Taxed	Malt, Energy drinks (Plus), juice drinks
	Untaxed	Powdered juice (Turbo), sugar-sweetened coffee & tea, iced tea
9-10.9	Taxed	Soda (Sprite, Busta), flavoured milk
	Untaxed	Powdered juice (Koolaid), homemade sweet juice, NAS fruit juice
11.-12.9	Taxed	Soda (Coca Cola, Frutee), juice drinks (Pinehill Dairy, Fruta)
	Untaxed	Lemonade, NAS fruit juice, homemade juices/shakes/punch
13-14.9	Taxed	Juice drinks (Pinehill Dairy, Fruta), soda (Frutee, Ju-C)
	Untaxed	Mauby, homemade sweetened juice, NAS fruit juice (Pinehill Dairy), sugar-sweetened coffee & tea
15-16.9	Taxed	Soda, juice drinks
	Untaxed	Sugar-sweetened coffee & tea

6.3.3 Appendix Text 1: Definition of beverage categories and nutrient composition

We categorised drinks as summarised in Chapter 6: Appendix Table 1.

Nutribase includes nutrient information from the United States Department of Agriculture and Canadian food composition databases. For products not included in Nutribase (e.g. local and regional brands of sodas, juices; internationally produced beverages imported from South Africa, Turkey, etc.) we assigned nutrient information (sugar in grams and total calories) based on nutrient label data collected from product packages in stores and from websites. When a specific brand and flavour were reported in the dietary recall, we used nutrient information from the corresponding product. When no flavour was reported, we used the mean nutrient values across a range of available flavours. We relied on Nutribase nutrient information for available international brands (e.g. Coke, Sprite, etc.). When no brand was reported in the dietary recall, we used the mean nutrient information for that beverage category.

For powdered drinks (powdered juices and hot chocolate) we used packet instructions to estimate reconstituted levels. Most powdered drinks reported in the recalls already include sugar and do not require additional sugar to be added. While people may add additional sugar, this was not included as a prompt in the standard 24-hr dietary recall, so our estimates of sugar intake from powdered drinks may be an underestimate.

For powdered milk we assumed a 1:5 dilution ratio and corrected levels of total calories and sugars accordingly (since the product was previously entered as undiluted powdered milk in Nutribase).

For homemade SSBs, a previous Barbados-based study used the weighed recipe approach to estimate nutrient content for three popular drinks: mauby, ginger beer and lemonade.[195] For other homemade drinks, we used the recipes that participants reported to identify similar products within Nutribase. Participants had been prompted for recipes and we used the ingredients to identify similar products within Nutribase. For homemade SSBs (smoothies and juice drinks), we categorised these as “fruit punch drink,” “pina colada,” “blended smoothie: banana, oats, milk, honey, yogurt,” “flavoured milks,” “blended shake, milkshake vanilla,” “mixed berry fruit smoothie,” “fruit ‘n’ yogurt smoothie, strawberry kiwi,” “tropical fruit smoothie,” “golden apple juice,” “lemonade,”

"juice apple & cherry juice," "island guava drink," "orange flavour drink" "passion fruit juice," "dock, boiled (sorrel)," "mixed fruit juice," or "grape juice" as appropriate.

For homemade non-SSB (no added sugar smoothies and juices), we categorised these as "blended carrot, beet, celery, cucumber, apple juice without sugar," "cranberry juice," "carrot juice," "V8 60% vegetable juice, V-Lite," "aloe vera juice, " "mango juice," "orange juice, unsweetened," "lemon juice, raw," "passion fruit juice, raw," "soy milk," or "mandarin papaya drink" as appropriate.

Mauby is a local bark that is boiled with water and sugar to make a sweet drink (and can also be bought as a ready-made syrup and diluted at home or purchased ready-to-drink).

Sorrel is a flower (similar to hibiscus) that is used to make a sweetened drink. Golden apples are a fruit that are used to make a juice (often sweetened with added sugar).

We excluded snowcones, as we considered these to be a dessert and not a drink.

Several drinks were categorised within Nutribase as "pina coladas" although upon review these were identified to be homemade punches or smoothies. The sugar and total calorie content of these four observations were reclassifed, with pineapple punch and coconut punch reclassfied to "fruit punch drink" and "smoothie homemade" and "mango shake, homemade blended almond milk" reclassified based on "blended smoothie - banana oats milk honey yogurt".

To exclude galactose and lactose sugars, we subtracted these from total sugars. Where Nutribase did not automatically assign lactose or galactose sugar content to milk products, we assumed all sugars were from lactose/galactose in no added sugar milk products.

When sweetened condensed milk was reported with coffee or tea, we estimated the total sugar concentration per quantity of coffee/tea consumed and reported this under "sweetened tea or coffee" rather than "sweetened condensed milk."

Throughout this report, "SSBs" refer to both taxed and untaxed SSBs (excluding non-SSBs), while "soft drinks" refer to both SSBs and non-SSBs. Some non-SSBs (such as no added sugar juice) contain free sugars. To clarify when non-SSBs are included, we use the term "soft-drinks" rather than "SSBs."

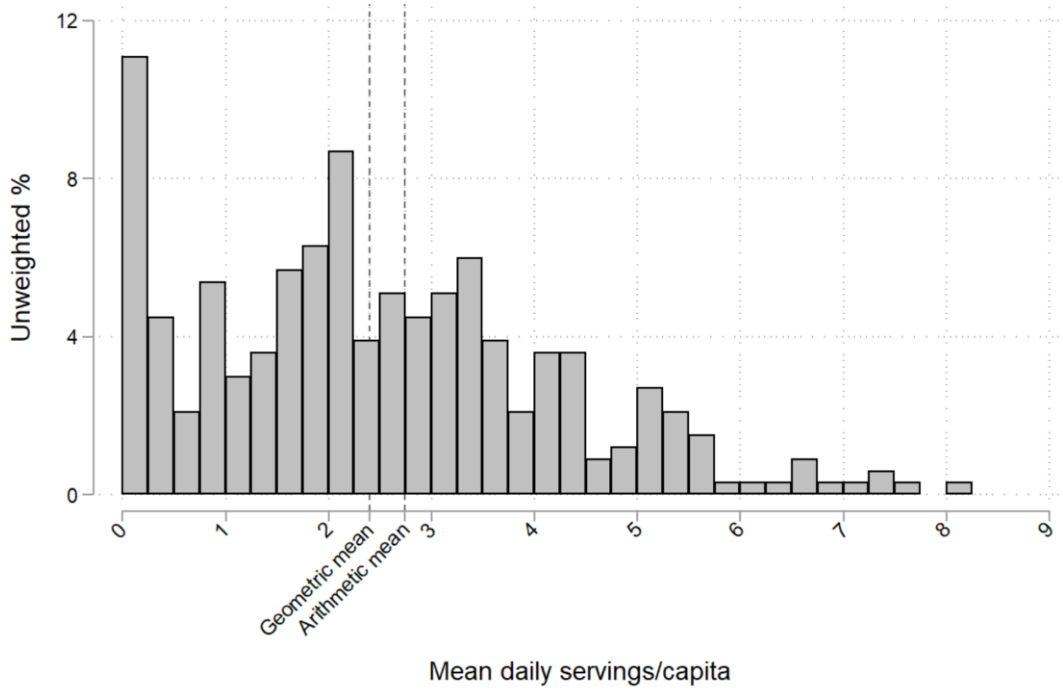
For participants with more than two recalls (n=1) we used only the first two recalls, assuming that reporting quality may have changed with repeated exposure to the survey instrument.

We converted all reported beverage volumes into millilitres.

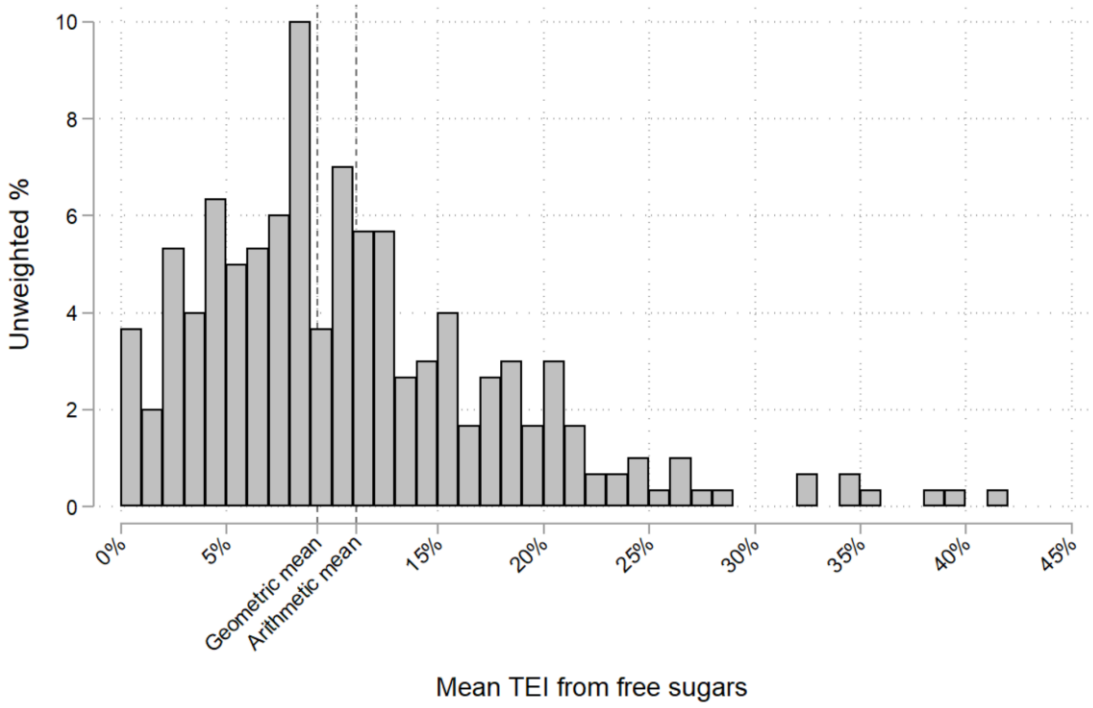
6.3.4 Appendix Text 2: Sugar concentration by product types

The sugar concentration of some product types varied greatly, such as for home-prepared SSB tea and coffee with reported consumption at a wide range of sugar concentration levels. Other product types were more narrowly defined (such as flavoured water, which was only found in the 3-4.9 g/100mL category). Most of the sweetest products (13+ g/100mL) were locally or regionally produced fruit drinks or sodas. Some flavours of NAS juice (non-SSBs) had a higher sugar concentration than juice drinks (SSBs), and some flavours of sodas had notably lower levels of sugar concentration than other flavours under the same brand.

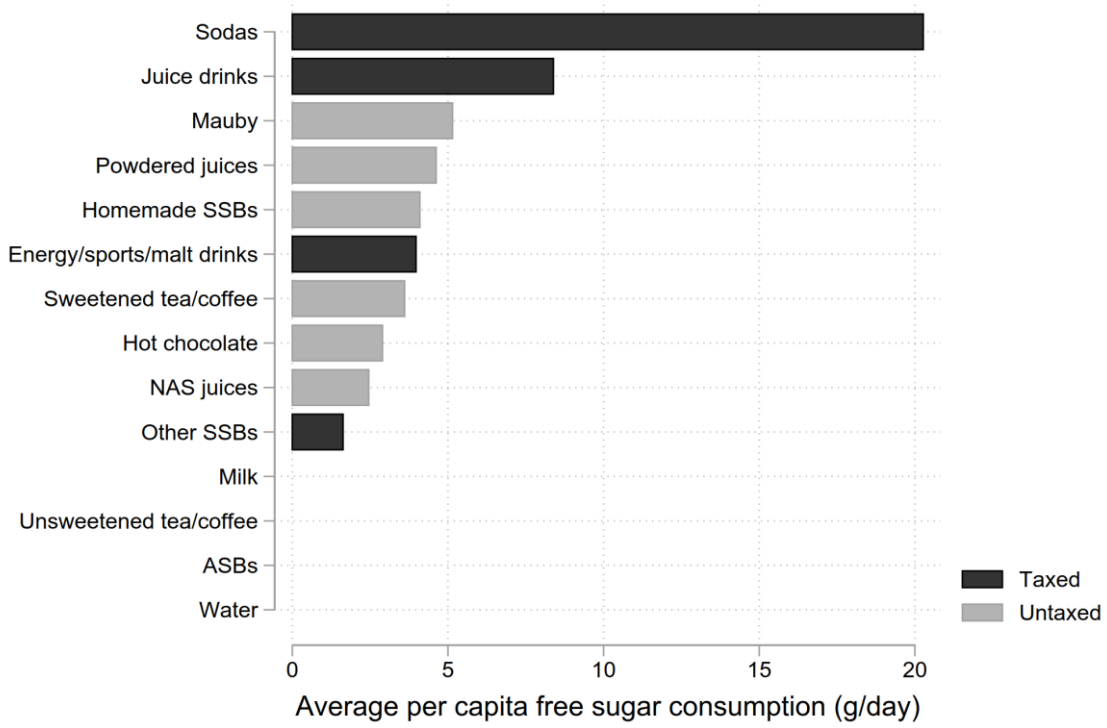
6.3.5 Appendix Figure 1: Distribution of sugar-sweetened beverage (SSB) consumption in mean daily servings/capita, for SSB consumers only, Barbados 2012-2013: the Barbados Salt Intake Study



6.3.6 Appendix Figure 2: Per-person mean Total Energy Intake (TEI) attributable to sugar-sweetened beverage (SSB)-related free sugars consumption (%), for consumers only, Barbados 2012-2013: the Barbados Salt Intake Study



6.3.7 Appendix Figure 3: Mean per-person free sugar consumed from soft drinks amongst adults aged 25-64, by product type and taxable status, Barbados 2012-2013: the Barbados Salt Intake Study



7 TESTING THEORY AROUND A RISK SIGNALLING MECHANISM

Based on this analysis I was invited to present a paper titled “Seeking causal explanations in policy evaluation: Applying process tracing to the Barbados sugar-sweetened beverage tax evaluation” at the Society for Social Medicine & Population Health in Cork, Ireland, September 2019.

7.1 Abstract

Context

The introduction of a sugar-sweetened beverage (SSB) tax has been hypothesised to convey information about the health risks of SSBs, which may contribute to dampening demand. If so, there may be important policy opportunities to amplify the impact of an SSB tax on purchasing by strengthening this risk signal. Our aim was to assess whether there is evidence of a risk signalling effect following the introduction of the Barbados SSB tax.

Methods

We used process tracing to assess the existence of a signalling effect around soda and sugar-sweetened juices ("juice drinks"). We evaluated whether our findings increased or decreased our confidence in each component of the theory. We used three pre-existing data sources: archived transcripts of local television news, interviews with members of the public and electronic point of sales data from a major grocery store chain. We used directed content analysis to assess the qualitative data, and an interrupted time series analysis to assess the quantitative data.

Findings

We found evidence consistent with a risk signalling effect following the introduction of the Barbados SSB tax for sodas but not for juice drinks. Our findings increased our confidence that consumers were aware of the tax, believed in a health rationale for the tax, understood that sodas were taxed and perceived that sodas and juice drinks were unhealthy, but decreased our confidence that consumers understood that juice drinks were taxed. Overall, the study increased our confidence that a signalling effect may have influenced soda sales, but not sales of juice drinks. In addition, we found evidence to suggest that the tax may have incentivised companies to 1) increase advertising around juice drinks and 2) introduce low-cost SSBs.

Conclusions

Our findings suggest that there may be a risk signalling effect for sodas but not for juice drinks following the introduction of the Barbados SSB tax. In the future, SSB policies could be introduced alongside co-interventions to 1) amplify this signalling effect and/or

2) reduce opportunities for industry to undermine this signal. Applying theory-testing process tracing was a useful approach and has potential applications across a wider range of public health policy evaluations.

7.2 Introduction

Sugar-sweetened beverage (SSB) taxation has been recommended as a response to the obesity epidemic.[74] The dominant economic theory around SSB taxation suggests that the introduction of a tax increases prices, which in turn dampens demand and leads to a reduction in sales of taxed products.[67] However, it has also been hypothesised that the introduction of an SSB tax may have a 'signalling effect' by conveying additional information that prompts behaviour change.[69,142,196] This new information may be about the expectation of future prices of a product,[197] the health risks (or long-term costs) of consuming SSBs,[198] and/or the social attitudes towards SSBs. While the existence of a price change following the introduction of an SSB tax has been documented in many settings,[103,104,108,109,116,143,199,200] there has been relatively less investigation into the existence of signalling effects.[69,116]

If taxation operates (in part) through a signalling effect, there may be important opportunities to amplify the impact of an SSB tax by improving its signalling potential. Developing a more comprehensive understanding of the ways in which SSB taxes lead to a change in purchases of SSBs will enable policymakers and practitioners to design policies that may be more effective from a health perspective.

7.2.1 Theory: The expressive function of law

As McAdams writes in *The Expressive Powers of Law*, laws not only function through sanctions but can also "convey or 'signal' information, which affects beliefs and behaviour."[201] The expressive function of law has been hypothesised to operate in part through informational signalling, in which a "law provides information; information changes beliefs; new beliefs change behaviour." [201] A further subset of this theory focuses on risk signalling, in which "a law conveys information about the costs and benefits of the legally regulated behaviour."[201] We summarise key elements of this theory below, and then identify implications for SSB taxation.

Central to the expressive function of law theory is the premise that the public "makes certain inferences from the existence of the law" (which requires that they are aware of the law).[201] McAdams elaborates: "Law is not informative when an individual is unaware that the law exists, which is often the case…or if they know the law exists, but significantly misunderstand its content."[201]

The ways in which people interpret a law may not be uniform but may vary across sub-groups: "there might be more than one actual audience; a law might have one expressive effect for one subpopulation based on the meaning that audience received, but a different expressive effect, or no effect, for a second subpopulation."[201] Although some people may "strongly resist 'learning' from the law's revelation of information […] the law can still, *on average*, change beliefs about risks."[201]

The expressive function of law may also have unexpected consequences which operate counter to the law's original intent.[201] For example, the Americans with Disabilities Act (ADA) was intended to extend civil rights protections to people with disabilities in the US. However, Fox & Griffin suggest that the ADA may have had the unintended consequence of signalling to would-be parents the challenges of raising children with disabilities, and this new information may have led to an increase in the termination rates of foetuses with Down's syndrome.[202]

Risk signalling is a particular type of expressive signal, with additional implications. First, the strength of a risk signal may be amplified or diminished depending on the public's perception of lawmakers' interests. If lawmakers are seen to enact a law despite strong industry lobbying, this may strengthen the risk signal. For example, when a law around

tobacco control is passed despite lobbying efforts by the tobacco industry, a "strong signal of harm" is conveyed.[201] On the other hand, when a law is passed which is seen to be in line with special interests, the signal of harm is likely to be weaker.[201] Second, risk signals may change behaviour both directly (through altered risk perception) and indirectly (through changed social norms). A direct effect may be seen, for example, when a ban on smoking in public places signals new information about risks, leading some smokers to change their behaviour.[201] The same ban could also have an indirect effect, by encouraging non-smokers to be more vocal about their disapproval of smoking behaviour.[201]

7.2.2 Implications of expressive function of law theory for understanding SSB taxation

If SSB taxation operates (in part) through a risk signalling effect, there may be several implications from a health perspective. First, a risk signal may only apply to the products that consumers perceive as being subject to the tax. Second, a risk signal may not be perceived uniformly, but may be stronger amongst certain sub-groups as compared to others (e.g. based on sociodemographic characteristics, baseline beliefs or SSB consumption, media exposure, etc.). Third, the introduction of an SSB tax may also be associated with unexpected expressive consequences (counter-signals), such as industry advertising. Fourth, if lawmakers are perceived to have implemented the SSB tax despite industry opposition, this may strengthen the risk signal, whereas if the perceived intention was to raise revenue, the signal may be weakened. Finally, a risk signal may have direct and indirect effects, by 1) incentivizing consumers to reduce consumption out of concern for their health and 2) encouraging others to voice disapproval of SSB consumption more strongly.

7.2.3 Empirical evidence around the existence of a risk signalling effect around SSB taxation

While the existence of an expressive signalling effect following an SSB tax has not be studied extensively, many economic and public health experts have hypothesised that it may be important.[67,203–205] Cornelsen and Smith suggest that identifying the extent to which price and/or signalling are potential mechanisms represents one of four critical unanswered questions around SSB taxation.[203] An Institute for Fiscal Studies report

suggests that it is feasible that "the label 'tax' acts as a social signal of disapproval."[204] Mytton et al. hypothesised that "purchasing decisions may also be influenced by other factors such as social norms that could also be influenced by a tax."[67] However, limited attention has been given to detailing the specific causal mechanisms through which such a signalling effect may operate.

Empirical evidence of a signalling effect for SSB taxes is beginning to emerge. An evaluation of France's SSB tax using household purchase data demonstrated that the tax was associated with reductions in purchases of regular soft drinks, even when the price of these drinks did not increase.[116] Conversely, the researchers found an increase in the purchases of diet drinks, even when these were taxed and associated with price increases, suggesting that the "effect of soda taxes might have a broader reach than the taxes themselves." [116] An evaluation of an unhealthy food tax in Hungary found that 22-38% of consumers who self-reported reducing their SSB intake ascribed this change to an "increased health consciousness."[74]

An evaluation of the Mexico SSB tax explored whether awareness of the policy was associated with self-reported reductions in post-tax SSB consumption.[69] They found that 65.2% of adults "reported being aware of the existence of the SSB tax," and that adults who knew about the tax were significantly more likely to report consuming fewer SSBs. However, as the study authors acknowledged, people who were aware of the tax may have been more likely to report reduced consumption due to a social desirability bias or other unobserved confounding. In Barbados, a study conducted by Harry Singh Lalli (which I co-supervised) found that newspaper coverage of the health risks associated with SSBs increased in the three month period following tax announcement.[206]

Overall, while there is some emerging evidence in support of a signalling effect, much is still unknown.

7.2.4 Case study: the Barbados SSB tax

In 2015, the Government of Barbados introduced a 10% ad valorem SSB tax, as described previously (Section 3.3).

7.2.5 Aims

Our aim was to assess whether there is evidence of an expressive risk signalling effect following the introduction of the Barbados SSB tax.

7.3 Methods

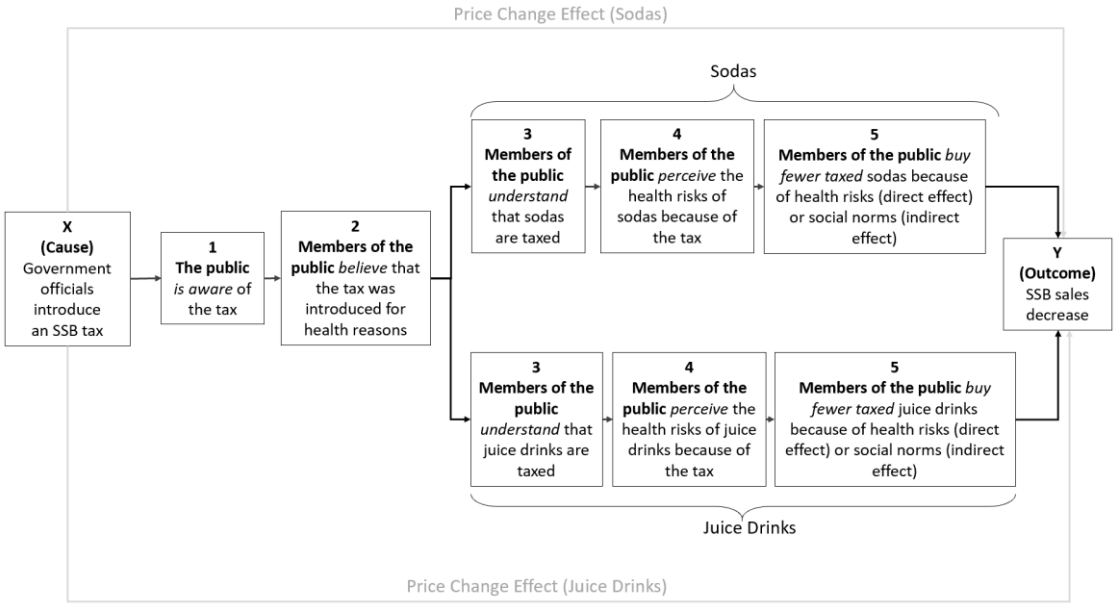
We used process tracing (PT) to evaluate each component of the proposed theory. We present results in terms of updated posterior beliefs, following process tracing best-practice.[207]

7.3.1 Process tracing as a method

Process tracing is appropriate for use in single case studies when the research aim is to confirm the presence of a hypothesised causal mechanism in an effort to understand "how and why an intervention led to change."[138,207,208] Theory-testing process tracing is useful when "we know both X [the cause] and Y [the outcome], and we either have existing conjectures about a plausible mechanism or are able to deduce one relatively easily from existing theorisation." [207] Here, a "mechanism" is defined as the "causal chain or story," which is made of a number of parts that are all necessary for X to lead to Y.[208]

The detailed steps and inferential logic of process tracing have been described extensively elsewhere.[137,207] Briefly, we identified expressive risk signalling as a plausible but under-studied potential mechanism linking X (the introduction of an SSB tax) with Y (reductions in SSB sales).[209] We operationalised this theory to apply to SSB taxation (Figure 22). Since SSBs represent a heterogeneous group of products, we identified the two most commonly consumed SSBs in the Barbados population: sodas and juice drinks (see Chapter 6). We assessed the existence of an expressive risk signal around sodas and juice drinks separately, driven by the hypothesis that the risk signal produced by a tax may vary by product type. For the purposes of this study, we refer to sugar-sweetened carbonated drinks (without caffeine) as 'sodas,' sugar-sweetened juices as 'juice drinks,' and unsweetened juices as 'no-added sugar juice' (or 'NAS juice'). Sodas and juice drinks are taxed under the Barbados SSB tax while NAS juices are not.

Figure 22: Expressive function of law theory applied to sugar-sweetened beverage (SSB) taxation for sodas and juice drinks separately[a]



[a] Note that price change represents another mechanism through which the introduction of an SSB tax may influence SSB sales.

For each component of the theorised causal mechanism in Figure 22, we assessed our prior beliefs based on existing theory, empirical studies and case-specific knowledge (Table 12).[207]

Table 12: Components of risk signalling theory, including pre-existing evidence and prior beliefs

Part	Hypotheses (h)[a]	Rationale according to risk signalling theory	Prior p(h)[b]
1	**The public** is *aware* of the SSB tax	If people are not aware of a law at all, it cannot have an expressive function.	Likely, given evidence of SSB tax awareness in other settings, e.g. 65% awareness in Mexico,[69] 68% in Berkeley, US.[144]
2	**Members of the public** *believe* that the tax was introduced for health reasons	If people perceive that the government implemented a law despite industry opposition, it is likely to have a stronger signal; if they perceive that the government implemented a law primarily to raise revenue, it is likely to have a weaker signal.	Agnostic
3	**Members of the public** *understand* which products are taxed	The ways in which people interpret the law is more important than the actual law, in terms of the risk signal transmitted.	Agnostic
4	**Members of the public** *increase* their perception of health risks of SSBs because of the tax	A risk signal affects the public's beliefs around the riskiness of a behaviour.	Likely, given evidence of increased newspaper coverage of SSBs as unhealthy in Barbados.[206]
5	**Members of the public** *buy fewer* SSBs based on new information about health risks (direct effect) or social norms (indirect effect)	The public's new beliefs about the riskiness of a behaviour change that behaviour, either directly (through new information about a behaviour) or indirectly (through heightened social norms against the behaviour).	Agnostic

[a] *h: hypothesis that part of a causal mechanism exists*
[b] *p(h): probability of the hypothesis being true*

We then developed a priori predictions by specifying what we would expect to find if each component of the causal mechanism had operated (Table 13). We identified what type of process tracing test each prediction represented (straw-in-the-wind, hoop, smoking gun, doubly decisive) by assessing the probability of finding that evidence if the hypothesis was true, compared to the probability of finding the same evidence if the hypothesis was not true. Briefly, Schmitt and Beach define a straw-in-the-wind test as one that "combines low certainty and low uniqueness, resulting in little updating," and can be thought of as a test with low sensitivity and low specificity.[210] In contrast, a doubly-decisive test has high sensitivity and high specificity. Finding evidence in support of a doubly decisive test "increases our confidence because there are few plausible alternative explanations for the evidence," while failing to find the predicted evidence reduces our confidence in that component of the theory.[210]

There are also two asymmetric tests. The first is a hoop test, for which "finding the predicted evidence means little updating takes place, whereas a negative result (i.e. not finding evidence) significantly disconfirms the hypothesis."[210] The second is a smoking gun test, which when found "enables strong confirming inferences, whereas not finding the predicted evidence usually does not enable us to conclude anything beyond 'we did not find the smoking gun.'"[210] A hoop test can also be thought of as a test with a high false positive rate (low specificity), while a smoking gun test can be thought of as a test with a low true positive rate (low sensitivity). These four tests have been summarised further in Chapter 7: Appendix Table 2.

Table 13: Predicted empirical evidence and test types

Hypotheses (*h*)	Part	Means of Verification	Predicted Empirical Evidence (*e*)	Test Type
(1) The public is *aware* of the SSB tax	1a	Interviews with members of the public	Participants report being aware of the tax, and are able to describe details (e.g. when/how they heard about the tax, how it was introduced, etc.)	Hoop • Finding *e* does not necessarily confirm *h* given potential bias of participants to report awareness • Not finding *e* disconfirms *h*
	1b	Archived media data	Major news sources cover the tax, providing a plausible mechanism for the public to have learned about the policy	Hoop • Finding *e* does not necessarily confirm *h* given potential bias of participants to report awareness/news consumption • Not finding *e* disconfirms *h* given the news is likely to be the main channel through which people learn about government actions
(2) Members of the public *believe* that the tax was introduced for health reasons	2a	Interviews with members of the public	Participants report that the tax was introduced because of the health risks of SSBs	Doubly Decisive • Finding *e* confirms *h*, • Not finding *e* disconfirms *h*

Hypotheses (*h*)	Part	Means of Verification	Predicted Empirical Evidence (*e*)	Test Type
(3) Members of the public *understand* which products are taxed	3a	Interviews with members of the public	Participants report that the tax is applied on sodas and/or juice drinks	Doubly Decisive • Finding *e* confirms *h*, • Not finding *e* disconfirms *h*
(4) Members of the public *increase* their perception of the health risks of SSBs because of the tax	4a	Interviews with members of the public	Participants mention health risks of sodas and/or juice drinks	Hoop • Finding *e* does not necessarily confirm *h* given that participants may be aware of health risks of sodas and/or juices for reasons unrelated to the tax • Not finding *e* disconfirms *h*
	4b	Interviews with members of the public	Participants mention increasing their perception of the health risks of sodas and/or juice drinks because of the tax	Smoking Gun • Finding *e* confirms *h*, • Not finding *e* does not necessarily disconfirm *h* given that participants may not report this so directly (or even be consciously aware of it)
	4c	Archived media data	News media coverage of SSBs as unhealthy increases following introduction of the tax	Hoop • Finding *e* does not necessarily confirm *h* given that people may not have seen the news or updated their beliefs based on it

Hypotheses (*h*)	Part	Means of Verification	Predicted Empirical Evidence (*e*)	Test Type
				• Not finding *e* disconfirms *h*
(5) Members of the public *buy fewer* SSBs based on new information about health risks (direct effect) or social norms (indirect effect)	5a	Electronic point of sale data from a major grocery store chain	Sales of taxed sodas and/or juice drinks decrease over time	Hoop • Finding *e* does not necessarily confirm *h* given that other mechanisms could explain the decrease (e.g. price changes due to the tax) • Not finding *e* disconfirms *h*
	5b	Electronic point of sale data from a major grocery store chain	Sales of soda/juice drinks *decrease* post-tax, despite *no* tax-driven increases in price, OR Sales of soda/juice drinks *do not* decrease post-tax, despite tax-driven *increases* in price	Hoop • Finding *e* does not necessarily confirm *h* given that other mechanisms could explain the decrease/lack of decrease • Not finding *e* disconfirms *h*

Note: e: evidence; h: hypothesis that part of a causal mechanism exists

We aimed to specify a test or combination of tests that would allow us to confirm and/or disconfirm each component of the theory, as summarised in Table 13. Where we were only able to identify hoop tests, we developed multiple tests noting that they can, in combination, strengthen confidence in a causal hypothesis.[210] When we were able to identify doubly decisive tests, no other tests were necessary given the strong confirmatory and disconfirmatory power of this test type.

We analyzed the data that were relevant for each test, taking into account potential biases and limitations in each dataset. We then assessed each component of the hypothesised theory by evaluating the associated empirical tests, guided by test type and prior beliefs. If a test provided evidence in support of (against) a component of the theory we upgraded (downgraded) our prior belief accordingly, as summarised in Table 14. Finally, we updated the original theory to reflect our posterior belief in each component of the theory (Figure 28).

7.3.2 Data and analytical methods for empirical tests

We used three pre-exiting data sources: archived transcripts of local television news, interviews with members of the public conducted as part of a public acceptability study and electronic point of sale data from a major grocery store chain.

7.3.2.1 Local news television transcripts

We reviewed transcripts of local televised evening news programming from June 15, 2014 (one year prior to announcement of the Barbados SSB tax) to July 31, 2017 (2+ years after tax announcement). The Caribbean Broadcast Corporation (CBC) is the only televised local news programme in Barbados, and the CBC Evening News programmes have been uploaded to the video-sharing website Youtube.com. Televised news footage was available on 639 of the 1,143 day period (56%). Automated text transcriptions were available for all but 28 videos, for a total of 611 news-days.

Transcripts were analyzed using a directed approach to qualitative content analysis.[211] The initial coding scheme was determined by the theory, and included codes such as “SSB tax covered in news” and “SSBs portrayed as unhealthy,” which were reviewed by a senior qualitative researcher (MM). We conducted an initial text keyword search for terms related to SSBs (see Chapter 7: Appendix Text 1). All results were reviewed and

coded, and we explored whether new codes should be developed to capture additional emergent themes. The coded transcripts were then analyzed to assess the extent to which they provided confirming or disconfirming evidence of the relevant empirical tests (1b,4c). To assess the frequency of news coverage over time, coded news-days were displayed as a proportion of total observed days in each month over time. All transcripts were coded and analyzed in Nvivo 12 Pro, and graphical displays were produced in Stata 14.0.[150]

7.3.2.2 Public Acceptability Interviews

Twenty participants (30+ years old) were recruited from the Health of the Nation (HotN) study, a cross-sectional study conducted between 2012-2013 in Barbados. Further details of the original HotN study have been published elsewhere.[125] Participants were identified using a stratified sampling procedure based on age, gender and parish. Since the HotN sampling frame did not include participants under the age of 30, ten additional participants between the ages of 18-29 were recruited from a popular local shopping mall. A trained investigator (AF) led semi-structured interviews with each participant around general tax knowledge, views on taxation, and views on the Barbados SSB tax in particular. Written informed consent was obtained from all participants prior to the interview. Interviews lasted 30 minutes or less, were tape-recorded and transcribed verbatim, and were conducted between March 2017-July 2017. The original purpose of the study was to inform views of the public acceptability of the Barbados SSB tax, and to gain insight into the potential acceptability of policy amendments or additional policies (unpublished). Ethics approval was given by the Research Ethics Committee of the University of the West Indies and Barbados' Ministry of Health.

Transcripts were re-analyzed for the purpose of this study, using a directed approach (as above) and a coding scheme developed from the theory. All transcripts were read initially, then re-read and coded according to the coding scheme. New codes were added to capture emergent themes. The coded transcripts were then analyzed to assess the extent to which they provided confirming or disconfirming evidence of the relevant empirical tests (1a,2a, 3a, 4a, 4b). All transcripts were coded and analyzed in Nvivo 12 Pro.

7.3.2.3 Electronic Point of Sale Data

Overall, we re-analyzed post-tax trends in sales and prices, and assessed the extent to which they confirmed or disconfirmed the related empirical tests (5a, 5b).

Electronic point of sales data were available from one major grocery store chain from January 2013 to October 2016, including weekly price and sales of 191 unique soda products and 387 unique sugar-sweetened juice drinks. Additional details have been provided elsewhere.[209] Sales trends (in litres sold per week) were re-analyzed using the interrupted time series (ITS) model presented in Chapter 5. Juice drinks were re-analyzed because the original product category (non-carbonated SSBs) presented in Chapter 5 included other SSBs, such as sport drinks and sugar-sweetened flavoured waters.[209]

In order to assess post-tax price trends (an alternative explanation for any observed changes in sales), we re-analyzed price data using a step-change ITS model[212] to assess the consumption-weighted mean cost per litre of sodas and juice drinks (see Chapter 7: Appendix Text 2 for further details). The main model was limited to those products with no missing data over the study period, consistent with previous price change estimates.[143] We conducted a sensitivity analysis to test the impact of including all data (i.e. including products which may have been discontinued or introduced during the study period). Given discrepancies between the main model and the sensitivity analysis, we conducted a post-hoc descriptive analysis of post-tax price trends amongst juice drinks.

7.4 Results

Results of each analysis are presented below, with the corresponding process tracing tests summarised in Table 14 and Chapter 7: Appendix Table 3. Broadly, we found evidence consistent with the existence of an expressive risk signalling effect around sodas, but not juice drinks. More specifically, we found evidence consistent with: consumer awareness of the tax (1), consumers' belief in the health rationale for the tax (2), consumers' understanding that the tax applied to sodas (3), consumers' perception that sodas and juice drinks were unhealthy (4), and a reduction in sales of sodas (5). However, our findings reduced our confidence that consumers understood that the tax applied to juice drinks (3) or that the tax was associated with a decrease in sales of juice drinks (5). Finally, we found evidence that companies may have increased advertising of

SSBs in response to the introduction of the tax, potentially undermining a signalling effect. We also found evidence that companies may have introduced low-cost SSBs, potentially undermining the price change effect.

In the following section, we summarise the evidence for each hypothesis and then present an overall updated version of the theory in Figure 28.

7.4.1 Were participants aware of the tax? (1a)

The majority of participants reported being aware of the tax. Participants recalled specific sources of information about the tax (e.g. the radio, televised news), and associated the tax with the 2015 budget announcement.[127] Many participants were able to provide details, for instance explaining "that was a big hot topic last year […] that's when you heard that the supermarkets would absorb the cost of it…"(Female, mid-30s), lending additional support to the hypothesis that they were aware of the tax. However, a third of participants who were aware of the tax were surprised to learn that it had already come into effect at the time of the interviews: "It was implemented yet, though?" (Female, early 30s).

7.4.2 Did popular news sources cover the tax? (1b)

Over a third of participants referred specifically to the CBC local television station provider (otherwise referred to as "Channel 8") as a source of information about the SSB tax. When the tax was first announced in June 2015, it was covered several times per week on the CBC Evening news. After this initial two-week period, the tax was not mentioned on CBC Evening News from July 2015-October 2016. This may partially explain why, despite being aware of the tax, some participants were not aware that the tax had already been implemented (1a).

Taken together, these two hoop tests suggest that it is likely that consumers were aware of the tax. However, lower awareness of tax *implementation* and lack of subsequent media coverage suggests that any potential signalling effect may have been limited to a specific period of time.

7.4.3 Do people believe that the tax was introduced for health reasons? (2a)

Participants reported several reasons for the introduction of the tax. Some believed that the tax was primarily about health:

> *It was a deterrent to make us stop drinking so many soft drinks. […] They don't actually think they're going to make … They're not using it, I think, in my mind's eye, to make money. But I do think, um, it is used as a deterrent. (Female, early 40s)*

These participants tended to be middle-aged women. Other participants suggested that the tax was introduced for both health and revenue reasons:

> *The government thought that a way to curb that [childhood obesity], plus make some money on the side is to implement this tax. (Female, mid-20s)*

Some participants (more men) suggested that the primary motivation for introducing the tax was to raise revenue and that the health rationale was used to justify the introduction of a new tax:

> *I think to get more revenue and then also it has a nice wrapping, a nice story to say 'oh by the way we help diabetes' which I mean it will but. Obviously I think right now they in a point they trying to make as much money as they can. (Male, late 20s)*

Some participants reported that the government had acted in its own self-interest by taking advantage of the tax as a revenue-raising opportunity.

This doubly decisive test strongly suggests that some (but not all) consumers believed that the tax was introduced for health reasons.

7.4.4 Do participants perceive sodas and/or juice drinks as taxed SSBs? (3a)

Almost every participant who was aware of the tax reported that it was applied to sodas (e.g. "…so like Sprite, Coke, Frutee, Fanta, those kind-a things that are colourful"). However, half of participants who knew about the tax reported being unsure about the status of juice drinks:

> *I'm not sure if they went on juices as well. (Male, late teens)*

Only a few participants identified juice drinks as taxed SSBs without any prompting: "It's on the sweet, sweet drink beverages and stuff like that which are sodas, juice, certain juices […] I'm not mistaken" (Male, late 20s). Others reported that juice drinks were untaxed. This doubly decisive test strongly suggests that consumers were aware that sodas were taxed, but were mostly unaware that juice drinks were taxed.

7.4.5 Do participants view sodas and/or juice drinks as unhealthy? (4a)

Every participant referred to the health risks of sodas. Specific risks included high levels of sugar ("I guess the bad sugars would be, like, the carbonated drinks and stuff") and associations with obesity, diabetes and chronic diseases more generally:

> *Look at our, am, our chronic disease rates. The high, the blood pressure, the cholesterol, the … And all them tie back into sugar, sugar uses. And, like, when we were younger we, we would get a sweet drink once in a blue moon—children drinking three and four sweet drinks right now. So by the time them reach adult, twenty-five, some of them done diabetic already. (Female, mid 40s)*

Participants demonstrated a high level of awareness of various health risks associated with soda consumption. In addition, a few participants referred to exerting or experiencing peer pressure around soda consumption because of health-related risks:

> *More and more people make comments on you when you drink soft drink—friends, am, generally. […] because there's now the pressure of 'will people see me drinking this and think that I am irresponsible for drinking it' makes you far more conscientious about drinking. It's why you buy bottled water, because you look more conscientious. So when you're a big woman like myself and somebody sees you drinking a Coke, they're going to think, 'oh, you're being irresponsible!' (Female, early 40s)*

This suggests that perceptions of health risks around sodas may have both a direct and indirect effect (social norm enforcement), at least amongst some sub-groups.

In comparison, only half of the participants referred to the health risks of juice drinks. Those that did frequently focused on the high sugar content of juice drinks:

> *They will line up drinks and then they will show you after they put them to boil and all the water evaporate, how much sugar is left. And the Coke and the Sprite, even the same juices the, they supposed to be health juices ya a big, a big clump of sugar left in it. (Male, early 30s)*

None of these participants linked juice drinks directly with diabetes or other specific health risks beyond containing high sugar levels, and no one referred to social norms around juices. However, some participants suggested that juice drinks were healthy alternatives to sodas:

> *It would be more healthier on their bodies 'cause they more would go to box juice [sugar-sweetened juice drinks sold in small cartons] than more than they would go to a Coke, a Sprite (Female, mid 40s).*

Overall, there was decisive evidence that participants viewed sodas as unhealthy, passing this hoop test. There was mixed evidence around juices, with some (but not all) participants aware of juice drinks as unhealthy. Even amongst this group however, the link between juices and specific health risks was less clear than it was for sodas.

7.4.6 Do participants view sodas and/or juice drinks as unhealthy because of the tax? (4b)

It was less clear whether awareness of the health risks of sodas was a direct result of the tax. Some participants drew comparisons between SSBs and cigarettes or alcohol, suggesting that SSBs were now in a similar conceptual category as other unhealthy products because of the tax:

> *I think that is, this is perhaps a mechanism being put in place to kind-a curb the consumption of so much sugar. But they want do it with alcohol and the people still drinking. They want do it with cigarettes and people still smoking. But it is a good effort—I can, I can see that—and I think that's one of the reasons behind it. (Female, mid-30s)*

News coverage of the SSB tax also included references to the similarities between taxation on alcohol and cigarettes:

> *"The idea is very similar to how we treat alcohol and cigarettes in terms of taxing [...]" (CBC News, Jan 8, 2017)*

While it is not clear whether people have associated SSBs with alcohol and cigarettes prior to the introduction of the tax, it seems likely that the tax may have at re-enforced this association, strengthening the health risk signal. One participant suggested that the differential price change between sugar-sweetened and non-sugar-sweetened sodas caused by the tax would signal differences in health risk:

> *That [unsweetened club soda] stays at one price but the other ones [regular sodas] go up, then people are obviously going to realise, alright, they sending us a message here. (Male, early 40s)*

One participant suggested that the tax re-enforced existing views of health risks of sodas but did not change existing perceptions of juice as healthy:

> *Lots of parents didn't let, don't let their children drink soft drinks. But these same parents give their children a box juice every single day, sometimes two, because they don't see that as damaging. So when you think of the tax, you're going to think soft drink, but you're not going to think of the Pinehill Dairy juices that you've been buying your kids. (Female, early 40s)*

Overall, we did not find strong enough evidence to support the smoking gun test that people changed their views around the health risks of sodas because of the tax (as opposed to re-enforcing pre-existing views). We found no evidence that people changed their views around the health risks of juice drinks.

7.4.7 Did news media coverage of SSBs as unhealthy increase following the introduction of the tax? (4c)

News coverage clearly linking SSBs with specific health risks increased around the time of the tax announcement:

> *"Litreally every home in Barbados has someone that is living with diabetes or they have a friend or they have a co-worker […] people are not educated about what and what sweet drinks can do'"(CBC News, June 26, 2015)*

In the lead-up to the two-year review of the tax, SSBs continued to be portrayed as a health risk:

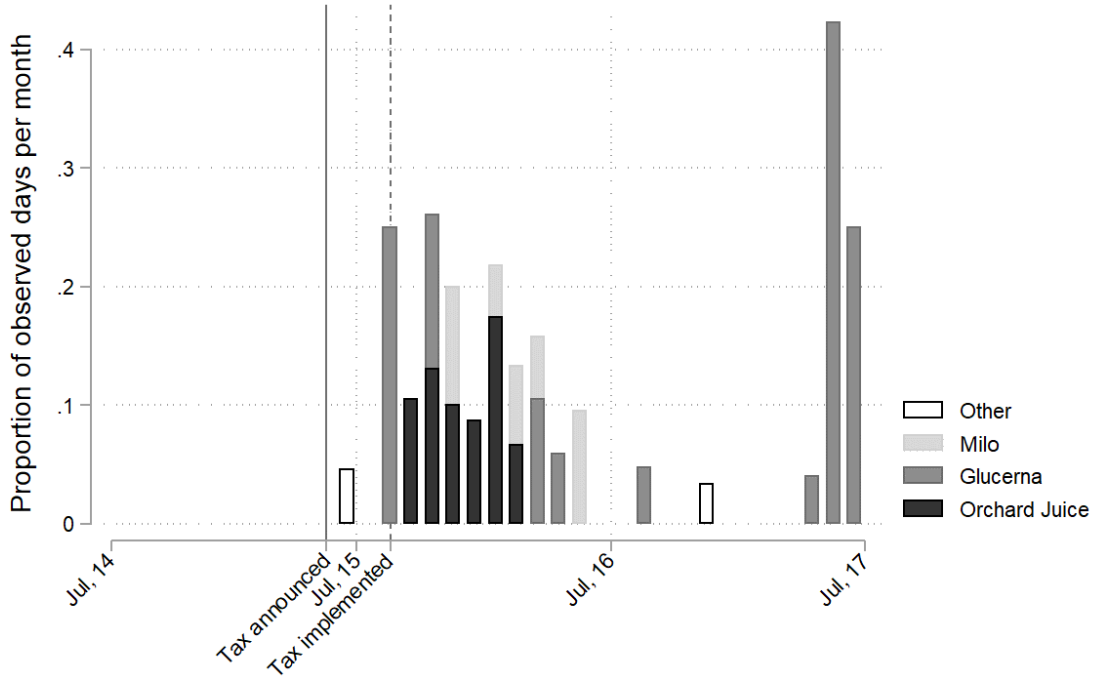
"A doctor at the forefront of the fight against non-communicable diseases is supporting a proposal for the tax on sweet drinks to be increased." (CBC News, April 19, 2017)

However, no news coverage focused on health risks of juice drinks specifically, and vague terms like "sweet drinks" were dependent on the public's interpretation. Interviews with members of the public suggest that these vague terms are primarily understood to refer to sodas (3a).

7.4.8 Unexpected expressive consequences of the SSB tax

Although not part of the original coding framework, it became apparent from reviewing the archived news transcripts that juice drinks were frequently portrayed on televised ads shown during the CBC Evening News programming. We added additional codes and keyword searches to capture SSB-related advertising and summarised the frequency and distribution of these ads over time in Figure 23.

Figure 23: Frequency and distribution of sugar-sweetened beverage (SSB) related advertisements shown during Caribbean Broadcast Corporation (CBC) Evening News, June 2014 - July 2017



Note: Orchard is a juice drink brand, Glucerna is a meal-replacement shake targeted at diabetics and Milo is a malt-based drink.

Given the timing of the increase in these advertisements (ads), it seems likely that they were introduced in response to the SSB tax. The content of these ads tended to focus on health benefits of specific SSBs. For example, one ad portrayed juice drinks as a healthy beverage:

> *Naturally better Orchard. Time for fun, bring out the sun, nutrition so delicious, way less sugar, way less sugar, no artificial sweeteners. Orchard your natural choice. Orchard with real juice...*

The word "natural" was used to describe a sugar-sweetened juice drink four times. Although this ad emphasised sugar reductions, Orchard juices contained 11.6 grams of sugar per 100mL as of July 2017 making it more sugary than regular Coca Cola, which has 10.6 grams of sugar per 100ml.

During interviews with participants, the word "natural" was also used to describe juice drinks as healthy:

> *I mean if it's natural, if it's, am, orange j, natural orange juice, or so they say, I, I really couldn't see how the sugar tax would apply to that. […] I know they got drinks with artificial sugars and so on, but…" (Male, early 40s)*

While it was not always clear if participants were referring to NAS juices, colloquial references to "fruit juices" often refer to juice drinks rather than NAS juices. The association between juice drinks and "natural" may have confused some participants' interpretation of which beverages were taxed (3a):

> *Some sugar beverages are supposed to be natural, like fruit juices and stuff like that so. […] when I hear, when I heard about the sugar-beverage tax, I just study sweet drinks. That's, that's just what come off my mind. But then when you look at it in-depth you might be, the fruit juices, the … And this is the things that, that they will tell you to let you children drink juices rather than, than the sweet drinks, so […] It would be a bit confusing. (Female, mid-40s)*

There is strong emergent evidence that the introduction of the Barbados SSB tax may have inadvertently led to an increase in SSB advertisements, which strongly implied that certain SSBs were healthy (e.g. juice drinks). There is suggestive evidence that these

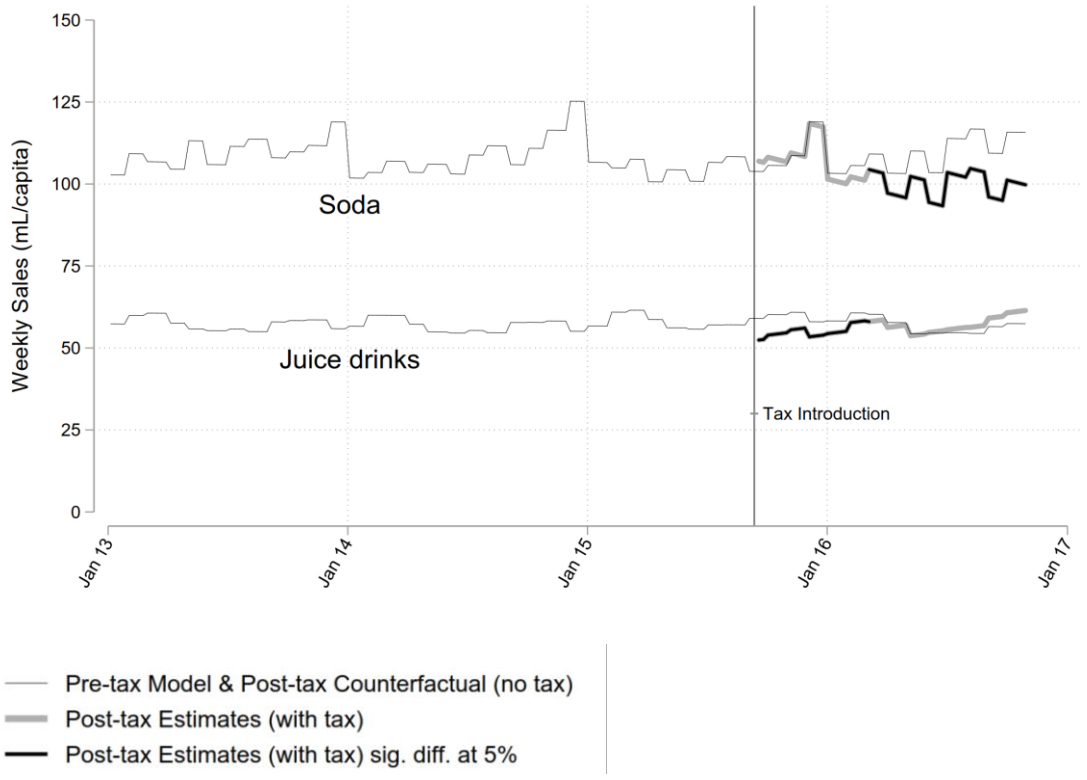
advertisements may have influenced or re-enforced existing views of juice drinks, given the parallels between the advertising messages and participant reflections.

7.4.9 Did consumers buy fewer SSBs? (5a)

Sales of sodas decreased in the post-tax period, as shown in Figure 24. On average, sales changed by -5.0 mL/capita/week [95% CI -4.2 to -5.7] or -4.6% [95% CI -3.9 to -5.3] compared to the estimated counterfactual. By the end of the period, soda sales were 16.6% lower than expected in the absence of the SSB tax [95% CI 5.8 to 27.4].

Sales of juice drinks decreased immediately following the tax and then increased back to pre-tax levels. On average, juice drink sales changed by -2.1 mL/capita/week [95% CI -1.8 to -2.4] or -3.7% [95% CI -3.1 to -4.2] compared to the estimated counterfactual. By the end of the period, juice drink sales were 5.3% higher than expected in the absence of the SSB tax [95% CI -0.9 to 11.6].

Figure 24: Soda and juice drink sales following the introduction of the Barbados sugar-sweetened beverage (SSB) tax, 2013-2016

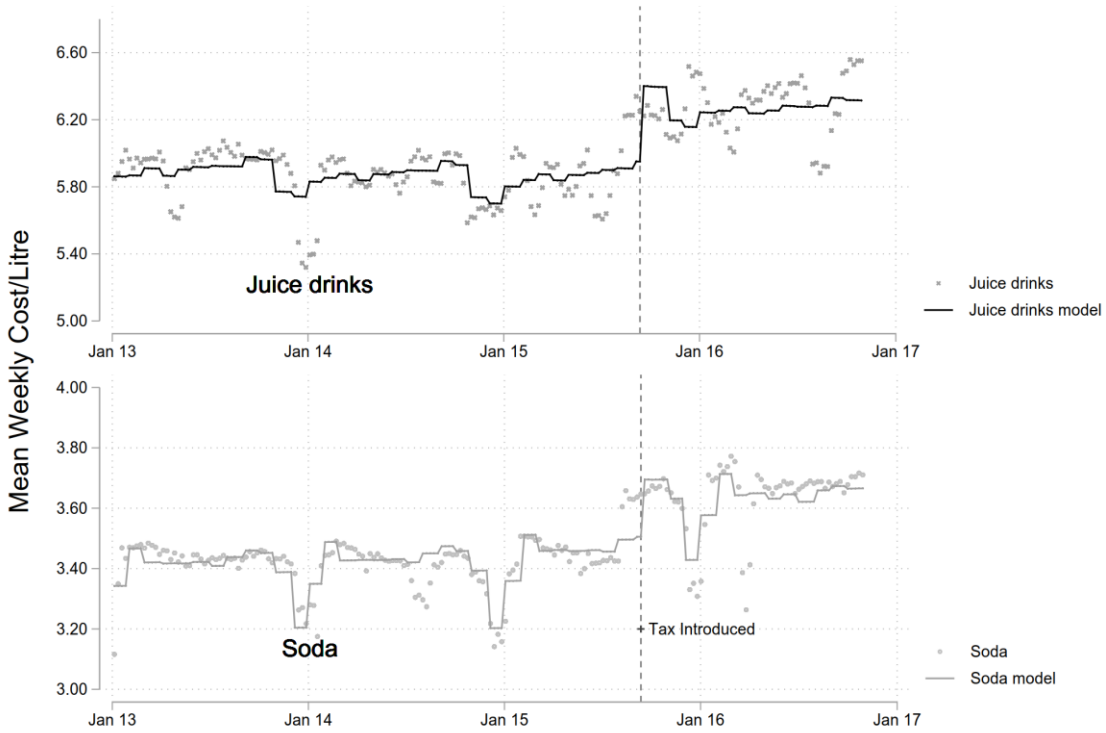


7.4.10 Do changes in price explain changes in SSB sales? (5b)

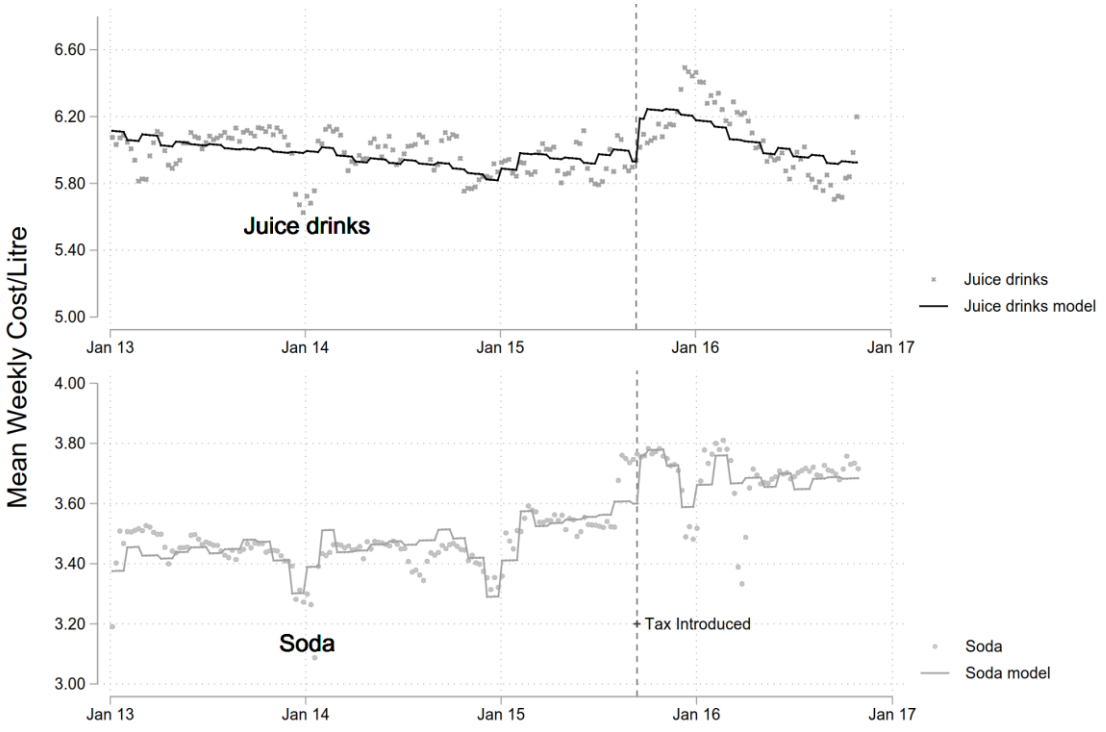
The mean consumption-weighted cost per litre increased by 5.4% [95% CI 5.3 to 5.5] for sodas and increased by 7.6% [95% CI 7.4 to 7.8] for juice drinks (see Figure 25, Panel A and Chapter 7: Appendix Text 2 and Appendix Table 1). As a sensitivity analysis, we re-estimated the model including all products (regardless of missingness over time). The results were consistent for sodas but varied considerably for juice drinks. For juice drinks, the underlying data suggest that the mean cost per litre increased immediately following the tax and then decreased to below pre-tax levels, as summarised in Figure 25 Panel B.

Figure 25: Price of soda and juice drinks following the introduction of the Barbados sugar-sweetened beverage (SSB) tax, 2013-2016, based on products with data in every week of the study period (Panel A) and all products (Panel B)

Panel A:

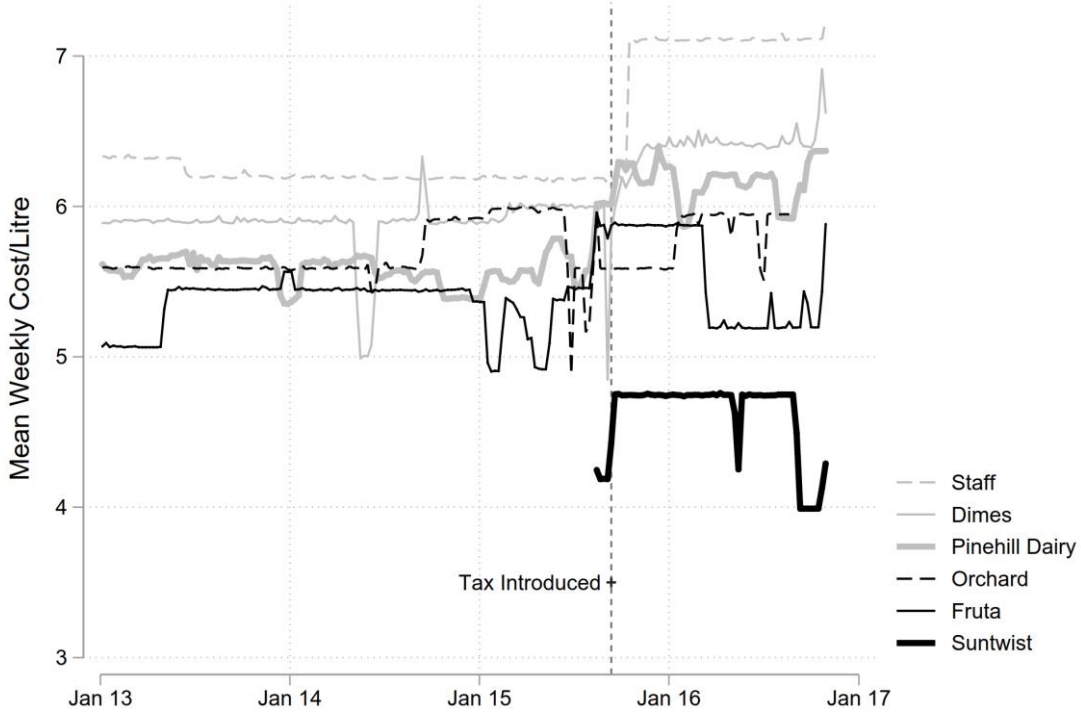


Panel B:



This sensitivity analysis suggests that the inclusion of all products substantially changes estimated post-tax trends in juice drink prices. To further explore this, we summarised mean cost per litre for each of the top-selling juice drink brands (which together comprise 75% of sales by volume) in Figure 26. We demonstrate that 1) a new brand was introduced around the time the tax was implemented and 2) the cost per litre of this new brand was substantially lower than other top-selling brands. Sales of this new brand were substantial and increased over the post-tax period. In addition, another major brand reduced prices considerably during the post-tax period. Taken together, these changes may explain the post-tax trend for juice drinks observed in the sensitivity analysis.

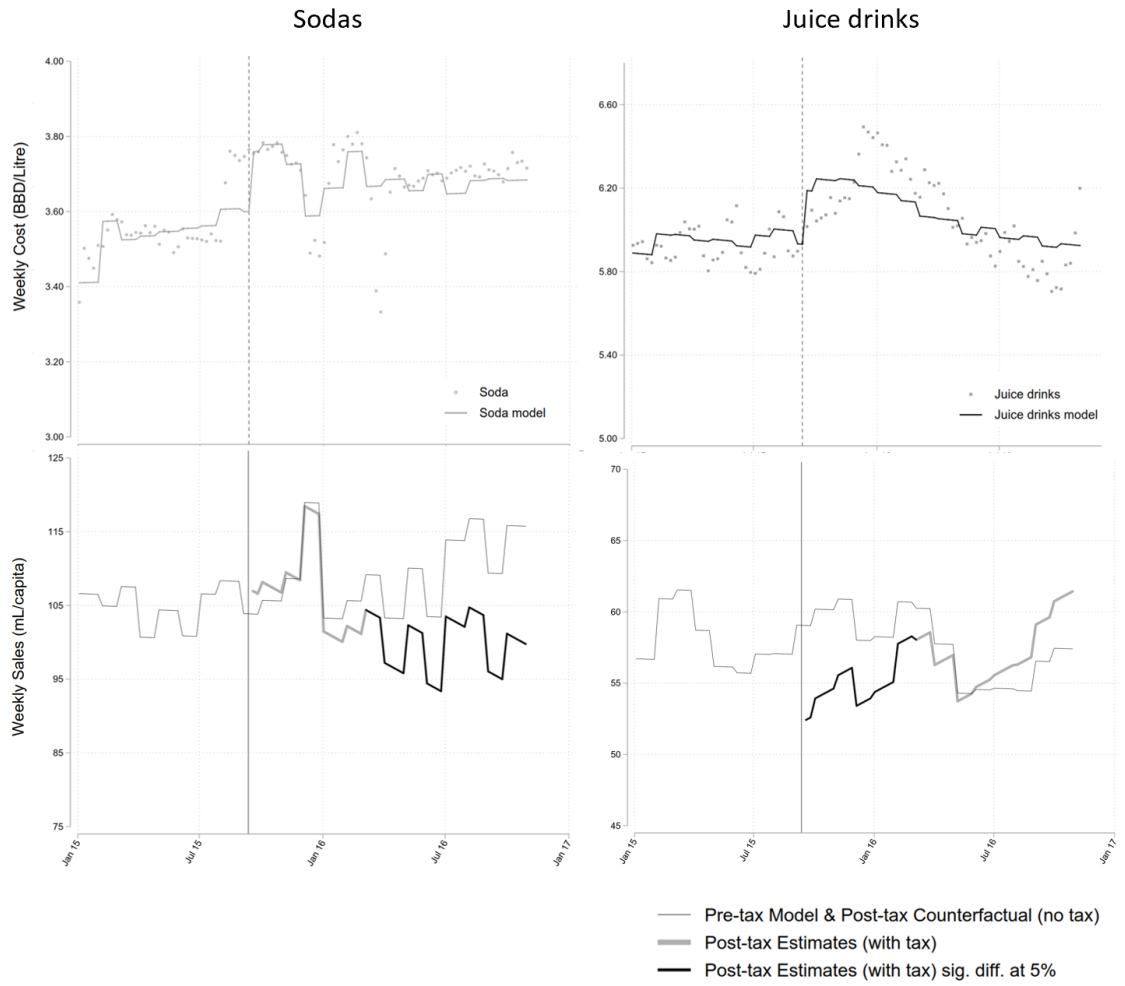
Figure 26: Mean weekly cost per litre, top-selling juice drink brands



Given our interest in consumers' post-tax purchasing patterns (i.e. including potential purchases of newly introduced products), we focus on results from the sensitivity analysis for the purpose of assessing test 5b. For sodas, post-tax trends in sales did not track price change trends closely (see Figure 27). Although there was a sharp increase in soda prices around the time of the tax, sales did not drop immediately. Instead, we observed greater reductions in soda sales over time, although prices remained stable

throughout the post-tax period. This provides weak evidence in favour of the hoop test (5b).

Figure 27: Comparison of cost per litre (Barbados dollars, BBD) and sales trends (mL/capita) for sodas and juice drinks

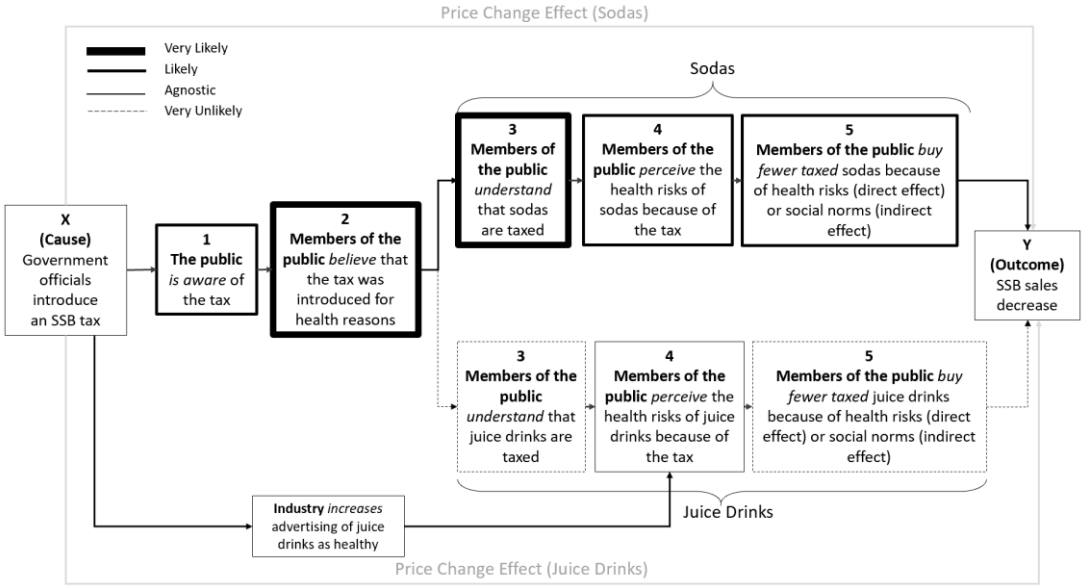


In comparison, post-tax trends in sales of juice drinks do track price change trends closely. Immediately following the tax, prices increased and sales decreased. Subsequently, mean prices reverted back to pre-tax level (and below) and sales increased back to pre-tax levels. This provides evidence against the hoop test (5b), implying that the hypothesis that consumers bought fewer juice drinks because of new health information is unlikely (or suggesting that trends in price change were more important).

7.4.11 Revisiting overall theory

Our interpretation of the evidence and updated posterior beliefs are summarised in Table 14, Chapter 7: Appendix Table 3 and Figure 28.

Figure 28: Updated risk signalling theory based on process tracing [a]



[a] Note that our reported levels of confidence do not correspond to the strength of the effect, but rather to the level of confidence we have in each component of the theory after considering the evidence presented above.

Table 14: Results of empirical tests and implications

Hypotheses (*h*)	**Interpretation (prior → posterior)**
(1) The public is *aware* of the SSB tax	Likely → Likely It seems likely that people were aware of the tax. However there is evidence that there were limited reminders of the tax after announcement, which may have dampened any potential risk signal over time.
(2) Members of the public *believe* that the tax was introduced for health reasons	Agnostic → Very likely It seems very likely that at least some sub-groups believed the tax was introduced for health reasons. However, other sub-groups believed the tax was introduced because of the government's interest in raising revenue, which may have dampened any potential risk signal amongst this sub-group.
(3) Members of the public *understand* which products are taxed	Agnostic → Very likely (for sodas) Agnostic → Very unlikely (for juice drinks)
(4) Members of the public *increase* their perception of the health risks of SSBs because of the tax	Likely → Likely (for sodas) None of this evidence was decisive enough to increase our confidence in whether people increased their perception of sodas as risky following the introduction of the tax. It is also possible that the tax may have re-enforced pre-existing beliefs, and we were not able to rule this out with existing data sources. However, we found no evidence to disconfirm this hypothesis for sodas. Likely → Unlikely (for juice drinks) For juice drinks, the media test was failed, reducing our confidence in this component of the theory. We also found evidence of a potentially unexpected effect: the tax may have incentivised industry to increase advertisements about juice drinks, which may have *reduced* public perception of the health risks of juice drinks.
(5) Members of the public *buy fewer* SSBs based on new information about health risks (direct effect) or social norms (indirect effect)	Agnostic → Agnostic (for sodas) While the evidence is consistent with this hypothesis for sodas, it is not decisive. Agnostic →Very Unlikely The evidence disconfirms this hypothesis for juice drinks.

Note: e: evidence; h: hypothesis that part of a causal mechanism exists

7.5 Discussion

7.5.1 Statement of principal findings

Overall, we found evidence consistent with the existence of a health risk signalling effect following the introduction of the Barbados SSB tax for sodas, but not for juice drinks. We found evidence that maintained or increased our prior confidence in the public's awareness of the tax (1), belief in the health rationale for the tax (2), understanding that the tax applied to sodas (3), perception that sodas and juice drinks were unhealthy (4), and a reduction in sales of sodas (5). However, we found evidence that decreased our prior confidence in public understanding that the tax applied to juice drinks (3) and that the tax was associated with a decrease in sales of juice drinks (5).

In addition, we found evidence to suggest that the introduction of the Barbados SSB tax may have incentivised companies to increase advertising around juice drinks as healthy, either re-enforcing existing confusion or counteracting any signalling effect around juice drinks. We also found evidence to suggest that companies may have introduced low-cost SSBs in response to the tax, potentially undermining some of the price change effect of the tax.

7.5.2 Strengths and limitations

7.5.2.1 Related to data sources

This study faced several limitations related to data availability. First, given the short timeframe between the announcement of the tax and implementation (four months), no baseline data on perceptions of different SSBs were collected. Instead, we relied on interview data collected 20-25 months after the implementation of the tax, limiting our ability to assess whether perceptions changed over time.

Second, as with other studies that rely on self-reported data, the interviews that we re-analyzed may have been subject to social desirability bias. We identified the tests which may have been most influenced by a social desirability bias (1a, 4a) and interpreted the results of these tests conservatively. However, the empirical tests with the most probative value (2a, 3a, 4b) made use of spontaneously reported descriptions, which may be less likely to be biased.

Third, we were not able to access data on the viewership of CBC Evening News programming. However, many participants spontaneously identified CBC Evening News as a source of information about the tax (1a), increasing our confidence in using it as a proxy for news media coverage more broadly. Fourth, participants did not always explicitly refer to *sugar-sweetened* juice in comparison to *no-added sugar* juice. However, given context clues throughout interviews, it is likely that most references were to sugar-sweetened juice drinks. Fifth, we did not intend to assess industry responses to the introduction of the Barbados SSB tax, and did not pre-specify related theory or empirical tests. Our assessment of the effects of the tax on advertising are limited to the effects on televised advertising during local evening news programming. Finally, as summarised previously, our assessment of price and sale trends faced a variety of strengths and limitations (see Sections 4.7.2).

7.5.2.2 Related to process tracing as a method

There were several strengths and limitations related to our use of process tracing. First, using theory-testing process tracing led to novel insights around SSB taxation. Second, using process tracing encouraged us to identify and use relevant mid-range theory,[201] which allowed us to explore additional levels of nuance. Third, process tracing provided a transparent and structured framework within which to pre-specify what we would expect to find and critically assess the limitations of each piece of potential evidence. Fourth, process tracing allowed for inductive insights to be incorporated as new, hypothesised components of theory.

At the same time, using process tracing was very demanding in terms of time, data requirements, and methodological skills required. It was difficult to identify appropriate smoking gun or doubly decisive tests and we frequently relied on hoop tests. As a result, we were able to make stronger claims about eliminating components of the theory (i.e. through failed hoop tests) than we were about confirming components of the theory (i.e. through passed hoop tests), and our confidence in any causal chain can only be as a strong as the weakest link. This is often a limitation of theory testing more generally, and is perhaps also a reflection on the challenges inherent in evaluating complex policy interventions.

7.5.3 In relation to other studies

7.5.3.1 Around SSB taxation and signalling mechanisms

Several other studies have assessed various components of a signalling mechanism following SSB taxation, including awareness of SSB taxation (1) and change in purchases due to new information (5).[69,116,213] In terms of awareness of taxation, at least two evaluations of the Mexico SSB tax explored whether people were aware of the tax.[69,214] One study found that 65.2% of adults reported being aware of the tax, and further found that adults who knew about the tax were significantly more likely to report consuming fewer SSBs.[69] However, as the study authors acknowledged, people who were aware of the tax may have been more likely to report reduced consumption due to a social desirability bias. Another study amongst adolescents found that few participants were aware of the SSB tax,[214] demonstrating that awareness may vary considerably by age. We were not able to assess awareness amongst adolescents in this study, but if a similar pattern exists in Barbados this would reduce any potential signalling effect amongst younger age groups.

Other studies have either 1) partially attributed changes in purchases to new information or 2) demonstrated that price change alone does not explain observed trends in purchases.[116,215] For example, in a sub-national SSB tax evaluation in Catalonia, Spain, participants were asked if they had changed their SSB consumption following the introduction of a tax and whether "the reasons for the change were connected with the increase in the price of SSBs, enhanced awareness of their health effects, or some other reasons."[215] At least some participants (22%) reported "enhanced awareness of their health effects" as the primary reason for having changed their SSB consumption.[215] However, these results may have been influenced by the study design (i.e. a closed, single-response question, rather than an open-ended or multiple-response question) or social desirability bias. In comparison to this study, we assessed several nuanced intermediary steps (e.g. were people aware of which products were taxed) and used sales data instead of self-reported data to assess whether purchases changed following tax introduction.

An evaluation of the SSB tax in France (which targeted both SSBs and ASBs) demonstrated that purchases of SSBs decreased even though prices did not change (e.g. the tax was not passed on to consumers).[116] At the same time, purchases of ASBs

increased despite tax-driven price increases.[116] The authors suggest that this discrepancy is evidence of a signalling effect.[116] They relied on a similar test to the one we used (5b), but were able to draw stronger conclusions than we were (i.e. having two failed hoop tests allowed them to draw stronger inferences). Overall, while some studies have assessed various components of the theory we considered here, we are not aware of any studies which have assessed these components collectively.

7.5.3.2 In relation to the expressive function of theory and other types of excise taxation

In addition to studies which considered SSB taxation in particular, other studies have assessed the signalling effect of other types of excise taxation.[213,216] For example, Rees-Jones and Rozema used McAdams' theory to assess cigarette taxation in the US. They defined expressive effects broadly to include all non-price changes that may coincide with a tax, focusing on changes in 1) place-based legal restriction on smoking, 2) media coverage of smoking, 3) anti-smoking information campaigns, and 4) tobacco lobbying efforts. They hypothesised that these factors change in conjunction with the introduction of a cigarette tax, potentially confounding subsequent evaluation efforts if not taken into account.[216] Ree-Jones and Rozema reviewed data across US states and confirmed empirically that 1) these four factors changed concurrently with the introduction of cigarette taxes, and 2) omitting these factors confounded the relationship between cigarette taxation and demand, exaggerating the impact of taxation alone.[216] They found that place-based legal restrictions were the most important non-price factor in explaining changes in cigarette demand. However, a place-based legal restriction can more accurately be thought of as a separate law, rather than as an expressive component of taxation legislation itself. In comparison to our study, their analysis is based on a broader interpretation of the expressive function of law theory.

7.5.3.3 In relation to process tracing in public health

Although examples of applied process tracing remain rare,[137,217,218] especially within public health settings,[219,220] there are a few published examples. For example, Bamanyaki and Holvoet used process tracing to assess gender-responsive budgeting interventions and their impact on maternal health service delivery in rural Uganda.[220] They used a theory-based evaluation approach to develop initial programme theory and

then applied process tracing to test two parts of the theory, clearly specifying prior beliefs and test types, and updating their confidence in various aspects of the causal theory. As another example, te Lintelo et al. used process tracing to evaluate the impact of the Hunger and Nutrition Commitment Index (HANCI) on international commitments around hunger and nutrition in Bangladesh, Nepal, Malawi and Zambia.[219] They specified test types and assessed a variety of evidence across their four sites, although they did not clearly specify priors or updated beliefs. Our study was more closely aligned with Bamanyaki and Holvoet's application of process tracing. In addition, both studies relied on interview and documentary data (e.g. meeting reports, financial documents, etc.), while we integrated quantitative analysis as well.

7.5.4 Meaning of the study: possible mechanisms and implications for policymakers

7.5.4.1 SSB taxation

We found suggestive evidence that there was a signalling effect around sodas, but no clear signalling effect around juice drinks. This may have been in part because 1) juice drinks were not understood to be taxed and 2) advertising messages (introduced after the tax) emphasised the healthiness of juice drinks.

There are several broader implications from this. First, the ways in which consumers interpret a tax (in particular, which products they understand it is applied to) may have important implications for the effectiveness of an SSB tax. If this is the case, policymakers, journalists and health advocates need to be clearer about what a "sugar-sweetened beverage" is, with a focus on products that are currently perceived as healthy (e.g. juice drinks).

Second, introducing or enhancing marketing restrictions may amplify the effect of the tax by reducing counter-signalling effects led by industry. Finally, other co-interventions, such as front-of-package warning labels may help to reduce confusion around what is a healthy beverage and may re-enforce signalling effects when combined with a tax. Policymakers need to be aware that the choice of which products to tax may have a signalling effect and convey more meaning than anticipated to consumers, potentially contributing to confusion about what constitutes a "healthy diet."

7.5.4.2 Expressive Function of Law Theory

In terms of the expressive function of law theory, McAdams suggests that laws have a signalling effect because they convey the aggregated opinions of a legislative body.[201] For McAdams, it is this *aggregation* which gives authority to legislative signals. However, we demonstrated the existence of a legislative signal following the introduction of the Barbados SSB tax. The Barbados SSB tax was not the product of a legislative body (it was introduced by the Minister of Finance during a budget speech),[127] and yet it can be seen as having produced a legislative signal. Thus, we suggest that it may be useful to relax McAdams' assumption that risk signals are produced through legislative aggregation of information and instead focus on how the public perceives government action more broadly.

7.5.4.3 Process Tracing

From a methodological perspective, process tracing may be useful when research questions involve 1) testing a theory, rather than assessing the strength of an association, and 2) when the object of study is a large-scale complex intervention, rather than an individual or household-based intervention. While process tracing guidance centers around developing a linear causal pathway, we suggest that PT could also be used to test components of a more complex non-linear theory. However, the time and effort required increases with every additional component of theory included. We suggest that PT may be most valuable, from a public health perspective, when it is used to test causal mechanisms which are 1) less well understood, and 2) may be readily intervened upon (e.g. policy-related mechanisms). Finally, while process tracing is not intended to produce generalisable conclusions,[207] we suggest that the updated theory that process tracing produces may be *analytically* generalisable[221] and can be usefully tested in other settings.

7.5.5 Unanswered questions and future research

In the future, it would be useful to assess the extent to which various SSB taxes have operated through a signalling effect and evaluate the impact of variation in signalling strength on changes in SSB sales or consumption. Variation in signalling may be due to how a tax is introduced, media coverage of a tax, co-interventions introduced alongside a tax, industry reactions, etc. As with all observational evaluations, care should be taken

to address sources of potential confounding. It would also be useful to systematically assess the extent to which the introduction of other SSB taxes was associated with changes in advertising of SSBs (both in terms of frequency and nature of messaging). Finally, future research around signalling effects could investigate whether there is evidence of variation by sub-groups, which may have an impact on the distributional consequences of SSB taxation.

7.6 Conclusions

We demonstrated that the available evidence is consistent with a health risk signalling effect for sodas following the introduction of the Barbados SSB tax, but not for juice drinks. We found that consumers were 1) not aware that the tax was applied to juice drinks and 2) unclear about the health risks associated with juice drinks. We found suggestive evidence that some companies may have increased advertising around the healthiness of juice drinks following the introduction of the tax, which may have re-enforced or increased this confusion around juice drinks. We suggest that introducing SSB taxes along with related co-interventions (e.g. front-of-package warning labels, marketing restrictions) may amplify any potential signalling effects by clarifying the health risks associated with specific SSBs.

We build on the expressive function of law theory to describe how a signalling effect may operate following the introduction of an SSB tax and present a refined version of this theory which may be useful for evaluations of SSB taxes in other settings. Finally, we found that applying theory-testing process tracing was a useful approach, with potential applications across an increased range of public health policy evaluations.

7.7 Contributions

I designed the study alongside Jean Adams and Tarra Penney. I identified the methodology and sought training from a leading process tracing methodologist (Andrew Bennet). I contributed to the design of a semi-structured interview guide as part of a public acceptability study, and re-analysed the data using Nvivo 12. I assessed the feasibility of accessing different types of news media data (e.g. newspaper articles, news television transcripts, etc.) and systematically collected and curated media data from CBC (also analysed using Nvivo 12). I re-analysed electronic point of sale grocery store

data, building on previous analyses (Chapter 5). I conducted all analyses, interpreted the results and wrote the manuscript draft. Madhuvanti Murphy reviewed all qualitative data, conducted quality checks on a subset of transcripts and media files and suggested revisions to the coding frame. Jean Adams, Tarra Penney, Nigel Unwin and Madhuvanti Murphy reviewed multiple versions of this manuscript and provided feedback throughout.

I gratefully acknowledge contribution to the study design and data collection conducted by Ashley Foster-Estwick on the public acceptability study, methodological discussion with Tarra Penney and Dolly Theis, as well as the guidance of the broader Barbados SSB tax Evaluation Steering Group.

7.8 Appendix to Chapter 7

7.8.1 Appendix Text 1: Search strategy for news media data

Search criteria were identified after reviewing the original SSB tax legislation, which describes SSBs as "carbonated soft drinks, juice drinks, sports drinks, fruit juices."[127] We aimed to include a wide range of SSBs, and final search criteria consisted of ((beverage* or drink*) and (sugar* OR sweet* or soft)) OR soda* OR juic* OR ("sport* drink*") (136 transcripts, 598 mentions). We developed initial codes based on the process tracing tests and developed additional codes as necessary to reflect emergent themes.

7.8.2 Appendix Text 2: Price change ITS

I revisited the price change analysis from Chapter 4 and use a longer time series to assess changes in price change in more detail, with a focus on 1) disaggregating price changes for soda and juice drinks, and 2) assessing the impact of including and excluding products that were discontinued or introduced over the study period.

7.8.2.1 Main analysis

First, I conducted a simple ITS analysis, using all products with non-missing data over the period from January 2013 to October 2016, separately for sodas and juice drinks. I anticipated that prices would change around the time of the tax introduction and then level off, so I pre-specified a step-change only ITS model (i.e. without a post-tax trend effect for price change), following ITS best practice.[212]

To specify the dependent variable, I calculated the consumption-weighted mean weekly log-transformed cost per litre separately for sodas and juice drinks. I use the log-transformed cost per litre since the Barbados SSB tax is an ad valorem tax and I was primarily interested in the percent change in price following the introduction of the tax, rather than the absolute price change. The cost per litre was consumption-weighted to prevent products which are rarely purchased from skewing the analysis. I used the model described in Equation 1:

Equation 1: Price Interrupted Time Series Model

$$\boldsymbol{Consumption\ weighted\ mean\ LN(Cost\ per\ liter)_{wy} \sim \beta_{1-11} M_m + \beta_{12} Trend_{wy} + \beta_{13} Tax_{wy} + \beta_{14} CPI_{my} + \varepsilon_{wy}}$$

where *M* corresponds to monthly indicators to take into account seasonality, *Trend* corresponds to the overall linear trend in cost per litre over the whole period, *Tax* corresponds to an indicator for the post-tax period and *CPI* corresponds to the consumer price index (to account for inflation). The coefficient on *Tax* is the coefficient of interest, and 100*(exp(β_{13})-1) corresponds to the mean estimated percentage change in prices. I summarised the coefficients from this model for sodas and juice drinks in Chapter 7 Appendix Table 1, and plot the data and model predictions in Figure 25.

Appendix Table 1: Post-tax change (%) in average weekly cost per litre (consumption weighted by sales volume)

SSB Type	**Products (#)**	**Coef.**	**95% CI**	
Soda	54	5.4%	5.3%	5.5%
Juice Drinks	48	7.6%	7.4%	7.8%

*Note: Regression coefficients and 95% CIs were back-transformed to the original scale using (exp(β_{13})-1*100) to estimate mean percentage change.*

7.8.2.2 Sensitivity analysis

As a sensitivity analysis, I re-estimated both models using all available data per week. However, based on visual inspection it was clear that the step-change ITS model was not appropriate for juice drinks (see Figure 25, Panel B).

This highlights the impact that excluding products based on missingness over time may have on price change results. To investigate this further, I focused on the top-selling brands for juice drinks (defined by reviewing the top-selling individual products which collectively made up 75% of total sales by volume). I plotted the mean cost per litre by brand over time to descriptively assess whether any top-selling products were introduced or discontinued during this period.

As demonstrated in Figure 26, at least one major brand was introduced around the same time of the tax introduction. This brand (Suntwist) was 1) popular and 2) low-priced, relative to other juice drinks. The introduction of Suntwist products decreased the average cost per litre faced by consumers, reducing the price impact of the tax on juice drinks. Importantly, Suntwist juice drinks have the same amount of sugar (11.6 g/100mL)[222] as other juice drinks or sodas (i.e. a higher sugar concentration than regular Coca Cola at 10.6 g/100mL). Another brand (Fruta) appears to have reduced prices some

time after the introduction of the tax, further bringing down the average cost per litre faced by consumers. Consideration of these factors is important for future estimates of price change following the introduction of an SSB tax.

7.8.3 Appendix Table 2: A summary of process tracing test types used for causal inference

		SUFFICIENT FOR AFFIRMING CAUSAL INFERENCE	
		No	Yes
NECESSARY FOR AFFIRMING CAUSAL INFERENCE	No	**1. Straw-in-the-Wind**	**3. Smoking-Gun**
		a. Passing: Affirms relevance of hypothesis, but does not confirm it.	**a. Passing:** Confirms hypothesis.
		b. Failing: Hypothesis is not eliminated, but is slightly weakened.	**b. Failing:** Hypothesis is not eliminated, but is somewhat weakened.
		c. Implications for rival hypotheses: **Passing** *slightly* weakens them. **Failing** *slightly* strengthens them.	**c. Implications for rival hypotheses:** **Passing** *substantially* weakens them. **Failing** *somewhat* strengthens them.
	Yes	**2. Hoop**	**4. Doubly Decisive**
		a. Passing: Affirms relevance of hypothesis, but does not confirm it.	**a. Passing:** Confirms hypothesis and eliminates others.
		b. Failing: Eliminates hypothesis.	**b. Failing:** Eliminates hypothesis.
		c. Implications for rival hypotheses: **Passing** *somewhat* weakens them. **Failing** *somewhat* strengthens them.	**c. Implications for rival hypotheses:** **Passing** *eliminates* them. **Failing** *substantially* strengthens.

Source: Adapted from Bennett (2010, 210), who builds on categories formulated by Van Evera (1997, 31–32).

Note: Reproduced from Collier et al.[223]

7.8.4 Appendix Table 3: Empirical results compared to hypotheses, predictions and test type

Hypotheses (*h*)	**Part**	**Means of Verification**	**Predicted Empirical Evidence (*e*)**	**Test Type**	**Empirical Results**
(1) The public is *aware* of the SSB tax	1a	Interviews with members of the public	Participants report being aware of the tax, and are able to describe details (e.g. when/how they heard about the tax, how it was introduced, etc.)	Hoop • Finding *e* does not necessarily confirm *h* given potential bias of participants to report awareness • Not finding *e* disconfirms *h*	Passed (but some unaware of implementation)
	1b	Archived media data (determined by popular news sources reported in interviews with members of the public)	The main news sources that participants report learning about the tax from did in fact cover the tax, providing a plausible mechanism for the public to have learned about the policy	Hoop • Finding *e* does not necessarily confirm *h* given potential bias of participants to report awareness/news consumption • Not finding *e* disconfirms *h* given the news is likely to be the main channel through which people learn about government actions	Passed (but no coverage for a year after announcement)

Hypotheses (*h*)	**Part**	**Means of Verification**	**Predicted Empirical Evidence (*e*)**	**Test Type**	**Empirical Results**
(2) Members of the public *believe* that the tax was introduced for health reasons	2a	Interviews with members of the public	Participants report that the tax was introduced because of the health risks of SSBs	Doubly Decisive • Finding *e* confirms *h*, • Not finding *e* disconfirms *h*	Passed (for some sub-groups)
(3) Members of the public *understand* which products are taxed	3a	Interviews with members of the public	Participants report that the tax is applied on sodas and/or juice drinks	Doubly Decisive • Finding *e* confirms *h*, • Not finding *e* disconfirms *h*	Passed (for sodas) Failed (for juice drinks)
(4) Members of the public	4a	Interviews with members of the public	Participants mention health risks of sodas and/or juice drinks	Hoop • Finding *e* does not necessarily confirm *h* given that participants may be aware of health risks of	Passed (for sodas) Passed (for some sub-groups for juice drinks)

Hypotheses (*h*)	**Part**	**Means of Verification**	**Predicted Empirical Evidence (*e*)**	**Test Type**	**Empirical Results**
increase their perception of the health risks of SSBs because of the tax				sodas and/or juices for reasons unrelated to the tax • Not finding *e* disconfirms *h*	
	4b	Interviews with members of the public	Participants mention increasing their perception of the health risks of sodas and/or juice drinks because of the tax	Smoking Gun • Finding *e* confirms *h*, • Not finding *e* does not necessarily disconfirms *h* given that participants may not report this so directly (or even be consciously aware of it)	Failed (not enough evidence)
	4c	Archived media data (determined by popular news sources reported in interviews with members of the public)	News media coverage of SSBs as unhealthy increases following introduction of the tax	Hoop • Finding *e* does not necessarily confirm *h* given that people may not have seen the news or updated their beliefs based on it • Not finding *e* disconfirms *h*	Passed (for sodas, assuming "sweet drinks" and "soft drinks" are interpreted as sodas) Failed (for juice drinks, assuming "sweet drinks" and "soft drinks" are interpreted as sodas)
(5) Members of the	5a	Electronic point of sale data from a major	Sales of taxed sodas and/or juice drinks decrease over time	Hoop • Finding *e* does not necessarily confirm *h* given that other	Passed (for sodas) Failed (for juice drinks)

Hypotheses (*h*)	**Part**	**Means of Verification**	**Predicted Empirical Evidence (*e*)**	**Test Type**	**Empirical Results**
public *buy fewer* SSBs based on new information about health risks (direct effect) or social norms (indirect effect)		grocery store chain		mechanisms could explain the decrease (e.g. price changes due to the tax) • Not finding *e* disconfirms *h*	
	5b	Electronic point of sale data from a major grocery store chain	Sales of soda/juice drinks *decrease* post-tax, despite *no* tax-driven increases in price OR Sales of soda/juice drinks *do not* decrease post-tax, despite tax-driven *increases* in price	Hoop • Finding *e* does not necessarily confirm *h* given that other mechanisms could explain the decrease/lack of decrease • Not finding *e* disconfirms *h*	Passed (for sodas) Failed (for juice drinks)

Note: e: evidence; h: hypothesis that part of a causal mechanism exist

8 OVERALL DISCUSSION

8.1 Principal findings

In this discussion, I summarise the overall findings, review some of the major strengths and limitations, consider these findings within the context of other evaluations of SSB taxes and broader SSB taxation theory and reflect on evaluation methods for SSB taxation and population-level health interventions more generally. I revisit my original aims, reflect on implications for policymakers in Barbados and elsewhere and on future evaluations. I begin with a brief summary of study results.

8.1.1 Overall

This evaluation had two aims: 1) to assess the Barbados-specific effect of introducing an SSB tax on price and sales, and 2) to contribute to the development of broader SSB taxation theory.

In terms of the first aim, I found that the Barbados SSB tax led to an increase in prices of SSBs and a reduction in SSB sales. Specifically, I estimated an average 5.9% price increase and a 4.3% reduction in SSB sales in a major grocery store chain. Prices of non-SSBs did not increase and sales of non-SSBs increased by an average of 5.2%.

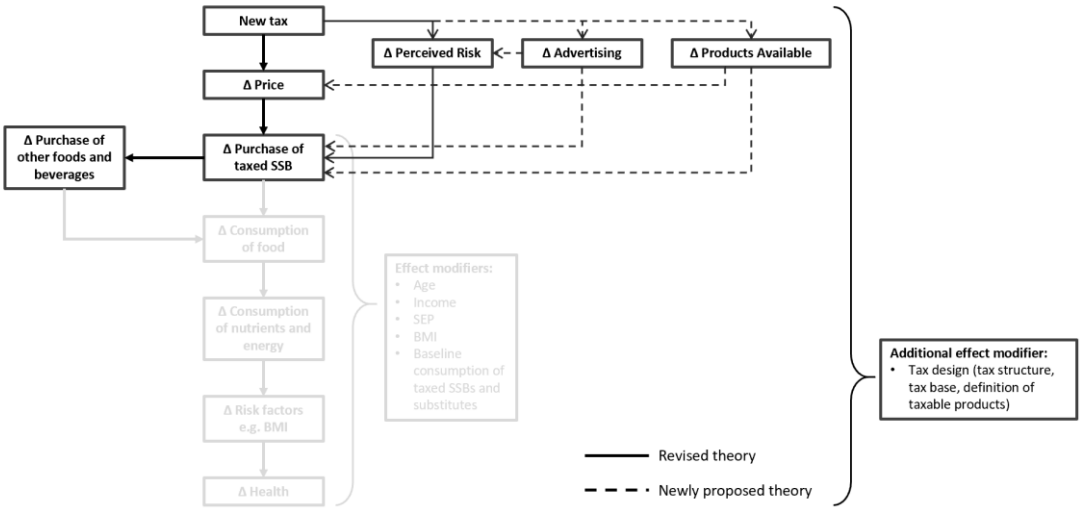
In addition, I found that the definition of taxable products used in Barbados may have incentivised consumers to substitute to 1) untaxed store-bought SSBs (e.g. powdered juices) or untaxed home-prepared SSBs (e.g. sweetened teas/coffees), some of which may be as sugary (or more) than taxed SSBs.

In terms of the second aim, I considered 1) aspects of SSB tax design which may influence effectiveness and 2) risk signalling as a non-price mechanism. With respect to tax design, I found evidence consistent with the hypothesis that the tax structure (e.g. specific vs. ad valorem) may impact effectiveness by incentivizing substitution to lower-cost products (e.g. brand down-switching). I also suggest that the choice of tax base (e.g. producer price vs. retail price) may influence the price change effect of SSB taxes. In addition, I demonstrated that it may be feasible to use pre-existing nutritional survey data to inform the definition of taxable products in ways that are likely to improve the effectiveness of SSB taxation.

With respect to risk signalling, I found evidence consistent with the hypothesis that SSB taxes may operate through a risk signalling mechanism (in addition to price change) and suggest that this mechanism may operate differently for various types of SSBs. Finally, I found evidence that SSB taxes may incentivise companies to respond by 1) increasing advertising around SSBs and 2) introducing new low-cost SSB products.

To summarise these findings, I revisit the original SSB taxation theory (outlined in Figure 2) and update it in Figure 29 to reflect the findings and emergent hypotheses from these empirical analyses. Consistent with the original theory, I found evidence of a change in price and sales. In addition to the original theory, I found evidence a change in perception (through a risk signalling mechanism), and hypothesise that a tax may also lead to an increase in SSB advertising and/or the introduction of new SSBs. I suggest that 1) changes in SSB product availability may change the cost that consumers face, and 2) changes in advertising may influence perceptions of risk, as illustrated in Figure 29.

Figure 29: Revised sugar-sweetened beverage (SSB) taxation theory



Finally, although not an original aim, I reflected on some commonly used SSB tax evaluation methods. I suggest that some approaches (e.g. using pass-through as a summary measure of price change and using panel data to assess price change) may obscure important consequences of SSB taxation. In addition, I suggest that integrating multiple types of data and using a broader theory of SSB taxation to frame research questions will improve the SSB tax evidence base.

8.2 Strengths and limitations of this thesis

8.2.1 Data availability

As illustrated in Chapter 2, there are few "perfect" datasets available to evaluate SSB taxes. Near-ideal datasets may include 1) repeated 24-hour dietary recalls (with multiple before and after tax observations and a sufficiently large sample size to detect potential changes), 2) electronic point of sale data from all retail outlets that sell SSBs, 3) household panel data that include on-the-go purchases or 4) longitudinal data on perceptions of SSB risk. However, I was not able to access these near-ideal datasets and instead made the best use of available data. For example, although I had access to a pre-tax dietary intake survey, the sample size was small (n=334), limiting the statistical power to detect a potential pre/post change. Instead, I use these pre-tax dietary data to assess baseline SSB consumption patterns and to evaluate the feasibility of informing SSB tax design with pre-existing nutritional survey data (Chapter 6). There are no commercial household panel data available in Barbados, but I was able to negotiate access to

electronic point of sale data from one major grocery store chain. To assess the extent to which findings around price change from this grocery store reflected trends across other store types, I conducted a simple sensitivity analysis across nine grocery store chains and other store types. Finally, to test emerging hypotheses around how SSB taxes may operate, I 1) used pre-existing qualitative interviews (conducted as part of a separate public acceptability study) and 2) developed a new database drawing on publicly available televised news transcripts. Given the data I was able to access, I was not able to assess some politically salient questions, for example around 1) distributional effects of SSB taxation, 2) impacts on children/adolescents, or 3) changes in purchases of SSBs in other settings (e.g. schools). However, these data did enable me to evaluate the Barbados-specific effect sizes around price and sales change and to test several aspects of broader SSB taxation theory. In addition, I conducted a brief sensitivity analyses to further assess potential limitations of the data, and found evidence that the patterns in price change I observed in the primary analysis were likely to be representative of price changes across the majority of other grocery store chains and store types.

It was beyond the scope of this evaluation to assess whether the Barbados SSB tax was associated with changes in consumption, nutrient intake, BMI or health outcomes (the grey portion of Figure 29). However, the empirical results around change in price and sales may be used to inform modeling studies around these more distal outcomes in the future.

8.2.2 Internal validity

To assess the internal validity of this evaluation, I considered the potential impact of measurement bias, confounding and random error.[151]

8.2.2.1 Errors and bias in measurement

Bias may occur if measures are influenced systematically (e.g. by a social desirability bias).[151] The electronic point of sales data used in Chapters 4 and 5 were collected using a consistent, automated process and are unlikely to be biased. The dietary survey data used in Chapter 6 relied on 1) the multi-pass 24-hour recall method,[224,225] 2) double data extraction, and 3) Barbados-specific nutrient content data, increasing the study's internal validity. It is likely that most potential sources of bias (underreporting, social

desirability bias, etc.) would result in an underestimation of SSB consumption, suggesting that our estimates may be conservative.

The semi-structured interview transcripts used in Chapter 7 may have been influenced by a social desirability bias. However, the potential for systematically biased answers was carefully considered and informed the choice of each process tracing test type, such that even strong bias in the expected direction would not dramatically change the results. The use of televised new transcripts, which are routinely uploaded and auto-transcribed in a consistent manner, are unlikely to be subject to measurement bias.

8.2.2.2 Confounding

A concern with any natural experimental evaluation is the potential for other factors to confound the association of interest.[151] I used the timing of the introduction of the Barbados SSB tax to assess variation in SSB price and sales. However, the associations I observed may have been impacted had there been a simultaneous change around the time that the Barbados SSB tax was introduced and impacted either of these outcomes (either directly or indirectly). I considered a number of alternative explanations for my study findings (e.g. pre-existing trends, substitution to other store types, unobserved regional factors) but did not find strong evidence of confounding.[131,221,226] The Barbados SSB tax was introduced in relative isolation from other obesity-related programmes or interventions (in comparison to other settings, where SSB taxes have been introduced alongside taxes on energy dense foods, etc.) and is unlikely to be confounded by these types of potential co-interventions.[117]

8.2.2.3 Random error

To limit the extent to which chance may have contributed to study findings, I used a sufficiently long time series and integrated multiple datasets to assess both 1) the strength of associations and 2) plausible causal mechanisms for these associations.[151]

Overall, evaluation studies such as this one are likely to have greater internal validity than modeling studies because they reflect real-world dynamics (e.g. industry and consumer responses).[99]

8.2.3 External validity

To assess the external validity of this evaluation I consider 1) the extent to which these findings can be generalised across Barbados, and 2) the extent to which these findings can be generalised to settings beyond Barbados.

8.2.3.1 Generalisability to the broader Barbados population

As previously discussed in Section 4.7.1, the grocery store chain which provided data for this evaluation may not be representative of other stores across Barbados. Although a similar price differential was observed between SSBs and non-SSBs across the majority of grocery store chains and other store types considered, the findings around price and sales change presented here may not fully reflect changes in other retail environments. In addition, both the nutritional survey data and the interview data focused on adults and it is unclear to what extent these findings may generalise to younger age groups.

8.2.3.2 Generalisability to other settings

A single natural experimental evaluation is not intended to produce results that will be generalisable to other settings. However, by contributing to the development of broader SSB taxation theory, this evaluation aims to contribute to the development of *analytical* generalisability.[221] By developing new theoretical hypotheses (Figure 29), this study has tested and proposed revised theory around SSB taxation which may be relevant in other settings.

8.3 Interpretation within context of SSB taxation literature

My findings are broadly consistent with other evaluations of price and sales change, which have found that the introduction of an SSB tax leads to price increases in SSBs and decreases in SSB sales and an increase in non-SSB sales.

8.3.1 Comparison to other price change evaluations

Previous studies estimated pass-through rates of between 39% and 152%.[106,107] I was unable to estimate the pass-through rate given the Barbados SSB tax structure (an ad valorem tax applied on the producer price) and the data available (no data on producer price or profit margins). However, a comparison of the observed price change (5.9%) and the tax rate (10%) provides the lower bound for the pass-through rate (59%), within the range of pass-through rates observed in other settings. In comparison to evaluations of

specific excise taxes,[109] I found a higher percentage change in price amongst non-carbonated SSBs (e.g. juice drinks), which may be explained by the ad valorem tax structure in Barbados leading to a larger absolute price change amongst more high-cost products. These findings are consistent with the pattern of price change observed in Chile, the only other national evaluation of an ad valorem SSB tax.[110] Consistent with the majority of previous studies, I found no price increase amongst non-SSBs.

8.3.2 Comparison to other sales change evaluations

Previous studies estimated an average 10% reduction in SSBs following the introduction of a 10% ad valorem equivalent (AVE) tax. As discussed previously, it is unclear how to estimate the Barbados AVE (given the Barbados SSB tax structure, assuming an AVE of 10% would represent an upper bound and would likely overestimate the true value). The observed price change (5.9%) may be seen to represent a lower bound, suggesting that the true Barbados AVE is somewhere between 5.9% and 10%. Given the observed reduction in sales of 4.3%, this suggests that the Barbados SSB tax led to a relatively lower change in sales as compared to the average impact of other SSB taxes. It is unclear what may explain this, although the relatively lower price change amongst carbonated SSBs, the introduction of low-cost juice drinks, and/or the increase in SSB advertising may offer partial explanations. In addition, the price elasticity around SSBs may be lower in Barbados than in other settings, and/or SSBs may be relatively more affordable given average incomes.[70]

In comparison to other studies, I assessed potential brand down-switching and found evidence to suggest that consumers shifted towards lower cost SSBs following the introduction of the tax. This type of quality substitution has been hypothesised to reduce the true price elasticity of SSBs,[90] but has not been formally assessed (to my knowledge) in the context of SSB taxation. However, these findings are consistent with other studies, which found that sales of non-SSBs increased suggesting some substitution from SSBs to non-SSBs.

8.4 Interpretation within the context of SSB taxation theory

Theories around how SSB taxes may operate have developed since I first conceptualised this thesis. For example, an evaluation of the UK SSB tax (otherwise known as the UK

Soft Drinks Industry Levy or UK SDIL) produced a complex systems map to illustrate the multiple pathways through which the UK SDIL may influence and be influenced by a range of potential outcomes (see Appendix 7).[227] This model highlights a number of drivers of purchasing of SSBs, including price, tastes and preferences, social norms, household budget and reformulation. In comparison, the theory I present here is more narrowly focused on the tax-related mechanisms that directly influence SSB sales, but is intended to be applicable to a wide range of settings. Similar to the UK SDIL map, I suggest that the introduction of an SSB tax may influence 1) public awareness and attitudes around SSBs and their associated health risks, 2) marketing of SSBs, and 3) product and brand change, and that these mechanisms may influence purchases of SSBs in addition to price. In comparison to the UK SDIL map, I suggest that baseline SSB consumption and total sugar consumption should be determinants of tax design (including the decision to introduce an SSB tax), whereas the UK SDIL systems map focuses on how a particular SSB tax may influence the context-specific system.

A second example of SSB taxation theory is included in Heise et al.'s protocol for a forthcoming systematic review and illustrates how SSB taxation may influence a range of outcomes through price change (see Appendix 8).[54] This causal pathway highlights potential feedback loops between price, supply and demand. In comparison, the theory I present is at a lower level of abstraction (i.e. I highlight "introduction of new products" as a potential mechanism, rather than the broader concept of "changes in supply"). While Heise et al.'s model includes a number of contextual factors, it does not include baseline SSB consumption as a determinant of taxation effectiveness. However, it does highlight the importance of various aspects of tax structure, including SSB tax definitions, the basis for calculating taxation and rates of taxation.

While the UK SDIL systems map is focused on describing one particular tax structure, both the theory proposed here and the Heise et al.'s theory aim to include aspects of SSB tax design which may influence effectiveness. Although these theories vary in terms of 1) level of abstraction and 2) scope of factors considered, the additional theoretical mechanisms that I propose are broadly consistent with other emerging theories around SSB taxation.

8.5 Reflections on SSB taxation evaluation methods

My attempts to understand the various ways in which the Barbados SSB tax may have operated led me to re-assess some of the standard methods used to evaluate SSB taxes. For example, I found that using estimates of pass-through rates as a summary measure for price change may not be feasible following the introduction of some types of SSB taxes (e.g. ad valorem taxes applied on producer prices). In addition, I found that using balanced panel data to assess price change (as has been done in several other SSB tax evaluations) excludes SSBs that are either discontinued or introduced in response to the introduction of a tax and may bias estimates of post-tax price change. In particular, if low-cost SSBs are introduced in response to a new tax, excluding these products from price change evaluations may overestimate price change.

8.6 Reflections on PHI evaluation methods more generally

My attempts to evaluate the Barbados SSB tax also led me to consider the strengths and limitations of commonly used approaches for population-level health intervention (PHI) evaluation more generally (e.g. the use of ITS analyses followed by meta-analyses of effect sizes across a range of diverse interventions/settings). I found guidance from the Tobacco Control Working Group around policy evaluation particularly useful:

> *The WG [Working Group] concluded that policy evaluation should be conceptualized in a manner analogous to how epidemiologists approach the task of inferring conclusions about the causes of disease (US Department of Health, Education and Welfare, 1964; Hill, 1965). This is a framework that encourages researchers to triangulate all the available evidence to help rule out alternative explanations of observed effects, rather than focus on attempting to draw conclusions only from individual studies or from meta-analyses of studies using the same study design.*[151]

This seems likely to apply in the context of SSB taxation specifically and PHI evaluation in general. I found that using theory-testing process tracing in Chapter 7 helped me to operationalise this guidance by 1) providing a framework within which I could integrate multiple types of evidence and 2) encouraging me to consider and transparently report the assessment of alternative explanations. In retrospect, it may have been helpful to frame the whole Barbados SSB tax evaluation as a process tracing study, embedding the

hypothesis-driven analyses of price change, sales change, etc. within an over-arching process tracing design. This approach would have emphasised the integration of middle range theory in the design of each research question from the outset (i.e. testing rational addiction theory[228] as one explanation for trends in SSB sales, etc.). A similar approach may be valuable for other PHI evaluations as well.

8.7 Revisiting the two goals of natural experimental evaluation: Implications for practice and policy

As discussed previously, the findings from a natural experimental study should "be used to adjust existing policies, or inform future actions around the world..."[133] Here I summarise implications of this study for 1) the Barbados SSB tax specifically, and 2) for SSB taxation more broadly.

8.7.1 Goal 1: Context-specific estimates of effect sizes

When the Government of Barbados introduced the Barbados SSB tax in 2015, there was sufficient evidence to suggest that 1) reducing SSB consumption was a warranted public health goal and 2) SSB taxation was a promising policy option. However, at the time few countries had introduced SSB taxes, empirical evaluations were limited and policy guidance was yet to be developed.[74] This evaluation has demonstrated that the Barbados SSB tax was associated with an increase in prices of SSBs and a modest decrease in SSB sales in one major grocery store chain, providing support for SSB taxation in Barbados and other small island developing states in the region. In addition, this evaluation highlighted that SSB consumption was more than three times higher than the global average, suggesting that targeting SSBs in this was more likely to have an impact on health compared to countries with much lower SSB consumption levels. However, there may be opportunities to amend the Barbados SSB tax to improve its effectiveness (from a health perspective) by 1) changing the tax base (from producer price to VAT-exclusive retail price), 2) expanding the definition of taxable products (i.e. to include tariff codes that correspond to powdered juices and chocolate mixes), 3) considering a specific tax structure, 4) increasing the tax rate and 5) developing co-interventions to target important sources of soft-drink derived free sugars (e.g. home-prepared sweetened tea and coffees) which are not readily addressed through a tax.

8.7.2 Goal 2: Broader SSB taxation theory

This evaluation has also highlighted several criteria which may help to improve the design of future SSB taxes and identified additional mechanisms through which SSB taxes may operate.

First in terms of tax design, I suggest that an assessment of baseline diet (often using pre-existing nutritional survey data) may improve tax design and reduce opportunities for substitution to untaxed high-sugar alternatives. Care should be taken to ensure that the definition of taxable products captures as large a proportion of these sources as possible, and in particular, that products with the highest levels of sugar concentration are taxed. There may be contexts in which this assessment of baseline consumption suggests that introducing an SSB tax is less likely to influence health and other PHI approaches may be more appropriate. For example, in settings in which the majority of SSB intake is from home-prepared sweetened teas and coffee (e.g. Malaysia),[229] the extent to which an SSB tax can contribute to reducing free sugar intake may be limited and other approaches should be prioritised.

Second, I suggest that SSB taxes may operate in part through a risk signalling effect. The likely existence of a risk signalling effect around some but not all SSBs highlights the opportunity to produce a risk signal around a broader range of SSBs by 1) clearly articulating which products are taxed and why (i.e. avoid reducing the public framing of an SSB tax to, for example, a "soda tax"), 2) promoting messages around the health risks of SSBs that are perceived to be healthy, 3) introducing or enforcing marketing restriction to prevent industry from implying that SSBs are healthy, and 4) introducing front-of-package warning labels to clearly associate these products with health risks.

In addition to the aspects of SSB taxation theory that I set out to assess, I developed several other hypotheses. First, I suggest that SSB taxes may have the unintended effect of encouraging industry counter-actions, including 1) increasing advertising around SSBs to decrease the risk signalling effect of the tax (as discussed above), and 2) the introduction new low-cost SSBs to decrease the price-change effect of the tax. While introducing or enforcing marketing restrictions may help address the first point, it is unclear how to address the second. In theory, SSB taxes based on sugar content (as in South Africa) or tiered based on sugar content (as in Chile and the UK) should reduce incentives for the introduction of new low-cost high-sugar SSBs. However, taxes based

on sugar content require additional monitoring and strong tax collections systems, and some countries may not have the capacity to introduce these types of taxes (implying that ad valorem tax structures may continue to be used in some settings).

Second, I found evidence of 1) consumer substitution towards lower-cost SSBs and 2) industry introduction of low-cost SSBs. This is consistent with existing excise taxation theory which suggests that ad valorem taxes incentivise these responses since they vary based on the value of the product, favouring lower-cost products (unlike *specific* excise taxes). Specific taxes, mixed taxes (combinations of specific and ad valorem rates) or minimum tax/price floors may decrease the incentives around low-cost SSBs, and have been used in tobacco taxation. However, much is still unknown about how these tax designs would operate if applied to SSB taxation.

Third, I found evidence that, at least in some stores, prices of SSBs and non-SSBs are not clearly labelled (based on the sensitivity analysis in Section 4.7.1). If price differences between SSBs/non-SSBs are not apparent (because they are not labelled), this may dampen the price change effect of the tax. Governments may introduce or enforce price labelling regulations to address this issue.

Fourth, I suggest that in settings in which an ad valorem excise tax is applied on the producer price, higher tax rates will be required to achieve commensurate increases in retail price. The current WHO recommendation is for taxes to be high enough to produce at least a 20% increase in prices of SSBs,[74] although countries with ad valorem taxes applied on producer price would need to introduce tax rates above 20% to meet this recommendation.

8.8 Implications for future research

8.8.1 Future SSB tax evaluations and evidence syntheses

Additional estimates of context-specific effect sizes will continue to be of interest, especially to relevant governments. However, future SSB tax evaluations and evidence syntheses should also aim to contribute to the development of broader SSB taxation theory by testing specific theory driven hypotheses. I highlight some important areas of remaining uncertainty below.

First, future evaluations should aim to assess the impact that different tax designs (e.g. tax structure, rate, tax base, etc.) may have on price, sales, risk signalling and industry counter-actions by testing specific hypotheses about these aspects of tax design. This would enable the further development of SSB taxation best practices. Second, evaluations should assess changes in total diet, including the demand for potential substitutes, the extent to which SSB taxes target major sources of soft drink-derived free sugar and how taxes influence on-the-go SSB consumption,[203] particularly in settings with high levels of on-the-go SSB consumption (e.g. Mexico).[113] Third, it will be important to consider other contextual measures, such as SSB market structure and size and measures of affordability (e.g. the proportion of GDP/capita needed to purchase a set amount of SSBs in a year). It may be especially important to assess changes in affordability as some countries experience rapid economic growth, with implications for SSB demand. Fourth, it will be important for future SSB taxes to assess distributional effects, and the associated impact these may have on potential health outcomes. Fifth, evaluations should assess SSB taxes along with co-interventions to help inform the optimal combinations of policies.

Finally, it would be useful if future SSB tax evaluations focused on integrating different types of evidence and eliminating alternative explanations around hypothesised causal mechanisms. As described above, there are no perfect data sources and evaluations need to draw on and balance strengths and limitations between multiple datasets to capture a more holistic understanding of the impact of SSB taxation. To enable this, future evaluations may benefit from the inclusion of an interdisciplinary team including expertise in economics, political science, philosophy, sociology, law, epidemiology, etc.[230]

Evaluations which consider the role of context, tax design and multiple causal mechanisms may also enable more complexity-informed evidence syntheses. Given the observed heterogeneity in evaluations,[99] a variety of evidence synthesis methods may be useful (e.g. qualitative comparative analysis, realist synthesis) in addition to traditional approaches (e.g. meta-analysis).[231–233]

8.9 Conclusions

In this evaluation of the Barbados SSB tax, I aimed to assess context-specific price and sales change effects, and to contribute to the development of broader SSB taxation theory. In terms of context-specific estimates, I found that the 10% Barbados SSB tax was associated with a 5.9% price increase and a 4.3% reduction in sales of SSBs at a major grocery store chain. I found no price change for non-SSBs, and an increase in sales of non-SSBs. In addition, I found that baseline SSB consumption levels were high, and that the Barbados SSB tax only addressed around 60% of soft drink-derived free sugars and did not clearly differentiate between high- and low-sugar SSBs. This highlights that the tax design may have incentivised substitution towards untaxed SSBs and in particular, towards higher-sugar untaxed SSBs. Finally, I evaluated the existence of a risk signalling effect for sodas and juice drinks in the context of the Barbados SSB tax and found evidence to suggest that there was a risk signalling effect for sodas but not juice drinks.

In terms of theoretical contributions, I proposed three criteria to improve the design of SSB taxes using pre-existing nutritional survey data. I operationalised the expressive function of law theory in the context of SSB taxation, and suggest this may be an additional mechanism through which SSB taxes operate.

In addition, I found evidence to suggest that the introduction of an SSB tax may encourage industry to respond by increasing advertising around SSBs (diminishing any potential risk signal) and/or introducing new low-cost SSBs (diminishing any potential price effect).

After considering these findings in the context of the broader SSB taxation evidence base, I identify a number of implications for policymakers, civil society organisations and future SSB tax evaluation teams. Finally, I suggest that evaluations of SSB taxes and population-level health interventions in general may benefit from the integration of multiple types of evidence, a focus on eliminating alternative explanations and an emphasis on contributing to theory development.

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10 APPENDICES

APPENDIX 1: SYSTEMATIC REVIEWS USED TO INFORM WORLD HEALTH ORGANISATION (WHO) FREE SUGAR GUIDELINES

Study	Data, Outcome, Methods	Findings	Assessment
Morenga et al. (2013). BMJ. *Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies.*	Studies Included: 30 RCTs and 38 prospective cohort studies Outcome: Weight change (kg). Methods: Systematic review and meta-analysis.	Main effect: Decreased free sugar intake in adult trials (but not trials w/ children) associated with -0.80 kg [95% CI −1.21 to −0.39]. Increased free sugar intake in adult trials associated with 0.75 kg [95% CI 0.30 to 1.19]. Amongst cohort studies, 11 out of 16 (adult) and 15 out of 23 (children) demonstrated a positive association. 12 trials of isoenergetic exchange found no association with weight change.	Sugar reduction trials (especially amongst children) associated with low compliance and low reductions in free sugar amongst treatment groups, undermining exposure. Several studies focused on SSB and juice consumption only rather than free sugar consumption. If SSBs/juices impact weight differently than other free sugars, this may have biased the overall estimate.
Moynihan et al. (2014). Journal of Dental Research. *Effect on Caries of Restricting Sugars Intake: Systematic Review to Inform WHO Guidelines.*	Studies Included: 8 prospective cohort studies (children); 20 population/cross-sectional studies (1 adults/children; 19 children only) Outcomes: Dental caries Method: Systematic review and narrative synthesis.	Main effect: 7 of 8 cohort studies demonstrated a positive association. 18 of 20 population studies suggested a positive association. >10% TEI from sugar was associated with higher dental caries >5% TEI associated with higher dental caries in 3 population studies.	Two studies reported on total sugar intake, although it was unclear what proportion of total sugars were likely to have been from free sugars. All studies of the 5% threshold were conducted in Japan following World War II, with unclear generalisability to other settings.

APPENDIX 2: RECENT SYSTEMATIC REVIEWS AROUND SUGAR-SWEETENED BEVERAGE (SSB) CONSUMPTION AND RISK OF NON-COMMUNICABLE DISEASES (NCDS) AND OBESITY/OVERWEIGHT

Study	Data, Outcome, Methods	Findings	Assessment
Imamura et al. (2015). BMJ. *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.*	Studies Included: 17 prospective cohort studies Outcome: Incident diabetes Methods: Systematic review and meta-analysis.	Main effect: 18% increase in incidence of type 2 diabetes, and a 13% increase after controlling for body weight.	Ascertainment of SSB intake primarily based on FFQs, which may be subject to recall biases, potentially underestimating SSB consumption. Majority of studies were from the US (n=9).
Xi et al. (2015). British Journal of Nutrition. *Sugar-sweetened beverages and risk of hypertension and CVD: a dose–response meta-analysis.*	Studies Included: 17 prospective cohort studies Outcome: Incident hypertension, CHD and stroke Methods: Systematic review and meta-analysis.	Main effect: Relative risk for incident hypertension of 1.08 [95% CI 1.04 to 1.12] for every additional daily serving of SSB intake; Relative risk of 1.17 [95% CI 1.10 to 1.24] for incident CHD;	Ascertainment of SSB intake primarily based on FFQs, which may be subject to recall biases, potentially underestimating SSB consumption. No comparison of models adjusted/unadjusted for BMI, although adjusted models may underestimate the total impact of SSB intake if BMI is on the causal pathway between SSB intake and outcomes.

		Relative risk of 1.06 [95% CI 0.97 to 1.15] for incident stroke.	Majority of studies were from the US (n=11).
Malik et al. (2013). American Journal of Clinical Nutrition. *Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis.*	Studies Included: 15 cohort studies, 5 RCTs (children); 7 cohort studies and 5 RCTs (adults) Outcome: Bodyweight Methods: Systematic review and meta-analysis.	Main effect: Cohort studies of children: 0.07 change in BMI [95% CI 0.01, 0.12] for each additional SSB serving/day consumed. Trials with children: No significant change. Cohort stuies of adults: 1-year weight gain of 0.22 kg [95% CI 0.09 to 0.34] associated with additional 12 oz. SSB serving/day. Trials with adults: Significant increases in body weight with additional serving of SSBs.	Majority of studies were from the US (n=19). Studies which only report estimates adjusted for total energy intake (TEI) may be biased (since TEI may partially mediate the SSB-weight change association). Sugar reduction trials (especially amongst children) produced low compliance and low reported reductions in free sugar amongst treatment groups, undermining exposure. Amongst adult RCTs, most studies used ASBs as controls, which may not be appropriate if ASBs have an independent impact on health.

APPENDIX 3: EVIDENCE BASE AROUND GLOBAL SUGAR-SWEETENED BEVERAGE (SSB) CONSUMPTION LEVELS

Study	Data, Definition, Methods	Findings	Assessment
Singh et al. (2015). PLoS One. *Global, Regional, and National Consumption of Sugar-Sweetened Beverages, Fruit Juices, and Milk: A Systematic Assessment of Beverage Intake in 187 Countries.*	Data: Nationally and sub-nationally representative survey data, household consumption and expenditure surveys, United Nations Food and Agriculture Organisation (FAO) food balance database for country-level estimates of total sugar availability SSB definition: Soft drinks with ≥50 kcal/8 oz. Method: Age-specific hierarchical modeling to generate estimates by age, sex, country, standardising total energy intake to a 2000 kcal/day diet, focused on adult consumption.	Global estimate of 0.58 [95% CI 0.37, 0.90] 8 oz. SSB servings/day. Highest SSB consumption amongst younger age groups and in the Caribbean region.	Survey data only available for 27% of countries, with the majority of surveys from Western Europe and only five from Latin America/Caribbean. Total sugar was used as a proxy for SSB consumption in FAO database,[234] although the relationships between total sugar and SSB consumption may vary substaintially between countries. FAO food availability data may miss SSBs sold through informal markets, which may be especially important sources for SSBs in many low/middle-income countries.[235] Standardising total energy intake may not be an appropriate approach if SSB intake is associated with increased TEI.[236]
Yang et al. (2017). American Journal of Pubic Health. *Consumption of Carbonated Soft Drinks Among Young*	Data: Global School-based Student Health Surveys (2009 to 2013). SSB definition: Number of reported daily instances of soda consumption in the past 30 days.	Adolescents aged 12 to 15 years reported consuming sodas 1.39 times per day.	Unclear how closely *number* of instances of consumption correlates with total volume consumed (no data on volume). Participants who respond “less than 1 time per day” (and not “I did not drink carbonated soft drinks during the past

Study	Data, Definition, Methods	Findings	Assessment
Adolescents Aged 12 to 15 Years in 53 Low-and Middle-Income Countries.	Method: Meta-analysis used to estimated pooled summay measures by region and overall.	Highest consumption in Central/South America.	30 days") were assumed to have consumed soda every other day. No data on non-carbonated SSBs.

APPENDIX 4: ESTIMATES OF DISEASE BURDEN ATTRIBUTABLE TO SUGAR-SWEETENED BEVERAGES (SSBS) WORLDWIDE

Study	Data, Definition, Methods	Findings	Assessment
Singh et al. (2015). Circulation. *Estimated Global, Regional, and National Disease Burdens Related to Sugar-Sweetened Beverage Consumption in 2010.*	Data: GBD 2010 estimates of cause-specific mortality and disability, estimates of the associations between SSB intake and body weight and diabetes from systematic reviews of prospective cohort studies, SSB consumption from Singh et al. 2015. PloS One. SSB definition: Soft drinks with ≥50kcal/8 oz. Methods: Estimated cause-specific population attributable fractions for SSB consumption, multiplied by cause-specific morbidity and mortality.	184,000 deaths globally in 2010 [95% CI 161,000 to 208,000] Majority of deaths due to diabetes (72.3%). 8.5 million DALYs (0.7% of total DALYs worldwide).	Limitations around assessing SSB consumption may bias estimates. Data on high SSB intake only covered 27% of 195 countries considered. Considered BMI-mediated effects.
Afshin et al. (2019). The Lancet. *Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017.*	Data: Global Burden of Disease (GBD) 2017 estimates of cause-specific mortality and disability, estimates of the associations between SSB intake and body weight and diabetes from systematic reviews of prospective cohort studies, SSB consumption data updated. SSB definition: Soft drinks with ≥50kcal/8 oz. Methods: Estimated cause-specific population attributable fractions for 15 dietary risks, multiplied by cause-specific morbidity and mortality.	137,000 deaths globally in 2017 (95% variance estimates not available). Majority of deaths due to cardiovascular disease (85%). 4.5 million DALYs.	Limitations around assessing SSB consumption may bias estimates. SSB consumption estimated to be 49 g/day (lower than previous estimates). Data on high SSB intake only covered 36.9% of 195 countries considered. Drew on estimates of relative risk from studies adjusted for TEI, which may be inappropriate as calories from SSBs may be additional rather than compensatory.[236]

APPENDIX 5: SUMMARY OF ACADEMIC OUTPUTS (PUBLICATIONS, PRESENTATIONS AND AWARDS)

Peer review publications

Alvarado M, Kostova D, Suhrcke M, Hambleton I, Hassell T, Samuels TA, Adams J, Unwin N. Trends in beverage prices following the introduction of a tax on sugar-sweetened beverages in Barbados. Prev Med. 2017 Dec;105S:S23–5.

Alvarado M, Unwin N, Sharp SJ, Hambleton I, Murphy MM, Samuels TA, Suhrcke M, Adams J. Assessing the impact of the Barbados sugar-sweetened beverage tax on beverage sales: an observational study. Int J Behav Nutr Phys Act. 2019 Jan 30;16(1):13.

Foster N, Thow AM, Unwin N, Alvarado M, Samuels TA. Regulatory measures to fight obesity in Small Island Developing States of the Caribbean and Pacific, 2015 – 2017. Rev Panam Salud Pública. 2018;42:1–7.

Conference abstracts and presentations

Alvarado, M, Unwin, N, Adams, J. (2020). Assessing the impact of the Barbados sugar-sweetened beverage tax: A mixed method evaluation. Exploring Enhanced Approaches to Increased Taxation on Sugar-sweetened Beverages in Barbados. Heart and Stroke Foundation of Barbados, Barbados. Keynote Speaker.

Alvarado, M, Unwin, N, Adams, J. (2019). Assessing the impact of the Barbados sugar-sweetened beverage tax: A mixed method evaluation. University of the West Indies, Bahamas. Bahamas. Keynote Speaker.

Alvarado, M. (2019). Sugar consumption and its health impact in the Caribbean: A Mandate for Public Polices. University of the West Indies, Bahamas. Bahamas. Keynote Speaker.

Alvarado, M, Unwin, N, Adams, J. (2019). Assessing the impact of the Barbados sugar-sweetened beverage tax: A mixed method evaluation. University of the Witwatersrand. South Africa (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2019). Evaluation of the Barbados SSB tax and Opportunities in the Caribbean. Leveraging the impact of sugary beverage tax

evaluations, Radcliffe Institute for Advanced Study, Harvard University. US (oral presentation).

Alvarado, M, Gill, C. (2018). Evaluation of the Barbados tax on sugar-sweetened beverages. Meeting to develop a standardised tax share indicator for alcoholic and sugar-sweetened beverages, PAHO. US (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2018). Seeking causal explanations in policy evaluation: Applying process tracing to the Barbados sugar-sweetened beverage tax evaluation. Society for Social Medicine & Population Health. Ireland (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2018). Seeking causal explanations in policy evaluation: Applying process tracing to the Barbados sugar-sweetened beverage tax evaluation. International Conference on Public Policy. Canada (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2018). Evaluation of the Barbados tax on sugar-sweetened beverages. Society for Social Medicine & Population Health. UK (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2018). Evaluation of the Barbados tax on sugar-sweetened beverages. Caribbean Public Health Agency. Saint Kitts and Nevis. (oral presentation).

Alvarado, M, Unwin, N, Adams, J. (2017). The Barbados tax on sugar-sweetened beverages: An overview of the evaluation and preliminary results. Caribbean Public Health Agency. Guyana. (oral presentation).

Awards

Sir Henry Wellcome Postdoctoral Fellowship (Four-year funding to assess 'How do sugar-sweetened beverage taxes really work? A complexity-informed synthesis to guide best-practice development')

APPENDIX 6: REPORTING GUIDELINES FOR OBSERVATIONAL NUTRITIONAL EPIDEMIOLOGY STUDIES: STROBE-NUT

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract. (b) Provide in the abstract an informative and balanced summary of what was done and what was found.	**nut-1** State the dietary/nutritional assessment method(s) used in the title, abstract, or keywords.	116
Introduction				
Background rationale	2	Explain the scientific background and rationale for the investigation being reported.		117-118
Objectives	3	State specific objectives, including any pre-specified hypotheses.		119
Methods				
Study design	4	Present key elements of study design early in the paper.		119
Settings	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection.	**nut-5**Describe any characteristics of the study settings that might affect the dietary intake or nutritional status of the participants, if applicable.	119
Participants	6	Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants.	**nut-6** Report particular dietary, physiological or nutritional characteristics that were considered when	119-120

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
			selecting the target population.	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	**nut-7.1**Clearly define foods, food groups, nutrients, or other food components. **nut-7.2** When using dietary patterns or indices, describe the methods to obtain them and their nutritional properties.	120-121
Data sources measurements	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).Describe comparability of assessment methods if there is more than one group.	**nut-8.1** Describe the dietary assessment method(s), e.g., portion size estimation, number of days and items recorded, how it was developed and administered, and how quality was assured. Report if and how supplement intake was assessed. **nut-8.2** Describe and justify food composition data used. Explain the procedure to match food composition with consumption data. Describe the use of conversion factors, if applicable. **nut-8.3** Describe the nutrient requirements,	119-120 119-120 121 NA 120-121 119-120

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
			recommendations, or dietary guidelines and the evaluation approach usedto compare intake with the dietary reference values, if applicable. **nut-8.4** When using nutritional biomarkers, additionally use the STROBE Extension for Molecular Epidemiology (STROBE-ME). Report the type of biomarkers used and their usefulness as dietary exposure markers. **nut-8.5** Describe the assessment of nondietary data (e.g., nutritional status and influencing factors) and timing of the assessment of these variables in relation to dietary assessment. **nut-8.6** Report on the validity of the dietary or nutritional assessment methods and any internal or external validation used in the study, if applicable.	

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
Bias	9	Describe any efforts to address potential sources of bias.	**nut-9** Report how bias in dietary or nutritional assessment was addressed, e.g., misreporting, changes in habits as a result of being measured, or data imputation from other sources	119-120 and 136-138
Study Size	10	Explain how the study size was arrived at.		119-120
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	**nut-11** Explain categorisation of dietary/nutritional data (e.g., use of N-tiles and handling of nonconsumers) and the choice of reference category, if applicable.	120
Statistical Methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine sub-groups and interactions. (c) Explain how missing data were addressed. (d) Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy. (e) Describe any sensitivity analyses.	**nut-12.1** Describe any statistical method used to combine dietary or nutritional data, if applicable. **nut-12.2** Describe and justify the method for energy adjustments, intake modeling, and use of weighting factors, if applicable. **nut-12.3** Report any adjustments for measurement error, i.e,. from a	119-120 119-120, 122

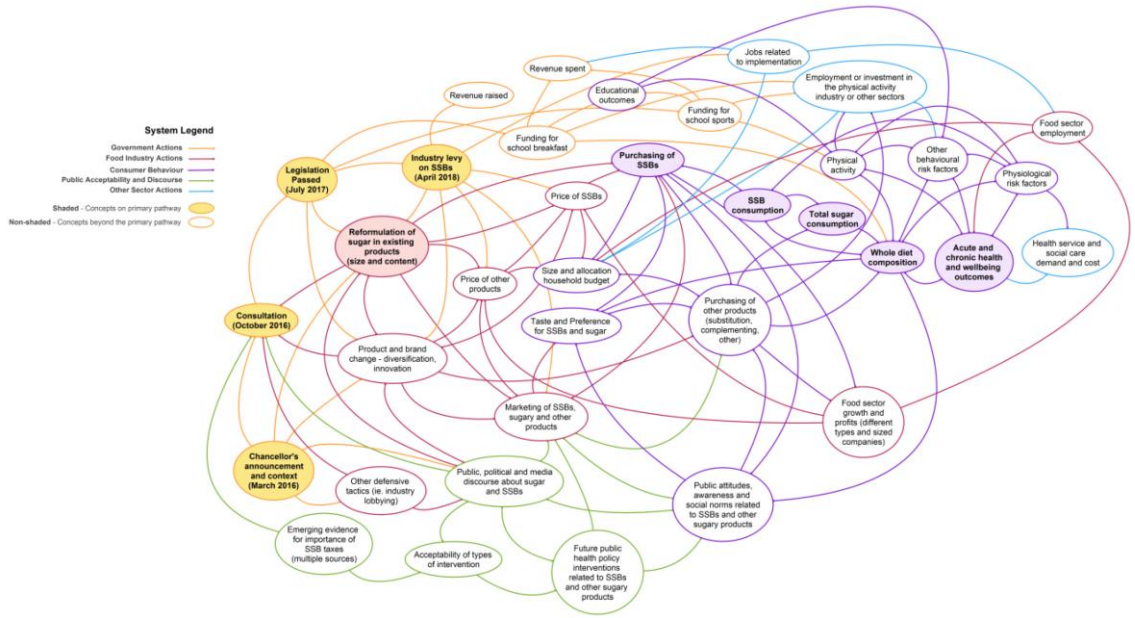
Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
			validity or calibration study.	
Results				
Participants	13	(a) Report the numbers of individuals at each stage of the study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed. (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram.	**nut-13** Report the number of individuals excluded based on missing, incomplete or implausible dietary/nutritional data.	120
Descriptive data	14	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest	**nut-14** Give the distribution of participant characteristics across the exposure variables if applicable. Specify if food consumption of total population or consumers only were used to obtain results.	124
Outcome data	15	Cross-sectional study—Report numbers of outcome events or summary measures.		
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were	**nut-16** Specify if nutrient intakes are reported with or without inclusion of dietary supplement intake, if applicable.	NA

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
		adjusted for and why they were included. (b) Report category boundaries when continuous variables were categorised. (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period.		
Other analyses	17	Report other analyses done—e.g., analyses of sub-groups and interactions and sensitivity analyses.	**nut-17**Report any sensitivity analysis (e.g., exclusion of misreporters or outliers) and data imputation, if applicable.	NA
Discussion				
Key results	18	Summarise key results with reference to study objectives.		122
Limitation	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	**nut-19** Describe the main limitations of the data sources and assessment methods used and implications for the interpretation of the findings.	128
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	**nut-20** Report the nutritional relevance of the findings, given the complexity of diet or nutrition as an exposure.	129
Generalisability	21	Discuss the generalisability (external validity) of the study results.		130
Other information				

Item	Item #	STROBE recommendations	STROBE-nut Extension	Reported on page #
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based.		
Ethics			**nut-22.1**Describe the procedure for consent and study approval from ethics committee(s).	120
Supplementary material			**nut-22.2** Provide data collection tools and data as online material or explain how they can be accessed.	133

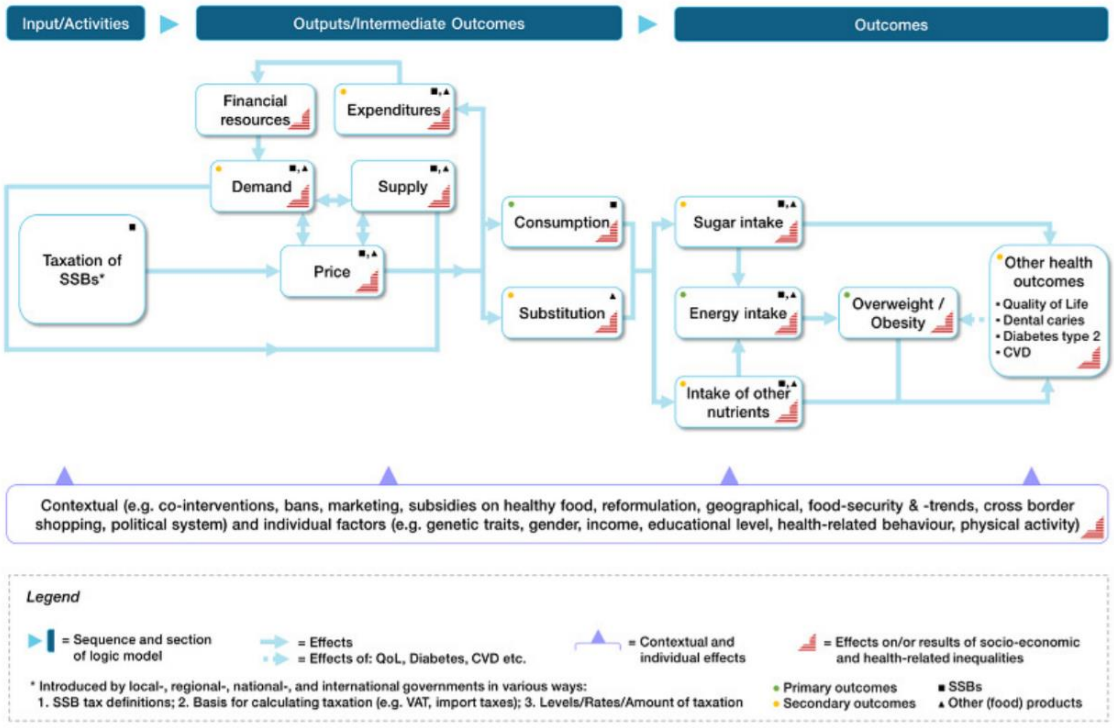
Note: Based on Lachat C et al., 2016.

APPENDIX 7: THE UNITED KINGDOM SOFT DRINKS INDUSTRY LEVY (UK SDIL) SYSTEMS MAP



Note: Reproduced from Penney et al.[227]

APPENDIX 8: A LOGIC/CAUSAL-PATHWAY MODEL OF SUGAR-SWEETENED BEVERAGE (SSB) TAXATION



Note: Reproduced from Heise et al.[54]