On Taxing Sugar-sweetened Beverages as a Public-health Measure

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Sugar, rum, and tobacco are commodities which are nowhere necessaries of life, which are become objects of almost universal consumption, and which are therefore extremely proper subjects of taxation.

Adam Smith, The Wealth of Nations, 1776

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Summary

1. Consumption of sugar-sweetened beverages (SSBs) has risen substantially over the past 25 years. Seventeen percent of the total sugar intake of adults in New Zealand is from non-alcoholic beverages; this is higher among those aged 15-18.
2. SSBs cause dental caries and this is a particular problem among children.
3. Both added-sugar and SSBs are associated with a higher risk of disordered cardiometabolic function (including in adolescents), obesity and weight gain, visceral adiposity, cardiovascular disease, type 2 diabetes, and non-alcoholic fatty-liver disease.
4. There is extensive evidence from econometric studies of price elasticity (PE) of demand – using real-world data over many decades and in many communities – that shows that the own-PE of SSBs is around -1.0. i.e., an increase of, say, 10% in the price of SSBs leads to an approximate 10% reduction in purchase. The recent Public Health England review concluded that "evidence suggests that increasing prices of high sugar foods and non-alcoholic drinks, potentially through taxation, may reduce purchases of these products proportionate to the level of the price increase imposed".
5. Experimental studies show that increases in the price of SSBs can result in: a reduction of consumption of SSBs; a shift to non-SSBs; and a reduction even in non-taxed SSBs. A very recent online shopping experiment – in which participants received the groceries that they purchased – found that SSB taxes are an effective means of altering food purchasing with a 20% rate being sufficient to make a significant impact.
6. Real-world taxation is the most informative of all. For instance, the Finnish tax on confectionery, ice cream, and SSBs showed a continuing decline in consumption of high-sugar products with the imposition of steadily increasing taxes over consecutive years. There are similar data from other countries. A study followed the introduction of an SSB tax in Mexico – involving an approximate 10% increase in price – and reported a steadily increasing mean reduction of 6.1% over 2014: the average urban Mexican purchased about seven fewer 600mL bottles of taxed beverages than expected based on pre-tax trends. Over the following 2 years, purchases of taxed beverages decreased 5.5% in 2014 and 9.7% in 2015 - average 7.6%, whereas untaxed-beverage purchases increased 2.1%. These data confirm that the Mexican taxation policy has maintained its impact on consumption of SSBs over the medium term. The recent Berkeley study showed that a tax of one cent per ounce decreased consumption of SSBs in low-income communities and increased water consumption.
7. Reduction of consumption via a tax will probably be greatest among the households with the lowest disposable income. In New Zealand, Māori and Pacific will benefit strongly.
8. Manufacturers are able to respond in rational ways, for instance, by systematic reformulation of products that attract taxes to bring them below a relevant threshold – resulting, again, in lower sugar consumption.
9. SSB taxes do not cause unemployment.
10. There is substantial evidence from taxation policies in relation to tobacco to show that price increases change behaviour. Indeed, price is central in determining smoking uptake and smoking cessation.

11. Shifts in price are most effective in changing behaviour among young people – both for tobacco and sugar.
12. Whether there is halo effect that arises as a result of a government signal and public discussion about deleterious health effects remains to be clearly established. However, existing data on real-world taxation are consistent with there being a signal separate from the direct impact of the tax itself.
13. There is sufficient evidence to show that any tax has to be sufficiently large to actually motivate change. Twenty percent has been shown to be effective. As with tobacco, steady increases are likely to be of additional benefit.
14. John Gibson (Waikato University) has made the point (as yet unpublished) that price-elasticity-of-demand estimates from household-survey data conflate both quality and quantity choices that an SSB tax forces on a purchaser; this, in turn, would overstate the efficacy of price rises in reducing consumption. There are a number of responses to his argument but the most telling is that this applies only to "added value" taxes (i.e., a % tax on sales price). A tax based on sugar content (the UK solution) or a volumetric tax (e.g., $0.40 tax per liter for all SSBs irrespective of price) results in cheap drinks having a higher % tax and reducing the drive to consume SSBs of lower quality.
15. An SSB tax that results in lower consumption of empty calories – based on the relationship, in both adults and children, between energy balance and obesity and between SSBs and caries, obesity, cardiovascular disease, diabetes, etc. – will, in turn, result in beneficial changes in average BMI, in overweight and obesity, and in the associated burden of morbidity and mortality. Over time, there may be, in New Zealand, 50 deaths "saved" per year, especially deaths due to diabetes and cardiovascular disease and it will save at least $6 million per year in health costs. More immediately, it will raise about $40 million in revenue. Over time, an SSB tax is likely to be cost-saving for the health system, as well as health improving.
16. An SSB tax is only one component of a comprehensive strategy to tackle obesity – including healthy school-food policies, restrictions on marketing to children, increased opportunities for physical activity, safer biking routes, clear policies and information for the public (including social marketing), incentives, controls, and nudges.
17. An SSB tax has the virtue of being an evidence-based action that can anchor and reinforce all other strategies.

Sugar-Sweetened Beverages and the Health of Adults and Children

Consumption of sugar-sweetened beverages (SSBs) has risen substantially over the past 25 years. Seventeen percent of the total sugar intake of adults in New Zealand is from non-alcoholic beverages[1]; among 15-18 year olds, that proportion is 27-29%, whereas in those over 71 years, it is 7–8%[1]. In 5-14 year olds, it is 14%[2]. In the US, of all food types, SSBs are the single largest contributor to total energy intake, accounting for 7% of all energy consumed daily in 1999-2001 compared with 2.8% in 1977-1978[3,4].

There is a clear causal relationship between consumption of SSBs and dental caries[5-7]; this is a substantial problem among children[8], in whom there is a dose-response between SSB consumption and caries[9]. A large randomised controlled trial conducted over 18 months has established that consumption of SSBs leads to weight gain in children[10].

Glucose and fructose occur separately but the major source of sugar in many human diets, sucrose, is one glucose molecule linked to one fructose molecule. After absorption, glucose is widely transported into most tissues, importantly into skeletal muscles, liver, adipose, and brain. In contrast, fructose (whether from sucrose, from fruit, or from fructose-dense sweeteners, as in high-fructose corn syrup) is largely taken up and metabolized in the liver where it induces lipogenesis[11].

In the liver, fructose, uniquely, is phosphorylated immediately by fructokinase. This induces a transient, but critical, decrease in intracellular adenosine triphosphate (ATP) and phosphate in liver cells. This stimulates the activation of AMP deaminase (AMPD) and an enzymatic cascade that terminates in elevated uric acid. Both AMPD and uric acid act to promote hepatic fat accumulation via mitochondrial oxidative stress and this contributes to insulin resistance[12]. High uric acid also raises blood pressure (perhaps via decreases in renal function or activation of the renin–angiotensin system)[13] and leptin levels[13,14]. Insulin resistance, fatty liver and elevated blood pressure are all hallmarks of metabolic syndrome.

Furthermore, there is good evidence that consumption of both added-sugar and SSBs are associated with a higher risk of disordered cardiometabolic function[15-19] (including in adolescents[20-23]), obesity and weight gain[24,25], visceral adiposity[26], cardiovascular disease[17,27], type 2 diabetes[24,28-30], and non-alcoholic fatty-liver disease[31-33]. At least some of this association may be due to high-fructose corn syrup, which is widely used in the USA (but not New Zealand) as a sweetening agent. However, fructose is one half of the sucrose molecule and both more disruptive of cardiometabolic function and under less metabolic regulation than glucose[34,35]. There are data that suggest that, in many ways, fructose behaves metabolically like alcohol[36,37].

Luo and colleagues compared fructose and glucose ingestion in a double-blinded, random-order cross-over study of 24 healthy volunteers Compared with glucose, ingestion of fructose resulted in smaller increases in plasma insulin levels and, using functional magnetic resonance imaging (fMRI), greater brain reactivity to food cues. Further, fructose produced greater hunger and desire for food and a greater willingness to give up long-term monetary rewards to obtain

immediate high-calorie foods. The authors concluded that ingestion of fructose rather than glucose results in greater activation of brain regions involved in attention and reward processing and probably promotes feeding behavior[34].

There is still debate as to whether, in relation to cardiometabolic function, the effect of sugars is direct, indirect or both[14,38,39]. There is little debate, however, on the direction, strength, and consistency of these relationships.

Price Elasticity of Demand

Data relevant to the impact of tax-related price changes on products are found both in the epidemiologic/public health literature and in the economics literature. Price elasticity (PE) of demand is the degree to which consumption changes (either up or down) as a result of changes in price (down or up). Own price elasticity (own-PE) of demand is the impact of price changes on consumption of the product under consideration. Cross price elasticity (cross-PE) of demand is the impact of price changes on plausible substitutes for the product under consideration. Studies of price elasticity of demand do not necessarily ask specifically about the impact of taxes but rather ask a more neutral question about the impact of price variability from any cause. All such studies are useful because those of the impact of fluctuations in the market place provide data on real-world behaviour in the absence of any social/government signals related to possible deleterious consequences of consumption. In contrast, studies of "sin" taxes (e.g., such as we are used to seeing on tobacco and alcohol[40]) and for which there are now real-world data on sugar-sweetened beverages (see below) provide data on the impact of both tax on own-PE as well as signals of such deleterious consequences. There is a possibility that taxation produces a larger effect than market fluctuations because there is a clear message in taxing something because it is unhealthy: a 'halo' effect, where increased taxation is associated with media attention and increased public awareness[41]. (Such taxes are also used, of course, to raise revenue, which may or may not be used to mitigate those deleterious consequences on society and individuals.) Here, we focus particularly on the own-PE of sugar-sweetened beverages (SSBs) but canvass relevant data on PE of other commodities where these cast light on the principal question.

Price Elasticity in the Real World

There have been many studies on the price elasticity of demand for foods in a variety of cultural and geographic settings. A number of meta-analyses have been completed. Among the most useful is that undertaken by Andreyeva et al.[42], which encompassed studies in English from 1938 to September 2007 done in the US and available in the peer-reviewed literature, in government reports, and in the grey literature more generally. The price elasticity (measured as the percentage change in consumption associated with a 1% change in price) ranged from -0.27 (eggs) to -0.81 (food away from home). The most elastic commodities (i.e., those for which purchasing behaviour is most subject to price change) were "food away from home", -0.81; soft drinks, -0.79; juice, -0.76. The most inelastic were eggs, -0.27 and sweets/sugars, - 0.34. See Table 1.

Table 1. Absolute price elasticity of demand for various foods in the US (1938-2007) from a meta-analysis of a total of 160 studies

Food and Beverage Category*	Value of Mean Price Elasticity† Estimate (95% CI)	No. of Estimates
Food away from home	-0.81 (0.56-1.07)	13
Soft drinks	-0.79 (0.33-1.24)	14
Juice	-0.76 (0.55-0.98)	14
Milk	-0.59 (0.40-0.79)	26
Cheese	-0.44 (0.25-0.63)	20
Sweets/sugars	-0.34 (0.14-0.53)	13
Eggs	-0.27 (0.08-0.45)	14

*Includes restaurant meals and fast food

†The price elasticity of demand measures the percentage change in purchased quantity or demand with a 1% change in price.

Adapted from Andreyeva et al. (2010)[42]

Interpreting these findings specifically for SSBs, the authors concluded[42], "Assuming no substitution of soft drinks with other caloric beverages and no change in other factors affecting purchasing behavior, our estimate of the price elasticity of soft drinks [-0.79] suggests that a 10% tax on soft drinks could lead to an 8% to 10% reduction in purchase of these beverages." As can be seen below, the estimates from other meta-analyses are similar and, thus, have similar implications for the impact of shifts in price.

The meta-analysis of Eyles et al.[43] was structured similarly to that of Andreyeva et al.[42] but included studies across the OECD from 1990 to October 2011. The price elasticity of carbonated soft drinks was -0.93.

The meta-analysis of Green et al.[44] encompassed studies from 1990 onwards: 136 studies undertaken in 162 countries. The focus of the study was the impact of rising food prices on countries and individuals at different levels of wealth. Nonetheless, it also informs the discussion here. The greatest impact of rising food prices was seen among poorer countries and among poorer individuals within countries. The absolute price elasticity of demand for a combined variable of sugar-sweetened beverages, sweets, and confectionery was, in low-income countries, 0.74; in middle-income countries, 0.68 and, in high income countries 0.56, paralleling differences in the flexibility of discretionary spending.

The study of Cabrera Escobar[45] involved a meta-analysis of studies from the United States, France, Mexico, and Brazil from 2000 to 2013 and examined the effect of price of sugar-sweetened beverages on their own sales (own-PE) and the effect of the price of SSBs on BMI/overweight/obesity. In addition to own-PE, the meta-analysis reported on the impact on sales of other beverages (cross-PE). The own-PE of SSBs was -1.299 and the cross-PE (i.e., the change in consumption of another product in response to an increase in the price of SSBs) of fruit juice was +0.388; of milk, +0.129; and of diet drinks, -0.423. The 95% confidence limits on the first two estimates of cross-PE included zero, suggesting that there was only weak evidence

for substitution and the negative value for the diet drinks (and 95% confidence limits that excluded zero) means that consumption of these actually fell in parallel with the fall in demand for SSBs.

In a recent systematic review, Thow et al.[46] explored the world literature on food taxes and subsidies from January 2009 to March 2012 – largely econometric modelling studies that used real-world data: on expenditure and consumption from household expenditure surveys; on reported population dietary behaviour; on sales data; on data from longitudinal studies; on studies of taxation; and on survey data regarding preferences rather than observed behaviour. They reported on both the peer-reviewed literature and the grey literature and included 16 studies on sugar-sweetened beverages. All 16 showed that SSB taxes from 5% to 30% resulted in reductions in consumption of between 5% and 48% and demonstrated that the reduction in consumption was proportional to the tax applied. Four of these studies modelled the impact of substitutions for SSBs (i.e., allowed for increase in consumption of other drinks in response to an SSB tax: low-energy drinks, milk, tea, and coffee) and showed that a 5% to 20% tax was associated with a 10% to 48% reduction in energy derived from SSBs in adults and a 5 to 8% reduction among children. Further, three of these four studies showed a reduction in total energy from beverages; the fourth showed a switch to milk in children with no reduction in energy. Six studies that did not investigate substitution showed a reduction in SSBs of 10% to 25% in response to taxes of 10% to 30%. Thow et al.[46] also specifically recapped the data from two longitudinal epidemiologic studies: the US CARDIA study showed that a 10% tax resulted in a 7% decline in consumption[47] and Wang et al. used data from the Harvard Nurses' Health Study and the Coronary Heart Disease Policy Model to estimate that a 1-cent-per-ounce tax would be associated with a 15% reduction in consumption[48].

Powell and colleagues[49] examined the English-language peer-reviewed literature for empirical evidence regarding the impact of restaurant prices – of a variety of foods – on body mass and obesity between 1990 and September 2008. The literature search involved obesity/BMI crossed with price(s)/tax(ation)/subsidy and focused particularly on US data. The authors concluded that small taxes (such as are currently found in the US) are not likely to produce substantial changes in BMI or obesity. However, Powell and Chaloupka's review of the wider literature concluded that "nontrivial pricing interventions may have some measurable effects on Americans' weight outcomes, particularly for children and adolescents, low-SES populations, and those most at risk for overweight."[50]

Experimental Settings

Epstein et al.[51] reviewed experimental studies involving direct price manipulation with increases and subsidies in cafeteria settings and farmers' markets. They concluded that, overall, behaviour can be influenced by price in a direction consistent with the findings described above and noted, specifically, the study of Block et al.[52], which showed that increases in the price of SSBs resulted in a shift to non-SSBs and that there was a reduction even in non-taxed SSBs. For most of the experimental studies, the exact effects that would best inform policy, including effects on reduction of, or substitution for, SSBs were often not established. One intriguing and important observation from the experimental studies is that taxes resulted in reduced energy

intake[53-55] and that subsidies resulted in increased energy intake[53] – again perhaps reflecting an impact on capacity for discretionary spending, even in a simulated setting. There is also evidence that less impulsive people are less influenced by price changes, whereas the more impulsive adjusted their calories to prices; this is a rather surprising finding[54].

A relevant report was recently released by the Centre for Health Economics at the University of York; it described an online shopping experiment in which participants received the groceries that they purchased. What they found was that SSB taxes are an effective means of altering food purchasing with a 20% rate being sufficient to make a significant impact[56].

The most recent experimental approach was a collaborative study between Dutch researchers and Cliona Ni Mhurchu from the University of Auckland[57]; its aim was to examine the effects of a price increase on SSBs on beverage and snack purchases using a randomized controlled design within a three-dimensional web-based supermarket. There were two arms: the experimental condition with a 19% tax on SSBs (to reflect an increase in Dutch VAT from 6% to 19%); and a control condition with regular prices. One hundred and two participants were randomized and purchased groceries on a single occasion. Participants in the experimental arm purchased statistically significantly fewer SSBs than the control group (B = −0.90; 95% CI = −1.70 to −0.10 litres per household per week). There were no effects on purchases of other beverages or snack foods[57].

Taxation in the Real World

In studies undertaken directly in relation to taxation, the Danish food-tax studies stand out. Jensen et al.[58] undertook a panel study in Denmark of 2000 households and showed that the introduced tax on fat produced a 10-15% reduction in consumption of butter, margarine, and oils between January 2008 and July 2012. The Danish confectionery tax showed a fall in demand following the tax imposition. The fall in demand (-11.2%) was greater for confectionery on which there was a tax increase of 8.4% than for chocolate where the tax increase was 0.6% and the consumption decline was 0.4%[59]. Following the abolition of the Danish saturated fat tax, demand did not return to pre-tax levels, suggesting that, at least over the short term, there were some lasting changes in behaviour. Again, the question arises as to whether this is the impact of some wider signal to the community, namely, that a tax on saturated fat means: “this is deleterious for health” or simply inertia because people had adopted new behaviours[41,59].

The imposition of sugar taxes in Hungary[59,60] are also informative. In 2011, Hungary increased taxes on prepackaged sweetened products, SSBs, jams and preserves, flavoured beer with added sugar(!), alcoholic soda drinks, alcoholic beverages, energy drinks, and excessively salty snacks. There were several important consequences:

1) after the tax was imposed, 40% of unhealthy product manufacturers changed the formulation (28% reducing the content of the deleterious ingredient and 12% eliminating it);
2) sales declined by 27% and prices rose by 29%;
3) 7 to 16% of consumers switched to "cheaper often healthier"; 5 to 16% reduced consumption of the taxed product; 5 to 11% changed to another brand or substituted an

"often healthier" choice;
4) changes were sustained in that 59 to 73% of people were consuming less in 2014 than in previous years.

In its first four years, the tax raised more than US$200 million for public health spending. This was equivalent to 1.2% of all health spending in 2013 in Hungary[60].

One other lesson can be derived from the Hungarian experience: among those who stated that awareness of the negative health impact was what influenced their change, energy drinks declined 61%; this decline was 38% among those who said price was the cause of their behaviour change. For sugar sweetened beverages, the comparable estimates were 67% and 27%[60]. This argues that the impact of a tax on price and the signal that the product carries deleterious consequences both motivate change.

The Finnish tax[59] on confectionery, ice cream, and SSBs showed marked effects and is informative. Table 2 (adapted from the ECSIP consortium report[59]) shows the continuing decline in consumption of high-sugar products associated with the imposition of steadily increasing taxes over consecutive years. Note that ice-cream seems to be more inelastic than confectionery and SSBs. Note, also, that smaller taxes have smaller effects, suggesting, again, that the actual price increase is important even in the presence of clear signals about deleterious consequences.

Table 2. Impact of the Finnish taxation policy on consumption of confectionery, ice cream, and sugar-sweetened beverages

	Tax			Consumption		
	2011	2012	2013	2011	2012	2013
Confectionery	+14.8	+6.0	+2.9	-2.6	-1.4	-0.1
Ice cream	+15.7	+4.9	+2.9	-1.6	-0.9	+1.4
SSBs	+7.3	+7.3	+2.7	-0.7	-3.1	-0.9

Adapted from the ECSIP consortium report (2014)[59]

Fletcher et al.[61] undertook a study of the correlation between US state taxes on SSBs and obesity/overweight/BMI. They showed that soft-drink taxes are related to behaviour and weight but that the magnitude is small. An increase of 1% in the tax rate results in a decline of: 0.01% in obesity; 0.02% in overweight; and 0.003 points of BMI. They noted a greater association among lower-income individuals, such that the decline in obesity was 0.08% and in overweight 0.10%. They showed a bigger influence on the behaviour of women, the middle-aged, and older people.

Colchero et al. took a pre-post quasi-experimental approach to the first data available following the introduction of the SSB tax in Mexico[62]. They used difference-in-difference analyses along with fixed-effects models. Their sample represents more than 16 million households (~90-100 million residents). They showed that, for taxed beverages, the absolute and relative differences between the post-tax volume and its counterfactual (based on pre-tax trends) widened over the 12 post-tax months from a reduction in consumption of 11 mL/capita/day (−5.6% relative to

the counterfactual) in June to a reduction of 22 mL/capita/day (−12% relative to the counterfactual) by December 2014. This represents a mean reduction of 6.1% over 2014. During that year, the average urban Mexican purchased 4241 mL (~seven 600 mL bottles) fewer taxed beverages than expected based on pre-tax trends. This was related to a 17% decrease in purchases of non-carbonated sugar-sweetened beverages and a 1.2% decrease in taxed sodas. For untaxed beverages, there was an average increase per person in the purchase of untaxed beverages of 36 mL/capita/day.

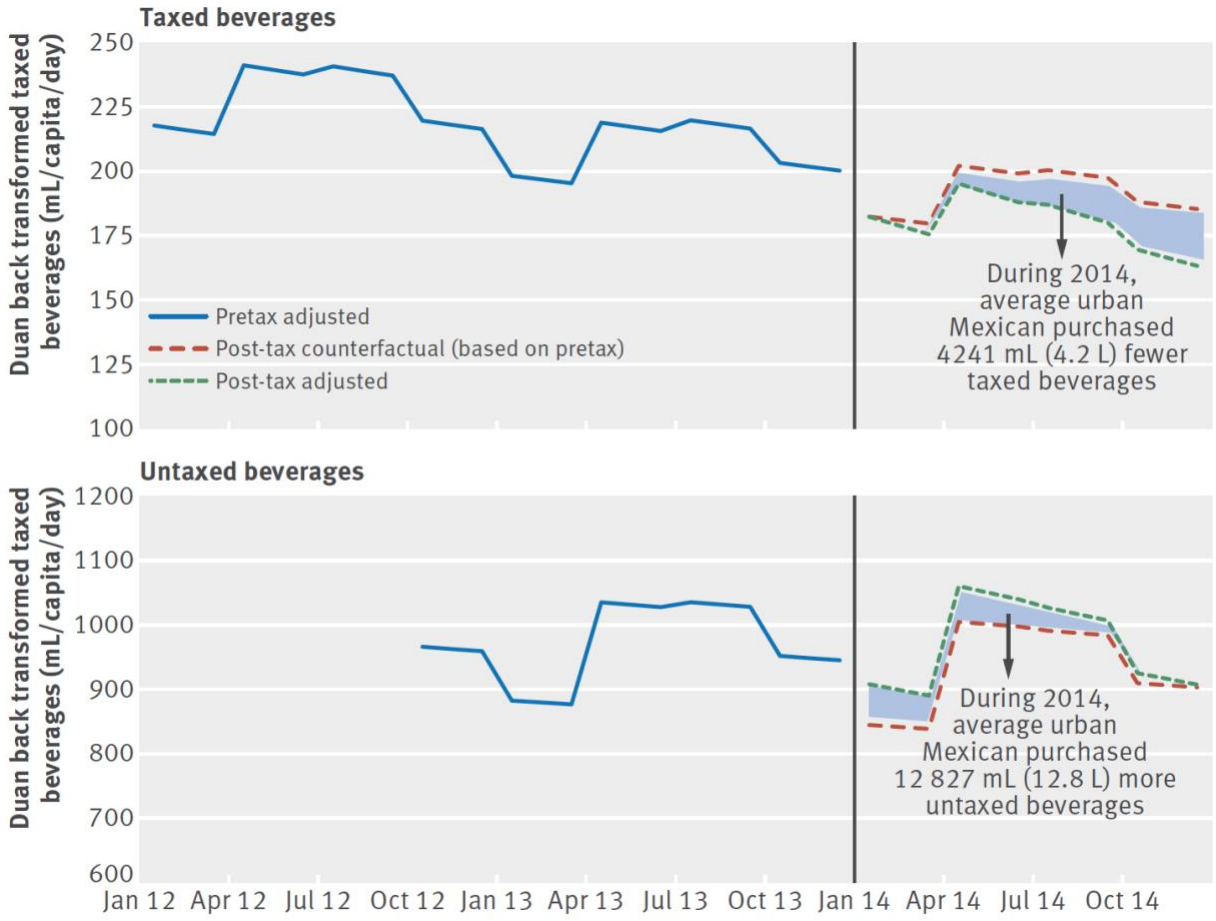

Figure 1 from Reference 57

(4% relative to the counterfactual), which translates to the purchase of 12,827 mL (twenty-one 600 mL bottles) more untaxed beverages than expected. See Figure 1 from Colchero et al. The reduction was greatest among the households with the lowest socioeconomic status[62]. The Colchero et al. findings, published in the BMJ, have been subject to the expected distortions and misinformation that routinely characterizes industry response regarding tobacco, alcohol, sugar, etc[63].

In a follow-up study, Colchero et al. estimated changes in beverage purchases for 2014 and 2015, using Nielsen's Mexico Consumer Panel Services data for 6,645 households in fifty-three cities (populations 50,000 to 8.9 million) from January 2012 to December 2015. Changes in

beverages – both taxed (carbonated sodas and noncarbonated sugar-sweetened beverages) and untaxed (carbonated drinks such as diet sodas; bottled water; and all other untaxed drinks) were estimated, comparing 2014/2015 purchases with predicted (counterfactual) purchases based on the trends in 2012–13. They summed the monthly household volume in each beverage category, then calculated the volume per capita per day. Their models adjusted for relevant economic factors and time trends. Purchases of taxed beverages decreased 5.5% in 2014 and 9.7% in 2015 - average 7.6%. Untaxed-beverage purchases increased 2.1%. Lowest SES households showed the largest decreases in purchases of taxed beverages in both years[64]. These data confirm that the Mexican taxation policy has maintained it impact on consumption of SSBs over the medium term.

Berkeley, California instituted an excise tax of one cent per ounce on SSBs in March 2015. Falbe et al.[65] used a difference-in-differences approach to evaluate the impact on SSB consumption using a repeated cross-sectional design that examined changes in consumption between pre- and post-tax periods in low-income neighborhoods in Berkeley and compared these with behaviour in Oakland and San Francisco. A questionnaire on frequency of beverage intake was administered by interviewers to 990 participants before the tax and 1689 after the tax (approximately 8 months after the vote that approved the tax and 4 months after implementation) to examine relative changes in consumption. They found that consumption of SSBs decreased 21% in Berkeley and increased 4% in comparison cities ($p = 0.046$). Water consumption increased more in Berkeley (+63%) than in comparison cities (+19%; $P < .01$). This is a real world before-and-after comparison across similar low-income communities in Californian cities. The pre-tax data were collected in winter and post-tax data in summer when increases in beverage consumption might reasonably be expected. In reality, however, this was true only in the comparison communities and in water consumption in Berkeley, whereas SSBs declined by 21% in Berkeley. Furthermore, the water-consumption increases in Berkeley were in line with expectations associated with the seasonal differences and made up for the decline in SSBs. The researchers' conclusion that the excise tax caused a reduction in SSB consumption in low-income neighborhoods in Berkeley seems appropriate.

Cawley has shown that the actual pass-through of the Berkeley tax to consumers was, on average, 43.1% (95% confidence interval: 27.7-58.4%)[66], suggesting that the impact of the tax on price is not as great as is often modelled. Nonetheless, the impact on consumption, even via this somewhat weaker agency, is clear and robust.

Although it is not yet part of the real world of experience, the UK Government in 2016 proposed a tax on SSBs that is structured as high on drinks with >8 grams of sugar per 100 mL, moderate on 5–8 g, and none on <5 g. Briggs et al.[67] modelled the plausible effect – on obesity, diabetes, and dental caries – of responses likely to be made by industry to this tax. This is informative and useful because it provides some directions both for policy makers and for industry. They modelled three responses: a) reformulation by manufacturers to reduce sugar content (a response seen clearly in Hungary as reported above); b) increasing price; and c) inducing a change in the market shares of each class of SSB: high-sugar, mid-sugar, and low-sugar. For each, they defined better and worse outcomes for health, producing assessments of

the impact in the UK on the prevalence of obesity and the incidence of dental caries and type 2 diabetes. The underlying model combined data on sales and consumption of SSBs, disease incidence and prevalence, estimates of price elasticity, and estimates of the association between SSB consumption and disease outcomes. The strengths of association between SSB consumption and disease outcomes were drawn from the literature.

They found that, for health, the best outcome was derived from reformulating SSBs (assuming a best-case scenario of 30% reduction in sugar concentration in high-sugar drinks and 15% for mid-sugar drinks). This would reduce: a) the prevalence of obesity by about 0.9% (95% uncertainty interval: 0.03-1.9%) overall but an approximately 10% reduction in obesity prevalence in 4-10 year olds; b) the incidence of type 2 diabetes by 31.1 per 100 000 person-years annually; and c) decayed, missing, or filled teeth by 4.4 per 1000 person-years) annually. The impact of increasing the price of SSBs in the better-case scenario would be less marked as would changes in market shares that increased the proportion of low-sugar drinks sold. The largest impact on obesity and oral health would be among those younger than 18 years; the largest absolute decrease in diabetes incidence would be in those older than 65 years[67].

The researchers noted that the health impact of a tax on SSBs is dependent on how industry responds. They conclude that the impact on health would be "maximised by substantial product reformulation, with additional benefits possible if the levy is passed on to purchasers through raising of the price of high-sugar and mid-sugar drinks and activities to increase the market share of low-sugar products."[67]

A *Lancet Public Health* editorial by Lennert Veerman that accompanied the paper noted that the most likely response from industry would be some as-yet-undefinable mix of the three responses modelled in the study. The editorial concluded, optimistically but for less than entirely clear reasons, that "the health impact of the UK SSB tax is likely to be considerably greater than Briggs and colleagues' results suggest."[68]

Impact on Those with Low Income

The study of Smed et al.[69] showed that there is a greater impact on those with low versus higher incomes when studying the Danish household panel data. These findings are consistent with those from the US[61,70] as well as more generally in the world[43]. Food pricing also affects the young more markedly than older adults (see below), an outcome that, in part at least, is also related to income. In New Zealand, there are specific benefits among Māori and Pacific[71,72]. The Berkeley study was undertaken specifically in low-income US communities[65].

The impact of any consumption tax is regressive[73] even when the tax is not being imposed to raise revenue (though it does) but rather to change behaviour. However, although it is economically regressive, the impact is greater – and therefore the health benefit is greater – in low SES groups[46].

Impact on Manufacturers

Manufacturers are able to respond in rational ways over and above just passing the additional

cost to consumers – although they often do that also. In Hungary, for instance, there was systematic reformulation of products that had attracted taxes to bring them below the relevant threshold – resulting, again, in lower consumption[60].

Impact on Employment

A recent modelling study of the 20% SSB tax in two US states, California and Illinois, found that, rather than causing unemployment, there would be increases in employment of more than 4000 (+0.06%) jobs in Illinois and more than 6000 (0.03%) jobs in California[74]. There were, indeed, declines in employment within the beverage industry but these were offset by new employment in other industries and in government. They conclude that claims by the beverage industry of employment losses due to proposed SSB taxes are over-stated and potentially misleading to lawmakers and voters[74].

Relevant Tobacco-taxation Data

There is substantial evidence from taxation policies in relation to tobacco to show that price increases change behaviour[75,76]. Indeed, price is central in determining whether an individual starts smoking and in cessation[75]. Worldwide consumption of tobacco could be reduced by more than 30% by doubling the price of cigarettes[76,77]. Past, current, and future smoking behaviour are markedly malleable to price shifts, despite the fact that tobacco is highly addictive. The US[78] and the UK[79] took more than 30 years to halve cigarette consumption. In contrast, by aggressive taxation policies, South Africa[80] and France[81] each managed this change in less than 15 years.

Data on the Young

Shifts in price are most effective in changing behaviour among young people – both for tobacco[75,82] and sugar[69,70]. It has been suggested that this is the result of the young being less committed in their behaviours and life choices. As the young generally have lower incomes and wealth than older adults and as those adults who have fewer resources are also more sensitive to price[43,69] — and perhaps receive greater benefit[43] — this may simply be a matter of disposable income. In either case, the empirical observation is encouraging in relation to the potential for limiting both the uptake and the continuation of deleterious behaviours. It also suggests however, as we have seen with tobacco, the sooner we get started the better.

Impact of Taxes Versus Market Fluctuations – is There a Halo Effect?

At present, there are too few data on real-world taxation to determine whether there is a difference between the impact of price changes due to market fluctuations and the impact of direct taxation and whether, therefore there is a halo effect (i.e., the tax also sends a 'signal' to society regarding deleterious consequences). The recent Public Health England review[41] concluded that "evidence suggests that increasing prices of high sugar foods and non-alcoholic drinks, potentially through taxation, may reduce purchases of these products proportionate to the level of the price increase imposed", a conclusion also consistent with the data presented above[41-46,50]. Whether there is halo effect that arises as a result of a government signal and public discussion[41] remains to be established but, as noted above, data both from Denmark[59] and Hungary[60] are consistent with there being a signal separate from the direct impact of the

tax itself.

Size of the Tax

There is sufficient evidence to show that any change in price brought about by taxation (or other causes) has to be sufficiently large to actually motivate change[50,83-85]. Although the exact level is hard to specify, there are both data and a general consensus that it has to be at least 10% and probably 20% to be effective[56]; it would probably be a good place to start both in New Zealand[71] and elsewhere[84] and, clearly, we have not stinted, particularly lately, on the size of a tobacco tax.

SSB Taxes Elsewhere

At the present time, there are at least 13 countries with taxes on SSBs, not all of which are for the purposes of changing behaviour[86]. In addition, five Pacific countries have import duties on sugar or SSBs, including Cook Islands, Fiji, French Polynesia, Nauru, and Samoa[86]. Further, there are parts of both the US and the UK where local SSB taxes are in place[86]. As already discussed, the UK government has announced that there will be a two-tier tax on SSBs beginning in 2018[87].

The impact of a 20% tax on SSBs in New Zealand

Ni Mhurchu et al. have estimated that a 20% tax on carbonated drinks would reduce daily energy intakes by 0.2% (20kJ/day) (because there tends to be no one-for-one energy substitution with a reduction in empty calories) and avert or postpone 67 (95% UI = 60-73) deaths per year from cardiovascular disease, diabetes, and diet-related cancers. This equates to 0.2% of all deaths in New Zealand per year, comparable to the number of annual deaths from cervical cancer[71]. The impact would probably be larger among Māori and Pacific because of the greater price elasticity among these members of the New Zealand population[72].

Obesity and overweight account for about 9% of all illness, disability, and premature mortality in New Zealand[88]. Approximately 66% of New Zealanders are overweight (35%) or obese (31%)[88]. New Zealand expenditure directly on health care is around $12.8 billion. Expenditure for the obese and overweight equals 9% of $12.8 billion, which is $1.152 billion. A 20% tax on sugar would reduce obesity by 1.3% (n=~14,000) and overweight by a further 0.9% (n=~11.000)[89]. A reduction of the overweight and obese population by about 1% represents a saving in health costs of around $6-11 million per year, depending on how many of the formerly obese will still be in the overweight category.

New Zealanders consume 48.2 kg of sugar per year which equals 33 teaspoons per person per day[90]. As noted above, approximately 17% of the total sugar intake of adults in New Zealand is from non-alcoholic beverages[1]; among 15-18 year olds, that proportion is 27-29% whereas in those over 71 years, it is 7–8%[1]. In 5-14 year olds, it is 14%[2]. Expenditure on sugar-sweetened beverages in New Zealand has been estimated at around $257 million per year[71]. Ni Mhurchu et al. further estimated that a 20% tax on this would raise about $40 million (even allowing for reductions in consumption following the introduction of the tax)[71,72].

Some modelling studies have explored cost-effectiveness of taxes, all of which find them to have a favourable ratio. An Australian study compared a 10% tax on seven 'junk food' categories with mandatory 'traffic-light' labelling. Simulated steady-state policy scenarios were compared with current practice and were found to be cost-saving, with predicted reductions in health expenditures of $A5,550 (2003 prices) and $A455 million, respectively and DALY gains of 559,000 and 45,100[91]. A US study comparing a sodium tax (assumed to produce a 6% reduction in intake) with those of a voluntary sodium reduction programme by food manufacturers (assumed to produce a 9.5% reduction) concluded that both strategies were cost-saving, with reduced medical expenditures of $22 billion (2008 prices) and $32 billion, respectively, and QALY gains of 1.3 and 2 million, over the lifetime of a cohort of individuals aged 40 to 85[92].

Recent Policy Reviews and Recommendations

A technical meeting of experts was convened by WHO on 5–6 May 2015 in Geneva to address member-country requests for guidance on the design of fiscal policies on diet; the purpose was to review evidence and existing guidance, discuss case studies, and provide input on scope, design, and implementation of fiscal policies on diet[93]. The meeting concluded that there was reasonable and increasing evidence that appropriately designed taxes on sugar-sweetened beverages would result in proportional reductions in consumption, especially if aimed at raising the retail price by 20% or more. They concluded that there was similar strong evidence for the effectiveness of subsidies on vegetables and fruit (V and F) and that a greater impact on net energy intake and weight may be accomplished by combining subsidies on V and F with taxes on target foods and beverages. They note, as have others, that vulnerable populations are "most price-responsive" and that their health benefits "most from changes in the relative prices of foods and beverages."[93]

They concluded that taxes that are based on nutrient content have greater impact and noted that advocacy should be included in the development and implementation of such policies. Most crucially, they underlined the importance of actively rebutting industry arguments and rebuffing efforts to oppose the development and implementation of tax measures. They might have warned us also about the same behaviour among some of our colleagues who work toward the same end, apparently without even having skin in the game. Nonetheless, the WHO meeting did acknowledge that there are evidence gaps that need to be addressed, including empirically by having more countries introduce relevant policies[93].

Beginning with the high and increasing prevalence of obesity among Australians, a recent report from the Grattan Institute, presented data on personal and third-party costs[94]. They estimated that third-party (largely government) costs of adult obesity in 2014/15 were more than AU$5 billion. They argued that the primary cause of the obesity epidemic is excessive consumption of unhealthy processed food, attributing this, in turn, to people: a) having a limited understanding of processed foods and of behavioural factors that can limit self-control; and b) "not bearing the full costs of over-consumption of unhealthy foods."[94]

Based on econometric modelling, they proposed that the Australian Government reduce third-party costs by imposing an excise tax on the sugar content of sugar-sweetened beverages

(SSBs) – specifically soft drinks, flavoured mineral waters, energy drinks, cordials, and fruit juices with added sugar. From this model, they argued that, although taxation by itself will not solve the obesity problem, a tax levied at a rate of about 40 cents per 100 grams of sugar in SSBs, would: a) increase the price of two litres of soft drink by about 80 cents; b) generate around AU$500 million per year; c) reduce consumption of SSBs by about 15 per cent; and d) lead to a reduction of about 2 per cent in the prevalence of obesity. They went further, noting that, as about 80 per cent of Australia's sugar production is exported. Australia would need to export an additional 1% of annual sugar production to make up for the reduced domestic consumption, suggesting transition assistance for affected producers (making up for domestic consumption by increasing export feels a bit like, "My jewels are weighing me down to hell; I'll give them to my sister," but, in the absence of international consensus and coordinated action, what recourse does a national government have?) They proposed that the revenue could be hypothecated for obesity-reduction programmes or used just as general revenue[94].

The equivalent return in New Zealand would be perhaps NZ$100 million and we do not have a domestic sugar industry to nurture.

The Committee of Presidents of Medical Colleges is the peak body that represents specialist medical practitioners in Australia. All of the specialist medical colleges support the following recommendations to tackle obesity[95]:

1. All Australians be actively encouraged to regularly monitor their weight and know about healthy limits;
2. Introduce a tax on sugar, and regulate fast food availability in schools;
3. Promote physical activity and better lifestyle behaviours;
4. Create better urban and regional plans which actively encourage daily exercise;
5. Enhance opportunities for health professionals to provide opportunistic advice and support.

The need for more than legislation

Consistent with this broader approach from the Australian Medical Colleges, a recent thoughtful discussion[96] of why the Danish tax on saturated fat was abolished concludes that if a tax is to survive it needs more than merely to be passed. Further, it probably needs to be politically supported for health, rather than fiscal, reasons. It also needs to be supported, or at least accepted, by prominent actors in the food arena, including researchers[96]. And it needs to be set within a broader set of policies, information (including social marketing), incentives, controls, and nudges[56,97]. For instance, the 2014 WHO Comprehensive Implementation Plan on Maternal, Infant and Young Child Nutrition[98] notes, "Trade measures, taxes and subsidies are an important means of guaranteeing access and enabling healthy dietary choices. They can be powerful tools when associated with adequate information for consumers through nutrition labelling and responsible food marketing, and with social marketing and promotion of healthy diets and healthy lifestyles."

Response to Gibson

Prof John Gibson of Waikato University, made the point – in a July 13, 2016 presentation at the Ministry of Health in Wellington that is currently still unpublished – that price-elasticity-of-demand estimates from household-survey data have a problem, namely that the usual use of budget-share data ignores the fact that these reflect, not just quantity, but both quantity and quality.

Based on an insight from Prais and Houthakker[99] that household surveys do not provide data on expenditures on, and quantity consumed of, specific goods but rather on classes of goods (i.e., with no distinction between higher-cost and lower-cost versions of food that may represent plausible alternates), Gibson argued that, because there are many different varieties, brands, package sizes etc. within a commodity group, the purchaser faces choices both about quantity and quality (at least as determined by price per unit) of items; therefore, if demand estimates do not allow for both choices, there will be conflation of quality responses and quantity responses to changes in price and this, in turn will overstate the efficacy of price rises in reducing the quantity of the taxed item and therefore overstate the reduction in consumption of, say, sugar-sweetened beverages.

He further showed that the assumptions underlying Deaton's method[100] to untangle quality responses and quantity responses do not seem to hold in practice, although not everyone agrees with that assessment. He argued that, because part of the budget-share response to change in price is change in choice of quality, both prices and unit values are needed to get unbiased quantity elasticities from budget-share equations. Therefore, he concluded, the quantity of food and drink purchased is likely to be much less price-responsive than is suggested by the studies that underpin the introduction of taxes on SSBs.

Gibson's argument, based on Indonesian and other studies, if it holds, would mean that our traditional estimates of own-PE are overestimated by perhaps 5-fold (e.g., if we find an own-PE of -1.0, then it really is -0.2 (and, thus, any tax would be 80% less effective in its impact on purchase and consumption). However**, t**here are a number of issues that Gibson failed to consider:

i. This 80% estimate is derived from low-income country data. The recent Sharma et al. modelling study, using Australian data, puts it at more like 30% (own-PE of -0.63 allowing for the quality/quantity trade-off (endogeneity) v. -0.89 ignoring this problem)[101].

ii. The problem that Gibson is addressing is real but applies only to "valoric" or "added value" taxes (i.e., a % tax on sales price) – and indeed, an analysis of the impact of the added value sales taxes in Maine and Ohio showed that neither had a statistically significant impact on the consumption of soft drinks[102]. This difficulty can be easily disposed of with tax based on sugar content (the UK solution) or a volumetric tax (e.g., $0.40 tax per liter for all drinks irrespective of price) which results in cheap drinks having a higher % tax and reducing the drive to consume SSBs of lower quality[101].

iii. Gibson is (again, correctly) identifying a downward bias in the own-PE. However, he did not speak to the bias that acts in the other direction. Specifically, econometric theory states that each time you subdivide a food group (e.g., break soft drinks into diet and sugary soft drinks) that the own-PE **increases**. This is because, if the price of sugary drinks, but not diet drinks, increases, the purchaser has a substitute to which they can move (i.e., diet instead of sugary beverage). It is highly likely that the own-PE of SSBs is greater than soft drinks overall.

iv. Even with a valoric rather than volumetric tax, the quality-response issue becomes increasingly less important once SSB taxes are high enough so that non-SSB beverages are typically cheaper per litre than SSBs. In the initial stages – when SSB taxes are still low – setting minimum prices (by law) could help prevent a shift to lower-priced products. Although such a policy may reduce the revenue gain (again, revenue gain is not the primary aim), it may reduce industry opposition as supermarkets may increase profit.

v. It is true that none of the studies cited above explicitly addresses the brand/quality issue that Gibson highlights but that could be addressed specifically in future experiments and perhaps also by analysing Nielsen NZ Homescan data.

vi. Further, however, we need to consider the totality of the evidence in this area and not privilege one study or one study design over all others: a) the data on own-PE are widely consistent across geography and time; b) there have been, as noted above, a number of informative and, again consistent, experimental studies, using a virtual supermarket or other settings; c) the results following the introduction of SSB taxes in various cities and countries are arguably the strongest evidence available – these real-world data, again as noted above, are entirely consistent with the modelling studies; d) the details within the real-world findings (the persistence of behaviour after withdrawal; the shift by manufacturers; the evidence that there is a halo effect just from instituting a tax; the evidence from Berkeley that a decline can occur across a seasonal shift that should have produced a rise) are all reassuring observations that make nit-picking at the edges of the general argument hard to sustain.

vii. Finally, it is worth considering, perhaps, how odd it is that, even though an SSB tax has more evidence (albeit still not 100% certain) than any of the other interventions in the current obesity-control plan, nonetheless, the idea of an SSB tax seems to be treated as not being evidence-based – at least by Gibson.

Conclusions

There is good evidence of price elasticity of demand for sugar-sweetened beverages, with observational data (from the real world) – involving both market fluctuations and taxation – and experimental data. The greatest benefit is likely to be among those on low incomes, among young people, and, in New Zealand, among Māori and Pacific. A small tax is likely to be less beneficial than a larger one but, from about 10% and up, the impact on population

consumption approximates the magnitude of the tax. There can be rational responses from manufacturers, resulting in product reformulation to reduce levels of sugar. Thus, taxing – or otherwise elevating the price of – SSBs results in market responses, a reduction in purchases, and lower consumption.

An SSB tax that results in lower consumption of empty calories – based on the relationship, in both adults and children, between energy balance and obesity and between SSBs and caries, obesity, cardiovascular disease, diabetes, etc. – will, in turn, result in beneficial changes in average BMI, in overweight and obesity, and in the associated burden of morbidity and mortality. Over time, there may be, in New Zealand, 50 deaths "saved" per year, especially deaths due to diabetes and cardiovascular disease and it will save at least $6 million per year in health costs. More immediately, it will raise about $40 million in revenue. Over time, an SSB tax is likely to be cost-saving for the health system, as well as health improving.

Finally, it is worth noting that an SSB tax is only one component of a comprehensive strategy to tackle obesity – including healthy school-food policies, restrictions on marketing to children, increased opportunities for physical activity, safer biking routes, etc. – but it has the virtue of being an evidence-based action that can anchor and reinforce those other steps.

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