



# Sugar taxes

## A review of the evidence

NZIER report to Ministry of Health  
August 2017



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## Key points

Sugar taxes of various designs are being used around the world in a range of different policy contexts. Those countries that have not yet implemented sugar taxes are under pressure from lobby groups to do so, with claims that the evidence is strong that a sugar tax will improve population health by reducing the intake of sugar.

To be effective at improving health, a sugar tax must be effective across a five-step intervention logic:

- Imposing a tax must increase the price of the targeted item
- The increase in price must lead to a reduction in consumption of the item
- Reducing consumption of the item must lead to a reduction in sugar and/or energy intake
- Lower energy intake must result in lower physiological risk factors
- Lower physiological risk factors must improve health outcomes.

This report provides an assessment of the evidence for sugar taxes as a fiscal instrument to improve health. Forty-seven peer-reviewed studies and working papers published in the last five years were reviewed, summarised and assessed for key methodological issues.

Experience with sugar taxes is complicated by inconsistencies in their design and context. Most sugar taxes apply to sugar-sweetened beverages, but some also include pure fruit juices or other foods with high sugar content. Some are valoric taxes while others are volumetric. Some taxes were implemented alongside other measures to improve diets or increase awareness of the danger of excess sugar consumption.

Sugar taxes are also implemented in some jurisdictions as a means to raise additional tax revenue, with no particular expectation that any reduction in intake will translate into health benefits but sometimes with revenues being earmarked for health programmes.

In our review of the literature, we find that:

- Taxes do generally appear to be passed through to prices and some reduced demand is likely
- Estimates of reduced intake are often overstated due to methodological flaws and incomplete measurement
- Price elasticities from early studies with fundamental methodological flaws have later been used in a number of other studies to assess the impact of sugar taxes, resulting in significantly overestimated reductions in demand
- There is insufficient evidence to judge whether consumers are substituting other sources of sugar or calories in the face of taxes on sugar in drinks
- Studies using sound methods report reductions in intake that are likely too small to generate health benefits and could easily be cancelled out by substitution of other sources of sugar or calories
- No study based on actual experience with sugar taxes has identified an impact on health outcomes

- Studies that report health improvements are modelling studies that have assumed a meaningful change in sugar intake with no compensatory substitution, rather than being based on observations of real behaviour.

The evidence that sugar taxes improve health is weak.

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# 1. Introduction

Sugar taxes have been implemented in several countries and regions, with a view to reducing consumption of drinks or other foodstuffs with added sugar, to discourage unhealthy diets and offset the fiscal and economic costs of obesity.

In 2015, the Ministry of Health published a review of the evidence for the effectiveness of interventions to address childhood obesity, which included sections on sugar and a sugar tax.<sup>1</sup> The Review observed:

*While theoretical models indicate a tax should lead to reduced consumption and consequently body weight, real-world evidence is less clear. A number of countries have introduced such taxes, but there isn't yet robust evaluative evidence on whether they are effective, or on the size and persistence of any impacts.*

The Ministry has asked us to review any new evidence on the effectiveness of a sugar tax as a tool for improving health outcomes. The Ministry is especially interested in the effect of taxes on sugar-sweetened non-alcoholic beverages.<sup>2</sup>

## 1.1. Background

Rates of mortality (death) and morbidity (incidence of disease, disability and ill-health) are falling in New Zealand. The Ministry of Health says:

*New Zealanders are living longer, and are living longer in good health (i.e., both life expectancy and health expectancy are increasing). Health loss, measured in DALYs, is declining by an estimated 1.2% per year, once adjusted for changes in population size and age structure – a major achievement for the health and wider social sectors. Yet because the population is growing and ageing, the absolute number of DALYs is still increasing. This finding suggests that improvements in health do not necessarily reduce health care expenditure.<sup>3</sup>*

But within this overall positive trend, some diseases continue to cause major reductions in health status.

More specifically related to the issue of sugar taxes, the Ministry has identified risk factors that contribute to health loss across different diseases, including diet, high body mass index, high blood glucose and high cholesterol. The effects of these risk factors on health loss is shown in Figure 1.

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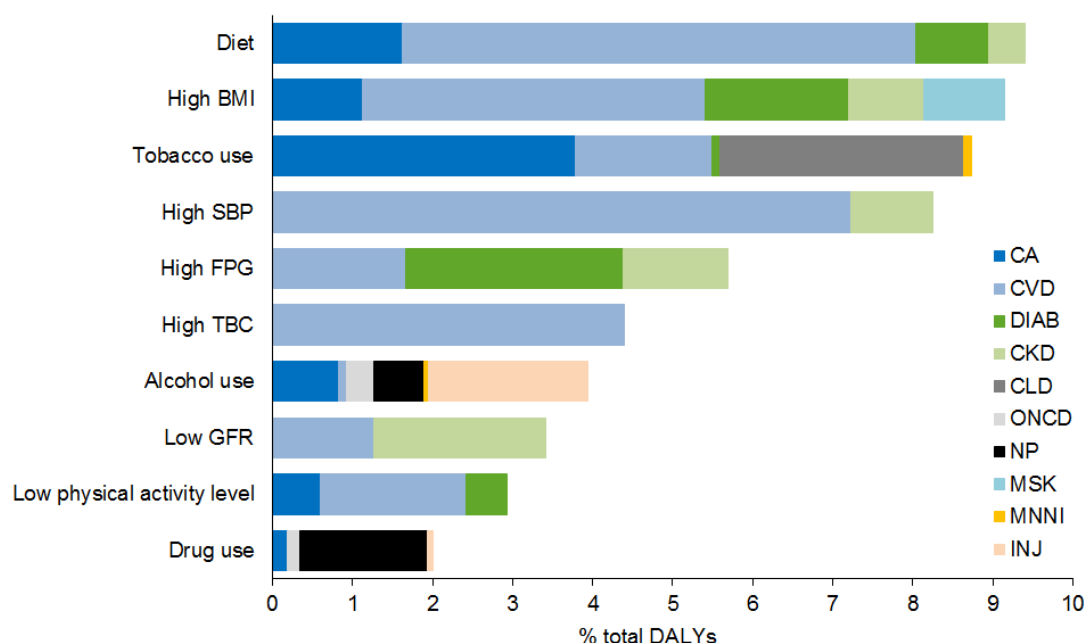
<sup>1</sup> Ministry of Health (2015b).

<sup>2</sup> Taxes on sugar-sweetened non-alcoholic beverages go by many names. Examples include “soda tax” (especially in North America, “sugar-sweetened beverage tax”, “sugar tax” and the more generic “fat tax” (which often include foods as well as drinks). In this paper, we will use the term sugar taxes.

<sup>3</sup> Ministry of Health (2016). “DALY” is an acronym for disability-adjusted life years. This is a commonly used measure of health status. DALYs are calculated by combining years of life lost to disease and years lost to disability, which in turn are based on the incidences, duration and severity of conditions. See Ministry of Health (2001) for details on the methods of calculation.

**Figure 1 Health losses caused by selected risk factors**

Percentage total DALYs, 2013



Key: CA = cancers; CVD = cardiovascular disorders; DIAB = diabetes; CKD = chronic kidney disease; CLD = chronic lung disease; ONCD (which here includes chronic liver disease) = other non-communicable diseases; NP = neuropsychiatric disorders; MSK = musculoskeletal disorders; MNNI = maternal, neonatal, nutritional deficiency and infectious disorders plus birth defects; INJ = injuries, unintentional and intentional; BMI = body mass index; SBP = systolic blood pressure; FPG = fasting plasma glucose; TBC = total blood cholesterol; GFR = glomerular filtration rate.

**Source: Ministry of Health (2016)**

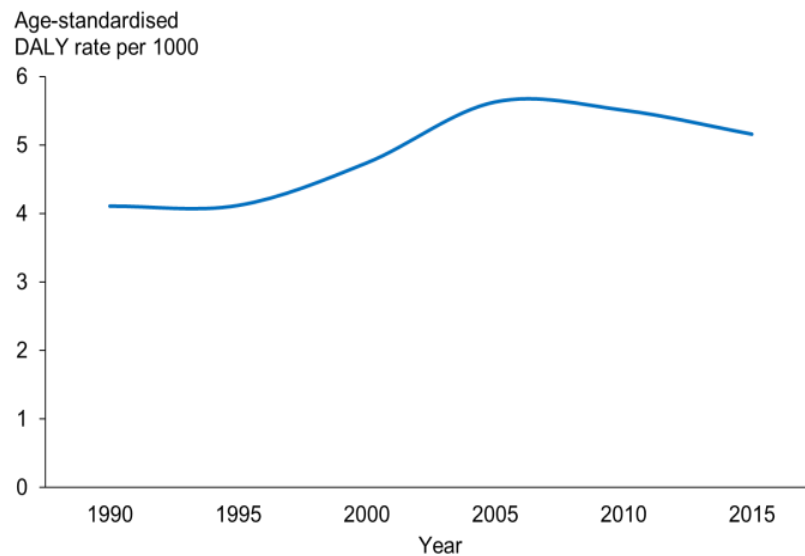
While not yet one of the top causes of health loss, diabetes has been advancing in rank since 1990: from 16th to 7th for males; and from 22nd to 12th for females. Even here, there is some good news:

*Per capita age-adjusted health loss from diabetes began increasing in 1995 and rose steeply to 2005 when it peaked and has since declined slowly, even though the prevalence of diabetes has continued to increase. This finding may reflect earlier diagnosis and/or more effective treatment of this disease – which has had the effect of decoupling burden from prevalence.<sup>4</sup>*

<sup>4</sup> Ministry of Health (2016).



**Figure 2 Health loss from diabetes is falling slowly**



Source: Ministry of Health

There are major ethnic and socio-economic disparities in the prevalence of diabetes and long-term outcomes for people with diabetes. Māori and Pacific people develop diabetes 10 to 20 years earlier than Europeans, and experience worse outcomes. These groups are also more likely to be heavy consumers of sugar-sweetened beverages.

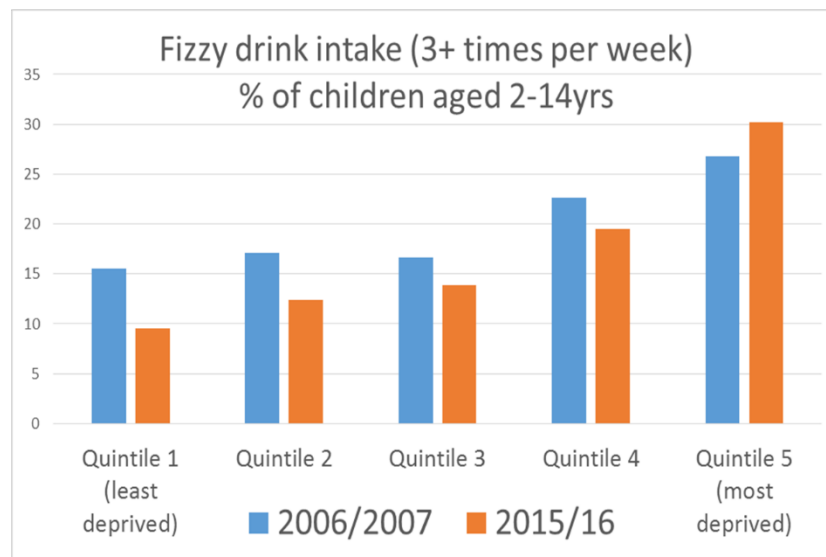
Childhood obesity is a priority of the current government. The New Zealand Health Survey notes:

*Twenty percent of children living in the most socioeconomically deprived areas were obese, compared with 4% living in the least deprived areas. Ten percent of children living in the most deprived areas were extremely obese (that is, in obese class 2 or 3, with a BMI equivalent to an adult BMI of 35.0 or more), compared with 1% living in the least deprived areas<sup>5</sup>.*

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<sup>5</sup> Ministry of Health (2016).

**Figure 3 Fizzy drink intake**



Source: Ministry of Health

A separate concern is the high rate of tooth decay in children from high deprivation areas where the latest New Zealand Health Survey shows consumption of sugary drinks is higher for those children, and is not falling.

There is a correlation between sugar consumption and poor health outcomes. Hence the interest in sugar taxes: can they cost-effectively prevent health loss directly, allowing people to live healthy lives without having to undergo (costly) treatment?

## 1.2. Outline

To put the discussion of the evidence into context, we begin by outlining an analytical framework for thinking about the role of taxes in promoting health outcomes. This framework draws on both public finance and health economics.

We have developed this framework as a way of assessing the relevance of the literature we have reviewed. The framework describes the intervention logic behind a sugar tax as a tool for improving health outcomes and sets out the issues that studies should address if they are to help policymakers answer the question about the appropriate role of a sugar tax within the New Zealand health and tax systems.

We then review the literature on sugar taxes considering this framework, focusing on the evidence that is available on whether sugar taxes have been effective in other jurisdictions at solving the problem that it is intended to address in New Zealand.

## 2. Framework

In this section, we outline a framework for thinking about sugar taxes.

The purpose of this framework is to provide a benchmark against which the studies we have reviewed should be assessed. It allows us to determine whether an individual study is likely to provide valuable evidence in deciding whether a sugar tax might be warranted in New Zealand.

### 2.1. Building the framework

We have built the framework by posing three questions:

- What is the public policy problem that the tax is trying to address?
- Is a sugar tax an effective way of addressing the problem?
- Is a sugar tax the best way of addressing the problem?

We start with a discussion of the effects the intake of sugar has on health, as this is an important context within which sugar taxes should be considered.

### 2.2. Reducing sugar intake

The World Health Organization has strongly recommended that the intake of free sugars<sup>6</sup> be less than ten percent of total energy intake for adults and children.<sup>7</sup> This recommendation is based on substantial evidence linking intake of sugar to increased body mass and chronic non-communicable diseases, including heart disease, type 2 diabetes, gout and fatty liver disease.<sup>8</sup>

In relation to type 2 diabetes, a background paper prepared for a joint WHO/FAO expert consultation in 2002 concluded:

*Based on the strength of available evidence regarding diet and lifestyle in the prevention of type 2 diabetes, it is recommended that a normal weight status in the lower BMI range (BMI 21–23) and regular physical activity be maintained throughout adulthood; abdominal obesity be prevented; and saturated fat intake be less than 7% of the total energy intake.<sup>9</sup>*

The New Zealand Ministry of Health's *Eating and Activity Guidelines for New Zealand Adults* includes recommendations to choose foods with the lowest amount of added

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<sup>6</sup> The World Health Organization defines “free sugars” to mean all simple sugars (monosaccharides) and double sugars (disaccharides) added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, fruit juices and syrups (WHO 2003). Free sugars distinguish between sugars that are naturally present in an unrefined form, such as sugars in fruit, from those that have been refined at some point, either by humans or animals (for example, in honey).

<sup>7</sup> WHO (2015).

<sup>8</sup> Te Morenga et al. (2013).

<sup>9</sup> Steyn et al. (2004).

sugar and replace high-sugar drinks like fizzy drinks and sports drinks with plain water.<sup>10</sup>

Despite these, and many other recommendations that people consume less sugar, backed up with ongoing information campaigns, consumption continues to grow (see Figure 3), leading many groups to call for the introduction of a sugar tax.<sup>11</sup>

## 2.3. What is the public policy problem a sugar tax is trying to address?

That high sugar consumption causes adverse health effects is not the problem that a sugar tax is trying to address, it is a symptom. The underlying problem is that people do not always make decisions about their behaviour when it comes to health matters that will improve their ability to lead the lives that they value.

When it comes to making decisions, economics proceeds on three broad principles: rationality, consumer sovereignty and market efficiency. Rationality assumes that individuals are rational, maximizing agents.<sup>12</sup> The consumer sovereignty principle states that the basis of assessing policies should be the welfare of individuals, as they judge their own welfare to be. Market efficiency means that as a result of people making their own decisions, based on their preferences, the economy as a whole will arrive at a position where there is no better use of resources available: “an activity is economically efficient if there is no other use of the resources that would yield a higher value or net benefit”.<sup>13</sup>

*The central theoretical result in welfare economics is that markets, when they are perfectly competitive and otherwise well functioning, result in a level of economic efficiency on which government policy cannot improve.*<sup>14</sup>

However, there are cases where the conditions that lead to an efficient outcome don’t hold: where a “market failure” is said to exist. While often used as a general term in general discussions and debate, in the economic literature, “market failure” is a technical term that leads to equally technical policy responses.<sup>15</sup> Friedman (2014) defines market failures as “... a situation where individual rationality does not lead to group rationality, where, if each person calculates correctly their own interest and acts accordingly, everybody will be worse off than if they had all acted in a different way”.<sup>16</sup>

Market failures are not the same as the common critique of economics which proceeds along the lines of: “the model assumes A; A does not hold, therefore the model and all

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<sup>10</sup> Ministry of Health (2015a).

<sup>11</sup> See, for example, New Zealand Medical Association (2014), New Zealand Beverage Guidance Council (2014). In the international sphere, see World Health Organization (2016).

<sup>12</sup> “Rationality” has a technical meaning in economics when it comes to describing consumer behaviour and preferences. Preferences are “rational” if they possess two properties: completeness (people can always make a choice between alternatives) and transitivity (if A is preferred to B and B is preferred to C, then A will always be preferred to C). See Mas-Colell et al. (1995). This is very different from the dictionary definition of rational, which is “based on or in accordance with reason or logic”.

<sup>13</sup> Australian Productivity Commission (2013).

<sup>14</sup> Congdon et al. (2011).

<sup>15</sup> See Ledyard (1987).

<sup>16</sup> “Everybody” is probably going too far. “At least somebody” is a better description of most market failures.

its conclusions, are invalid" or more specifically "economics assumes rationality, I have identified an instance where rationality does not hold (a "market failure"), thus government intervention is justified (or, sometimes, is required) to "correct" the market failure". It is clearly true that the neoclassical model of markets makes several highly stylised assumptions as the basis of providing "a system of generalisations that can be used to make correct predictions about the consequences of any change in circumstances".<sup>17</sup> The important point is that the performance of an economic model is to be judged not on the reality of its assumptions, but by the accuracy of the predictions it makes. The market failure model makes most of the same assumptions as the perfect competition market model of neoclassical economics.<sup>18</sup>

A standard list<sup>19</sup> of market failures is:

- Imperfect competition<sup>20</sup>
- Externalities<sup>21</sup>
- Incomplete information<sup>22</sup>
- Increasing returns to scale<sup>23</sup>
- Public goods<sup>24</sup>

If the conditions for market failure hold, then it is possible for government intervention to either directly "correct" the reason for the failure (for example, by defining a property right that is otherwise deficient) or by counteracting the effects of the market failure (for example, by imposing a tax or subsidy to align private costs and benefits with public costs and benefits). In these circumstances, government intervention can increase welfare, not because governments know better than private players in markets what decisions to make, but because of the existence of some technological or institutional features which means that the fundamental workings of markets that normally ensure that all opportunities for gains from trade will be exhausted will not hold.

Note that the possibility that consumption might involve risks of harm is not included in the list of market failures. Even when it comes to harmful behaviours, economists tend to defer to the preferences of individuals, even those who are addicts:

*The traditional economic approach to such activities has been to treat consumers as "rational addicts", to use the term of Becker and*

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<sup>17</sup> This is Friedman's (1953) description of the task of positive economics.

<sup>18</sup> See Bator (1958).

<sup>19</sup> This one is adapted from Barr (1992).

<sup>20</sup> Where some producers are not price takers and can sustain prices and quantities that are not efficient.

<sup>21</sup> Where the full benefits or costs of an activity are not accurately reflected in market prices. Externality, external economics and external effects are used interchangeably in the literature to describe this phenomenon.

<sup>22</sup> Where information about a product is not known to consumers (asymmetric information) or is costly to acquire. Asymmetric information can also apply when information about the consumer is not known to the supplier. This is a common concern in insurance markets, where the purchasers of insurance know more about the risks that they involve than the sellers of insurance, leading to adverse selection: the people buying insurance are more likely to make a claim than the insurer expected, which leads to insurers charging premiums that are too low and thus facing losses.

<sup>23</sup> Which leads to "natural monopolies".

<sup>24</sup> Public goods cannot be charged for because of free-riding. Note: public goods are not goods provided by the public sector. The distinction is technological, not institutional. In the article introducing the concept that has become known as "public goods", Paul Samuelson used the term "collective consumption goods". See Samuelson (1954).

*Murphy (1988). Their seminal article codified what had become the standard approach among economists to thinking about regulation of addictive bads. In their model, consumption of addictive bads is governed by the same decision-making process as is consumption of all other goods. Consumers trade off the utility gains from consuming the good against the costs of doing so, and as rational forward-looking agents they recognize that those costs include the damage that they are doing to themselves through consumption, as well as the additional future damage to which they are driving themselves by consuming more of an addictive good.<sup>25</sup>*

However, if there is a lack of information about risks, then this can result in market failure. As we note below, the developing field of behavioural economics provides insights into how people process the information that they have, even when that information is complete. That is not, however, technically a “market failure”.

### 2.3.1. Externalities

Provided economic decision makers are taking all the costs and benefits of their actions into account (along with other conditions), then markets will operate to produce an equilibrium outcome and this outcome will be optimal.<sup>26</sup> If they do not, then an externality occurs.<sup>27</sup>

Despite the central place of externalities in economics, their treatment in the literature is often problematical. A precise technical definition remains elusive:

*[A]lthough economists have been investigating the concept of externalities for a long time, both theoretically and empirically, externalities still prove to be an area of slippery ice. Frequently one finds fuzzy discussions on the policy implications of external costs. This may often result from, for instance, mixing up equity and allocative efficiency arguments, from mistaking pecuniary externalities for ‘true’ or technological externalities, or from some sense of compassion with the victims of externalities on equity grounds, leading to pleas for ‘compensation’ which may often be unwarranted from the perspective of allocative efficiency.<sup>28</sup>*

For example, a recent Treasury Working Paper on sugar taxes stated:

*The theoretical basis for a sugar tax is that overconsumption of high-sugar products is a market failure which imposes negative externalities*

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<sup>25</sup> Gruber and Koszegi (2002).

<sup>26</sup> Pigou (1920/2005) is often credited as being the first person to state this result, although Sidgwick is also credited at having touched on the matter in his *Principles of Political Economy*. As a result, taxes that correct market failures are often called “Pigouvian taxes”. Baumol (1972) was an early developer of the formal version of the modern concept of Pigouvian taxes and Baumol and Oates (1988) did much to popularise its use.

<sup>27</sup> Externalities can be both positive and negative. A positive externality occurs when a consumer does not take account of the benefits of their activity that accrue to others in making their decisions. A common example in the literature is vaccinations, which as well as reducing the impact of disease on the person vaccinated, can also reduce its spread to others. A negative externality arises when there are unaccounted for costs imposed on others. Pollution is the quintessential example.

<sup>28</sup> Verhoef (1999) p. 197.

*on society through increased health costs and higher rates of premature death from a range of non-communicable diseases.<sup>29</sup>*

We cannot agree with this statement, as it involves a misunderstanding of the concept of externality.

An externality exists if and only if some of the economic costs or benefits of an action do not accrue to the actor.<sup>30</sup> The costs here are the economic resources used up as the result of the action and the benefits are the increases in satisfaction that comes from the action.

That New Zealand has a publicly-funded health system (and funds medical treatment for accidents out of taxes via ACC<sup>31</sup>) does **not create the conditions for externalities**. While it is true that public funding changes incentives, this is true for all areas of government.<sup>32</sup>

Likewise, that spending on one health issue has an opportunity cost, in that funding one activity may mean that another cannot be funded, is not an externality. Indeed, it is not any sort of market failure. Rather, it is the unavoidable consequence of nature and sits at the very core of economics.<sup>33</sup> Reducing the incidence of diseases that are costly to treat will result in fiscal savings. Our simple point is that this is not an externality, the correction of which will lead to an improvement in welfare.

Corrective taxes that address true market failures are welfare enhancing. This distinguishes them from general taxes used to raise revenue, which reduce welfare, via the concept of deadweight loss or excess burden.<sup>34</sup> Deadweight loss is a transfer of welfare from the taxpayer to nobody, unlike the revenue raised by a tax that is a transfer from the taxpayer to the beneficiaries of the government expenditure financed by the tax.

From a national perspective, revenue raised is **not** a benefit of taxation. This is an important, but often overlooked, aspect of the analysis of taxes. What this means is that, when comparing costs and benefits of a tax that will finance an activity, what needs to be compared are the welfare benefits of the spending program with the

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<sup>29</sup> Gardiner (2016).

<sup>30</sup> There was an intensive debate in the 1930s to 1950s on the issue of whether all behaviours that had consequences for other actors should be classed as “externalities” and thus constitute failures of the market to achieve an optimum, or whether there were some actions with consequences that constituted the efficient working of the market. One example discussed was the change in relative prices that resulted in a large change in demand within a market. Such a change in relative prices would have an impact on all players in that market. Was this an “externality” that needed correcting? The debate was finally resolved by Viner (1931) and Scitovsky (1954) identifying two separate “concepts” of externalities. The first is termed “pecuniary externalities”, which can be thought of movements along a supply or demand curve because of shifts in the other curve. These are not regarded as a market failure. The second type are “technological externalities”. Technological externalities directly impact on the welfare of another party, while pecuniary externalities indirectly affect others by way of changes in relative prices. Buchanan and Stubblebine (1962) refer to a similar concept of “Pareto-relevant” externalities, being those that prevent an economy from reaching a Pareto-efficient outcome.

<sup>31</sup> ACC is funded from a combination of levies on employees, employers and vehicle owners and taxpayer funding, especially for the “non-earners” account, that provides funding for injuries that are neither employment or vehicle-related).

<sup>32</sup> This is akin to the problem of moral hazard in all insurance systems: by reducing the costs of the event that is insured, people are less likely to take actions to prevent those events. The usual way of correcting for moral hazard is charge an “excess” or “co-pay”: the insured person incurs some costs, which will provide an incentive to avoid insured events.

<sup>33</sup> Robbins (1932) defined economics as “the science that studies human behaviour as a relationship between ends and scarce means which have alternative uses”. In developing his definition, Robbins suggested that there are four elements to the “conditions of human existence” of interest to economists: that ends are various; that the means to achieve those ends are limited; that the means to achieve those ends have alternative uses; and that different ends have different importance.

<sup>34</sup> See Creedy (2003) for a non-technical discussion and, for a survey, see Auerbach and Hines (2002).

welfare costs of raising the tax. Note that neither these costs or benefits include the amount raised in revenue or spent on the programme.

It is difficult to see how consumption of sugar can lead to externalities, as that term is understood in welfare economics.

### 2.3.2. Incomplete information

Included in the rational choice model is an assumption of perfect knowledge and zero information costs. Consumers know everything they need to know about the products and services on offer to make good decisions. Research suggests that positive search costs mean that many consumers only have imperfect knowledge about the quality and prices of many products in their purchasing decisions (due to limited budgets of time and money). This leads to welfare losses, because consumers buy things which do not fit optimally to their preferences.<sup>35</sup>

There are two possible responses to this form of market failure:

- Increase the amount of information consumers have (more specifically, reduce the cost of gathering information, which will lead to more of it being gathered)
- Use price (via taxes) to compensate for inadequate information.

The price effect works by mimicking the effect that having full information would have, in that it leads consumers to reduce consumption to the level that equals what they would buy if they had perfect information about the full effects of the product.

Excessive consumption of sugar due to incomplete information does come within the standard definition of market failures.

### 2.3.3. Insights from behavioural economics

Behavioural economics is a relative new branch of economics, that grew out of the work of psychologists Amos Tversky and Daniel Kahneman, who in a series of papers provided alternative explanations about human nature to those held by mainstream economics.<sup>36</sup> They are perhaps best known for the development of prospect theory which shows that decisions are not always optimal.<sup>37</sup>

Alain Samson provides a simple summary of behavioural economics:

*According to behavioral economics (BE), people are not always self-interested, benefits maximizing, and costs minimizing individuals with stable preferences—our thinking is subject to insufficient knowledge, feedback, and processing capability, which often involves uncertainty and is affected by the context in which we make decisions. Most of our choices are not the result of careful deliberation. We are influenced by readily available information in memory, automatically generated affect, and salient information in the environment. We also live in the moment, in that we tend to*

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<sup>35</sup> Kerber (2014).

<sup>36</sup> Tversky and Kahneman (1973), Tversky and Kahneman (1974) and Tversky and Kahneman (1981).

<sup>37</sup> Kahneman and Tversky (1979).



*resist change, are poor predictors of future behavior, subject to distorted memory, and affected by physiological and emotional states. Finally, we are social animals with social preferences, such as those expressed in trust, reciprocity and fairness; we are susceptible to social norms and a need for self-consistency.*<sup>38</sup>

While undoubtedly questioning the idea that the rational choice model is an accurate description of how people behave, behavioural economics also provides additional insights into why a sugar tax, or other interventions, might not be effective.

As Leonardo Mautino notes, the idea from behavioural economics that suggests that people aren't always rational applies equally to people who are deciding to buy a drink that has a tax imposed on it as it does to a person not facing a tax. He also points out that an increase in price does not automatically signal the sugar content of the drink: consumers must make that link themselves. Behavioural economics also suggests that the effectiveness of interventions declines with time, as people become habituated to them. He concludes:

*Fizzy drinks and sugar are only part of the health story. A sugar tax on soft drinks will raise awareness of the dangers of excessive consumption of free sugars, but it may only have limited impact on consumer behaviour in practice. Education has a role, but by itself can be ineffective. Behavioural insights indicate that simple, impactful labelling, and limits to convenience, may have a greater impact.*<sup>39</sup>

Finally, we note the warning of McCaffery and Slemrod (2004) that moving away from the traditional principles of public finance based on a rational choice model should not be considered lightly:

*In most cases, people's judgment of what is in their best interest is best. It is a safeguard against authoritarian government, as Richard Epstein reminds us. Overruling the choices that citizens—even confused, time-inconsistent, and downright irrational ones—make places tremendous responsibility on the benevolence of decision makers.*

## 2.4. How does a sugar tax address the problem?

The case for a sugar tax addressing the problem of obesity in a way that improves health outcomes and reduces the fiscal and economic costs is based on a series of separate steps. The simplified stages in this “intervention logic” are:

- Imposing a tax will increase the price of the taxed item
- The increase in price leads to a reduction in consumption of the item
- Reducing consumption of the item leads to a reduction in energy intake
- Lower energy intake leads to lower physiological risk factors

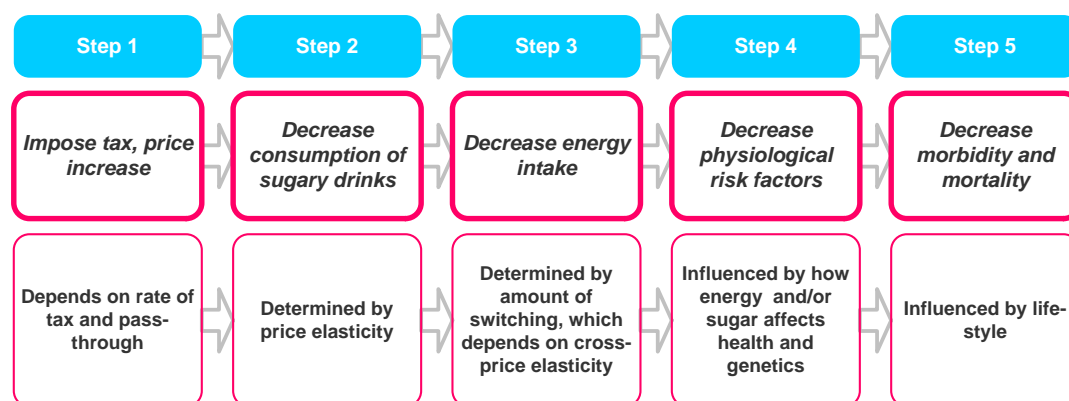
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<sup>38</sup> Samson (2014).

<sup>39</sup> Mautino (2016).

- Lower physiological risk factors lead to better health outcomes.

**Figure 4 Intervention logic**



**Source: Ministry of Health**

However, none of these steps follows automatically from the others. We address each in turn.

### 2.4.1. Step one: Impose tax, increase price

For now, we leave aside the legal or economic nature of the tax (e.g. whether it is a retail sales tax on drinks when sold, an excise imposed at the point of manufacture of the drink or a tax imposed on sugar), but will return to these matters in Section 2.5.

Most taxes on final consumer products are levied on the seller or some other entity in the supply chain, rather than being imposed on the purchaser. In New Zealand, for example, the obligation to pay GST is imposed on sellers, but experience is that the full cost of the tax is passed on to final buyers.<sup>40</sup> This is also the case with taxes like fuel excise, which is imposed at the point of import or refining, but is passed on through the various steps in the value chain until it is paid by the final consumers.

For taxes like GST, which apply to virtually all goods and services and taxes like the fuel excise, where there are few close substitutes to the taxed product, it is in the commercial interests of the seller to pass on the tax, since to not do so would reduce their profits for little commercial gain.<sup>41</sup> If, however, there are untaxed close substitutes for the product in question, then the seller may have an incentive to bear some of the economic burden of the tax themselves if they are seeking to maintain sales volume. However, in the long term, this is unlikely, since it would imply that the vendor is selling at a loss, which is not sustainable.<sup>42</sup>

<sup>40</sup> For example, when the rate of GST was increased from 12.5% to 15% in October 2010, data released by Statistics New Zealand showed that there was a high concentration of price increases in October of between 2.0 and 2.5%, with increases falling dramatically in the following two months. See: Statistics New Zealand (2010). This suggests that there was significant pass-through of the GST increase. Benedek et al. (2015) show that in the Eurozone, increases in standard rates of consumption taxes (those that apply to most goods and services) tend to be fully-passed through, but increases in rates that apply to narrower bands of goods, pass-through is significantly less.

<sup>41</sup> For a general discussion of the issue of tax incidence, see Lecture Six of Atkinson and Stiglitz (2015).

<sup>42</sup> A possible exception is that the vendor is earning excess profits which have not induced a rival to enter the market. This is also unlikely unless the vendor has some degree of market power, or example if they are a monopolist.

## 2.4.2. Step two: Decrease consumption

One of the most basic principles of economics is that increases in price lead to a reduction in quantity demanded. However, this proposition is always subject to the qualification of “everything else being equal”, or *ceteris paribus*.

Observations of what happens in actual markets when prices increase are not subject to the *ceteris paribus* qualification, as many things that might affect the quantity demanded of an item will also be changing. For example, on a hot sunny day, sellers of cool drinks might increase their prices, knowing that their thirsty customers will be willing to pay a premium for a cool drink on such days.

### Elasticities

The extent of the general (*ceteris paribus*) reduction in demand due to a price increase is determined by a factor called “price elasticity”, which measures the proportional change in demand due to a small change in price. There are two types of price elasticity that are relevant to sugar taxes: “own-price elasticity” and “cross-price elasticity”.

As the name suggests, own-price elasticity measures the change in demand due to a change in that good’s price. Because of the inverse relationship between prices and demand, own-price elasticities are negative.<sup>43</sup> Goods that are very responsive to price changes are referred to as being “(own-) price elastic”. Two types of goods that are normally highly price elastic are luxury goods (as opposed to necessities) and goods for which there are close substitutes. At the other end of the scale are “(own-price) inelastic” goods, which are necessities (basic food stuff), items for which there are no close substitutes and, importantly in the case of sugar taxes, as we will see below, things that are addictive.<sup>44</sup>

Price elasticity is not necessarily associated with levels of consumption. It measures how consumption changes when prices change, not the starting point of consumption. This is determined by income, relative prices (the price of the good compared to all other goods) and preferences. For example, some goods that people consume small amounts of occasionally (for example lightbulbs or pepper) might be very unresponsive to price changes.

The effect of close substitutes on consumption is caught by the idea of “cross-price elasticity”, which measures the change in demand for Good A when the price of Good B changes. Unlike own-price elasticity, cross-price elasticity can and often is positive as well as negative. Goods that are close substitutes (Coke and Pepsi) will generally have positive cross-price elasticity: an increase in the price of one of the goods will cause an increase in consumption of the other. Goods that are complements (toast and jam), will tend to have negative cross-price elasticity (an increase in the price of toast will cause demand for both toast and jam to fall).

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<sup>43</sup> Goods that have a positive own-price elasticity, where an increase in prices caused an increase in consumption, are known as Giffen Goods. Only one example of a Giffen Good has ever been conclusively established: potatoes during the Irish famine.

<sup>44</sup> Addiction is a term of long-standing and variable use. It is not a diagnostic term in the World Health Organization’s *International Classification of Diseases*. The WHO does, however, define a disease called “substance dependence” and the American Psychiatric Association’s *Diagnostic and Statistical Manual* (DSM V) includes “substance use disorder” as a disease. It is usually understood to mean prolonged, compulsive use of a substance, with associated tolerance (increasing amounts of the substance must be used to gain pleasure or maintain feelings of normality) and withdrawal (adverse symptoms occur if use ceases).

There is a third elasticity of demand that is also important in considering the effects of sugar taxes, and that is income elasticity, which measures the effect of changes in a consumer's income on consumption of a good. Again, income elasticity can be positive or negative. Goods that have a positive income elasticity are said to be superior goods; consumption increases with income. Food, especially high quality food (think fillet steak and caviar) is a superior good. Inferior goods are those goods with a negative income elasticity.

## The elasticities of demand for sugar

The extent to which a tax that increases the price of sugar will lead to a reduction in consumption in goods containing sugar is determined by the own-price, cross-price and income elasticity of the demand for sugar, compared to close substitutes.

In the literature review in Section 3, we examine the evidence around this question in greater detail. In this framework section, we will limit our discussion to a few important points of principle.

The first is the difference between market elasticity and individual elasticity. People have different preferences, and these preferences will lead to different elasticities. However, these individual preferences are combined when looking at what is happening in a market for a product or class of products. So, a study that only looks at the effect of price changes on market demand will say nothing about how individuals have reacted: there will be range of responses. This is important when considering the introduction of a new tax or a tax at a low level. The people who respond with the greatest reduction in demand will be those with the highest elasticity, which, as we noted above, may not be the people with the highest levels of consumption. And even if they are, they may not be the people whose health is most at risk and who would benefit most from reducing their sugar intake.

This leads on to the second point, which is about addiction. People who are addicted to a product will be price unresponsive. We see this in the case of cigarettes in New Zealand, where the significant, ongoing, increases in price have been associated with persistent use by some people. This suggests that there may be limits to the effectiveness of a tax on sugar.

Thirdly, price is not the only thing that influences demand. Preferences matter just as much, or even more so. And preferences change through time, at both the individual and societal level. Part of this is related to age: as you get older, what you like changes too. Fads and fashions come and go. What was once cool can become passé very quickly. And what was once acceptable can become unacceptable. What was once thought to be harmless and admired can become to be seen thought dangerous and bad. Smoking is a clear example here. While New Zealand has seen rates of smoking reduced because of increased taxes and other government campaigns, in other countries rates of smoking have also fallen without high taxes, as people have become aware of the adverse effects of smoking on health. For example, in the United States the rate of cigarette smoking has fallen from over 50% for males in 1965 (when the Surgeon-General issues his first warnings about the health effects of smoking) to

around 25% today, while rates of tax on cigarettes are significantly lower in the US than in other OECD countries.<sup>45</sup>

Finally, taxes that are imposed on goods that have close (untaxed) substitutes may see large reductions in consumption in the taxed good and switching to consumption of the untaxed good. The effect of this switching on health status will depend on the combined effect of the total bundle of consumption. For example, if a tax on sugary drinks results in people increasing their consumption of fatty foods (that is, if fatty foods have a positive cross-price elasticity with respect to the prices of sugary drinks), the effect on overall health outcomes might be uncertain.

### 2.4.3. Step three, decrease energy intake

This last point about the effect of a tax on one good (sugar or sugary foods and drinks) on overall health outcomes takes us to the third step in the chain of intervention logic. It is also related to what the problem the tax is trying to address.

Sugar in drinks is one source of energy and drinks are one source of sugar: but there are many others. While a tax on sugar in drinks may lead to an increase in its price, as we have seen above, the effect on health outcomes is less certain, as it depends on multiple cross-price and income elasticities and preferences.

### 2.4.4. Step four, decrease physiological risk factors

This is not a study about physiology. There is, however, one important physiological issue that we wish to discuss, and that is the idea of acceptable minimum dose.

As we understand it, in the case of tobacco, it is now accepted that there is no acceptable minimum dose and, importantly, any reduction in smoking is beneficial to health and this is universally true across the whole population. In the case of alcohol, on the other hand, for some people, moderate consumption can have beneficial health effects.

If sugar is like tobacco, then any reduction in consumption induced by a tax would be beneficial. However, if there is a level of consumption that is not harmful, then a tax might have no health benefits if the level of pre-tax consumption is below that threshold. It is likely that most people in New Zealand consume at or above that level, given our average intake of added sugars is estimated to be twice the WHO recommended maximum intake.

Thus, is it possible, though unlikely (given our level of consumption), that a sugar tax will have no or limited health benefits, while reducing overall welfare.

<sup>45</sup>

US Department of Health and Human Services (2014) and ITC Project (2014). OECD (2016) reports that in 2015, the retail price of a pack of cigarettes in the US was US\$6.23, of which 42.5% was tax. In New Zealand, the price was US\$11.85, of which taxes were 77.34%. OECD's data base and show for the United States and New Zealand, the prevalence and incidence of smoking has fallen dramatically since 1960, with the US having the lower prevalence rate (11.4% v 15% in 2015).

## 2.4.5. Step five: decrease morbidity and mortality

The final step in the intervention logic is that morbidity and mortality will be reduced and that this represents the desired welfare gain, rather than any reduction in consumption of sugar itself.

Establishing clear evidence of a link between a sugar tax and improved health outcomes requires other material factors to be considered. As with all scientific research, the test should be “with and without”, not “before and after”. That is, controlled studies that involve a treatment group and a control group provide better evidence of effectiveness than studies that just observe behaviour before and after the tax is imposed. Studies at the national level that do not have a counterfactual against which to test the results need to be treated with appropriate caution.

## 2.5. Is a tax on sugar the best way of addressing the problem?

If a sugar tax can achieve all the steps in the intervention logic set out above, then we would expect it to improve health.

However, that would not be the end of the matter. Taxes are costly to administer and comply with and, especially in the case of people who are not the target of the intervention, come with deadweight losses that reduce their welfare. They should only be introduced if they are the best way to improve health. Recent behavioural economics research suggests that other initiatives, like publicity campaigns and restricting access should also be tested to see if they have a better effect.

Governments also have choices about how a tax is imposed and these choices should also be evaluated to determine how they affect health outcomes. In Table 1, we briefly outline the features of the three most common forms of taxes that could be imposed on sugar.<sup>46</sup>

**Table 1 Different types of taxes have different effects**

	Retail sales tax	Wholesale tax	Excise
Product taxed	Sugar-sweetened beverages	Sugar-sweetened beverages	Sugar
Point of imposition	Sale to final consumers	When sugar is added to a drink	Manufacture or import
Party responsible for collection	Retailers	Manufactures of sugar-sweetened beverages	Refiners or importers of sugar

<sup>46</sup> New Zealand currently operates a broad-base consumption tax (GST), which taxes value-added at each point of the production process. It has operated retail and wholesale sales taxes in the past. Currently, New Zealand imposes excise taxes on the manufacture of alcohol and an excise-equivalent duty on imported alcohol and tobacco.

Information required to calculate tax	Amount of sugar in each drink (if tax is on sugar content) Price of drinks (if an <i>ad valorem</i> tax)	Volume of sugar added to drinks	Volume of sugar refined or imported.
Impact (if passed-through)	Increases price of sugar-sweetened beverages	Increases price of sugar-sweetened beverages	Increases price of items containing sugar, regardless of use.

Source: NZIER

## 3. Literature review

We have undertaken a review of the recent literature on the effectiveness in other jurisdictions of taxes on sugar.

### 3.1. Review methodology

The literature reviewed for this report was identified by first searching for English-language peer-reviewed papers published in the last five years with evidence of an impact of a tax or levy on sugar-sweetened beverages, sugar or sugary foods through the following databases: Econlit, Pubmed/Medline, Google Scholar, National Bureau of Economic Research (NBER), Research Papers in Economics (RePEc), Te Puna. The search used a combination of keywords and phrases, including "sugar", "soda", "sugary", "sugar-sweetened", "beverage", "drink", "tax", "levy", "impact", "effect", "evidence", "consumption" and "intake". As searching is an iterative process, other keywords were introduced later, including "elasticities", "price", etc. and additional targeted searches were added for authors with multiple relevant publications, for papers that were already known to the reviewers, or for papers identified in the references of other included papers where these appeared relevant. Opinion pieces, letters to editors, media articles, presentations, and authors' replies to comments on published papers were excluded.

### 3.2. Results

The full literature review is at Appendix A. Here we summarise the key findings.

There exists a great deal of published evidence regarding sugar taxes, highlighting the high degree of interest around the world in the potential of fiscal interventions to improve population health. Because experience with sugar taxes has been in varied settings – high-, middle- and low-income countries; valoric, volumetric, sales and excise taxes of varying magnitudes; accompanied by varying other policies and including different ranges of food and beverage items – the evidence from observational studies is more appropriately seen as several small bodies of evidence rather than one large body of evidence.

#### 3.2.1. Causality is hard to determine

In countries that have introduced a sugar tax, the presence of other factors influencing consumption, often implemented at the same time as a sugar tax, has complicated the attribution of causality of any consumption effects to the tax. No study has been able to control for:

- the effects of taxation of other foods and beverages (as in the junk food tax in Mexico, the tax on diet varieties of carbonated beverages in France, and the wide range of taxes on foods considered unhealthy in Hungary)
- the influence of media coverage and political campaigns that often precede and accompany a sugar tax



- other policies designed to enhance the effects of the tax (such as the increased availability of safe drinking water in Mexico or bans on sugary drinks in schools and public facilities).

Varying contexts may be a reason for the inconsistent results of studies that have estimated the extent to which sugar taxes are passed through to retail prices. The type of tax, the degree of market concentration, the size and type of retailer, and other market conditions are likely to explain variations from full pass-through (as in Mexico) to partial or negative pass-through (as in France), but these have not been well explored within the context of sugar taxes. More robust evidence for pass-through of sugar taxes in New Zealand would likely come from experience with taxation of other goods facing similar market conditions.

The Berkeley, California tax on sugar-sweetened beverages has been the subject of extensive research but these results should be treated with caution because this is an example of a city-wide tax where consumers have the option of purchasing from neighbouring areas. The reported reduced consumption of taxed beverages in Berkeley is often cited as evidence that a national tax on sugar-sweetened beverages would be successful at reducing consumption. It is not clear, however, how consumers would respond to the tax if there is no option of making purchases elsewhere: Berkeley provides no evidence to indicate to what extent consumers with no other option would reduce consumption entirely or just absorb the additional cost of the tax.

### 3.2.2. Estimates of elasticities

Notwithstanding these concerns, the experience with sugar taxes in Mexico, France, Hungary, and Berkeley, California suggests that consumers as a group are responsive in some way to taxation of unhealthy foods and/or the heightened awareness that tends to accompany these policies. There is also evidence that the heaviest consumers of sugar-sweetened beverages in particular – individuals with lower incomes – may be more responsive to changes in prices, as shown by the higher price elasticity estimates and higher measured declines in consumption for lower socio-economic groups. It should be noted, however, that where actual declines in consumption have been measured, these have been at the household level rather than the individual level, so it is unclear whether those individuals who would benefit most from reduced intake are in fact the ones reducing their intake. It should also be noted that responses have tended to be small, which raises the risk that estimation or measurement error, or substitutions which have not been well explored, could make the reported effect negligible.

A major concern around the evidence with regards to estimation of price elasticities is the extensive use of unit values rather than prices and the aggregation of sugar-sweetened beverages into broad categories where brand and variety are obscured. Those studies that have explored the effects of these methods and the potential for within-category substitution, which can allow consumers to maintain their intake without increasing expenditure in the face of higher prices, suggest that many published results may be optimistic and that research methodology needs more attention. Nevertheless, the results of these studies often form the basis of studies that model the long-term health outcomes expected to be associated with sugar taxes.

### 3.2.3. Links between a tax and health outcomes have been hard to find

There are very few studies linking a tax to any improvement in health status or even to physiological risk factors, and those that do have made a range of assumptions to which results are highly sensitive. The difficulty in making the link from a tax to improvements in health is that long-term effects are involved and sugar taxes have not been in place long enough for these to be captured by existing data. The best that can be done in the meantime is to accurately measure responses to price changes, control for other possible influences, and make predictions based on epidemiological models that assume behaviours will not change. Quite apart from the lack of evidence that behaviour change will be permanent, these models rely on existing estimates of elasticities which may be flawed and typically assume that few or no substitutions involving compensatory calories take place.

Some key questions have been underexplored. Although many studies attempted to identify different effects across socio-economic groups, and a few attempted to identify effects for males and females separately or across age groups or geographic areas, other groups are under-explored. In particular, it may be relevant to consider effects on the overweight or obese population, the populations with diabetes, children and adolescents, and, in New Zealand, effects by ethnicity. Although oral health – especially dental caries in children -has been used as an argument for sugar taxes, no observational study was identified that reported on this outcome. Finally, many studies analyse household level data to identify effects on consumption, but little is known about intra-household allocation: are parents reducing intake while children's intake remains constant? Are low consumers in the household reducing intake while the high consumers refuse to? Are people at higher risk of diabetes responding more than people at lower risk? These questions have important implications for the health outcomes that are estimated by long term models.

### 3.2.4. Little evidence of an optimal design

Few studies provide evidence as to the optimal design of a sugar tax. There is some evidence that a broader tax, such as an excise tax on sugar itself rather than a tax applied only to sugar-sweetened beverages, would achieve greater results (Harding and Lovenheim 2014), but most of the research is concerned with taxes on sugar-sweetened beverages.

Alongside the insights on sugar taxes that emerge from the research, there are also important considerations about alternative or complementary approaches. This review focused on sugar taxes, but the potential benefits of other food taxes and subsidies, food labelling, industry reformulation, public awareness, water availability, restrictions on marketing of unhealthy foods, and availability of sugar-sweetened beverages in and around schools should be considered as policy options in addition to or instead of sugar taxes.

## 4. Conclusion: the evidence remains inconclusive

As we noted in the section on frameworks, there are multiple steps in the chain of intervention logic from the well-established principle that an increase in the price of a good leads to a reduction in consumption of that good and, all else equal, to an improvement in health outcomes.

There have been several recent examples of governments imposing taxes on sugar with the intention of improving health outcomes and, thus an extensive literature examining the effects of those taxes.

Our conclusion is that the evidence base gets weaker further along the chain of intervention logic.

If taxes did not have economic costs, through deadweight losses and implementation costs, then even a slight causal link between a tax and an improvement in health outcomes might be justified. That, however, is not the case.

We have yet to see any clear evidence that imposing a sugar tax would meet a comprehensive cost-benefit test.

We conclude by quoting from Shemilit et al. (2013).

*Whilst economic instruments have been suggested in several studies to hold promise, mixed patterns of findings for most intervention types are likely to reflect the heterogeneous evidence base, as well as the complexity of behavioural responses to economic stimuli and of the causal pathways involved. This suggests a need for caution in developing policy based on limited evidence and overly simple assumptions about how people will respond to changes in prices and income. It does not necessarily imply that underlying economic theory, which holds that people respond rationally to incentives, or behavioural economic theory, which holds that rationality of choice is moderated by heuristics and biases attributable to various social, cognitive, and emotional factors, are flawed. Rather, it is likely that people's responses to, say, a tobacco control tax are relatively predictable, whereas their responses to, say, a tax-stimulated increase in the prices of specific foods, relative to the vast array of alternative foods available, are less predictable and more complex in their relationships to health behaviours and corollary outcomes.<sup>47</sup>*

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<sup>47</sup>

Internal references omitted.

# Appendix A Literature reviewed

This evidence review is based on a broad range of studies from 2013 to 2017. In total 47 studies were reviewed, including four systematic reviews, four evidence reviews, one cost-effectiveness study, sixteen observational studies, twenty modelling studies of long-term impacts and hypothetical taxes, one meta-analysis, and one case study.

## A.1 Systematic reviews

Four systematic reviews of studies pertaining to sugar tax were included in this evidence assessment. One review included evidence from high-income countries (Backholer et al. 2016), one review included evidence from middle-income countries (Nakhimovsky et al. 2016) and one review (Powell et al. 2013) included only US studies. The fourth review (Maniadakis et al. 2013) was broader, including a range of studies from 1999 to 2013.

All systematic reviews reported on the study findings with respect to the price elasticity of demand for sugar-sweetened beverages.

Overall conclusions were consistent regarding the effect of a tax on intake of sugar-sweetened beverages and on intake of calories from sugar-sweetened beverages (SSBs): a tax was expected to reduce consumption of SSBs by a small amount on average, with a corresponding small decrease in caloric intake, although few studies included consideration of substitution effects.

One systematic review found that studies were inconsistent with regards to differential effects across socio-economic groups: Backholer et al. (2016) reported that some studies found no difference in consumption effects for different socio-economic groups while other studies found greater effects on lower socio-economic groups.

**Backholer et al. (2016)** reviewed studies estimating the effects of an increase in the price (or a tax) of sugar-sweetened beverages on purchases or consumption and weight outcomes regressivity, within high-income countries. Price elasticity estimates varied considerably across studies as did resulting consumption changes and weight changes. The review found that few studies statistically tested differences in outcomes between socio-economic groups. Seven studies reported on changes in weight outcomes for the total population following an increase in SSB prices. Studies either found no association between a tax on sugar-sweetened beverages and BMI or a very small association, with insignificant weight loss implications of up to less than 2kg over ten years. Some found similar reductions in weight for all socio-economic groups while others found greater reductions for lower income groups compared to higher income groups. A tax on sugar-sweetened beverages was associated with a wide range of estimated impacts on the population obesity rate: from a less than 0.1 percentage point decrease in obesity prevalence to a more than 10 percent (3 percentage point based on a 30 percent obesity rate) prevalence reduction. All studies that examined the average household tax burden reported that tax on sugar-sweetened beverages would be regressive, but with small differences between higher and lower income

households (0.10-1.0% and 0.03%-0.60% of annual household income paid in tax by low- and high-income households, respectively).

**Maniatakis et al. (2013)** reviewed 55 studies published from 1990 to 2013 to assess the effects of taxes (including on sugar-sweetened beverages) on consumption of the targeted item, caloric intake, and body weight. Taxes in included studies were either excise or sales taxes. Roughly half of the studies reported only on consumption effects of the tax and the remainder reported on other outcomes such as energy intake, weight, or BMI.

The high degree of heterogeneity observed in the findings of the included studies was explained by the significant heterogeneity in policy settings and study designs employed to investigate the issue.

The relationship between prices and taxes on food and beverage items and health outcome measures was found to be very weak. Results suggested that a 10 percent increase in prices (including by imposition of a tax) would be expected to reduce energy intake by a maximum of 50 calories per day, resulting in a weight loss of up to 0.3 kilograms per year, which was deemed to be insignificant.

The reviewers conclude that the effectiveness of a taxation policy in reducing or preventing obesity is doubtful. The evidence in most studies was found to be lacking due to the complex nature of consumer behaviour especially with regards to substitution effects which were not well-explored in the included studies.

**Nakhimovsky et al. (2016)** conducted a systematic review of evidence from studies published between 1990 and 2016 from middle-income countries with regards to taxation of sugar-sweetened beverages. Outcomes of interest were post-tax price increases, changes in demand for sugar-sweetened beverages and other products, differential responses by socio-economic group, and prevalence of overweight and obesity.

Estimates for own-price elasticity ranged from -0.6 to -1.2, and decreases in consumption of sugar-sweetened beverages ranged from 5 to 39 kilojoules per person per day based on a ten percent increase in prices of sugar-sweetened beverages. Milk was found to be a likely substitute, and foods prepared away from home, snacks, and candy are likely complements to sugar-sweetened beverages. Three studies found a negative relationship between sugar-sweetened beverage prices and obesity outcomes after accounting for substitution effects.

The evidence included in the review indicates that taxing sugar-sweetened beverages will increase the price of sugar-sweetened beverages in markets with few producers. There was no evidence that taxing sugar-sweetened beverages would reduce population weight permanently. The reviewers concluded that further research based on more robust survey data and stronger study designs is needed.

**Powell et al. (2013)** conducted a systematic review of studies based on US data and estimating price elasticities of demand for sugar-sweetened beverages, fast food, and fruits and vegetables, as well as direct effects of prices/taxes on body weight.

Ten studies were identified that provided price elasticity of demand estimates. The mean price elasticity of demand for sugar-sweetened beverages was -1.21, suggesting that a 20 percent increase in the price of sugar-sweetened beverages would reduce demand by 24 percent.

Evidence linking changes in food and beverage prices to changes in weight was considered to be mixed. Associations tended to be small or statistically insignificant. For sugar-sweetened beverages in particular: one study found a very small association between soda taxes and weight outcomes for adults; one found no association between obesity and the price of regular soft drinks for children and adolescents; four studies found no or limited associations between soda taxes and children's and adolescents' weight outcomes; and one study found that higher soda taxes were associated with lower weight gains, particularly in overweight children.

## A.2 Evidence reviews

Four studies were identified that reviewed selected evidence of sugar-sweetened beverage taxes. Two were concerned with the Mexican experience, and one of these (Andalon and Gibson 2017) sought to expose fundamental flaws in the methods used to estimate price elasticities in previously published studies. One study reviewed evidence and analysed New Zealand data and one study presented evidence for low-, middle- and high-income countries separately.

**Bonilla-Chacin (2016)** summarised evidence on the Mexican experience with taxes on sugar-sweetened beverages and calorie-dense foods of low nutritional value for a World Bank Knowledge Brief. The review of the evidence suggested that the tax had been successful at raising prices and revenues. There was also some evidence that the consumption of sugar-sweetened beverages had decreased, however the magnitude of the decrease is unclear and there is no evidence of impact on health outcomes. Across income quintiles, the own-price elasticity of demand for sugar-sweetened beverages decreases with income quintile; while the own price elasticity of demand for sodas is highest among people in the middle of the income distribution. Insufficient evidence exists to determine whether any of the effects of the taxes in Mexico will be sustained over the long term.

**Andalon and Gibson (2017)** reviewed a number of observational studies based on the Mexican tax with regards to methodology and implications for estimates of price elasticity of demand for sugar-sweetened beverages. The authors found that many previously published studies were subject to significant methodological flaws resulting from a lack of price data and the use of unit values as proxies for prices. Because unit values are calculated as expenditure divided by quantity, these measures conflate two types of consumer response to a price increase: a reduction in quantity purchased and a shift toward lower-priced items. The authors show, using Mexican data including specific price information, that without any ability to observe or measure the consumer shift to lower-priced items, previous studies have assumed that the observed changes in consumption have been entirely due to a reduction in quantity purchased. Consequently, those studies have overestimated the price elasticity of demand. The study shows that when prices are included instead of unit values, the reduction in quantity purchased is much lower than previously published estimates suggest and the tax on sugar-sweetened beverages in Mexico is unlikely to have made any difference to body weight significant enough to translate into health benefits.

**Gardiner (2017)** included three parts to this working paper: a description of the problem motivating the sugar tax debate; a review of some of the literature on effects of sugar taxes; and, an analysis of New Zealand household survey data to determine

the potential incidence of a SSB tax and a broader sugar tax on New Zealand households.

The report highlights the weak links in the intervention logic from a tax to a price increase, to a reduction in consumption, to reduced caloric or sugar intake, to reduced risk factors, and ultimately to reduced morbidity and mortality.

The paper notes that when the percentage of total energy intake attributable to SSBs is considered, a tax appears to be poorly targeted. It cites New Zealand Ministry of Health data that suggests five percent of total energy intake is attributable to non-alcoholic beverages (some of which will not be sugar-sweetened beverages), these being the fifth most important contributor to total energy intake. As a percentage of total sugar intake, sugar-sweetened beverages are more important but are still only the second highest source of sugar for New Zealand adults.

**Sassi et al. (2013)** reviewed the evidence on the role of fiscal policies, including taxes, for health promotion. The review noted that policies across various countries are heterogeneous and that the effectiveness of the tax is determined in part by the design of the tax, noting that because the key public health rationale for taxes on foods and beverages is their ability to change people's consumption behaviours, the proximity of the tax point to the behaviour being targeted is a key issue for its effectiveness: the closer the tax to the behaviour, the more likely the tax is to have the desired effect. This is particularly relevant to the debate about excise taxes versus sales taxes.

The review also noted that studies undertaken in different countries provide a range of elasticity estimates for foods and non-alcoholic beverages, with these estimates being partly dependent on the definitions and the ways in which food categories are aggregated to facilitate estimation. The demand for most foods is inelastic, and more so in higher income countries, with published estimates of the price elasticity of demand for sugar-sweetened beverages in high-income countries ranging from  $-0.48$  to  $-0.65$ . However, if people are aware that a product was taxed for public health reasons, they may have a higher price elasticity of demand. Cross-price elasticities indicate that the potential for substitution across beverage categories is high.

### A.3 Cost-effectiveness and cost-benefit studies

One cost-effectiveness study was included in this review.

**Gortmaker et al. (2015)** built cost-effectiveness models of the nationwide implementation of four childhood obesity interventions in the United States, including an excise tax on sugar-sweetened beverages. Outcomes were estimated for a simulated cohort representative of the 2015 US population over 10 years (2015–2025). A societal perspective was used, with future outcomes discounted at 3 percent.

Previously published elasticities of demand were used to estimate reductions in sugar-sweetened beverage consumption. No consideration of substitution to other sources of calories or sugar was made.

The population reach of the interventions varied widely, and the cost per BMI change ranged from US\$1.16 for eliminating a subsidy on TV advertising to children to US\$401 for active physical education. After 10 years, assuming maintenance of the intervention effect, the tax on sugar-sweetened beverages was estimated to save US\$55 for every dollar spent, and elimination of subsidies on TV advertising to children



was estimated to save US\$38 for every dollar spent. The model also predicted that the sugar-sweetened beverage tax would avert disability-adjusted life years, and increase quality-adjusted life years. Yearly revenue from the tax was estimated at US\$12.5 billion.

## A.4 Observational studies

Sixteen observational studies were included in this evidence review. Five of these pertained to the Mexican experience, five pertained to the Berkeley, California experience, three used other US data, one pertained to the Hungarian experience with unhealthy foods taxes, and one pertained to the French soda tax. One study was based on New Zealand price elasticities that might be relevant to a sugar tax and another estimation of elasticities was based on Ecuadorian data.

The Mexican government implemented an excise tax of 1 Mexican peso per litre (about 5.5 US cents) to all non-alcoholic beverages with added sugar starting in January 2014. The tax is applied to carbonated beverages, flavoured waters, sweetened teas, sweetened milks, sweetened sports drinks, and energy drinks with added sugar. It excludes beverages with artificial sweeteners and 100 percent fruit and/or vegetable juices.

Berkeley, California was the first US city to implement an excise tax on sugar-sweetened beverages in January 2015. The one cent per ounce tax was approved by 76 percent of Berkeley voters. Because Berkeley is only twenty kilometres from San Francisco, which does not have a tax on sugar-sweetened beverages, it is not clear how relevant consumption effects estimated for Berkeley might be for national taxes.

The Hungarian Public Health Product Tax, otherwise known as the Hungarian 'junk food tax' was introduced in 2011 with the objective of improving population health. The tax applies to broad categories of pre-packaged food and beverage items that are high in salt, sugar or caffeine. In the years that followed the implementation of the tax, the Hungarian government introduced a number of other measures intended to improve population health, including restrictions on foods served at public canteens, regulation of trans fat content, and provision of healthy foods in schools.

The French tax was implemented on 1 January 2012, and applied to both sugar-sweetened and artificially-sweetened varieties of non-alcoholic beverages. The tax was set at 7.16 Euros per hectoliter, corresponding to approximately 11 Euro cents on a 1.5 litre bottle, or approximately six percent of the average price of soda.

Various taxes on sugar-sweetened beverages or carbonated beverages are in place in a number of US states. Many of these were implemented to raise revenues rather than as public health measures, although a number of new taxes on sugar-sweetened beverages have been implemented recently and some of these have improvements in population health as an objective. The US taxes are typically lower than other examples around the world and are more often implemented as additional sales taxes.

**Andalon and Gibson (2017)** estimate the price elasticity of demand for sugar-sweetened beverages in Mexico, using robust methods and data that is sufficiently detailed to allow separate identification of both possible consumer responses to a price increase: a reduction in quantity purchased and a shift toward lower-priced items.



Resulting price elasticity estimates of -0.2 to -0.3 suggest that the 10 percent Mexican tax would have resulted in a two to three percent reduction in consumption of sugar-sweetened beverages. A key feature of this study is the comparison of methods and results with previously published studies. The use of incorrect methods arising from a lack of price data was found to be associated with estimated elasticities that are four to six times higher. The authors point out that those over-estimates have been influential in public discussion of sugar taxes, including the WHO advice that a 20 percent tax on sugar-sweetened beverages would result in proportional reductions in consumption. The study also demonstrates the impact of the lower price elasticity estimates by calculating the expected weight loss under the assumption that there is no substitution for sugar or calories. Using the methodology of Grogger (2016), the estimated price elasticities are expected to result in an average weight reduction of approximately 400g – significantly less than the 1-2 kg weight loss associated with higher estimates of price elasticity.

**Berardi et al. (2017)** estimated the extent to which the French tax beverage tax, an excise tax on both sugar-sweetened and artificially-sweetened varieties, was passed through to prices. A difference-in-differences approach was used along with fixed effects models.

The study found that the tax was gradually passed through to the prices of the taxed beverages: six months post-implementation, the tax was fully shifted to soda prices and almost fully shifted to the prices of fruit drinks, while the pass-through for flavoured waters was incomplete at approximately 85 percent. Pass-through was also found to be heterogeneous across brands and retail groups: some retailing groups were found to have over-shifted the tax on their own brands while others had taken an opposite approach. The authors suggest that the impact of a tax is strongly dependent on the nature of competition that prevails in the market. The study did not attempt to estimate price elasticity of demand, effects on consumption of sugar or sweetened beverages, or impacts on weight or health.

**Biro et al. (2015)** analysed Hungarian data for evidence of a price increase in food items targeted by the Hungarian junk food tax. Beverages were excluded from the analysis due to a lack of data that would allow meaningful categorisation of beverage types. The available data also did not allow for specific identification of taxed and untaxed foods. Consequently the analysis identified processed and unprocessed foods, with unprocessed foods known to be untaxed and processed foods known to include many taxed items. The results of the study indicate that the prices of processed foods that were identified as potentially taxable rose faster than the rate of food inflation from 2011 to 2012 and increased at the rate of food inflation thereafter. It was noted that the import price of sugar had also increased drastically in 2011. The study also measured consumption of processed foods after the introduction of the tax and found a 3.4 percent reduction alongside a 1.1 percent increase in the quantity of unprocessed food consumed. Quantities of food were measured in kilograms. Sugar and calorie content were not estimated, so no estimates of sugar or calorie intake were produced.

**Cawley and Frisvold (2015)** estimated the pass-through of the Berkeley, California tax on sugar-sweetened beverages using prices of various brands and sizes of taxed items and other beverages before and after the implementation of the tax from convenience stores and supermarkets in Berkeley and San Francisco. Estimates are derived from a difference-in-differences model in which the post-tax trend in prices is compared to

the trend in neighbouring San Francisco, where a tax was considered but not introduced.

The study noted that prices varied considerably within both cities in each time period and this was considered to be an indication of differing retail costs, and/or differing shoppers' elasticities of demand. It was also noted that price variation is consistent with imperfect information, costly search, and difficulties to arbitrage. The authors suggest that previous studies' estimates of pass-through of the tax may have been biased due to the use of average prices.

The results indicate that pass-through of the Berkeley tax was incomplete, with pass-through percentages from 14 percent to 50 percent five months after the tax was implemented. On average, across a range of brands and sizes, retail prices rose by less than half of the amount of the tax.

**Colantuoni and Rojas (2015)** estimated the effect of two state-level taxes on sugar-sweetened beverages: the 5.5 percent sales tax on soft drinks implemented in Maine in 1991 and the 5 percent sales tax on soft drinks implemented in Ohio in 2003.

Using a scanner data on sales and pre-tax prices in supermarkets across cities in Maine and Ohio as well as cities in states without a tax, the study estimates effects on prices and sales through a difference-in-difference matching estimator approach.

The analysis found no statistically significant difference in pre-tax price or sales volume from three quarters before the tax was applied to three quarters after the tax was applied. The lack of effect on price was taken as an indication that the tax was fully passed through to consumers. A more recent dataset for Maine (2001-2006) was also analysed to determine whether increased awareness had increased consumer responsiveness to the tax. Results showed no statistically significant difference in sales. The authors suggest that the use of elasticities to form counterfactuals of consumer response may be inappropriate as they will predict an actual reduction in consumption which may or may not occur depending on how visible the tax is to consumers. A limitation of the analysis is that Maine also had a tax on other high calorie foods, which may have limited substitution to other sources of sugar and calories. This could not have affected the results for Ohio, however, as Ohio did not have a tax on potential substitutes.

**Colchero et al. (2015)** used US household survey data based on recall by the household head to estimate price elasticity and cross-price elasticity of demand for sugar-sweetened beverages. Estimates were derived from an almost ideal demand system with linear approximation for beverages and high-energy foods by simultaneous equations. Due to the absence of price data, the study relied on unit values derived from household expenditure and volumes from which to estimate price elasticities. A further limitation of the data was the inability to differentiate between diet- and non-diet soft drinks. The resulting price elasticities were -1.06 for soft drinks and -1.16 for all sugar-sweetened beverages. Cross-price elasticities suggested that a price increase for soft drinks would be expected to result in increased consumption of water, milk, snacks and sugar alongside decreased consumption of other sugar-sweetened beverages, candies and traditional snacks. The cross-price elasticities were noted as indications that further research into possible substitution to other sources of sugar or calories needed further investigation.

**Colchero et al. (2016a)** estimated the reduction in consumption of sugar-sweetened beverages in Mexico in the year after the tax was implemented using difference-in-differences analysis with fixed effects models based on household survey data. Household data was collected from the household head and relied on consumer recall. The data included the number of units purchased, and the volume and price of each unit. Noting that purchases of sugar-sweetened beverages were already declining for all socio-economic groups before the tax was implemented, a counterfactual of continued decline, based on observed trends was constructed for the difference-in-differences analysis.

Results suggest that consumption of sugar-sweetened beverages declined relative to the counterfactual for all socio-economic groups, with the difference between the counterfactual level of consumption and the estimated level of consumption widening over time, reaching a 12 percent decline relative to the counterfactual by December 2014, for an average decline of 6 percent over the year. Reductions relative to the counterfactual were found to be greater for households in lower socio-economic groups.

Changes in sugar intake and caloric intake were not able to be measured due to a lack of data on the nutritional content of beverages consumed. Substitutions to untaxed beverages were noted and attributed mainly to an increase in purchases of bottled water.

The study provided no estimates of effects on body weight or health. The counterfactual was limited in that data on consumption of dairy-based drinks was incomplete. The analysis did not control for other effects that may have contributed to the accelerated decline in consumption, including the Mexican junk food tax, the increased availability of clean drinking water, and increased public awareness of the health effects of excess sugar consumption.

**Colchero et al. (2016b)** used the Monthly Surveys of the Manufacturing Industry to estimate changes in sales of sugar-sweetened beverages and plain water after the introduction of the Mexican sugar tax. Sales data are recorded in monetary terms as well as by volume. The study estimated Ordinary Least Squares models to assess changes in per capita sales (in litres per capita) after adjusting for seasonality and the Global Indicator of Economic Activity (GIEA), with a dummy variable representing the pre- and post-tax periods. The categories of beverages assumed to represent sugar-sweetened beverages contained a mixture of sugar-sweetened and artificially-sweetened beverages.

Results suggested that without taking into account population growth, seasonality and general economic activity, sales of sugar-sweetened beverages appear to have increased subsequent to implementation of the tax. Population growth was found to reduce the magnitude of the increase. Further controlling for season and general economic activity result in a 7.3 percent decrease in per capita sales of sugar-sweetened beverages and an increase of 5.2 percent in per capita sales of plain water in 2014–2015 compared to the pre-tax period (2007–2013).

This study did not attempt to estimate the extent to which the tax was passed through to prices, the extent of consumer substitution within or outside the category of taxed beverages, or total intake of sugar or calories. No conclusions are drawn with respect to health outcomes.

**Colchero (2017)** estimated changes in purchases of sugar-sweetened beverages in Mexico for 2014 and 2015 using purchase data for 6,645 households from January 2012 to December 2015. The purchase data was collected directly from households in the form of receipts, empty packages, and daily reports or food and beverage purchase diaries. All items with a barcode or packaging with brand and size information was included. Volume per capita per day was calculated by summing the volumes of beverages in the taxed and untaxed categories and dividing by the survey population.

The model used to estimate changes in purchases was the same as used in Colchero et al. (2016a), namely a difference-in-differences analysis, with two adjustments: a control for inflation was introduced and two separate models were estimated for 2014 relative to the counterfactual and 2015 relative to the counterfactual.

Purchases of taxed beverages were found to have decreased by 5.5 percent in 2014 and 9.7 percent in 2015, for an average reduction of 7.6 percent over the two years. Households at the lowest socio-economic level had the largest decreases in purchases of taxed beverages in both years. Purchases of untaxed beverage increased 2.1 percent in the study period.

Limitations were acknowledged to include: the inability to attribute causality to the tax due to an inability to fully control for other changes that occurred simultaneously, including the 8 percent ad valorem tax on energy-dense foods implemented at the same time, increased public awareness of the health impacts of excess sugar consumption, and other Mexican government regulation especially with regards to food and beverages in schools and marketing to children. The construction of a counterfactual was also limited by the lack of data on sales of dairy-based beverages, a category which includes both taxed and untaxed items that may be substitutes for non-dairy beverages. The authors further acknowledge that the household survey purchase data suggests significantly different consumption from industry sales data, with industry sales data suggesting that per capita consumption of sugar-sweetened beverages is approximately 50 percent higher than the household survey data indicated. The study did not attempt to estimate sugar intake or calorie intake from beverages or in total, nor did it attempt to draw conclusions as to the specific health impacts of the tax.

**Falbe et al. (2016)** evaluated the impact of the excise tax on sugar-sweetened beverage consumption in Berkeley, California, using a repeated cross-sectional design to examine changes between pre-tax consumption and post-tax consumption in low-income neighbourhoods in Berkeley, compared with the cities of Oakland and San Francisco, California, where no tax had been introduced. A beverage frequency questionnaire was interviewer-administered to 990 self-selected participants before the tax and 1689 after the tax (approximately 8 months after the vote and 4 months after implementation) to examine relative changes in consumption.

The study found that consumption of sugar-sweetened beverages had decreased 21 percent in Berkeley and increased 4 percent in comparison cities, while water consumption increased more in Berkeley than in comparison cities.

The study did not validate self-reported consumption data against sales data or attempt to identify substitution effects.

**Grogger (2016)** analysed data from Mexico's Consumer Price Index program, using a synthetic control method and time-series intervention analysis to estimate the extent

to which prices of sugar-sweetened beverages increased after the Mexican tax was implemented.

The estimates suggest that the tax was more than fully passed-through to prices. Analysis of the prices of substitute beverages was not able to identify an associated price increase which was considered as a possible indication that consumers did not substitute to unsweetened beverages. The study goes on to estimate the weight loss that would be associated with the observed price increase for sugar-sweetened beverages, using assumed caloric content of sugar-sweetened beverages, previously published estimates of relatively elastic demand and the Harris-Benedict equation, which calculates basal metabolic rate as a function of weight and weight loss as a function of basal metabolic weight. Resulting weight loss, based on no substitution for sugar or calories from other sources, was estimated to be 1.6 to 2.7 percent of mean BMI – 1 to 1.5kg in the year after the tax was implemented.

**Ni Mhurchu et al. (2013)** estimated price elasticities and cross-price elasticities of demand for 24 commonly consumed food groups in New Zealand, by income and ethnicity, using an Almost Ideal Demand System. Estimates of elasticities were based on food expenditure data (not prices) from national household surveys in 2007/08 and 2009/10 and Food Price Index data from 2007 and 2010. Price elasticities for sugar-sweetened beverages were estimated to be in the range of from –0.44 to –1.78, with –1.27 being the price elasticity estimate for carbonated soft drinks (including sugar-sweetened and artificially and unsweetened varieties). Cross-price elasticity estimates were smaller. Carbonated soft drinks had the highest price elasticities in quintiles 1, 2 and 4. Māori people had the lowest price elasticity of demand for carbonated soft drinks, although all groups' demand for carbonated soft drinks was estimated to be relatively elastic. No attempt was made to correct for endogeneity resulting from the use of expenditures in lieu of prices.

**Silver et al. (2017)** examined the effects of the one cent per ounce excise tax on sugar-sweetened beverages in Berkeley, California, on prices, sales, store revenue, consumer spending, and intake of sugar-sweetened beverages. The study consisted of a comparison of pre-taxation (before 1 January 2015) and first-year post-taxation (1 March 2015–29 February 2016) measures of: beverage prices at 26 Berkeley stores; point-of-sale scanner data on beverage prices, sales, and store revenue for two supermarket chains covering three Berkeley and six control non-Berkeley large supermarkets in adjacent cities; and a telephone survey of 957 adult Berkeley residents.

Tax pass-through for sugar-sweetened beverages was found to have varied in degree and timing by store type and beverage type. Pass-through was 100 percent in large chain supermarkets, small chain supermarkets and chain gas stations, partial in pharmacies, and negative in independent corner stores and independent gas stations.

Sales-unweighted mean price change from scanner data was +0.67¢/oz. For sodas and energy drinks, the price change was +0.65¢/oz and +1.09¢/oz respectively, while price changes were lower in other categories.

Scanner data revealed that sales of sugar-sweetened beverages in Berkeley stores had declined 9.6 percent compared to the counterfactual estimate. Non-Berkeley stores experienced an increase in sales of 6.9 percent for non-Berkeley stores. Sales of untaxed beverages in Berkeley stores rose by 3.5 percent compared with 0.5 percent for non-Berkeley stores. Bottled water sales in Berkeley increased 15.6 percent;

untaxed fruit, vegetable, and tea drinks, by 4.37 percent; and plain milk, by 0.63 percent. Revenue and consumer spending (measured in dollars per transaction) fell by less in Berkeley than in comparison stores.

Baseline and post-tax Berkeley sales of sugar-sweetened beverages and usual dietary intake were significantly lower than the national average (45 kcal/day in Berkeley compared with 131 kcal/day nationally). Reductions were measured by self-reported mean daily sugar-sweetened beverage (-19.8 percent) intake obtained by telephone survey. When converted into grams of sugar, the reductions in intake were not statistically significant.

**Taylor et al. (2016)** examined how consumers alter their behaviour due to a local excise tax aimed at reducing sugar consumption by targeting sugar-sweetened beverages. A key question was whether behaviour change was caused by the tax or by media coverage and resulting heightened awareness of the issue. The Berkeley California tax on sugar-sweetened beverages was different to the Mexico tax, in that Berkeley residents were aware of the campaign and played an active part in bringing about the tax, whereas Mexicans were mostly surprised by the tax and public awareness campaigns that began simultaneously, making causality difficult to attribute in the Mexican case.

Using panel data of product purchases from university retailers in Berkeley, California, the study measures the consumption effects of a soda tax campaign and election. A difference-in-differences approach was used alongside an event study empirical strategy to estimate the change in soda consumed relative to the change in consumption of control product categories, identified as products sold by the same retail outlets with the same pre-tax-campaign sales trend as soda. The analysis compares the pre-campaign period to three separate post-campaign periods: The pre-election campaign period July 2014 to October 2014; The post-election but pre-implementation period November 2014-February 2015; and, the post-implementation period March 2015-December 2015. The authors also note that while the City of Berkeley implemented the SSB tax in March 2015, campus retailers did not begin receiving the tax on invoices from vendors until August 2015, and did not pass the tax on to consumers until August 2016, which is after the end of the sample period, so that any change in beverage purchases estimated for the study sample are not attributable to a price increase at the retail outlets covered by the study.

The results of the analysis show that, compared with control categories which exhibited the same pre-campaign trends, soda sales dropped by a small and insignificant amount during the soda tax campaign, and then dropped significantly (-30 percent) immediately after the election, several months before the tax was implemented. Using the same data, beverages were found to be inelastic goods, suggesting that the tax had potential as a revenue earner.

## A.5 Experimental studies

Experimental studies are based on observations from experiments on a group of individuals recruited to simulate the impact of a change in one or more independent variables.

Two experimental studies were identified. Both studies randomly allocated individuals to an intervention group and a control group. One study (Bollard et al.) was based in



New Zealand. The other (Gollust et al. 2017) was based in the US. Both studies aimed to assess effects on young people.

One study (Bollard et al.), administered an online survey to gauge young people's perceptions of packaging, labels and taxes on sugar-sweetened beverages. The other study administered an online survey to university students to determine whether the rationale for a sugar-sweetened beverage tax would influence consumer responsiveness to the tax.

Neither experiment involved subjects making actual purchasing decisions facing actual prices and a budget constraint.

**Bollard et al. (2016)** conducted a New Zealand-based experiment designed to assess the effects of plain packaging, warning labels, and a 20 percent tax on predicted sugar-sweetened beverage preferences, beliefs and purchase probabilities in young people. The between-group experimental study was conducted over a one-week period in August 2014. Interventions were delivered and outcome data was collected via an anonymous online survey. Participants consisted of 604 young people (aged 13–24) who self-identified as regular consumers of soft drinks. A computer-generated algorithm randomly allocated participants to be exposed to one of 12 experimental conditions involving images of branded beverages or plain packaged beverages, with either no warning, a text warning, or a graphic warning, and with or without a 20 percent tax. Participant perceptions of the allocated product and of those who might consume the product were measured using seven-point Likert scales.

All three intervention scenarios had a significant negative effect on preferences for sugar-sweetened beverages. Plain packaging and warning labels also had a significant negative impact on reported likelihood of purchasing sugar-sweetened beverages. The reduction in purchase probability associated with the 20 percent tax on sugar-sweetened beverages was not statistically significant.

**Gollust et al. (2017)** set out to identify whether the rationale provided for a sugar-sweetened beverage tax-induced price increase affects young adults' intentions and attitudes towards sugar-sweetened beverages. Participants were randomly assigned to receive one of eight sugar-sweetened beverage price increase rationales, including obesity reduction, healthcare cost offset, children's health concerns, and no rationale. Intentions and attitudes were measured by way of a forty-six-item cross-sectional - internet-based survey of 494 undergraduate students at a large US Midwestern university.

Rationale type was significantly associated with differences in participants' purchasing intentions. Presenting the rationale for a sugar-sweetened beverage price increase as a user fee, an effort to reduce obesity, a strategy to offset healthcare costs or to protect children led to reduced purchasing intentions compared with a message with no rationale. A significant association was also identified between rationale type and differences in perceptions of soda companies. For low consumers of sugar-sweetened beverages, messages describing the price increase as a user fee or tax led to more negative perceptions of soda companies.

## A.6 Modelling studies of long-term impacts and hypothetical sugar taxes

Twenty studies were reviewed that included modelling of future impacts of existing taxes or hypothetical taxes. All of these were based on a tax on sugar-sweetened beverages although one (Harding and Lovenheim 2014) compared the product tax to a nutrient tax (sugar-sweetened beverages versus sugar).

Two of the studies (Sanchez Romero 2016 and Barrientos-Gutierrez 2017) modelled future impacts of the Mexican tax on sugar-sweetened beverages based on results of previously published observational studies. Both studies assumed reported effects would be maintained over the long term to generate future population health impacts.

Four studies modelled an industry levy on sugar-sweetened beverages in the UK, with one (Briggs 2017) being based on the proposed tax, due to be implemented in 2018. That study also took a unique approach in modelling effects of possible industry response to the levy.

Four studies modelled a hypothetical tax on sugar-sweetened beverages in Australia and seven studies modelled hypothetical taxes on sugar-sweetened beverages in the United States. One study modelled an Irish tax (Briggs et al. 2013a), and one study modelled a German tax (Schwendicke 2017), and one modelled an Indian tax on sugar-sweetened beverages (Basu et al. 2014).

Three studies modelled ad valorem taxes of 10 and 20 percent. Ten studies modelled excise taxes. Three studies compared excise and ad valorem taxes or other tax scenarios. One study (Zhen 2014a) compared a tax based on calorie content to a simple volume-based tax.

Nine studies used previously published estimates of price elasticities to model impacts of taxes and eleven studies either estimated elasticities or changes in consumption.

**Barrientos-Gutierrez et al. (2017)** modelled the expected population weight and diabetes impact of the 1-peso-per-litre tax to sugar-sweetened beverages in Mexico to determine what effect on body mass index, obesity and diabetes can be expected in the future if estimated short-term effects are maintained over the long run. Assumed reductions in beverage purchases due to the tax were based on previously published estimates. These impacts were inputted to a microsimulation Markov population model using a nationally representative dataset built into an age-period-cohort model of diabetes incidence to identify long-term impacts on body mass index (BMI), obesity and diabetes. To analyse the potential of tax increases the study also modelled a 2-peso-per-litre tax scenario.

Ten years after the implementation of the tax, the model predicted an average reduction of 0.15 kg/m<sup>2</sup> per person, resulting in a 2.54% reduction in obesity prevalence. People in the lowest income groups and those aged between 20 and 35 experienced the largest reductions in BMI. By 2030, under the current 1-peso-per-litre, 86,000 to 134,000 cases of type 2 diabetes would have been avoided. The 2-peso-per-litre scenario was estimated to produce twice the reduction. The estimates assume that the effect of the tax on consumption is maintained over time. No substitutions were considered as potential sources of sugar or calorie substitution.

**Basu et al. (2014)** attempted to estimate the potential health effects of a 20 percent excise tax on sugar-sweetened beverages in India across socio-demographic groups.



Data on consumption and household characteristics were drawn from the India National Sample Survey (NSS), a cross-sectional survey which collected data from household heads based on consumer recall. The NSS also included price data for beverage categories with district level validation of reported prices.

It is unclear whether price elasticities, estimated using a Quadratic Almost Ideal Demand System, were calculated from prices for broad categories of beverages or from unit values or budget shares.

The estimated price elasticity of demand for sugar-sweetened beverages is -0.94. Cross-price elasticities for beverage categories were estimated but not reported.

Based on baseline consumption and the estimated elasticities, and assuming full pass-through of the tax, changes in consumption of sugar-sweetened beverage consumption were estimated. A 0.94 percent decline was observed for each 1% increase in price, resulting in an 18.8 percent reduction in consumption for a fully passed-through 20 percent excise tax. This reduction in consumption translated into a reduction in the prevalence of overweight and obesity of 1.6 to 5.9 percent and a reduction in type 2 diabetes incidence by 1.2 to 1.9 percent. Younger, male, low-income, and rural populations experienced the largest declines relative to baseline.

**Briggs et al. (2013)** conducted an econometric and comparative risk assessment modelling study of a hypothetical 20 percent tax on sugar-sweetened beverages in the UK. The tax is assumed to be fully passed on to the consumer. The model generated outcome estimates for the number and percentage of overweight and obese adults as well as the amount of tax revenue generated by the tax and the impact on weekly expenditures for adults aged 16 and over, by income group, by age group and by constituent country. Data on sugar-sweetened beverage consumption was drawn from a national nutrition survey at the individual level, based on a four-day food and drink diary. Beverage categories were matched to the Living Costs and Food Survey. National Health Surveys provided estimates of prevalence of overweight and obesity.

The price elasticities of demand for sugar-sweetened beverages and other categories were estimated by applying a Bayesian approach to an Almost Ideal Demand System to ensure that substitutions are consistent across food and beverage groups and the budget remains constant. The study treated quantity demanded as a latent variable due to the possibility that household stocks can be built up and run down so that purchases may not reflect consumption in any given period. A comparative risk assessment model known as PRIME was used to estimate the effects of dietary change on mortality due to chronic disease in the UK.

The price elasticity of sugar-sweetened beverages was estimated to be between -0.81 and -0.92. Diet varieties had cross-price elasticities indicating they were likely substitutes for sugar-sweetened beverages. Elasticities varied between -0.79 and -1.03 across income groups with those with the lowest incomes having the highest price elasticity of demand for concentrated beverages and the lowest price elasticity of all income groups for non-concentrated beverages. Cross-price elasticities indicated that substitution effects would be larger for lower income groups. The estimated reduction in sugar-sweetened beverage consumption was between 15 and 16 percent with significant compensatory increases in the consumption of diet drinks, tea and coffee, milk and fruit juice. The lowest income group showed a greater tendency to substitute to diet varieties and fruit juice. Reductions in energy intake were estimated to be 16.7kJ per person per day on average with those in the highest income groups

predicted to have the greatest reductions in energy intake. The model predicted a 1.3 percent reduction in the number of obese people in the UK, again with the biggest reduction being in the highest income group. In total, the tax is estimated to generate £276m annually, with the highest increase in expenditure occurring in the lowest income group. Substitutions outside the beverage category were not considered.

**Briggs et al. (2013a)** used assumed price elasticities based on previously published studies to calculate the effect of a 10 percent tax (assumed to be fully passed through to consumers) on energy intake and obesity. The price elasticity of demand for sugar-sweetened beverages was assumed to be -0.9 based on previously published studies, one being a systematic review of US studies and the other being an observational study of an Irish tax on sugar-sweetened and artificially-sweetened beverages in the 1980s. The study used the Survey on Lifestyle and Attitude to Nutrition to estimate national consumption of sugar-sweetened beverages within two broad categories: fizzy soft drinks, which included diet varieties as well as sugar-sweetened varieties, and fruit squash. Consumption by age, sex and income group was estimated from data on consumption of carbonated and non-carbonated sugar-sweetened beverages from a Willet food frequency questionnaire. The prevalence of obesity was estimated from self-reported BMI in the same survey. A comparative risk assessment model known as PRIME was used to estimate changes in the obese and overweight population using estimated changes in intake of energy.

A 10 percent tax on sugar-sweetened beverages was estimated to result in a mean reduction in energy intake of 2.1 kcal per person per day, with the biggest reductions among the young, lower income women and higher income men. The tax is predicted to reduce the obese population in Ireland by 1.3 percent.

**Briggs et al. (2017)** attempted to estimate the potential effects of the proposed UK levy on sugar-sweetened beverages by considering three possible industry responses: reformulation of SSBs to reduce sugar concentration; an increase in the price of SSBs and potentially non-sugar-sweetened beverages produced by the manufacturers of SSBs; and, a change in the market share of high sugar, mid-sugar, and low-sugar SSBs. The possible outcomes of the levy are evaluated using a comparative risk assessment model.

The UK government has explained that the purpose of the levy is not to raise prices to consumers but rather to motivate product reformulation. For each possible industry response, the study defines a best case and worst case scenario described as a set of assumptions. For each scenario, a comparative risk assessment model estimates the effect of changes in purchases of sugar-sweetened beverages and the associated impact on tooth decay, on the incidence of type 2 diabetes, and on the prevalence of obesity. Outcomes were estimated using a two-step process involving first calculating the effect of consumption of sugar-sweetened beverages on the risk of disease, and then calculating the effect on disease incidence and prevalence due to changes in consumption. Relationships between risk factors and diseases are assumed to be causal. Results were applied to the 2014 UK population and describe what the incidence of tooth decay and type 2 diabetes, and the prevalence of obesity would be if consumption patterns followed estimated patterns for a number of years.

A 30 percent reduction in the sugar content of all high-sugar drinks and a 15 percent reduction in mid-sugar drinks was estimated to result in 144,000 fewer adults and

children with obesity, 19,000 fewer cases of type 2 diabetes per year, and 269,000 fewer teeth suffering from tooth decay annually.

Passing on half of the cost of the levy to consumers leading to an increase in the price of high and mid-sugar drinks of up to 20% was estimated to reduce the number of adults and children with obesity by 81,600, result in 10,800 fewer cases of diabetes and 149,000 fewer decaying teeth per year.

The study also included two possible unintended outcomes: intensified marketing of mid-sugar varieties which could result in consumers switching from both high and low sugar varieties, which was estimated to result in potentially negative health effects; and, manufacturers could pass on the levy across all drinks or other products in their portfolio rather than just those targeted by the levy, which was estimated to attenuate the effect of the levy on reducing consumption of sugar-sweetened beverages.

The study made no attempt to estimate the likely duration of impacts, implicitly assuming that impacts are long-lasting. The study also does not make any attempt to identify possible substitutions to cheaper presentations of the targeted goods or to other foods and drinks (in scenarios where the levy was passed on to consumers), or substitutions to other products in response to industry reformulation.

**Cobiac et al. (2017)** used a population model of diet-related diseases, healthcare costs and food price elasticities, to simulate the effect of taxes on saturated fat, salt, sugar (AU\$0.94 per 100ml of ice cream and AU\$0.85 per 100g of sugar), a AU\$0.47 per litre tax on sugar-sweetened beverages and a subsidy on fruits and vegetables, over the lifetime of the Australian population.

The sizes of the taxes and subsidy were set such that, when combined as a package, there would be a negligible effect on average weekly expenditure on food (<1% change). We evaluated the cost-effectiveness of the interventions individually, then determined the optimal combination based on maximising net monetary benefit at a threshold of AU\$50,000 per disability-adjusted life year (DALY). The simulations suggested that the combination of taxes and subsidy might avert as many as 470,000 DALYs in the Australian population of 22 million, with a net cost-saving of AU\$3.4 billion to AU\$4.6 billion to the health sector. Of the taxes evaluated, the sugar tax produced the biggest estimates of health gain: 270,000 whereas the sugar-sweetened beverage tax resulted in only 12,000 DALYs averted. The magnitude of health benefits was found to be sensitive to measures of price elasticity.

**Cornelsen et al. (2016)** attempted to assess the impact of a hypothetical levy of ten pence per drink on sales of sugar-sweetened beverages delivered nationally in the UK within a restaurant setting using electronic point of sale data. Point of sale data for non-alcoholic drinks were obtained from eligible restaurants in one restaurant chain. An interrupted time-series analysis using linear mixed-models was conducted to identify a step-change in sales per customer of levy-eligible beverages at 12 weeks and 6 months after the implementation of the levy. Effects on untaxed drinks were also estimated to identify substitution effects.

Compared with the period pre-levy, sales per customer of levy-eligible beverages fell by nearly 12 percent by 12 weeks but increased slightly to a decrease of under 10 percent by 6 months. Untaxed beverages increased in sales per customer by nearly 15 percent showing a strong degree of substitution, with the exception of diet cola and bottled water, which showed a decrease at six months of nearly eight percent and

nearly seven percent. There were also significant regional variations, with declines in sales of taxed beverages in London and the South, but no change in the North, suggesting that elasticities may not be consistent across geographic areas.

**Etile et al. (2015)** used a finite mixture IV-Tobit model to compare the effects of a tax on sugar-sweetened beverages on moderate and high consumers of sugar-sweetened beverages in Australia. Price elasticities were estimated from unit values which were derived from monthly household consumption and expenditure data. Some correction for endogeneity was introduced by constructing unbiased Laspeyres price indices from the unit prices. Purchases and characteristics of ten types of non-alcoholic beverages were collected from the 2010 ACNielsen HomeScan Panel Data set. A broad category of sugar-sweetened beverages was constructed from three categories in the dataset, namely regular soft drinks (including sports and energy drinks), cordials, and fruit drinks. For each household, aggregate consumption of sugar-sweetened beverages at the monthly level was divided by the number of individuals in the household to estimate monthly per capita consumption.

In addition to estimating price elasticities for different consumers, the model was used to compare a 20c per litre excise tax and a 20 percent ad valorem tax on sugar-sweetened beverages. Both taxes were assumed to be fully passed through to consumers.

The estimated price elasticities of demand for sugar-sweetened beverages across consumption quantiles showed a decreasing trend, from -2.3 at the median to -0.2 at the 95th quantile, suggesting that while moderate consumers of sugar-sweetened beverages may be highly responsive to price changes, high consumers of sugar-sweetened beverages have inelastic demand. However, because high consumers have a much higher baseline consumption level, a change in the price of sugar-sweetened beverages is predicted to result in a higher reduction in consumption and higher health gains for individuals whose baseline consumption is highest.

The reduction in consumption as a result of a tax on sugar-sweetened beverages is found to be highest for the 20c per litre excise tax, particularly for the highest consumers of sugar-sweetened beverages (a reduction for consumers at the 75th quantile of 1.4 litres per month under an excise tax and 1 litre per month under the ad valorem tax).

The results also suggest that a tax on sugar-sweetened beverages would be a small fiscal burden for consumers whatever their pre-policy level of consumption but highest under an excise tax and highest for those with higher baseline consumption under either tax.

The study did not estimate cross-price elasticities or consider substitution within or outside the category of sugar-sweetened beverages.

**Finkelstein et al. (2013)** used a US 2006 Nielsen Homescan panel to estimate the changes in energy, fat and sodium purchases expected to result from a 20 percent increase in the price of sugar-sweetened beverages as a result of a hypothetical sugar-sweetened beverage tax, and the effect of the tax on body weight. The model includes substitutions to other beverages as well as substitutions between sugar-sweetened beverages and 12 major food categories.

People who are high consumers of sugar-sweetened beverages were found to be significantly less price elastic than moderate and low consumers.

The tax was estimated to result in a decreased energy intake 24.3 kcal per day per person, which was estimated to translate into an average weight loss of 1.6 pounds (approximately 0.6 kg) during the first year and a cumulated weight loss of 2.9 pounds (approximately 1.2 kg) in the long run. Despite their significantly lower price elasticity, the heaviest purchasers of sugar-sweetened beverages experience similar reductions in caloric intake due to higher baseline consumption levels.

No evidence of substitution to sugary foods was found. The model predicted that reductions in consumption of complementary foods could contribute to decreasing energy intake.

**Harding and Lovenheim (2014)** used Nielsen HomeScan data including detailed transaction-level observations for a large, nationally-representative sample of US consumers over the period 2002-2007. Matching purchase data to product-specific nutritional information, food and beverage purchases were classified into 33 mutually exclusive product-nutrient groups. The authors estimated a quadratic Almost Ideal Demand System to derive price and cross-price elasticities and simulate the effects of product taxes, including a tax that results in a 20 percent price increase for sugar-sweetened beverages and a tax that results in a 20 percent price increase for sugar.

The estimated price elasticities suggest that most food and beverage items are price inelastic, with soda, milk and other cold, non-alcoholic beverages being exceptions. The two soda groups in the study had price elasticities of  $-2.26$  and  $-2.20$  and the price elasticities of other cold beverages ranged from  $-1.81$  to  $-2.06$ . Cross-price elasticity estimates suggest that there would be significant within category substitution for sodas and for milk. Overall, the study finds a complex pattern of complements and substitutes across food and beverage items that indicates that food and beverage taxes have the potential to create unintended effects.

The tax simulation results suggest that a fully passed through 20 percent sugar tax has a significantly larger impact on nutrition than an equivalent tax on sugar-sweetened beverages, due to the broader base of the tax. Specifically, the simulation estimates that a tax on sugar would cause sugar consumption to decrease by 16.41 percent (1,211 grams per month based on average US intake per person per month), accompanied by a 18.54 percent drop in total caloric intake, and would reduce fat and salt intake by 12 percent and 9.63 percent, respectively. Of the total reduction in sugar intake, only 14 percent is the consequence of reduced purchases of sugar-sweetened beverages. The broad-based reduction associated with a tax on sugar reflects both income and substitution effects which combine to mean that consumers purchase less of the taxed items overall and more healthier food and beverage items generally. In contrast, the 20 percent tax on sugar-sweetened beverages is estimated to reduce sugar purchases by 10.35 percent and overall caloric intake by 4.84 percent.

**Kristensen et al. (2016)** used a microsimulation model to estimate the potential impact of three proposed US federal policies to reduce childhood obesity prevalence by 2032. Results are estimated for 20 years after implementation. The three policies are an afterschool physical activity programme, a 1 cent per ounce excise tax on sugar-sweetened beverages, and a ban on child-directed fast food TV advertising. The model used a simulated school-aged US population to determine how federal policies affect obesity-related behaviours, BMI and obesity prevalence. The initial population was drawn randomly from a sample of simulated school-aged children and adolescents with demographic characteristics matching that of the US using 2010 Census data.

Yearly changes in physical activity, diet, and BMI were estimated using multivariable equations developed using the 2001-2010 continuous National Health and Nutrition Examination Survey data. Effectiveness data was drawn from previously published studies, including a 25 percent reduction in consumption of sugar-sweetened beverages by children and a 35 percent reduction in consumption of sugar-sweetened beverages by adolescents as a result of existing state-level soda taxes. Complete substitution to zero calorie beverages was assumed.

The model predicted that 20 years after implementation, an excise tax on sugar-sweetened beverages would have reduced the daily consumption of sugar-sweetened beverages of children aged 6-12 by 1.5 servings and of adolescents aged 13-18 by 2.2 servings and would reduce the number of children and adolescents consuming two or more sugar-sweetened beverages per day by 11.4 percent and 16.6 percent, respectively.

**Lal et al. (2017)** modelled a hypothetical 20 percent sales tax on sugar-sweetened beverages in Australia, assuming full pass-through to consumers, to estimate effects on BMI, and outcomes in terms of health-adjusted life years gained, healthcare cost savings, and out-of-pocket healthcare costs. Changes in consumption of sugar-sweetened beverages and substitution (within the beverage category) were calculated using previously published estimates of price elasticities and cross-price elasticities (from Sharma et al. 2014). Two additional cross-price elasticities (for socioeconomic SE groups not included in Sharma et al.) were interpolated from the three previously published estimates by linear estimation.

Reductions in intake of sugar-sweetened beverages were estimated from baseline consumption for households across five socio-economic groups, using consumption data from the 2011-12 Australian Health Survey. From baseline BMI, also extracted from the Australian Health Survey, changes in BMI were calculated by inputting reduced intake of sugar-sweetened beverages into energy balance equations. The estimated changes in BMI formed the basis for estimated population health impact, gains of health-adjusted life years, and healthcare costs avoided, simulated by Markov cohort models based on nine diseases caused by obesity. Healthcare costs for the nine diseases were based on the Disease Costs and Impact Study (DCIS) 2001 data from the Australian Institute of Health and Welfare (AIHW), inflated to 2010 prices.

The tax was estimated to lead to health-adjusted life years (HALY) gains of 175,300 and healthcare cost savings of AU\$1,733 million over the lifetime of the population. The two lowest quintiles benefited from nearly 50 percent of the total health gains estimated. Estimated tax expenditure was highest for the lowest SE quintile but the difference between the lowest and highest quintiles was small. Annual tax revenue was estimated at AU\$642.9 million.

The cost of implementing the tax was estimated for government and industry. Costing methods from a study of two US state excise taxes were used and costs were converted to Australian dollars. Estimates of legislation costs associated with tobacco plain packaging were used as proxies for the cost of establishment, implementation, ongoing compliance, and administration. These amounted to AU\$12.69 million over 10 years. The cost to the beverage industry was assumed to be equal to the government administration cost, based on sales tax evidence from a US study. The cost of passing legislation in the Australian parliament, including parliamentarians' time, annual expenses for the House of Representatives and the Senate, legislation drafting,



and publication and policy advice, was estimated using a previously published framework. The cost of policy advice was drawn from available New Zealand costs.

Cost-benefit analysis based on the estimated benefits and costs of the tax, all discounted at three percent per year, suggested that the tax would be cost saving: For every dollar invested in the first 10 years, the tax was estimated to result in AU\$17 in healthcare cost savings. Additional scenarios modelled included: a 30 percent sales tax; a 50 percent pass-through of the 20 percent tax; and a 50¢ per litre volumetric tax (assumed to result in an average 17% increase in price across all sugar-sweetened beverages). Results for additional scenarios were also favourable.

**Miao et al. (2013)** constructed a comprehensive food demand system to estimate intake of sugars and solid fats in response to a tax on sugars for a hypothetical US tax. If a tax on added sugars is implemented, intake of fats could decrease as consumers reduce intake of high fat/high sugar foods, or increase as consumers substitute from low fat/high sugar foods to high fat/low sugar foods.

The modelling is based on a two-stage budgeting approach to consumer demand based on homothetic separability. The first level demand system is characterized as a LINQUAD demand system for aggregate food goods, which is linear in income and linear and quadratic in prices of aggregate food groups and flexible enough not to impose restrictions on income responses or substitution among aggregate food groups. At the second stage, each food group was decomposed into Constant Elasticity of Substitution aggregate of four sub-categories of high fat/high sugar (HH), high fat/low sugar (HL), low fat/high sugar (LH), and low fat/low sugar (LL).

Elasticities were drawn from the USDA/ERS Commodity and Food Elasticity Dataset augmented with some drawn from published studies. Annual household incomes and baseline consumption values were drawn from the NHANES (National Health and Nutrition Examination Survey) 2003-2004. Food prices were drawn from the CNPP (Center for Nutrition Policy and Promotion) Food Prices database. The estimated price elasticity used in the model is -0.89. Controlling for price endogeneity, results in elasticity estimates that are substantially lower, suggesting ignoring endogeneity in prices overestimates elasticity and corresponding changes in body weight.

The tax scenarios evaluated by the model are a tax on solid fats and a tax on added sugars designed to be calorie reduction equivalent to a soda tax of 1 cent per liquid ounce, which is estimated to reduce caloric intake by 2.19 percent.

Results suggest that both the sugar tax and the fat tax are expected to reduce the intake of both added sugars and fat, with the sugar tax reducing intake of added sugars by up to 11 percent and solid fats by one percent, and the fat tax reducing intake of solid fats by 4.1 percent and added sugars by over one percent.

The study does not investigate the impact on intake of other nutrients, such as salt.

**Sanchez-Romero et al. (2016)** used a state-transition model of Mexican adults aged 35-94 (the Cardiovascular Disease Policy Model-Mexico) to project the future impacts of the Mexican sugar tax on the incidence of diabetes, cardiovascular events, diabetes healthcare costs and mortality over 10 years. Scenarios were modelled based on a previously published (Cochero et al. 2016a) estimated reduction in consumption of sugar-sweetened beverages and a reduction of double that size, assumed to be possible with increased taxation levels and/or additional measures to curb consumption. The study produced estimates of outcomes based on a base case of 10

percent reduction in consumption of sugar-sweetened beverages with 39 percent calorie substitution as well as no calorie substitution and 100 percent calorie substitution. In the base case, the results indicate that a ten percent reduction in consumption of sugar-sweetened beverages (assumed to be the impact of a 10% tax on sugar-sweetened beverages) would be associated with the prevention of 189,300 new cases of type 2 diabetes, 20,400 incident strokes and heart attacks, and 18,900 deaths over a ten year period. The prevention of diabetes was estimated to result in US\$983 million in saved healthcare costs. The study estimated that if the lost calories from reduced consumption of sugar-sweetened beverages were fully replaced by calories from other sources, there would still be a reduction in incidence of type 2 diabetes of 66,000 cases. No information was provided as to the source of substitute calories. A twenty percent reduction in consumption (assumed to be possible with increased taxation and other measures to curb consumption) was found to result in approximately double the impact of the 10 percent reduction. Because the evidence of reduced consumption of sugar-sweetened beverages was based on only two years post-implementation, the remaining eight years over which impacts were modelled were based on assumption of continued reduced consumption of sugar-sweetened beverages.

**Sharma et al. (2014)** derived price elasticities and cross-price elasticities for beverages and simulated the introduction of a 20 percent valoric tax and a 20 cent per litre volumetric tax on sugar-sweetened beverages in Australia. The analysis relies on Australian Homescan data, household level panel data collected by ACNielsen on purchases of sugar-sweetened beverages over a period of one year. The data includes in-store packaged beverage purchases from supermarket/retail outlets and does not take into account purchases in restaurants and bars.

Prices and quantities are available directly from the data and these are linked with caloric content of sugar-sweetened beverage based on Australian nutrition tables. Household characteristics, including income, are also included in the model which uses an Almost Ideal Demand System to estimate elasticities across 10 categories of non-alcoholic beverages. The estimated impacts on consumption are translated into kilojoules and reductions in weight. The study also estimates the additional cost faced by households in the presence of the tax. Although prices and up to six non-price characteristics (brand, variety, flavour etc.) are included in the dataset used for the study, elasticities are calculated for broad categories of beverages and estimation of elasticities is based on the category budget shares and unit values rather than prices. To control for endogeneity, the authors follow a Deaton (1988) methodology, using a price index calculated based on brand level prices and quantities instead of the unit values to reduce the bias. The taxes are assumed to be fully passed through to consumers.

The study estimates that demand for sugar-sweetened beverages in Australia is elastic for all beverages except for regular soft drink, cordial, tea and coffee. Elasticity values range from -0.63 for regular soft drinks to -2.07 for low-fat milk. Substitutions outside of the beverage category are not considered. Cross-price elasticities indicate that regular soft drink and diet soft drinks are substitutes; regular soft drink and fruit drink are substitutes; regular soft drink and fruit juice are substitutes; cordial and fruit juice are substitutes; low-fat milk and high-fat milk are substitutes; cordial and fruit drink are complements; fruit drink and fruit juice are complements. Sub-group analysis



reveals that high-income households have the least elastic demand for regular soft drinks.

The volumetric tax was estimated to result in a greater per capita weight loss than the valoric tax (0.41 kg vs. 0.29 kg). The difference in estimated weight loss for the two tax scenarios is biggest for heavy purchasers of sugar-sweetened beverages in low-income households, with a weight reduction of up to 3.20 kg for the volumetric and 2.06 kg for the valoric tax.

The average yearly per capita tax burden on low-income households is estimated to be AU\$17.87 compared with AU\$15.17 for high-income households for the valoric tax, and AU\$13.80 and AU\$10.10 respectively for the volumetric tax.

**Schwendicke and Stolpe (2017)** conducted a modelling study based on a 20 percent ad valorem sales tax on sugar-sweetened beverages in addition to the existing VAT in Germany. Elasticities used were from a previously published meta-analysis (Long et al. 2015). The assumed price elasticity of demand for sugar-sweetened beverages was -1.21 (mean across groups). Cross-price elasticities for juice and milk were assumed to be 0.637 and 0.150 (means). Full pass-through of the tax was assumed in the base case. 80 percent pass-through was modelled as an alternative scenario. German data on beverage consumption and individual characteristics were used to establish baseline consumption and population groups.

Spreadsheet-based Monte Carlo simulations were used to estimate the effect of the tax on BMI. For each modelled group, 100 individuals were simulated and each group was modelled 100 times. Based on the simulations, a 20 percent tax on sugar-sweetened beverages is expected to reduce daily energy intake in males and slightly less in females. The reduction was greater in younger than in older people, and was also greater in low-income individuals than in middle- or high-income individuals. In older individuals, especially females, taxation even increased caloric intake slightly. This was found to be due to increased consumption of fruit juices compensating for minimal reduction in SSB consumption. The study did not consider substitutions outside the beverage category.

**Tiffin et al. (2015)** used a Quadratic Almost Ideal Demand System estimated with household level data on beverage purchases in the UK to analyse the potential effects of a tax on sugar-sweetened beverages. The study includes separate modelling of effects for low, moderate and high consumers of sugar-sweetened beverages to identify differences in impact between groups. For simplicity, substitutions outside the beverage category are not considered. Beverages are grouped according to flavour, carbonation and type of sweetener. Conditional and unconditional elasticities are estimated to allow for expenditure on a category to be fixed or flexible.

The food and drink model is estimated with data from a repeated cross-sectional living costs and food survey which provides two weeks of household expenditure and food consumption. An infrequency of purchase model is used to allow for zero purchases to be reflective of previous stockpiling. A second dataset from KANTAR WorldPanel provided details on beverage purchases by UK households from supermarkets, confectioners, tobacconists, and newsagents over a 51-week period starting in 2010. For the 51-week data, zero purchases are assumed to mean the household does not purchase the good.

Price elasticities, estimated using a superlative price index, suggest that the demand for sugar-sweetened beverages is elastic for high consumers of sugar-sweetened beverages and inelastic for moderate and low consumers with elasticity decreasing as consumption levels decrease.

The tax scenarios simulated include: a French-style volumetric tax on sugar-sweetened beverages and diet soft drinks; A French-style tax at a lower rate; a 6 pence per litre tax on sugar-sweetened soft drinks and fruit drinks with less than 25 percent fruit; a tax of 7 HUF per litre (2 pence per litre) on regular soft drinks and juice drinks with sweeteners, based on the Hungarian tax regime. In all cases, it was assumed that the full burden of the tax would be passed through to consumers. For high consumers of sugar-sweetened beverages, the French-style tax set at approximately 6 pence per litre and the alternative of 6 pence per litre on only sugar-sweetened beverages or low fruit content fruit drinks achieved the greatest increase in the prices of regular soft drinks, regular cola, and juices with sweeteners: 8.38 percent, 8.89 percent and 5.42 percent in both cases. Overall, the French-style tax set at approximately 6 pence per litre achieves the greatest reduction in the consumption of sugar-sweetened beverages by high consumers. The authors point out that the French-style tax shows the importance of understanding the substitute/complement relationship between diet and regular soft drinks. In this analysis, a tax on diet cola was found to reinforce the tax on regular cola.

**Veerman et al. (2016)** estimated the impact of a hypothetical, fully passed-through 20 percent ad valorem tax on sugar-sweetened beverages in Australia on health and healthcare expenditure. A lifetable-based epidemiological model was used, including a population of adults aged 20 and over, alive in 2010 and modelled over their remaining lifetime. Outcomes estimated included total lifetime disability-adjusted life years (DALYs), incidence, prevalence, and mortality of obesity-related disease, and healthcare expenditure.

The model, which used previously published estimates of price elasticity of demand for sugar-sweetened beverages and assumed that these would remain for 25 years, predicted that over the lifetime of an adult Australian even modest changes in average body mass would translate into gains of 112,000 health-adjusted life years for men and 56,000 for women, and a reduction in overall healthcare expenditure of AU\$609 million. The tax was estimated to result in 800 fewer incident cases of type 2 diabetes per year. Twenty-five years after the introduction of the tax, the model predicted there would be 4,400 fewer prevalent cases of heart disease and 1,100 fewer individuals living with the consequences of stroke and 1,606 deaths would have been avoided. The tax was estimated to generate an estimated AU\$400 million in revenue annually.

Substitutions other than to diet drinks were not considered so no compensatory calorie or sugar intake was included in the model.

**Wang (2015)** estimated price elasticities using a dynamic demand model designed to address potential intertemporal substitution (stockpiling during price promotions) and unobservable persistent heterogeneous tastes (brand and variety choices being conditional on characteristics of previous purchases). Weekly scanner data for a randomly selected panel of households in the United States provided data on purchases of sugar-sweetened beverages and household characteristics. A store panel provided weekly prices and advertising information, including price promotions.

Analysis of the data reveals that the market for sugar-sweetened beverages in the US is highly concentrated, suggesting that consumers have strong preferences for top brands which may indicate that capturing households' intrinsic product tastes in a model of demand is important. Evidence of stockpiling behaviour was apparent, with sales volumes dropping dramatically after a price promotion ends before slowly resuming growth. Weekly quantities sold of each product are regressed on the store's current week's price with inflation adjustment and on the number of weeks since the last sale, with a result of a high positive and statistically significant coefficient on the number of weeks since the last sale, further supporting the hypothesis that households engage in stockpiling behaviour, suggesting that models in which current purchases are interpreted as current consumption inappropriate for measuring response to policy change. Across income groups, the results suggest that lower income households are less able to stockpile, which may result in a tax being more regressive than other studies have suggested.

The long-run price elasticity of demand for regular soda is estimated to be -0.5744, suggesting that demand for regular soda is inelastic and households are not likely to substitute away from regular soda in response to small permanent price increases, such as due to a small tax. Within the category of regular soda but across some brands, demand is found to be price elastic, indicating that consumers are likely to switch brands within the category, taking advantage of price promotions to maintain consumption levels. The cross-price elasticity of demand for diet-soda in relation to the price of regular soda is estimated to be 0.6302, suggesting that when the price of regular soda increases, consumers are not likely to switch to diet soda – an unsurprising result given the low price elasticity of demand for regular soda.

Results suggest that static models overestimate the long-run own-price elasticity of sugar-sweetened beverages by over 60 percent, leading to significantly (up to 58 percent) overestimated reductions in consumption of sugar-sweetened beverages attributed to a tax.

Effects on consumption are estimated for a 10 percent sales tax on sugar-sweetened beverages and a one cent per ounce excise tax. Both taxes are modelled with pass-through at 25, 50, 75 and 100 percent. For all combinations of tax and pass-through, poorer households are expected to experience the largest reduction in consumption. The largest reduction in consumption (nearly 10 percent) is found for the one cent per ounce tax at 100 percent pass-through, which is equivalent to 68 cents on a two litre bottle of regular soda where the pre-tax price is around US\$1.50. In other words, the greatest reduction in consumption is a 10 percent reduction and this occurs with a tax of approximately 45 percent. Analysis of the reduction in regular soda intake to identify substitutions determined that 76 to 97 percent of reduced consumption of regular soda is replaced by consumption of diet soda. The remainder is either no purchases or purchases outside of the range analysed. Both taxes are found to be associated with little deadweight loss and to be regressive.

**Zhen et al. (2014)** examined the differential effects on US demand for sugar-sweetened beverages of taxing the beverages by calorie content versus by total volume. To estimate the degree to which other items are substitutes or complements, a fully modified distance metric model of differentiated product demand with endogenous cross-price effects was constructed. The model was estimated as a linear approximate almost ideal demand system using supermarket scanner data of 178 beverage items.

A tax on sugar-sweetened beverages where the amount of the tax depended on calorie content was estimated to cost US\$1.40 less in compensating variation than a simple volume-based tax per 3,500 beverage calories reduced. A hypothetical 0.04 cent per kcal tax on sugar-sweetened beverages is estimated to reduce annual per capita sugar-sweetened beverage intake by 5,800 kcal.

**Zhen et al. (2014a)** used a censored Exact Affine Stone Index incomplete demand system which is argued to be an improvement on the Almost Ideal Demand System for estimating price elasticities in that it allows for more flexible Engel curves which has a substantial effect on price coefficients. The model is used to estimate the effects across 23 packaged foods and beverages of a hypothetical excise tax on sugar-sweetened beverages in the US which is assumed to be fully passed through to consumers. Nielsen Homescan data are used to provide prices and quantities, so that elasticities could be estimated without unit value bias. The data also provided nutritional content of foods so that sugar, salt, fat and total energy intake could be estimated.

By estimating effects with correction for endogeneity bias and an incomplete demand framework, the authors show that the magnitude of predicted reductions in caloric intake from 23 foods and beverages is significantly lower than other studies have suggested. The correction also shows that there would be an increase in the intake of salt and fat as a result of substitution.

An increase in the price of sugar-sweetened beverages of a half-cent per fluid ounce was found to be associated with a reduction in energy intake of 13.2 kcal per person per day for the lowest income group and 5.6 kcal per person day for the highest income group. Using a dynamic weight loss model, these estimates are translated into weight reductions of 0.37 per person in one year to 0.7 kg per person in 10 years for the lowest income group and 0.16 kg per person in one year to 0.31 kg per person in 10 years for the highest income group. Tax revenue was estimated at US\$20 per household.

## A.7 Meta-analyses

One meta-analysis was included in this review.

**Cabrera Escobar et al. (2013)** conducted a meta-analysis of potential taxes on sugar-sweetened beverages, with estimates drawn from studies identified in a systematic review of publications from 2000 to 2013. The nine studies included in the meta-analysis reported price elasticity of demand, cross-price elasticity of demand and some impact on BMI, and overweight or obesity prevalence for price increases on sugar-sweetened beverages ranging from one percent to 20 percent. Meta-XL was used to synthesise results for price elasticity and cross-price elasticity of demand for sugar-sweetened beverages.

The estimate of price elasticity was based on nine studies, six from the US, and one each from Mexico, Brazil and France. All showed negative price elasticity of demand for sugar-sweetened beverages ranging from -0.85 to -2.206. The pooled price elasticity estimate was -1.299. Four studies provided cross-price elasticities, three from the US and one from Mexico, including consistently negative values for diet drinks, consistently positive values for fruit juice, and mostly positive values for whole milk. Once pooled, cross-price elasticity estimates were 0.388 for fruit juice, 0.129 for milk, and -0.423 for diet drinks. Six studies, all from the US, estimated some association between a higher price on sugar-sweetened beverages and a small reduction in BMI

(from -0.0031 kg/m<sup>2</sup> to -0.065kg/m<sup>2</sup> or up to 0.2kg of weight loss), as well as in overweight and obesity (a decrease in prevalence between -0.0001 and -0.34).

## A.8 Case studies

One case study was included in this review.

**Fletcher et al. (2015)** conducted a two-part study of soft drink taxes (defined as tax on soft drinks net of taxes on other food and beverage items): first, estimating non-linear consumption responses and threshold effects to taxes on sugar-sweetened beverages to determine whether large taxes might be effective in reducing weight; and, second, analysing the effects of the sudden and relatively large soda tax increases in the US states of Arkansas and Ohio in the early 1990s by estimating a difference-in-differences specification comparing weight outcome changes in those two states to changes occurring in all other states without changed tax rates and with similar BMI in the year before the tax change as well as to states within the same region during the same period. A further control group is constructed as a synthetic cohort of weighted state averages with matching on a broad set of characteristics of states prior to the tax increase.

The National Health and Nutrition Examination Surveys (NHANES) dataset provided data on BMI, soft drink consumption, other beverage consumption, and demographic characteristics obtained through a 24 hour recall survey. This data was able to be matched with state-level tax information. Measures of total calories consumed, total calories from soft drinks, total calories from other beverages, and total grams of soft drinks consumed were constructed. More than five percent of adult caloric intake was found to be derived from soft drink consumption even though only 59 percent of adults consume any soft drinks. 64 percent of adults were found to be overweight and 30 percent were obese.

A linear specification of the soft drink tax rate variables was preferred on the basis of Bayesian Information Criterion (BIC). This specification suggests the relationship between soft drink taxes and calories from soft drinks is small and not statistically significant: A one percentage point increase in the soft drink tax rate was found to be associated with a 27.7 calorie increase in the daily caloric intake of adults, suggesting important compensatory substitution effects. The authors conclude that an increase in tax on soft drinks is unlikely to result in reductions in total caloric intake.

The results of the difference-in-differences comparisons of the two state-level taxes suggest that the Ohio tax increase had no detectable effect on population weight. In the case of Arkansas, the results vary depending on the comparison group: Arkansas experienced a BMI decrease of 0.278 kg/m<sup>2</sup> when compared with no-tax states and an increase of 0.152 kg/m<sup>2</sup> when compared with other states in its Census Division.

## Appendix B Evidence from the studies

This table summarises the evidence presented by each study with regards to: the tax design and context; indicators that a tax has the potential to generate health benefits (tax pass-through, elasticities, and evidence of reduced consumption of taxed and untaxed items as well as evidence of change in sugar and/or energy intake); evidence that health outcomes are actually achieved (indicators of overweight and obesity and specific health measures such as the incidence of diabetes); and, fiscal considerations (tax burden and tax revenue). Systematic and other reviews of pre-existing evidence are not included. As such, the table summarises evidence from the included observational studies, experimental studies, modelling studies, and case studies.

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/ tax revenue
Andalon and Gibson (2017)	Mexican tax on sugar-sweetened beverages.	n/a	Price elasticity of demand for SSBs -0.2 to -0.3 (lower than previously published estimates which are shown to be biased by flawed methodology)	n/a	n/a	Weight loss of 400g on average.	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/ tax revenue
Barrientos-Gutierrez et al. (2017)	Mexican tax on SSBs – impacts modelled 10 years after implementation.	n/a	n/a	n/a	n/a	BMI reduction: 0.15 on average. 2.54% reduction in obesity prevalence.	86,000 to 134,000 cases of T2 diabetes prevented.	n/a
Basu et al. (2014)	India – hypothetical 20% excise tax on SSBs.	n/a	n/a	n/a	n/a	Overweight and obesity prevalence reduced by 3%. Type 2 diabetes incidence reduced by 1.6%.	n/q	n/q
Berardi et al. (2017)	French tax on sugar-sweetened and artificially-sweetened beverages.	Six months post implementation: full pass-through on sodas, almost full on fruit drinks, 85% on flavoured water. Inconsistent pass-through across retail outlets with some negative pass-through at smaller outlets	n/a	n/a	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Biro et al. (2015)	Hungarian junk food tax.	Some evidence of pass-through.	n/a	Some evidence of reduced consumption of taxed foods and increased consumption of untaxed foods.	n/a	n/a	n/a	n/a
Bollard et al. (2016)	New Zealand – young people – hypothetical 20% tax.	n/a	n/a	No statistically significant reduction in purchase probability.	n/a	n/a	n/a	n/a
Briggs et al. (2013)	Hypothetical 20% UK tax on SSBs.	Assumed 100%.	Estimated -0.81 to -0.92 price elasticity of demand. Cross-price elasticities suggest bigger substitution effects for poorer groups.	Reduced consumption of SSBs by 15-16%. Poorer groups more likely to substitute to diet varieties and fruit juice.	Reduced energy intake 16.7 kJ per person per day. Biggest effect on richer groups.	1.3% reduction in number of obese adults. Biggest effect on richer groups.	n/a	Tax burden highest on poorer groups with greatest health benefits to richer groups.



Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/ tax revenue
Briggs et al. (2013a)	Hypothetical 10% tax on SSBs in Ireland.	Assumed 80% to 100%.	Assumed -0.9 price elasticity of demand. No cross-price effects modelled.	Reduced.	Reduced energy intake of 2.1 kcal per person per day. Women's intake reduction declines with income. Men's intake reduction increases with income. Bigger reductions in younger groups.	1.3% reduction in obese population.	n/a	n/a
Briggs et al. (2017)	UK proposed industry levy on SSBs: high tax for drinks with >8g per 100ml; moderate tax for 5-8g per 100ml; no tax for <5g.	Modelled on 100% and 50% pass-through	Based on previously published estimates – not explicitly stated.	Reduction from 10.7 to 58.5ml per person per day. One scenario resulted in an increase of 3.6ml per person per day. No substitution considered.	Not explicitly stated.	Reduction of up to 0.9% of the obese population in the UK.	Reductions in Type 2 diabetes incidence, tooth decay.	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/ tax revenue
Cabrera Escobar (2013)	Meta-analysis drawing from price increase impacts.	n/a	Price elasticity of demand for SSBs: -0.85 to -2.206 (-1.299 pooled). Pooled cross-price elasticities: 0.388 for fruit juice, 0.129 for milk, -0.423 for diet drinks.	n/a	n/a	Small reduction – weight loss up to 0.2kg based on top of range BMI reduction of 0.065kg/m <sup>2</sup> .	n/a	n/a
Cawley and Frisvold (2015)	Berkeley, California tax on SSBs, introduced in January 2015.	Incomplete, with pass-through 5 months after implementation. 14 percent to 50 percent across different brands and sizes. On average, 43% of the tax was passed through.	n/a	n/a	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Cobiac et al. (2017)	Australia – hypothetical tax on SSBs AU\$0.47 per litre compared with a tax on sugary foods, a fat tax, a salt tax and a subsidy on fruit and vegetables.	Assumed 100%.	Used elasticities previously published by Ni Mhurchu et al. (2013).	n/a	Change in energy intake: with SSB tax: -30 kJ/day. With sugar tax: -278 kJ/day.	n/a	SSB tax saves 12,000 DALYs. Sugar tax saves 270,000 DALYs.	n/a
Colantuoni and Rojas (2012)	5.5% sales tax on soft drinks imposed in the state of Maine in 1991 and 5% sales tax on soft drinks imposed in the state of Ohio in 2003.	No statistically significant effect on pre-tax price – indicating tax was fully passed through to consumers.	n/a	No statistically significant effect on overall consumption of soft drinks.	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Colchero et al. (2015)	No tax - price and purchase data used to estimate elasticities.	n/a	PEs: -1.06 for soft drinks -1.16 for all sugar-sweetened beverages. Cross-price elasticities suggest increased consumption of water, milk, snacks and sugar, decreased consumption of other sugar-sweetened beverages, candies and traditional snacks.	n/a	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Colchero et al. (2016a)	Mexican tax on SSBs – effects after one year.	n/a	n/a	SSB consumption averaged 6% decline over the first year post-implementation. -12% at the one year point. Bigger reductions for low SE groups.	n/a	n/a	n/a	n/a
Colchero et al. (2017)	Mexican tax on sugar-sweetened beverages – 2 years post-implementation.	n/a	n/a	5.5% reduction in year 1, 9.7% reduction in year 2 – average 7.6% reduction over 2 years. Largest reductions in low SE groups. Untaxed beverages rose 2.1%.	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Cornelsen et al. (2016)	UK – hypothetical levy of 10 pence per SSB serving.	Assumed 100%.	Regional variation in sales changes suggesting different elasticities in different areas.	Sales of levied beverages fell 12% by 12 weeks but increased to a less than 10% decline by 6 months. Untaxed beverages rose 15%, except diet cola and bottled water which fell.	n/a	n/a	n/a	n/a
Etile and Sharma (2015)	Comparison of 20c/l excise tax and 20% ad valorem tax on SSBs in Australia.	Assumed 100%.	-2.3 for individuals with consumption level at the median. -0.2 for individuals with consumption at the 95 <sup>th</sup> quantile. No cross-price elasticities.	Excise tax: -0.6 litre per person per month at median consumption; -1.4 litre per person per month at the 75 <sup>th</sup> quantile. Ad valorem tax: same for median; -1 litre per person per month at the 75 <sup>th</sup> quantile. No consideration of substitution.	n/a	Bigger reduction for higher consumers assumed to translate into more weight loss. No consideration of substitution.	n/a	Heavier burden for high consumers than lower consumers. For high consumers, heavier burden under excise tax than ad valorem tax.

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/ tax revenue
Falbe et al. (2016)	Berkeley, California soda tax.	n/a	n/a	Reduced consumption by 21% in Berkeley compared with increase of 4% in comparison cities. Increased water consumption.	n/a	n/a	n/a	n/a
Finkelstein et al. (2013)	US – hypothetical 20% increase in price of SSBs.	n/a	n/a	No evidence of substitution to sugary foods.	24.3 kcal per day reduction in energy intake.	Weight loss 0.6 kg in year 1. Weight loss of 1.2kg in the long run.	n/a	n/a
Fletcher et al. (2015)	Case study of 2 US state excise taxes on SSBs: Arkansas (2c per 12 oz) and Ohio (1c per 12 oz).	n/a	n/a	Increase in caloric intake post-tax suggests possible substitution to increased consumption of other foods and beverages.	Caloric intake of adults estimated to increase slightly as a result of substitution.	BMI decrease of 0.278 kg/m <sup>2</sup> associated with Arkansas tax. No detectable effect of Ohio tax.	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Gollust et al. (2017)	New Zealand – young people – hypothetical 20% tax on SSBs.	n/a	n/a	More likely to perceive soda companies negatively if a rationale for the tax is given – no evidence of actual reduction in consumption.	n/a	n/a	n/a	n/a
Grogger (2016)	Mexican tax on sugar-sweetened beverages.	More than fully passed through.	n/a No price increase observed in substitute beverages.	n/a	n/a	Weight loss of 1 to 1.5kg in the year after the tax was implemented (1.6 to 2.7% of BMI).	n/a	n/a



Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Harding and Lovenheim (2014)	US – hypothetical 20% tax on sugar versus 20% tax on SSBs.	Assumed fully passed through.	Two soda groups elasticities between - 2.26 and - 2.20. Other cold beverages elasticities from -1.81 to -2.06. Cross-price elasticities suggest lots of scope for substitution.	n/a	Tax on sugar reduces sugar intake by 16% and reduces energy intake by 18.5%, fat by 12% and salt by 10%. Tax on SSBs reduces sugar intake by 10% and energy intake by 5%.	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Kristensen et al. (2016)	Microsimulation of 3 hypothetical interventions in the US to reduce childhood obesity, including a 1 cent per ounce excise tax on SSBs.	n/a	n/a	Assumed 25% reduction in SSB consumption in children and 35% reduction in adolescents based on previously published studies. Assumed 100% substitution to a zero calorie beverage.	n/a	20 years after implementation, largest impact on child obesity was found for after school physical activity programmes. Largest impact on adolescent obesity was found for SSB taxation. SSB tax results in 1.6% drop in obesity in children 6-12 years old and 2.4% drop in obesity in 13-18 year olds.	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Lal et al. (2017)	Hypothetical 20% Australian sales tax on SSBs. Also, 30% sales tax, and 50c per litre volumetric tax.	Assumed 100% in base case. 50% pass-through for sensitivity. 50c/litre volumetric tax assumed to result in 17% price rise.	Assumed from previously published study (Sharma et al. 2014).	n/a	n/a	n/a	175,300 HALYs gained over the Australian population lifetime.	Healthcare cost savings of AU\$1,733m. Annual tax revenue was estimated at AU\$642.9m. Increase in annual expenditure on SSBs: AU\$35 per capita for lowest quintile, less than AU\$40 per capita for highest quintile.

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Miao et al. (2013)	US – hypothetical tax on sugars versus tax on solid fats: 1 cent per liquid ounce.	n/a	Assumed PE of -0.89.	n/a	Sugar tax reduces sugar intake by 11% and solid fats by 1%. Fat tax reduces sugar intake by 1% and fat by 4%. Caloric intake reduced by 2.19% in both cases.	n/a	n/a	n/a
Ni Mhurchu et al. (2013)	No tax. Study based on consumer expenditure on food and beverage categories. New Zealand.	n/a	PE for all carbonated soft drinks - 1.27 overall. Price elasticity of demand for carbonated soft drinks lowest for Māori and deprivation quintile 3.	n/a	n/a	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Sanchez-Romero et al. (2016)	Mexican tax on sugar-sweetened beverages (approx. 10%) + hypothetical increase to 20%.	n/a	Based on previously published estimates by Colchero et al. (2016).	Based on previously published estimates by Colchero et al. (2016) – 10% decline in SSB consumption from a 10% tax, assumed to be maintained for 10 years.	Assumed 39% calorie substitution, resulting in 61% reduction in calories from SSB consumption.	n/a	With base case 39% calorie substitution: 4.9% lower incidence of type 2 diabetes - US\$983m savings in healthcare costs; 46,300 fewer incident cases of CHD, 6,200 fewer incident cases of stroke, 18,900 fewer deaths from all causes.	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Schwendicke and Stolpe (2017)	Germany – hypothetical 20% ad valorem tax.	Assumed 100% and 80%.	Assumed PE = -1.21. Cross-price elasticities of 0.637 for juice, 0.150 for milk.	Substitution to fruit juice by older women.	Bigger reduction in males than females, in young than old, in low-income than high-income households. Older women increased caloric intake as a result of substitution.	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Sharma et al. (2014)	Hypothetical 20% valoric and 20c/litre volumetric tax on SSBs in Australia.	Assumed 100%	Price elasticity of demand: -0.63 for regular soft drinks.	n/a	n/a	Volumetric tax: 0.41 kg lost. Valoric tax: 0.29 kg lost. For high consumers of SSBS, 3.20 kg (volumetric tax) 2.06 kg (valoric tax).	n/a	Yearly valoric tax burden \$17.87 for low-income households, \$15.17 for high-income households, compared with \$13.80 and \$10.10 respectively for the volumetric tax.
Silver et al. (2017)	Berkeley California, excise tax on SSBs – one cent per ounce.	Varying degrees of pass-through depending on type of beverage and retail outlet (from full-pass-through to negative pass-through).	n/a	Reduction in consumption was not statistically significant. Sales fell in Berkeley but increased in neighbouring areas.	Reduction in sugar intake no statistically significant.	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Taylor et al. (2016)	Berkeley, California sugar-sweetened beverage tax.	n/a	PE of SSBs: -0.343.	SSBs sales dropped by 30% before the tax was implemented – attributed to heightened awareness/media coverage.	n/a	n/a	n/a	n/a
Tiffin et al. (2015)	Hypothetical UK sales tax (various scenarios, including 6 pence per litre on SSBs).	Assumed 100%.	Regular soft drinks: -1.271 for high consumers; -0.456 for low consumers.	40% reduction in consumption for high consumers of regular soft drinks, no statistically significant reduction in regular cola consumption. Diet cola is a substitute for high consumers of regular cola but a complement for moderate and low consumers.	n/a	n/a	n/a	n/a



Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Veerman et al. (2016)	Hypothetical 20% ad valorem tax on SSBs in Australia.	Assumed 100%.	Assumed from previously published estimates.	n/a	Reduction in sugar/energy resulting from reduction in SSB consumption. Assumed no compensatory calorie or sugar intake due to lack of substitutes other than diet drinks.	n/a	112,000 health-adjusted life years for men, 56,000 health-adjusted life years for women over the lifetime of population living in 2010. Incident cases of type 2 diabetes reduced by 800 per year. 4400 heart disease and 1100 strokes averted by 25 years.	Reduction in Australian healthcare expenditure: AU\$609m.

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Wang (2015)	Hypothetical US tax on sugar-sweetened beverages: 1 cent per ounce excise tax compared with 10% ad valorem tax.	Assumed at 25%, 50%, 75% and 100%.	Demand for regular soda found to be inelastic at -0.5744. Cross-price elasticity of diet soda: 0.6302.	1 cent per ounce ad valorem tax (equivalent to a 45% tax on a 2 litre bottle of regular soda) reduces consumption by less than 10% when fully passed through. Most of reduction results in substitution to diet soda.	n/a	n/a	n/a	Both taxes are regressive but efficient (little deadweight loss).
Zhen et al. (2014)	US – hypothetical tax on SSBs: Compared tax based on volume to tax based on caloric content.	n/a	n/a	n/a	Tax based on calorie content reduces intake by 5,800 kcal annually.	n/a	n/a	n/a

Study	Tax/context	Tax pass-through	Price elasticities	Consumption of taxed item and substitutes	Sugar/energy intake	Weight/BMI/obesity prevalence	Health outcomes	Tax burden/tax revenue
Zhen et al. (2014a)	US -hypothetical tax on sugar-sweetened beverages.	Assumed 100%.	Price elasticity lower than some studies suggest after correcting for endogeneity bias. Cross-price elasticities result in significant compensatory substitution.	Reduction in consumption of sugar-sweetened beverages. Increased intake of salt and fat.	Reduction of 15.1 kcal per day per person from SSBs.	0.16 to 0.37 kg weight loss per person in one year. 0.31 to 0.7 kg weight loss per person.	n/a	\$20 per household on average.

Source: NZIER

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