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Building upon the sugar beverage tax in Mexico: a modelling study of tax alternatives to increase benefits

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ABSTRACT

Introduction In 2014, Mexico implemented a one peso-per-litre tax to sugar-sweetened beverage (SSB). Even though this tax reduced household purchases and predicted population health gains, the magnitude is lower compared with taxes implemented in other settings. In this study, we assessed what would happen if Mexico modified its existing tax to get higher benefits based on currently implemented taxes elsewhere.

Methods For each tax scenario, we estimated net benefits as the difference between healthcare savings and lost jobs. We created hypothetical scenarios in which the current tax doubled or would be modified based on existing tax designs around the world including specific taxes (sugar-density or volumetric) and ad-valorem taxes.

Results We found that the largest benefits would correspond to a tax increase of 7.4 Mexican pesos (0.45 US dollars (USD)) per SSB litre, following the current tax in Bahrain (the highest tax rate option). This tax is predicted to yield net benefits equivalent to USD 24.7 billion after 10 years of the tax redesign. We also found that sugar-density taxes can result in larger net benefits since, in addition to reductions in consumption associated with responses to prices, they induce product reformulation. Middle-income households are the most benefited group because they reported the highest baseline prevalence of obesity and the largest price elasticity.

Conclusion Policymakers should consider pursuing a tax reform adding to the current tax, with significant increases in prices linked to a sugar-density strategy to reach a higher benefit.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Mexico faces a high burden of non-communicable diseases. Sugar-sweetened beverage (SSB) taxes have been proved to be associated with increases in prices and reductions in consumption. The SSB tax implemented in Mexico in 2014 was effective in reducing household purchases, but it is low as it represents 5.3% of final price. A modification of the tax should consider different designs and amounts.

WHAT THIS STUDY ADDS

⇒ This study defined different scenarios to modify the existing SSB tax in Mexico using taxes implemented in other countries under different designs and amounts. The study estimates the net benefits of the different scenarios by subtracting from lost jobs healthcare savings. The highest net benefits correspond to the fiscal policy implemented in Bahrain (the highest tax rate). However, larger benefits could be achieved with sugar-density taxes that provide larger reductions in consumption due to reformulation.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The results of the study can be used to redesign the SSB tax in Mexico. Increases in taxes require defining amounts and designs based on the social welfare impacts. Findings could also be used to estimate scenarios of taxes for implementing or redesigning a fiscal policy in other countries.

INTRODUCTION

In January 2014, as part of a national policy to tackle the high prevalence of overweight, obesity and diabetes, the Mexican government implemented an excise tax of one peso-per-litre to all non-alcoholic beverages with added sugar. The tax led to reductions in household purchases of sugar-sweetened beverages (SSB), higher among low-income households.[1 2] Observational studies also linked the tax to oral health improvements and reductions in body mass index (BMI) among female teenagers.[3 4] A modelling study showed that the SSB tax was cost-effective as healthcare savings were three times higher than implementation and monitoring costs over 10 years.[5] The SSB tax was not associated with reductions in employment in the beverage industry not in commercial stores.[6]

Despite the effectiveness of the SSB tax in Mexico, the rate is low. The tax in Mexico represents only 5.3% of the final retail price, compared with Chile, where the tax represents 15.1%.[7] In addition, the current

SSB tax in Mexico remains below recommendations by public health experts who propose doubling the existing tax. [8] Recent international SSB taxes target sugar content rather than volume, such as the per-sugar gram tax in South Africa or the multitier sugar tax in the United Kingdom. Sugar-density taxes have been effective in reducing sugar intake by reducing both consumption and sugar content.[9 10] Considering the different SSB taxes worldwide, it remains unknown whether modifying the existing SSB tax in Mexico following recent international SSB tax designs could provide extra benefits.

With the different SSB tax designs around the globe, it becomes challenging to identify which design will be the most appropriate for Mexico. Recent empirical studies have compared different tax designs within a country under the approach of optimal taxes.[11 12] In general, optimal taxes are those that lead to the maximum level of social benefits. Prior studies have defined optimal taxes as those that produce higher health savings, consumer surplus and private gains, while others have used consumer surplus, health benefits and redistribution of wealth.[11 12] Yet, these definitions can be modified according to a specific objective and social perspective. For instance, the evaluation of soda taxes has primarily focused in health gains, healthcare cost reductions and secondarily in jobs lost and fiscal revenue, disregarding producer gains under the lens that health as a human right is above commercial interests.

In this study, we assessed what would happen if Mexico modified its existing tax to get higher benefits based on currently implemented taxes elsewhere with different amounts and designs. For each tax scenario, we estimated net benefits as the difference between healthcare savings and lost jobs. We included an equity assessment by exploring differential health benefits by income quintile.

METHODS

Our study does not use a standard cost benefit analysis as we are not including implementation costs and we added job losses as a cost. However, as in several cost benefit analyses, we included healthcare savings; thus, we completed the Consolidated Health Economic Evaluation Reporting Standards (Cheers) 2022 Checklist (see online supplemental file 1). We excluded implementation costs as we are adding tax scenarios to the existing tax and we do not expect additional costs over time. In addition, implementation costs would not change across tax scenarios. Unlike other cost benefit analyses, job losses were included because the potential social and economic burden of losing jobs should be contrasted with benefits (healthcare savings). High SSB tax rates may have negative impacts on employment that should be accounted for. We adopted a social perspective as obesity costs include direct healthcare costs and indirect costs. Fiscal revenues were not included as benefits in our model as taxes imply costs to consumers.

SSB Tax designs and amounts

In this study, we assessed multiple tax scenarios if Mexico would: (1) double the existing excise tax from 1.17 Mexican pesos (1.17 as the one peso per litre in 2014 was adjusted to inflation) to 2.34 Mexican pesos per SSB litre; (2) implement a sugar-density tax, based on sugar content, such as the tax implemented in South Africa (a tax per gram of sugar above four sugar grams/100 mL) and tiered sugar taxes (excise and ad valorem) where the tax increases based on sugar-density thresholds such as the ones in the United Kingdom, Portugal, Ireland, Chile, Peru and Ecuador; (3) implement an ad valorem tax where the tax amount is a function of consumer prices, such as in Thailand, India, Kiribati and Bahrain and (4) implement an excise tax to volume such as the tax in Mexico regardless of the amount of added sugar, such as in the Philippines and cities in the USA (Berkeley, Boulder and Philadelphia). For the sugar-density tax scenarios, we assumed production reformulation based on observed changes in South Africa as explained below. Considering the complexity to compare ad valorem taxes and excise tax amounts with different currencies, we standardised each tax design as the expected price increase under the assumption of full tax pass-through.

Model overview

We built a simulation model to analyse the impact of SSB tax designs on calories, weight, obesity cases and obesity costs, as summarised in figure 1. We followed the next steps: (1) we used data from a nationally representative survey in 2018 to obtain baseline SSB consumption, age, sex, weight, height and socioeconomic status; (2) the expected change in SSB consumption in millilitres (ml) under each tax design was calculated from the difference between the baseline SSB consumption and the SSB consumption according to the expected SSB price change and the price elasticity of the demand for SSB in Mexico by households' socioeconomic status (for sugar-density taxes, we included the potential sugar content reduction due to reformulation); (3) we transformed volume reductions in SSB consumption (mL) into caloric reductions using the caloric content per 100 mL; (4) using these caloric changes, we estimated the projected change in body weight using Hall's dynamic weight change model[13]; (5) changes in body weight were translated into BMI and obesity prevalence using the WHO cut-off point for obesity; (6) we computed the obesity cases using the change in obesity prevalence and the projected yearly adult population[14]; (7) we estimated the expected obesity costs saved using the prevented cases of obesity and the cost per obesity case[15]; (8) using the change in consumption in milliliter, we estimated changes in employment.

Baseline SSB consumption

Baseline SSB consumption was estimated using a food frequency questionnaire included in the 2018 National Health and Nutrition Survey (ENSANUT).[16] More details on the characteristics of the database, or sample size used

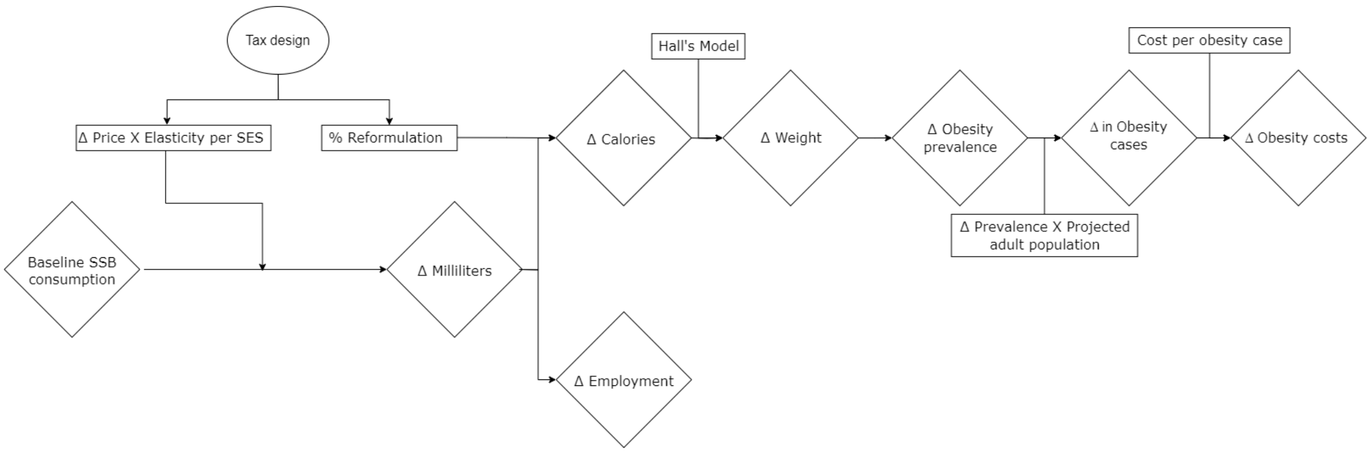

Figure 1 Model conceptualisation to generate the expected health outputs (obesity cases and obesity costs) and employment. Reformulation is zero for ad valorem and volume excise taxes. SSB, sugar-sweetened beverage; SES, socioeconomic status.

is available in the online supplemental file section 2. We selected taxed beverages that match the definition of SSB tax in Mexico.[17] We included carbonated beverages, industrialised juices, industrialised flavoured water '*aguas frescas*' and non-diet yoghurt to drink. SSB prepared at home or in restaurants was excluded from this category because the tax does not apply to home-cooked meals.

Baseline weight and BMI

Bodyweight (kilograms) and height (meters) were measured directly with standardised procedures and instruments.[16] BMI was calculated as weight divided by height squared and classified by the WHO as normal (BMI <25 kg/m^2), overweight (BMI ≥25 and <30 kg/m^2) or obese (BMI≥30 kg/m^2).[18]

Reformulation scenarios

Sugar-density taxes define a tax level that is directly dependent on sugar concentration, inducing product reformulation to reduce sugar content and achieve a lower tax. To simulate this effect, we used data from South Africa in the context of the Health Promotion Levy (HPL), implemented in April 2018. We obtained baseline sugar content and sugar reformulation after HPL implementation from Stacey *et al*[19] and assumed that product reformulation would be similar between Mexico and South Africa. Using data from Nielsen MX CPS, we selected the top 47 SSB by market share and divided them into one-gram sugar/100 mL groups on their sugar content and applied the expected reformulation as observed in South Africa.[20] We assumed no reformulation in Mexico for the top two cola brands, as they did not reformulate in South Africa.

For tiered sugar-density taxes, we assumed that producers, when reformulating, bunched their products to be just below the threshold of the closest lower tax tier. This assumption is based on observed changes across reformulated products in Chile due to front-of-package warning labels.[21] For all sugar-density taxes, we calculated average reformulation using products' monthly purchases in 2013 in Nielsen MX as weights.

We constructed two sensitivity analyses for sugar-density taxes: one in which there is no reformulation and another in which the two top cola brands reformulate in the same amount as the other brands, that is, just below the threshold to the closest lower tax tier.

SSB tax effect on prices

We assumed a full tax pass-through to consumer prices for all tax scenarios in line with findings by Colchero *et al*.[22] Since the baseline data on SSB consumption corresponded to a post-tax year (ie, 2018), when we calculated the expected SSB price increase in 2018 for each tax design, we accounted for the existing SSB tax in Mexico as follows: (1) we calculated the average SSB price per litre based on consumer price index data in 2018[23] (2) we subtracted one Mexican peso from these prices to obtain pre-tax prices, (3) we added the expected percentage price increase under the various international tax designs to these pre-tax prices and (4) when comparing prices from the third step to observed average SSB prices in 2018, we calculated the marginal price increase associated with the SSB tax redesign as a percentage price increases. For the third step, we used pre-tax prices in Mexico because the calculated percentage price increases in the countries of interest used their respective pre-tax prices as a reference. For all tax designs, we derived prices assuming a retailer's profit equivalent to 10.52%. More details are provided in the online supplemental section 3. In all tables and in the results section we show changes in prices after removing the current tax to show how much each tax would represent in terms of price increase.

Change in caloric consumption (kcal)

Expected SSB consumption reductions were calculated by multiplying the expected percent price increase by the price elasticity of the demand for SSB, assuming that the reduction occurred at the start of the first year and remained constant over time. We retrieved information on the price elasticity of the demand for SSB by households' quintile of income level in Mexico based on expenditure and income information (see online supplemental section 4.1).[24] We merged the price elasticity by households' income quintile to participants in ENSANUT-2018, according to their household SES and calculated the expected SSB consumption reduction under each tax design. For sugar-density taxes, we adjusted the change in caloric consumption according to the per cent of reformulation; for other taxes, the change in caloric consumption was proportional to the SSB consumption reduction.

Change in body weight (kg)

To estimate weight change, we used Hall's model, which has been previously validated with experimental weight change data,[13] and has been previously used to estimate the potential impact of SSB taxes in Mexico.[25] The model simulates the adult human metabolism to predict the time course of individual weight change in response to behavioural interventions. It estimates an individual's body weight at a given time by considering changes in extracellular fluid, glycogen, fat and lean tissues (see online supplemental section 4.2 for more details of the model).

To initialise the model and obtain intermediate variables such as resting metabolic rate, we used sex, age, weight and height assuming all participants were sedentary (physical activity level=1.5). We assumed that body weight is at steady state, meaning that the individual body weight is constant under no intervention (increases in obesity over time were not considered). We presented the projections over a 10-year timeframe.

Change in obesity prevalence

We used the estimated postintervention body weight and BMI to determine the expected change in BMI for each individual (see online supplemental section 4.3 and 4.4 for more details). We calculated changes in obesity prevalence using each individual's estimated post-intervention BMI and categorised them using WHO's cut-off points.

Obesity cases averted in adults

We assumed that obesity prevalence in 2019 would be equal to that reported in ENSANUT 2018. We derived adult population for 2019 to 2028 using the National Council on Population projections (see online supplemental section 5).[14] We calculated total averted cases of adult obesity by multiplying the estimated adult population by the change in prevalence.

Saved costs in obesity

Cost of overweight and obesity was previously estimated in Mexico as $26.1 billion US dollars (USD), including direct healthcare costs and indirect costs that include economic loss from premature mortality, absenteeism (loss days of work due to illness) and presenteeism (productivity reduced at work).[15] Using a systematic review that estimated that 86.6% of the overweight and obesity costs were attributed to obesity,[26] we estimated the obesity costs in Mexico to be $22.6 billion USD. The total cost of obesity was then divided by the number of people with obesity (35,139,475) and estimated the cost per obesity case in 2019 (643.37 USD per person: 189.81 USD as direct healthcare cost and 453.57 USD as indirect costs). Finally, we calculated averted cases, averted direct healthcare costs and indirect costs for each tax scheme by multiplying the individual cost of an obesity case by the estimated obesity cases reduced (see online supplemental section 7).

Tax effect on employment

For the effect of the different tax designs on employment, we calculated lost jobs attributable to the additional reduction in SSB purchases under each tax design compared with the existing SSB tax in Mexico. Thus, we multiplied this additional SSB reduction in purchases (in litres) by the ratio of lost jobs per SSB litre reduction. We calculated this ratio based on the input–output matrix in Mexico that assumes constant returns to scale (the inputs required to produce a product vary in the same proportion as changes in production).[27] This matrix is built on the assumption of constant returns to scale, that is, thus the lost jobs reduce proportionally to the SSB production reduction regardless of SSB production level. We calculated a reduction of 1566 jobs per 1% reduction in SSB purchases, equivalent to a reduction in the national employment rate by 0.0027%, in the workforce of 57.4 million people.[27] We transformed the number of jobs lost to monetary values using the per-employee yearly salary in the SSB sector.[28]

Net benefits

We subtracted costs (tax effect on employment) from benefits (savings from direct healthcare costs and indirect costs). We expressed all monetary results in 2019 real prices in USD. We calculated net benefits for 10 years and brought future economic results into net present value using a discount rate of 4%, as recommended for upper middle-income countries such as Mexico.[29] For the tax with the highest net benefit, we conducted an equity analysis to determine how health benefits are distributed across household income quintiles. Because the largest benefits could be just the result of a higher tax rate, we also discuss potential larger effects from tax designs that incentivise reformulation.

In addition, to see how much tax payments vary by income quintile, we used the 2018 National Income and Expenditure Survey to estimate the quantity of SSB purchased by income quintile in litres per adult equivalent per quarter among those with purchases greater than zero.[30] We then multiplied the litres purchased by the tax (1.1689 pesos/litre) and the population per income quintile.

We used the 2018 Mexican National Health and Nutrition Survey (ENSANUT) as the source of uncertainty because we lacked confidence intervals (CIs) or standard errors for price elasticities and obesity costs—not reported in the papers used—and for job losses as the input–output matrix provides point estimates only.

ENSANUT is a nationally representative survey that uses a complex sampling design. Our estimates are based on individual-level data for baseline consumption and body weight from the ENSANUT. For each individual, we estimated changes in weight status every year for 10 years based on the estimated changes in consumption. For each person/year, we added annual direct healthcare costs and indirect costs, if the weight status was obese and added all costs for the 10 years. For employment, for each person/year, we estimated job losses from on a fraction of job losses per litre not consumed based on the input–output matrix. The sample expands every year to consider population growth. We then estimated net benefits per person as the difference between job losses and healthcare costs. Finally, we obtained the mean for the complete sample and derived CIs using the sampling weights of ENSANUT.

RESULTS

Table 1 shows the tax scenarios based on international taxes for the four groups of fiscal policies including doubling the existing tax in Mexico, sugar-density taxes, ad valorem and excise taxes. The table shows the specific tax designs, changes in prices associated with the tax (additional price increase for each tax scenario excluding the current tax), the tax amount for each scenario (adding the current tax in Mexico and the tax under each scenario) and the caloric change due to responses to prices and to reformulation (for tiered taxes). Taxes ranged between 2.3 Mexican pesos per litre (ie, 0.12 USD) when doubling the tax to 8.6 Mexican pesos (ie, 0.45 USD) for the tax design in Bahrain (the highest tax rate), equivalent to additional price increases between 6.3% and 46.9%, respectively.

Table 1 Description of the SSB tax effect on prices and caloric change if Mexico would implement each tax design

Country	Tax design	Change in price (%)*	Tax (USD)	Caloric change: Due to price change (%)†	Caloric change: Due to reformulation (%)†*
Scenario doubling the existing excise tax					
Mexico	Tax to volume (1.17 pesos/litre)	6.3	$0.12	7.1	0.0
Scenarios with sugar density taxes (tiered taxes)					
United Kingdom	Specific tax (0.26 USD:5–8 g sugar/100 m) (0.35 USD>8 g sugar/100 mL)	7.0	$0.12	7.9	8.2
South Africa	Specific tax (0.003 USD per gram of sugar for beverages>4 g sugar/100 mL)	7.4	$0.12	8.4	15.0
Portugal	Specific tax (0.14 USD<8 g sugar/100 mL) (0.28 USD>8 g sugar/100 mL)	11.4	$0.15	12.9	8.2
Chile	Ad valorem tax (10%: <6.25 g sugar/100 mL) (18%: >6.25 g sugar/100 mL)	14.6	$0.18	16.5	9.5
Peru	Ad valorem tax (12%: <0.5 g sugar/100 mL) (17%: 0.5–6 g sugar/100 mL) (25%: >6 g/100 mL)	21.3	$0.24	24.1	12.4
Ireland	Specific tax (0.25 USD: 5–8 g sugar/100 mL) (0.38 USD: >8 g sugar/100 mL)	26.6	$0.28	30.1	8.2
Scenarios with ad valorem taxes					
Ecuador	10% on drinks>2.5 g sugar/100 mL	9.4	$0.14	10.6	0.0
Thailand	10% to juices, 14% to other SSB	13.1	$0.17	14.9	0.0
India	28% to SSB	26.2	$0.28	29.8	0.0
Kiribati	40% to SSB	37.5	$0.37	42.5	0.0
Bahrain	50% to SSB, 100% to energy drinks	46.9	$0.45	53.1	0.0
Scenarios with specific taxes (volume)					
Philippines	0.31 /litre USD to SSB	12.2	$0.16	13.8	0.0
Berkeley, USA	0.34 /liter USD to SSB	22.1	$0.24	25.1	0.0
Philadelphia, USA	0.51 /liter USD to SSB	33.2	$0.33	37.6	0.0
Boulder, USA	0.68 /liter USD to SSB	44.2%	$0.42	50.2%	0.0

*The change in price corresponds to the additional price increase for each tax scenario, excluding the current tax. For tiered taxes, it considers changes change in price after reformulation.
†Calculated based on the price increase and the price elasticities (online supplemental section 3.1).
‡Calculated based on South Africa evidence where the two main top coca brands do not reformulate.[19]
SSB, sugar-sweetened beverage.

Table 2 presents the expected health outcomes across tax designs 10 years after implementation. Doubling the existing tax should lead to a 7.6% caloric reduction. For sugar-density taxes, the highest caloric reduction is expected for the tax design as in Ireland, equivalent to 38.3% price increase, which corresponds to the highest tax amount across sugar-density taxes. This reduction comes from two effects: price effect of 30.1% and from reformulation (8.2%). For ad-valorem taxes, the highest caloric reductions were 57.3% (tax from Bahrain) and 54% among specific volume taxes (tax implemented in Boulder, USA).

For obesity prevalence, the lowest reduction is 2.9% for the scenario of doubling the existing tax in Mexico and the highest was 18.7% for the scenario of adding a tax as in Bahrain (the highest tax rate option). Ad valorem and excise taxes had similar caloric and obesity reductions under similar

Table 2 Caloric, weight and obesity changes attributable to each tax scenario over 10 years

	Change in price (%)*	Caloric change (kcal/day)	Weight change (kg)	Absolute change in obesity (pp)	Relative change in obesity (%)	Change in obesity cases (millions)
Scenario doubling the existing excise tax						
Mexico	6.3%	7.6	0.4	1.0	2.9	0.97
		(−7.9 to −7.4)	(−0.4 to −0.4)	(−1.4 to −0.7)	(−3.8 to −2.0)	(−1.31 to −0.65)
Scenarios with sugar-density taxes						
United Kingdom (tiered excise)	7.0%	16.6	0.8	2.1	5.9	1.97
		(−17.3 to −16.0)	(−0.8 to −0.8)	(−2.5 to −1.7)	(−7.1 to −4.7)	(−2.33 to −1.59)
South Africa (fixed excise)	7.4%	23.8	1.1	3.1	8.8	2.94
		(−24.8 to −22.9)	(−1.2 to −1.1)	(−3.7 to −2.6)	(−10.2 to −7.4)	(−3.45 to −2.42)
Portugal (tiered excise)	11.4%	21.6	1.0	2.8	7.9	2.63
		(−22.4 to −20.8)	(−1.1 to −1.0)	(−3.3 to −2.3)	(−9.3 to −6.5)	(−3.08 to −2.14)
Chile (tiered ad valorem)	14.6%	26.3	1.2	3.6	10.0	3.34
		(−27.3 to −25.3)	(−1.3 to −1.2)	(−4.1 to −3.0)	(−11.5 to −8.5)	(−3.82 to −2.80)
Peru (tiered ad valorem)	21.3%	36.1	1.7	4.6	13.0	4.32
		(−37.5 to −34.8)	(−1.8 to −1.6)	(−5.2 to −4.0)	(−14.6 to −11.3)	(−4.85 to −3.73)
Ireland (tiered excise)	26.6%	38.6	1.8	4.9	13.8	4.61
		(−40.1 to −37.2)	(−1.9 to −1.8)	(−5.6 to −4.3)	(−15.5 to −12.1)	(−5.13 to −4.01)
Scenarios with Ad Valorem taxes						
Ecuador	9.4%	11.5	0.5	1.5	4.2	1.40
		(−11.9 to −11.0)	(−0.6 to −0.5)	(−1.9 to −1.1)	(−5.3 to −3.1)	(−1.77 to −1.03)
Thailand	13.1%	16.0	0.8	2.0	5.7	1.89
		(−16.6 to −15.4)	(−0.8 to −0.7)	(−2.5 to −1.6)	(−6.9 to −4.5)	(−2.33 to −1.49)
India	26.2%	32.1	1.5	4.2	11.8	3.93
		(−33.3 to −30.8)	(−1.6 to −1.5)	(−4.8 to −3.6)	(−13.4 to −10.2)	(−4.48 to −3.36)
Kiribati	37.5%	45.8	2.1	5.7	16.0	5.33
		(−47.5 to −44.1)	(−2.2 to −2.1)	(−6.4 to −5.1)	(−17.8 to −14.1)	(−5.97 to −4.76)
Bahrain	46.9%	57.3	2.7	6.7	18.7	6.23
		(−59.4 to −55.1)	(−2.8 to −2.6)	(−7.4 to −6.0)	(−20.6 to −16.7)	(−6.90 to −5.60)
Scenarios with specific volumetric taxes						
Philippines	12.2%	14.9	0.7	1.9	5.2	1.74
		(−15.4 to −14.3)	(−0.7 to −0.7)	(−2.3 to −1.5)	(−6.4 to −4.1)	(−2.14 to −1.40)
Berkeley, USA	22.1%	27.0	1.3	3.7	10.5	3.49
		(−28.0 to −26.0)	(−1.3 to −1.2)	(−4.3 to −3.2)	(−12.0 to −8.9)	(−4.01 to −2.98)
Philadelphia, USA	33.2%	40.5	1.9	5.0	14.1	4.71
		(−42.1 to −39.0)	(−2.0 to −1.8)	(−5.7 to −4.4)	(−15.8 to −12.4)	(−5.32 to −4.10)
Boulder, USA	44.2%	54.0	2.5	6.4	17.9	5.98
		(−56.1 to −52.0)	(−2.6 to −2.4)	(−7.1 to −5.7)	(−19.8 to −16.0)	(−6.62 to −5.32)

Confidence Intervals were derived for sample means using the sampling weights of the 2018 National Health and Nutrition Survey.
*The change in price corresponds to the additional price increase for each tax scenario, excluding the current tax.

tax-related increases in price. In contrast, under similar price increases, tiered taxes produced higher reductions in caloric intake and obesity due to the effect of reformulation, additional to the price effect.

Table 3 shows lost jobs, healthcare savings and net present benefits for each tax design over a 10-year span. Across all tax designs, net benefits are positive: costs in terms of lost jobs are lower relative to benefits, mostly associated with reductions in indirect costs. The tax design from Bahrain (the highest tax rate option) yielded the maximum net benefit equivalent to USD $24.7 billion. Very close is the tax in Boulder, USA that has a similar amount and tax as in Bahrain, with a net benefit of USD $23.7 billion. However, the largest taxes among sugar-density taxes (Ireland and Peru) that represent about half the taxes in Bahrain and Boulder are associated with large net benefits (USD $18.1 and USD $18.7, respectively).

Table 4 presents an equity analysis for the scenario with the highest benefits and highest tax rate (Bahrain) using price elasticities by household income quintile. While the lowest and low-income quintiles have the highest price elasticities, the tax scenario with the highest net benefits favours more the low and middle quintiles as their baseline obesity prevalence is the highest. The highest price elasticity for the low-income level also contributes to the largest benefits as their reductions in calories are higher. The last column shows the amount of tax paid quarterly for each quintile as for 2018. Tax payments increase with income; the lowest income quintile pays the smallest amount: $18 912 thousand dollars compared with $26 969 in the highest income quintile. The smallest payments among lower income households are explained by a lower proportion of SSB purchasers: 56.7%, 67.5% for the lowest and low-income group, respectively, compared with more 72.6%, 76.4% and 75.0% for the middle, high and highest income groups as the quantity purchased among those with purchases greater than zero are similar across income groups (results not shown).

DISCUSSION

We assessed what would happen if Mexico modified its existing tax to get higher benefits based on currently implemented taxes elsewhere with different amounts and designs. In addition to doubling the existing tax, we included sugar-density taxes, ad valorem taxes and volumetric taxes. All tax scenarios were added to the existing tax in Mexico. We identified taxes that maximise health-related savings and reduce lost jobs. We conducted an equity analysis estimating how health benefits were distributed across income quintiles for the scenario that maximised net benefits and added for comparison the amount of tax payments in 2018 by income quintile. We found that the ad valorem tax in Bahrain of 46.9% would yield the highest net benefits of 24.7 billion USD after 10 years. These benefits came from reductions in health costs of $29.1 billion USD, in contrast to $4.4 billion USD associated with lost jobs. The equity analysis showed that this tax would favour the population in the low-income group with a 19.6% reduction in obesity because it has the highest price elasticity and a high prevalence of obesity. The lowest income group experienced a lower benefit from the tax as their baseline prevalence is the smallest, however, obesity reductions amounted to 15.9%, and significant net benefits are expected. Quarterly tax payments as for 2018 increase with income, the lowest income quintile pays 42% less compared with the highest income quintile. The small difference in health benefits between the middle-low and the lowest income quintile may be compensated by the difference in tax payments (18% higher for the middle-low group) and, eventually, mitigated by allocating SSB tax revenues to fund public services or programmes directed to this group.

All scenarios were added to the existing tax, but this does not affect our comparisons as all scenarios add to the existing tax. We consider this to be a reasonable approach because we are using the 2018 National Health and Nutrition Survey to estimate health impacts, which already includes the impact of the tax implemented in 2014. Also, for policy implementation, it would be easier to build on the previous tax that demonstrated to reduce consumption and add it to the previous tax.

As expected, the job loss costs are small as the SSB represents a small share of the economy. For instance, the number of employees in the beverage industry represents 1.85% of the overall manufacturing industry.[28] We acknowledge that the estimation of job losses may be overestimated as there may be increases in employment from the government related to fiscal revenues or productivity gained due to a reduction of cases or premature deaths associated with the tax.

While Bahrain was the option with the largest net benefits for Mexico, our analysis also shows that at a similar price increase from sugar-density taxes could produce larger benefits. For example, doubling the existing tax in Mexico and the scenarios of the UK and South Africa have similar price increases, but the net benefits are larger for the last two tax designs. In general, sugar-density taxes produced larger benefits as a result of two mechanisms: responses to price increases and reformulation. Thus, at the same level of price increase, sugar-density taxes incentivise reformulation, leading to a net reduction in sugar concentration and a reduction in caloric intake. Thus, while largest benefits come from Bahrain that has the highest tax rate option, a tax to sugar content could potentially yield larger benefits with similar tax rates.

The potential advantage of sugar-density taxes depends on the willingness of brands to reformulate. To illustrate this point, we developed a hypothetical scenario comparing the same tax amount under three conditions: (1) no reformulation, (2) average reformulation (our main scenario, where the two top cola brands do not reformulate as observed in South Africa)[19] and (3) all brands reformulate (see online supplemental section 8, Tables J,K, and L). Using South Africa as an example,

Table 3 Net benefits attributable to each tax scenario over 10 years

				Costs	Benefits		
	Tax-related change in price	Marginal decrease in SSB consumption (million litres)	Lost jobs	Lost jobs ($ billion)	Reduction in direct costs ($ billion)	Reduction in indirect costs ($ billion)	Net benefits ($ billion)
Scenario doubling the existing tax							
Mexico	6.30%	5623.90 (5408.3 to 5839.5)	119 119 (114 551 to 123 686)	0.59 (0.57 to 0.61)	1.26 (0.82 to 1.7)	3.02 (1.96 to 4.07)	3.69 (2.2 to 5.18)
Scenarios with sugar density taxes							
United Kingdom	7.00%	6274.10 (6033.5 to 6514.6)	132 890 (127 794 to 137 985)	0.66 (0.63 to 0.68)	2.67 (2.1 to 3.23)	6.37 (5.01 to 7.73)	8.38 (6.45 to 10.3)
South Africa	7.40%	6678.30 (6422.2 to 6934.4)	141 452 (136 028 to 146 876)	0.70 (0.67 to 0.73)	3.96 (3.3 to 4.62)	9.45 (7.87 to 11.04)	12.71 (10.48 to 14.94)
Portugal	11.40%	10 257.50 (9864.2 to 10650.8)	217 262 (208 931 to 225 592)	1.07 (1.03 to 1.12)	3.55 (2.92 to 4.18)	8.49 (6.98 to 10)	10.96 (8.84 to 13.09)
Chile	14.60%	13 095.50 (12593.4 to 13597.6)	277 374 (266 739 to 288 009)	1.37 (1.32 to 1.42)	4.44 (3.75 to 5.12)	10.6 (8.96 to 12.24)	13.66 (11.35 to 15.97)
Peru	21.30%	19 091.70 (18359.6 to 19823.7)	404 378 (388 873 to 419 883)	2.00 (1.92 to 2.08)	5.95 (5.16 to 6.73)	14.21 (12.34 to 16.08)	18.16 (15.53 to 20.79)
Ireland	26.60%	23 892.00 (22975.9 to 24808.0)	506 052 (486 648 to 525 455)	2.50 (2.41 to 2.6)	6.28 (5.48 to 7.07)	15.00 (13.1 to 16.9)	18.77 (16.11 to 21.44)
Scenarios with Ad Valorem taxes							
Ecuador	9.40%	8421.60 (8098.7 to 8744.5)	178 376 (171 536 to 185 215)	0.88 (0.85 to 0.92)	1.87 (1.36 to 2.38)	4.47 (3.26 to 5.68)	5.46 (3.75 to 7.17)
Thailand	13.10%	11 790.20 (11338.1 to 12242.3)	249 726 (240 151 to 259 301)	1.24 (1.19 to 1.28)	2.57 (2 to 3.13)	6.13 (4.79 to 7.48)	7.46 (5.57 to 9.35)
India	26.20%	23 580.40 (22676.2 to 24484.5)	499 452 (480 301 to 518 602)	2.47 (2.38 to 2.57)	5.36 (4.61 to 6.11)	12.81 (11.01 to 14.6)	15.7 (13.18 to 18.21)
Kiribati	37.50%	33 686.20 (32394.6 to 34977.9)	713 503 (686 145 to 740 860)	3.53 (3.39 to 3.67)	7.24 (6.4 to 8.09)	17.31 (15.29 to 19.33)	21.02 (18.21 to 23.84)
Bahrain	46.90%	42 107.80 (40493.3 to 43722.3)	891 878 (857 681 to 926 075)	4.41 (4.24 to 4.58)	8.59 (7.67 to 9.5)	20.52 (18.33 to 22.71)	24.7 (21.65 to 27.75)
Scenarios with specific volumetric taxes							
Philippines	12.20%	10 948.00 (10528.2 to 11367.8)	231 888 (222 997 to 240 780)	1.15 (1.1 to 1.19)	2.39 (1.84 to 2.94)	5.71 (4.39 to 7.02)	6.95 (5.1 to 8.8)
Berkeley, USA	22.10%	19 874.90 (19112.8 to 20636.9)	420 966 (404 825 to 437 108)	2.08 (2 to 2.16)	4.61 (3.92 to 5.31	11.02 (9.36 to 12.69)	13.56 (11.22 to 15.89)
Philadelphia, USA	33.20%	29 812.30 (28669.2 to 30955.4)	631 450 (607 238 to 655 661)	3.12 (3 to 3.24)	6.48 (5.67 to 7.29	15.48 (13.56 to 17.41)	18.84 (16.15 to 21.53)
Boulder, USA	44.20%	39 749.80 (38225.6 to 41273.9)	841 933 (809 651 to 874 215)	4.17 (4.01 to 4.32)	8.23 (7.33 to 9.13	19.66 (17.51 to 21.82)	23.73 (20.72 to 26.73)

Confidence Intervals were derived for sample means using the sampling weights of the 2018 National Health and Nutrition Survey.
SSB, sugar-sweetened beverage.

Table 4 Changes on calories, weight and obesity attributable to each tax scenario over ten years and quarterly tax payments by income quintile

			Based on the tax scenario in Bahrain				
Income quintile	Price elasticity	Obesity prevalence	Caloric change (kcal/day)	Absolute change in obesity (pp)	Relative change in obesity (%)	Change in obesity cases (millions)	Quarterñy tax payments as for 2018 (thousands 2019 USD)
Lowest	−1.16	31.5 (29.2 to 33.8)	−48.1 (−52 to −44.2)	5.0 (−6.2 to −3.8)	−15.9 (−19.8 to −12.0)	−0.93 (−1.16 to −0.71)	18912
Low	−1.22	34.4 (31.7 to 37.0)	−63.1 (−67.6 to −58.7)	−6.7 (−8.1 to −5.4)	−19.6 (−23.7 to −15.6)	−1.25 (−1.51 to −1.01)	22335
Middle	−1.16	39.6 (36.6 to 42.6)	−63.4 (−68.6 to −58.3)	−7.7 (−9.3 to −6.0)	−19.4 (−23.6 to −15.1)	−1.44 (−1.73 to −1.12)	24592
High	−1.1	37.4 (34.6 to 40.3)	−59.4 (−63.8 to −54.9)	−6.9 (−8.3 to −5.5)	−18.4 (−22.1 to −14.8)	−1.29 (−1.55 to −1.03)	25248
Highest	−1.06	35.2 (31.9 to 38.4)	−52.6 (−57.9 to −47.2)	−6.8 (−8.5 to −5.0)	−19.3 (−24.3 to −14.3)	−1.27 (−1.59 to −0.93)	26969

Confidence Intervals were derived for sample means using the sampling weights of the 2018 National Health and Nutrition Survey.

in the first scenario reformulation is 0%, compared with 15% in scenario 2 and 59.9% in scenario 3. The tax corresponds to a 9.6% increase in price in scenario 1, decreases to 7.4% in scenario 2 and 0.9% in scenario 3, due to reformulation. In scenario 1, calories decrease by −11.8 kcal/day, lost jobs account for $0.9 billion dollars and healthcare savings sum 5.9 billion dollars. In scenario 2, caloric change is −23.8 kcal/day, lost jobs sum $0.6 billion dollars and healthcare savings account for $13.4 billion dollars. In the last scenario, calories decrease by 65.0 kcal/day, job lost are $0.1 billion dollars and healthcare savings amount $32.3 billion dollars. Net benefits are higher for the scenario where all brands reformulate: 32.2 billion dollars compared with $5.1 when no reformulation and $12.2 in our main scenario. This example shows the relevance of creating incentives for all brands to reformulate. Most countries have opted for relatively small taxes, but steeper sugar-density taxes could create enough pull for large brands to decide to reformulate and increase the health and social benefits of this fiscal measure.

We analysed the potential tax designs to modify the existing tax for Mexico estimating the option with the highest benefits: taxes that maximise health-related savings and reduce lost jobs. Other studies use optimal tax frameworks as a function of externalities (healthcare costs associated with SSB consumption), internalities (cost associated with lack of knowledge about the harms associated with SSB consumption or lack of self-control) and regressivity (how much the burden of taxation affects the poor).[11 31] This framework requires calculations of internalities by estimating how much less would a group of the population consume SSB if they had information and self-control. While our study includes healthcare savings as in Allcott, we are unable to include consumer surplus changes because we lack data on the proportion of the population with imperfect information or lack of self-control. However, we conducted an equity analysis looking at the distribution of health outcomes and tax payments by income quintile, showing largest benefits for the low and middle low groups.

Our study has some limitations. First, we acknowledge that some benefits such as an increase in quality of life from the reduction of obesity-related morbidity were not be included. Our analysis includes direct healthcare costs (healthcare spending, travel costs and costs incurred by caregivers) and indirect costs (economic loss from premature mortality), absenteeism (loss days of work due to illness) and presenteeism (productivity reduced at work). We acknowledge that the value of living longer and healthier is not accounted for in our analysis and may underestimate health gains. However, this underestimation does not invalidate comparisons between tax scenarios as all follow the same estimation method for healthcare costs.

Second, we did not account for implementation and monitoring costs by the government after the SSB tax change. However, an additional component for the existing tax may require additional initial resources for its implementation and this could vary across tax designs. Third, we estimated the impact of the scenario that yielded the highest net benefits by income quintile. We recognise that we would expect a higher price elasticity for the lowest income quintile, although we can see a clear gradient between income quintiles as the middle–high and high have smaller price elasticities compared with the rest. Moreover, for the evaluation of the SSB tax in Mexico using the same source of data as the price elasticities estimates, a study found larger reductions among the lowest income tertile.[1] A different paper that used data from urban areas showed the highest reductions of taxed beverages in the lowest socioeconomic group (based on three groups from an index of household assets).[2] Fourth, we acknowledge that our assumption on the extent of the reformulation for sugar-density taxes may differ from the effective response of SSB producers in Mexico. However, evidence suggests that sugar-density taxes have been effective in encouraging reformulation in South Africa and the United Kingdom.[9 10] Finally, we assessed the potential impact of redesigning taxes as a stand-alone intervention; however, recent evidence from Chile shows that coupling taxes with front-of-package warning labels and regulation of food and beverages offered in schools, could lead to larger gains.[32]

We acknowledge that we lack comprehensive uncertainty intervals for our estimates because we could not obtain CIs or SEs for price elasticities and obesity costs—not reported in the papers used—and for job losses as the input–output matrix provides point estimates only. Thus, our CIs underestimate the uncertainty associated with all of these data sources and should be interpreted cautiously.

To estimate the expected caloric reduction, we did not consider cross-price elasticities; by failing to include them, we could have overestimated caloric reductions and consequently, obesity reductions and costs. However, evidence exists about increases in the consumption of non-caloric beverages after the tax, such as bottled water, which would not modify our results.[1 2] Also, an observational study in Mexico showed that industrialised beverages are not usually substituted, on the contrary, most of them are complemented, meaning that when not consumed, the energy intake would reduce from beverages and from complementary food.[33]

As for the estimation of the expected caloric reduction, we are not considering cross-price elasticities in the estimation of job losses. In addition, although a study that evaluated the impact of the SSB and food tax in Mexico did not show any reduction in the number of employees,[6] the scenarios included in our study have higher tax rates and the input–output matrix includes all sectors of the economy.

Given the high burden of non-communicable diseases in Mexico, increasing and redesigning the SSB tax, could provide additional benefits. In this study, we provided evidence of a potential tax design equal to 0.45 USD per SSB litre, but further gains may be obtained if this price increase is implemented as a sugar-density tax as it incentivises reformulation. Future studies should assess the impact of modifying SSB taxes along with other policies aimed at improving the population's diet in Mexico, such as the recently implemented front-of-package warning labels for food and beverages.

Contributors MAC, TBG, ABA and JCSH conceived the work and interpreted data. IJB and LAMA interpreted data. All authors drafted and critically reviewed the content of the work, approved the version to be published and agreed on all aspects of the work.

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