Health Care Reform

Impact of Targeted Beverage Taxes on Higher- and Lower-Income Households

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Background: Sugar-sweetened beverage (SSB) taxes are increasingly being considered as a strategy for addressing the obesity epidemic. We sought to investigate the differential impact of targeted beverage taxes on higher- and lower-income households.

Methods: This analysis relied on data from the 2006 Nielsen Homescan panel, which included a national sample of households that scan and transmit their store-bought food and beverage purchases weekly for a 12-month period. We assessed associations among beverage prices, energy intake, and weight using multivariate regression models.

Results: A 20% and 40% tax on carbonated SSBs only would reduce beverage purchases by a mean (SE) of 4.2 (1.6) and 7.8 (2.8) kcal/d per person, respectively. Extending the tax to all SSBs generates mean (SE) reductions of 7.0 (1.9) and 12.4 (3.4) kcal/d per person, respectively. Estimated mean (SE) weight losses resulting from a 20% and 40% tax on all SSBs are 0.32 (0.09) and 0.59 (0.16) kg/y per person, respectively. The 40% tax on SSBs, which costs a mean (SE) of $28.48 ($0.87) per household per year, would generate $2.5 billion ($77.5 million) in tax revenue, with the largest share coming from high-income households.

Conclusions: Large taxes on SSBs have the potential to positively influence weight outcomes, especially for middle-income households. These taxes would also generate substantial revenue that could be used to fund obesity prevention programs or for other causes.

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Obesity rates have more than doubled in the past few decades, and the link between obesity and an increased risk for many adverse health conditions is well established. Moreover, obesity has been estimated to cost as much as $147 billion per year, with roughly half of this total paid by Medicare and Medicaid. Therefore, governments have both public health and financial motivations to contain rising rates of obesity.

Falling food and beverage prices have been associated with an increase in food consumption, especially for calorie-dense foods. It is generally agreed that successful obesity prevention efforts will need to be multifaceted and affect all components of the socioecological model. One increasingly contentious option concerns the use of targeted taxes to discourage consumption of obesity-promoting foods by making them more expensive. Economic theory suggests that, by raising prices, this approach could be part of an effective obesity prevention strategy. However, the questions of which foods to tax and the size of the tax remain a source of major debate given that no single food source is responsible for the obesity epidemic.

Although many foods are viable candidates, carbonated and other sugar-sweetened beverages (SSBs) are increasingly targeted. Consumption of these beverages has been steadily increasing; however, a growing body of literature suggests that their consumption is associated with increased caloric intake, weight gain, and obesity and that a reduction in consumption would result in weight loss. Although other foods may also be appropriate targets, there is a rationale from a public health perspective for targeting SSBs as a means to reduce overall caloric intake.

Proponents of a targeted beverage tax often raise 2 primary concerns. The first is the extent to which the tax would reduce caloric intake and obesity and the second is whether the tax disproportionately affects lower-income households. Concerning the first point, Andreyeva et al report that the average price elastic-
ity of demand for carbonated SSBs is $-1.00$ and for SSBs overall is $-0.79$. These results indicate that taxes would reduce consumption of these beverages by a considerable amount. For example, based on the overall elasticity estimate, a tax that raised the market price of SSBs by 20% would result in a 15.8% decrease in quantity demanded of these beverages. However, given that consumers may switch to other beverages or even other foods, perhaps with equal or greater caloric value, the net effect of the tax on total calories purchased could be far less.

To date, only 1 empirical study has attempted to calculate the net reduction in energy intake resulting from a beverage tax while taking into account cross-price elasticity, which is the change in consumption of other products as a result of a price increase on a selected product (such as SSBs). Duffey et al\textsuperscript{15} used 20 years of data from the CARDIA (Coronary Artery Risk Development in Young Adults) Study, merged with regional price data for soda, whole milk, burgers, and pizza, to simulate the effect on caloric intake and weight resulting from a carbonated SSB price increase. They estimated that an 18% increase in the price of carbonated SSBs would result in a slight decrease of 8 kcal/d from soda but roughly 2.3 kg of weight loss per person per year resulting from reductions in energy intake from other products. Their weight loss estimate seems implausibly high given the small reduction in energy directly from soda and, as the authors note, may result from the omission of other food and beverage prices that also significantly changed during the study period.

This analysis revisits the extent to which targeted beverage taxes would reduce caloric intake and weight using current and more detailed data on household purchases and a larger set of price data than was available in the analysis by Duffey et al\textsuperscript{15}. Specifically, we simulated the effects on caloric intake and weight resulting from a 20% or 40% tax on (1) carbonated SSBs only or (2) carbonated SSBs, fruit drinks, and sports/energy drinks simultaneously. We quantified the effects separately for higher- and lower-income households to address the extent to which these taxes may be regressive. The analysis focused on store-bought purchases, as opposed to restaurant or other purchases, because these remain the largest single source of caloric consumption\textsuperscript{16} and are the most likely target for a beverage tax and because of the detailed data available at the store level.

Although the Nielsen data do not include nutritional information, calorie content for each product was merged at the UPC level using data available from Gladson Interactive Services, Lisle, Illinois, or via Web searches in which matches were not available (>30% of UPCs). Based on the merged data, we present estimates of mean daily kilocalories purchased per household member, the percentage of households that purchased each type of beverage, the mean daily kilocalories purchased per household member for those households with positive purchases, and the average price paid per 1000 kcal. Estimates are presented for each SSB category separately and for the included non-SSB overall by income quartile.

To predict the effects of the 20% and 40% price increases, we used multivariate regression models to estimate the association between changes in monthly beverage prices and changes in monthly kilocalories purchased. For ease of exposition, we converted monthly purchases at the household level to daily purchases per individual by dividing by 30 (days per month) and by the number of individuals residing within each household. Separate analyses were run for (1) carbonated SSBs and (2) all SSBs, which included carbonated SSBs, fruit drinks, and sports/energy drinks. A final analysis with the dependent variable equal to total beverage kilocalories across the 7 beverage categories was used to simulate the impact of different tax strategies on net kilocalories from beverages purchased.

The estimation strategy followed the methods presented in Duffey et al.\textsuperscript{13} For each analysis, we estimated 2-part marginal effects models. The first part of the 2-part model is a logistic regression that estimates the probability of positive purchases in a given month as a function of average monthly prices in the market for each beverage category and other covariates; the second part estimates a regression of the same prices and covariates on log-kilocalories (per person per day) for those with positive purchases. The results were then combined to predict per capita average daily beverage kilocalories purchased and to estimate how these purchases would change in response to (1) a 20% tax on carbonated SSBs only, (2) a 20% tax on all SSBs, (3) a 40% tax on carbonated SSBs, and (4) a 40% tax on all SSBs. The tax simulations were conducted by raising the relevant prices faced by each household member by either 20% or 40% and using the model coefficients to estimate reductions in kilocalories (in levels and percentages) purchased as a result of the tax. The percentage reductions were then divided by the corresponding tax increases to estimate elasticities.

The analyses were conducted at the monthly level (384 252 household-months) to take advantage of fluctuations in prices over time and across markets. Each market-level price is a Fisher ideal price index calculated using brand-level prices reported in individual household purchase records weighted by brand-level quantities purchased. Each regression controlled for household demographic characteristics, including income quartile, head-of-household age, race, region, number of children in the household, number of adults in the household, and head-of-household education status. To generate separate price effects by income strata, both parts of the 2-part model also included interaction terms between the income quartile and price variables. Based on the regression results and tax simulations, we conducted a crude estimate of the reduction in per capita weight resulting from each tax strategy during the course of 1 year by dividing the per capita kilocalorie reductions by 7716, the estimated number of kilocalories in 1 kg, and multiplying by 365 (days per year). Finally, we used the predictions from the tax simulations to estimate per capita and aggregate tax revenue by income quartile resulting from each tax strategy. This was accomplished by using the 2-part model to directly estimate volume, rather than kilocalories, of each SSB category under each tax scenario, multiplying these estimates by the average prices paid for the corresponding income strata under each tax
Table 1 presents descriptive statistics of store-bought beverage purchases for SSBs and the included non-SSB categories by income quartile. Across all SSBs, purchases from stores totaled 78 (0.71) kcal/d per household member for those in the lowest income quartile and steadily decreased to 52 (0.48) kcal/d per household member for those in the highest income quartile. However, when restricted to households with positive purchases, the differences are much more pronounced. Purchases in the lowest income quartile increased to 128 (1.05) kcal/d, whereas this figure was only 80 (0.68) kcal/d for those in the highest income quartile. Table 1 also shows that the lowest-income households purchased their SSB kilocalories at a much lower cost. The lowest-income households spent roughly $2.34 ($0.24) per 1000 SSB kcal compared with an average cost of $2.78 or more for households in the remaining income strata. Although trends for the SSB subcategories showed similar results, much of the differences across SSBs were driven by carbonated SSBs. These beverages accounted for more than two-thirds of SSB kilocalories for each income group and more than three-fourths for those in the lowest income quartile. Sports/energy drinks, although perhaps purchased in greater volume from vending machines or other venues, represented a very small percentage of store-bought beverage purchases. The bottom portion of Table 1 shows store-bought beverage purchases for the included non-SSBs and for SSBs and non-SSBs combined. For non-SSBs and overall, households in lower income quartiles purchased greater amounts of beverage calories from stores compared with those in higher-income quartiles and again at lower prices. In total, per capita purchases from stores were roughly 183 (1.04) kcal/d for those in the lowest income quartile. This figure steadily decreased to 139 (0.73) kcal/d for those in the highest income quartile, in which roughly 37% of their beverage calories were from SSBs (ie, 5-6 percentage points less than lower-income households).
Based on regression results, **Figure 1** and **Figure 2** present the estimated energy reductions resulting from a 20% or 40% tax on carbonated SSBs or on all SSBs. The first 2 sets of bar charts in Figure 1 show that a 20% and 40% tax on carbonated SSBs would reduce their per capita purchases by an average of roughly 6.0 (0.7) and 10.4 (1.2) kcal/d, respectively. Effects were similar in magnitude across income strata, and all results were statistically different from 0. Across all households, the estimated own price elasticity was −0.73 (0.09), with estimates ranging from −1.02 (0.17) for households in the 50% to 75% income quartile to −0.49 (0.20) for the 0% to 25% income quartile of households. (A table showing regression results for each 2-part model is available on request from the authors.)

The last 2 bar charts in Figure 1 show the effects of the tax on total beverage calories. Because consumers were switching from soda to other beverages, the reduction in caloric intake was moderated. On average, a 20% tax on carbonated SSBs would reduce per capita beverage kilocalories purchased by only 4.2 (1.6) kcal/d; a 40% tax would reduce beverage purchases by roughly 7.8 (2.8) kcal/d. Both reductions were entirely driven by middle-income households. The estimated beverage energy elasticity with respect to a carbonated SSB price increase was −0.14 (0.05), with no statistically significant differences by income strata.

**Figure 2** presents similar results for a tax on all SSBs. Across all households, the estimated own price elasticity of energy from SSBs was −0.87 (0.09). When expanded to include total beverage kilocalories (accounting for substitution), the elasticity was reduced to −0.22 (0.06). As a result, whereas daily per capita kilocalories from SSBs were reduced by 10.0 (1.0) and 17.1 (1.6) kcal/tax increase on all sugar-sweetened beverages (SSBs) and a change in SSB or all beverage calories purchased. These values are derived from 2-part marginal effects models of the association between per capita average daily energy (in kilocalories) from all SSBs or from all beverages and the price of SSBs. All models are adjusted for the following covariates: logged values for the price of carbonated SSBs, fruit drinks, sports/energy drinks, diet carbonated beverages, fruit juices, skim milk and whole milk, interaction terms between the income and price variables, age of the head of the household, race, education, household income, household composition (number of adults and number of children), and the presence of a female head of household younger than 35 years. Standard error estimates (bars) were generated through the bootstrap method. Groups represent quartiles of income.

**Figure 1.** Association between a 20% or 40% tax increase on carbonated sugar-sweetened beverages (SSBs) and a change in carbonated SSB or all beverage calories purchased. These values are derived from 2-part marginal effects models of the association between per capita average daily energy (in kilocalories) from carbonated SSBs or from all beverages and the price of carbonated SSBs. All models are adjusted for the following covariates: logged values for the price of carbonated SSBs, fruit drinks, sports/energy drinks, diet carbonated beverages, fruit juices, skim milk and whole milk, interaction terms between the income and price variables, age of the head of the household, race, education, household income, household composition (number of adults and number of children), and the presence of a female head of household younger than 35 years. Standard error estimates (bars) were generated through the bootstrap method. Groups represent quartiles of income.

**Figure 2.** Association between a 20% or 40% tax increase on all sugar-sweetened beverages (SSBs) and a change in SSB or all beverage calories purchased. These values are derived from 2-part marginal effects models of the association between per capita average daily energy (in kilocalories) from all SSBs or from all beverages and the price of SSBs. All models are adjusted for the following covariates: logged values for the price of carbonated SSBs, fruit drinks, sports/energy drinks, diet carbonated beverages, fruit juices, skim milk and whole milk, interaction terms between the income and price variables, age of the head of the household, race, education, household income, household composition (number of adults and number of children), and the presence of a female head of household younger than 35 years. Standard error estimates (bars) were generated through the bootstrap method. Groups represent quartiles of income.
for a 20% and a 40% tax, respectively, total beverage calorie reductions were smaller, roughly 7.0 (1.9) and 12.4 (3.4) kcal/d, respectively. Middle-income households had the largest estimated reductions in SSB kilocalories as a result of the tax; results for households in the lowest and highest income quartiles were not statistically different from 0. Estimated total beverage elasticities for an SSB price increase ranged from −0.49 (0.11) for households in the 50% to 75% income quartile to 0.06 (0.12) for the 76% to 100% income quartile. During the course of a year, this could come to roughly an additional 44 kcal/d in beverages from stores than those in the highest income quartile. For a 40% tax on SSBs, households in the lowest income quartile would pay roughly 20% of the tax, those in the middle income quartiles would each pay roughly 25%, whereas the highest income quartile would pay 30% of the tax. Across all households, for a 40% tax on all SSBs, the average annual burden was $28.48 ($0.87) per household per year.

Table 2 presents estimated weight losses resulting from the different tax strategies. Taxes on carbonated SSBs of 20% and 40% generated per person annual weight losses of 0.20 (0.07) and 0.37 (0.13) kg, respectively. Expanding the tax to include all SSBs increased weight losses to an average of 0.32 (0.09) and 0.59 (0.16) kg per person per year for a 20% and a 40% tax, respectively. The reductions were almost entirely driven by households in the middle income quartile.

Table 3 presents aggregate tax revenue resulting from each tax strategy. A 20% tax on carbonated SSBs only would generate $878.9 million ($17.5 million) in revenue per year. Because doubling the tax would further restrict consumption, this figure increased by only 71% to $1.5 billion ($25.6 million) per year, whereas a 40% tax raised annual revenue to $2.5 billion ($77.5 million). Although lower-income households purchase more SSBs than higher-income households, because they do so at lower average prices and because they are more price sensitive, their share of the tax was less than that of higher-income households. For a 40% tax on SSBs, households in the lowest income quartile would pay roughly 20% of the tax, whereas the middle income quartiles would each pay roughly 25%, whereas the highest income quartile would pay 30% of the tax. Across all households, for a 40% tax on all SSBs, the average annual burden was $28.48 ($0.87) per household per year.

COMMENT

Lower-income households purchase more beverage calories from stores than those in higher-income households. For example, we show that those in the lowest-income quartile purchased roughly an additional 44 kcal/d in beverages from stores than those in the highest income quartile. During the course of a year, this could equate to a difference in weight of more than 1.8 kg. Although the differences in beverage calories may be offset by differences in calories from food or non–store-bought purchases, this finding is consistent with greater rates of obesity among lower-income households. The extent to which targeted beverage taxes could reduce obesity rates depends on which beverages are taxed.
and on the size of the tax. These results show that large sales taxes on carbonated beverages only can improve weight outcomes, but that reductions in weight are roughly 60% greater when the tax is expanded to include all SSBs. This happens because the expanded tax makes it more difficult to substitute similar products in efforts to avoid the price increase. However, we also found that the reductions in weight largely accrued to middle-income households. Because of their higher disposable income, households in the highest income quartile are least likely to change their purchasing behavior as a result of even fairly large sales taxes on SSBs. Therefore, the tax offers no direct benefit to them in terms of reduced weight. The results also show that household members in the lowest income quartile also may not see reductions in weight (reductions were not statistically significant). This finding is consistent with lower-income households being most likely to change their purchasing behavior in efforts to circumvent the tax, perhaps by purchasing more generic, bulk, or sale items or by switching to nontaxed items that are equally high in calories.

In the introduction, we suggested that whether a targeted beverage tax is viable should depend, at least in part, on the tax burden it imposes on higher- and lower-income households. Our results demonstrate that the largest tax, enough to generate a 40% price increase on SSBs, would have only a modest effect on food expenditures, less than $30 per household per year on average. The tax is not regressive in that higher-income households pay the largest share, although they receive no benefit in terms of weight loss. Across all households, the revenue from a 40% sales tax on all SSBs was estimated to be $2.5 billion per year; a 20% tax would raise $1.5 billion. If this revenue were used directly for obesity prevention efforts, this could indirectly increase the effectiveness of targeted beverage taxes.

Our results are generally consistent with those of previous studies. Our estimated elasticity for carbonated SSBs (−0.73) is very close to that reported by Duffy et al19 (−0.72). Our overall SSB elasticity (−0.89) is similar to the average across the studies reviewed by Andreyeva et al14 (−0.79). With the exception of the 2.25-kg weight loss reported by Duffy et al, our modest weight loss estimates from the 20% tax are also consistent with those from previous studies. Using a simulation model, Schroeter et al17 estimated that a 10% tax on nondiet soft drinks would lead to an average weight reduction of 0.09 kg. Focusing on youth, Sturm et al18 and Fletcher et al19 separately used variations in state beverage taxes and found no relationship between these taxes and children’s body mass index. Powell and Chaloupka20 reviewed 9 econometric studies that estimated the relationship between beverage and other prices and weight outcomes and concluded that “when statistically significant effects were found between food and restaurant prices (taxes) and weight outcomes, the effects were generally small in magnitude.” All these studies focused on small price increases of 18% or less. These findings, combined with our results, suggest that large broad-based taxes will be required to positively influence weight outcomes.

This analysis has several limitations. First, the data were self-reported, which may lead to underreporting. Second, the data were limited to store-bought beverage purchases only. If a tax were extended to restaurants and other venues, the effect on SSBs would be greater than those reported herein. However, if individuals substitute foods for SSBs as a result of a tax, our results would be biased, although the direction of effect is unknown. Schroeter et al17 present a theoretical model showing the circumstances under which taxes on select high-calorie foods result in a net increase in caloric consumption. This could occur if, for example, consumers switch from carbonated beverages to foods of even greater calorie value.

With respect to our estimated weight losses, recent work by Katan and Ludwig21 suggest that the assumption of a linear relationship between kilocalories and weight (ie, that a reduction of 3500 kcal translates into 0.45 kg of weight loss) is overly optimistic because it fails to take into account the body’s compensatory mechanisms that limit long-term effects of caloric reductions on body weight. For these reasons, our estimated weight losses may be optimistic.

Finally, to estimate a demand elasticity, it is necessary that price changes be determined by changes in supply. Because our elasticity estimates were negative, we know they were at least partially determined by supply shifts. However, we cannot rule out that some of the price changes were a result of movements of the supply and demand curves.

In summary, these results show that large taxes on SSBs are likely to be effective at positively influencing weight outcomes, especially among middle-income households. These taxes would also generate substantial revenue that could be used to fund obesity prevention efforts or for other causes.

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REFERENCES