Effects of Taxing Sugar-Sweetened Beverage and Subsidizing Milk: Beverage Consumption, Nutrition, and Obesity among US Children

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Abstract

Taxing sugar-sweetened beverages (SSBs) has been proposed as a means to improve U.S. diet and health and generate revenue to address obesity-related issues. A related concern is that children's intake of SSBs, a third that of milk consumption in the late 1970s, now equals milk consumption. Displacing milk by SSBs may shortchange the buildup of bone mass, increasing the risk of fractures and osteoporosis in later life. Accordingly, we examine the effects that a 20-percent SSB tax and a 20-percent milk price subsidy would have on the diet and health of American children. We estimated US beverage demand systems and used the estimated demand elasticities to examine the impacts of the hypothetical SSB tax and milk subsidy. Our results suggest that a 20-percent tax-induced increase in soda price alone would reduce calorie intakes by 40 calories a day among children, lowering the obesity rate from 16.1 percent to 13.4 percent and the overweight rate from 32 percent to 26.9 percent. When a 20-percent price subsidy for milk is bundled with the SSB tax, children would on average decrease their calorie intake (21 calories a day) and increase their calcium intake, but the overweight and obesity rates would actually increase by around 2 percent. The seemingly contradiction between the two averages, lower calories and higher obesity, is due to the fact that the majority of children (90 percent) remain unchanged in their weight classification under the price interventions but on average reduce their calorie intake. Six percent of children increase their calorie intake and gain enough weight to cross the overweight threshold, whereas four percent of children decrease their calorie intake to improve from being overweight to healthy weight. Therefore, when averaging the effects of the price interventions, we found a decrease in calorie intake and higher overweight and obesity rates.

Keywords: Sugar-sweetened beverages (SSB), soda tax, milk subsidy, beverage demand, and obesity

JEL: C30, D12, Q18

1. Introduction

Rising obesity prevalence is a major health and economic concern in the United States. Today, two-thirds of adults are overweight, and half of them are obese. Likewise, about one-third of children and adolescents are either overweight or obese (Flegal et al., 2010; Ogden et al., 2010). Obesity is a costly health condition. A quantitative review of the literature suggests that the medical cost associated with overweight and obesity in the U.S. totaled $114 billion in 2008 (Tsai et al., 2010).

As researchers look for causes of obesity and interventional strategies to tackle the enormous health problem, the association between rising obesity and consuming sugar-sweetened beverages (SSB) has attracted considerable attention. Between 1976-80 and 2003-06, obesity prevalence rose from 5 to 12.4 percent among children aged 2 to 5; from 6.5 to 17 percent for children 6 to 11 years old; and from 5 to 17.6 percent for those aged 12 to 19 (figure 1). Meanwhile, over the same period, children's daily consumption of regular soft drinks has reached equal levels of milk in 203-6, up from a third of milk consumption in the later 1970s (figure 2). Displacement of milk by SSBs is a health concern because milk is the primary source of calcium in children's diets. Low calcium intake among children and adolescents may increase the risk of bone fractures as well as the risk of osteoporosis in older age by contributing to low peak bone mass. According to the National Osteoporosis Foundation (2010), osteoporosis-related fractures were responsible for an estimated $19 billion in costs (in terms of human suffering and health care) in 2005.

In 2009, the severity of childhood obesity prompted the Institute of Medicine (IOM) to recommend taxing SSB to curtail its consumption (IOM, 2009). Such a strategy has been proposed as a means of reducing the intake of SSBs, improving diet and health, and generating revenue that governments can use for addressing obesity (Brownell and Frieden, 2009; Jacobson and Brownell, 2000; Powell and Chaloupka, 2009). The White House Task Force on Childhood Obesity (2010) has recommended conducting research to analyze the effect of taxing less healthy, energy-dense foods (such as soft drinks, candy, snack foods, and fast foods).

In this study, we estimate a beverage demand system using national household purchase data, specifically focusing on SSB and milk by fat content. We then apply the demand elasticities and hypothetical price interventions to individual consumption data reported in national food consumption surveys to estimate dietary and health effects of taxing SSBs and subsidizing milk consumption. We examine how adjustments in beverage consumption result in changes in calorie intake. Using a calorie-intake to body-weight relationship, we calculate changes in children's body weight by two income classes and the resulting outcomes on overweight and obesity prevalence. In the following section we review previous research on beverage demands. We identify the research needs for improving demand elasticity estimates in order to analyze the effects of price interventions. We then briefly present our approach followed by a description of the data. A demand system is specified and the results are presented in the subsequent section. A detailed discussion on dietary, health, and economic impacts ensues.

2. Review of Beverage Demand Literature

A recent comprehensive review of research on food demands revealed that the own-price elasticity for soft drinks has been reported to range from -0.8 to -1.0 (Andreyeva et al., 2009). This elasticity range has been used to predict consumers' responses to taxing soft drinks. There are deficiencies in the reported elasticities for such an evaluation. First, when a particular beverage is taxed, consumers will respond by reallocating their beverage expenditure among all relevant beverages. Lacking estimates of cross-price elasticities among beverages has led researchers to rely on the own-price elasticity and assume away cross-price effects (Brownell et al., 2009; Chaloupka et al., 2009). This is a major limitation for evaluating the impact of a SSB tax on obesity because some juices and milk are more energy dense by volume than regular soft drinks (USDA/ARS, 2009). Schoreter et al. (2008) utilized the own- and cross-price elasticities for regular and diet soft drinks, but no other beverages (such as juice, milk, or bottled water) were considered.

Secondly, in order to reduce energy intake, and hence obesity, there is a need to distinguish between SSBs from their low-calorie counterparts. There are studies that differentiate regular and diet soft drinks (Pittman, 2004; Dhar et al., 2003), but to our knowledge there has been no attempt to separate sugar-sweetened fruit drinks, sports drinks, and energy drinks from their low-calorie counterparts.

In this study, we specify a demand system to addresses the above limitations in the SSB demand literature as well as enable us to evaluate the effect of subsidizing milk consumption. Because the calorie content in milk varies by its fat content, we disaggregate milk consumption into three categories—whole, low-fat, and skim milk.

3. Analytical Approach and Data

In this study, we estimate the effect of taxing SSBs and subsidizing milk on beverage consumption, calorie intake, and body weight among children ages 2 to 19. Our approach involves the estimation of beverage demand using national household purchase data. We then apply the demand elasticities and a hypothetical SSB tax rate and a hypothetical milk price subsidy to nationally representative surveys of individual beverage consumption to estimate adjustments in calorie intake from beverages and resulting body-weight changes. The use of nationally representative data allows us to calculate the changes in overweight and obesity prevalence under hypothetical price interventions. Two beverage demand systems stratified by household income are estimated to improve elasticity estimates and to examine whether the effect of price interventions differ by income.

3.1. Data Sources

This study uses two datasets to evaluate dietary and health impacts of levying a tax on SSBs and providing a subsidy on milk. Data from Nielsen's Homescan panel are used to estimate beverage demand systems for two income classes (Nielsen, 2007). The demand price elasticities and hypothetical tax and subsidy are applied to individual food intake data from the 2003-6 National Health and Nutrition Examination Survey (NHANES) conducted by the CDC (CDC/NCHS, 2009) to estimate changes in beverage consumption. Energy and calcium contents in foods developed by USDA and recorded in the NHANES are used to convert beverage consumption to calorie and calcium intakes. Using the measured body weight and height in NHANES, we estimate the change in the prevalence of overweight and obesity from implementing price interventions. The two datasets are briefly discussed below.

3.1.1. Nielsen Homescan Panel

According to Nielsen, the Homescan panel consists of a national sample of U.S. households that provide food purchase information for at-home consumption. Each household either scans the Uniform Product Code (UPC) for packaged foods or a designated code provided by Nielsen for random-weight (unpackaged) products for all their purchases from grocery stores or other retail outlets. The data include quantity, expenditures, product characteristics, and promotional information as well as household income and demographic information. On average, 22,750 households participated in the Homescan panel between 1998 and 2007. We aggregated household purchase data recorded during 1998 and 2007 into 120 monthly observations.

Beverages are grouped into eight categories—sugar-sweetened beverages, diet (low-calorie) beverages, three types of milk, 100-percent fruit and vegetable juices, coffee/tea, and bottled water (see table 1 for definitions). Beverages in powdered or frozen concentrate form are converted into ready-to-drink equivalent weight. The price was imputed as a unit value by dividing total expenditure (promotional and sale discounts incorporated) by the total quantity purchased. Homescan panelists report household income in a specific range. We use the midpoint of the income range and the household size to express household income as a percent of the Federal poverty threshold. A 185 percent of the poverty threshold is used to classify households into high and low income. The 185 percent of poverty threshold is the income eligibility cutoff for the Special Supplemental Nutrition Program for Women, Infants, and Children administrated by the U.S. Department of Agriculture (USDA/FNS, 2009). Sample means and standard errors of the variables in the demand system are reported in table 2. Note that low-income households allocated a higher proportion of their beverage budgets to SSB and whole milk than high-income households; while high-income households allocated a higher share of their beverage budget to diet drinks than low-income households.

3.1.2. National Health and Nutrition Examination Survey (NHANES)

The NHANES sample is nationally representative of non-institutionalized persons residing in the U.S. Respondents report their 24-hour dietary intakes for two non-consecutive days. Respondent's body weight and height are measured as part of a comprehensive medical examination. Social, demographic, and income data are also collected. Nutritional contents of the food reported in NHANES are developed by USDA allowing us to aggregate beverage consumption into eight categories, matching the specification from the Homescan data. We use 2003-6 NHANES data in this study. Each year, NHANES surveys up to 5,000 individuals of all ages. Excluding those with missing information on food intakes, body weight and height, income, children younger than 2 (lacks the growth curve for body weight classification) 7,291 children ages 2 to 19 are included in this study.

4. Demand Model Specification and Results

4.1. Almost Ideal Demand System

This study focuses on beverage consumption, and therefore, beverages are assumed to be weakly separable from all other goods. The Almost Ideal Demand System (AIDS, Deaton and Muellbauer, 1980) is used for our empirical estimation of a beverage demand system, as shown in equation (1)

(1) $w_i = \alpha_i^* + \sum_i \gamma_{ij} \ln p_j + \beta_i \ln(m/\boldsymbol{P}^*) + e_i \qquad i = 1, \ldots, n,$

where w_i is the beverage expenditure share for beverage i; p_j is the price for beverage j; m is the total expenditure for all beverages; and e_i is the disturbance term. $\boldsymbol{P}^*$ is a price index defined by

$$\ln\boldsymbol{P}^* = \alpha_0^* + \sum \alpha_i^* \ln p_i + 1/2 \sum_i\sum_j \gamma_{ij}^* \ln p_i \ln p_j$$

We hypothesized that monthly beverage consumption is influenced by temperature and it exhibits a time trend over the sample period. The method developed by Alston et al (2001) was used to incorporate temperature and time trend variables are incorporated into the constant terms in the AIDS model:

$\alpha_i^* = \alpha_i + \varphi_{1i}$ (temperature) + φ_{2i} (time trend) and

$\alpha_0^* = \alpha_0 + \upsilon_{1i}$ (temperature) + υ_{2i} (time trend).

Parameters to be estimated are α_i, φ_{1i}, φ_{2i}, υ_{1i}, υ_{2i}, γ_{ij}, and β_i. Conditional expenditure (ε_i) and uncompensated price (ε_{ij}) elasticity estimates at sample means can be calculated as:

(2) $\varepsilon_i = 1 + \beta_i / w_i$ and

(3) $\varepsilon_{ij} = (\gamma_{ij} - \beta_i (w_j - \beta_j \ln (m/ \boldsymbol{P^*}))/w_i - \delta_{ij}$;

where δ_{ij} is the Kronnecker delta that is unity if $i = j$ and zero otherwise.

The iterative seemingly-unrelated-regression technique was used to estimate the AIDS model with homogeneity and symmetry conditions imposed. The data for the AIDS model (1) add up by construction. The estimates were corrected for the first-order autocorrelation (Berndt and Savin, 1975). For brevity, the parameter estimates are not reported (but available upon request) and the demand elasticities are reported in tables 3 and 4.

4.2. Results of Beverage Demands

All own-price elasticities for both low- and high-income populations are found to be negative and statistically significant at the 1% probability level, except for skim milk for the low-income population. For low-income households, diet (low-calorie) drinks, skim milk, whole milk, and bottled water are found to be own-price inelastic, with own price elasticities ranging from -0.65 for whole milk to -0.72 for bottled water. Demands for SSBs, low-fat milk, juices, and coffee/tea are found to be about own-price unitary elastic, with own-price elasticities ranging from -0.84 for low-fat milk to -1.01 for juices. Of the 56 cross-price elasticities for low income, 19 of them are statistically different from zero at least at the 5% probability level, and 6 (13) of them are positive (negative) indicating substitution (complement) relationships. The expenditure elasticities suggest that as the total beverage budget changes, a proportionally larger expenditure change would be expected for SSBs and diet drinks. A slightly less than proportional change would be expected for skim and low-fat milk and juices.

It is interesting to see that high-income households are found to be more responsive to price than low-income households for some beverages. For example, the demand for SSBs among high-income households is found to be own-price elastic with a mean value of -1.30, indicating that these households are about 30 percent more responsive to the changes in SSB prices than low-income households (-0.98). However, the demand for diet drinks is found to be less price responsive for high-income than for low-income households (-0.47 vs. -0.69). Likewise, the demands for low-fat milk, juices, and coffee/tea are also found to be less price responsive among high-income households, ranging from -0.34 for coffee/tea, -0.39 for low-fat milk, and to -0.93 for juices. The demands for skim milk, whole milk, and bottled water are found to be more responsive to price changes for high-income households than those for low-income households. Results also show that the demands for SSBs, diet drinks, bottled water, and coffee/tea are more responsive to changes in beverage expenditure than milk and juices for high-income households. Similar to low-income demands, a mixture of complements and substitutes are found among the eight beverages for high-income households. Of the 56 cross-price elasticities, 23 were statistically different from zero at the 5% probability level. Results also show that diet drinks are more responsive to changes in beverage expenditures, while milk and juices are less responsive.

5. Assumptions for Evaluating Price Interventions

There are several key assumptions we have to make in order to use the estimated demand elasticities to evaluate taxing SSBs and subsidizing milk. First, there are potential differences between the demand for beverages at home and away from home. Previous research on beverage demand utilized different types of data and some investigated particulars facets of demand. For example, Kinnucan et al. (2001) and Zheng and Kaiser (2008) analyzed the USDA disappearance data (at-home and away-from-home combined) and estimated the effects of advertising on national beverage demand; Brown and Lee (2007) and Uri (1986) estimated beverage sub-demand systems using scanner data (for at-home consumption); Yen et al. (2004), Pofahl et al. (2005), and Pittman (2004) used household purchase data in their studies of beverage demand for at-home consumption. In this study, we chose to use grocery purchases for at-home consumption to estimate beverage demand because of the research question about whether the impacts of SSB tax and milk subsidy differ by income level. The USDA food disappearance data are not suitable for addressing such a research focus.

Estimating away-from-home demand for beverages is a challenge due to data limitations. Consumers often pay a single price for a meal, such as a combo meal at a fast food restaurant, which often includes a beverage. Additionally, some restaurants offer free refills for soft drinks. Thus, quantity is ill-measured for the price. At school cafeterias, milk is a required component in the meals offered through the National School Lunch Program. Milk is not priced individually and low-income children receive free lunches or pay a discount price, making it difficult to estimate milk demand at school. In this study, we assumed the same demand elasticities for at-home and away-from-home consumption. This assumption was made implicitly in the past studies estimating changes in beverage consumption from taxation (Andreyeva et al., 2009; Brownell et al., 2009; Chaloupka et al., 2009; Schroeter at al., 2008).

A tax can be levied as an ad valorem excise tax based on price (e.g., sales tax) or as a specific excise tax based on quantity or volume. Sales tax is usually paid by consumers making retail purchases, whereas a specific excise tax is usually paid by those who are further up in the distribution chain (i.e., manufacturers or distributors). A sales tax is generally not displayed on the shelf in grocery stores or on a menu in restaurants, and thus consumers may not be aware of the tax burden (McLaughlin, 2009). Further, beverage prices vary by brand, container size, and other factors creating an incentive for consumers to substitute lower priced beverages for the higher price ones, resulting in limited response to a sales tax (Brownell et al., 2009). Individuals receiving food stamp benefits from the Federal Government are exempt from paying sales tax on beverages and hence not affected by such a policy.

When a specific excise tax is levied, it will be shared by producers and consumers depending on the demand and supply conditions. In the case that the taxed food has many (few) substitutes, manufacturers (consumers) will bear a larger share of the tax. In the case of away-from-home beverage demand, the relatively low cost of the sugary input (syrup) may create a situation in which restaurants bear a part or even the full price of the tax. In this study, we assumed that an excise tax is levied such that consumers face a 20-percent price increase on all SSBs. A 20-

percent tax rate is chosen in part because it is close to the 18-percent tax recently proposed by the State of New York (New York Post, 2009). We also assumed a 10-percent tax and the reduction in beverage consumption and calorie intake is about half of the reduction from a 20-percent tax. However, the reduction in overweight and obesity rates is non-linear of the tax rate and we will report, for brevity, the reduction in obesity for the 20-percent tax rate.

We assume the milk subsidy is offered exclusively to milk consumed as a beverage, but not milk used in food processing before reaching retail market, such as cheese. As mentioned earlier, milk is offered at a discount price or free at school cafeteria. USDA reimburses schools for the cost associated with milk subsidy. The same subsidy mechanism can theoretically be adopted for grocery purchases. The subsidy is assumed to be reflected in the shelf price.

A final assumption addresses the inevitable waste between the amount purchased and consumed. Our demand estimates were based on purchase data and impacts were measured using intake data. Without an accurate estimate of waste, we assumed a constant proportion waste measure; so that a percentage change in purchase translates into the same percentage change in consumption.

6. Effects of Price Interventions

6.1. Average consumption and calories

Using children's first-day intake data in 2003-6 NHANES, we calculated the average per-capita daily consumption of the eight beverage categories and their associated calories contents (table 4). Beverage choices vary by income. High-income children consumed SSBs, bottled water, and coffee/tea than low-income children. High-income children also consumed more bottled water and coffee/tea than low-income individuals, while low-income children, on average, consumed more juices and whole milk. As a result, low-income children consumed more calories from beverages than their high-income counterparts (411 vs. 394 calories a day).

The estimated demand elasticities are applied to the individual beverage intake data in NHANES to simulate the potential effects of two hypothetical price interventions. In the first simulation, we consider the case in which a tax is levied on SSB such that consumers realize a 20-percent price increase. In the second simulation, we apply a 20-percent price subsidy to all three milk beverages (skim, low-fat, and whole milk) on top of the SSB tax. Changes in beverage consumption are converted to calorie and calcium intakes. Then the resulting changes in body weight are derived using the commonly used relationship of 3,500 calories equal to one pound of body weight (Whitney et al., 2002). Children body weight status is classified before and after the price interventions using the Child Growth Charts (CDC, 2009b).

6.2. Effects of taxing SSB

The effects of a 20-percent price increase in SSBs on calorie intake and prevalence of overweight and obesity are summarized in table 5. On average, a reduction of 40 calories a day from the eight beverages is predicted for all children, with a reduction of 44 calories from SSB and a net increase of 4 calories from the remaining seven beverages. With a larger intake from SSB and a higher own-price elasticity of demand for SSB, high-income children are predicted to reduce more calories from a SSB tax, compared to low-income children (50 calories vs. 36 from SSB alone; 45 calories vs. 33 from the eight beverages). Our results suggest a mixed substitutes and complements among the eight beverages such that changes in calorie intake from the non-SSBs cancel each other out, but still result in a measurable net change in total calories from the non-SSB beverages. It is also important to point out that excluding all relevant beverages would result in an incomplete beverage demand system and hence bias the demand elasticity estimates.

Under the assumption that 3,500 calories a year equates to one pound of body weight, we compared the overweight and obesity prevalence before and after taxing SSB. The prevalence of childhood overweight (at the 85^{th} percentile or higher) was predicted to decline from 32 percent to 26.9 percent and the obesity prevalence (95^{th} percentile or higher) would decline from 16.1 percent to 13.4 percent from a 20-percent tax. The reductions in the prevalence of overweight and obesity are predicted to be larger for high-income children than for low-income children.

6.3. Effects of simultaneous SSB taxation and milk subsidy

In the second price intervention scenario, we consider a hypothetical 20-percent price subsidy on milk purchase on top of the 20-percent price increase in SSBs. This price intervention strategy is predicted to decrease calorie intake and increase calcium intake (table 6). Among all children, an average decrease of 21 calories and an increase of 40 milligrams of calcium in a day from all eight beverages are predicted. The effects are predicted to be larger for high-income children than for low-income children.

Surprisingly, despite the prediction of a decrease in calories on average for all children, the prevalence of overweight and obesity is predicted to rise (from 32 percent to 33.6 percent for overweight and from 16.1 percent to 18.1 percent for obesity among all children, not reported in table 6 but the overweight prevalence can be calculated from the figures represented in the table). This seemingly contradiction points out the fact that averages can be misleading.

To demonstrate, children are classified into two categories--not overweight (called healthy weight for simplicity) and overweight (including obese)--before and after the price interventions (table 6). Our results suggest that 90 percent of children do not change their body weight status as a result of the price interventions--62 percent of children are healthy weight and 28 percent of children are overweight before and after the price interventions. Among these children, an average reduction of 26 calories and 16 calories a day is predicted for healthy weight and overweight, respectively.

The price interventions would result in an average reduction of 93 calories a day and hence help four percent of children improve from overweight to healthy weight. These four percent of children are predicted to gain the least amount in calcium intake, suggesting they shy away from milk in making beverage choices. On the other hand, six percent of children are predicted to increase their calorie intake by an average of 52 calories a day and gain enough weight to change from healthy weight to overweight. These children represent the only class who are predicted to increase their average calorie intake. They also gain the largest amount in calcium intake, suggesting they increase milk consumption more than other children and hence increase their calorie intake. As a result, on one hand the price interventions result in a decrease in average calorie intake among all children. On the other hand, six percent of children change from healthy weight to overweight and four percent of children change from overweight to healthy weight, resulting in a net increase in the overweight and obesity prevalence.

7. Discussion

Rising prevalence of obesity correlates with several dietary patterns, such as increasing popularity in eating out and consumption of nutrition-poor but energy dense foods and beverages. The use of economic incentives or disincentives to encourage healthy food choices, and hence reduce the incident of obesity, has received heightened support and attracted research efforts.

It has been documented in the literature that food demands are generally own-price inelastic. Under inelastic demand, price manipulations alone will not induce large consumer responses. Researchers have examined the effects of taxing salty snacks and fat in dairy products, as well as the effects of subsidizing the consumption of fruits, vegetables, and milk (Kuchler et al., 2004; Chouinard et al., 2007; Lin et al., in press). These three empirical studies support the economic theory that "[the] first fundamental theorem of taxation: a tax has little effect on inelastic goods" (McCloskey, 1982, p. 309). The U.S. demand for food has been found to be price inelastic in general, but the price elasticity varies by food groups. A recent literature review found the own-price elasticity of demand for sugar-sweetened beverage (SSB) to center around -0.8 to -1.0 (Andreyeva et al., 2009). However, a void exists in the beverage demand literature for the elasticities needed to address the budget allocation among competing beverages distinguished by calorie contents. These elasticities are vital because recent taxation proposals have targeted sugar-sweetened beverages as a means to reduce obesity.

Three studies have found limited effectiveness of SSB taxes, as currently levied, on body weight reduction (Powell et al., 2009; Fletcher et al., 2009; Schroeter et al., 2008). However, some have pointed to the evidence of large favorable responses to the experiments that cut the price of healthy snacks and raise the price of unhealthy snacks at the school cafeterias (Jeffrey et al., 1994; French et al., 2001). It should be noted that the variety of foods at school cafeterias is generally restricted. Further, school-age children have limited resources and may have unique utility function, making the cafeteria setting quite distinct from retail food markets in which a tax or a subsidy will be implemented.

In this study, we estimated a demand system for eight beverage categories for the needed elasticities to investigate the impacts of taxing SSBs on caloric intakes. Because of the displacement of milk by SSBs and low intake of calcium could be a costly dietary deficiency, we also examined a simultaneous SSB tax and milk subsidy. We utilized recent household purchase data from a national sample to estimate price responsiveness for low- and high-income households. We found the own-price elasticity of SSBs for low-income households (-0.98) to fall in the range reported by Andreyeva et al. (2009). However, the own-price elasticity for high-income households (-1.30) was found to be more responsive to price changes. The demands for skim, low-fat, and whole milk are found to be own-price inelastic for both high- and low-income households. These elasticity estimates and a hypothetical 20-percent tax and subsidy were used to estimate changes in beverage consumption and associated calorie and calcium intakes for low- and high-income children in the U.S. using the food intake data collected by the National Health and Nutrition Examination Survey (NHANES). The changes in calorie intakes resulting from a tax on SSBs and a subsidy on milk were used to estimate the reduction in the prevalence of overweight and obesity among children by income.

In *Healthy People 2010*, the Federal Government set the goal to reduce child overweight and obesity rates from 11 percent to 5 percent (USDHHS, 2009). The obesity rate has risen sharply since setting these goals. In the present study, we found a 20-percent SSB tax (or a 0.4 cent per ounce based on the 1998-2007 national average prices of SSB) would reduce the obesity rate from 16 percent to 13.2 percent for children. When a 20-percent price subsidy on milk consumption is added to the SSB tax, our results suggest that the childhood obesity rate would actually increase by 2 percent to 18 percent. Therefore, our results suggest that taxing sugar-sweetened beverages could have a measurable contribution to the goal of reducing obesity incident in the U.S. but a milk subsidy would encounter a tradeoff between forgone reductions in calorie intake and increase in calcium intake.

Because many individuals, children and adults, are just a few pounds over or shy from the overweight and obese thresholds. A small change in calorie intake and hence body weight will potentially change these individuals' body weight classification. Therefore, a discrete yes-or-no weight classification may not accurately reflect the effect of intervention programs on obesity prevalence. Future research is needed to examine the implication of using alternative prevalence measures, such as the one adjusted by the distance from the overweight and obesity thresholds (Jolliffe, 2004). Another future research need involves the biological relationship of 3,500 calories for one pound of body weight. This relationship plays a crucial role in evaluating the effectiveness of the intervention programs for obesity prevention and reduction. As suggested by the recent medical literature, the 3,500 calories for one pound of body weight could be an understatement of the amount of calorie reduction for weight loss (Swinburn et al., 2009). Medical research aiming at improving the robustness of the predictive model for the calorie and weight relationship is needed to help evaluating the effectiveness of obesity intervention programs.

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Table 1. Beverage categories and definitions.

Beverage Category	Types of beverages included
Sugar-sweetened beverages (SSB)	Soda, fruit drinks, sports drinks, powdered mixes with added sugars
Diet (low-calorie) beverages	Low- or no-calorie versions of the above SSB category
Skim milk	Milk with less than 0.5g fat per cup
Low-fat milk	Milk with less than 4.7g of fat per cup, includes 0.5 – 2%
Whole milk	Milk with 8g of fat per cup
Juices	All fruit and vegetable juices containing 100% juice
Coffee/tea	Liquid coffee and teas, excludes dry beans and leaves
Bottled water	Bottled water, excludes tap water

Note: Milk is as defined by Food and Drug Administration, per 240 ml (1 cup), http://permanent.access.gpo.gov/lps1609/www.fda.gov/fdac/features/1998/198_milk.html

Table 2. Variable definitions and summary statistics, 1998-2007.

		Low-income		High-income	
Variable	Definition	Mean	St. Dev.	Mean	St. Dev.
p_1	Nominal price for SSB, $/gal	2.53	0.15	2.66	0.19
p_2	Nominal price for diet, $/gal	1.68	0.21	2.12	0.16
p_3	Nominal price for skim milk, $/gal	2.79	0.27	2.80	0.26
p_4	Nominal price for low-fat milk, $/gal	2.72	0.29	2.80	0.29
p_5	Nominal price for whole milk, $/gal	2.94	0.31	3.02	0.31
p_6	Nominal price for juice, $/gal	4.23	0.42	4.40	0.44
p_7	Nominal price for coffee/tea, $/gal	3.72	0.54	4.12	0.35
p_8	Nominal price for bottled water, $/gal	1.28	0.19	1.43	0.15
w_1	Beverage budget share for SSB	0.39	0.04	0.32	0.03
w_2	Beverage budget share for diet drinks	0.13	0.02	0.17	0.01
w_3	Beverage budget share for skim milk	0.04	0.01	0.06	0.01
w_4	Beverage budget share for low-fat milk	0.14	0.01	0.14	0.01
w_5	Beverage budget share for whole milk	0.09	0.01	0.05	0.00
w_6	Beverage budget share for juice	0.14	0.01	0.17	0.01
w_7	Beverage budget share for coffee/tea	0.02	0.01	0.03	0.01
w_8	Beverage budget share for bottled water	0.05	0.02	0.06	0.03
φ_1	Average U.S. monthly temperature	54.37	14.93	54.37	14.93

Notes: Temperature is measured in Fahrenheit (NOAA, 2009). Means for all budget shares are significantly different at least at the 5 percent level using *t* tests for independent samples.

Table 3. Low-income population beverage demand elasticities in the U.S., 1998-2007.

	Uncompensated Price Elasticities								Expenditure Elasticities
Beverage	ε_{i1}	ε_{i2}	ε_{i3}	ε_{i4}	ε_{i5}	ε_{i6}	ε_{i7}	ε_{i8}	ε_{i}
Sugary drinks	-0.949***	-0.079**	-0.055**	-0.099**	0.053*	0.163***	-0.022	-0.034	1.023***
	(0.082)	(0.036)	(0.023)	(0.041)	(0.030)	(0.045)	(0.015)	(0.023)	(0.0190
Diet drinks	-0.230**	-0.695***	0.025	0.183***	-0.312***	-0.014	0.032	-0.013	1.024***
	(0.104)	(0.093)	(0.036)	(0.063)	(0.052)	(0.069)	(0.025)	(0.039)	(0.021)
Skim milk	-0.583***	0.085	-0.367	0.417	-0.023	-0.395	-0.031	-0.146	1.042***
	(0.236)	(0.128)	(0.320)	(0.354)	(0.308)	(0.246)	(0.081)	(0.109)	(0.048)
Low fat milk	-0.250**	0.185***	0.115	-0.820***	0.097	-0.214**	-0.035	-0.032	0.955***
	(0.115)	(0.059)	(0.095)	(0.188)	(0.142)	(0.101)	(0.034)	(0.047)	(0.037)
Whole milk	0.242*	-0.459***	-0.007	0.146	-0.631***	-0.328**	0.061	-0.014	0.990***
	(0.129)	(0.077)	(0.128)	(0.221)	(0.244)	(0.136)	(0.043)	(0.062)	(0.021)
Juices	0.473***	-0.010	-0.106	-0.223**	-0.215**	-1.017***	0.010	0.093*	0.995***
	(0.127)	(0.067)	(0.067)	(0.103)	(0.089)	(0.130)	(0.033)	(0.049)	(0.016)
Coffee/tea	-0.408	0.268	-0.057	-0.256	0.323	0.099	-0.802***	0.020	0.813***
	(0.326)	(0.188)	(0.169)	(0.269)	(0.215)	(0.253)	(0.148)	(0.138)	(0.150)
Bottled water	-0.255	-0.027	-0.114	-0.095	-0.023	0.282**	0.005	-0.718***	0.945***
	(0.199)	(0.113)	(0.088)	(0.141)	(0.121)	(0.144)	(0.053)	(0.114)	(0.047)

Notes: ***, **, and * indicate a level of significance of 1, 5, and 10 percent, respectively. Standard errors are in parentheses. Highlighted numbers indicate uncompensated own-price elasticities; all other uncompensated elasticities are cross-price estimates.
Source: Authors' calculations based on Nielsen Homescan data, 1998-2007.

Table 3. High-income population beverage demand elasticities in the U.S., 1998-2007.

Beverage	Uncompensated Price Elasticities								Expenditure Elasticities
	ε_{i1}	ε_{i2}	ε_{i3}	ε_{i4}	ε_{i5}	ε_{i6}	ε_{i7}	ε_{i8}	ε_{i}
Sugary drinks	-1.292***	-0.283***	0.056***	0.061*	-0.020	0.253***	-0.013	0.201***	1.036***
	(0.096)	(0.059)	(0.021)	(0.035)	(0.021)	(0.049)	(0.023)	(0.039)	(0.045)
Diet drinks	-0.591***	-0.464***	-0.024	-0.045	-0.058	0.024	-0.015	-0.101	1.274***
	(0.112)	(0.125)	(0.033)	(0.052)	(0.036)	(0.076)	(0.035)	(0.063)	(0.052)
Skim milk	0.344***	0.004	-0.883***	-0.114	0.476***	-0.402***	-0.022	-0.265***	0.863***
	(0.107)	(0.092)	(0.170)	(0.160)	(0.127)	(0.086)	(0.033)	(0.057)	(0.050)
Low fat milk	0.227***	0.029	-0.046	-0.383***	-0.145**	-0.279***	0.018	-0.197***	0.777***
	(0.081)	(0.064)	(0.072)	(0.107)	(0.073)	(0.058)	(0.024)	(0.041)	(0.043)
Whole milk	-0.054	-0.114	0.564***	-0.383**	-0.804***	-0.135	-0.020	0.129*	0.817***
	(0.130)	(0.118)	(0.149)	(0.190)	(0.202)	(0.106)	(0.042)	(0.071)	(0.061)
Juices	0.529***	0.089	-0.153***	-0.248***	-0.048	-0.928***	-0.046*	-0.106**	0.911***
	(0.093)	(0.077)	(0.031)	(0.047)	(0.033)	(0.084)	(0.028)	(0.048)	(0.048)
Coffee/tea	-0.185	-0.069	-0.067	0.047	-0.055	-0.322*	-0.331***	-0.124	1.106***
	(0.278)	(0.227)	(0.079)	(0.125)	(0.083)	(0.181)	(0.128)	(0.159)	(0.143)
Bottled water	1.005***	-0.229	-0.264***	-0.452***	0.095*	-0.290**	-0.049	-0.832***	1.015***
	(0.192)	(0.164)	(0.054)	(0.087)	(0.058)	(0.126)	(0.065)	(0.155)	(0.104)

Notes: ***, **, and * indicate a level of significance of 1, 5, and 10 percent, respectively. Standard errors are in parentheses. Highlighted numbers indicate uncompensated own-price elasticities; all other uncompensated elasticities are cross-price estimates.
Source: Authors' calculations based on Nielsen Homescan data, 1998-2007.

Table 4. Children beverage consumption and calories by income

	Low Income	High Income
Sugary drinks	480	508
Diet drinks	28	40
Skim milk	15	42
Low-fat milk	123	171
Whole milk	126	61
Fruit juice	135	107
Tea/Coffee	70	75
Bottled water	72	119
Total	1070	1123
Average calories		
Sugary drinks	189	195
Diet drinks	1	1
Skim milk	6	14
Low-fat milk	64	85
Whole milk	79	38
Fruit juice	63	50
Tea/Coffee	11	10
Bottled water	0	0
Total	411	394
Sample size	4080	3211

Source: 2003-06 NHANES.

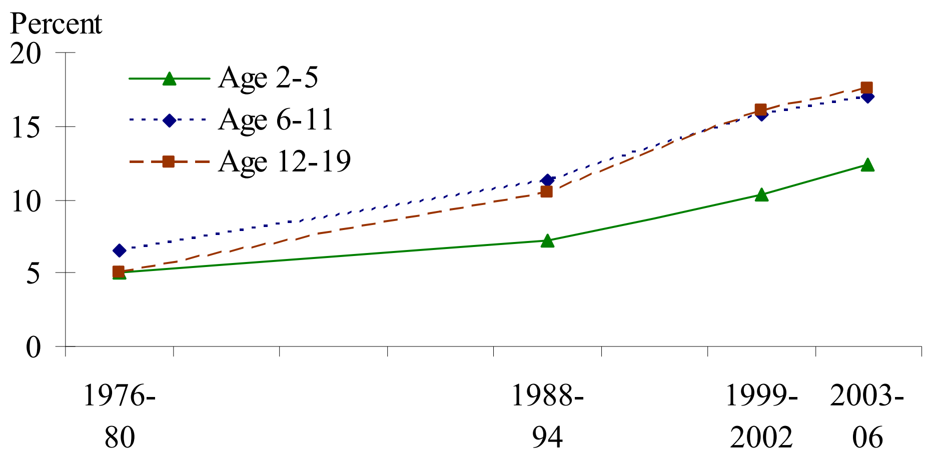
Table 5. Effects of a 20% SSB tax on beverage calories and body weight status among children by income

	Low income	High income	All
Change in calories (kcal/day):			
All beverages	-33.1	-44.7	-40.0
Sugary drinks	-35.8	-50.3	-44.4
Overweight prevalence before tax (%)	34.2	30.5	32.0
Overweight prevalence after tax (%)	29.9	24.8	26.9
Obesity prevalence before tax (%)	17.7	14.9	16.1
Obesity prevalence after tax (%)	15.4	12.0	13.4

Table 6. Effects of a 20% SSB tax and a 20% milk subsidy on nutrient intakes and body weight status among children by income

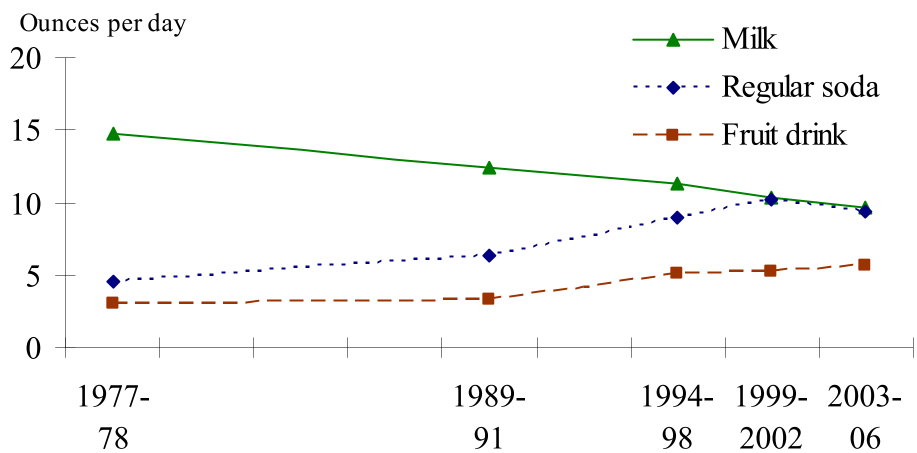
Body weight status		Percent of population	Changes in calories	Changes in calcium
Before	After			
Price intervention				
		%	kcal per day	mg per day
Healthy →	Healthy	62%	-26	35
Healthy →	Overweight	6%	52	105
Overweight →	Healthy	4%	-93	9
Overweight →	overweight	28%	-16	42
	All children	100%	-21	40
	High income	59%	-28	41
	Low income	41%	-10	38

Figure 1. Childhood and adolescent obesity prevalence, 1976-2006.



Source: Sex-and age-specific BMI ≥ 95th percentile based on Centers for Disease Control and Prevention growth charts, National Health and Nutrition Examination Surveys.

Figure 2. Childhood and adolescent daily beverage consumption, 1977-2006.



Source: Authors' calculation of 1977-78, NFCS (Nationwide Food Consumption Survey), USDA; 1989-91 and 1994-98 CSFII (Continuing Survey of Food Intakes by Individuals), USDA; 1999-2002 and 2003-06 NHANES.