

CAN SOFT DRINK TAXES REDUCE POPULATION WEIGHT?

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Soft drink consumption has been hypothesized as one of the major factors in the growing rates of obesity in the United States. Nearly two-thirds of all states currently tax soft drinks using excise taxes, sales taxes, or special exceptions to food exemptions from sales taxes to reduce consumption of this product, raise revenue, and improve public health. In this paper, we evaluate the impact of changes in state soft drink taxes on body mass index (BMI), obesity, and overweight. Our results suggest that soft drink taxes influence BMI, but that the impact is small in magnitude. (JEL I18, H75)

I. INTRODUCTION

Obesity has been labeled as an ongoing epidemic in the United States and many other developed countries (James et al., 2001) as a result of the substantial increase in the prevalence of adult obesity over the last 30 yr (Ogden et al., 2006).¹ Increases in obesity rates may pose substantial externalities on society through increases in healthcare costs and losses in productivity (Lakdawalla et al., 2005). The long-term health consequences of adult obesity include increases in type II diabetes, coronary heart disease, stroke, and cancer (National Task Force on the Prevention and Treatment of

Obesity, 2000). In 2000, the social costs of obesity were estimated at \$117 billion (Office of the Surgeon General, 2001). Sturm (2002) suggests that the influence of obesity on chronic health conditions is similar to aging 20 yr and its impact on health and health costs is greater than both smoking and drinking.

Soft drink consumption has been hypothesized as one of the major factors in the growing rates of obesity in the United States. One primary reason for this hypothesis is that relatively small increases in consumed calories can accumulate over time and may generate large changes in population weight. For instance, the medical literature suggests that changes in soft drink consumption as small as one serving per day can lead to significant weight change over time if not offset by caloric expenditures (e.g., Ludwig et al., 2001). In fact, the U.S. Department of Agriculture (USDA) has reported that per capita soft drink consumption has increased by almost 500% over the past 50 yr (Putnam and Allshouse, 1999), and soft drinks have been the single largest contributor of energy intake during the last decade (Block, 2004).

One policy through which governments can influence individuals' consumption choices and potentially affect the increase in obesity rates is the taxation of specific categories of food that

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1. Obesity increasingly afflicts young children and adolescents (Fletcher 2007, Kimbro et al., 2007), and it has been shown to persist into adulthood (Dietz 1998, Freedman et al., 2001). An analysis on the influence of soft drink taxes on childhood obesity is beyond the scope of this paper.

ABBREVIATIONS

AMA: American Medical Association
BMI: Body Mass Index
BRFSS: Behavioral Risk Factor Surveillance System
USDA: U.S. Department of Agriculture
WHO: World Health Organization

contribute to weight gains. Similar to “sin taxes” imposed on alcohol and tobacco, taxes on soft drinks have been introduced by states to reduce consumption of this product, raise revenue, and improve public health. In fact, nearly two-thirds of all states currently tax soft drinks using excise taxes, sales taxes, or special exceptions to food exemptions from sales taxes. Additionally, in recent years, many states and localities have proposed excise taxes on soft drinks in an effort to curb the rise in obesity (Chouinard et al., 2007). Although there is extensive research on the impact of alcohol and tobacco taxes on a variety of health outcomes, there is little research regarding the influence of soft drink taxes.

This paper contributes to the literature by providing the first empirical examination of the effectiveness of soft drink taxation to reduce adult weight outcomes using a robust empirical strategy that accounts for state and time effects. States have taxed soft drinks directly through excise taxes and indirectly by excluding soft drinks from the food exemptions to sales taxes. We examine the impact of both the *incremental* soft drink tax rate, which is the tax specifically on soft drinks that is net of any taxes on other foods, and the *total* soft drink tax rate, which incorporates states’ specific exclusions of soft drinks from the food exemptions to the sales tax. We analyze the impact of changes in states’ taxation rates from 1990 to 2006 on changes in body mass index (BMI) and obesity status utilizing the repeated cross sections of the Behavioral Risk Factor Surveillance System (BRFSS). During this time period, approximately half of all states changed their soft drink tax rate. By estimating regression models that include state, year, and quarter-of-year fixed effects, we identify the impact of soft drink tax rates on individuals’ weight from changes in the tax rate within states over time.

Our results demonstrate that weight responds to changes in soft drink tax rates. An increase of 1 percentage point in the state soft drink tax rate leads to a decrease in BMI of 0.003 points. The influence of soft drink taxes varies across demographic groups; we find that soft drink taxes have a larger influence on BMI and obesity for low-income adults and Hispanics. Overall, we find that at the current tax rates, with an average of approximately 3%, the behavioral response of adults is small in magnitude. Our results suggest that even a relatively large increase of 18 percentage points, as recently proposed by New York’s Governor Paterson (2008),

may not have a substantial effect on population weight.

II. BACKGROUND

Cutler et al. (2003a, 2003b) suggest that the increase in obesity rates since the 1970s has resulted largely because of an increase in calories consumed, as opposed to a decrease in calories expended. These increases in calories consumed need not be dramatic to affect population weight, however. For example, Hill et al. (2003) suggest that affecting energy balances by only 100 calories per day could prevent weight gain in over 90% of the population. A decrease in energy intake of this magnitude could be achieved by consuming one fewer 12-oz can of sugar-sweetened soda per day.² On the other hand, an increase of energy expended of this magnitude would require walking approximately 1 mi per day.

Such small energy balance magnitudes have suggested to some researchers and policymakers that targeting specific consumption goods could promote weight reduction in the population. In particular, soft drink consumption has been of interest for several reasons.³ First, Block (2004) shows that the single largest contributor of energy intake during the last decade was soft drinks, contributing to over 7%. Second, drinks that are rich in free sugars⁴ (such as soft drinks) have been shown to reduce appetite control, leading to increases in weight gain and greater risk of obesity [World Health Organization (WHO) 2003].⁵ Third, the increase in soda consumption has mirrored the increase in obesity rates (Vartanian et al., 2007). In particular, the USDA has reported that per capita soft drink

2. A typical 12-oz can of soft drink contains approximately 150 calories and 40–50 g of sugar (Apovian, 2004). Further, increasing sugar-sweetened soda consumption by one 12-oz can per day can lead to a 15-pound weight gain in 1 yr (Apovian, 2004). In 1999, Americans on average consumed nearly 50 gallons, or 530 12-oz cans, of soft drinks (Kuchler et al., 2005).

3. See Malik et al. (2006) and Vartanian et al. (2007) for reviews of the literature on the association between soft drink consumption and health. James and Kerr (2005) suggest that decreasing soft drink consumption could substantially affect rates of youth obesity.

4. The term “free sugars” refers to all monosaccharides and disaccharides added to foods by the manufacturer, cook, or consumer, plus sugars naturally present in honey, syrups, and fruit juices.

5. In particular, it has been shown that when individuals increase liquid carbohydrate consumption, they do not respond by reducing their solid food consumption. In fact, increases in liquid carbohydrate consumption lead to even greater caloric consumption (DeMaggio and Mattes, 2000).

consumption has increased by almost 500% over the past 50 yr (Putnam and Allshouse, 1999). Further, Ludwig et al. (2001) find that for each additional serving of soft drink consumed, BMI increases by 0.24 over a 2-yr period. Similarly, Ebbeling et al. (2006) show in a randomized, controlled trial that the availability of free non-caloric beverages significantly reduces the consumption of sugar-sweetened beverages and BMI in adolescents with a high initial BMI. Recently, the WHO has recommended a population goal of consuming less than 10% of energy through free sugars and has specifically recommended restricting the intake of sugar-sweetened soft drinks for children and adolescents (WHO, 2003).

Soft drink consumption has garnered enough attention that many states have attempted to affect consumer behavior through the price mechanism (Jacobson and Brownell, 2000). Although soft drink taxes have existed since at least 1920 (*New York Times*, 1920) and until recently these taxes have been used primarily to generate revenue (Caraher and Cowburn, 2005), states and localities are increasingly viewing the taxation of soft drinks as a policy to curb the rise in obesity (Chouinard et al., 2007). For example, six states proposed legislation in 2006 to tax soft drinks (National Conference of State Legislatures, 2007).⁶ State representatives in Maine have recently (April 2008) raised the tax on soft drinks to help fund state health programs and reduce childhood obesity.⁷ Further, in 2005 the American Medical Association (AMA) developed a resolution calling for a small federal tax on soft drinks (AMA, 2006).⁸ Outside of the United States, many other countries, including Mexico, Canada, Australia, and the United Kingdom, have implemented or are considering similar taxes (Chouinard et al., 2007). Additionally, many leading public health researchers are advocating for soft drink taxes (e.g., Jacobson and Brownell, 2000). Although the taxation of soft drinks is increasingly being considered as a policy to influence obesity, there is little research regarding the efficacy of these policies.

6. The six states are California, Indiana, Kansas, Maryland, New Mexico, and Wisconsin.

7. <http://www.timesrecord.com/website/archives.nsf/56606056e44e37508525696f00737257/8525696e00630dfe0525742c00522811?OpenDocument> (last accessed April 28, 2008).

8. The AMA has since dropped its resolution supporting a federal soft drink tax and has instead developed a resolution supporting collaborative efforts with the beverage industry to reduce obesity (Stanek, 2007).

Why might an increase in soft drink taxes influence obesity?⁹ The sequence of effects linking soft drink taxes to obesity includes: (1) the tax increase is passed on to consumers through higher prices, (2) the higher prices reduce the consumption of soft drinks, and (3) the decrease in consumption will reduce obesity (Ebbeling et al., 2006).¹⁰ As we outline below, prior research has provided evidence of each effect individually. But little research has estimated all of the effects taken together, in other words asking whether soft drink taxes influence obesity.¹¹

For example, Besley and Rosen (1999) estimate that an increase in soft drink tax rates leads to an increase in the price of soft drinks. In fact, the authors show that the change in price exceeds the tax change by 29% and suggest that this “overshifting” of the tax burden is the result of imperfect competition in the soft drink industry.

Researchers have also linked prices to soft drink consumption. For example, Zheng and Kaiser (2008) estimate that the price elasticity of demand for soft drinks is approximately $-.15$. Combining the results from Besley and Rosen (1999) and Zheng and Kaiser (2008) suggests that a 10% increase in the soft drink tax will reduce the consumption of soft drinks by 2% ($10 \times 1.29 \times .15$).¹² This calculation is consistent with the conclusion reached by Tefft (2008)

9. The taxation of tobacco and alcohol demonstrates that it is possible to influence consumer behavior and health outcomes through the tax system. Cigarette taxes have been shown to reduce youth and adult smoking (e.g., Carpenter and Cook, 2007) and improve health outcomes (e.g., Evans and Ringel, 1999). Grossman et al. (1993) document that adults, especially young adults, are sensitive to the price of alcohol and that increases in alcohol taxes would reduce mortality, injuries, and crime.

10. More generally, much previous research has shown that food consumption is sensitive to price changes (French et al., 2001; Jeffrey et al., 1994), and changes in food prices have been linked to changes in obesity. Lakdawalla and Philipson (2002) estimate that declining food prices can explain approximately 40% of the rise in obesity between 1976 and 1994. Gelbach et al. (2007) find that a decrease in the prices of unhealthy foods, including soft drinks, relative to the prices of healthy foods increased BMI between 1982 and 1996.

11. Other food-related taxes have also been shown to reduce food consumption. Chouinard et al. (2007) calculate that a 10% ad valorem tax on the percentage of fat in dairy products would reduce fat consumption, albeit by less than 1%. Kuchler et al. (2005) find that “junk food” tax rates of 20% would reduce the consumption of calories from salty snacks and chips by 830 per year.

12. Bahl et al. (2003) find a greater elasticity in an analysis of soft drink excise tax changes in Ireland, but this result may not be as readily generalized to the United States.

that an increase in soft drink taxes reduces the probability of any household expenditure on soft drinks.¹³

The findings that soft drink taxes reduce consumption and that soft drink consumption is related to obesity suggest that increases in soft drink taxes could reduce obesity. On the other hand, the effectiveness of soft drink taxes as a policy to reduce obesity will be influenced by the availability of close substitutes to soft drinks and the associated cross-price elasticity (Schroeter et al., 2008). As discussed by Schroeter et al. (2008), an increase in soft drink taxes will be less effective in reducing obesity if there are strong substitutes available with similar caloric composition.¹⁴ Thus, although it is plausible that an increase in soft drink taxes will reduce obesity, analysis of the efficacy of this increasing popular proposal as a means to reduce obesity is important for policy.

III. DATA

A. Soft Drink Taxes

We construct a set of total and incremental soft drink taxes at the state and quarter level from 1990 to 2006. We follow the strategy used by Tefft (2008) and describe it in this section.¹⁵ The total effective soft drink tax rate is the total tax collected on soft drinks after accounting for sales taxes, food exemptions, and specific excise taxes. The incremental effective soft drink tax rate is the tax on soft drinks relative to the level of taxation on other foods.

We first collect information on states' taxation of soft drinks with respect to specific excise taxes on soft drinks and other snack taxes, general state sales taxes, and special soft

drink exceptions to food exemptions from sales taxes. Jacobson and Brownell (2000) provide guidelines and in many cases served as a comparison to measure accuracy in data collection (see tables 1 and 2 of that article). Research tools used in this effort included Web searches, LexisNexis Academic searches, and information gathered directly from states' Departments of Revenue Web sites.

We convert all tax descriptions¹⁶ such that they may be incorporated into total and incremental tax rates. For taxes that are quoted in dollars per quantity, we refer to the Bureau of Labor Statistics' annual nationwide price index for a quantity of soda,¹⁷ and convert any level tax into a percent of expenditure. We do not include taxes on soft drink syrups because we do not have information on the expected amount of syrup per quantity of soft drink.

In order to build total and incremental soft drink tax rates we must account for general sales tax and food tax information. First, we collect state-level sales tax information between 1990 and 2006. The primary sources for this collection effort include *The Book of the States*, published annually or biennially during the period of interest by the Council of State Governments (CSG, 1990–2007), and LexisNexis Academic database searches. In some cases, we also used information from *All States Tax Handbook*, published by the Research Institute of America (RIA, 2001). These sources include information on the sales tax rate for each state and effective dates of changes in those tax rates.

Next, a special consideration with respect to the taxation of food is that a number of states exempt food from the sales tax. One reason for this is that food is considered to be a basic necessity, so including it in the sales tax is a particularly regressive policy. We included these exemptions (identified in the sources listed above) in calculating the soft drink tax rates by coding net food taxes as zero when exempted. It is also important to note that some states that exempt food from the sales tax do not include some snack foods in this exemption, so we adjusted the rates accordingly in these cases.

We merge the specific soft drink tax rates with the information on general sales taxes and

13. Tefft (2008) estimates the relationship between soft drink taxes and household expenditure and finds that an increase in soft drink taxes does not change household soft drink expenditures and reduces the probability of having any expenses on soft drinks. These results are consistent with the conclusion that soft drink taxes reduce soft drink consumption because an increase in the tax rate without a reduction in consumption would have increased soft drink expenditures.

14. A strong substitute for high calorie soft drinks is diet soft drinks. However, the availability of diet soft drinks as a substitute for high calorie soft drinks is not likely to reduce the effectiveness of the taxes in our study because diet soft drinks are commonly included in states' definition of "soft drinks" for taxation. Additionally, although diet soft drinks are low- or no-calorie drinks, consumption of diet soft drinks is linked to obesity because of the artificial sweeteners used in diet soft drinks (Fowler et al., 2008).

15. See Chriqui et al. (2008) for additional discussion of soft drink taxes in 2007.

16. "Soft drinks" are commonly defined similarly across states, although this is not always true. They are often defined broadly to include non-alcoholic, artificially sweetened or "diet" drinks and carbonated water.

17. See <http://www.bls.gov/cpi/home.htm> (last accessed June 16, 2008).

food exemptions to generate total and incremental effective soft drink tax rates. The total soft drink tax rate for each state is calculated by summing the specific soft drink tax rate and the general sales tax if the state does not exempt food from the sales tax or if the state exempts food from the sales tax but excludes soft drinks from the food exemption. If the state exempts food from the sales tax and does not exclude soft drinks from this exemption, then the total soft drink tax rate is equal to the specific soft drink tax rate. The incremental soft drink tax rate for each state is calculated as the total soft drink tax rate net of the tax rate for other food categories. Using the effective dates of each tax, we are able to calculate quarterly soft drink tax rates for each state. We determine mean annual tax rates by aggregating quarterly tax rates. An annual summary of the tax rates faced by respondents, including mean rates and the proportion of rates greater than zero, is reported in Table 1A.

B. Person Data

In order to examine the potential effect on population weight status of soft drink taxes, we use data from the 1990 through 2006 waves of the BRFSS. BRFSS is conducted annually by state and U.S. territory health departments and the Centers for Disease Control and Prevention

(CDC) to provide up-to-date information on health risks for use by local health officials and health researchers.

Some of the advantages of the BRFSS sample are that it is a nationally representative survey with a large sample size and contains relevant geographic information. These characteristics allow for a comprehensive analysis of tax changes across the United States for the duration of our soft drink tax data. Each respondent identifies his or her state of residence, thus allowing us to assign a soft drink tax rate to each observation. Finally, as a result of the large sample size, we are able to precisely estimate small weight responses to the low levels of taxation that would be difficult to detect in smaller data sets.

BRFSS includes information on the height and weight of each respondent, and BMI is calculated from these variables. Because self-reports of height and weight are known to be biased, following Cawley (2000), we compare self-reported measures of height and weight to measured values using NHANES III for each race and gender, and adjust the self-reported height and weight of respondents in the BRFSS accordingly. We then recalculate BMI based on these adjustments. Dichotomous variables measuring overweight ($BMI \geq 25$) and obesity

TABLE 1A
Summary Statistics (Tax Rates)

Year	Mean Incremental Tax	Mean Total Tax	Percentage Incremental > 0	Percentage Total > 0
1990	1.741	3.367	0.392	0.647
1991	1.873	3.556	0.412	0.667
1992	1.969	3.691	0.431	0.686
1993	3.277	5.020	0.471	0.725
1994	3.277	5.035	0.471	0.725
1995	1.986	3.743	0.431	0.686
1996	1.978	3.733	0.431	0.686
1997	1.978	3.710	0.431	0.686
1998	1.856	3.469	0.392	0.667
1999	1.836	3.434	0.392	0.647
2000	1.875	3.493	0.392	0.667
2001	1.758	3.388	0.373	0.647
2002	1.728	3.355	0.353	0.647
2003	1.755	3.328	0.353	0.647
2004	1.895	3.484	0.373	0.647
2005	1.888	3.349	0.373	0.627
2006	1.890	3.296	0.373	0.627

Note: Column variables represent means or percents across all states for the given year. “Incremental Tax” refers to the state soft drink tax rate net of taxes on other foods whereas “Total Tax” refers to the total state soft drink tax rate. The third and fourth columns refer to the percent of states with tax rates greater than zero for each tax.

TABLE 1B
Summary Statistics (Means)

Variable	All	Men	Women
BMI (reported)	26.223	26.765	25.689
BMI (adjusted)	26.668	26.928	26.412
Obese	0.209	0.201	0.217
Overweight	0.577	0.641	0.514
Underweight	0.010	0.006	0.014
Age	45.307	43.917	46.675
Black	0.105	0.097	0.113
Hispanic	0.105	0.111	0.100
White	0.863	0.868	0.858
High school graduate	0.866	0.867	0.865
College graduate	0.272	0.296	0.249
Married	0.597	0.627	0.568
Income < \$10k	0.078	0.058	0.099
Income \geq \$10k and <\$15k	0.070	0.059	0.082
Income \geq \$15k and <\$20k	0.087	0.079	0.095
Income \geq \$20k and <\$25k	0.104	0.101	0.108
Income \geq \$25k and <\$35k	0.159	0.161	0.157
Income \geq \$35k and <\$50k	0.183	0.193	0.174
Income \geq \$50k	0.317	0.349	0.285
<i>N</i>	2,709,422	1,126,325	1,583,097
<i>N</i> (education)	2,705,954	1,124,837	1,581,117
<i>N</i> (income)	2,364,590	1,007,142	1,357,448
<i>N</i> (married)	2,705,061	1,124,661	1,580,400

Note: Means are weighted using the BRFSS survey weights.

(BMI \geq 30) are constructed from this adjusted measure of BMI.

We exclude from our analysis individuals who are residents of Guam, Puerto Rico, and the Virgin Islands, restricting attention to the 50 states and the District of Columbia. We drop observations for which either age or race is not reported (approximately 1.6% of the sample). Next, we drop women who identify themselves as pregnant (1.1% of the remaining sample). Finally, we drop individuals from the sample who do not report BMI (7.9% of the remaining sample) or whose calculated BMI is less than 13 or greater than 70 (0.02% of the remaining sample), based on individuals' unadjusted self-reports of height and weight.

The final sample used in the analysis is reported in Table 1B, with men and women shown separately. Reported values are weighted using the BRFSS survey weights to be representative of the national adult population. BRFSS interviews only individuals who are 18 yr or older (with a top code at age 99), so our analysis does not apply to children or adolescents. Over 57% of the sample respondents are overweight

and 20% are obese, whereas a very small fraction are underweight (BMI < 18). The BMI correction yields an overall mean upward shift of approximately 0.4 units relative to the reported values.

IV. EMPIRICAL METHODOLOGY

In order to estimate the effects of soft drink taxation on weight outcomes, we closely follow the methodology used in the large literature that estimates the effect of taxation and prices on tobacco consumption.^{18, 19} The most recent work in this area uses within-state variation in taxes to identify changes in cigarette consumption. As discussed by Carpenter and Cook (2007), there are several data requirements necessary to use the state fixed effects approach. First, we require multiple observations on states. Second, the tax rate must vary

18. See Chaloupka and Warner (2000) for a review of this literature.

19. Although there is a large literature that estimates price and income elasticities of consumption goods (e.g., Chouinard et al., 2007; Kuchler et al., 2005; Tefft 2008), we estimate the reduced form of relationship between soft drink taxes and weight because the BRFSS does not have information on consumption.

within states over time (or else the tax variable will be perfectly collinear with state dummies). A third limitation with the approach is the potential for time-varying state-level unobservables that predict both changes in weight and changes in taxes. In the tobacco-tax literature, measures of “anti-smoking sentiment” have been shown to be important omitted state-level variables that substantially change the estimated price elasticities of tobacco consumption (DeCicca et al., 2006).

We use a two-way fixed effects ordinary least squares (OLS) framework in order to estimate the effect of state soft drink prices on various weight outcomes, including BMI, overweight status, and obesity. In particular, we specify the following model:

$$(1) \quad \begin{aligned} outcome_{istq} = & \beta_1' X_{istq} + \beta_2 T_{stq} + \mu_s \\ & + \delta_t + \gamma_q + \varepsilon_{istq}, \end{aligned}$$

where $outcome_{istq}$ is the weight outcome of individual i in state s at time t in quarter q , X is a vector of individual-level covariates (e.g., race, gender, etc), T is the state-level tax on soft drink sales, μ represents state fixed effects, δ represents year fixed effects, γ represents quarter-of-year fixed effects, and ε is the error term.²⁰ The coefficient of interest is β_2 , which captures the effect of state soft drink taxes on weight by comparing individuals in the same state who face different soft drink taxes over time. Standard errors are clustered to allow for arbitrary correlation at the state level and observations are weighted using the BRFSS survey weights in all regressions.

Within the fixed effects framework, the impact of state soft drink taxes is identified from changes within states over time.²¹ By using BRFSS data from 1990 to 2006, which is a period when 28 states changed their soft drink tax rates, we are able to overcome the two primary data limitations of this empirical strategy. To demonstrate that there is sufficient variation in soft drink tax rates within states over time, we calculated the R -squared from regres-

sions of the tax rates on state, year, and quarter fixed effects. An R -squared above .90 suggests a lack of sufficient variation (Carpenter and Cook, 2007), and the values for the incremental and total tax rates are .50 and .86, respectively.

An additional limitation of this strategy, as outlined above, is the potential that unobserved characteristics that vary within states and over time are related to soft drink taxes and BMI. To address this limitation, following Gruber and Frakes (2006), we modify Equation (1) to include state-specific time trends and estimate the relationship between soft drink taxes and weight outcomes as:

$$(2) \quad \begin{aligned} outcome_{istq} = & \alpha_1' X_{istq} + \alpha_2 T_{stq} + \mu_s + \delta_t \\ & + \gamma_q + \phi_s \times t + \phi_s \times q + \varepsilon_{istq}. \end{aligned}$$

In Equation (2), α_2 measures the effect of state soft drink taxes on weight outcomes.

To further examine the potential that time-varying state characteristics are related to soft drink taxes and BMI, we estimate additional specifications that include state economic conditions, specifically the 1-yr lagged state annual unemployment rate and annual cigarette taxes. To address the possibility that unobserved state social norms regarding physical health and obesity are related to soft drink taxes and BMI, we estimate specifications that include 1-yr lagged values of state BMI averages and also estimate the impact of state soft drink taxes on whether an individual exercises outside of work activities. Finally, as falsification tests, we estimate the impact of state soft drink taxes on mental health status (recorded as a component of CDC’s Healthy Days measures) and whether the individual received a flu shot.

V. RESULTS

Table 2 displays the impact of both total and incremental state soft drink taxes (as defined in the Data section) on BMI, overweight, and obesity as estimated by Equation (2), which includes state-specific time trends. These results demonstrate that state soft drink taxes have a statistically significant impact on behavior and weight; however, the magnitude of the effect is small. An increase in the state soft drink tax rate of 1 percentage point leads to a decrease in BMI of 0.003 points and a decrease in obesity and overweight of 0.01 and 0.02 percentage points, respectively. We present results for both the total soft drink tax rate and the incremental soft drink

20. A variant of this model was first introduced in the economics literature in the context of liquor taxation by Cook and Tauchen (1982).

21. An alternative approach, implemented by Chouinard et al. (2007) and Kuchler et al. (2005), is to estimate demand systems to investigate price elasticities and then simulate the effects of a tax. A drawback to their approach is that price is not exogenous. Our approach directly examines the effects of a tax on health outcomes and therefore bypasses issues surrounding price endogeneity.

TABLE 2
The Impact of Soft Drink Taxes on BMI, Obese, and Overweight

	BMI		Obese		Overweight	
Total soft drink tax rate	−0.0029*** [0.0004]		−0.0001* [0.0000]		−0.0002*** [0.0001]	
Incremental soft drink tax rate		−0.0028*** [0.0005]		−0.0001** [0.0000]		−0.0002*** [0.0000]
Male	0.572*** [0.045]	0.572*** [0.045]	−0.013*** [0.003]	−0.013*** [0.003]	0.135*** [0.004]	0.135*** [0.004]
Age	0.309*** [0.004]	0.309*** [0.004]	0.016*** [0.000]	0.016*** [0.000]	0.027*** [0.000]	0.027*** [0.000]
Age squared	−0.003*** [0.000]	−0.003*** [0.000]	−0.000*** [0.000]	−0.000*** [0.000]	−0.000*** [0.000]	−0.000*** [0.000]
Black	1.851*** [0.058]	1.851*** [0.058]	0.113*** [0.004]	0.113*** [0.004]	0.139*** [0.004]	0.139*** [0.004]
Hispanic	1.091*** [0.154]	1.091*** [0.154]	0.059*** [0.010]	0.059*** [0.010]	0.106*** [0.015]	0.106*** [0.015]
Observations	2,709,422	2,709,422	2,709,422	2,709,422	2,709,422	2,709,422
R-squared	.08	.08	.04	.04	.08	.08

Notes: Heteroskedasticity-robust standard errors in parentheses that allow for clustering within states. Additional variables include state, year, and quarter fixed effects and state-specific time trends. Observations are weighted using the BRFSS survey weights in all regressions.

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

tax rate and find similar results.²² In Appendix Table A1, we show that excluding state-specific time trends does not affect the results. In Appendix Table A2, we show that limiting the analyses to states with non-zero soft drink taxes also does not change the main results.

Table 3 displays the results of the impact of state soft drink taxes based on income categories. We present only the results for the incremental soft drink tax rate in this table and the remaining tables; the results for the total soft drink tax rate are similar. We find evidence that state soft drink taxes have a greater influence on behavior for adults in the tails of the income distribution. A 1 percentage point increase in the soft drink tax rate decreases BMI by over 0.01 points for the lowest three categories (income below \$20,000) and nearly 0.01 points for the highest category (income above \$50,000). For individuals with the lowest category of income

(income below \$10,000), a 1% increase in the soft drink tax rate decreases obesity by 0.08 percentage points and overweight by 0.10 percentage points. For individuals with the highest category of income, the corresponding decreases are 0.05 percentage points for obesity and 0.08 percentage points for overweight.

Table 4 presents the impact of state soft drink taxes for various demographic groups. The impact of state soft drink taxes is larger for females, middle-aged and older individuals, individuals with greater education, and varies according to race and ethnic categories. A 1 percentage point increase in the soft drink tax rate decreases BMI by nearly 0.02 points for Hispanics, 0.003 points for whites, and 0.001 for blacks, although this last result is not statistically significant.

The results in Tables 2–4 demonstrate a statistically significant impact of soft drink taxes on weight that varies according to demographic and economic characteristics, but is generally small in magnitude. These results suggest that soft drink taxes influence behavior but that these behavioral changes are not sizeable enough to lead to large changes in population weight, based on the current magnitudes of state soft drink tax rates.

In order to provide further confidence in our results, we examine the robustness of our results to a variety of additional specifications that are summarized here and are available upon request.

22. We also estimated models using the relative soft drink tax rate, which we define as the total soft drink tax rate divided by the total food tax rate (when non-zero). The coefficients in the BMI and obesity models are significant at the 5% and 10% levels and have the same signs as those in the main estimation models, whereas the coefficient in the overweight model is not significant. For example, the estimated coefficient in the BMI model is -0.0147 with a standard error of 0.0067. At the mean relative soft drink tax rate for the sample of 1.926, this would imply that a 10% increase in the soft drink tax rate relative to the food tax (i.e., an increase in the ratio to 2.026) would result in a decrease in BMI by 0.001 points.

TABLE 3

The Impact of Incremental Soft Drink Taxes on BMI, Obese, and Overweight by Income Category

	BMI	Obese	Overweight	N
Income <\$10k	-0.0153*** [0.0014]	-0.0008*** [0.0001]	-0.0010*** [0.0001]	175,751
Income >=\$10k and <\$15k	-0.0130*** [0.0021]	-0.0005*** [0.0001]	-0.0005*** [0.0002]	167,220
Income >=\$15k and <\$20k	-0.0099*** [0.0020]	-0.0008*** [0.0002]	0.0003*** [0.0001]	208,096
Income >=\$20k and <\$25k	0.0117*** [0.0013]	0.0001 [0.0001]	0.0002** [0.0001]	253,257
Income >=\$25k and <\$35k	0.0032** [0.0014]	0.0002** [0.0001]	0.0006*** [0.0001]	373,025
Income >=\$35k and <\$50k	-0.0059*** [0.0012]	-0.0001 [0.0001]	-0.0005*** [0.0001]	429,271
Income >=\$50k	-0.0081*** [0.0010]	-0.0005*** [0.0001]	-0.0008*** [0.0001]	757,970

Notes: Heteroskedasticity-robust standard errors in parentheses that allow for clustering within states. Each cell represents a separate regression. Additional variables include male, age, age squared, black, Hispanic, state, year, and quarter fixed effects, and state-specific time trends. Observations are weighted using the BRFSS survey weights in all regressions.

Significant at 5%; *Significant at 1%.

First, in addition to state time trends and the control variables outlined above, we include controls for several time-varying state-level factors, such as lagged average BMI in each state, lagged unemployment rates, and also state-level cigarette taxes. In each case, our results are unaffected, which suggests that the estimate of the impact of soft drink taxes on weight is not influenced by unobserved state-level characteristics. Second, we conduct a series of falsification tests and conclude that soft drink taxes are not statistically related to mental health status, flu shot receipt, nor to exercise outcomes. Finally, we examine the potential dynamic effects of soft drink taxation by estimating the relationships between past tax rates and current weight. All of the results are small and not statistically significant, except for the previous year tax rate, which is small (less than half the size of the contemporaneous effect for BMI, for example), positive, and statistically significant.²³ Overall, our results suggest little dynamic effects of soft drink taxes on weight and that our preferred estimates are robust to several specification checks.

VI. CONCLUSION

In this study, we estimate the effects of current soft drinks taxes on weight outcomes for

the U.S. population. As the “obesity epidemic” has garnered considerable attention in the United States in the last decade, we examine the usefulness of attempts to control population weight gain through taxation of undesirable consumption. In doing so, we make several important contributions to estimating the effects of taxation on weight changes in the U.S. population. We use state, year, and quarter-of-year fixed effects, along with state-specific time trends in our baseline specification and find that a 1 percentage point increase in soft drink taxes decreases adult BMI by 0.003. Although soft drink consumption is the single largest contributor of energy intake in the United States in the past decade (Block, 2004), it represents only 7% of the total energy intake. Therefore, we should expect only modest changes in population weight through soft drink consumption responses to small tax increases. We verify the robustness of our results by including a variety of time-varying state characteristics in our estimation specifications. We also performed falsification tests on variables that should not be affected directly by soft drink taxes (e.g., mental health status). Overall, our results are robust.

Although our results suggest modest changes in weight as a result of soft drink taxation, we should note that soft drinks are currently taxed at a low rate and many states are proposing sizeable changes to the soft drink tax rate. Over the period of our data (1990–2006), we calculate the average incremental tax rate on soft drinks

23. This result could indicate that consumers overcompensate for their reduced soft drink consumption in the short term, but we have no direct evidence in determining the cause of this pattern.

TABLE 4

The Impact of Incremental Soft Drink Taxes on BMI, Obese, and Overweight by Demographic Category

	BMI	Obese	Overweight	N
Female	−0.0040*** [0.0008]	0.0000 [0.0001]	−0.0005*** [0.0001]	1,583,097
Male	−0.0009** [0.0004]	−0.0001 [0.0000]	0.0001** [0.0000]	1,126,325
Black	−0.0012 [0.0017]	−0.0001 [0.0001]	0.0001 [0.0001]	235,642
White	−0.0026*** [0.0005]	0.0000 [0.0000]	−0.0002*** [0.0001]	2,413,637
Hispanic	−0.0164*** [0.0019]	−0.0021*** [0.0002]	−0.0022*** [0.0001]	157,002
High school graduate	−0.0031*** [0.0005]	−0.0002*** [0.0000]	0.0002*** [0.0000]	2,389,880
College graduate	−0.0076*** [0.0007]	−0.0004*** [0.0000]	−0.0004*** [0.0001]	792,385
Married	−0.0044*** [0.0006]	−0.0003*** [0.0000]	−0.0005*** [0.0001]	1,481,699
Age >65	−0.0038*** [0.0012]	−0.0001 [0.0001]	−0.0002 [0.0001]	553,913
Age 18–25	0.0022 [0.0014]	0.0000 [0.0001]	0.0001 [0.0001]	236,521
Age 25–40	−0.0032*** [0.0006]	−0.0001 [0.0001]	−0.0005*** [0.0001]	740,654
Age 40–65	−0.0037*** [0.0005]	0.0000 [0.0001]	−0.0001* [0.0001]	1,178,334

Notes: Heteroskedasticity-robust standard errors in parentheses that allow for clustering within states. Each cell represents a separate regression. The white and high school graduate samples were estimated using a 50% random sample. Additional variables include male, age, age squared, black, Hispanic, state, year, and quarter fixed effects, and state-specific time trends. Observations are weighted using the BRFSS survey weights in all regressions.

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

to be approximately 3%. Maine has recently increased its soft drink tax rate by approximately 20 percentage points. Our results suggest that a 20 percentage point change will lead to a decrease in BMI of 0.06 and that the impact could be larger for some demographic groups.

The tax rate of soft drinks is especially low compared to other consumption items like cigarettes. In New York City, smokers pay \$0.39 per pack of cigarettes to the federal government, \$1.50 to the state government, and \$1.50 to the city (Kuchler et al., 2005), so that the price per pack is over \$5.75 (Boonn, 2007). The average federal and state taxes on cigarettes across the United States are \$1.66 of the average retail price of \$4.54 (Boonn, 2007)—these taxes are comparable to an ad valorem tax of nearly 58%. Although a tax rate of 58% is out of the support of our data, we perform a back-of-the-envelope calculation to estimate the effects of imposing a soft drink tax of a similar magnitude to current cigarette taxes

in the United States. Our results suggest that raising the soft drink tax to 58% would decrease the mean BMI in the United States by 0.16 points.²⁴ In comparison, the average gain in BMI between 1990 and 2006 was more than 2.3 points. A similar calculation suggests that increasing the tax rate by 55 percentage points would decrease the proportion of the population who are obese or overweight by nearly 0.7 percentage points. Although increasing the tax rate on soft drinks to be comparable with cigarettes will not halt the obesity epidemic, the impact on population weight would likely be non-negligible.

Although the impact of soft drink taxes on population weight is small in magnitude, a more complete evaluation of the effectiveness of this

24. We perform this calculation by multiplying the coefficients in Table 2 that represent the change in BMI for each 1 percentage point increase in soft drink tax rates by the proposed change in tax rates of 55 points.

policy would compare a wider array of outcomes to the costs of these taxes. Reducing soft drink consumption may lead to improvement in other areas of health, including dental health (WHO, 2003). Additionally, an increase in the soft drink

tax of this size would likely raise considerable revenue for the federal and state governments. The downside of the policy of increasing taxes on soft drinks is the likelihood that the tax is regressive.

APPENDIX TABLE A1

The Impact of Soft Drink Taxes on BMI, Obese, and Overweight, Without Time Trends

	BMI		Obese		Overweight	
Total soft drink tax rate	-0.0030***		-0.0001		-0.0001	
	[0.0006]		[0.0001]		[0.0001]	
Incremental soft drink tax rate	-0.0025***		-0.0001		-0.0001*	
	[0.0006]		[0.0000]		[0.0001]	
Male	0.572***	0.572***	-0.013***	-0.013***	0.135***	0.135***
	[0.045]	[0.045]	[0.003]	[0.003]	[0.004]	[0.004]
Age	0.309***	0.309***	0.016***	0.016***	0.027***	0.027***
	[0.004]	[0.004]	[0.000]	[0.000]	[0.000]	[0.000]
Age squared	-0.003***	-0.003***	-0.000***	-0.000***	-0.000***	-0.000***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Black	1.851***	1.851***	0.113***	0.113***	0.139***	0.139***
	[0.058]	[0.058]	[0.004]	[0.004]	[0.004]	[0.004]
Hispanic	1.088***	1.088***	0.058***	0.058***	0.107***	0.107***
	[0.154]	[0.154]	[0.010]	[0.010]	[0.015]	[0.015]
Observations	2,709,422	2,709,422	2,709,422	2,709,422	2,709,422	2,709,422
R-squared	.08	.08	.04	.04	.08	.08

Notes: Heteroskedasticity-robust standard errors in parentheses that allow for clustering within states. Additional variables include state, year, and quarter fixed effects. Observations are weighted using the BRFSS survey weights in all regressions.

*Significant at 10%; ***Significant at 1%.

APPENDIX TABLE A2

The Impact of Soft Drink Taxes on BMI, Obese, and Overweight for the Sample of States with a Soft Drink Tax

	BMI		Obese		Overweight	
Total soft drink tax rate	-0.0031***		-0.0001**		-0.0002***	
	[0.0005]		[0.0000]		[0.0001]	
Incremental soft drink tax rate	-0.0030***		-0.0001***		-0.0002***	
	[0.0005]		[0.0000]		[0.0000]	
Male	0.528***	0.528***	-0.016***	-0.016***	0.132***	0.132***
	[0.050]	[0.050]	[0.004]	[0.004]	[0.004]	[0.004]
Age	0.311***	0.311***	0.016***	0.016***	0.028***	0.028***
	[0.005]	[0.005]	[0.000]	[0.000]	[0.000]	[0.000]
Age squared	-0.003***	-0.003***	-0.000***	-0.000***	-0.000***	-0.000***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Black	1.844***	1.844***	0.114***	0.114***	0.139***	0.139***
	[0.067]	[0.067]	[0.005]	[0.005]	[0.004]	[0.004]
Hispanic	1.115***	1.115***	0.061***	0.061***	0.109***	0.109***
	[0.182]	[0.182]	[0.012]	[0.012]	[0.018]	[0.018]
Observations	1,984,068	1,984,068	1,984,068	1,984,068	1,984,068	1,984,068
R-squared	.08	.08	.04	.04	.08	.08

Notes: Heteroskedasticity-robust standard errors in parentheses that allow for clustering within states. The results in the table are based on specification similar to those from Table 2, except that the sample is restricted to individuals living in states with a positive soft drink tax rate. Additional variables include state, year, and quarter fixed effects and state-specific time trends. Results use a 50% random sample of observations. Observations are weighted using the BRFSS survey weights in all regressions.

Significant at 5%; *Significant at 1%.

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