Selection Effects and Heterogeneous Demand Responses to the Berkeley Soda Tax Vote

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Abstract

Early evidence from household-level surveys suggests that the one-cent-per-ounce tax on sugar-sweetened beverages which took effect March 1, 2015 in Berkeley, California decreased consumption of sugar-sweetened-beverages by 21%[2]. Even if these findings are robust, the welfare implications of expanding the Berkeley soda tax policy at a national level are complicated by selection effects inherent in the populations of both voters and consumers. Based on their demographic composition, the soda preferences of voters who supported the Berkeley referendum likely differ from the preferences of high-soda-consuming households, and from the preferences of the average-soda consuming household in the United States. Further, we find consumption responses related to the tax interact nontrivially with consumer heterogeneity. Some of these responses directly counter the public policy goals of a soda tax: first, high-consuming households are less price sensitive, and therefore less responsive to price changes following a tax; and, second, "reactance" among high-consuming populations led to increases in soda consumption immediately following the passage of the tax, partially mitigating reductions in soda consumption.

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[2] Falbe et al., "Impact of the Berkeley Excise Tax on Sugar-Sweetened Beverage Consumption."

The consumption of sugar-sweetened beverages (SSBs), defined as drinks which contain added sugar (e.g. soft drinks, sports drinks, and some fruit drinks) has been associated with increased risk of diabetes, obesity, and heart disease[3]. In response to public health concerns, in November of 2014 the first city in the United States – Berkeley, California – passed a one-cent-per-ounce excise tax on SSBs[4] in an effort to reduce soda consumption. In November of 2016, four additional U.S. cities followed suit – Boulder Colorado, and Albany, Oakland, and San Francisco passed similar one- and two-cent-per-ounce excise taxes on soda and sugar-sweetened beverages.

Much-discussed work by Falbe et al. (2016) on the Berkeley SSB excise tax finds that 47% of the Berkeley excise tax was passed through to consumers in the form of higher prices[5]. Further, through in-person household surveys concentrated in minority populations, the authors find a large decrease in self-reported soda consumption following the implementation of the tax – a 21% decrease in consumption of SSBs. This work was prominently quoted by proponents of the recently passed soda taxes, and has been used to argue the effectiveness of soda taxes generally. However, Berkeley, California (as well as the other cities instituting soda taxes) are not particularly representative of the U.S. population as a whole. It is unclear whether results from this survey are externally valid. Is the response to soda taxes in Berkeley indicative of how soda taxes might play out in the rest of the country? Are there peculiarities in the soda habits of Berkeley households that contributed to the passage of the tax, potentially creating a selection effect?

[3] Pereira, "The Possible Role of Sugar-Sweetened Beverages in Obesity Etiology."
[4] Sugar-sweetened infant formula, drinks for medical or weight-loss use, and drinks containing milk as the primary ingredient or alcohol are exempted from the tax.
[5] Falbe et al., "Impact of the Berkeley Excise Tax on Sugar-Sweetened Beverage Consumption."

Using a large dataset of 50,741,408 of the most recent household purchases available from the Nielsen Homescan Panel we identify two welfare-relevant effects of the Berkeley SSB excise tax on high-SSB-consuming households. First, we find that high-SSB-consuming households (own-price elasticity for SSBs = 0.446) are much less price sensitive than low-SSB-consuming households (own-price elasticity for SSBs = 1.653). This implies that the incidence of any SSB excise tax falls disproportionately on high-consuming households. This occurs not just because these households consume more SSBs, but they reduce their consumption less in response to price changes. Second, we find that following the passage of the referendum instituting the Berkeley tax on SSBs, high-consuming households disproportionately increased their consumption of soda by a small but statistically significant amount in the short-term, the consumption of these households shifted slightly in the opposite direction of that intended by policymakers. We demonstrate that this effect cannot be explained by household intertemporal substitution. Finally we note that, even if the findings by Falbe et al. are robust, we should not expect them to be generalizable; both the population which voted for the tax and the consumers impacted by it are atypical relative to the rest of the United States. Thus, studies of the Berkeley SSB tax provide something of a cautionary tale for natural experiment type studies of policies that are implemented by ballot measure and for which the appeal is somewhat correlated with outlier status in general.

Data Description

Data for our empirical analyses comes from the Nielsen Homescan Household Panel, a longitudinal panel dataset of participants from across the United States which documents each household purchase made by each of roughly 60,000 households annually. This panel has been used for demand estimation for goods including dairy products (Davis et al. (2010); Bouhlal,

Capps, and Ishdorj (2013)), sugar-sweetened beverages (Zhen et a. (2013)), and snack foods (Kuchler, Tegene, and Harris 2005). The Homescan Consumer Panel sample is balanced along categories of household size, income, age of head, education of head, occupation of head, presence of children, race, and Hispanic origin. For our primary estimations we use purchasing data from 2010 through 2014, the most recent year for which data is available. For each household item purchased, a customer scans the UPC code of the item or manually enters the name of the item purchased, and further indicates the time of the purchase, the location of the purchase, and whether or not the item was purchased on promotion. We additionally observe household level demographic and socio-economic characteristics. Participation in the panel is incentivized by a system of reward points and eligibility for sweepstakes and monthly prize drawings; points increase both in the number of items purchased and in the household's length of participation. The panel is not fully balanced, with an average of 20% of households in the panel exiting each year. For tractability, we draw a random sample of 10% of the households in each year of the dataset, maintaining the full set of households in the areas surrounding Berkeley, California (Alameda and San Mateo counties) for a sample of over 50.741 million purchases made. A few things are evident from the summary statistics presented in Table 1. With an average household income of $63,487.34 our resulting sample is wealthier, better educated and more Caucasian than that of the United States. On average, our households purchase 33.68 household items per week, conditional on making any observed household purchases. While we have no a priori reason to believe that purchasing-weeks in our sample should be distributed proportionally along sociodemographic groups, the composition of weekly-purchasers in our sample appears roughly equivalent to the composition of households within the sample at least

along the demographic categories we observe (see Appendix for Summary Statistics for Purchaser-Households in the sample).

Table 1: Summary Statistics of Sampled Households (2010 – 2014)

Household Summary Statistics ($n_{households}$ =10,155)	
Household Size	2.455 (.013)
Income[6]	$63,487.34 (415.282)
No Male Household Head	2,536 (24.98%)
Male Household Head Less than High School	388 (3.82%)
Male Household Head High School	1,865 (18.37%)
Male Household Head Some College	2,267 (22.33%)
Male Household Head College	2,157 (21.24%)
Male Household Head Graduate School	941 (9.27%)
No Female Household Head	986 (9.71%)
Female Household Head Less than High School	242 (2.38%)
Female Household Head High School	2,072 (20.41%)
Female Household Head Some College	2,997 (29.52%)
Female Household Head College	2,820 (27.77%)
Female Household Head Graduate School	1,037 (10.21%)
Married	6,399 (63.02%)
Widowed	694 (6.83%)
Divorced/Separated	1,579 (15.55%)
Single	1,482 (14.60%)
White/Caucasian	8,444 (83.16%)
Black/African American	954 (9.40%)
Asian	282 (2.78%)
Other	474 (4.67%)

[6] Nielsen records household income in broad income categories. We recode these as continuous variables by defining each household's income as the median of the income range which they report, save for the lower ($0 - $5,000) and upper bound ($100,000 +) categories which we recode as $5,000 and $150,000 respectively.

Demand Estimation for Soda and Sugar-Sweetened Beverages in the United States

There have been numerous studies examining the own-price elasticity of demand for sugar-sweetened beverages (for a review, see Andreyeva, Long, and Brownell (2010)), and estimating the effect of sugar-sweetened beverage taxes on food and beverage demand more generally (see Zhen et a. (2013). These studies, however, do not explicitly allow for heterogeneity in the elasticities of demand by household-consumption type. High-SSB-consuming households and low-SSB-consuming households may have different price elasticities of demand for SSBs. We therefore conduct an estimation of demand for soda and sugar-sweetened beverages allowing for heterogeneous elasticities by household-consumption type. We define high-SSB-consuming households to be households which consume greater than household-average quantities in 2013, and low-SSB-consuming households to be all other households[7].

To estimate the price elasticities of soda demand for both high-SSB- and low-SSB- consuming households, we follow Bouhlal, Capps, and Ishdorj (2013), and adopt a random effects Tobit approach to account for the fact that the demand for soda and sugar-sweetened beverages is censored. We estimate a model of demand where the outcomes y_{it} are defined as 1) an aggregate good of all soda purchased by household *i* in month *t;* and 2) an aggregate good of all sugar-sweetened beverages purchased by household *i* in month *t*. The vector of household-level explanatory variables, x_{it}, includes own-price (where price is aggregated across all purchases of y_{it} for a given household-month), monthly variables to control for seasonality, household income, household size, and age, education, race, and marital status of household head:

[7] Our main result – that high-consuming-households have a less elastic demand for both soda and sugar-sweetened beverages; and that this elasticity is statistically different from that of low-soda-consuming households – is robust to defining high-consuming households using 2010, 2011, 2012, or 2014 level consumption levels.

$$y_{it}^{*} = \beta' x_{it} + u_{it} \quad (1)$$
$$u_{it} = v_i + \epsilon_{it} \; ; \; v_i \sim N(0, \sigma_v^2) \; ; \; \epsilon_{it} \sim N(0, \sigma_\epsilon^2) \quad (2)$$

Where the error component of the model contains a time-varying random error term, ϵ_{it}, and a time-invariant household-level random effect v_i.

The observed dependent variable, the ounces of soda or sugar-sweetened beverages purchased by household *h* in month *t,* is given by:

$$y_{it} = \begin{cases} y_{it}^{*} & if \; y_{it}^{*} > 0 \\ 0 & otherwise \end{cases} \quad (3)$$

Due to the high degree of censoring, where no purchases of soda or sugar-sweetened beverages are observed for a given household-month we impute prices with a price predicted by regressing the logarithm of price on a seasonal indicator variable, the year of purchase, and household income. In so doing, we introduce more variation into prices faced by households than would be present if we adopted the standard approach of either ignoring these households or imputing prices using mean price, and avoid the inconsistent estimates which arise from using only positive purchase data to estimate demand. For a discussion of the advantages of our price imputation approach, see Dunn et al. (2011). We calculate the unconditional own-price income elasticities of demand for soda and sugar-sweetened beverages, $\epsilon_{p_{ii}}$, from the estimated β coefficients, following the Bouhlal, Capps, and Ishdorj (2013) adaptation of the McDonald and Moffitt (1980) decomposition:

$$\epsilon_{p_{ii}} = \frac{\partial E(q_i)}{\partial p_i} \frac{\overline{p_\iota}}{\overline{q_\iota}} = \left(\frac{\partial E(q_i)}{\partial ln p_i} \frac{\partial ln p_i}{\partial p_i}\right) \frac{\overline{p_\iota}}{\overline{q_\iota}} = \frac{\partial E(q_i)}{\partial ln p_i} \frac{1}{\overline{q_\iota}} = \Phi\left(\frac{\overline{x_\iota}\beta}{\sigma}\right) \frac{\beta_{ii}}{\overline{q_\iota}} \quad (4)$$

Estimations of Price Elasticities

From the estimation of the random effects Tobit model and equation four, we find that own-price elasticities of demand for both soda and sugar-sweetened beverages are higher for low-SSB-consuming households than for high-SSB-consuming households. For high-SSB-consuming households, we estimate the unconditional own-price elasticity for soda to be inelastic (own-price elasticity = 0.446). For low-SSB-consuming households, we estimate this unconditional own-price elasticity for soda to by 1.653. Wald testing for equality of the elasticities of these two groups rejects the null hypothesis that the elasticities are the same at $\alpha = .001$ significance level.

Estimates of own-price elasticity for all sugar-sweetened beverage hold the same pattern. For high-SSB-consuming households, the estimated unconditional own-price elasticity for sugar-sweetened beverages is 0.340; for low-SSB-consuming households, this estimate is 1.653. Again, Wald testing for equality of the elasticities of these two groups rejects the null hypothesis that the elasticities are the same at the $\alpha = .001$ significance level.

Our estimates of the own-price elasticities of demand for soda and sugar-sweetened beverages lie at the upper and lower bounds of previous estimates found in the literature. Andreyeva, Long, and Brownell (2010) review 14 existing estimations of the price elasticity of demand for "soft-drinks", where the precise definition of "soft-drinks" overlaps with that of sugar-sweetened beverages, yet imperfectly so. In this review, the mean elasticity estimate across these studies is 0.79 with a 95% confidence interval defined by the authors as the range between 0.33 and 1.24.

The elasticities we find have two important implications for the welfare effects of excise taxes on soda. First these estimates imply that, relative to high-SSB-consuming households, low-SSB-consuming households will more readily decrease their quantity of soda demanded in response to an excise tax. Given that high-SSB-consuming households are the households most likely to contain individuals at risk for the chronic conditions associated with SSBs, this means that

simple changes in aggregate consumption are likely to overstate the public health benefits of a soda excise tax. Second, if vendors of SSBs are able to discriminate between high- and low-SSB consuming households (perhaps based on location), high-SSB consuming households are likely to bear a greater tax burden per unit purchased.

Estimating Demand Shifts Following Berkeley Soda-Tax Vote

While the elasticities estimated in the preceding section give information about the responsiveness of household demand to excise taxes under a soda tax regime, here we consider a different question – how might individuals adjust their behavior in *anticipation* of an excise tax on soda? Further, how might a household's baseline level of consumption interact with this effect?

We anticipate that in the face of a well-publicized sin tax on soda, some households may be motivated to consume more soda than they otherwise would as a form of protest. This type of consumption is a behavior of *psychological reactance*. Originated by Brehm in 1966, the notion of psychological reactance captures the idea that when an individual is facing a restriction on her behavior, she may be motivated to take some action to restore or affirm that behavior. Empirical work in psychology finds evidence of reactance behaviors in increased desires to engage in a threatened or restricted behavior (Pennebaker and Sanders 1976) and in increased preference for threatened or restricted good (Mazis, Settle & Leslie 1973; Cacioppo and Petty 1979; Calder and Sternthal 1980; Pechmann and Stewart 1988; Petty and Cacioppo 1986). If true, the latter reactance mechanism is problematic for would-be regulators – if individuals respond to choice set restrictions with stronger preferences for restricted items, the price incentives created by excise taxes will also generate countervailing reactance effects.

Under the theory of reactance, individuals act out of a desire to restore a restricted freedom. This implies that the individuals who feel most threatened by a policy will also be the most likely to act out in response to it, and that those who are not threatened by the policy should not display reactance. In our case, high-SSB-consuming households should be most likely to display psychological reactance in the face of an excise tax on soda, and households which are not faced with an excise tax on soda should not display psychological reactance.

To investigate whether or not we observe reactance responses to the Berkeley soda tax, we use a quasi-experimental "fuzzy" regression discontinuity design. This design identifies changes in aggregate consumption of soda and sugar-sweetened beverages in Berkeley, California following the soda tax referendum vote. Our estimation procedure provides information about shifts in consumption which co-occur with the date of the referendum vote, controlling for underlying time trends and household-level sociodemographic characteristics. We are interested in the effect of exposure on consumption; absent any purely exogenous shocks, our empirical strategy is subject to several limitations. Specifically, we are vulnerable to the effects of unrelated co-occurring events and to the effects of longer term consumption shifts which may or may not be related to the policy of interest. While we cannot completely eliminate these concerns, we address them through a series of robustness checks.

Empirical results estimate the following at the household-week-level, clustering standard errors at the household level:

$$y_{ht} = \alpha + \beta x_h + \gamma_1 D_{AfterVote} + \gamma_2 Time + \gamma_3 (Time \cdot D_{AfterVote}) + \gamma_4 (D_{Berkeley} \cdot D_{AfterVote}) + \gamma_5 (D_{Berkeley} \cdot D_{AfterVote} \cdot D_{h-type}) + \varepsilon_{ht} \quad (5)$$

Where y_{ht} is the dependent variable of interest, ounces of either soda or sugar-sweetened-beverages consumed by household *h* in week *t*. Demographic characteristics x_h include

household income, household size, household composition, age and education of household head, hours worked by household head, and marital status. The propensity to consume soda varies along sociodemographic and income groups. Our specification allows for the consumption impacts of exposure to each policy event to differ by socioeconomic and demographic group membership (For a recent discussion in the public health literature of the relationship between the propensity to consume soda and demographic factors, cf. Rehm et al. 2008, who use data from a community health survey in New York City and find that being a frequent soda consumer is linked to belonging to a low income household, male sex, and identifying as black). For geographic residence dummies, a household is defined as living in Berkeley, California ($D_{Berkeley} = 1$) if the Federal Information Processing Standard (FIPS) state and county codes associated with its address identifies Alameda County, California.

Estimates of equation five for soda consumption are given in the first two columns in Table 2. The last two columns perform the same estimation, but instead for households living in a neighboring county in which no excise tax vote was held, San Mateo County, California.

Table 2: Estimation of Equation 1 for All Soda Purchases (oz.)

	Alameda Co. Households		San Mateo Co. Households	
	(1)	(2)	(3)	(4)
Income	0.00000591 (0.00000523)	.00000595 (0.00000523)	0.00000577 (0.00000524)	0.00000575 (0.00000524)
Household Size	-0.284 (0.186)	-0.283 (0.186)	-0.280 (0.187)	-0.280 (0.187)
Household Head Age	-0.0350* (0.0161)	-0.0350* (0.0161)	-0.0351* (0.0161)	-0.0351* (0.0161)
County X After Vote	-0.000148	-0.000213	0.000171	0.0000903

	(0.000180)	(0.000200)	(0.000462)	(0.000597)
County X After Vote X Hi-SSB-Household	--	0.000599*** (0.000205)	--	0.000334 (0.000569)
Constant	-49.50*** (3.320)	-49.49*** (3.321)	-49.53*** (3.320)	-49.52*** (3.320)
Race/ Education Controls	YES/YES	YES/YES	YES/YES	YES/YES
Date/ Geog. Controls	YES/YES	YES/YES	YES/YES	YES/YES
N	1229803	1229803	1229803	1229803

Standard errors in parentheses

* p < 0.05, ** p < 0.01, *** p < 0.0001

From Table 2, we see evidence consistent with reactance behaviors. First, there is no statistically significant consumption adjustment in the volume of soda consumed following the Berkeley referendum vote by households living in San Mateo County, California, households for whom the excise tax represented no threat. For high-SSB-consuming households living in the county in which Berkeley, California is located, however, we do find a positive and extremely statistically significant increase in consumption of soda following the vote. This reactance effect is small, equivalent to a 0.01% increase in the volume of soda consumed by the average Alameda county household within the average week. We find similar evidence consistent with reactance when we estimate equation five and limit our estimations to full-calorie-soda only (a reactance effect size of 0.09% of consumption), and low-calorie-soda (a reactance effect size of 0.01% of consumption. Table 3 repeats the exercise for sugar-sweetened beverages.

Table 3: Estimation of Equation 1 for All Sugar-Sweetened Beverages (oz.)

	Alameda Co. Households		San Mateo Co. Households	
	(1)	(2)	(3)	(4)

Income	0.00000919 (0.00000642)	0.00000924 (0.00000642)	0.00000893 (0.00000642)	0.00000890 (0.00000642)
Household Size	-0.316 (0.234)	-0.316 (0.234)	-0.310 (0.234)	-0.311 (0.234)
Household Head Age	-0.0458* (0.0161)	-0.0459 (0.0202)	-0.0460* (0.0202)	-0.0460* (0.0202)
County X After Vote	-0.000323 (0.000205)	-0.000411 (0.000226)	0.000188 (0.000448)	0.0000301 (0.000534)
County X After Vote X Hi-SSB-Household	--	0.00110*** (0.000238)	--	0.000819 (0.000505)
Constant	47.88*** (4.258)	47.92*** (4.258)	47.84*** (4.261)	47.85*** (4.261)
Race/ Education Controls	YES/YES	YES/YES	YES/YES	YES/YES
Date/ Geog. Controls	YES/YES	YES/YES	YES/YES	YES/YES
N	1229803	1229803	1229803	1229803

Standard errors in parentheses

* p < 0.05, ** p < 0.01, *** p < 0.0001

As was the case for consumption of soda following the Berkeley excise tax vote, we again find evidence consistent with reactance responses in the patterns of consumption for sugar-sweetened beverages. We do not find statistically significant evidence that unaffected San Mateo households adjust their consumption of sugar-sweetened beverages following the Berkeley soda tax vote. Likewise, we do not find evidence the households in Alameda County generally adjust their consumption following the vote. We instead find statistically significant evidence that those households most likely to be affected by the excise tax on sugar-sweetened beverages, high-SSB households, increase their consumption following the vote (by an amount 0.03% of the average weekly sugar-sweetened beverage consumption of a household living in Berkeley). While this

effect size is small, it is in the direction counter to the public policy goals of the soda tax and captures only the shortest-term impacts (which may be the first-stages of longer-term consumption adjustments). Further, the consumption increase we observe has been aggregated across all high-SSB households and reactance effects may be heterogeneous within this group, with some households making even larger changes in consumption.

A Comment on the Selection Inherent in the Berkeley Soda Tax

Along many dimensions, the population of Berkeley, California is atypical of the United States. Demographic summary statistics for Berkeley, California, San Mateo, California, and the United States are shown in Table 4. The demographic characteristics most likely to predict soda consumption – low-income status, male gender, and being African-American (Rehm et al. 2008) – are under-represented in Berkeley relative to the broader population of the United States. The modal household in both Alameda and San Mateo counties drinks zero ounces of soda in a given month. The modal household in the across the United States, in contrast, consumes 120 ounces of soda in a month in our sample. Likewise, the modal household in Alameda and San Mateo counties consumes zero ounces of sugar-sweetened beverages in a month, while in the entire sample this statistic is 192 ounces.

These summary statistics illustrate a simple point – since laws enacted through referenda reflect the majority view of local voters, we are likely to observe sugar-sweetened beverage excise taxes voted into law in places where the demand for these beverages is already low.

If the impetus for such taxes is to address the public health concerns associated with high levels of sugar-sweetened beverage consumption, local excise taxes are likely to be an ineffective tool with which to accomplish this goal. First, implementing the tax requires a voting base that is willing to implement the tax; this is unlikely to occur in populations that are heavy users of

SSBs. Second, the impact of the tax on consumption is primarily concentrated among those who are relatively light consumers of SSBs.

Table 4: Berkeley, California and Other Household Summary Statistics [8]

	City of Berkeley, California	City of San Mateo, California	United States
Race and Hispanic Origin			
White	59.5%	57.8%	72.4%
Black or African American	10.0%	2.4%	12.6%
Asian	19.3%	18.9%	4.8%
Hispanic or Latino	10.8%	26.6%	16.3%
Female	51.1%	51.2%	50.8%
Education			
High school graduate or higher	95.5%	88.9%	86.3%
Bachelor's degree or higher	70.2%	45.4%	29.3%
Income			
Median value of owner-occupied housing	$719,500	$736,600	$175,700
Median household income (in 2014 dollars)	$65,283	$90,087	$53,482
Per capita annual income (in 2014 dollars)	$42,406	$46,782	$28,555
Population	120,972	103,536	321,418,820

Conclusion

Based on their demographic composition, the soda preferences of voters who supported the Berkeley referendum likely differ from the preferences of high-soda-consuming households, and from the preferences of the average-soda consuming household in the United States. Further, we find consumption responses related to the tax interact nontrivially with consumer heterogeneity; some of these responses directly counter the public policy goals of a soda tax: first, individual-level estimations of soda demand among high-and-low-soda consuming households find that high-consuming households are less price sensitive, and therefore less responsive to price

[8] †United States Census Bureau Estimates retrieved from QuickFacts in November of 2016. The demographic trends across these geographic regions are preserved in the Nielsen Homescan data set used for the empirical analysis, but the Nielsen sample is consistently better educated, wealthier and whiter.

changes following a tax; and second, "reactance" among high-consuming populations led to small but significant increases in soda consumption immediately following the passage of the tax, partially mitigating reductions in soda consumption.

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