Economics and Human Biology 37 (2020) 100856

Contents lists available at ScienceDirect

Economics and Human Biology

journal homepage: www.elsevier.com/locate/ehb

The impact of Seattle's Sweetened Beverage Tax on beverage prices and volume sold

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ARTICLE INFO

Article history:
Received 15 September 2019
Received in revised form 19 January 2020
Accepted 20 January 2020
Available online 21 January 2020

JEL classification:
I12
I18

Keywords:
Sugar-sweetened beverages
SSB tax
Tax pass-through
Tax policy
Fiscal policy
Cross-border shopping

ABSTRACT

On January 1, 2018 the city of Seattle, WA, implemented a 1.75-cent per ounce (oz) Sweetened Beverage Tax (SBT) on sugar-sweetened beverages with at least 40 calories per 12 oz. This study drew on universal product code-level store scanner data and used a pre-post intervention-comparison site difference-in-differences (DID) study design to assess the impact of the SBT on taxed beverage prices in Seattle, the volume sold of taxed beverages in Seattle and in its 2-mile border area (cross-border shopping), and the volume sold of untaxed beverages (substitution) relative to changes in its comparison site of Portland, OR. The DID results showed that, on average, in the first year post-tax implementation, prices of taxed beverages rose by 1.03 cents per oz ($p < 0.001$) corresponding to a 59% tax pass-through rate. Volume sold of taxed beverages fell, on average, by 22% ($p < 0.001$) in the first year following the implementation of the tax. Volume sold of taxed beverages fell to a greater extent for family- versus individual-size beverages (31% versus 10%) and fell to a greater extent for soda (29%) compared to all other beverage types. Moderate substitution to untaxed beverages was found – volume sold of untaxed beverages increased by 4% ($p < 0.05$). The results revealed no significant increases in the overall volume sold of taxed beverages in the 2-mile border area of Seattle relative to its comparison site suggesting that tax avoidance in the form of cross-border shopping did not dampen the impact of the tax.

1. Introduction

Obesity continues to be a significant risk factor for non-communicable disease burden in the United States (U.S.). Obesity rates among adults in the U.S. increased over the last decade from 33.7% in 2007–08 to 39.6% in 2015-16; and, rates of obesity among children aged 2–19 years increased slightly over the same period from 16.8%–18.5%, although that change was not statistically significant (Hales et al., 2018). Parallel to the rise in obesity, the percent of U.S. national medical expenditures for treating obesity-related illness in adults rose from 6.13% in 2001 to 7.91% in 2015, an increase of 29% (Biener et al., 2018). Although energy intake from sugar-sweetened beverage (SSB) consumption fell by 55% among children aged 2–19 years and by 45% among adults (≥20 years) from 2003-04 to 2015-16 (Marriott et al., 2019), half of U.S. adults and 61% of U.S. youth still consumed at least one SSB on a given day in 2013-14 (Bleich et al., 2018). Additionally, SSBs are the largest contributor of added sugar in the American diet and added-sugar intake is above recommended levels (Johnson et al., 2009; Reedy and Krebs-Smith, 2010; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). An estimated 30.3 million Americans (9.4% of the total population), of which 30.2 million were adults (12.2% of the adult population), had diabetes in 2015 (Centers for Disease Control and Prevention, 2017). SSB consumption is linked to obesity and independently related to adverse health outcomes including type 2 diabetes, cardiovascular disease, dental caries, and osteoporosis (Hirahatake et al., 2019; Malik et al., 2013,2010; Vartanian et al., 2007).

In line with the public health aim of reducing SSB consumption and related health risks, SSB taxes have been a major policy focus worldwide and have been recommended domestically by the Institute of Medicine (Institute of Medicine, 2012) and internationally by the World Health Organization (World Health Organization, 2016). Indeed, fiscal policy recommendations have led to the implementation of sweetened beverage taxes in more than 40 countries and, since 2015, in seven cities and one county (though subsequently repealed) in the U.S. (University of North Carolina, 2019). It is recognized that such policies should be evaluated not only for their effectiveness but also to assess potential 'unintended' consequences.

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http://dx.doi.org/10.1016/j.ehb.2020.100856
1570-677X/

The evidence base on the impact of SSB taxes is growing worldwide and a number of studies have been published that have evaluated the extent of tax pass-through and impacts on beverage sales, purchases or consumption, and substitution from SSB taxes in countries such as Denmark, France, Mexico, Chile and Barbados (Cawley et al., 2019c). Given that these studies have evaluated national-level taxes, their study designs have generally lacked comparison sites.

This study contributes to the evidence base that is developing for local-level sweetened beverage taxes in the U.S. by evaluating the impact of the Seattle, WA, Sweetened Beverage Tax (SBT) on beverage prices (tax pass-through), the volume sold of taxed SSBs in Seattle and in its 2-mile border area to account for potential offsetting from cross-border shopping, and the volume sold of untaxed beverages in Seattle to assess substitution. On January 1, 2018, the City of Seattle implemented a 1.75-cent per ounce (oz) excise tax on the distribution of sugar-sweetened beverages with at least 40 kilocalories (kcal) per 12 fluid oz (Seattle City Council, 2017).

The extent to which the recent U.S. local-level sweetened beverage taxes have been passed on to consumers in the form of higher prices has been examined for several jurisdictions (using models with comparison sites) and studies reveal substantial variation by site. In 2015 in Berkeley, CA, where the first SSB excise tax was implemented at a penny per oz, studies consistently found tax pass-through to be only about half complete (Falbe et al., 2015; Cawley and Frisvold, 2017). At one year post-tax in Berkeley, another study found varying pass-through rates with, for example, full pass-through in chain supermarkets but lower pass-through in small independent stores (Silver et al., 2017). A slightly higher tax pass-through rate (61%) was found for the one-cent per oz Oakland, CA, SSB tax (Cawley et al., 2019b) and a higher level of tax pass-through of 79% at three-months post-tax was found for the two-cent per oz SSB tax in Boulder, CO (Cawley et al., 2018a). In Philadelphia, PA, where both SSBs and artificially sweetened beverages (ASBs) were taxed, a number of studies found approximately full tax pass-through though differences were found by store type. One study that used data from airport terminal stores located within and outside the city limits found almost complete (93%) tax pass-through (Cawley et al., 2018c). Another study that used store audits in Philadelphia compared to untaxed neighboring communities found full tax pass-through (Cawley et al., 2018b). A recent study that used scanner data found full tax pass-through in pharmacies (104%) but partial pass-through in supermarkets (43%) and mass merchandise stores (58%) (Roberto et al., 2019). A study of the Cook County, IL, one-cent per oz Sweetened Beverage Tax (subsequently repealed), which also taxed both SSBs and ASBs, found over-shifting of the tax (114%) onto beverage prices relative to prices in comparison area stores (Leider et al., 2018). Only one study to date has assessed tax pass-through for Seattle's SBT and, based on store audit data, it found that at six-months post-tax the 1.75-cent per oz tax was almost fully (97%) passed on to consumers (Public Health-Seattle and King County, 2019).

Evidence on the impact of local U.S. beverage taxes on demand for beverages as measured by either individual-level survey data or by retail-level sales data is much more limited, with particularly few studies assessing potential offsetting impacts of cross-border shopping. The largest body of evidence exists for the penny per oz tax implemented in Berkeley in 2015. One of the first studies to be published focused on low-income areas in Berkeley and found that SSB consumption fell 21% compared to a 4% increase in comparison cities, while relative water consumption increased (63% compared to 19%) (Falbe et al., 2016). Another study found that supermarket volume sold of taxed beverages fell 9.6% in Berkeley compared to an increase of 6.9% in non-Berkeley stores and that sales of untaxed beverages rose 3.5% in Berkeley versus 0.5% in non-Berkeley stores; although, this same study found no significant changes in SSB intake when using individual-level data (Silver et al., 2017). A more recent Berkeley study, based on individual-level data three years post-tax, found that SSB consumption fell by 0.55 times per day and water consumption increased by 0.85 times per day relative to changes in comparison cities (Lee et al., 2019). For the Oakland penny per oz SSB tax, recent evidence based on cross-sectional individual-level store-exit purchase data and longitudinal individual-level survey data on consumption revealed no impact of the tax on consumption of SSBs or added-sugar intake from beverages, although the study may have been under-powered based on the particularly small sample size for the individual-level consumption survey (Cawley et al., 2019b). Regarding the 1.5-cent per oz tax on both SSBs and ASBs implemented in Philadelphia, a study based on repeated cross-sectional random-digit-dial phone surveys found a reduction in the odds of daily regular soda (−40%) and energy drink (−64%) consumption and an increase in daily bottled water consumption (+58%) (Zhong et al., 2018). Using store scanner data, a recent Philadelphia study found a 51% reduction in volume of taxed beverages in the taxing jurisdiction with a net decrease of 38% when accounting for cross-border shopping and no significant increases in sales of untaxed beverages (Roberto et al., 2019). Another recent study, which used cross-sectional data from consumers at stores and longitudinal data on household beverage consumption, found that post-tax the frequency of adults' soda consumption fell by 10.4 times per month (approximately 30% lower) but there were no changes in other beverages consumed and there were no changes in beverage consumption for children (except for frequent consumers) (Cawley et al., 2019a). This latter paper also examined cross-border shopping patterns and found that although there was no evidence that Philadelphia residents were more likely to travel outside of Philadelphia to shop as a result of the tax, those who already shopped outside of the city increased their purchases of taxed beverages (Cawley et al., 2019a).

In this study, we began by estimating the extent to which the Seattle SBT increased prices faced by consumers, also known as tax pass-through. Next, we assessed the impact of the tax on volume sold of taxed beverages in Seattle and on volume sold in the 2-mile border area of Seattle to understand the extent to which any reduction in volume sold may have been offset by cross-border shopping. Finally, we examined changes in volume sold of untaxed beverages to understand the extent of substitution from taxed to untaxed beverages. We assessed the extent of heterogeneity of the impact of the Seattle SBT on all outcomes by beverage type and size. We drew on universal product code (UPC)-level store scanner data and used a pre-post intervention-comparison site difference-in-differences (DID) study design to estimate the causal impacts of the tax. This is the second study, to our knowledge, to assess tax pass-through of the Seattle SBT and the first to use UPC-level scanner data to examine this outcome. Also, to our knowledge, no other study has been published to date on the impact of the Seattle SBT on sweetened beverage consumption, purchasing, or volume sold. Thus, this study provides the first comprehensive evaluation of the impact of the Seattle SBT including an assessment of the extent to which tax avoidance in the form of cross-border shopping may offset its impact. Based on our DID models, we find that in the first year following the implementation of the Seattle SBT relative to the changes in the comparison site: 1.03 cents of the tax was passed through to consumers reflecting a tax pass-through rate of 59%; volume sold of taxed beverages in Seattle fell by 22% and this reduction was not dampened by cross-border shopping in its two-mile border area; and, there was moderate substitution to untaxed beverages whose volume sold increased by 4%.

2. Data

Retail scanner data at the UPC-level on total unit sales and the dollar amount of sales at the site level for each non-alcoholic beverage product were obtained from Nielsen. Custom-ordered data were provided from store outlets geocoded within the boundaries of the taxing jurisdiction of Seattle, WA, the comparison site, Portland, OR, and the 2-mile border area around each site. The data covered supermarkets and grocery, convenience (including some non-chain), drug, mass merchandise, and dollar stores. We estimated our sample of Nielsen's store scanner data coverage for Seattle to be just over 45% based on comparing the volume of taxed beverages reported in 2018 (Sweetened Beverage Tax Community Advisory Board, 2019) to the corresponding volume sold of taxed beverages from our Nielsen data, after accounting for the proportion of SSB calories for adults (as a proxy) that come from supermarkets/grocery or convenience stores (An and Maurer, 2016).

The available sample included data at the site level on dollar sales and volume sold for both Seattle and Portland (and their border areas) weekly for two years prior to the tax being implemented on January 1, 2018 and weekly for one-year following the implementation of the tax. An important identifying assumption of our DID study design is that, in the absence of the tax, the trends in the outcomes in our intervention and comparison sites are parallel. Figs. 1–4 based on our analytical sample show that the pre-trends were generally similar. More formally, parallel trends for weekly volume-weighted mean prices and volume sold per capita (U.S. Census Bureau, 2018) in the intervention and comparison sites were tested using a Wald test for joint significance of site by month interactions in linear regression models with robust standard errors. Tests were initially run for December 2016 through the end of November 2017, the year before the tax, excluding the month immediately before the tax where stockpiling may have occurred. Differences were found, so tests were rerun excluding two additional months before the tax, for the period October 2, 2016 through September 30, 2017. Those tests revealed no significant differences in volume of taxed ($p = .55$) or untaxed ($p = .21$) beverages or price of taxed ($p = .92$) or untaxed ($p = .10$) beverages in the two sites.

Results for the parallel trends suggested some divergence in trends in the months prior to tax implementation so we excluded those months and estimated models that covered the weeks over the 8-month period post-tax from February 4, 2018 to September 29, 2018 and the corresponding pre-tax weeks in the year before. The analysis excluded the first month of the tax when retailers and distributors may have just begun adjusting to the tax. This original analytic sample consisted of 9060 distinct beverage UPCs sold in Seattle, Portland, and the 2-mile borders surrounding them during that time period. The analytic sample focused on ready-to-drink beverages and excluded powdered drink mixes, frozen juices, fountain drink syrups, and energy shots. Excluded from the analysis were juices, soda, sports drinks, energy drinks, and tea/coffee with indeterminate sweetened/unsweetened status (99 UPCs representing 0.20% of volume) and sugar-sweetened juices, soda, sports drinks, energy drinks, and tea/coffee where it could not be determined whether the beverage fell above or below the calorie threshold for taxation (362 UPCs representing 2.07% of volume). Balanced samples of UPCs within Seattle and Portland and balanced samples of UPCs within each of their 2-mile borders were analyzed separately. The final analytical samples for Seattle and Portland included 1600 taxed and 2203 untaxed UPCs within the sites (representing 89.78% of the volume of the original analytic sample) and 1662 taxed and 2403 untaxed UPCs in their 2-mile border areas (representing 87.53% of the original volume).

Drawing on brand characteristics and nutritional and caloric information available from the Nielsen data, Label Insight, the United States Department of Agriculture Food Composition Databases, and Internet searches (Open Food Facts, 2018; U.S. Department of Agriculture, 2018), we classified the beverages as taxed and untaxed based on the tax classification from the City of Seattle Ordinance including the specification that only SSBs with at least 40 kcal per 12 fluid oz were taxable (Seattle City Council, 2017), and we classified the beverages by type. Taxed and untaxed beverage types included soda, sports drinks, energy drinks, tea/coffee, and juice drinks. Untaxed other beverages were categorized as water, milk, and unsweetened 100% juice (which could include, for example, sparkling water). Beverages were also sub-categorized by size as individual-size (single items $\leq$1 L in volume) or family-size (multi-packs or single items >1 L in volume).

The total volume sold in fluid oz of each UPC was computed for the corresponding pre- and post-tax 34-week period for each site both within their borders and their 2-mile border areas. The average price per oz of each of these unique UPCs within each combination of site and year was computed by dividing the total sales in dollars by the total volume sold in fluid oz over the same 34-week time periods in both sites.

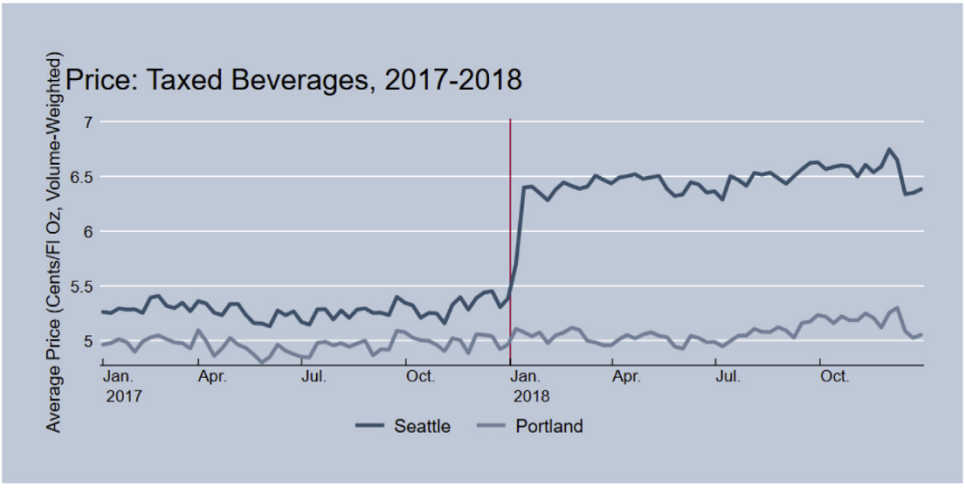

Fig. 1. Prices of Taxed Beverages in Seattle, WA, and Portland, OR, One-year Before and After Tax Implementation.

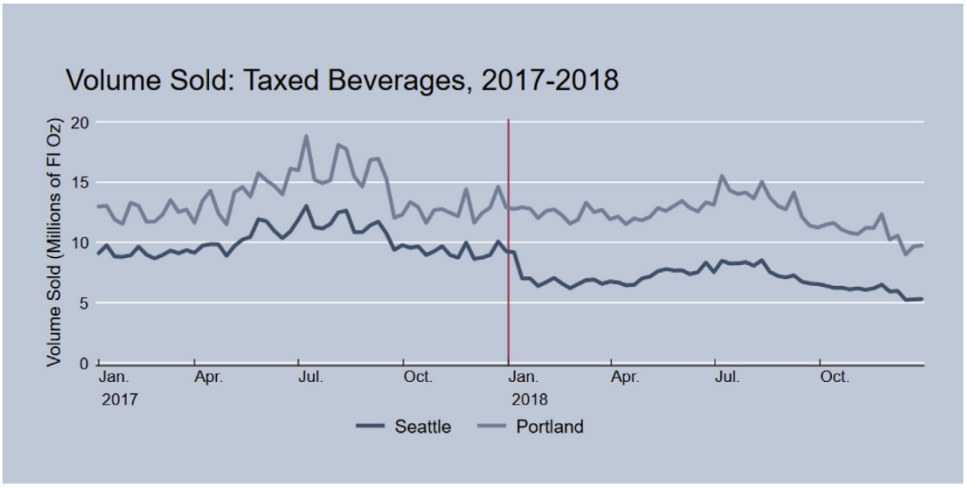

Fig. 2. Volume Sold of Taxed Beverages in Seattle, WA, and Portland, OR, One-year Before and After Tax Implementation.

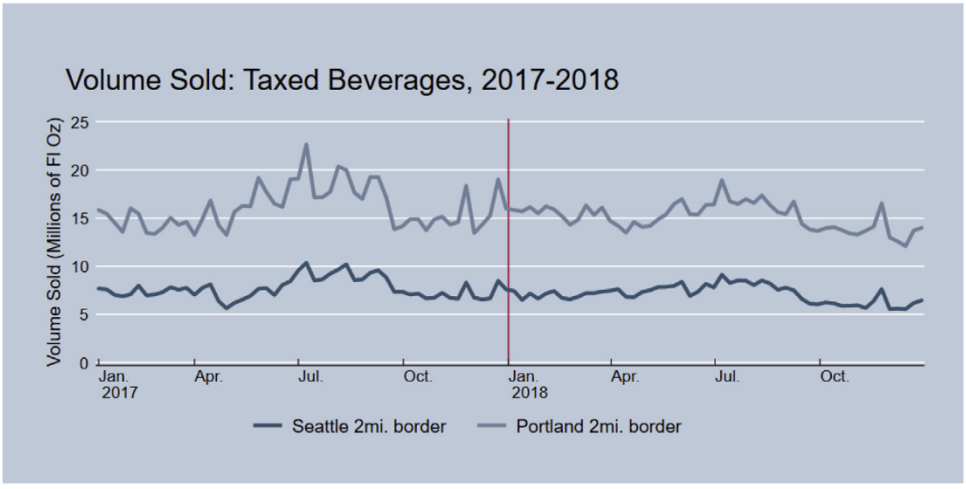

Fig. 3. Volume Sold of Taxed Beverages in the 2-mile Border Area of Seattle, WA, and Portland, OR, One-year Before and After Tax Implementation.

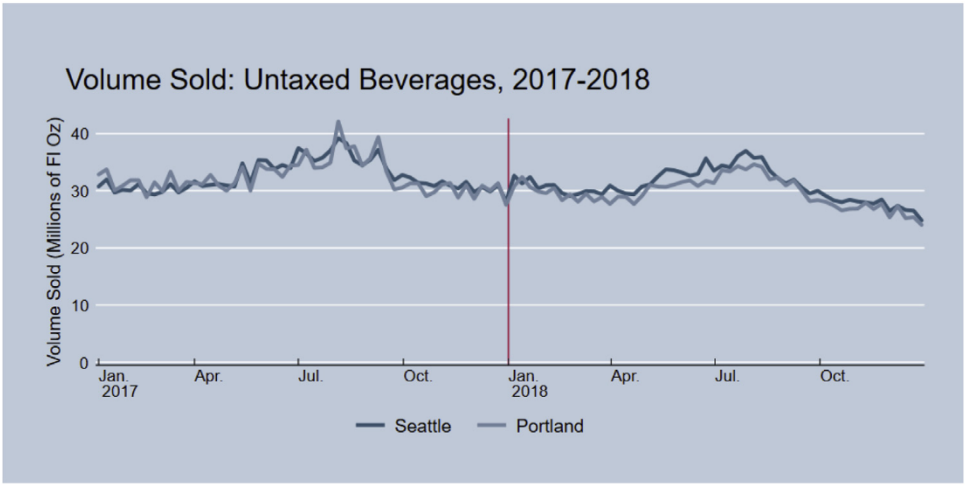

Fig. 4. Volume Sold of Untaxed Beverages in Seattle, WA, and Portland, OR, One-year Before and After Tax Implementation.

3. Empirical models

We estimated the relative change in beverage prices in Seattle and volume sold in Seattle and its 2-mile border area using a DID study design, which compared changes pre-SBT (8-month period in 2017 treated as the pre-tax time unit) to post-SBT (corresponding 8-month period in 2018 treated as the post-tax time unit) implementation in Seattle to the changes over the same pre- and post-SBT time periods in the comparison site of Portland. Portland, OR, was selected as the comparison site for Seattle, WA, based on

Mahalanobis distance matching to evaluate the four largest municipalities in each of Washington and Oregon as potential comparison sites. We matched on population size, median household income, the percent of the population below 125% of the poverty line, the percent of the population that was non-Hispanic black or Hispanic, and the percent of the population that was non-Hispanic Asian.

We estimated a DID regression model of the general following form:

$$Y_{ist} = \beta_0 + \beta_1 Posttax_t + \beta_2 Seattle_s + \beta_3 Posttax_t \cdot Seattle_s + \beta_4 X_i + \varepsilon_{ist} \quad (1)$$

where Y_{ist} is either outcome of interest for (a) price per oz in cents or (b) volume sold in oz for beverage UPC i, in site s at time period t. $Posttax_t$ is a binary indicator for the post-intervention time status (i.e., time unit after the tax was implemented). $Seattle_s$ is a binary indicator that the beverage product was sold in the intervention site of Seattle (or its 2-mile buffer). X_i is a vector of characteristics for beverage UPC i including beverage type (soda, sports drinks, energy drinks, tea/coffee, juice drinks, water, milk, and unsweetened 100% juice) and beverage size (individual-size [single items $\leq$1 L in volume] or family-size [multi-packs or single items >1 L in volume]). The β_3 coefficient on the interaction term estimates the effect of the SBT on the change in price/volume sold pre- to post-tax in Seattle relative to the change in the comparison site.

To assess the impact of the SBT on beverage prices in Seattle, UPC-level DID linear regressions were estimated. The beverage price analyses were weighted to reflect the volume sold by UPC in Seattle and Portland and their border areas from October 2, 2016 to September 30, 2017. Poisson DID regressions were estimated to assess changes in volume at the UPC level, pre-post between the intervention and comparison sites for volume sold of taxed beverages both within and in the border area of Seattle, and changes in sales volume of untaxed beverages (substitution) in Seattle. Poisson regressions were used because we expected multiplicative (i.e., relative percentage change in volume) rather than additive (i.e., fixed number of oz) effects of the Seattle SBT on volume (Ciani and Fisher, 2018). Specifically, the exponentiated interaction term from this model is a ratio of incidence rate ratios which shows the change in volume in Seattle relative to its comparison site. To assess differences in the changes of these outcomes by product characteristics, we estimated models stratified by beverage type and size format. In sensitivity analyses, we estimated models at three different time points (2–3 months post-tax, 5–6 months post-tax, and 8–9 months post-tax) to assess potential differential impacts at different time points, and these results revealed that the impacts were generally the same over time. Therefore, we present estimation results for the one year (covering the 8-month time period from February through September) average effect following tax implementation. We do not report summary statistics or estimation results for small sample size cases with fewer than 50 UPC observations in a given time period per site. In both the price and volume sold DID models, robust standard errors were clustered at the UPC level. It should be acknowledged (and as has been highlighted in previous SSB tax work) that since we only have one intervention (Seattle) and one comparison (Portland) site we are unable to cluster at the site level and, hence, our standard errors may be underestimated (Cameron and Miller, 2015; Cawley and Frisvold, 2017). All analyses for this study were conducted in Stata/SE 15.1.

4. Results

4.1. Impact on beverage prices – tax pass-through

Table 1 shows that the mean price of taxed SSBs in Seattle at baseline in the year prior to the implementation of the SBT was, on average, 5.22 cents per oz. The price of soda was the lowest at 3.90 cents per oz and the price of energy drinks was by far the highest at 14.62 cents per oz. Similar patterns in the pre-tax prices of taxed beverages by beverage type and beverage size were present in Portland. In Seattle, the mean estimates pre- to post-tax show that the prices of taxed beverages overall and by category rose, while they remained relatively flat in Portland. On average, the unadjusted change in the mean price of taxed beverages in Seattle was an increase of 1.15 cents per oz.

The results reported in Table 2 from the DID models that assessed tax pass-through show that, on average, in the first year post-tax, the price of taxed beverages rose by 1.03 cents per oz in Seattle relative to changes in Portland ($p < 0.001$). Based on the imposed tax of 1.75 cents per oz this corresponds to a tax pass-through of 59%. Tax pass-though was lowest for juice drinks, which increased in price by 0.75 cents per oz ($p < 0.001$) (pass-through rate of 43%) and highest for energy drinks, which increased in price by 1.34 cents per oz ($p < 0.001$) (pass though of 77%). Tax pass-through was higher for individual-size compared to family-size taxed beverages overall at 1.15 cents per oz ($p < 0.001$) compared to 0.97 cents per oz ($p < 0.001$) (that is, 66% compared to 55%); although this finding was not consistent across beverage types. Prices on average of untaxed beverages were generally unchanged, with just a 0.04 cent per oz increase, equivalent to less than 3% pass-through (not shown in tables).

4.2. Impact on taxed beverage volume sold in Seattle and its border area

The summary statistics presented in Table 1 of the mean UPC-level volume of taxed beverage products sold over the 8-month period in the first year following the implementation of the Seattle SBT compared to the analogous period in the previous year show that volume sold fell from a mean of 222,818 oz to 154,879 oz in Seattle, representing an unadjusted decrease of 30%. Table 1 reveals that the mean volume of taxed beverages sold in Seattle's border area and both within Portland and its border area remained generally unchanged.

Table 3 reports the DID regression estimates of the changes in volume sold of taxed beverages in Seattle and its 2-mile border area relative to its comparison site of Portland and its border area, for all taxed beverages and by beverage type (soda, sports drinks, energy drinks, tea/coffee and juice drinks) and size (individual- versus family-size). The DID estimates reported in the top panel show that volume sold of taxed beverages decreased by 22% ($p < 0.001$) in Seattle relative to Portland. By beverage type, volume sold decreased the most for soda (29%, $p < 0.001$) and the least for energy drinks (13%, $p < 0.001$). Across all beverage types, volume sold fell by a greater extent for family-size taxed beverages (31%, $p < 0.001$) compared to individual-size taxed beverages (10%, $p < 0.001$). This was driven by the differences by size for soda where family-size volume sold for soda fell by 36% ($p < 0.001$) compared to a 6% ($p < 0.01$) reduction for individual-size, and for juice drinks which were down 25% ($p < 0.001$) for family size with no statistically significant change for individual size.

The DID regression estimates reported in the lower panel of Table 3 show that volume sold of taxed beverages overall in the 2-mile border area of Seattle relative to its comparison site were unchanged in the first year following the introduction of the SBT. There was some heterogeneity in this finding by beverage category with a slight increase in volume sold in Seattle's border area relative to its comparison for sports drinks (8%; $p < 0.001$) and a slight relative decrease for energy drinks (3%; $p < 0.05$). There was also some heterogeneity by beverage type by size. The overall, null finding for volume sold in Seattle's border area suggests that cross-border shopping did not offset the 22% reduction in volume sold of taxed beverages in Seattle following the implementation of the SBT.

Table 1
Summary Statistics for Beverage Prices and Volume Sold in Seattle, WA, and Portland, OR, 2017-2018.

	Seattle, WA		Portland, OR	
	2017 Mean (95% CI)	2018 Mean (95% CI)	2017 Mean (95% CI)	2018 Mean (95% CI)
Price (cents per oz) inside Seattle/Portland				
Taxed Beverages (N = 6400)	5.22 (4.75,5.68)	6.37 (5.89,6.85)	4.90 (4.46,5.34)	5.02 (4.57,5.47)
Soda (N = 1992)	3.90 (3.47,4.33)	5.11 (4.66,5.56)	3.70 (3.29,4.12)	3.83 (3.39,4.26)
Individual (N = 924)	8.33 (7.87,8.78)	9.80 (9.30,10.29)	7.96 (7.51,8.41)	8.27 (7.77,8.77)
Family (N = 1068)	2.98 (2.83,3.13)	4.14 (3.96,4.31)	2.82 (2.67,2.97)	2.91 (2.75,3.07)
Sports Drinks (N = 600)	4.42 (4.05,4.79)	5.70 (5.26,6.14)	3.98 (3.65,4.32)	4.14 (3.82,4.46)
Individual (N = 420)	4.70 (4.20,5.20)	6.08 (5.49,6.68)	4.18 (3.72,4.63)	4.36 (3.92,4.80)
Family (N = 180)	IS	IS	IS	IS
Energy (N = 576)	14.62 (12.48,16.76)	16.17 (14.01,18.33)	13.68 (11.43,15.93)	13.89 (11.73,16.05)
Individual (N = 480)	14.56 (12.24,16.88)	16.16 (13.81,18.51)	13.53 (11.09,15.97)	13.77 (11.42,16.12)
Family (N = 96)	IS	IS	IS	IS
Tea/Coffee (N = 1444)	7.67 (6.28,9.05)	8.71 (7.26,10.16)	7.38 (6.01,8.74)	7.51 (6.14,8.88)
Individual (N = 1032)	11.22 (8.84,13.59)	12.48 (10.01,14.95)	10.74 (8.39,13.09)	10.93 (8.59,13.26)
Family (N = 412)	4.55 (3.64,5.47)	5.41 (4.46,6.36)	4.43 (3.50,5.35)	4.52 (3.59,5.46)
Juice Drinks (N = 1788)	4.84 (4.42,5.25)	5.64 (5.23,6.06)	4.49 (4.08,4.90)	4.54 (4.11,4.97)
Individual (N = 1056)	8.35 (7.15,9.56)	9.36 (8.21,10.52)	7.70 (6.52,8.89)	8.03 (6.81,9.24)
Family (N = 732)	3.93 (3.63,4.24)	4.69 (4.37,5.01)	3.66 (3.34,3.98)	3.65 (3.33,3.97)
Volume Sold (oz) of Taxed Beverages inside Seattle/Portland				
Taxed Beverages (N = 6400)	222818 (194131,251505)	154879 (135543,174215)	305406 (267084,343728)	273365 (236760,309969)
Soda (N = 1992)	324108 (243922,404295)	218555 (165465,271645)	467828 (361893,573763)	442634 (338833,546436)
Sports Drinks (N = 600)	418283 (335502,501064)	298233 (236403,360063)	558050 (450470,665631)	481391 (386454,576329)
Energy (N = 576)	175048 (117002,233094)	147265 (96698,197833)	239452 (139198,339706)	230321 (132502,328140)
Tea/Coffee (N = 1444)	109768 (87657,131879)	83386 (67060,99711)	136282 (106683,165882)	120297 (94174,146421)
Juice Drinks (N = 1788)	151069 (122668,179470)	96023 (79455,112592)	197504 (161726,233282)	152459 (125996,178922)
Volume Sold (oz) of Taxed Beverages in 2-mile border area of Seattle/Portland				
Taxed Beverages (N = 6648)	163606 (139976,187237)	154039 (129112,178965)	338065 (291631,384499)	318537 (272428,364646)
Soda (N = 1972)	262052 (190181,333923)	265308 (187048,343569)	561873 (422344,701402)	567596 (425859,709332)
Sports Drinks (N = 648)	269063 (216645,321481)	256314 (205076,307552)	551678 (438605,664751)	486213 (387814,584611)
Energy (N = 544)	112448 (73330,151567)	108723 (70867,146579)	255369 (152956,357782)	254716 (151598,357833)
Tea/Coffee (N = 1420)	70688 (54198,87178)	63685 (48666,78704)	154952 (117577,192326)	135627 (104180,167073)
Juice Drinks (N = 2064)	113851 (93234,134467)	89725 (74968,104482)	204945 (169860,240029)	170598 (142873,198322)
Volume Sold (oz) of Untaxed Beverages inside Seattle/Portland				
Untaxed Beverages (N = 8812)	516217 (424594,607841)	494736 (410759,578714)	514507 (401905,627110)	473542 (370994,576090)
Water (N = 1964)	1006312 (717728,1294897)	1010073 (747291,1272855)	910322 (647876,1172767)	861555 (630370,1092741)
Milk (N = 1384)	1003078 (614311,1391844)	963113 (607128,1319098)	1131270 (534239,1728300)	1063991 (514316,1613666)
Unsweetened Juice (N = 2672)	153839 (129457,178221)	127459 (107911,147006)	158099 (131814,184385)	129459 (108087,150831)
Juice Drink (N = 700)	149598 (118911,180285)	138697 (107669,169725)	131295 (102453,160136)	116930 (90085,143775)
Soda (N = 892)	540759 (399789,681730)	473077 (340241,605912)	536201 (419339,653064)	450751 (341515,559988)
Sports Drink (N = 304)	227123 (161314,292931)	232995 (162702,303287)	212493 (153144,271842)	205980 (146705,265255)
Energy Drink (N = 404)	146747 (97823,195672)	146383 (96112,196654)	163483 (101382,225583)	166724 (104218,229230)
Tea/Coffee (N = 492)	117451 (81710,153193)	108278 (70541,146016)	115866 (76119,155613)	98338 (62905,133770)

Total volume sold and average price per ounce (oz) (equal to total dollar amount of sales divided by total volume sold) computed for each universal product code (UPC) within each site/time period combination. Estimated means across UPCs shown with 95% confidence intervals in parentheses for months 2–9 of the tax (2/4/2018–9/29/2018) and the same period one year prior (2/5/2017-9/30/2017). Statistics for price are weighted based on volume sold in Seattle, Portland, and the 2-mile buffers surrounding both sites in 10/2/2016-9/30/2017. Sample sizes for mean estimation across the two sites and two time periods, equal to four times the number of UPCs included, are shown in the first column. IS: Insufficient sample size (fewer than 50 UPCs per site per time period).

Table 2
Difference-in-differences Estimates from Linear Regression Models of Estimated Pre- to Post-tax Effect on Taxed Beverage Prices in Seattle, WA, Relative to Portland, OR, 2017–2018.

	Overall Beverages	Individual-Size Beverages	Family-Size Beverages
Taxed Beverages (N = 6400, 3912, 2488)	1.03*** (0.99,1.08)	1.15*** (1.07,1.22)	0.97*** (0.91,1.04)
Soda (N = 1992, 924, 1068)	1.09*** (1.03,1.15)	1.16*** (1.06,1.27)	1.07*** (1.00,1.14)
Sports (N = 600, 420, 180)	1.12*** (1.01,1.24)	1.20*** (1.05,1.35)	IS
Energy (N = 576, 480, 96)	1.34*** (1.18,1.51)	1.35*** (1.18,1.53)	IS
Tea/Coffee (N = 1444, 1032, 412)	0.91*** (0.80,1.02)	1.08*** (0.89,1.26)	0.76*** (0.64,0.88)
Juice Drinks (N = 1788, 1056, 732)	0.75*** (0.66,0.85)	0.69*** (0.49,0.89)	0.77*** (0.66,0.89)

Linear regression models compared Seattle to Portland in months 2–9 of the tax (2/4/2018–9/29/2018) relative to the same period one year prior (2/5/2017-9/30/2017). Models controlled for beverage category and size and were clustered on universal product code (UPC) and weighted based on volume sold in Seattle, Portland, and the 2-mile buffers surrounding both sites in 10/2/2016-9/30/2017. Difference-in-differences estimates in cents per ounce shown with 95% confidence intervals in parentheses. Sample sizes (equal to four times the number of unique UPCs included) shown in the first column separated by commas.
IS: Insufficient sample size (fewer than 50 UPCs per site per time period).
+ p < .10 * p < .05 ** p < .01 *** p<.001.

4.3. Impact on untaxed beverages sold in Seattle – substitution

The summary statistics presented in Table 1 show moderate change in the unadjusted means of volume sold of untaxed beverages in Seattle and Portland. In Table 4, we report the DID regression results that assess the extent of substitution across beverages following the implementation of the tax in the form of changes in volume sold of untaxed beverages in Seattle relative to its comparison site. The results show that the volume sold of untaxed beverages overall increased by 4% ($p < 0.05$) in Seattle

Table 3
Difference-in-differences Estimates from Poisson Regression Models of Estimated Pre- to Post-tax Effect on Volume Sold of Taxed Beverages in Seattle, WA, and its 2-mile Border Area, Relative to Portland, OR, and its 2-mile Border Area, respectively, 2017–2018.

	Overall Beverages	Individual-Size Beverages	Family-Size Beverages
Volume Sold of Taxed Beverages in Seattle			
Taxed Beverages (N = 6400, 3912, 2488)	0.78*** (0.75,0.81)	0.90*** (0.87,0.92)	0.69*** (0.66,0.73)
Soda (N = 1992, 924, 1068)	0.71*** (0.67,0.76)	0.94** (0.90,0.98)	0.64*** (0.61,0.68)
Sports (N = 600, 420, 180)	0.83*** (0.80,0.86)	0.82*** (0.78,0.85)	IS
Energy (N = 576, 480, 96)	0.87*** (0.84,0.91)	0.88*** (0.85,0.91)	IS
Tea/Coffee (N = 1444, 1032, 412)	0.86*** (0.82,0.91)	0.90*** (0.85,0.95)	0.81*** (0.74,0.89)
Juice Drinks (N = 1788, 1056, 732)	0.82*** (0.77,0.88)	1.06 (0.98,1.14)	0.75*** (0.69,0.82)
Volume Sold of Taxed Beverages in Seattle's 2-mile Border			
Taxed Beverages (N = 6648, 3748, 2900)	1.00 (0.97,1.03)	0.99 (0.96,1.01)	1.01 (0.96,1.05)
Soda (N = 1972, 892, 1080)	1.00 (0.95,1.06)	0.89*** (0.87,0.92)	1.03 (0.97,1.09)
Sports (N = 648, 416, 232)	1.08*** (1.04,1.13)	1.03 (0.99,1.08)	1.19*** (1.12,1.26)
Energy (N = 544, 456, 88)	0.97* (0.94,1.00)	0.95*** (0.92,0.97)	IS
Tea/Coffee (N = 1420, 1004, 416)	1.03 (0.97,1.09)	1.06 (0.99,1.14)	1.01 (0.93,1.10)
Juice Drinks (N = 2064, 980, 1084)	0.95 (0.88,1.02)	1.11** (1.04,1.18)	0.92* (0.85,1.00)

Poisson regression models compared Seattle to Portland in months 2–9 of the tax (2/4/2018–9/29/2018) relative to the same period one year prior (2/5/2017-9/30/2017). Models controlled for beverage category and size and were clustered on universal product code (UPC). Difference-in-differences estimates corresponding to ratios of incidence rate ratios (RIRRs) shown with 95% confidence intervals. Sample sizes (equal to four times the number of unique UPCs included) shown in the first column separated by commas.
IS: Insufficient sample size (fewer than 50 UPCs per site per time period).
+ p < .10 * p < .05 ** p < .01 *** p<.001.

Table 4
Difference-in-differences Estimates from Poisson Regression Models of Estimated Pre- to Post-tax Effect on Volume Sold of Untaxed Beverages in Seattle, WA, and its 2-mile Border Area, Relative to Portland, OR, and its 2-mile Border Area, respectively, 2017–2018.

	Overall Beverages	Individual-Size Beverages	Family-Size Beverages
Untaxed (N = 8812, 4264, 4548)	1.04* (1.01,1.08)	1.03* (1.00,1.06)	1.04* (1.00,1.08)
Water (N = 1964, 864, 1100)	1.06+ (1.00,1.13)	0.98 (0.92,1.04)	1.07* (1.00,1.15)
Milk (N = 1384, 452, 932)	1.02 (0.96,1.08)	1.07*** (1.04,1.11)	1.02 (0.96,1.08)
Unsweetened Juice (N = 2672, 1336, 1336)	1.01 (0.95,1.08)	1.04 (0.97,1.12)	1.00 (0.93,1.09)
Juice Drink (N = 700, 420, 280)	1.04 (0.98,1.10)	1.14*** (1.09,1.19)	0.89+ (0.79,1.00)
Soda (N = 892, 352, 540)	1.04* (1.00,1.08)	1.07*** (1.03,1.12)	1.03 (0.99,1.08)
Sports (N = 304, 216, 88)	1.06+ (0.99,1.13)	1.07+ (0.99,1.16)	IS
Energy (N = 404, 296, 108)	0.98 (0.93,1.03)	0.97 (0.92,1.03)	IS
Tea/Coffee (N = 492, 328, 164)	1.09* (1.01,1.17)	1.06 (0.95,1.18)	IS

Poisson regression models compared Seattle to Portland in months 2–9 of the tax (2/4/2018–9/29/2018) relative to the same period one year prior (2/5/2017-9/30/2017). Models controlled for beverage category and size and were clustered on universal product code (UPC). Difference-in-differences estimates corresponding to ratios of incidence rate ratios (RIRRs) shown with 95% confidence intervals in parentheses. Sample sizes (equal to four times the number of unique UPCs included) shown in the first column separated by commas.
IS: Insufficient sample size (fewer than 50 UPCs per site per time period).
+ p < .10 * p < .05 ** p < .01 *** p<.001.

relative to its comparison site. There was some slight heterogeneity in the findings by beverage type and size.

5. Discussion

Overall, this study found that in the first year following the introduction of the SBT in Seattle, there was partial tax pass-through to the prices of taxed beverages, a substantial reduction in the volume sold of taxed beverages, no evidence of cross-border shopping, and moderate substitution to untaxed beverages. The price of taxed beverages rose by 1.03 cents per oz in Seattle relative to changes in Portland, which represented a pass-through rate of 59%. Based on the pre-tax mean price of the taxed beverages of 5.22 cents per oz this pass-through represented, on average, a 20% increase in the price of taxed beverages. The volume sold of taxed beverages in Seattle relative to its comparison site fell by 22% and there was no evidence that this reduction was offset by cross-border shopping in the 2-mile border area of Seattle relative to the 2-mile border area of its comparison site. Based on these estimates of the percentage change in price and percentage change in volume sold, we are able to calculate an estimate of the elasticity of demand of -1.1. This estimate is in the range of a previously reported average price elasticity of demand for SSBs of -1.21 (Powell et al., 2013) based on U.S. studies.

The results from this study revealed heterogeneity in the impacts of the SBT by beverage type and size. The tax pass-through rate was higher for individual- versus family-size beverages (66% versus 55%) and by beverage type was highest for energy drinks (77%) and lowest for juice drinks (43%). It is important to keep in mind that because prices per oz vary substantially across beverage types and the SBT is a specific rather than an ad valorem excise tax, it can result in substantially different effective changes in baseline prices by beverage type. Overall, the estimated tax pass-through of 1.03 cents per oz increased prices of taxed beverages, on average, by 20%. By beverage size, prices increased, on average, by 13% for individual-size beverages compared to 28% for family-size beverages, and by beverage type prices increased, on average, by 28% for soda, 25% for sports drinks, 15% for juice drinks, 12% for tea/coffee drinks, and 9% for energy drinks. Consistent with the relative changes in prices, volume sold of taxed beverages fell by a greater extent for family-size versus individual-size beverages (31% versus 10%) and to a greater extent for soda (29%) compared to all other beverage types, falling the least for energy drinks (13%).

The partial tax pass-through rate of 59% found in this study is in the mid-range of pass-through rates previously reported for other U.S. jurisdictions (Berkeley, Boulder, and Oakland) that have taxed SSBs (Cawley et al., 2018a; Cawley and Frisvold, 2017; Cawley et al.,

2019b; Falbe et al., 2015; Silver et al., 2017) and within the range of results reported by store type from a recent Philadelphia study using store scanner data (Roberto et al., 2019). However, it is lower than the full tax pass-through reported in other Philadelphia studies and the over-shifting reported for Cook County (Cawley et al., 2018b,c; Leider et al., 2018).

Our finding of a tax pass-through rate of 59%, on average, in the first year following tax implementation is substantially lower than the magnitude of the finding from the only other study to date for Seattle, which found based on store audit data that 97% of the tax was passed on to consumers in the form of higher prices at six-months post-tax implementation (Public Health-Seattle and King County, 2019). There are a number of reasons why the Seattle Public Health report store audit approach may have over-estimated tax pass-through, and an important reason why our store scanner data study may have under-estimated pass-through. First, in store audit studies, pass-through is estimated using a limited mix of products (i.e., store audits typically collect data from the most popular brands) whereas the scanner data contain all beverage UPCs. Weights cannot be applied to store audit data to address this point because the data are simply missing from the store audit data. To shed light on how this may contribute to differences in estimates, we re-estimated tax pass-through (without weights) using our scanner data sample based on UPCs from the listed brands used in the Seattle Public Health report and the non-listed brands and found the tax pass-through rate to be 64% for the listed brands and 46% for the non-listed brands. Second, audit data include a given number of products of different types (e.g., soda, juice drink, sports drink, etc.) of SSBs, which may under/over-represent certain beverage types that would otherwise contribute more/less volume to overall SSB sales. For example, juice drinks made up only 5.5% of the Seattle Public Health report sample, but based on our volume data, juice drinks made up 18.9% of the pre-tax volume in Seattle. Note that the tax pass-through rate for juice drinks in the Seattle Public Health report was 63% compared to their reported average of 97%. Additionally, taxed energy drinks, for which the Seattle Public Health report estimated high tax pass-through (111%), made up 18% of their estimation sample for taxed beverages but only made up 7% of volume sold of our estimation sample of taxed beverages pre-tax in Seattle. Third, store audits typically select a variety of sizes for each type of beverage, which will likely be an over-representation of smaller sizes given their relatively lower contribution to overall volume. Fourth, the selection of store types audited may not be representative of volume sold by store type. For example, the sample for the Seattle Public Health report included a substantially higher number of small stores compared to supermarkets, and the smaller stores had a higher rate of tax pass-through of 103% compared to 86% in supermarkets. A recent Oakland study using store audits to assess tax pass-through addressed this issue by sampling their stores and using weights for over-sampling proportional to sales based on data from a national commercial data set of store outlets (Cawley et al., 2019b). Finally, with respect to this study, because the store scanner data provide the price scanned for each product, if any taxable beverage product in any store had the tax added at the register as a separate line item, the store scanner data would not capture this and, therefore, we may have underestimated the tax pass-through. The Seattle Public Health report found that at six-months post-tax, 17.2% of its sample of taxed beverages had price tags that indicated that the tax was not included in the posted price and it would be added at the register.

This is the first study to assess the impact of the Seattle SBT on taxed beverages in terms of either consumption or sales volume. The finding from this study that the volume sold of taxed beverages fell substantially in Seattle following the introduction of the SBT is consistent with findings from previous studies of U.S. jurisdictions that have used store scanner data to evaluate the impact of the tax (Roberto et al., 2019; Silver et al., 2017). Direct comparisons across studies of the magnitude of the impact on sales volume should be couched in terms of the extent of increases in prices – that is, using a common metric such as the elasticity of demand. Our study with an estimated elasticity of -1.1 suggests that consumers' store purchases were responsive to the Seattle SBT but less so than the responsiveness of consumers' store purchases in Philadelphia where a recent evaluation study that also used store scanner data and accounted for cross-border shopping found an elasticity of -1.7 (Roberto et al., 2019). Also, different from the Philadelphia study, we did not find any evidence of cross-border shopping, whereas that study found that the estimated impact on sales volume was offset by 24.4% (Roberto et al., 2019). Indeed, this suggests that geographic context and the proximity with which the population lives to the borders are important considerations and must be accounted for when assessing the overall impact of a given tax.

While our study found significant reductions in taxed beverage volume sold including by beverage type, results from studies that have used individual or household-level data have generally been mixed. For example, for Philadelphia, an individual-level cross-sectional study found reductions in frequency for soda and energy drink consumption but not generally for SSB consumption (Zhong et al., 2018) and another based on longitudinal household survey data also found no significant changes overall for adults' SSB consumption but did find that consumption of soda was responsive to the tax with an estimated elasticity of -1.02 (Cawley et al., 2019a). For Berkeley, a study based on surveys in low-income neighborhoods found significant reductions in SSB consumption (Falbe et al., 2016). However, another Berkeley study that found reduced sales volume based on store scanner data did not find statistically significant impacts on consumption based on individual-level survey data (Silver et al., 2017). Further, a recent study for Oakland revealed small changes in purchases of SSBs but no evidence of changes in consumption (Cawley et al., 2019b).

This study found moderate substitution to untaxed beverages following the introduction of the Seattle SBT – volume sold of untaxed beverages increased by 4% in Seattle relative to its comparison site. This estimated change seems to fit squarely within the context of evidence on the cross-tax impacts for other U.S. taxing jurisdictions where findings on substitution remain mixed. There has been evidence from Berkeley of post-tax increases in consumption/sales of untaxed beverages, particularly water (Falbe et al., 2016; Silver et al., 2017) and post-tax increases in water consumption for Philadelphia (Zhong et al., 2018). But other studies reveal no post-tax increases in volume sold or consumption of untaxed beverages for Philadelphia (Cawley et al., 2019a; Roberto et al., 2019), or for Oakland (Cawley et al., 2019b).

This study is subject to several limitations. First, the scanner data for the full set of retailers covered by Nielsen were protected for confidentiality based on store name, type, and location and thus we were not able to stratify our analyses by store type or distance to the border. That is, our data came aggregated at the site and UPC-level across transactions. Previous studies have found differential levels of tax pass-through and impacts on sales by store type (Roberto et al., 2019; Silver et al., 2017) and lower tax pass-through has been found in stores located closer to the border (Cawley and Frisvold, 2017). Second, because the store scanner data provide the price scanned for each product, if any taxable beverage products in stores had the tax added at the register as a separate line item, we would not have captured this in our price and would have underestimated the tax pass-through. As noted above, a store audit study in Seattle found that at six-months post-tax, 17.2% of its sample of taxed beverages had price tags indicating the tax was not included in the posted price and would be added at the register

(Public Health-Seattle and King County, 2019). Third, the Seattle SBT has a standard rate of 1.75-cents per oz; but there is a reduced rate of 1-cent per oz for certified manufacturers, which we were not able to account for in our assessment of the extent of tax pass-through. However, we do not expect this to impact our results since, based on 2018 tax collection data from the City of Seattle, there were only four manufacturers, accounting for less than 0.1% of the volume of taxed SSBs, who qualified for the lower tax rate (Sweetened Beverage Tax Community Advisory Board, 2019). Finally, although we estimated that our sample covered just under one half of beverages sold in stores, we were unable to assess its representativeness to the full food store retail sector. Further, the results from this study cannot generalize to overall impacts on prices or consumption because we do not cover prices or volume sold in other venues such as restaurants, workplace cafeterias, vending machines, etc.

The results from this study reveal that the demand for SSBs in Seattle was responsive to the SBT introduced on January 1, 2018. On average, in the first year following the introduction of the Seattle SBT, the 20% increase in prices that occurred due to the tax reduced the volume sold of taxed beverages by 22% (equivalent to an elasticity of demand of -1.1) and this impact was not offset by cross-border shopping. Future evaluation with longer follow-up periods will be informative to provide evidence on whether tax pass-through increases over time and the extent to which this yields greater reductions in volume sold. Further, if the tax is eventually fully passed through it will be important to understand whether it may then induce some cross-border shopping, which is not presently observed.

Funding

This study was supported by grants from the Bloomberg Philanthropies' Obesity Prevention Initiative (www.bloomberg.org) and Arnold Ventures Philanthropy. The contents of this publication do not necessarily reflect the views or policies of Bloomberg Philanthropies or Arnold Ventures. The funders had no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

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