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Impact of a sweetened beverage tax on beverage prices in Seattle, WA

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ABSTRACT

Seattle's Sweetened Beverage Tax is an excise tax of 1.75 cents per ounce on sugar-sweetened beverages and is one of the highest beverage taxes in the U.S. This study examined the impact of Seattle's tax on the prices of beverages. We conducted audits of 407 retail food stores and eating places (quick service restaurants and coffee shops) before and 6 months after the tax was implemented in Seattle and in a comparison area. Ordinary least squares difference-in-differences models with store fixed effects were used to estimate the effect of the tax on prices, stratified by beverage type and store type. In secondary analyses, we assessed the effect of the tax on the price of non-taxed beverages and foods. Results from the adjusted difference-in-differences models indicated the tax was associated with an average increase of 1.58 cents per ounce among Seattle retailers, representing 90 % of the price of the tax. By store type, price increases were highest in smaller grocery stores and drug stores. By beverage type, price increases were highest for energy beverages and soda and lowest for bottled coffee and juice drinks. Prices of some non-taxed beverages also increased while the prices of select healthy foods generally did not. The sweetened beverage tax in Seattle is higher than beverage taxes in most other cities, and nearly the full cost of the tax is being passed through to consumers for many beverage types and stores types.

1. Introduction

Sugar-sweetened beverage taxes have been implemented in seven U.S. cities and in approximately 35 countries (Healthy Food America, 2020). These taxes are hypothesized to affect consumption by raising prices, thus prompting decreased demand for sweetened beverages. The majority of the beverage taxes in U.S. cities have been excise taxes levied on distributors (Change Lab Solutions and Healthy Food America, 2016). The only legal requirement of these excise taxes is that the distributor remit the tax to the tax collector. Distributors and retailers decide how much, if any, of the tax is passed onto the consumer via higher prices. It is therefore important to examine the degree to which prices of beverages increase in response to the tax in order to determine whether consumers are experiencing increased prices for taxed products (Powell et al., 2013).

Distributors may handle beverage taxes differently depending on the local consumer base, and distributors' strategies may change over time, depending on consumer response. Previous studies have found a wide range of impacts on beverage prices from beverage taxes (Cawley and Frisvold, 2017; Cawley et al., 2018a, 2018b; Falbe et al., 2015; Grogger, 2017; Roberto et al., 2019). Estimates suggest that the tax "pass-through," or how much of the tax is passed on to consumers, was approximately 40–70 % in Berkeley, CA (Cawley and Frisvold, 2017; Falbe et al., 2015), 60 % in Oakland, CA (Cawley et al., 2020), 120 % in Cook County (Powell et al., 2020), 80 % in Boulder, CO (Cawley et al., 2018a, 2018b), and 40–100 % in Philadelphia, PA (Cawley et al., 2019; Roberto et al., 2019). Additionally, one recent study evaluated pass-through in Seattle using point-of-sale purchase data and found an average of approximately 60 % pass through (Powell and Leider, 2020).

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The purpose of our study was to examine the impact of Seattle's Sweetened Beverage Tax on prices of taxed and non-taxed beverages using data from in-person audits of a variety of stores and eating places. Seattle's Sweetened Beverage Tax went into effect on January 1, 2018; it is an excise tax levied on distributors and is one of the largest taxes among U.S. cities at 1.75 cents per ounce and affects only sugar-sweetened beverages. In addition to the tax affecting the price of beverages subject to the tax, distributors or retailers may respond to the tax by spreading it across non-taxed beverages and other food items as well (Brand, 2018). To assess this, we collected prices of taxed and non-taxed beverages, as well as prices of a sample of fresh and packaged foods, through audits of 407 stores and eating places in Seattle and a comparison area, both before tax implementation (2017) and 6-months post-tax (2018). Our sample includes supermarkets and superstores, medium-sized grocery stores, chain and non-chain convenience stores, drug stores, chain and non-chain quick service restaurants, and coffee shops.

2. Materials and methods

2.1. Overview

We used in-person audits of stores and eating places in Seattle and a comparison area before tax implementation and approximately 6 months after tax implementation. The comparison area is a group of three smaller cities that are 8–20 miles south of Seattle, including Kent, Auburn and Federal Way. We chose this as the comparison area for several reasons including: 1) this area is subject to the same state and regional policies (these three cities are in the same county as Seattle) and thus has a similar economic climate, and 2) to avoid places that might introduce a beverage tax during the study period (e.g., larger nearby cities such as Tacoma, WA and Portland, OR were actively considering beverage taxes when we were identifying potential comparison areas).

2.2. Sample

We designed our sample to be geographically balanced and to reach a minimum number of stores within strata of store types. Each study area (Seattle, comparison area) was divided into 16 equal-sized spatial sampling units using the *spcosa* (Spatial Coverage Sampling and Random Sampling from Compact Geographical Strata) package in R (**Supplemental Fig. S1**). The sampling frame for food stores and eating places was a list of all permitted, permanent food establishments in 2016 in each area maintained by the county health department. All stores on this list were previously geocoded and classified into store type categories using NAICS codes, key words and manual searching and categorizing (Vernez Moudon et al., 2013). We calculated the distance of each store to the centroid location of each polygon (using Euclidian distances) and chose stores of each store type that were nearest to the centroid, working outward from the polygon centroid until a quota for each store type was met within each polygon. The polygon centroid was a random point due to the way the polygons are created. The quotas for most store types were based on *a priori* power calculations for detecting moderate-sized taxed beverage price changes in store-type stratified models. For polygons that had too few stores of any given type to meet the quota, we included additional stores from neighboring polygons that were not already included in the sample. We also worked with community liaisons and used "minority-owned business" lists to ensure inclusion of small stores and quick service restaurants owned by people of color. During the follow up surveys, we revisited every store and restaurant included in the baseline sample.

Of the 453 stores included in our sample at baseline, 407 (90 %) were re-surveyed during the 6-month post-tax follow up visit (Table 1). Nineteen (4%) were permanently closed and 27 (6%) refused to participate.

2.3. Data collection

At baseline and 6-months, data collectors received two six-hour trainings and practiced data collection in the field until 90 % raw agreement on responses was achieved. We conducted all in-store audits between October and mid-November 2017, for the pre-tax assessment and May-July 2018 for the post-tax assessment.

The survey tool was programmed into Redcap and data were collected on handheld tablets. The food store and quick service restaurant instruments were adapted from instruments developed by researchers at the University of Illinois, Chicago (Li et al., 2018) with modifications to reflect local availability. Survey items queried price (both regular and discounted if applicable) from major brands within 8 categories of taxed beverage types, and 15 categories of non-taxed beverage types. **Supplemental Table S1** shows surveyed beverages by beverage type and beverage tax category; instruments are included in the **Supplemental Materials**. For each beverage listed, we recorded the price and availability of multiple sizes of that product (e.g., 12oz cans, 20oz bottles, 1-liter bottles, 12 packs of 12oz cans) for a total of 172 possible unique beverage products.

In 13 % of surveyed Seattle food stores and eating places, at the 6-month follow-up, the shelf price of beverages subject to the tax included language indicating that the beverage tax would be added at the register (e.g. "plus beverage tax"). At these establishments, we purchased a beverage subject to the tax and recorded the amount of additional tax added at the register. This amount was then added to the shelf price amount for each taxed beverage exhibiting that signage at that store. We found that in these stores the amount of tax added at the register equaled exactly 1.75 cents per ounce and all taxed beverages were treated the same; in most cases the tax was added in a separate line on the receipt.

Table 1
Number of stores of each store type, at baseline and 6-months post-tax, for Seattle and comparison area.

	Seattle			Comparison area[1]		
Retail type	Baseline	6 months	Re-survey rate	Baseline	6 months	Re-survey rate
Superstore/superstore	31	29	94%	24	22	92 %
Grocery/drug store	50	46	92%	27	26	96 %
Small stores	71	60	85%	80	70	88 %
Warehouses	1	1	100%	1	1	100 %
Quick-service restaurant	47	43	91%	75	66	88 %
Coffee shops	21	18	86%	25	25	100 %
Total	221	197	89%	232	210	91 %

[1] Comparison area includes the cities of Federal Way, Kent, and Auburn, Washington.

2.4. Variables

2.4.1. Exposure variable

Our exposure of interest was the Seattle Sweetened Beverage Tax, which was implemented on January 1, 2018 and is imposed on distributors selling targeted beverages inside the City of Seattle.

2.4.2. Outcome variables

The primary outcome of interest was the change in the price of beverages (cents per ounce) that fall into one of the taxed beverage categories, as defined by the Seattle ordinance.

For all analyses, we used the lowest purchase price (excluding coupons, but including loyalty card discounts) for each beverage on the day the store was surveyed. In secondary analyses, we examined the change in the price per ounce of beverages that were not subject to the tax as well as the change in the price per serving of a sample of food items.

2.4.3. Covariates

Covariates included store type, beverage size, and beverage type. We included five different categories of stores or eating places (superstores/supermarkets, grocery stores and drug stores, small stores, quick service restaurants, and beverage shops (coffee or tea); for definitions see **Supplemental Materials**). Beverages were categorized into five size categories: grab-and-go (all bottled beverages under 32 oz, plus fountain drink cups), family size (1 L, 1.25 L, 2 L, half-gallon, and gallon), packs (all grab-and-go sized beverages sold in packs (e.g., a 12 pack of 12oz sodas)), wholesale bulk packages of beverages (e.g., a flat of 36 12oz sodas), and powder concentrates. Beverages were grouped into categories based on beverage type (e.g. soda, sports beverages, energy beverages).

2.5. Statistical analysis

Our primary analyses estimated the effect of the tax on the price of beverages subject to the tax. The unit of analysis was a beverage. We used regression-based difference-in-differences models to estimate the degree to which the price of taxed beverages in Seattle changed above and beyond price changes over the same period for the same beverages in the comparison area. These models controlled for all time-invariant observed and unobserved differences between Seattle and the comparison area (Allison, 2009). In secondary analyses, we examined non-taxed beverages and food. We ran ordinary least squares models with standard errors clustered at the store level of the general form:

$$Y_{ijt} = \beta_0 + \beta_1(time)_t + \beta_2(cityXtime)_{it} + \beta_4 \boldsymbol{X}_{it} + \omega_j + \varepsilon_{it},$$

Where, Y_{ijt} is the price per ounce of beverage *i*, in store *j* at time *t*. *City* is an indicator variable that takes the value of 1 for observations in Seattle and 0 for observations in the comparison area; *time* is an indicator variable that takes the value of 1 for prices measured in the post-tax period and 0 for prices measured in the pre-tax period. The coefficient for the interaction between *city* and *time* (cityXtime), β_2, is the difference-in-differences estimator. This is our estimate of the tax pass-through. A pass-through of the tax of 100 % would result in $\beta_2 = 1.75$, meaning that the price of beverages subject to the tax rose an additional 1.75 cents per ounce above and beyond the change seen in the comparison area. $\boldsymbol{X}$ is a vector of control variables, which includes beverage type and beverage size in the primary model. We also included ω as a fixed effect for each store or eating place, to control for price variations across individual establishments that do not vary across time.

We then ran models stratified by beverage type, since previous studies have noted different pass-through of the tax by beverage type (Roberto et al., 2019; Powell and Leider, 2020). We did this for both taxed and non-taxed beverages, separately. We were interested in the prices of non-taxed beverages to assess whether the tax was associated with increasing prices of all beverages and whether the tax was likely creating a price differential between taxed and non-taxed potential substitutes. These models included store fixed effects and beverage size as covariates. We additionally ran models stratified by store type; these models included store fixed effects, beverage size and beverage type as covariates.

Our primary models examined beverages that were surveyed in these stores at both time points (a balanced model). The definition for beverages observed at both time points is a beverage of the same brand, same specification, and same size was observed at both time points; examples include Coca-Cola 20oz, Coca-Cola 6 pack of 12 oz cans, Gatorade 20 oz, Red Bull 8.4 oz (see **Supplemental Materials** for instruments). In sensitivity analyses, we 1) included all beverages, regardless of whether they were present in a store at both time points (an unbalanced model; estimates can be driven by a change in the mix of products stocked or in the price of given product), 2) stratified by beverage size (in balanced models), and 3) limited the Seattle sample to stores within 1 mile of the North or South borders (in balanced models).

3. Results

We measured prices of 22,224 unique beverages within stores at baseline and 6-months post-tax.

3.1. Unadjusted mean prices of taxed beverages

Table 2 displays the unadjusted (raw) mean prices of taxed beverages, overall and according to beverage type and store type, in Seattle and the comparison area, at baseline and 6 months after tax implementation. Prices for most beverages were very similar between the comparison area and Seattle at baseline, although slightly more expensive in Seattle, on average. The price of all taxed beverages increased significantly in Seattle, while small non-statistically significant changes in price for these same beverages were seen in the comparison area.

3.2. Impact of the tax on taxed beverage prices overall and according to beverage type and store type from covariate-adjusted difference-in-differences models

The estimated price increase associated with the tax in Seattle was 1.58 cents per ounce for all taxed beverages pooled together. This represents a pass-through of 90 % (Fig. 1), after accounting for changes in the comparison area (the difference-in-differences) and controlling for price variations by store characteristics (store "fixed effects"), beverage type, and/or beverage size.

3.2.1. By beverage type

The difference-in-differences estimates indicated the pass-through of the tax was approximately 95% for soda [DD: 1.66 (95 % CI: 1.51, 1.80)] and 104% for energy drinks [DD: 1.82 (95 %CI: 1.39, 2.25)]. Price increases were lower (ranging from 58 to 83%) for bottled, sugar-sweetened tea, sports beverages, bottled, sugar-sweetened coffee drinks and juice drinks.

3.2.2. By store type

In models that stratify on store type while controlling for store fixed effects, beverage type and beverage size, average prices of taxed beverages increased significantly in Seattle versus the comparison area for supermarkets/superstores, grocery stores/drug stores, small stores, and quick service restaurants. Specifically, in Seattle supermarkets and superstores, prices on taxed

Table 2
Estimated mean prices of beverages in Seattle and comparison area: Baseline, 6-months post-tax, and unadjusted difference-in-differences.

	Seattle Baseline (95 % CI)[1]	Seattle 6-months (95 % CI)[1]	Seattle Difference (95 % CI)[1]	Comparison Baseline (95 % CI)[1]	Comparison 6-months (95 % CI)[1]	Comparison Difference (95 % CI)[1]	DID (95 % CI)[1,2]
Taxed Beverages							
All Taxed Beverages[3] (N = 11,096)	9.52 (9.10, 9.94)	11.18 (10.72, 11.65)	+1.66 (1.52, 1.80)*	9.04 (8.73, 9.35)	9.12 (8.80, 9.43)	+0.08 (0.00, 0.16)	1.58 (1.42, 1.75)*
Soda (N = 5,930)	6.02 (5.71, 6.32)	7.84 (7.49, 8.19)	+1.82 (1.70, 1.95)*	5.57 (5.36, 5.78)	5.73 (5.51, 5.96)	+0.17 (0.10, 0.24)*	1.66 (1.51, 1.80)*
Sports Beverages (N = 1,348)	5.95 (5.54, 6.37)	7.35 (6.88, 7.82)	+1.40 (1.18, 1.62)*	5.95 (5.51, 6.39)	6.02 (5.55, 6.49)	+0.07 (-0.07, 0.21)	1.33 (1.07, 1.59)*
Energy Beverages (N = 2,142)	20.92 (20.34, 21.51)	22.55 (21.88, 23.22)	+1.63 (1.30, 1.95)*	19.89 (19.50, 20.29)	19.70 (19.29, 20.10)	−0.20 (-0.48, 0.08)	1.82 (1.39, 2.25)*
Juice Beverages (N = 290)	5.08 (4.56, 5.60)	6.14 (5.45, 6.82)	+1.06 (0.75, 1.36)*	4.81 (4.18, 5.44)	4.65 (3.86, 5.45)	−0.16 (-0.59, 0.28)	1.21 (0.68, 1.74)*
Tea, Bottled (N = 858)	6.06 (5.66, 6.45)	7.62 (7.16, 8.08)	+1.57 (1.29, 1.84)*	6.01 (5.64, 6.38)	6.11 (5.68, 6.55)	+0.10 (-0.10, 0.31)	1.46 (1.12, 1.80)*
Sugary Syrup Add On[4] (N = 80)	55.59 (43.91, 67.27)	63.71 (54.26, 73.15)	+8.12 (-5.33, 21.57)	48.04 (40.48, 55.61)	46.78 (41.23, 52.33)	−1.26 (-6.41, 3.89)	9.38 (-5.03, 23.78)
Coffee, Bottled (N = 528)	20.31 (19.50, 21.13)	21.63 (20.66, 22.61)	+1.32 (0.63, 2.01)*	18.86 (18.05, 19.67)	19.16 (18.50, 19.82)	+0.30 (-0.37, 0.97)	1.02 (0.06, 1.98)*
Store Type							
Superstores/ Supermarkets (N = 3,230)	7.75 (7.38, 8.12)	9.25 (8.80, 9.71)	+1.50 (1.29, 1.72)*	7.14 (6.91, 7.36)	7.16 (6.92, 7.41)	+0.03 (-0.08, 0.13)	1.47 (1.24, 1.71)*
Grocery/Drug Stores (N = 2,792)	9.72 (9.06, 10.38)	11.52 (10.72, 12.31)	+1.80 (1.49, 2.10)*	8.74 (8.19, 9.29)	8.76 (8.19, 9.32)	+0.01 (-0.20, 0.22)	1.78 (1.41, 2.15)*
Small Stores (N = 4,540)	11.17 (10.71, 11.62)	12.89 (12.40, 13.37)	+1.72 (1.47, 1.97)*	10.00 (9.71, 10.30)	10.06 (9.76, 10.36)	+0.06 (-0.06, 0.18)	1.66 (1.38, 1.93)*
Warehouses[5] (N = 40)	6.52 (3.00, 10.04)	7.77 (4.24, 11.29)	+1.24 (-3.74, 6.22)	5.78 (2.59, 8.96)	5.78 (2.60, 8.97)	+0.01 (-4.50, 4.51)	1.24 (-5.48, 7.95)
Coffee Shops[4] (N = 80)	55.59 (43.91, 67.27)	63.71 (54.26, 73.15)	+8.12 (-5.33, 21.57)	48.04 (40.48, 55.61)	46.78 (41.23, 52.33)	−1.26 (-6.41, 3.89)	9.38 (-5.03, 23.78)
Quick Service Restaurants (N = 494)	10.87 (9.41, 12.33)	12.46 (10.87, 14.06)	+1.59 (1.06, 2.13)*	10.24 (9.41, 11.07)	10.96(10.10, 11.81)	+0.72 (0.30, 1.13)*	0.88 (0.21, 1.55)*

Values are cents per ounce unless otherwise noted.
[1] CI = confidence interval.
[2] Balanced sample included beverages (unique brand, specification and size) that were present at the same store at baseline and 6-month store audits.
[3] Excludes sugary syrup add on.
[4] Cents per sugary syrup flavor shot.
[5] Standard errors are not adjusted for clustering at the store level since there are only two warehouses.
* $p < 0.05$.

beverages increased by 1.47 cents per ounce (95 % CI: 1.23, 1.71), or 83 % of the price of the tax, more than they increased in the comparison area. Among grocery stores and drug stores, the price of taxed beverages increased a statistically significant 1.78 cents per ounce (95 % CI: 1.41, 2.15) more in Seattle than in the comparison area. For small stores, prices increased by 1.66 cents per ounce more than in the comparison area (95 % CI: 1.38, 1.93) (Fig. 1). The average change in warehouse stores was not statistically significant (DD: 1.24; 95 % CI: -1.60, 4.07).

In quick service restaurants, the price of taxed beverages increased significantly more in Seattle compared to the comparison area – by 0.88 cents per ounce, or 50 % pass-through (95 % CI: 0.20, 1.55). In coffee shops, we collected data on the price of the caloric flavor syrup that can be added to coffee drinks as the taxed beverage. The average price of additional caloric flavor syrup at coffee shops increased by 9.38 cents in Seattle versus the comparison area, but the price change varied considerably (95 % CI: -4.91, 23.67), and was not statistically significant.

3.3. Secondary analyses

3.3.1. Unbalanced sample

In analyses that do not limit the sample to include only the beverages observed at both time points (unbalanced sample column in **Supplemental Table S2**), the estimates of pass-through were somewhat larger, but substantively similar for the overall average and by beverage type and store type, with the exception of quick service restaurants in which the estimate suggests a substantially higher pass-through in the unbalanced sample of 1.61 cents per ounce (95 % CI: 0.20, 1.55) or 92 % of the price of the tax.

3.3.2. Stores close to the city borders

Price increases were lower for stores within 1 mile of the northern or southern border of Seattle (bodies of water surround the city on much of the east and west borders), with a difference-in-differences estimate of 1.42 cents per ounce (95 % CI: 1.07, 1.76) (Table 3).

3.3.3. By beverage size

Among popular beverage sizes, in balanced models, the average pass-through was lowest for two-liter bottles [DD: 1.52; 95 % CI: 1.31, 1.70)], higher for 20 oz bottles [DD: 1.79; 95 % CI: 1.57, 2.01)], and highest for 12 packs [DD: 1.86; 95 % CI: 1.56, 2.16)] (**Supplemental Table S3**).

3.4. Impact of the tax on non-taxed beverage prices overall and according to beverage type and store type from covariate-adjusted difference-in-differences models

Fig. 2 displays the difference-in-differences estimates for changes in price of non-taxed beverages. A table version of this

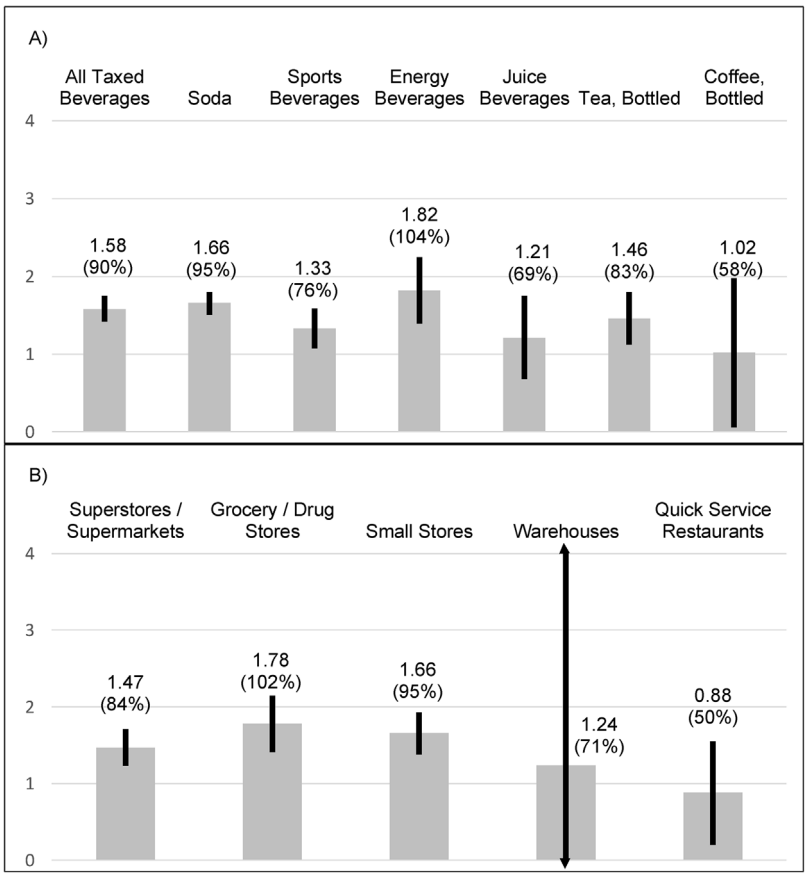

Fig. 1. Adjusted estimated effect of the tax on prices of beverages (in cents per ounce) in Seattle at 6-months post-tax from balanced difference-in-differences models. Point estimates, confidence intervals and estimates expressed as percent of the price passed through to consumers are displayed. Panel A displays the pooled estimate for all taxed beverages and the estimates from beverage-type-stratified models. Panel B displays estimates from store-type-stratified models. Estimates from sugary syrup add-on and coffee shops are not shown due to the fact that the sugary syrup add-on is in a different unit- price per flavor shot rather than price per ounce and is the only taxed item we collected in coffee shops (difference-in-differences estimate was 9.38 cents/oz (95 % CI[−4.93, 23.69])). Tax pass-through for the sugary syrup add-on is not calculated because it cannot be converted confidently to ounces since the size of the syrup add-on was not queried at each coffee shop and because the tax would have been calculated per the ounces of the average size beverage it is added to.

Table 3
The estimated effect of the tax among stores within 1-mile of Seattle's northern or southern border.

	DID (95 % CI)[1,2]	Percent Pass-through[1,3]
Taxed Beverages[4] (n = 6,922)	1.42 (1.07, 1.76) *	81 %
Non-taxed Beverages[5] (n = 7,256)	0.24 (-0.06, 0.53)	–

CI = confidence interval; DID = difference-in-difference.
[1] Balanced models include beverages (unique brand, specification and size) that were present in the same store at baseline and 6-month store audits.
[2] Models include store fixed effects, beverage size, and beverage type as covariates. Standard errors are clustered at the store-level.
[3] The percent of the 1.75 cents/ounce passed on to consumers.
[4] Taxed beverages include: soda, sports beverages, energy beverages, juice beverages, bottled tea, and bottled coffee.
[5] Non-taxed beverages include: diet soda, diet sports drinks, diet energy beverages, 100 % juice, milk, water, powered sugar-free beverages, sugar-free bottled tea, sugar-free prepared coffee.
* $p < 0.05$.

information with exact values of confidence intervals is provided in **Supplemental Table S4**. The overall mean price of non-taxed beverages increased more in Seattle than in the comparison area by 0.33 cents per ounce (95 % CI: 0.19, 0.47). Beverage-type- and store-type-stratified models indicate that this increase may be driven by the increase in the price of diet soda [DD: 0.48 (95 % CI: 0.31, 0.65)] and diet energy drinks [DD: 0.89 (95 % CI: 0.43, 1.34)]. By store type, increases in the price of non-taxed beverages were statistically significant only among grocery/drug stores and small stores as compared to changes in the comparison area (Fig. 2). The prices for milk, water, and 100 % juice did not increase significantly more in Seattle versus the comparison area.

3.4.1. Changes in the prices of food

None of the prices of healthier foods increased significantly more in Seattle versus the comparison area. Among snack foods, there was a small increase in the price of chips by 1 cent per serving and a decrease in the price of honeybuns (**Supplemental Table S5**).

4. Discussion

We assessed the impact of Seattle's sweetened beverage tax on the prices of taxed and non-taxed beverages and a selection of foods in a wide range of food retailers using in-person store audit methods. We additionally included quick service restaurants and coffee shops, which have only previously been studied in Boulder, CO (Cawley et al., 2018a). We find that the 1.75 cents per ounce tax on distributors is being largely passed through to the consumer in Seattle, with the average price of taxed beverages increasing by 90 % of the price of the tax. The prices of all taxed beverage categories (e.g. soda, energy beverages, juice-flavored drinks, etc.) increased more in Seattle versus the comparison area, and these increases were statistically significant for all categories except the sugar-sweetened flavor syrup added to coffee drinks. We also found price

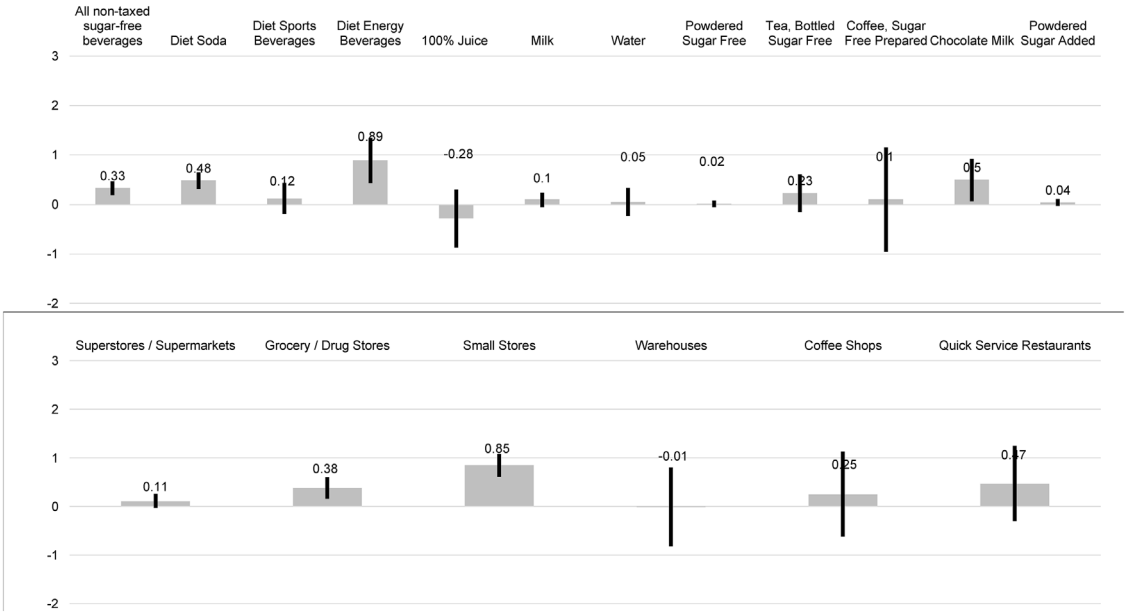

Fig. 2. Adjusted estimated effect of the tax on prices of non-taxed beverages (in cents per ounce) in Seattle at 6-months post-tax from balanced difference-in-difference models. Difference-in-difference point estimates and confidence intervals are displayed. Panel A displays the pooled estimate for all non-taxed, sugar-free beverages and the estimates from beverage-type-stratified models. Panel B displays estimates from store-type-stratified models.

increases for some non-taxed beverages (diet soda, diet energy drinks and diet bottled tea), particularly in smaller stores. Finally, we did not find any impact of the beverage tax on prices of a selection of healthier foods, contrary to claims in the popular press that beverage taxes may be driving up food prices (Brand, 2018).

Among all studies of beverage taxes in U.S. cities, pass-through estimates have varied from 40 % to 119 % (Cawley and Frisvold, 2017; Cawley et al., 2018b; Falbe et al., 2015). These previous studies have used either in-person store audit data collection (similar to our methods) or point-of-sale scanner data. We expect these two types of study designs to produce somewhat different results. In Seattle, a previous study (Powell and Leider, 2020) used point-of-sale estimates from a sample of supermarkets, superstores, grocery stores, drug stores, convenience stores, and dollar stores in Seattle and the comparison area of Portland, OR. They found an average pass-through of 59 %, which is substantially lower than our estimate of 90 %. Estimates might differ for many reasons, some of which are relevant to all comparisons between point-of-sale data and in-person store audit data and some likely specific to the Seattle context. Our in-person data collection in Seattle revealed that three large supermarket chains have opted to add the tax at the register (not on the shelf price) and as a separate line on the receipt. This is unusual, but not out of compliance with the Seattle tax regulations (Seattle's sweetened beverage tax, 2020). Because it is listed on a separate line and not included in the price associated with each product's UPC code, this part of the price of the beverage is missed in the point-of-sale data for retailers choosing to implement the tax in this way. Thus, the increase in the price of the beverage due to the tax is being omitted, resulting in a lower estimate of pass-through. Because we were aware of this, our data accounts for this in the estimate of pass-through; specifically, we include the price of the tax in the price of the beverage, even when added separately at the register. In our sample, 13 % of stores and 17 % of the products we surveyed were processed in this way, but we suspect this affected more of the products in the Powell and Leider study (Powell and Leider, 2020) since their estimates are based on the weighted frequency of ounces sold and since supermarkets likely make up the predominant source of ounces purchased of these beverages. To our knowledge, only the evaluation of the beverage tax in Boulder, CO has also reported on this potential discrepancy that would affect point-of-sale estimates of price pass-through.

There are additional reasons for differences between our study and the Powell and Leider study (Powell and Leider, 2020) that are generalizable to comparisons of most point-of-sale to retail audit studies. Point-of-sale estimates of pass-through may be lower if people are more likely to purchase the taxed products only when they are on sale in the post-tax period (e.g. the discounted price would be captured more frequently in the point-of-sale transactions compared to the in-person audits). Hand-collected data are typically unweighted by frequency of purchasing, whereas point-of-sale data are self-weighted in this way. Therefore, the pooled estimate of average pass-through can reflect sampling-induced differences based on the representation of store types and beverage types in the sample. This is one rationale for presenting the store-type and beverage-type stratified models.

Our results are most comparable to other studies that use in-person, store audits. Similar methods have been used in Berkeley, CA, and Philadelphia, PA (Cawley and Frisvold, 2017; Cawley et al., 2019; Falbe et al., 2015). Our findings are most similar to a recent study of Philadelphia, which used in-person audits of a variety of food retailers and found approximately 100 % of the 1.50 cent per ounce beverage tax was passed through to consumers (Cawley et al., 2018b). Similarly, in Boulder, a working paper analyzing in-person store audit price data reports that 79 % of the price of the 2 cents per ounce tax was passed through to consumers (Cawley et al., 2018a). Estimates from in-person store audits in Berkeley, suggest somewhat lower levels of pass-through, ranging from approximately 40%–67% (Cawley and Frisvold, 2017; Falbe et al., 2015). Berkeley is a smaller city, the first US city to pass a tax, and the tax was substantially lower, at 1 cent per ounce, which may have influenced pass through (Cawley and Frisvold, 2017; Falbe et al., 2015). The tax pass-through may be truly different by city due to various factors including how distributors anticipate how different populations will respond to the tax, potentially based on population demographic characteristics, as well as how well-

informed distributors and retail shop owners are about the tax, particularly in smaller stores (Chan et al., 2018).

Our finding that the price of non-taxed beverages increased is different from what was found by Falbe and colleagues (Falbe et al., 2015) and Silver and colleagues (Silver et al., 2017) in Berkeley, who found no increase in the price of non-taxed beverages. Roberto and colleagues report a small but statistically significant increase in the price of non-taxed products (Roberto et al., 2019). The increase we observed in the price of non-taxed beverages appears to be concentrated in medium-sized grocery stores, drug stores and small stores and in the price of diet soda, diet energy drinks and diet or unsweetened tea. The price of healthier non-taxed beverages, such as bottled water and milk, did not increase.

There were some qualitative differences in pass-through by beverage type. First, of the beverage types subject to the tax, only the syrup added to coffee at coffee shops did not increase significantly in price. The wide variation in response is likely because syrup-sweetened coffees are only taxed when they are added to a beverage for which the first ingredient is not milk, which could be a minority of the syrup-sweetened beverages. Coffee shops and distributors in Seattle were allowed to submit waivers indicating the proportion of the beverages to which syrup is added that contain milk as the first ingredient and are therefore not subject to the tax. Second, we found pass-through on juice beverages was notably lower than other taxed beverages, although there is a wide confidence interval around this estimate. These beverages are often consumed by children (Bleich et al., 2018) and may not be increasing in price as much as would be expected as a result of the tax. Price increases were also qualitatively lower (ranging from 58 to 83%) for bottled, sugar-sweetened tea, sports beverages, bottled, sugar-sweetened coffee drinks and highest for energy drinks and soda. In-person store audit findings from Philadelphia found that pass-through was also highest for energy drinks, which is consistent with our findings; however, juice drinks in Philadelphia had one of the highest pass-through rates, dissimilar to our results (Cawley et al., 2018b). Similar to our findings, sweetened tea also saw relatively lower pass-through rates in Philadelphia (Cawley et al., 2018b). In-person retail audit findings from lower income neighborhoods in Berkeley measured fewer beverage types and found lower pass-through for all measured products, but also found a qualitatively lower pass-through rate for juice drinks as compared to soda (Falbe et al., 2015). While we see some qualitative differences by beverage type, similar to other studies, the confidence intervals of these estimates overlap so we refrain from overinterpreting these differences. Additionally, looking across store audit-based pass-through estimates in other cities, the heterogeneity in pass-through by beverage type appears to be rather idiosyncratic.

There are limitations to this study. Although we think our estimates can be attributed to the tax, with our current study design, we cannot rule out the possibility that potentially all or some portion of the estimates are due to an unmeasured, time-varying confounding factor. This seems less likely due to the specificity of the price changes focused primarily on a large range of beverages subject to the tax and the similarities in baseline prices between Seattle and the comparison area. Although we measured a large number of stores and our sample accounted for approximately 27 % of all stores in Seattle according to the list of permitted establishments, we did not measure all stores. Additionally, we excluded from our sample Trader Joes, Whole Foods and a local co-op supermarket chain because these stores typically do not sell the same brands of beverages captured on our survey and they devote relatively little shelf space to sugar-sweetened beverages. Also, while we captured a large number of unique beverages, we did not capture all beverages. We also were unable to weight our results by purchasing frequency, however, we present stratified and adjusted models to account for some of the heterogeneity of effects that could be unduly amplified in unweighted pooled estimates. Finally, we accounted for correlated standard errors at the store level, but we were unable to account for additionally correlated errors at the geographic level since we have only one treated unit and two total areas. This leaves the possibility that standard errors are underestimates.

5. Conclusion

In summary, the sweetened beverage tax in Seattle is higher than those in Philadelphia and Berkeley, yet nearly the full price of the tax appears to be passed through to consumers, on average, for many beverage types and in many store types. Raising prices is believed to be a necessary step for the tax to result in decreased consumption. Future work will shed light on whether these price increases are sustained by sellers in the long run and coincide with a decrease in purchasing of taxed beverages.

CRediT authorship contribution statement

Jessica C. Jones-Smith: Conceptualization, Supervision, Methodology, Validation, Formal analysis, Writing - original draft, Funding acquisition. **Lina Pinero Walkinshaw:** Software, Formal analysis, Resources, Data curation, Writing - review & editing, Project administration. **Vanessa M. Oddo:** Formal analysis, Writing - original draft. **Melissa Knox:** Conceptualization, Writing - review & editing. **Marian L. Neuhouser:** Conceptualization, Writing - review & editing. **Philip M. Hurvitz:** Methodology, Software, Formal analysis, Writing - review & editing. **Brian E. Saelens:** Conceptualization, Writing - review & editing. **Nadine Chan:** Conceptualization, Writing - review & editing, Funding acquisition.

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Appendix A. Supplementary data

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