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Association of a Beverage Tax on Sugar-Sweetened and Artificially Sweetened Beverages With Changes in Beverage Prices and Sales at Chain Retailers in a Large Urban Setting

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Supplemental content

IMPORTANCE Policy makers have implemented beverage taxes to generate revenue and reduce consumption of sweetened drinks. In January 2017, Philadelphia, Pennsylvania, became the second US city to implement a beverage excise tax (1.5 cents per ounce).

OBJECTIVES To compare changes in beverage prices and sales following the implementation of the tax in Philadelphia compared with Baltimore, Maryland (a control city without a tax) and to assess potential cross-border shopping to avoid the tax in neighboring zip codes.

DESIGN, SETTING, AND PARTICIPANTS This study used a difference-in-differences approach and analyzed sales data to compare changes between January 1, 2016, before the tax, and December 31, 2017, after the tax. Differences by store type, beverage sweetener status, and beverage size were examined. The commercial retailer sales data included large chain store sales in Philadelphia, Baltimore, and the Pennsylvania zip codes bordering Philadelphia. These data reflect approximately 25% of the ounces of taxed beverages sold in Philadelphia.

EXPOSURES Philadelphia's tax on sugar-sweetened and artificially sweetened beverages.

MAIN OUTCOMES AND MEASURES Change in taxed beverage prices and volume sales.

RESULTS A total of 291 stores (54 supermarkets, 20 mass merchandisers, 217 pharmacies) were analyzed. In Philadelphia and Baltimore, the mean price per ounce of taxed beverages increased at all stores in the after-tax periods and taxed beverage volume sales per 4-week period decreased in all store types. Compared with Baltimore, Philadelphia experienced significantly greater increases in taxed beverage prices and significantly larger declines in volume of taxed beverages sold in the after-tax period.

	Philadelphia		Baltimore		Difference-in-Differences (95% CI)
	2016	2017	2016	2017	
Mean price, cents per ounce					
Supermarkets	5.43	6.24	5.33	5.50	0.65 (0.60 to 0.69)
Mass merchandise stores	5.28	6.24	6.34	6.52	0.87 (0.72 to 1.02)
Pharmacies	6.60	8.28	6.76	6.93	1.56 (1.50 to 1.62)
Mean volume sales, oz in millions per 4-wk period					
Supermarkets	4.85	1.99	2.83	2.81	−2.85 (−4.10 to −1.60)
Mass merchandise stores	2.98	1.72	1.05	1.00	−1.20 (−2.04 to −0.36)
Pharmacies	0.16	0.13	0.14	0.13	−0.02 (−0.03 to −0.01)

Total volume sales of taxed beverages in Philadelphia decreased by 1.3 billion ounces (from 2.475 billion to 1.214 billion) or by 51.0% after tax implementation. Volume sales in the Pennsylvania border zip codes, however, increased by 308.2 million ounces (from 713.1 million to 1.021 billion), offsetting the decrease in Philadelphia's volume sales by 24.4%.

CONCLUSIONS AND RELEVANCE In Philadelphia in 2017, the implementation of a beverage excise tax on sugar-sweetened and artificially sweetened beverages was associated with significantly higher beverage prices and a significant and substantial decline in volume of taxed beverages sold. This decrease in taxed beverage sales volume was partially offset by increases in volume of sales in bordering areas.

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Policy makers are interested in beverage taxes to raise revenue and reduce sugar-sweetened beverage intake, given its strong connection to obesity and poor health.[1] Seven US cities have implemented beverage excise taxes, where the tax is levied on the distribution of beverages and may only be partially passed through to consumers. Philadelphia implemented an excise tax of 1.5 cents per ounce on the distribution of sugar-sweetened and artificially sweetened drinks on January 1, 2017.[2] This tax is unique because it includes diet drinks and affects a large, racially/ethnically diverse, and low-income population (Philadelphia is the poorest of the 10 largest US cities).[3]

A study of Mexico's beverage tax reported a 7.6% decline in taxed beverage purchases and a 2.1% increase in nontaxed beverage purchases over 2 years[4] but lacked a control group. Published data on US beverage excise taxes are limited. Pass-through estimates of Berkeley's tax of 1 cent per ounce range from 43% to 100%.[5-7] One study reported a 10% decrease in sugar-sweetened beverage sales following the tax.[7] Existing studies are limited by close proximity of the intervention and control sites and/or a small number of stores.[5-8] One small study at the Philadelphia airport found that 93% of the tax was passed through to beverage prices,[8] but no peer-reviewed studies have examined the association between tax implementation and changes in beverage sales.

Using a difference-in-differences approach, this study compared Philadelphia (intervention) to Baltimore (control) to examine the association between Philadelphia's tax and changes in beverage prices and sales as well as the combined sales of food and household items at large chain retailers. To assess potential tax avoidance, sales in the zip codes neighboring Philadelphia were compared with Baltimore.

Key Points

Question What was the association between a beverage excise tax on sugar-sweetened and artificially sweetened beverages implemented in Philadelphia in 2017 with changes in beverage prices and volume of sales?

Findings In this difference-in-differences analysis of retailer sales data in the year before and the year after implementation of an excise tax of 1.5 cents per ounce on sugar-sweetened and artificially sweetened beverages, the tax was associated with significant increases in price-per-ounce of 0.65 cents at supermarkets, 0.87 cents by mass merchandise stores, and 1.56 cents at pharmacies. Total volume sales of taxed beverages in Philadelphia decreased by 1.3 billion ounces after tax implementation (51%), but sales in Pennsylvania border zip codes increased by 308.2 million ounces, partially offsetting the decrease in Philadelphia's volume sales by 24.4%.

Meaning A beverage excise tax on sugar-sweetened and artificially sweetened beverages in a large urban setting was associated with a significant increase in beverage prices and a significant reduction in volume sales of taxed beverages, although changes in sales volume were partially offset by purchases in neighboring areas.

Methods

The University of Pennsylvania institutional review board determined that this study did not meet the criteria for human participant research. This study examined before vs after tax beverage prices and sales in Philadelphia compared with those in Baltimore (a noncontiguous control city near Philadelphia with a similar sociodemographic and health profile).[9] To assess cross-border shopping, zip codes within approximately 3 miles of Philadelphia's border in 3 Pennsylvania counties (Bucks, Delaware, and Montgomery) were examined. Data (described elsewhere)[10] were purchased from Information Resources Inc (IRI), which obtains data from major US retailers. Retail sales data were reported in 4-week periods for all beverages sold from January 1, 2014 to December 31, 2017. Data were provided at the individual beverage level based on a unique universal product code and aggregated up to the store- and city-level where appropriate. These data represent store sales (eg, volume of beverages sold per store) and not transactions made by individuals. Store-level data on food and beverages and household product sales were also analyzed. The data from IRI had no missing values.

Store Categorization

Stores were classified by 2 coders (discrepancies were resolved through discussion) as supermarkets, mass merchandise stores, or pharmacies based on the North American Industry Classification System, eAppendix 1 A.1 in the Supplement). Stores were excluded if they were not open as of January 1, 2014, closed before December 31, 2017, or were not continuously open during this period.

Beverage Categorization

The data set had volume, units, and dollars of each beverage sold in each 4-week period for 24 004 unique universal product codes. Beverages were classified by tax status (hereafter referred to as taxed vs nontaxed beverages) and sweetener type (sugar-sweetened, including drinks with both sugar and artificial sweetener; artificially sweetened, or unsweetened; eAppendix 1 A.2 in the Supplement). Philadelphia's tax applies to the distribution of nonalcoholic beverages (or nonalcoholic syrups or concentrates used to prepare beverages for retail sale) listing any form of caloric sugar-based sweetener or artificial sugar substitute (eg, aspartame) as an ingredient with certain exemptions (eAppendix 1 A.3 in the Supplement). Energy drinks were excluded from the main analyses because they had a much higher price per ounce and much lower sales volume than other beverages. Beverages were also classified as individual- or family-sized, the latter of which was defined as more than 36 oz based on the US Food and Drug Administration's definition of a beverage serving size consumed in 1 sitting.[11] This definition was used rather than restricting only to certain sizes (eg, 2 L) so that all beverages could be analyzed. Sales of liquid and powder drink concentrates, which are not taxed and therefore potential substitutes, were also examined.

Outcomes

The primary outcomes were change in beverages' weighted price per ounce and volume sales in ounces. To convert ounces

to milliliters, multiply by 30. The weighted price of each beverage was calculated by IRI as the mean over a 4-week period weighted by unit sales of that item at that price. These prices were divided by volume (in ounces) to determine weighted price per ounce. The prices reflect what consumers actually paid at the register, incorporating promotional offers. Two secondary outcomes were dollar (and unit) sales of liquid and powder drink concentrates to assess potential substitution to these products and combined dollar sales of beverages, food, and household products to assess potential economic spillover associated with the tax. The IRI data does not include many product categories (eg, electronics, clothing, jewelry, prescription drugs), so although these were all sales available from IRI data, this outcome does not represent total product sales or stores' total revenue.

Statistical Analyses for Price Pass-Through

A difference-in-differences approach was used to compare the weighted price per ounce of taxed beverages before and after the Philadelphia tax with those of Baltimore over the same period. Analyses focused on the years 2016 and 2017 because the parallel trends assumption (ie, that the preintervention trend in the outcome is similar for the treatment and control locations) held for beverage volume sales in Philadelphia compared with Baltimore during 2016 but did not hold from January 1, 2014, to December 31, 2015, based on generalized estimating equations using a continuous time variable, the locations, and the interaction between the 2 (eAppendix 1 A.4.a in the Supplement).

Change in price analyses were based on universal product code–level data at each 4-week period at the store level. Beverages with prices higher than or lower than the 1st through 99th percentiles were excluded for these analyses and subsequent elasticity calculations. Generalized linear models with random intercepts were used with an unstructured covariance matrix, and observations were clustered at the store level (eAppendix 1 A.4.b in the Supplement).

Changes in prices over time for Philadelphia vs Baltimore were examined by including 2 binary variables (after vs before tax period and Philadelphia vs Baltimore) and their interaction; this interaction is the difference-in-differences estimate of the association between the tax and the outcomes or the "treatment effect." For the primary analyses, separate models for supermarkets, mass merchandise stores, and pharmacies were estimated to assess differences by store setting. Separate models were also estimated for taxed and nontaxed beverages. Percent pass-through was calculated by taking the difference-in-differences estimate of change in price per ounce and dividing by the tax of 1.5 cents per ounce. To assess changes in price across the Philadelphia border, difference-in-differences analyses compared the border stores to Baltimore.

For secondary analyses, separate taxed and nontaxed regressions were run to examine changes in unit sales for individual- and family-sized containers at supermarkets only because supermarkets had the highest beverage volume sales (63%) and a greater range of sizes. Separate regressions were also run to examine changes in sugar-sweetened and artificially sweetened drinks among taxed beverages at supermarkets only.

Statistical Analyses for Volume Sales

First, raw results aggregated at the city-level are presented to document the cumulative annual change in beverage sales for the before vs after tax periods separately for Philadelphia, Baltimore, and the Philadelphia border stores.

Second, store-level analyses are presented separately for each store type using generalized estimating equations incorporating random intercepts, an independence covariance matrix, and clustered observations at the store level. A difference-in-differences approach was used to examine the association of the tax with outcomes by store type (primary analysis) and container size and sweetener type (secondary analyses). The coefficients represent the absolute change in each outcome at the average (mean) store in an average (mean) 4-week period (eAppendix A.4.c in the Supplement). A calculation was done to generate implied price elasticity (ie, the percent change in volume divided by the percent change in price in which our estimate for the percent change in volume incorporates cross-border increases in volume) (eAppendix 1 A.4.d in the Supplement).

The significance threshold was .05, and all tests were 2-sided. Analyses applied a prespecified Bonferroni correction to adjust for multiple comparisons (6 comparisons for store type by tax status, 4 for beverage size by tax status, and 2 for sweetener type). Analyses were conducted using SAS version 9.4 (SAS Institute Inc) and replicated independently by a second analyst. Sensitivity analyses (reported in eAppendix 2 in the Supplement) using the same difference-in-differences approach examined whether results were consistent when using 2014-2017 data, when controlling for seasonality (using an indicator for fiscal quarter), and when using nonborder Pennsylvania zip code county stores as a control group. Before and after regression analyses examining Philadelphia alone also appear in eAppendix 2 in the Supplement.

Results

Store Sample

A total of 369 stores were classified, including 101 supermarkets, 31 mass merchandise stores, and 237 pharmacies. After excluding 21 stores that were not open when the study began, 50 stores that closed before 2017 (including 26 stores from 2 national chains that closed in 2015), and 7 stores that were not continuously open, the final sample included 291 stores (54 supermarkets, 20 mass merchandise stores, and 217 pharmacies, **Table 1**). Although mean combined sales among all stores in 2016 were higher in Philadelphia ($1.465 billion) than in Baltimore ($356 million) and border zip codes ($508 million), the percent of combined sales that were beverages was similar across study locations. Based on a list of all food retailers in Philadelphia compiled by the city of Philadelphia, the IRI data cover 86% of mass merchandise stores, 40% of pharmacies, and 37% of supermarkets in Philadelphia (eAppendix 1 A.5 in the Supplement).

Table 1. Descriptive Statistics of Aggregated Sales Data by Store Type, 2016[a]

	No. of Stores	Total Sales in Millions, $		Combined Sales That Are Beverages, %	% of All Beverage Sales at Each Store Type by City
		Combined[b]	Beverage		
Supermarkets					
Total No.	54				
Philadelphia	26	704	97	13.8	62.3
Baltimore	13	235	30	12.6	80.5
Pennsylvania border zip codes[c]	15	320	37	11.7	75.9
Mass merchandise stores					
Total No.	20				
Philadelphia	14	420	36	8.6	23.0
Baltimore	2	39	2	5.3	5.6
Pennsylvania border zip codes[c]	4	110	8	7.7	17.2
Pharmacies					
Total No.	217				
Philadelphia	140	341	23	6.8	14.7
Baltimore	45	82	5	6.2	13.9
Pennsylvania border zip codes[c]	32	78	3	4.4	6.9
All Stores					
Total No.	291				
Philadelphia	180	1465	157	10.7	NA
Baltimore	60	356	37	10.3	NA
Pennsylvania border zip codes[c]	51	508	49	9.7	NA

[a] Because of rounding, not all numbers sum exactly.

[b] Total combined sales include food, beverages, and some household products (eg, paper towels). Many product categories (eg, electronics, clothing, jewelry, prescription drugs) are not available, so although these data are all the sales available from Information Resources Inc, this outcome does not represent total store sales or total store revenue.

[c] Border stores refer to stores in the Pennsylvania zip codes that border Philadelphia; New Jersey is not included.

Beverage Sample

Of the 24 004 unique universal product codes, 0.9% of beverages were unable to be classified as sugar, artificial, or unsweetened because the ingredient list or a similar product could not be found. Because IRI cannot reveal the specific store associated with each sales data record, the brand (eg, Walmart) associated with private-label beverages (10.7% of all beverages) is unknown. These were either included in categories in which all products were similar with respect to sweetener and tax status (eg, regular soda) (n = 3074, 58% of private label) or excluded (n = 2251, 42% of private label) due to insufficient information for beverage categorization. Overall, 9325 (54%) sugar-sweetened, 1781 (10%) artificially sweetened, and 6047 (35%) unsweetened beverages were classified (eAppendix 1 A.2 in the Supplement).

Price Change and Pass-Through

There was a substantial price increase in taxed beverages immediately following the tax's implementation (**Figure 1** and **Table 2**). The mean price per ounce of taxed beverages between the before and after tax period at supermarkets in Philadelphia increased from 5.43 cents to 6.24 cents and in Baltimore from 5.33 cents to 5.50 cents (43.1% pass-through; 11.8% increase; difference-in-differences, 0.65 cents; 95% CI, 0.60-0.69 cents; $P < .001$). At mass merchandise stores the price per ounce increased in Philadelphia from 5.28 cents to 6.24 cents and in Baltimore from 6.34 cents to 6.52 cents (57.8% pass-through; 16.4% increase; difference-in-differences, 0.87 cents; 95% CI, 0.72-1.02 cents; $P < .001$). At pharmacies, the price per ounce increased in Philadelphia from 6.60 cents to 8.28 cents and in Baltimore from 6.76 cents to 6.93 cents at pharmacies (104.0% pass-through; 23.5% increase; difference-in-differences, 1.56 cents; 95% CI, 1.50-1.62; $P < .001$).

Nontaxed beverage prices at supermarkets increased 0.10 cents per ounce (95% CI, 0.02-0.18 cents; $P = .01$; 1.2% increase). There was no statistically significant change in the price per ounce of nontaxed beverages at mass merchandise stores. Nontaxed beverage prices at pharmacies increased 0.14 cents per ounce (95% CI, 0.04-0.24 cents; $P < .001$; 1.8% increase; Table 2). When comparing Philadelphia's bordering zip code stores with Baltimore, there was an increase in taxed beverage prices of 0.09 cents per ounce (95% CI, 0.04-0.14 cents; $P < .001$) at supermarkets and an increase of 0.15 cents per ounce at pharmacies (95% CI, 0.07-0.22 cents; $P < .001$), but no significant change at mass merchandise stores (eAppendix 2 B.1 in the Supplement).

Secondary Analyses

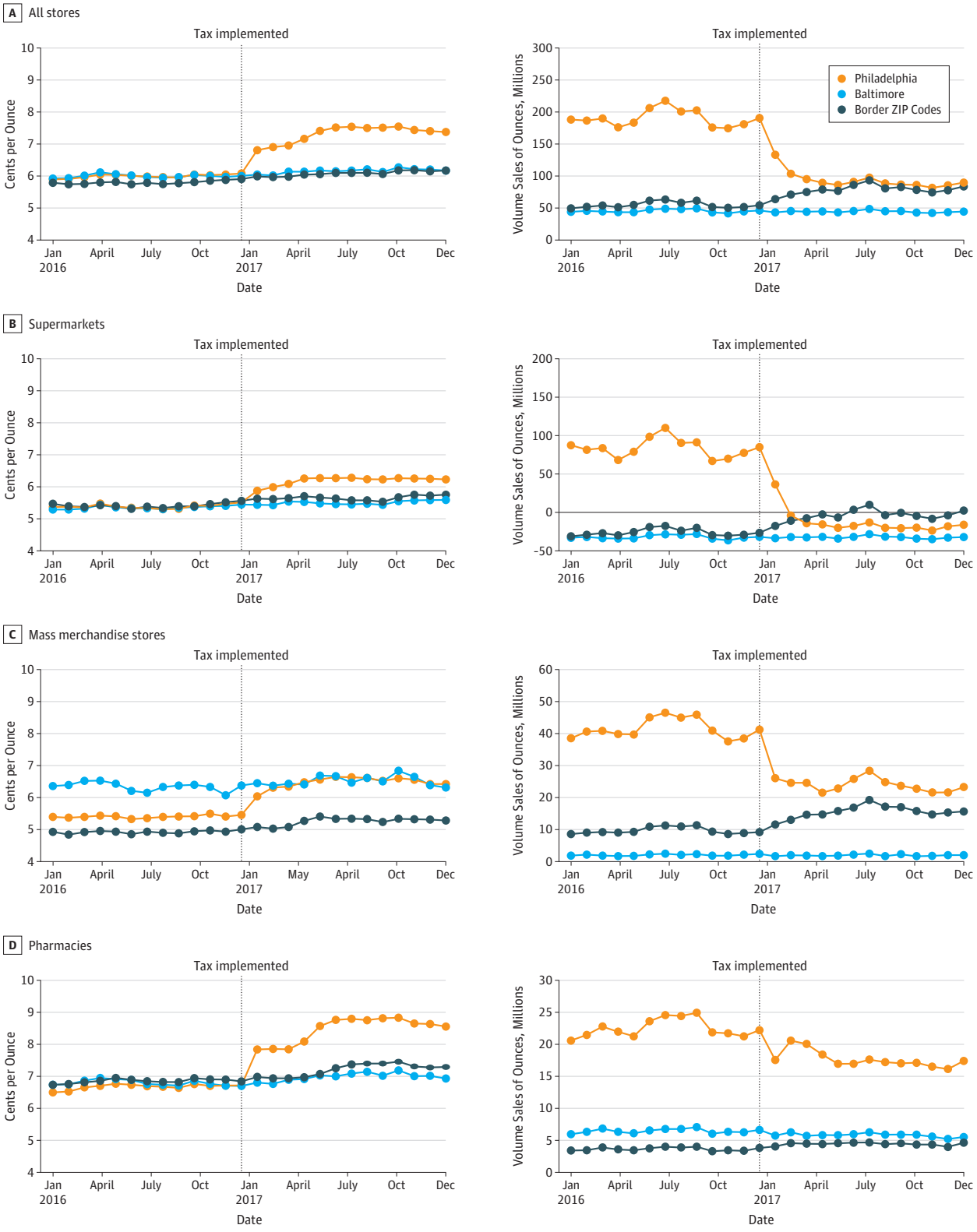
Beverage Size

The price increase in Philadelphia supermarkets compared with Baltimore was 0.41 cents per ounce (95% CI, 0.32-0.51 cents; $P < .001$; 27.5% pass-through; 4.7% increase) for individual-sized drinks and 0.60 cents per ounce (95% CI, 0.57 to 0.62 cents; $P < .001$; 39.7% pass-through; 15.4% increase) for family-sized drinks.

Sweetener Type

Taxed sugar-sweetened beverages had a price increase of 0.61 cents per ounce (95% CI, 0.57-0.65 cents; $P < .001$; 40.8%

Figure 1. Changes in Beverage Prices and Volume Sales in Philadelphia, Baltimore, and Bordering Zip Codes Before and After Tax Implementation



The breakdown of beverage sales by location and store type appears in Table 1. Weighted price was calculated by Information Resources Inc as the mean over a 4-week period weighted by unit sales of that item at that price; prices were divided by volume (in ounces) to determine weighted price per ounce.

Table 2. Regression Results for Change in Beverage Price-per-Ounce and Beverage Prices

	2016	2017	2016	2017	Adjusted % Change in Price	% of 1.5 Cents Per Ounce Tax Passed Through to Prices[a]	Difference-in-Differences Estimated Change in Price (95% CI), Cents per Ounce[a]	Corrected *P* Value[b]
Mean Price, Cents per Ounce	**Philadelphia**		**Baltimore**					
Price per oz[c]								
Taxed beverages								
Supermarkets	5.43	6.24	5.33	5.50	11.8	43.1	0.65 (0.60 to 0.69)	<.001
Mass merchandise stores	5.28	6.24	6.34	6.52	16.4	57.8	0.87 (0.72 to 1.02)	<.001
Pharmacies	6.60	8.28	6.76	6.93	23.5	104.0	1.56 (1.50 to 1.62)	<.001
Taxed beverage size[d,e]								
Individual	8.70	9.46	8.43	8.75	4.7	27.5	0.41 (0.32 to 0.51)	<.001
Family	3.85	4.42	3.80	3.82	15.4	39.7	0.60 (0.57 to 0.62)	<.001
Taxed sweetener type[e]								
Sugar	5.57	6.32	5.50	5.63	10.9	40.8	0.61 (0.57 to 0.65)	<.001
Artificial	4.83	5.85	4.60	4.90	16.4	53.0	0.80 (0.71 to 0.88)	<.001
Nontaxed beverages								
Supermarkets	8.25	8.43	8.85	8.90	1.2	NA	0.10 (0.02 to 0.18)	.01
Mass merchandise stores	7.35	7.41	8.88	8.90	1.6	NA	0.12 (−0.11 to 0.35)	>.99
Pharmacies	7.74	7.94	7.62	7.70	1.8	NA	0.14 (0.04 to 0.24)	.001
Nontaxed beverage size[d,e]								
Individual	12.36	12.41	13.05	13.02	0.4	NA	0.05 (−0.09 to 0.19)	>.99
Family	5.29	5.29	5.58	5.56	0.4	NA	0.02 (−0.02 to 0.07)	.91
Beverage prices, $								
Taxed beverages								
Supermarkets	2.73	3.00	2.59	2.62	8.6		0.24 (0.22 to 0.25)	<.001
Mass merchandise stores	3.53	4.48	2.81	2.85	14.2		0.53 (0.47 to 0.60)	<.001
Pharmacies	2.12	2.51	2.08	2.11	17.6		0.37 (0.36 to 0.39)	<.001
Nontaxed beverages								
Supermarkets	3.26	3.27	3.36	3.37	0.2		0.01 (−0.02 to 0.03)	>.99
Mass merchandise stores	3.81	3.98	3.24	3.33	0.3		0.01 (−0.06 to 0.08)	>.99
Pharmacies	2.70	2.78	2.65	2.68	2.0		0.05 (0.03 to 0.08)	<.001
Taxed beverage size[d,e]								
Individual	1.58	1.74	1.49	1.55	6.0		0.10 (0.08 to 0.11)	<.001
Family	3.29	3.69	3.14	3.18	11.3		0.37 (0.35 to 0.40)	<.001
Nontaxed beverage size[d,e]								
Individual	2.44	2.41	2.55	2.54	−0.9		−0.02 (−0.05 to 0.01)	.20
Family	3.84	3.94	3.99	4.05	1.4		0.05 (0.02 to 0.09)	<.001
Taxed sweetener type[e]								
Sugar	2.69	2.96	2.55	2.57	8.3		0.23 (0.21 to 0.24)	<.001
Artificial	2.93	3.20	2.82	2.85	10.0		0.29 (0.25 to 0.34)	<.001
Beverage Prices, $	**Pennsylvania Border Zip Codes**		**Baltimore**					
Taxed								
Supermarkets	2.76	2.79	2.59	2.62	0.0		0.00 (−0.02 to 0.02)	>.99
Mass merchandise stores	4.09	4.31	2.81	2.85	2.8		0.12 (0.05 to 0.18)	<.001
Pharmacies	2.15	2.20	2.08	2.11	0.7		0.02 (0.00 to 0.03)	.17
Nontaxed								
Supermarkets	3.30	3.33	3.36	3.37	0.6		0.02 (−0.01 to 0.05)	.41
Mass merchandise stores	4.26	4.35	3.24	3.33	−1.3		−0.06 (−0.14 to 0.03)	.52
Pharmacies	2.68	2.74	2.65	2.68	0.7		0.02 (−0.01 to 0.05)	.76
Taxed beverage size[d,e]								
Individual	1.64	1.72	1.49	1.55	1.1		0.02 (0.00 to 0.04)	.10
Family	3.22	3.27	3.14	3.18	0.4		0.01 (−0.01 to 0.03)	.86

(continued)

Table 2. Regression Results for Change in Beverage Price-per-Ounce and Beverage Prices (continued)

	2016	2017	2016	2017	Adjusted % Change in Price	% of 1.5 Cents Per Ounce Tax Passed Through to Prices[a]	Difference-in-Differences Estimated Change in Price (95% CI), Cents per Ounce[a]	Corrected *P* Value[b]
Nontaxed beverage size[d,e]								
Individual	2.53	2.55	2.55	2.54	1.3		0.03 (0.00 to 0.06)	.02
Family	3.87	3.97	3.99	4.05	0.9		0.04 (0.00 to 0.07)	.07
Taxed sweetener type[e]								
Sugar	2.74	2.78	2.55	2.57	0.4		0.01 (−0.01 to 0.03)	.33
Artificial	2.83	2.83	2.82	2.85	−1.4		−0.04 (−0.08 to 0.00)	.08

[a] Difference-in-differences estimates and percent change in price-per-ounce and price are based on regression estimates. The percent change in price was calculated by dividing the difference-in-differences estimate by the sum of the intercept plus the estimate for Philadelphia. The numerator represents the change in price in Philadelphia in 2017 compared with 2016 controlling for Baltimore and the denominator represents the mean price in Philadelphia in 2016. The difference-in-differences estimate is the point estimate of the interaction term and represents the change in price per ounce (or price) in Philadelphia in 2017 compared with 2016, controlling for secular trends using Baltimore as a control. The percent pass-through tax is not reported for nontaxed beverages because they were not subject to the tax.

[b] Bonferroni corrections used 6 comparisons for store analyses by tax status, 4 for beverage size by tax status, and 2 for sweetener type.

[c] Weighted price of each beverage was calculated by Information Resources Inc as the mean over a 4-week period weighted by unit sales of that item at that price. These prices were divided by volume (≤36 oz) to determine weighted price per ounce.

[d] Individual beverage size was defined as less than 36 ounces based on the US Food and Drug Administration's definition of a beverage serving size consumed in one sitting.

[e] Analyses of beverage size and sweetener type are for supermarkets only.

pass-through; 10.9% increase), whereas artificially-sweetened beverages in Philadelphia supermarkets compared with Baltimore had a price increase of 0.80 cents per ounce (95% CI, 0.71-0.88 cents; $P < .001$; 53% pass-through; 16.4% increase).

Beverage Volume Sales

Aggregate City-Level Descriptors

Total volume sales of taxed beverages in Philadelphia decreased by 1.261 billion oz (**Table 3**) after tax implementation, whereas the volume sales in Baltimore decreased by 13.3 million oz. Volume sales in border zip codes increased by 308.2 million ounces, which offset 24.4% of the approximate 1.3 billon ounce decrease in Philadelphia's volume sales, indicating an overall reduction of 38% (Table 3). Philadelphia revenue collections totaling $72.3 million for 2017 suggest these data cover 25% of ounces of taxed beverages sold (see eAppendix 1 A.6 in the Supplement).

Store Level

Volume sales of taxed beverages at the mean supermarket at the mean 4-week period in Philadelphia compared with Baltimore declined by 58.7%. The absolute decrease in Philadelphia went from 4.85 to 1.99 million oz and in Baltimore, from and 2.83 to 2.81 million oz. The difference-in-differences estimate was −2.85 million oz (95% CI, −4.10 to −1.60 million oz, $P < .001$).

Mass merchandise stores experienced a volume decrease of 40.4% for taxed beverages. The absolute decreases in Philadelphia went from 2.98 to 1.72 million oz and in Baltimore, from 1.05 to 1.00 million oz. The difference-in-differences estimate was −1.20 million oz (95% CI, −2.04 to −0.36 million oz, $P = .001$).

Pharmacies experienced a volume decrease of 12.6% among taxed beverages. The absolute decreases in Philadelphia went from 0.16 to 0.13 million oz and in Baltimore from 0.14 to 0.13 million oz. The difference-in-differences estimate was −0.02 million oz (95% CI, −0.03 to −0.01 million oz; $P < .001$; Figure 1 and **Table 4**).

There were no statistically significant changes in sales of nontaxed beverages in any store type. Inspection of beverage volume changes by zip code confirmed that increases in beverage sales occurred at the border (**Figure 2**). The implied price elasticity from the data is −1.7. Main results were generally consistent and statistically significant in sensitivity analyses when using stores consistently open from January 1, 2016, through December 31, 2017 (eAppendix 2 B.2 in the Supplement), all stores regardless of whether they were open continuously (eAppendix 2 B.3 in the Supplement), and when using 2014-2017 data, controlling for seasonality, examining Philadelphia alone, and using nonborder zip code county stores as a secondary control site (eAppendix 2 B.4. to B.7 in the Supplement).

Only 3 main results differed when using 2014-2017 data. The statistically significant 8% decline in combined sales at supermarkets became a nonsignificant 3.9% decline; the 12.6% decrease in taxed beverage volume sales at pharmacies became a nonstatistically significant 5.5% decrease; and the nonsignificant change in nontaxed beverage volume sales at supermarkets in Philadelphia became a statistically significant 16.6% increase (eAppendix 2 B.4 in the Supplement). Energy drink results appear in eAppendix 2 B.8 in the Supplement.

Beverage Size

Supermarkets in Philadelphia vs those in Baltimore experienced a greater decrease in unit sales of family-sized beverages of 28 481 (95% CI, −39 884 to −17 080; $P < .001$) and individual-sized beverages of 5465 (95% CI, −8024 to −2906; $P < .001$; Table 4). There were no statistically significant differences in change in unit sales for nontaxed family-sized or individual-sized drinks.

Sweetener Type

Ounces of sugar-sweetened beverages sold at supermarkets in Philadelphia compared with Baltimore declined by

Table 3. Descriptive Results for Aggregate Beverage Volume, Unit, and Dollar Sales in Philadelphia, Baltimore, and Stores Bordering Philadelphia Before and After the Beverage Tax

	Millions			
	2016	2017	Difference	% Change
Volume Sales, oz[a]				
Taxed				
Philadelphia	2475.5	1214.0	−1261.5	−51.0
Baltimore	589.50	576.20	−13.30	−2.3
Pennsylvania border zip codes[b]	713.10	1021.30	308.20	43.2
Nontaxed				
Philadelphia	3413.30	3417.60	4.30	0.1
Baltimore	544.50	537.30	−7.20	−1.3
Pennsylvania border zip codes[b]	978.30	1015.50	37.20	3.8
Unit sales				
Taxed				
Philadelphia	36.80	21.80	−15.00	−40.8
Baltimore	10.30	9.90	−0.40	−3.9
Pennsylvania border zip codes[b]	10.40	13.70	3.30	31.7
Nontaxed				
Philadelphia	27.80	27.20	−0.60	−2.2
Baltimore	6.20	6.00	−0.20	−3.2
Pennsylvania border zip codes[b]	9.20	9.60	0.40	4.3
Beverage sales, $				
Taxed				
Philadelphia	78.50	50.80	−27.70	−35.3
Baltimore	19.50	19.10	−0.40	−2.1
Pennsylvania border zip codes[b]	23.10	31.00	7.90	34.2
Nontaxed				
Philadelphia	78.10	77.10	−1.00	−1.3
Baltimore	17.20	16.60	−0.60	−3.5
Pennsylvania border zip codes[b]	26.10	27.40	1.30	5.0
Combined sales, $[c]				
Philadelphia	1464.90	1374.70	−90.20	−6.2
Baltimore	355.60	350.80	−4.80	−1.3
Pennsylvania border zip codes[b]	507.80	531.60	23.80	4.7

[a] To convert ounces to milliliters multiply by 30.

[b] Border stores refer to stores in the zip codes that border Philadelphia in Pennsylvania; New Jersey locations are not included.

[c] Total combined sales include food, beverages, and some household products (eg, paper towels). Many product categories (eg, electronics, clothing, jewelry, prescription drugs) are not available, so although these data are all the sales available from Information Resources Inc, this outcome does not represent total store sales or total store revenue.

2.41 million oz (95% CI, −3.36 to −1.47 million oz; $P < .001$), and artificially sweetened beverages declined by 432 137 oz (95% CI, −606 547 to −257 727 oz; $P < .001$; Table 4).

Liquid and Powder Drink Concentrates

There were no statistically significant changes in dollar or unit sales of concentrates among Philadelphia stores compared with Baltimore or among Philadelphia border stores compared with Baltimore (eAppendix 2 B.9 in the Supplement).

Combined Beverage, Food, and Household Product Sales

Beverage sales accounted for 10.7% of beverage, food, and household product sales combined in Philadelphia in 2016 (5.4% of combined sales were taxed beverages). Descriptive aggregated raw data for 2016 compared with 2017 are shown in Table 3.

Store-level analyses indicated that there was a significant decline in combined sales at supermarkets in the mean 4-week period equal to −$169 450 (95% CI, −$247 470 to −$91 420; $P < .001$) in Philadelphia compared with Baltimore for 2017 vs 2016. There were no statistically significant changes in combined sales at mass merchandise stores or pharmacies (Table 4). This reduction in combined sales was driven largely by reductions in food and beverage items (there were no significant changes in household items).

Discussion

In this study that examined the association between the Philadelphia beverage tax and changes in beverage prices and sales in the year prior to implementation of the tax compared with the year after tax implementation, there was significant pass-through of the tax to prices at supermarkets, mass merchandise stores, and pharmacies. Raw city-level volume sales of taxed beverages declined by half, while there was no substantial change for nontaxed beverages. Approximately one-quarter, however, of the decrease in taxed beverage sales volume was offset by increases in volume of sales in bordering areas, indicating an overall reduction of 38%.

Table 4. Regression Results for Beverage Volume Sales Comparing Philadelphia to Baltimore Stores and Stores in Zip Codes Bordering Philadelphia to Baltimore Stores

	2016	2017	2016	2017	Adjusted % Change in Volume[a]	Difference-in-Differences Estimate (95% CI)[b]	Corrected *P* Value[c]
	Philadelphia		Baltimore				
Mean volume sales in millions, oz[d]							
Taxed							
Supermarkets	4.85	1.99	2.83	2.81	−58.7	−2.85 (−4.10 to −1.60)	<.001
Mass merchandise stores	2.98	1.72	1.05	1.00	−40.4	−1.20 (−2.04 to −0.36)	.001
Pharmacies	0.16	0.13	0.14	0.13	−12.6	−0.02 (−0.03 to −0.01)	<.001
Nontaxed							
Supermarkets	6.13	6.36	2.70	2.67	4.3	0.26 (−0.08 to 0.61)	.25
Mass merchandise stores	5.47	5.13	1.33	1.38	−7.2	−0.39 (−0.97 to 0.18)	.42
Pharmacies	0.19	0.18	0.09	0.09	−0.9	0.00 (−0.01 to 0.01)	>.99
Taxed sweetener type[e]							
Sugar	4.14	1.72	2.37	2.37	−58.4	−2.41 (−3.36 to −1.47)	<.001
Artificial	0.72	0.27	0.46	0.44	−60.2	−0.43 (−0.61 to −0.26)	<.001
Unit sales							
Taxed beverage size[e,f]							
Individual	16 301	9756	16 136	15 057	−33.6	−5465 (−8024 to −2906)	<.001
Family	50 633	22 203	28 912	28 963	−56.3	−28 481 (−39 884 to −17 080)	<.001
Nontaxed beverage size[e,f]							
Individual	11 921	11 800	8323	8137	0.5	64 (−401 to 529)	>.99
Family	41 627	40 851	21 863	21 170	−0.2	−79 (−1557 to 1395)	>.99
Combined sales in thousands, $[g]							
Supermarkets	2084.11	1908.72	1387.81	1381.88	−8.1	−169.45 (−247.47 to −91.42)	<.001
Mass merchandise stores	2305.43	2185.81	1497.86	1459.96	−3.5	−81.72 (−199.72 to 36.28)	.29
Pharmacies	187.28	182.30	140.40	135.59	−0.1	−0.17 (−4.62 to 4.27)	>.99
Food and beverage sales in thousands, $							
Supermarkets	1769.47	1602.04	1172.88	1167.35	−9.1	−161.90 (−236.37 to −87.44)	<.001
Mass merchandise stores	1154.87	1073.82	514.91	499.09	−5.6	−65.23 (−137.86 to 7.41)	.10
Pharmacies	53.57	52.59	40.45	39.10	0.7	0.37 (−1.05 to 1.80)	>.99
Household product sales in thousand, $							
Supermarkets	314.64	306.68	214.94	214.52	−2.4	−7.55 (−16.98 to 1.89)	.17
Mass merchandise stores	1150.56	1111.98	982.95	960.87	−1.4	−16.49 (−73.25 to 40.27)	>.99
Pharmacies	133.71	129.71	99.94	96.49	−0.4	−0.55 (−3.93 to 2.83)	>.99
	Pennsylvania Border Zip Codes		Baltimore				
Mean volume sales in millions, oz[d]							
Taxed							
Supermarkets	2.76	3.90	2.83	2.81	41.9	1.16 (0.38 to 1.94)	.001
Mass merchandise stores	2.43	3.89	1.05	1.00	62.1	1.51 (0.53 to 2.49)	<.001
Pharmacies	0.11	0.14	0.14	0.13	34.2	0.04 (0.02 to 0.06)	<.001
Nontaxed							
Supermarkets	3.50	3.69	2.70	2.67	6.4	0.22 (0.03 to 0.41)	.01
Mass merchandise stores	4.67	4.69	1.33	1.38	−0.7	−0.03 (−0.13 to 0.07)	>.99
Pharmacies	0.13	0.13	0.09	0.09	1.9	0.00 (−0.01 to 0.01)	>.99
Taxed sweetener type[e]							
Sugar	2.00	2.89	2.37	2.37	44.7	0.89 (0.36 to 1.43)	<.001
Artificial	0.77	1.02	0.46	0.44	34.9	0.27 (0.11 to 0.42)	<.001

(continued)

Table 4. Regression Results for Beverage Volume Sales Comparing Philadelphia to Baltimore Stores and Stores in Zip Codes Bordering Philadelphia to Baltimore Stores (continued)

	2016	2017	2016	2017	Adjusted % Change in Volume[a]	Difference-in-Differences Estimate (95% CI)[b]	Corrected *P* Value[c]
Unit sales							
Taxed beverage size,[e]							
Individual	12 314	13 844	16 136	15 057	21.2	2609 (955 to 4259)	<.001
Family	27 998	38 984	28 912	28 963	39.1	10 934 (3749 to 18 119)	.001
Nontaxed beverage size[e,f]							
Individual	9898	10 518	8323	8137	8.1	805 (390 to 1220)	<.001
Family	28 181	29 005	21 863	21 170	5.4	1518 (310 to 2726)	.006
Combined sales in thousands, $							
Supermarkets	1639.18	1735.85	1387.81	1381.88	6.3	102.61 (34.03 to 171.19)	.001
Mass merchandise stores	2113.15	2227.53	1497.86	1459.96	7.2	152.28 (5.98 to 298.58)	.04
Pharmacies	188.26	185.74	140.40	135.59	1.2	2.29 (−5.48 to 10.06)	>.99
Food and beverage sales in thousands, $							
Supermarkets	1340.58	1430.28	1172.88	1167.35	7.1	95.22 (36.14 to 154.31)	<.001
Mass merchandise stores	1013.59	1091.37	514.91	499.09	9.2	93.60 (6.54 to 180.66)	.03
Pharmacies	38.15	38.49	40.45	39.10	4.4	1.69 (0.03 to 3.35)	.04
Household product sales in thousands, $							
Supermarkets	298.60	305.57	214.94	214.52	2.5	7.39 (−3.89 to 18.67)	.35
Mass merchandise stores	1099.56	1136.16	982.95	960.87	5.3	58.68 (−5.24 to 122.60)	.08
Pharmacies	150.11	147.26	99.94	96.49	0.4	0.60 (−5.99 to 7.19)	>.99

[a] Percent change and difference-in-differences estimates are based on regression analyses. The percent change was calculated by dividing the difference-in-differences estimate by the sum of the intercept plus the estimate for Philadelphia. The numerator represents the change in outcome (eg, volume sales) in 2017 compared with 2016 controlling for secular trends using Baltimore as a control and the denominator represents the mean of the outcome (eg, volume sales) in Philadelphia in 2016.

[b] The difference-in-differences estimate is the point estimate of the interaction term and represents the change in outcome (eg, volume sales) in Philadelphia in 2017 compared with 2016 controlling for secular trends using Baltimore as a control.

[c] Bonferroni corrections, see Table 2 footnotes.

[d] To convert ounces to milliliters, multiply by 30.

[e] Analyses of beverage size and sweetener type are for supermarkets only.

[f] For individual beverage size definitions see Table 2 footnotes.

[g] For total definitions of sales categories, see Table 2 footnotes.

Supermarkets and mass merchandise stores had a lower pass-through of the tax than pharmacies. As the largest sources of sweetened beverages,[12] these sellers or their distributors may have been relatively more reluctant to fully pass on the tax. The extent, however, that distributors passed on the tax to retailers is unknown, which could also differentially influence pass-through. Nontaxed beverages in pharmacies and supermarkets in Philadelphia and some taxed and nontaxed beverages in bordering locations also showed small price increases. This may be because stores on the border, facing reduced competition from Philadelphia, increased their prices. There were also greater price increases for family-sized than for individual-sized beverages and for artificially sweetened than for sugar-sweetened beverages. The latter may be associated with higher consumption of these beverages among wealthier individuals who may be less affected by the tax.

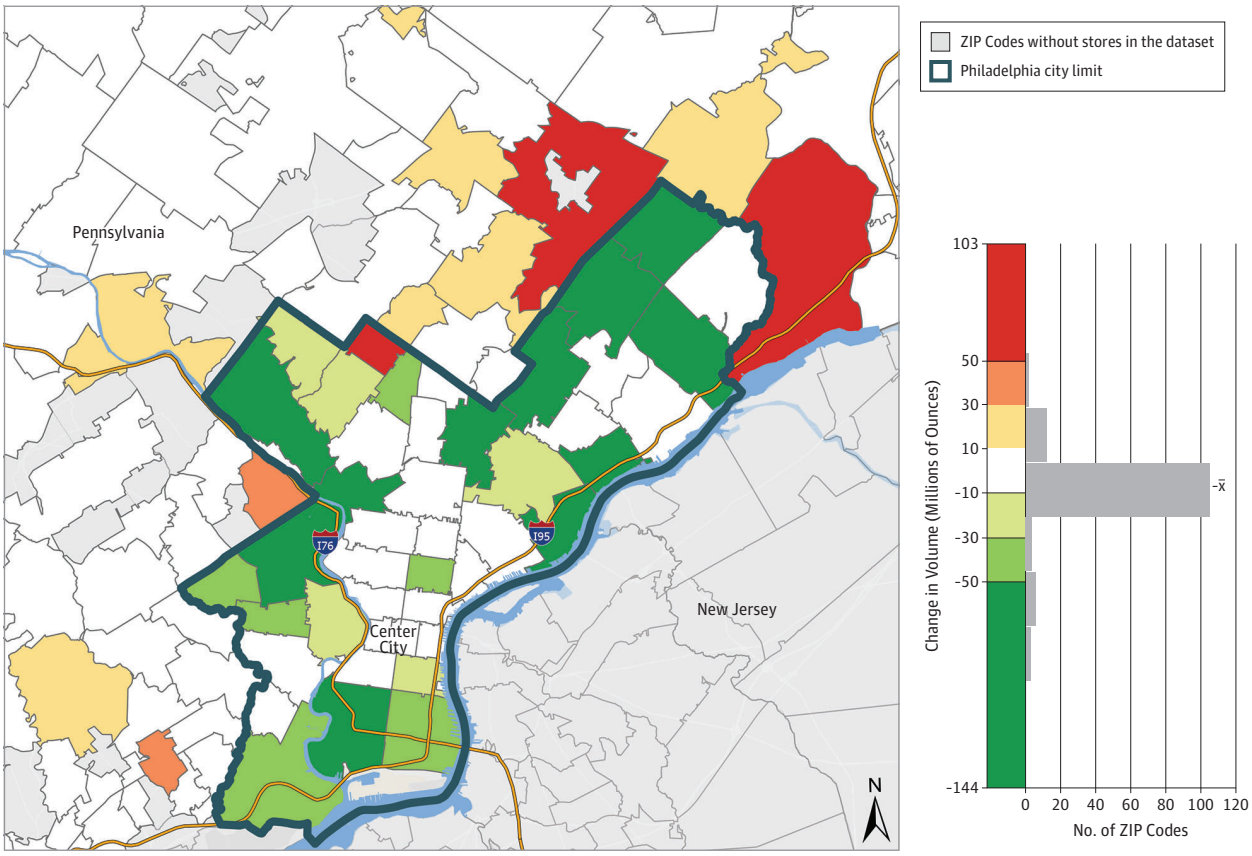
Although the implied price elasticity based on these results is similar to other estimates in the literature,[13] these declines are larger than Berkeley's results.[7] These differences may be due to Philadelphia's higher tax (1.5 vs 1 cents per ounce), greater pass-through, or greater poverty (26% vs 20%, respectively),[14] given that sugar-sweetened beverage intake is higher among low-income populations who are also generally more price-responsive.[15]

Supermarkets may have experienced larger volume decreases than other store types because they displayed more in-store signage about the tax, because there may have been a shift to purchasing sweetened beverages at mass merchandise stores instead of supermarkets, or because shopping behaviors and price sensitivity may have differed across store types.

In contrast to Mexico and Berkeley findings,[4,7] there were no statistically significant increases in nontaxed beverage sales, suggesting consumers were not substituting with these drinks in Philadelphia. There were similar declines in sugar-sweetened and artificially sweetened drink sales despite differences in pass-through and greater declines in family-sized beverage sales. Slightly smaller declines in unit compared with volume sales suggest there may be substitution to smaller sizes. There was no evidence of substitution to liquid and powder drink concentrates.

The mean supermarket experienced a decline in combined sales of food and household products, driven by grocery items; mass merchandise stores and pharmacies were unaffected. Supermarkets bordering Philadelphia, however, had

Figure 2. Changes by Zip Code in Unadjusted Total Volume of Taxed Beverages Sold at Large Chain Retailers in Philadelphia and Neighboring Pennsylvania Border Zip Codes After the Tax, 2016-2017



The histogram shows the distribution of changes by zip code in unadjusted total volume (millions of ounces) of taxed beverages sold at large chain retailers in Philadelphia and neighboring Pennsylvania zip codes after the tax (2016-2017). Neighboring counties included Bucks, Montgomery, and Delaware; New Jersey was not included in the analysis. Twenty-four zip codes that were not in or near Philadelphia are not shown to make it easier to see the changes at the Philadelphia border. Of 140 zip codes, 2 (18949 and 19407) were excluded due to being post office box zip codes. There were 138 zip codes. The mean (SD) beverage volume change per zip code was −6.5 million oz (28.9; minimum, 144; maximim, 103 million oz).

an increase of similar magnitude in combined sales, so chains with stores both inside Philadelphia and just across the border might not have experienced significant business losses. Few studies have examined economic effects of beverage taxes. One study found no effect on national unemployment and no employment changes in commercial food stores or manufacturing 2 years after Mexico's tax.[16] Other data from Philadelphia suggest no change in new monthly unemployment claims filings 14 months after the tax for supermarkets and industries most likely to be affected by it.[17]

This study's strengths include: a large data set of objective purchases from major chain retailers; the inclusion of a control city; and the assessment of potential tax avoidance at the Philadelphia border.

Limitations

This study has several limitations. First, the data only included beverages sold at chain retailers (reflecting approximately one-quarter of taxed beverage ounces sold in Philadelphia). Analogous large-scale transaction data do not exist for smaller stores and restaurants. Second, although cross-border shopping was assessed in nearly all counties neighboring Philadelphia, the study did not include data from New Jersey, where some cross-border shopping may have occurred (although tolls to enter New Jersey may have dissuaded some people). Although the estimate for cross-border shopping in this study is similar to estimates of cigarette tax avoidance,[18] future work examining spillover will be important for understanding locally based policy interventions such as this one. Third, the data did not include overall store revenue. Fourth, this study did not report on changes in beverage consumption or health outcomes associated with the tax.

Conclusions

In Philadelphia in 2017, the implementation of a beverage excise tax on sugar-sweetened and artificially sweetened beverages was associated with significantly higher beverage prices and a significant and substantial decline in volume of taxed beverages sold. This decrease in taxed beverage sales volume was partially offset by increases in volume of sales in bordering areas.

ARTICLE INFORMATION

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Correction: This article was corrected on September 10, 2019, to add an author name to the contribution section, edit a sentence in the Methods section, and attribute a footnote from Table 1 to Table 2.

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Concept and design: Roberto, Lawman, LeVasseur, Bleich.
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