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RESEARCH ARTICLE

No Evidence of Food or Alcohol Substitution in Response to a Sweetened Beverage Tax

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Introduction: Evidence suggests real-world beverage taxes reduce sweetened beverage purchases, but it is unknown if consumers consequently increase food or alcohol purchases. This study examines whether Philadelphia's 1.5 cents/ounce beverage tax was associated with substitution to 3 kinds of hypothesized substitutes: snacks, nontaxed beverage concentrates, and alcohol.

Methods: Using commercial retail sales data and a difference-in-differences approach, analyses compared logged volume and dollar sales of snacks and beverage concentrates between 2016 (pre-tax) and 2017 (post-tax) at chain food retail stores in Philadelphia (n=180) and Baltimore (non-taxed control city; n=60), and logged volume and dollar sales of wine and spirits at liquor stores in Philadelphia (n=44) and nearby Pennsylvania counties (alternate control; n=66). Additional food analyses examined change in logged volume sales of hypothesized products compared to control products (other foods). Analyses were conducted in 2020.

Results: Across store types, analyses showed no statistically significant increases in logged volume or dollar sales of snacks or spirits in Philadelphia stores compared to control sites (decreased, ranging from −10% to 0%). Supermarket analyses showed substitution to nontaxed beverage concentrates (27% increase in volume, 36% increase relative to other food) but remained a relatively small percentage of overall beverage dollar sales (12% at baseline, 15% at post).

Conclusions: At the population level, there is no evidence that Philadelphia's decline in taxed beverage purchases is offset by increases in snacks or spirits purchasing, but there is evidence of substitution to beverage concentrates in supermarkets. Future studies should explore individual-level purchasing changes.

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INTRODUCTION

Beverage taxes are being implemented globally to raise revenue and discourage consumption of sweetened beverages because of their link to health problems.[1−5] Evaluations of these taxes show variation in tax pass-through to prices by store type.[6−14] Most studies using objective sales or purchasing data find evidence that beverage taxes lead to volume reductions in taxed beverage sales, but the magnitude varies considerably based on store type and tax jurisdiction.[6,8,10,11,14−17] Results exploring the impact of beverage taxes on self-reported beverage consumption are mixed,[6,16,18,19] though many studies are limited by small samples.

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Although most evidence on beverage taxes points to behavior change, it is unknown whether people reduce sweetened beverage purchases, but then substitute to other high-calorie foods or alcohol. This study examines potential substitution for 3 plausible types of substitutes: (1) ready-to-eat sweet (e.g., cookies) and salty (e.g., potato chips) snacks that are similar to sweetened beverages in their common designation as junk food[20] and can be more energy dense per dollar than sweetened beverages; (2) beverage concentrates (liquids or powders often used to make sweetened beverages), those sold directly to consumers are exempt from most excise taxes[21]; and (3) alcohol, another beverage treat that may contain as much sugar as sweetened beverages and poses other health risks.[22] If a beverage tax leads consumers to replace a sweetened beverage with these substitutes, the potential health benefits of the tax could be diminished.[23]

Prior simulation studies using natural price variation mostly find no evidence of substitution to snacks and alcohol with higher beverage prices.[22−26] A total of 4 simulations suggest a beverage tax might actually reduce spending on these potential substitute products, although 1 found evidence that candy might be a substitute when compared with sports/energy drinks or juice drinks (not 100% juice), but not when compared to regular or diet soda.[23−26] A fifth showed substitution to alcohol (e.g., lagers instead of high-sugar drinks).[22] One virtual store experiment did not show substitution to snacks.[27] Although these studies suggest beverage taxes are unlikely to produce substitution to snacks and alcohol, this question has not been assessed in the context of a real-world beverage tax implementation.

To address this research gap, this study used a difference-in-differences (DID) approach to examine changes in store-level food sales at large chain retailers (supermarkets, mass merchandizers, and pharmacies) and wine and spirits sales at liquor stores 1 year before and after Philadelphia implemented a 1.5 cents/ounce tax on the distribution of sugar- and artificially-sweetened beverages. The authors' prior work using these same data found taxed beverage prices increased 9% at supermarkets, 14% at mass merchandizers, and 18% at pharmacies.[10] These higher prices led to a 59%, 40%, and 13% reduction, respectively, in taxed beverage volume sales before accounting for cross-border shopping,[10] and are consistent with other research showing larger tax effects in Philadelphia relative to other jurisdictions.[17] This suggests Philadelphia is an important place to study potential substitution effects. Effects may be larger in Philadelphia because it is the poorest of the taxed jurisdictions, the poorest of the 10 largest U.S. cities, and the only U.S. jurisdiction that also taxes artificially-sweetened beverages, limiting consumers' options to substitute with other sweet beverages. In addition, evaluations of the Philadelphia tax have not observed increases in nontaxed beverage sales,[10,17] suggesting people might be spending that money on other products.

The hypotheses were that if substitution occurred, it would most likely result in an increase in sales of (1) ready-to-eat snacks, (2) beverage concentrates (nontaxed), or (3) alcohol. By contrast, sales of other foods (e.g., flour, salmon) or nonedible products (e.g., paper towels) would not increase as they are unlikely substitutes for sweetened drinks. Analyses examined changes in sales for the 3 categories of interest and control categories from pre- to post-tax implementation (2016 to 2017 as the tax was implemented January 1, 2017) in Philadelphia stores relative to stores in 2 control locations (Baltimore and Pennsylvania ZIP codes not bordering Philadelphia). Analyses were separated by store type because the tax affected beverage prices and sales differently by store.

METHODS

Commercial sales data for chain retail stores purchased from Information Resources, Inc. (IRI), a firm with data agreements with large U.S. retailers, were used. All analyses and results are by the authors and not IRI. A total of 2 coders classified 28 chain retail brands as supermarkets/grocery stores (yielding n=201 stores), mass merchandizers (n=74), or pharmacies (n=408) based on the North American Industry Classification System; discrepancies were resolved through discussion. Stores had to be open continuously between 2014 and 2017 to create a stable sample of stores that existed for ≥3 years before tax implementation. Excluding convenience store chains (none were in Philadelphia in this data set), stores not continuously open between 2014 and 2017, and stores outside of the geographic ranges left an analytic sample of 509 food stores (111 supermarkets, 49 mass merchandizers, and 349 pharmacies). Alcohol data came solely from state-owned liquor stores in Pennsylvania, which do not sell beer (n=110).

Retail sales data for 862 subcategories of food (e.g., potato chips, frozen grape juice concentrate), wine and spirits (e.g., domestic table wine, sherry/vermouth/champagne), and some nonedible products (e.g., paper towels, coffee filters) were obtained in 4-week periods for all products with data available from IRI that were sold at stores between 2014 and 2017. The subcategory sales were aggregated up to the store level to represent 4-week store-level sales of each product category of interest within each store type. Alcohol was only sold at liquor stores, and all other categories of interest were only sold at food stores. These data had no missing values. The University of Pennsylvania IRB determined that this study was exempt.

Study Sample

Primary food analyses compared chain retail store sales in Philadelphia (n=180) to sales in Baltimore stores (n=60). Baltimore was chosen as a control location because it is near Philadelphia, but does not border it, and has a similar demographic and health profile.[28] Sensitivity analyses were conducted using ZIP codes >3 miles from the Philadelphia border (n=269 stores) located in 3 Pennsylvania counties adjacent to Philadelphia that do not have a sweetened beverage tax. These locations might better control for regional influences, but are not urban or demographically similar and may also be contaminated by some cross-border shopping induced by the tax. In 2016, Pennsylvania started allowing licensed grocery stores to sell beer and wine (but not liquor). Alcohol was not sold in Baltimore grocery stores and was not consistently sold in Pennsylvania grocery stores, so analysis of substitution to alcohol was limited to liquor stores in Philadelphia (n=44) compared with stores in Pennsylvania nonborder ZIP codes (n=66) that operated under the same state laws.

MEASURES

The primary outcomes were change in volume sales of the potential substitution categories (food in grams and alcohol in milliliters). Food volume sales required some assumptions to convert a variety of units for broad subcategories (e.g., brown/powder/flavored sugar) to weight (e.g., 16-ounce equivalent; detailed in Appendix A1, available online). Nonedible products were excluded from volume analyses. The food and alcohol datasets only include subcategory, not individual product, information. All analyses used the natural log of sales data (interpretable as percentage change for small changes) as Philadelphia had more sales per store than Baltimore and hypothesized substitutes had lower sales than control products. The natural log better accounts for these differences than absolute sales.[29]

Sales of food, alcohol, and nonedible products were aggregated to 17 product categories from 862 subcategories provided by IRI (examples in Appendix Table A2, available online). A total of 6 product categories contained the hypothesized potential substitutes for sweetened beverages: (1) candy, (2) sweet snacks, (3) salty snacks, (4) beverage concentrates, (5) wine, and (6) spirits. Food analyses were conducted separately from alcohol because data came from different stores and had different control locations. Food analyses included comparisons to 2 control product categories: nonedible products and other food composed of 10 categories (e.g., baby food; full list in Appendix Table A2, available online). The data set included many (e.g., paper towels), but not all (e.g., jewelry) nonedible subcategories.

Statistical Analysis

First, total dollar sales in 2016 by store at the city level and the proportion of these sales that were hypothesized substitution products were generated. Next, modeled changes in mean 4-week logged volume sales per store by store type and product category for Philadelphia compared with Baltimore from 2016 to 2017 were examined. All statistical analyses used a DID approach comparing product sales before and after the beverage tax, in Philadelphia stores compared with control stores. The DID approach minimizes bias by comparing changes in the treatment location to the expected changes in control locations assuming parallel trends. Although the data set included 2014−2017 data, analyses focused on 2016−2017 because the parallel trends for previous taxed beverage analyses were violated when including 2014 and 2015,[10] and these food substitution analyses needed to be compared to the same time period. The parallel trends assumption for logged sales was met for these product categories (Figures 1 and 2; Appendix Figures A3 and A4, available online).

Food store analyses compared store sales of snacks, beverage concentrates, and control products in Philadelphia to sales in Baltimore separately by store type (supermarkets, mass merchandizers, and pharmacies). Liquor store analyses compared store sales of wine and spirits in Philadelphia to sales in Pennsylvania nonborder ZIP codes. Generalized estimating equations that required a balanced sample of stores were used with robust SEs to account for clustering within stores. The DID estimate of the impact of the tax on food and alcohol sales (i.e., substitution) came from the interaction of period (pretax versus post-tax) and location (intervention versus control). The p-values were adjusted for the number of products tested within each store type using the Bonferroni−Holm method.

For food store sales, triple DID analyses tested the 3-way interaction of period by location by hypothesized versus other foods (control products). Sensitivity analyses expanded the sample to include 9 food and 6 liquor stores only continuously open between 2016 and 2017. Food sensitivity analyses also used the Pennsylvania nonborder ZIP codes as an alternate control. Finally, sensitivity analyses using logged dollar instead of volume sales were conducted in conjunction with analyses of changes in average prices per unit (at the subcategory level). Dollar sales analyses are limited in that prices may differ in the 2 locations, over time, or people may switch to a cheaper version of the same product. Assuming few differences in price or purchasing behavior, dollar sales can be a useful proxy for quantity purchased. Analyses were conducted in 2020 using SAS, version 9.4.

RESULTS

Baseline combined store sales across all food store types were higher in Philadelphia ($1.465 billion) than Baltimore ($356 million), and much higher in Pennsylvania nonborder ZIP codes ($2.924 billion). This relative magnitude of sales matches the relative number of food stores in each location. The percentages of combined

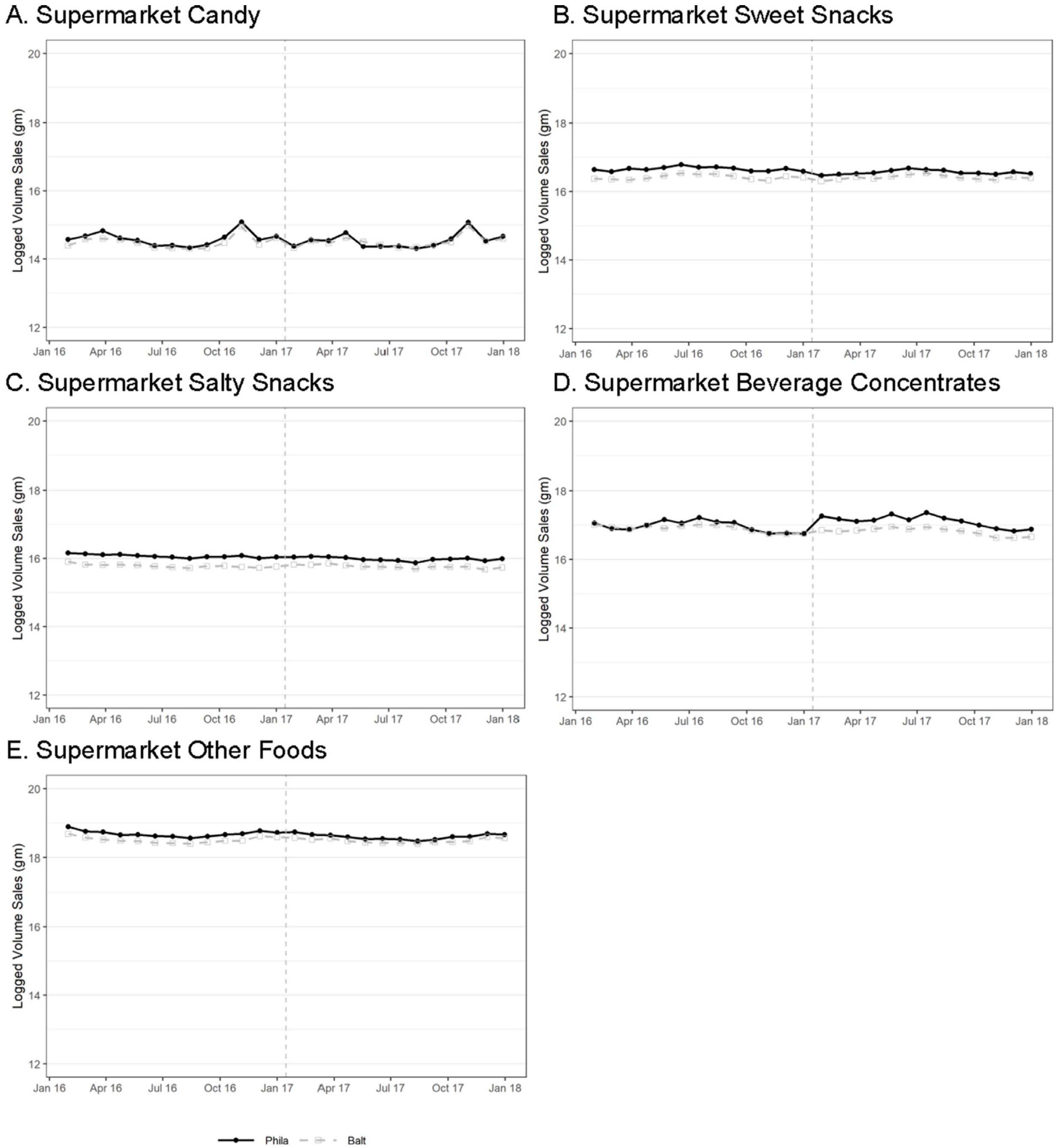

Figure 1. Mean food volume sales per store (logged gm) in 4-week periods 2016–2017 for supermarkets.
Note: Candy, sweet snacks, salty snacks, and beverage concentrates are hypothesized to be substitutes for taxed sweetened beverages. Appendix Figures A3 and A4 (available online) show mass merchandizer and pharmacy sales. Phila = treatment location, Balt = control location. Other foods (aggregating across 10 food categories such as baby food) is a control product category. Dashed vertical line indicates date of Phila beverage tax implementation, January 1, 2017. Balt, Baltimore; Phila, Philadelphia.

sales for snacks and beverage concentrates were similar across locations (Appendix Table A5, available online).

The volume sales DID for snack food categories at the mean food store at the mean 4-week period in Philadelphia compared with Baltimore (for each store type) did not increase, suggesting no large-scale substitution to snacks (Table 1). The supermarket volume sales DID showed significant decreases for all snacks and controls (ranging from −7% to −9%). There were no significant changes in volume sales at other store types. The snack results for the dollar DID were very similar (Appendix Table A6). The volume DID for supermarket

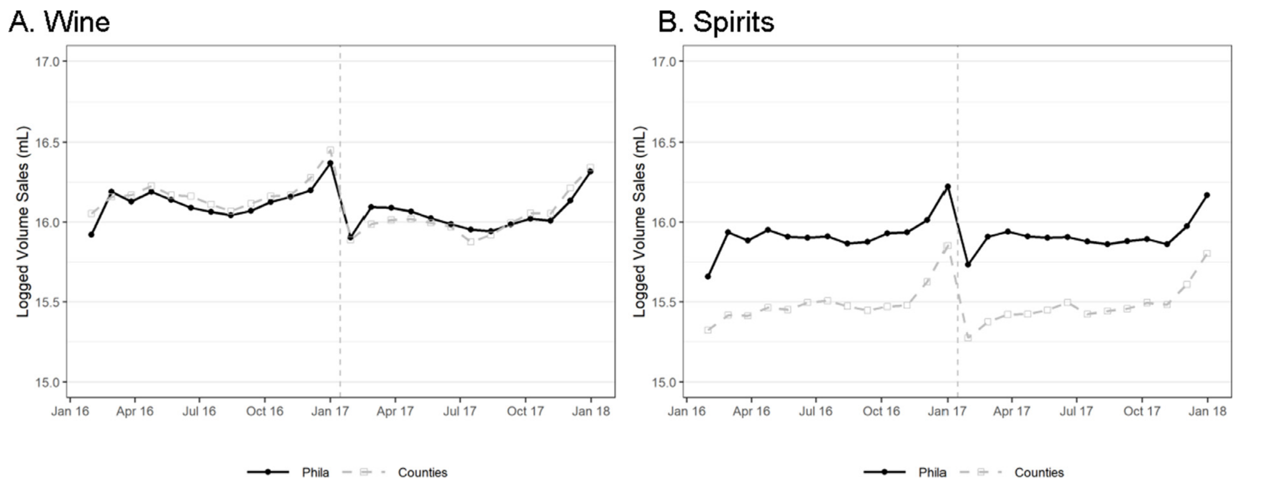

Figure 2. Mean alcohol volume sales per liquor store (logged mL) in 4-week periods 2016–2017.
Note: Wine and spirits are hypothesized to be substitutes for taxed sweetened beverages. Phila = treatment location, Counties = Pennsylvania nonborder ZIP codes (control location). Dashed vertical line indicates date of Phila beverage tax implementation, January 1, 2017. Phila, Philadelphia.

beverage concentrates, however, showed a significant 27% increase, compared with a nonsignificant 1% increase in dollar sales, though concentrates comprise only 12% of baseline Philadelphia beverage sales (15% at post). In addition, the volume sales triple DID showed a significant 36% increase in supermarket sales of beverage concentrates relative to other foods and a 20% increase in mass merchandizers (Appendix Table A7-1, available online). Follow-up volume sales triple DID analyses limiting beverage concentrates to more direct sweetened beverage replacements (i.e., fruit juice concentrates and mixes excluding coffees, teas, or milk mixes) showed similar increases in supermarket and mass merchandizer sales of these products (32% and 22%) (Appendix Table A7-2, available online).

Sensitivity analyses expanding the sample to include 9 additional food stores continuously open between 2016 and 2017 showed the same results (Appendix Table A8, available online). Sensitivity analyses comparing volume sales in Philadelphia stores to the alternate control (Pennsylvania nonborder ZIP codes) were the same for supermarkets (Appendix Table A9, available online). Pharmacies also showed a significant 28% increase in volume sales of beverage concentrates and a 2% increase in candy sales. The candy means show that this change is driven by larger decreases in Pennsylvania nonborder ZIP codes, not increases in Philadelphia, indicating it is not due to substitution.

Given the number of stores in each location, baseline combined liquor store sales were lower in Philadelphia ($167.6 million) than in Pennsylvania nonborder ZIP codes ($231.7 million). The alcohol DIDs for both volume and dollar sales showed no statistically significant changes in wine and spirits' sales after the tax at the mean liquor store in Philadelphia compared to nonborder stores (Table 2; Appendix Table A10, available online). Volume sales of wine decreased in both Philadelphia and nonborder liquor stores; however, Philadelphia's smaller decline resulted in a 5% relative increase in volume sales of wine, which was significant in sensitivity analyses including 6 additional stores open continuously between 2016 and 2017 (Appendix Table A11, available online). This 5% DID estimate is inconclusive evidence for substitution because changes in Pennsylvania's wine sales policies at the end of 2016 could also explain this relative increase. Suburban grocery stores may have obtained licenses to sell beer and wine sooner than Philadelphia grocery stores or suburban residents may have started buying wine from grocery stores sooner than Philadelphia residents. Both scenarios could cause confounding owing to differential reductions in wine sales at liquor stores losing business to supermarkets in the taxed and nontaxed locations.

DISCUSSION

Consistent with most simulation and experiment work,[23,24,26,27] there was no real-world evidence that the Philadelphia sweetened beverage tax was associated with increases in purchases of snacks or spirits across all store types at the population level. There was, however, evidence of substitution to beverage concentrates at supermarkets where volume sales increased by 27%, although they only represent 12% of baseline Philadelphia beverage sales. Prior research, using these same data, showed supermarkets increased taxed beverage prices the least (9%), but had the largest decrease in sweetened beverage volume sold (−59%) and declines in combined sales

Table 1. Mean Change in Volume Sales per Store 2016–2017 by Food Store Type

Product category	Philadelphia: Mean sales in logged gm 2016	Philadelphia: Mean sales in logged gm 2017	Philadelphia: Difference (95%CI)	Baltimore: Mean sales in logged gm 2016	Baltimore: Mean sales in logged gm 2017	Baltimore: Difference (95%CI)	DID estimate (95%CI)	Adjusted *p*-value
Supermarkets		*n*=26			*n*=13			
Snacks								
Candy	14.60	14.53	−0.06 (−0.10, −0.03)	14.49	14.51	0.02 (−0.02, 0.05)	**−0.08** (−0.13, −0.03)**	0.001
Sweet snacks	16.66	16.56	−0.10 (−0.13, −0.08)	16.42	16.41	−0.01 (−0.03, 0.01)	**−0.09** (−0.12, −0.06)**	<0.001
Salty snacks	16.07	15.98	−0.09 (−0.12, −0.06)	15.78	15.76	−0.02 (−0.03, −0.01)	**−0.07** (−0.10, −0.04)**	<0.001
Beverage concentrates	16.97	17.11	0.14 (0.06, 0.23)	16.90	16.81	−0.09 (−0.14, −0.05)	**0.24** (0.14, 0.33)**	<0.001
Control								
Other foods	18.69	18.60	−0.09 (−0.12, −0.06)	18.51	18.48	−0.02 (−0.03, −0.01)	**−0.07** (−0.10, −0.04)**	<0.001
Mass merchandizers		*n*=14			*n*=2			
Snacks								
Candy	15.45	15.38	−0.08 (−0.13, −0.02)	15.07	15.03	−0.04 (−0.10, 0.03)	−0.04 (−0.12, 0.05)	0.76
Sweet snacks	15.82	15.71	−0.11 (−0.19, −0.04)	15.13	15.11	−0.02 (−0.12, 0.08)	−0.09 (−0.21, 0.03)	0.43
Salty snacks	15.68	15.60	−0.08 (−0.14, −0.02)	15.35	15.33	−0.02 (−0.07, 0.03)	−0.06 (−0.14, 0.01)	0.43
Beverage concentrates	16.62	16.55	−0.07 (−0.22, 0.08)	15.91	15.68	−0.22 (−0.24, −0.20)	0.15 (0.00, 0.30)	0.28
Control								
Other foods	17.67	17.56	−0.12 (−0.19, −0.04)	17.33	17.25	−0.08 (−0.12, −0.04)	−0.04 (−0.12, 0.04)	0.76
Pharmacies		*n*=140			*n*=45			
Snacks								
Candy	13.54	13.53	−0.02 (−0.03, 0.00)	13.29	13.29	0.00 (−0.03, 0.02)	−0.01 (−0.04, 0.02)	0.73
Sweet snacks	12.87	12.78	−0.09 (−0.11, −0.07)	12.46	12.39	−0.06 (−0.10, −0.03)	−0.03 (−0.07, 0.01)	0.39
Salty snacks	13.00	12.97	−0.03 (−0.05, −0.02)	12.80	12.79	−0.01 (−0.03, 0.02)	−0.03 (−0.06, 0.00)	0.25
Beverage concentrates	12.89	12.97	0.08 (0.02, 0.14)	12.72	12.66	−0.06 (−0.16, 0.05)	0.14 (0.02, 0.26)	0.13
Control								
Other foods	13.68	13.62	−0.07 (−0.09, −0.05)	13.24	13.18	−0.06 (−0.10, −0.02)	−0.01 (−0.05, 0.04)	0.77

Note: Boldface indicates statistical significance (*$p<0.05$; **$p<0.01$). Natural logged volume sales (gm) difference for small changes ≤10% can be interpreted as percentage change for the product categories at the mean store (open continuously 2014–2017) from 2016 to 2017 at the mean 4-week period within location. DID estimate is the logged volume sales estimate of percentage change at the mean store in Philadelphia compared to Baltimore (positive estimates indicate substitution). Adjusted percentage change in beverage concentrate changes (exponentiated DID estimates) are 27% for supermarkets, 16% for mass merchandizers, and 15% for pharmacies. Other foods aggregates across 10 food categories such as baby food. Adjusted *p*-values are Bonferroni−Holm adjustments for the 5 food product categories within each store type.
DID, difference-in-differences.

Table 2. Mean Change in Volume Sales of Alcohol per Store 2016–2017 at State-Owned Liquor Stores

Product category	Philadelphia			PA nonborder ZIP codes				
	Mean sales in logged mL			Mean sales in logged mL				
	2016	2017 *n*=44	Difference (95%CI)	2016	2017 *n*=66	Difference (95%CI)	DID estimate (95%CI)	Adjusted *p*-value
Alcohol								
Wine	16.11	16.00	−0.11 (−0.14, −0.08)	16.15	16.00	−0.15 (−0.18, −0.12)	0.05 (0.00, 0.09)	0.06
Spirits	15.93	15.90	−0.03 (−0.05, −0.02)	15.46	15.44	−0.02 (−0.04, 0.00)	−0.02 (−0.05, 0.01)	0.31

Note: Natural logged volume sales (mL) difference for small changes ≤10% can be interpreted as percentage change for the product categories at the mean store (open continuously 2014–2017) from 2016 to 2017 at the mean 4-week period within location. DID estimate is the logged volume sales estimate of percentage change at the mean store in Philadelphia compared to Pennsylvania nonborder ZIP codes (positive estimates indicate substitution). Adjusted *p*-values are Bonferroni–Holm adjustments for the 2 alcohol product categories.
DID, difference-in-differences.

(−8%).[10] The significant declines in supermarket sales of snacks and control products reported here are consistent, suggesting some supermarket customers are shopping for groceries at stores outside Philadelphia to avoid the tax. Therefore, this study included an additional triple DID test of substitution effects that showed a 36% increase in supermarket volume sales of beverage concentrates relative to control products. This suggests supermarket shoppers who continued to buy products in Philadelphia bought more beverage concentrates, which they may be substituting for taxed beverages, relative to other foods. Although the authors previously found no evidence of substitution to beverage concentrates with dollar sales,[10] those analyses did not account for Philadelphia's overall decline in supermarket sales, and used a smaller sample of concentrates.

These results are particularly important because declines in taxed beverage sales appear larger in Philadelphia relative to other cities (perhaps because Philadelphia is poorer than other U.S. jurisdictions with beverage taxes, has a higher tax rate than most, and taxes artificially-sweetened drinks which limits drink substitution options).[17] Further, evaluations of the Philadelphia tax have not observed increases in nontaxed beverage sales,[10,17] although research examining substitution to high-calorie beverage subtypes is needed. Cost-effectiveness research suggests a 20% decline in sugary beverage intake could translate to reductions in BMI over 10 years among youth and adults,[30] assuming no substitution to similarly high calorie products. Therefore, the large declines in taxed beverage sales observed in Philadelphia in the absence of substitution to other high-calorie products might contribute to long-term health benefits. Policies should, however, address the potential for substitution to beverage concentrates. Future research is needed to further explore substitution effects at the individual level and in localities with consistent liquor laws.

Limitations

This study has several limitations, including only examining data at chain retail stores and not other retailers like independent stores and restaurants. Second, restrictive and changing liquor laws in Pennsylvania precluded examining substitution to beer and confounded wine analyses because beer and wine were not consistently available for sale in food stores. Third, changes in sales were at the store level and not the individual level, so testing for substitution effects among individuals who reduced their taxed beverage purchasing was not possible. Fourth, these data were at the subcategory level (e.g., potato chips), not the individual product level. Therefore, understanding whether people are purchasing more, but cheaper, food items, or stores are lowering prices, cannot be tested. Finally, the very small number of stores in low-income neighborhoods prevented analyses by neighborhood income level.

This study has a number of strengths. It provides some of the first data on behavioral responses to a beverage tax that might offset potential health gains from reduced purchases of sweetened beverages. A natural experiment design was used to examine a large data set of objectively measured food and beverage purchases from large chain retailers instead of relying on self-reported consumption measures, which are prone to measurement error. Baltimore is a strong comparison city because of similar demographic and purchasing patterns to Philadelphia; its lower absolute sales volumes were accounted for using logged outcomes to test percentage change. This research also improves upon other beverage tax studies that either lacked a control group or used a nearby control site likely influenced by the tax.

CONCLUSIONS

A key assumption of beverage tax policies is that they will reduce consumption of sweetened drinks, without substitution to other unhealthy foods, gradually leading to reductions in obesity risk, cardiovascular disease, and premature deaths.[30,31] This study is the first to test the unhealthy food substitution step of that pathway using real-world evidence. Encouragingly, and consistent with prior simulation work, there was no evidence that Philadelphia's decline in taxed beverage purchases is offset by increases in snacks or alcohol purchasing at the population level. Beverage excise taxes of at least 1.5 cents/ounce on sugar- and artificially-sweetened beverages may effectively reduce sweetened beverage purchases in large urban areas without leading to substitution with unhealthy snacks or spirits.

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LG and CR led the manuscript writing. CR, HL, SB, and LG conceptualized and designed the study. ML and JY contributed to study design and conducted statistical analyses. NM oversaw the statistical analyses. HL, CL, and SB provided feedback on drafts of the manuscript. All authors provided critical feedback on manuscript drafts.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2020.08.021.

REFERENCES

1. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev.* 2013;14(8):606–619. https://doi.org/10.1111/obr.12040.
2. Dong D, Bilger M, van Dam RM, Finkelstein EA. Consumption of specific foods and beverages and excess weight gain among children and adolescents. *Health Aff (Millwood).* 2015;34(11):1940–1948. https://doi.org/10.1377/hlthaff.2015.0434.
3. Malik VS, Willett WC, Hu FB. Sugar-sweetened beverages and BMI in children and adolescents: reanalyses of a meta-analysis. *Am J Clin Nutr.* 2009;89(1):438–439. ; author reply 439 https://doi.org/10.3945/ajcn.2008.26980.
4. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet.* 2001;357(9255):505–508. https://doi.org/10.1016/S0140-6736(00)04041-1.
5. Ebbeling CB, Feldman HA, Chomitz VR, et al. A randomized trial of sugar-sweetened beverages and adolescent body weight. *N Engl J Med.* 2012;367(15):1407–1416. https://doi.org/10.1056/NEJMoa1203388.
6. Silver LD, Ng SW, Ryan-Ibarra S, et al. Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: a before-and-after study. *PLOS Med.* 2017;14(4):e1002283. https://doi.org/10.1371/journal.pmed.1002283.
7. Falbe J, Rojas N, Grummon AH, Madsen KA. Higher retail prices of sugar-sweetened beverages 3 months after implementation of an excise tax in Berkeley, California. *Am J Public Health.* 2015;105(11):2194–2201. https://doi.org/10.2105/AJPH.2015.302881.
8. Cawley J, Frisvold D, Hill A, Jones D. Oakland's sugar-sweetened beverage tax: impacts on prices, purchases and consumption by adults and children. *Econ Hum Biol.* 2020;37:100865. https://doi.org/10.1016/j.ehb.2020.100865.
9. Cawley J, Frisvold D, Hill A, Jones D. The impact of the Philadelphia beverage tax on prices and product availability. *J Pol Anal Manage.* 2020;39(3):605–628. https://doi.org/10.1002/pam.22201.
10. Roberto CA, Lawman HG, LeVasseur MT, et al. 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. *JAMA.* 2019;321(18):1799–1810. https://doi.org/10.1001/jama.2019.4249.
11. Bollinger BK, Sexton S. Local excise taxes, sticky prices, and spillovers: evidence from Berkeley's soda tax. *SSRN Journal.* 2018 https://doi.org/10.2139/ssrn.3087966.
12. Colchero MA, Salgado JC, Unar-Munguía M, Molina M, Ng S, Rivera-Dommarco JA. Changes in prices after an excise tax to sweetened sugar beverages was implemented in Mexico: evidence from urban areas. *PLOS ONE.* 2015;10(12):e0144408. https://doi.org/10.1371/journal.pone.0144408.
13. Cawley J, Crain C, Frisvold D, Jones D. The Pass-Through of the Largest Tax on Sugar-Sweetened Beverages: the Case of Boulder, Colorado. NBER Work Pap Ser. Cambridge, MA: National Bureau of Economic Research. 2018;250250. https://doi.org/10.3386/w25050.
14. Rojas C, Wang EY. Do taxes for soda and sugary drinks work? Scanner data evidence from Berkeley and Washington. *SSRN Journal.* 2017 https://doi.org/10.2139/ssrn.3041989.
15. Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW. In Mexico, evidence of sustained consumer response two years after

implementing a sugar-sweetened beverage tax. *Health Aff (Millwood).* 2017;36(3):564–571. https://doi.org/10.1377/hlthaff.2016.1231.

16. Cawley J, Frisvold D, Hill A, Jones D. The impact of the Philadelphia beverage tax on purchases and consumption by adults and children. *J Health Econ.* 2019;67:102225. https://doi.org/10.1016/j.jhealeco.2019.102225.
17. Cawley J, Frisvold D, Jones D. *The Impact of Sugar-Sweetened Beverage Taxes on Purchases: Evidence From Four City-Level Taxes in the U.S. NBER Work Pap Ser. Cambridge, MA: National Bureau of Economic Research;*. 201926393. https://doi.org/10.3386/w26393.
18. Lee MM, Falbe J, Schillinger D, Basu S, McCulloch CE, Madsen KA. Sugar-sweetened beverage consumption 3 years after the Berkeley, California, sugar-sweetened beverage tax. *Am J Public Health.* 2019;109(4):637–639. https://doi.org/10.2105/AJPH.2019.304971.
19. Zhong Y, Auchincloss AH, Lee BK, Kanter GP. The short-term impacts of the Philadelphia beverage tax on beverage consumption. *Am J Prev Med.* 2018;55(1):26–34. https://doi.org/10.1016/j.amepre.2018.02.017.
20. Dunford EK, Popkin BM, Ng SW. Recent trends in junk food intake in U.S. children and adolescents, 2003−2016. *Am J Prev Med.* 2020;59(1):49–58. https://doi.org/10.1016/j.amepre.2020.01.023.
21. Compare Tax policies. Healthy food America. http://www.healthyfoodamerica.org/compare_tax_policies. Accessed May 20, 2020.
22. Quirmbach D, Cornelsen L, Jebb SA, Marteau T, Smith R. Effect of increasing the price of sugar-sweetened beverages on alcoholic beverage purchases: an economic analysis of sales data. *J Epidemiol Community Health.* 2018;72(4):324–330. https://doi.org/10.1136/jech-2017-209791.
23. Finkelstein EA, Zhen C, Bilger M, Nonnemaker J, Farooqui AM, Todd JE. Implications of a sugar-sweetened beverage (SSB) tax when substitutions to non-beverage items are considered. *J Health Econ.* 2013;32(1):219–239. https://doi.org/10.1016/j.jhealeco.2012.10.005.
24. Allcott H, Lockwood BB, Taubinsky D. Regressive sin taxes, with an application to the optimal soda tax. *Q J Econ.* 2019;134(3):1557–1626. https://doi.org/10.1093/qje/qjz017.
25. Colchero MA, Salgado JC, Unar-Munguía M, Hernández-Ávila M, Rivera-Dommarco JA. Price elasticity of the demand for sugar sweetened beverages and soft drinks in Mexico. *Econ Hum Biol.* 2015;19:129–137. https://doi.org/10.1016/j.ehb.2015.08.007.
26. Zhen C, Finkelstein EA, Nonnemaker J, Karns S, Todd JE. Predicting the effects of sugar-sweetened beverage taxes on food and beverage demand in a large demand system. *Am J Agric Econ.* 2014;96(1):1–25. https://doi.org/10.1093/ajae/aat049.
27. Waterlander WE, Ni Mhurchu C, Steenhuis IHM. Effects of a price increase on purchases of sugar sweetened beverages. Results from a randomized controlled trial. *Appetite.* 2014;78:32–39. https://doi.org/10.1016/j.appet.2014.03.012.
28. U.S. Census Bureau. QuickFacts. https://www.census.gov/quickfacts/philadelphiacountypennsylvania. Published 2017. Accessed February 15, 2019.
29. Wooldridge JM. Pooling cross sections across time: simple panel data methods. In: Wooldridge JM, editor. Introductory Econometrics: A Modern Approach. Nelson Education, 2016:448–483.
30. Long MW, Gortmaker SL, Ward ZJ, et al. Cost effectiveness of a sugar-sweetened beverage excise tax in the U.S. *Am J Prev Med.* 2015;49(1):112–123. https://doi.org/10.1016/j.amepre.2015.03.004.
31. Wang YC, Coxson P, Shen YM, Goldman L, Bibbins-Domingo K. A penny-per-ounce tax on sugar-sweetened beverages would cut health and cost burdens of diabetes. *Health Aff (Millwood).* 2012;31(1):199–207. https://doi.org/10.1377/hlthaff.2011.0410.