NBER WORKING PAPER SERIES

THE INCIDENCE OF TAXES ON SUGAR-SWEETENED BEVERAGES: THE CASE OF BERKELEY, CALIFORNIA

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Working Paper 21465
http://www.nber.org/papers/w21465

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2015

We thank Kenneth Couch and three anonymous referees for helpful comments. We thank our research assistants Natalie Veldhouse and Marcus Cassidy for collecting the price data from stores, and Barton Willage for data analysis. The authors thank the Department of Economics at the University of Iowa for financial support and Cawley thanks the Robert Wood Johnson Foundation for its support through an Investigator Award in Health Policy Research. We thank the following people for helpful comments and discussions: Ana Balsa, Kitt Carpenter, Jennifer Falbe, Kristine Madsen, Shu Wen Ng, Barry Popkin, Kyle Rozema, participants at the International Health Economics Association World Congress and Obesity Week, and seminar participants at Johns Hopkins University and the National University of Ireland Galway. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 21465
August 2015, Revised September 2016
JEL No. H2,H22,H71,I1,I12,I18

ABSTRACT

Obesity and diet-related chronic disease are increasing problems worldwide. In response, many governments have enacted or are considering taxes on energy-dense foods. Perhaps the most commonly-recommended policy is a tax on sugar-sweetened beverages (SSBs).

This paper estimates the extent to which a tax on SSBs is passed through to consumers in the form of higher prices. We examine the first city-level tax on SSBs in the U.S., which was enacted by the voters of Berkeley, California in November, 2014. We collected the prices of various brands and sizes of SSBs and other beverages before and after the implementation of the tax from a near-census of convenience stores and supermarkets in Berkeley, California. We also collected prices from stores in a control city: San Francisco, where in a similar voter referendum failed despite majority support.

Estimates from difference-in-differences models indicate that, across all brands and sizes of products examined, 43.1 percent (95 percent confidence interval: 27.7 percent - 58.4 percent) of the Berkeley tax was passed on to consumers. The estimates also are consistent with cross-border shopping. For each mile of distance between the store and the closest store selling untaxed SSBs, pass-through rose 33.3 percent for 2-liter bottles and 25.8 percent for 12-packs of 12-ounce cans.

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An online appendix is available at http://www.nber.org/data-appendix/w21465

INTRODUCTION

Worldwide, countries are struggling with the problems of obesity and diet-related chronic disease. A recent study of data from 186 countries estimated that, between 1975 and 2014, the worldwide prevalence of obesity rose from 3.2 percent to 10.8 percent for men and from 6.4 percent to 14.9 percent for women (NCD Risk Factor Collaboration, 2016). The prevalence is much higher in economically developed nations; for example, in the U.S., the prevalence of adult obesity is 37.7 percent as of 2013-2014 (Flegal et al., 2016).

More generally, diet-related chronic disease is a significant global problem. Worldwide, the annual deaths due to high blood pressure total 7.5 million, high blood glucose (diabetes) 3.4 million, overweight and obesity 2.8 million, and high cholesterol 2.6 million (WHO, 2009). For example, in Mexico, which has the highest per capita consumption of carbonated beverages in the world, the number one cause of death is diabetes. In the U.S., 37 percent of the adult population has cardiovascular disease, 16 percent has high total blood cholesterol, 34 percent has hypertension, and 11 percent has diabetes (USDA, 2010).

As a result of the rise in obesity and these high rates of chronic disease, there have been numerous calls to tax energy-dense (i.e. high-calorie), less-nutritious foods; see, e.g. World Health Organization (2015), U.S. Dietary Guidelines Advisory Committee (2015), British Medical Association (2015), Institute of Medicine (2009), International Obesity Task Force (2005), Brownell and Frieden (2009), Jacobson and Brownell (2000). Perhaps the most commonly-advocated policy is a tax on sugar-sweetened beverages (SSBs), which are high-calorie and low-nutrient. Consumption of SSBs does not invoke feelings of satiety, so people tend not to reduce the number of other calories consumed, resulting in an increase in calorie intake and contributing to overweight and obesity (Malik and Hu, 2011). In addition, SSBs have a high glycemic load (i.e. they significantly raise a person's blood sugar after consumption), which, independently of weight, contributes to insulin resistance and diabetes (Ibid). The Institute of Medicine, American Academy of Pediatrics, United Nations, and American Public Health Association, among others, have called for taxes on SSBs (Rudd Center, 2014).

Policymakers worldwide have responded to these calls for action. Numerous countries have recently levied taxes on SSBs, including Mexico (2014), France (2012), Finland (2011), Hungary (2011), Nauru (2007), Fiji (2006), and Australia (2000); see, for example, World Health Organization (2015), Sassi et al. (2013) and Thow et al. (2011). A majority of U.S. states tax soft drinks (Chriqui et al., 2014), but largely for revenue generation rather than for public health purposes; diet versions are taxed the same as caloric soft drinks (Fletcher, Frisvold, and Tefft, 2010b).[2] In early 2015, Berkeley, California became the first U.S. city to impose an excise tax on caloric (but not diet) SSBs with a tax of one cent per ounce (oz.). In 2016, Philadelphia passed a 1.5 cent/oz. tax on SSBs to take effect January 1, 2017, and several cities (including San Francisco, Oakland, and Albany, California) will have SSB taxes on the ballot in the November 2016 elections.

As illustrated in a recent Point-Counterpoint exchange in this journal, there is debate about the impact of SSB taxes on obesity (Fletcher, Frisvold, and Tefft, 2011a,b; Chaloupka, Powell, and Chriqui, 2011a,b). One important issue is the extent to which a tax on SSBs is passed on to consumers in the form of higher prices, the key mechanism by which the tax could affect consumption and ultimately health.[3] This paper contributes to the literature by estimating

[2] In the U.S. as of January 1, 2014, 34 states and the District of Columbia apply sales taxes to SSBs sold in stores (Chriqui et al., 2014). In 20 states, the sales tax on SSBs sold through food stores were higher than the sales tax on food generally.

[3] There is mixed evidence on the impact of SSB taxes on consumption and obesity, which may, in part, be due to differences in research design. For example, Fletcher, Frisvold, and Tefft (2010a, b, 2015) examine the reduced-form impact of taxes on consumption and obesity. These estimates imply that the taxes were at least partly shifted to consumers, but the pass-through rate was not directly estimated. In contrast, Dharmasena, Davis, and Capps Jr.

the extent to which taxes on SSBs are passed on to consumers in the form of higher prices, using data collected from the first city in the U.S. to enact a tax on caloric (but not diet) SSBs.

The incidence or shifting of excise and sales taxes is an important topic in public finance. Although policymakers and the media often emphasize the party on whom the tax is levied, economists have long recognized that in a perfectly competitive market who actually pays the tax is determined by the relative elasticities of supply and demand (for example, Fullerton and Metcalf, 2002; Kotlikoff and Summers, 1987). For example, if consumer demand is completely insensitive to price (i.e. demand is perfectly inelastic), then producers can fully pass on the tax to consumers without experiencing any decline in demand or sales; see Appendix Figure 1A.[4] At the other extreme, if demand is perfectly elastic, then producers do not pass on any of the tax to consumers because they would lose all of their sales; see Appendix Figure 1B. As an intermediate case, if demand is partially elastic (neither perfectly inelastic nor perfectly elastic) then the tax is paid partly by producers and partly by consumers, with the exact proportions determined by the relative elasticities of supply and demand; see Appendix Figure 1C. If the market is imperfectly competitive, due to strategic pricing, taxes could be undershifted, fully shifted, or even overshifted (i.e. the retail price could increase by an amount greater than the tax) (see, for example, Stern, 1987; Anderson, de Palma, and Kreider, 2001; Bonnet and Requillart, 2013).[5]

Previous empirical research on the pass-through of sales and excise taxes (in general, not just on SSBs) has tended to find that such taxes are fully shifted to consumers, or even

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(2014) estimate the price-elasticity of demand for SSBs but assume that a change in taxes is fully passed on to consumers through higher prices.

[4] All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

[5] For example, for a monopolist with a downward-sloping demand (and marginal revenue) curve, when a tax shifts its marginal cost curve upward, the monopolist may respond by reducing output (so that marginal revenue once again equals marginal cost) and raising prices. Because prices rise for two reasons (the shifting of the tax and the reduction in monopoly output), it is possible for the resulting change in price to exceed the tax.

overshifted (DeCicca et al., 2013; Alm et al., 2009; Kenkel, 2005; Besley and Rosen, 1999; Poterba, 1996). A smaller number of studies have found that taxes are less than fully shifted, in the range of 45 to 85 percent (Harris et al., 2015; Harding et al., 2012; Doyle and Samphantharak, 2008). These studies concern a wide variety of items, including clothing, cigarettes, and gasoline.

There are few studies of the pass-through of taxes on SSBs in particular. Three working papers estimate the pass-through of taxes on SSBs in Mexico, France, and Denmark. Grogger (2015) examines how retail prices responded to a nationwide one-peso-per-liter tax on SSBs that was implemented in Mexico in 2014. He examines data on prices from 46 cities that were used to calculate the Mexico Consumer Price Index; only city-level average prices were available. Lacking a geographic control group, Grogger (2015) estimates the change in prices within Mexico before and after the tax and concludes that the tax was overshifted; the tax of roughly 9 percent raised the price of caloric soda by 12 percent.

Berardi et al. (2012) estimate the impact of the French tax on soda of 7.16 euros per hectoliter (or roughly 11 euro cents per 1.5 liters) that took effect January 1, 2012. They use detailed data from 800 supermarkets that participated in a novel form of shopping in which customers order their groceries through the internet but then go in person to pick up their items; although fewer items may be available, they are sold at the same price as in the supermarket. They examine data from August 2011 to July 2012, using only the most frequently-observed price in each month for each product in each store. They estimate difference-in-differences models, estimating the change before and after the tax in the price of beverages subject to the tax and exempt from the tax. They find that, for soda, the tax was fully shifted to prices by the fourth month of the tax.

Bergman and Hansen (2012) estimate the pass-through that resulted from three tax changes to SSBs in Denmark: tax hikes in 1998 (of 0.2 DKK per liter) and 2001 (of 0.65 DKK per liter) and a tax cut in 2003 (of 0.50 DKK per liter). The authors examine micro price data at the item-chain level that are used by Statistics Denmark to create the Danish Consumer Price Index. Lacking a geographic control group, they estimate the change in prices over time in Denmark and estimate that both tax hikes were over-shifted to consumers; their estimates indicate a pass-through of at least 200 percent. The tax cut, however, was undershifted to consumers.

Although Besley and Rosen (1999) examine the shifting of sales taxes, not excise taxes on SSBs in particular, one of the 12 commodities they examined was a one-liter bottle of Coca-Cola. They estimate that sales taxes were overshifted for that item, which they interpret as consistent with imperfectly competitive retail grocery markets.

The most similar paper to ours is Falbe et al. (2015), which examines the pass-through of the Berkeley tax to retail prices. The authors examine the changes in prices of 20 oz. bottles in low-income, minority neighborhoods and conclude that the Berkeley tax was partially passed through to consumers. Our paper differs from theirs on several dimensions, including the econometric specification, data collected, timing of the data collection, and the breadth of the sample, as we further describe below.

A consistent finding from the previous literature is that the shifting of taxes to consumers happens quickly. Grogger (2015) finds that prices responded to the soda tax in the month that the tax took effect, Berardi et al. (2012) found that the French tax was fully shifted by the fourth month, Besley and Rosen (1999) find the shifting of sales taxes occurred by the next quarter (the frequency of their data), and Alm et al. (2009) find that gasoline excise taxes are shifted to consumers “almost instantly” (Ibid, p. 118).

We examine the first tax on caloric SSBs by a city in the United States. This tax, in Berkeley, California[6], is levied in the amount of one cent per ounce on sweetened beverages, which includes soda, energy drinks, and presweetened tea, but specifically excludes infant formula, alcoholic beverages and milk products.[7] The tax is levied on distributors.

The tax in Berkeley was passed by public referendum (it is sometimes still referred to as “Measure D” based on its placement on the ballot) on November 4, 2014. It passed with 76.17 percent voting yes after a bitter election campaign, with an estimated $2.5 million spent by soda manufacturers to defeat it, and an estimated $1 million spent by supporters (Dugdale, 2015).[8] Its passage was seen as a major victory for public health activists and a litmus test for future SSB taxes in other localities (Gagliardi, 2014; Abcarian, 2014). The tax was initially announced to take effect on January 1, 2015, but because of delays in implementation the first month that the tax was collected was March, 2015.

Based on prices before the tax took effect, the tax of one cent per ounce represents an average of an 11.0 percent tax on 20-oz. bottles, 30.8 percent tax on 2-liter bottles, and a 25.0 percent tax on a 12-pack of 12-oz. cans.[9] In percentage terms, the tax is smaller for 20 oz. bottles because of bulk discounts - SSBs are more expensive when bought in small quantities, so

[6] Berkeley, California is a city in Northern California, located northeast of San Francisco. Its population, which was 116,768 in 2013, is 59.5 percent white, 10.0 percent African-American, and 19.3 percent Asian, with 10.8 percent Hispanic or Latino (who could be of white or African-American race); see U.S. Census (2015a). Its area is 10.47 square miles (Ibid).

[7] The exact wording of the Berkeley ballot initiative was: Shall an ordinance imposing a 1¢ per ounce general tax on the distribution of high-calorie, sugary drinks (e.g., sodas, energy drinks, presweetened teas) and sweeteners used to sweeten such drinks, but exempting: (1) sweeteners (e.g., sugar, honey, syrups) typically used by consumers and distributed to grocery stores; (2) drinks and sweeteners distributed to very small retailers; (3) diet drinks, milk products, 100% juice, baby formula, alcohol, or drinks taken for medical reasons, be adopted?

[8] Former New York City mayor Michael Bloomberg spent $657,000 promoting Measure D in Berkeley, and also spent $10 million to promote the tax on SSBs that took effect in Mexico in 2014 (Dinkelspiel, 2014).

[9] Authors’ calculation based on December 2014 prices in Berkeley of regular (i.e. full calorie) Coke, Pepsi, and Mountain Dew in those sizes.

the flat one cent per ounce tax is a smaller percentage of the pretax price for a 20 oz. bottle than for larger quantities.

This paper offers numerous contributions to the literature. First, we provide information on the effects of the first SSB tax in the United States enacted for public health purposes rather than revenue generation; i.e. caloric SSBs are taxed while diet versions are exempt. Second, we collect longitudinal price data from a near-census of grocery stores, supermarkets, convenience stores, and pharmacies with posted prices in the treatment city. Many previous studies observe only average prices at the city level (e.g., Grogger, 2015; Besley and Rosen, 1999) or examine prices at a selected sample of stores within a city (Falbe et al., 2015), but there can be substantial variation in prices within markets (see the discussion in DeCicca et al., 2013). Having a near-census of stores ensures that we are accurately measuring the changes in prices. Third, we collected data for a nearby and similar control city, which allows us to control for any shocks to SSB prices in that vicinity around the time of the tax. This is a contribution because the previous literature on the pass-through of excise taxes on SSBs (with the exception of Falbe et al., 2015) has lacked a geographic control group. A particular strength of our approach is that our control community also gave majority support to an SSB tax, yet it did not pass because a supermajority was required. Fourth, we examine perfectly homogenous products, at the level of brand-item-size; thus, we avoid any variation in prices that could be due to differences in brand, quality, size, or other characteristics. Fifth, we estimate the pass-through separately for several sizes and quantities of SSBs. The previous study of the Berkeley tax (Falbe et al., 2015) examined only 20-oz. bottles; we also examine 2-liter bottles and cases of 12-oz. cans. Examining a variety of sizes is important because pass-through rates may vary by size or quantity (DeCicca et al., 2013).

DATA

We collected data in person, by hand, on the price of SSBs for the near-universe of stores in Berkeley and a random sample of stores in San Francisco, once prior to the Berkeley tax, and once after the Berkeley tax took effect. Data were collected from the same stores and for the same products in both waves. We collected data from the range of stores (both chain and independent) that sell SSBs: supermarkets, grocery stores, pharmacies, and convenience stores, and gas stations. The list of such stores was drawn from ReferenceUSA, which is a database of approximately 24 million U.S. businesses that is updated monthly. We attempted to collect data from the universe of such establishments in Berkeley and a randomly-selected sample of those in San Francisco.[10]

Prior to the tax taking effect, we collected data once from each store in Berkeley on December 22, 2014 and from each store in San Francisco between December 21 and 27, 2014. After the tax took effect, we collected data once from each store in Berkeley on June 1, 2015 and from each store in San Francisco between May 31 and June 3, 2015.[11]

The products and sizes chosen were those that are most commonly sold and consumed among different types of SSBs (Sierra Services, Inc., 2011); this was to ensure that we chose

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[10] More specifically, we created a list of all grocery stores, pharmacies, convenience stores, and gas stations with SIC codes 514105, 514110, 541103, 541105, 541107, 541108, 541109, 549948, 554101, and 591205 in Berkeley (zip codes: 94702, 94703, and 94704), San Francisco (zip codes: 94102, 94103, 94104, 94105, 94107, 94108, 94109, 94110, 94111, 94112, 94114, 94115, 94116 , 94117, 94118, 94121, 94122, 94123, 94124, 94127, 94129, 94130, 94131, 94132, 94133, 94134, and 94158). In Berkeley, 81 stores met these criteria. Of these listings, 22 were pharmacies and gas stations that did not sell soft drink products, 3 only sold specialty soft drinks, 3 were duplicate locations, 5 were closed locations, and 18 did not list prices on the items. This left 30 stores with at least one price for the products in our data collection in December and June. We randomly selected 123 stores from the San Francisco population, of which 23 did not sell soft drink products, 2 were duplicate locations, 7 were closed locations, and 26 did not list prices on the items. This left 56 stores with at least one price for the products in our data collection in December and June. Stores in San Francisco were randomly selected using the random number generator in Excel.

[11] Under the assumption that the tax would be implemented on January 1, 2015, as stated in the law, we also collected a round of data January 11-14, 2015. However, Berkeley revised its timetable and announced in January that the first month for which SSB distribution would be taxed would be March 2015. Because the January data are neither clearly pre-tax nor post-tax (distributors were unsure at the time whether taxes would actually be collected), we dropped the January wave of data from our analysis.

items for which there would be many store-level observations of prices and because these are of the greatest policy interest given that they are the ones consumers most often buy and consume. As a result, we collected prices for the following products: 20 oz. bottles, 2-liter bottles, and 12-packs of 12-oz. cans of Coke, Pepsi, and Mountain Dew; 20 oz. bottles of Gatorade; 8.4 oz. cans and 4 packs of 8.4 oz. cans of Red Bull; and 16 oz. bottle of Snapple Iced Tea.

The Berkeley SSB tax is levied on distributors, and their distributions to stores with less than $100,000 annual receipts are exempt from the tax. Based on the revenue data available in the ReferenceUSA database, no stores in our sample are exempt. Further, discussions with advocates of the tax confirmed that *no* stores in Berkeley qualified for the exemption, and that the threshold was specifically chosen to ensure that no stores would be exempt. Thus, we assume that all of the stores from which we collected data were subject to the tax.

In Berkeley, there are 30 stores for which we have prices both before and after the tax for at least one product, and in San Francisco, there are 56 stores for which we have such data. [12] However, not every product was available in every store, so the sample size varies by product size. For example, for a 20 oz. bottle of Coke, we have data for 24 stores in Berkeley both before and after the tax, as well as from 45 stores in San Francisco. The item carried by the fewest stores was 4-packs of Red Bull, which was available in 13 stores in Berkeley and 17 stores in San Francisco. Sample sizes by product and city are listed in Table 1.

METHODS

[12] A subset of stores (18 in Berkeley and 26 in San Francisco) did not have posted prices and we thus lack data for these. Comparing data from ReferenceUSA, the stores that did not post prices were much smaller, with significantly fewer employees (3.8 versus 29.7 in Berkeley) and less than one-quarter the revenue. To put our lack of data for these stores into perspective, low-income households buy the vast majority (78 percent) of their groceries at larger grocery stores and supermarkets (Alcott et al., 2015). Thus, our data for larger stores still reflect the prices paid in most (but not all) cases by lower-income individuals.

Difference-in-Differences (DD) Model: Berkeley compared to San Francisco

To identify the effect of the tax on prices, one must make an assumption about the counterfactual: i.e. how would prices have changed in the absence of the tax? We assume that the prices of a given item in Berkeley would have, in the absence of the tax, followed the trend in price of the same item in San Francisco.

Specifically, we estimate a difference-in-differences (DD) model to measure the relative change in price for each product after the implementation of the tax compared to before the tax, in the treatment city (Berkeley) compared to the control city (San Francisco):

$$\mathrm{P}_{st} = \alpha + \beta_{DD}\mathrm{Post}_t{*}\mathrm{Treat}_s + \beta_t\mathrm{Post}_t + \beta_s\mathrm{Store}_s + \beta_{day}\mathrm{Day} + \varepsilon_{st} \quad (1)$$

where P_{st} denotes the price per ounce of the product in store *s* and time *t*. Our coefficient of interest is the difference-in-differences estimator β_{DD}; it is the coefficient on the interaction term *Post*Treat*, which equals one if the store was in Berkeley (as opposed to San Francisco) and if the price was measured after the tax was implemented. This measures the effect of the tax on prices after controlling for the general time trend in prices for that product. The indicator variable *Post* equals one if the price is from after the tax as opposed to before the tax; this controls for any time trend or seasonality in prices common to Berkeley and San Francisco. The term *Store* represents a vector of indicator variables that control for any time-invariant heterogeneity associated with each store that could be related to differences in management or the willingness or ability to pay of customers. We also control for indicator variables for the day of the week.

Models are primarily estimated separately by product (Coke, Pepsi, Mountain Dew, Gatorade, Red Bull, and Snapple Iced Tea) and by size. For Coke, Pepsi, and Mountain Dew, the sizes are: 20 oz. bottle, 2 liter bottle, and a 12 pack of 12 oz. cans. For Red Bull, the sizes are: 8.4 oz. can and a four-pack of such cans. For Snapple Iced Tea, the size is a 16 oz. bottle.

In additional specifications, we seek further statistical power by pooling observations. Specifically, we pool observations for: 1) Coke, all sizes; 2) Pepsi, all sizes; 3) 20-oz. bottles, all brands; 4) 2-liter bottles, all brands; 5) 12-packs of 12-oz cans, all brands; 6) all sizes of all brands. These models are similar to equation (1) except that we include additional indicator variables for size and brand when relevant.

We assume that, had the tax not been implemented in Berkeley, prices in Berkeley would have followed the same trend as those in San Francisco. San Francisco is a reasonable control city for Berkeley for the following reasons: it is geographically proximate (less than 15 miles away), but does not share a boundary, which minimizes cross-market spillovers, and it is culturally and politically similar. The cities differ in that a higher percentage of the Berkeley population is white (59.5 percent versus 48.5 percent) and has a bachelor's degree (69.7 percent versus 52.4 percent), and Berkeley has a lower per capita income ($41,308 versus $48,486) and higher poverty rate (18.7% percent versus 13.5 percent); see U.S. Census (2015a, 2015b).

In many applications of difference-in-differences, there is concern about policy endogeneity. That is, the fact that the treatment jurisdiction passed the law while the control jurisdiction did not may reflect differences between the jurisdictions that bias the DD estimates. We have an unusually well-matched control city from the perspective of policy endogeneity. Both our treatment community of Berkeley and our control community of San Francisco had an SSB tax on its November, 2014 ballot. Importantly, the initiative in both cities won majority support from voters. However, the SSB tax did not pass in San Francisco; although 55.6 percent of those who cast ballots voted in favor, it needed two-thirds of the vote to pass.[13] In fact, the

[13] The reason that the San Francisco ballot initiative needed two-thirds of the vote to pass, whereas that for Berkeley needed only a simple majority, is that the San Francisco initiative stated that tax revenues would be dedicated to a special fund, whereas those from Berkeley would only go to the city's general fund (Dinkelspiel, 2014). However, Berkeley plans to appropriate amounts equal to the tax revenue to fund related public health goals (Dugdale, 2015).

proposed tax in San Francisco was twice as large as that in Berkeley (two cents rather than one cent per ounce) yet it still got majority support. A strength of our approach is that the treatment and control cities each have majorities supporting the policy being evaluated; as such, the match between treatment and controls should be particularly close with fewer problems of policy endogeneity than many applications of the DD model.

Number of Clusters, and Standard Errors

An important issue is that we have only two clusters (Berkeley and San Francisco), for one time period before and one time period after the policy; this has been called the two-by-two case of clustering (see, e.g., Donald and Lang, 2007). Cameron and Miller (2015) demonstrate that standard errors that do not account for this clustering can overstate precision unless the within-cluster correlation of errors is solely driven by a common shock process, which would be picked up by our store-level fixed effects. In the two-by-two case, clustering can lead to degenerate standard errors (Donald and Lang, 2007; Cameron and Miller, 2015). This is in fact what happens when we cluster standard errors by city or use the wild cluster bootstrap recommended by Cameron and Miller (2015): we find implausibly small standard errors (close to zero) and p values (of zero). We cluster standard errors by store in each of our models but acknowledge that these likely underestimate the true standard errors.

To put our limited number of clusters into context, three previous studies of the pass-through of taxes on SSBs (Grogger, 2015; Berardi et al., 2012; Bergman and Hansen, 2012), as well as some studies of the pass-through of taxes on other goods (e.g., Kenkel, 2005), had only one cluster – data for the treated country or state, with no geographic control. Despite the serious limitations of having only two clusters, it represents an improvement relative to the existing literature.

Sampling error is reduced because: 1) we have not sampled one of many treated cities, but instead have data for the *only* city treated by this policy to date.[14] Moreover, what happened in that one city is of great interest because it is viewed as a litmus test for soda taxes in other jurisdictions. 2) Within that treatment city we have data for a near-census of supermarkets, grocery stores, and convenience stores with posted prices, so we have unusually good data for stores that were treated by this policy. Still, we acknowledge the limitations of our standard errors that arise from having two-by-two clusters.

EMPIRICAL RESULTS

Summary Statistics

Table 1 lists the mean price in cents for each product and size, for each city (Berkeley and San Francisco) and time period (December which is pre-tax, and June which is post-tax). If there was 100 percent pass-through of the tax, and no other shocks to prices, one would expect the price of taxed items to rise by one cent per ounce (e.g., by 20 cents for a 20 oz. bottle). In Berkeley, the price of a 20-oz. bottle of Coke rose 8.3 cents, a 20-oz. bottle of Pepsi rose 10.3 cents, and a 20-oz. bottle of Mountain Dew rose 11.25 cents. However, these items may have risen in price even in the absence of the tax; for example, in San Francisco those same three items rose 0.2 cents, 2.4 cents, and 3.5 cents over that same period.

Also, it should be noted that prices vary considerably within cities in each time period. For example, in December 2014 in Berkeley, the average price of a 2-liter of Coke was $2.15, but the standard error was 5 cents and prices ranged from $1.66 to $2.49. A range in price of 50 percent may be surprising because it is a perfectly homogenous good and within a single city.

[14] Our control city, on the other hand, is just one of many possible control cities, although it is an unusually good match in that its populace gave majority vote to the same policy at the same time as that in the treatment city.

The variance in price may reflect differing retail costs by neighborhood or differing elasticities of demand for each store's shoppers. It is also consistent with imperfect information, costly search, and difficulties to arbitrage. The range in prices is relevant because previous studies often used a city average in each time period that may have been based on a varying set of stores, and changes in the sample of stores may have biased their estimates of pass-through.

In the online appendix, we show the basic, unconditional patterns in the data that illustrate the components of the DD model.[15] Appendix Figures 2A through 2F display the price per ounce for Coke and Pepsi of different sizes: 20 oz. bottles (Appendix Figures 2A and 2B), 2-liter bottles (Appendix Figures 2C and 2D), and 12-packs of 12 oz. cans (Appendix Figures 2E and 2F), in Berkeley and San Francisco in both December (before the Berkeley tax) and June (after the Berkeley tax was implemented). For each product and each size, the price per ounce in Berkeley rises after the tax, but by less than the full 1 cent per ounce of the tax. However, some of this may be due to general inflation or area-specific shocks to prices other than the tax. In some cases the prices of the same items in San Francisco show a small increase, but in many cases the price change in San Francisco during this time is quite small. These unconditional graphical comparisons provide an unconditional difference-in-differences estimate; they suggest that prices rose by less than the amount of the tax; in other words, that the tax was only partially passed through to consumers in the form of higher prices.

Estimates from the Difference-in-Difference (DD) Model

In order to estimate the relative change in price for the products after the implementation of the tax compared to before the tax, in the treatment city compared to the control city, we estimate our difference-in-differences model, equation (1). If the tax was 100 percent passed

[15] All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

through to consumers, then prices for caloric drinks would rise one cent per ounce in Berkeley compared to San Francisco.

Table 2 presents the results of the DD model. Because the outcome we examine is the price in cents per ounce, and the tax was one cent per ounce, it is straightforward to interpret the fraction of a cent that prices rose due to the tax as the percent pass-through. In Berkeley relative to San Francisco, the price of a 20 oz. bottle of Coke rose 0.411 cents per ounce, for a pass-through rate of 41.1 percent. The pass-through rate of a two-liter of Coke was 33.8 percent. Both of these estimates are significantly different from zero at the 5 percent level. The pass-through estimate of a 12-pack of cans of Coke is 13.7 percent, which is not statistically significantly different from zero. For all sizes of Coke pooled together, the pass-through rate is 38.6 percent, which is statistically significant. The 95 percent confidence intervals are shown in Table 2 below the standard errors, and these exclude 1.0 for all sizes of Coke and other products. In other words, the confidence intervals rule out full pass-through of the tax.

Subsequent rows of Table 2 provide estimates of pass-through for other products and sizes. For Pepsi, the pass-through of the tax was 45.8 percent for 20 oz. bottles, 45.6 percent for two-liter bottles, and 32.3 percent for 12-packs of 12 oz. cans. For all sizes pooled, the pass-through on Pepsi products was 41.8 percent. Each of these estimated pass-through rates for Pepsi is statistically significant, and in each case the confidence intervals rule out 100 percent pass-through.

For Mountain Dew, the pass-through of the tax was 44.3 percent on 20 oz. bottles, 50.6 percent on two-liter bottles, and 43.3 percent on 12-packs of 12 oz. cans. For all sizes pooled, the pass-through on Mountain Dew products was 45.3 percent. Each of the estimated pass-through rates for Mountain Dew is statistically significant, and in each case the confidence intervals rule out 100 percent pass-through.

We have data for 20 oz. bottles of Gatorade; we estimate that 43.7 percent of the tax was passed through to consumers for that item.[16]

In the final row of Table 2, we present estimates for the pass-through rate when we pool all of the products at a given size. Across the four brands for which we have data on 20 oz. bottles, the pass-through rate was 45.0 percent. For the three brands for which we have data on two-liter bottles, the pass-through rate averaged 43.6 percent. For the three brands for which we have data on 12-packs of 12-oz. cans, the pass-through rate averaged 33.0 percent. Across all sizes of all brands, the pass-through rate averaged 43.1 percent; we use this as the estimate of the overall pass-through rate of the tax, given that it is based on data from all brands and sizes. Each of these estimates is statistically significant and the confidence intervals rule out 100 percent pass-through of the tax. Figure 1 portrays these pass-through estimates for Coke, Pepsi, and all products pooled, for 20 oz. bottles, 2-liter bottles, 12-packs of 12 oz. cans, and for all sizes.

Cross-Border Shopping: The Role of Distance to Competing Stores Not Subject to the Tax

We find that Berkeley's tax on SSBs was passed through to consumers at a lower rate than SSB taxes at the national level (Grogger, 2015; Berardi et al., 2012; Bergman and Hansen, 2012). Although there are numerous differences in methods that could explain that difference (such as the lack of a control group in the national studies), one possible explanation is the ability to evade a city-level tax by cross-border shopping; this possibility would make the demand curve in Berkeley more elastic.

[16] In the online appendix, in Appendix Table 1, we present results for products that came in different sizes than those in Table 2: Red Bull in 8.4 oz. bottles and four-packs of such bottles and Snapple Iced Tea in 16 oz. bottles. In each of these cases, the pass-through rate is imprecisely estimated and not statistically significant. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

Berkeley is just 10.5 square miles (U.S. Census Bureau, 2015), and thus the tax may be relatively easy to avoid. In the U.S., the mean distance traveled to shop for groceries is 5.2 miles; even households that do not own cars travel a mean of 2.5 miles one way (Alcott et al., 2015). In light of this, Berkeley retailers may have shifted less of the tax to consumers, fearing loss of sales.

Previous research has found cross-border shopping in response to food taxes in the District of Columbia and even at the state level for West Virginia (e.g. Tosun and Skidmore, 2007; Fisher, 1980). There is even evidence of cross-border shopping in response to food taxes at the level of small nations. Denmark's tax on foods high in saturated fat was repealed in 2012 after Danish grocers complained that they were losing business due to consumers crossing borders into Germany and Sweden to buy these items (Strom, 2012).

Our store-level data allow us to examine this possibility more closely. We extracted from the ReferenceUSA database the addresses of stores in towns that adjoin Berkeley, and we then used ArcGIS to estimate the shortest straight line distance to the closest store outside of Berkeley (where SSBs would be untaxed), for each store within Berkeley. The mean distance to the closest store outside of Berkeley is 5,442 feet (1.03 miles), with a standard deviation of 1,879 feet. Appendix Figure 3 is a histogram showing the distribution of distances to the closest stores where SSBs are untaxed.[17] The mean distance to the closest store outside of Berkeley is just 20 percent of the average distance that shoppers in the US travel for groceries (Alcott et al., 2015). Further, as shown in the figure, the distance to the closest store outside of Berkeley for all stores is less than the average distance that all shoppers and low-income shoppers travel for groceries.

[17] All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

We depict the relationship between pass-through rates and the distance to rival stores visually in Figures 2A and 2B. Rather than present an exhaustive set of figures for every product and size, we use the example of 20 oz. bottles of Coke (Figure 2A), and 20 oz. bottles of Pepsi (Figure 2B). Each of the figures shows the locations of stores within Berkeley (circles) and the locations of stores in nearby communities where SSBs were untaxed (dots). The lack of stores to the immediate west is due to the bay, and to the immediate east is due to parkland. There are a substantial number of stores just over the northern and southern city limits of Berkeley, however, which suggests that stores near to the city border may experience consumer demand that is relatively elastic, limiting their ability to pass the tax onto consumers in the form of higher prices.

The circles that represent stores within Berkeley are shaded by the amount the price of that product rose after the tax. Thus, it is not an exact estimate of pass-through (for that, one would subtract off the change in price experienced in San Francisco), but it provides an approximate measure. A white/clear circle indicates that the price rose by 1 cent or more per ounce, a grey circle means that the price rose by more than zero but less than 1 cent per ounce, and a dark circle indicates that the price did not rise at all (zero or negative change in price). If the pass-through rate was strongly determined by distance to rival stores, stores in the center of Berkeley would exhibit high pass-through, and stores close to the border would exhibit little pass-through. Although the stores where prices rose by 1 cent per ounce or more are generally not near the city border, the maps indicate that there is considerable variation in pass-through rates even for stores in very close proximity.

To more formally test whether distance to untaxed stores affects pass-through rates, we estimate modified versions of equation (1) that omit the store fixed effect and control for distance (in miles) to the nearest store outside of Berkeley, and that distance interacted with *Post*Treat*; the coefficient on the latter will be informative about whether the effect of the tax on prices varies by the distance from the store to rival stores where the SSBs were untaxed.

The results are presented in Table 3. To be concise, we report only the coefficients on the main effect of the treatment (*Post*Treat* in equation 1), and its interaction with distance to the nearest store outside of Berkeley. The results contain some evidence that the pass-through of the tax is higher the further the store is from rival stores that are not subject to the tax. In general, the interaction of distance and the DD term is not statistically significant in the regressions at the level of product and size, but when we estimate size-level regressions for all products pooled, we find that pass-through rate is significantly higher for stores further from untaxed stores (see the final row of the first page of Table 3). Interestingly, this result is only found for 2-liter bottles and 12-packs of 12 oz. bottles, which are the larger items one would expect consumers to buy during regular shopping trips that may be more likely to involve driving or crossing borders. Specifically, the results indicate that for each mile of distance from the closest rival store selling untaxed SSBs, pass-through rises 33.3 percent for 2-liter bottles and 25.8 percent for 12-packs of 12-oz. cans. The pass-through rate of the tax does not vary with distance for 20 oz. bottles, which are more likely to be intended for immediate consumption and are unlikely to be worth a cross-border shopping trip in isolation.

Robustness Checks

We conduct a variety of robustness checks; the results are presented in Table 4. For simplicity, we omit results for each brand separately and instead report results for each size (with all brands pooled) as well as all sizes (and all brands pooled). For ease of comparison, we conduct robustness checks for the original model (equation 1) without the interaction with distance to the nearest untaxed store, and we reprint the original results from Table 2 in the first row of Table 4.

One possibility is that supermarkets and convenience stores pass through the tax to a different extent; in other words, perhaps soft drinks are a loss leader in one but not the other. To investigate this possibility, we re-estimate our DD models using only the data for convenience stores (there are not enough supermarkets in Berkeley to estimate the model separately for them). The results, in row 2 of Table 4, are very similar to those for the entire sample of stores. Specifically, each of the estimates implies a pass-through rate of less than 50 percent, and each of the confidence intervals rules out full pass-through of the tax.

Another possibility is that chain stores (whether convenience stores or supermarkets) pass through the tax differently than independent stores. The ReferenceUSA data indicate whether each store is part of a chain or independent. There are very few independent stores in our sample, so we cannot estimate models separately for them, but we are able to estimate models for chain stores only. The results, shown in row 3 of Table 4, are very similar to those for the entire sample of stores.

We also collected data on whether each of these items was listed as "on sale" at each store. We did not control for this in the main model because we are interested in the transaction price for the product, not whether it is framed as a regular or sale price. However, temporary sales could occur at different times in Berkeley and San Francisco, or for diet and regular versions, so we also estimated models that control for an indicator variable for whether the item was listed on sale. The results, listed in row 4 of Table 4, are very similar to those of the original DD model.

We also re-estimate each of the models without clustering standard errors by store. The standard errors without clustering are in some cases larger, and in other cases smaller, than those with clustering by store. In all cases, however, the 95% confidence intervals easily rule out full pass-through of the tax.

In summary, our main findings, which are that less than half of the Berkeley tax on SSBs was passed through to consumers in the form of higher prices and that confidence intervals rule out full pass-through of the tax, are robust to a wide variety of robustness checks.

DISCUSSION

This paper estimates the extent to which the first city-level tax on sugar-sweetened beverages in the United States was passed on to consumers in the form of higher prices. We consistently find that, on average, less than half of the tax was passed on to consumers in the form of higher prices. Averaging across four brands and three sizes, our DD models indicate that 43.1 percent of the tax was passed through to consumers. Our findings are consistent with journalists' anecdotal reports of incomplete pass-through by certain stores in Berkeley (see, e.g., Johnson, 2015; Barnidge, 2015).

A natural comparison for our results are those of Falbe et al. (2015). They estimate that the pass-through of the Berkeley tax to the retail price of soda, using San Francisco and Oakland as control communities (akin to our DD model), was 47 percent for all SSBs.[18] This is extremely similar to our estimate of 43.1 percent pass-through. Based on the 95 percent confidence intervals around their estimate and ours, both studies rule out full pass-through of the tax.

[18] See Falbe et al. (2015), Table 3, row for Overall SSBs.

Despite the small difference in point estimates, there are important differences in samples and methods between this study and Falbe et al. (2015). Their sample of stores was primarily drawn from neighborhoods in Berkeley that were low income and had a high percentage of minority residents. In contrast, we have data from the universe of convenience stores, grocery stores, and supermarkets with posted prices in Berkeley. Their sample includes liquor stores and stores that did not post prices for soft drinks, whereas ours does not. We collected data for multiple sizes of SSBs; they collected data only for 20 oz. bottles, but when that was not available, they collected the price of another size. Our methods also differ; our model controls for store fixed effects, the day of the week, and the size of the product, whereas theirs do not (they examine the change in price per ounce for beverages of varying size without controlling for the size of the product). Despite these differences, both studies provide important information, given that they are based on independently-collected samples and provide information on the only tax in the U.S. imposed on caloric drinks for public health purposes. It is also useful to have confirmation in both studies that the pass-through of the tax was partial, and that full pass-through can be ruled out for numerous products and models.

Our estimates are much lower than those from previous studies of the pass-through of nationwide taxes on SSBs in other countries (Grogger, 2015; Berardi et al., 2012; Bergman et al., 2010). Our estimates are also lower than most of the studies of the pass-through of taxes on other products in the U.S. such as cigarettes (DeCicca et al., 2013), alcohol (Kenkel, 2005), food (Besley and Rosen, 1999), and clothing (Poterba, 1996); these studies tended to find that taxes are fully shifted, or even overshifted, to consumer prices. Our results are more consistent with the subset of studies that found incomplete pass-through of taxes (ranging from 45 percent to 85 percent) on items such as tobacco and gasoline (e.g., Harris et al., 2015; Harding et al., 2012; Doyle and Samphantharak, 2008).[19]

One likely explanation for this lower rate of pass-through is the ability of consumers to evade the tax by crossing borders to buy their SSBs. Cross-border shopping to evade taxes on food was previously observed in the District of Columbia (Fisher, 1980), West Virginia (Tosun and Skidmore, 2007), and Denmark. This option would make consumer demand more elastic, leading stores to pass on less of the tax to retail prices. Consistent with this, we find evidence that stores in Berkeley that are further from stores not subject to the tax shift more of the tax to consumers; this is true only for larger sizes (2-liter bottles and 12-packs of 12 oz. cans), not for individual servings (20 oz. bottles), which is consistent with fixed costs to cross-border shopping. For each mile of distance from the closest rival store selling untaxed SSBs, pass-through rises 33.3 percent for 2-liter bottles and 25.8 percent for 12-packs of 12-oz. cans. Cross-border shopping implies that the deadweight loss of the Berkeley tax is less than otherwise; on the other hand, it also implies that the public health benefits of the tax are less: purchases may be simply moving from Berkeley to neighboring jurisdictions. Given cross-border shopping, taxes passed at the city level may be less effective at changing prices and consumption than taxes at higher levels of government that are harder to avoid through cross-border shopping. The previous literature on tax pass-through studied taxes at the level of the nation (e.g., Grogger, 2015; Berardi et al., 2012; Bergman et al., 2010) or U.S. state (e.g., DeCicca et al., 2013; Kenkel,

[19] Research in the empirical industrial organization and international trade literatures consistently find that upstream cost changes are imperfectly passed-through to retail prices. For example, Nakamura and Zerom (2010) estimate a pass-through rate of 0.30 in the coffee market. Potential explanations for the less than complete pass-through include market power, nominal price rigidities, long-term contracts, nonlinear pricing, consumer search behavior, and strategic markup adjustments along the supply distribution chain (Nakamura and Zerom, 2010; Bonnet et al., 2013; Richards et al., 2014).

2005; Besley and Rosen, 1999), so that may in part explain why we find lower rates of pass-through.

It is possible that stores in Berkeley were still in the process of adjusting their prices in June and that menu costs, customer antagonism, or general price stickiness could explain the low pass-through of the tax (Anderson and Simester, 2010; Nakamura and Zerom, 2010). However, previous studies have tended to find that similar taxes are passed through almost instantly, i.e. within a quarter, a month, or less (Grogger, 2015; Alm et al., 2009; Besley and Rosen, 1999). Our June data were collected more than three months after the tax took effect. It is possible that pass-through takes longer for a new tax than for an increase in an existing tax, but previous research on new SSB taxes finds that even new taxes are quickly passed through (e.g., Bergman and Hansen, 2012; Berardi et al., 2012; Grogger, 2015). For example, Berardi et al. (2012) found that the French tax on SSBs was 93 percent shifted to prices in the third month, and fully shifted in the fourth month, after implementation. Initially, the Berkeley tax was scheduled to be implemented on January 1. But, after initial confusion about the details of the tax and its collection, the effective date of the tax was delayed until March 1. The amount of revenue initially collected was well-advertised and our June data are three months after this revised date of implementation. Thus, it seems unlikely that distributors and retail stores are unaware of the tax or that delays in implementation or price stickiness explains the lack of pass-through in Berkeley.

The results from the robustness checks in Table 4 that the estimates are similar for different store types (particularly, convenience stores and chain stores) suggests that a loss-leader model of retail markups (Chevalier, Kashyap, and Rossi, 2003) is not the primary explanation for partial pass-through, since different store types are likely to differ in their use of advertising and, thus, their likelihood of using SSBs as a loss-leader to entice consumers into the store.

Another important consideration is that the demand of Berkeley consumers for SSBs may be price elastic for reasons unrelated to cross-border shopping. Previous research finds that the demand for SSBs and soft drinks is elastic (e.g., Powell et al., 2013; Harding and Lovenheim, 2014).[20] The price elasticity of demand for SSBs also appears to be higher for higher-income individuals (e.g., Lin et al., 2011), and Berkeley is a relatively high-income city (U.S. Census Bureau, 2015a). If the demand for SSBs is elastic in Berkeley, one should expect the pass-through to be less than if demand was relatively inelastic. However, this does not explain why some Berkeley stores in our sample raised their prices by one cent per ounce, while others did not raise them at all, unless there are dramatic differences in price elasticity between the shoppers at those stores. This would be plausible if the stores were located in neighborhoods with greatly varying socioeconomic status, but stores that increased prices by exactly the amount of the tax are often located close to stores that did not raise their prices at all. This suggests that differences across stores in pass-through may not be determined by either elasticity of customer demand or ease of cross-border shopping.

Another possible explanation is that we are able to do a better job of controlling for trends in prices, through the use of a control community that is a close match and a close substitute that was untaxed (diet versions of the same brand SSB). However, we observe low rates of pass-through (under 50 percent) even when we do not difference out trends in the control community. Another advantage of this study is that we have a balanced panel of store-level data, allowing us to estimate fixed effects models that eliminate time-invariant heterogeneity at the

[20] A review of the literature finds that the mean estimate of the price elasticity of demand for SSBs overall was -1.21, that for regular carbonated soft drinks was -1.25, and that for sports drinks was -2.44 (Powell et al., 2013).

store level and eliminate the possibility of changes in which stores were sampled. Like DeCicca et al. (2013), we find substantial variation in prices within cities, which underscores the importance of having data on a balanced panel of stores, as opposed to using average prices in a city.[21]

An additional influence on the differential pass-through by product size could be second-degree price discrimination (Busse and Rysman, 2005; Bonnet et al., 2013); larger sizes are sold at lower prices per ounce and we observe that less of the tax is shifted on cases of cans than on individual serving bottles. Overall, the evidence tends to rule out delays in implementation, price stickiness, SSBs as a loss leader, and that Berkeley customers are particularly price elastic, while supporting the possibility that cross-border shopping is a partial explanation for the low pass-through of the tax.

CONCLUSION

In this paper, we examine the first city-level tax on sugar-sweetened beverages in United States, which was introduced in March 2015 in Berkeley, California. Strengths of the study include: longitudinal data at the store level, data from a near-census of stores with posted prices in the treatment community, and an unusually closely-matched control community in which a majority of residents also voted for the policy in question. This allows us to estimate difference-in-differences (DD) models that eliminate contemporaneous price shocks that were specific to

[21] The ACCRA data used in Besley and Rosen (1999) were not consistently drawn from the exact same stores, and data collectors are allowed to substitute a similar product if the requested one was not available; to some extent, the Besley and Rosen (1999) estimates may have been confounded by differences in stores or products over time. Likewise, the data used in Grogger (2015) are city level and the set of stores may not be consistent over time. However, Kenkel (2005) collected store-level data from the same set of stores and still found that alcohol taxes in Alaska were overshifted.

the region. Overall, we estimate that, across all brands and sizes examined, SSB prices increased by 43.1 percent of the tax.

These results are relevant beyond the city of Berkeley. Simulations of the effect of proposed SSB taxes on consumption have often assumed that taxes will be fully passed through to consumers (e.g., Long et al., 2015; Dharmasena et al., 2014; Wang et al., 2012). A recent study of the cost-effectiveness of taxing SSBs in the U.S. (Long et al., 2015) conducted a robustness exercise which assumed that tax pass-through would range between 50 percent and 150 percent; many of our estimates lie below even that lower bound, implying that the study overestimated the behavior change that would result from such a tax.

To clarify, this paper does not argue that a tax on SSBs is unjustified. There is in fact a credible economic rationale for an SSB tax: to internalize the negative externalities associated with obesity and the chronic conditions associated with a poor diet (see, e.g., Cawley, 2015). In addition, such taxes raise revenue and internalize externalities.

This study has a number of limitations. The most important is that we have a two-by-two case of clusters, which makes it difficult to accurately calculate standard errors. However, this limitation is shared by the previous literature, which in many cases is further limited by a lack of a control community. Despite the clustering issue, this paper presents important information from the only city in the U.S. to enact a tax on SSBs and is based on a near-census of grocery stores, supermarkets, and convenience stores in the treatment city.

The control city, San Francisco, may be an imperfect counterfactual for Berkeley, which would bias our estimates in the DD models. Importantly, a majority of San Francisco voters voted for (yet did not get) a tax on SSBs, which suggests that San Francisco is an unusually well-matched control community for Berkeley in this context.

The outcomes we examine are the prices of national brands that are most commonly sold in grocery stores, convenience stores, and pharmacies. Anecdotal reports suggest that distributors responded in other ways to the tax. For example, one distributor temporarily stopped selling niche products (craft sodas and naturally sweetened beverages) in Berkeley out of confusion about the tax's implementation, and the two Dollar Tree stores in Berkeley stopped selling caloric SSBs altogether (Lee, 2015).

Finally, we do not observe prices charged by distributor to retailer, only the retail price to the consumer. Estimating the extent of pass-through from distributors to retailers would also be an interesting direction for future work.

Despite these limitations, this study provides important information on one of the most commonly-proposed anti-obesity policies: a tax on sugar-sweetened beverages. Specifically, we find that average pass-through rate was 43.1 percent, which is far from the full pass-through assumed in simulations of such taxes. Moreover, there is suggestive evidence that this lower pass-through rate is due in part to the ease of cross-border shopping; for larger sizes of SSBs, pass-through of the tax is higher for stores that are further from competitors not subject to the tax.

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Table 1: Mean Price in Cents by City and Time Period

	Berkeley			San Francisco		
	December 2014 (Pre-Tax)	June 2015 (Post-Tax)	Difference	December 2014 (Pre-Tax)	June 2015 (Post-Tax)	Difference
Coke 20 oz.	179.375	187.708	8.333	189.000	189.222	0.222
	(4.018)	(3.969)	(5.648)	(1.986)	(2.257)	(3.007)
	N=24	N=24		N=45	N=45	
Coke 2 Liter	215.687	240.625	24.938	237.808	237.808	0.000
	(5.014)	(10.635)	(11.758)	(8.259)	(7.600)	(11.224)
	N=16	N=16		N=26	N=26	
Coke	589.733	649.533	59.800	618.286	631.857	13.571
12 Pack 12 oz.	(19.846)	(14.254)	(24.435)	(11.648)	(12.154)	(16.834)
	N=15	N=15		N=14	N=14	
Pepsi 20 oz.	184.842	195.105	10.263	189.406	191.781	2.375
	(3.989)	(3.984)	(5.638)	(2.030)	(1.524)	(2.539)
	N=19	N=19		N=32	N=32	
Pepsi 2 Liter	217.812	250.063	32.250	223.296	225.889	2.593
	(6.137)	(10.613)	(12.259)	(4.086)	(4.342)	(5.962)
	N=16	N=16		N=27	N=27	
Pepsi	572.077	621.923	49.846	588.286	595.429	7.143
12 Pack 12 oz.	(17.555)	(17.420)	(24.732)	(10.714)	(6.343)	(12.451)
	N=13	N=13		N=14	N=14	
Mt Dew 20 oz.	183.050	194.300	11.250	189.793	193.241	3.448
	(3.503)	(3.864)	(5.216)	(2.235)	(1.519)	(2.702)
	N=20	N=20		N=29	N=29	
Mt Dew 2 Liter	215.733	251.467	35.733	220.895	222.474	1.579
	(6.172)	(11.246)	(12.828)	(5.115)	(4.922)	(7.099)
	N=15	N=15		N=19	N=19	
Mt Dew	564.000	626.400	62.400	604.556	604.556	0.000
12 Pack 12 oz.	(22.423)	(20.311)	(30.254)	(5.556)	(5.556)	(7.857)
	N=10	N=10		N=9	N=9	
Gatorade 20 oz.	171.308	178.231	6.923	175.154	174.615	-0.538
	(6.008)	(5.366)	(8.056)	(3.352)	(2.921)	(4.447)
	N=13	N=13		N=26	N=26	
Red Bull 8.4 oz.	233.826	242.000	8.174	243.735	250.118	6.382
	(4.882)	(3.328)	(5.909)	(4.298)	(4.279)	(6.065)
	N=23	N=23		N=34	N=34	
Red Bull	819.308	826.231	6.923	813.588	819.529	5.941
4 Pack 8.4 oz.	(17.838)	(15.631)	(23.717)	(19.745)	(14.577)	(24.543)
	N=13	N=13		N=17	N=17	
Snapple Iced Tea	170.333	188.667	18.333	139.650	141.950	2.300
16 oz.	(12.184)	(19.186)	(22.728)	(6.229)	(6.085)	(8.708)
	N=6	N=6		N=20	N=20	

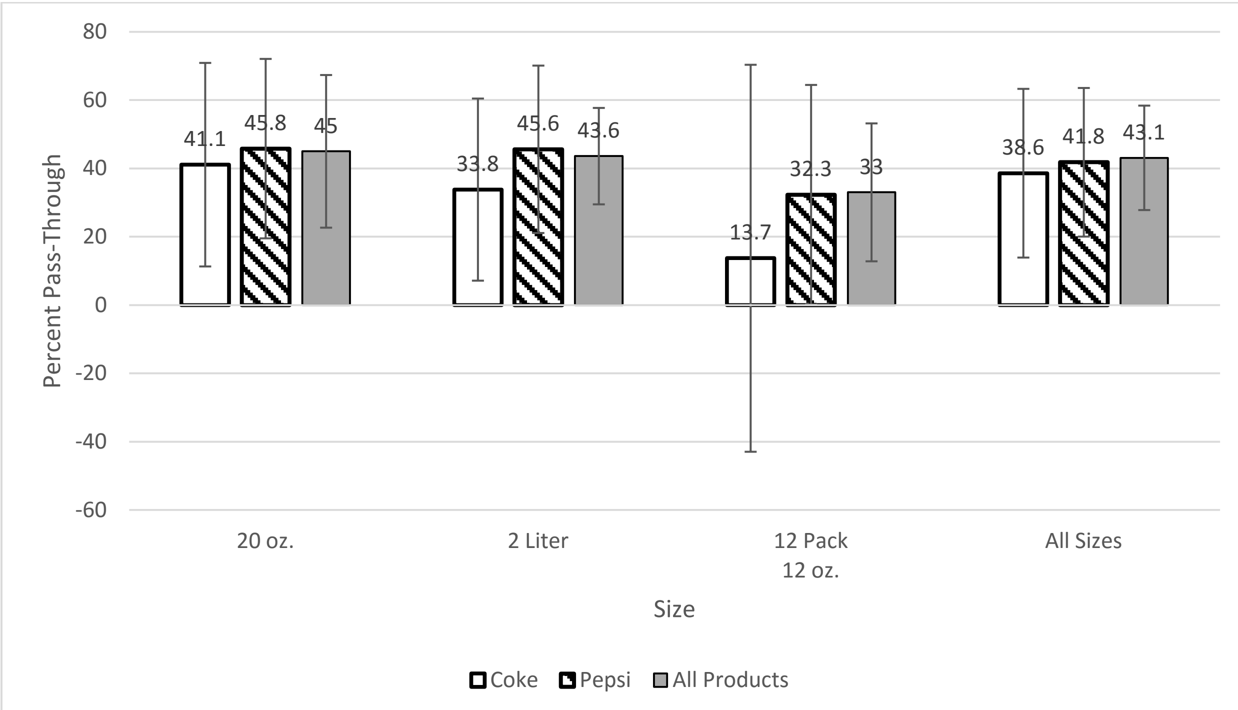
Notes: Standard errors in parentheses.

Table 2: Difference-in-Differences: Berkeley Versus San Francisco
Impact of Soda Excise Tax on Price (Cents/Oz), Product by Size

	20 oz.	**2 Liter**	**12 Pack 12 oz.**	**All Sizes**
Coke	0.411***	0.338**	0.137	0.386***
	(0.152)	(0.136)	(0.289)	(0.126)
	[0.108, 0.714]	[0.061, 0.614]	[-0.46, 0.735]	[0.137, 0.635]
	N=138	N=84	N=58	N=280
Pepsi	0.458***	0.456***	0.323*	0.418***
	(0.134)	(0.125)	(0.164)	(0.111)
	[0.187, 0.729]	[0.203, 0.71]	[-0.017, 0.662]	[0.199, 0.637]
	N=102	N=86	N=54	N=242
Mt Dew	0.443***	0.506***	0.433**	0.453***
	(0.156)	(0.155)	(0.183)	(0.104)
	[0.128, 0.757]	[0.19, 0.823]	[0.041, 0.825]	[0.247, 0.658]
	N=98	N=68	N=38	N=204
Gatorade	0.437**			
	(0.203)			
	[0.023, 0.85]			
	N=78			
All Products	0.450***	0.436***	0.330***	0.431***
	(0.114)	(0.072)	(0.103)	(0.078)
	[0.226, 0.674]	[0.294, 0.579]	[0.125, 0.534]	[0.277, 0.584]
	N=416	N=238	N=150	N=804

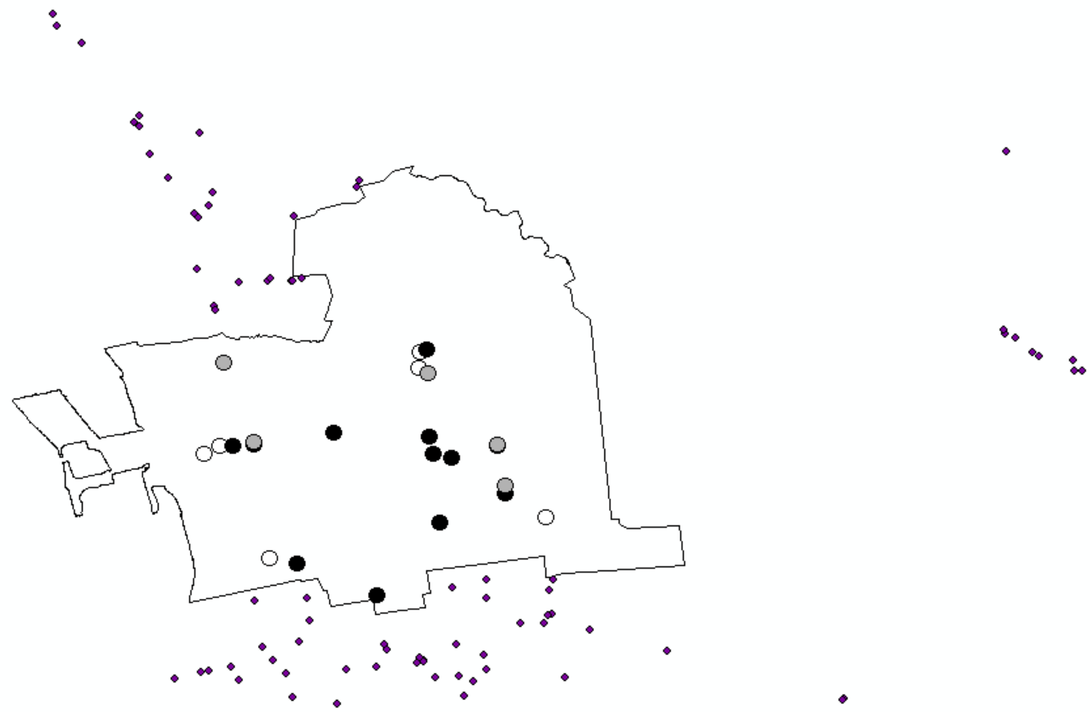
Notes: *p<0.10, **p<0.05, ***p<0.01
Standard errors are shown in parentheses and 95 percent confidence intervals are shown in brackets. Each cell contains the results of separate regressions based on equation (1) and are difference-in-differences estimates of the change in prices per ounce from after to before the tax in Berkeley relative to San Francisco for each product.

Figure 1: Graphical Depiction of Pass-Through of the Berkeley Tax on SSBs



Notes: Coefficient estimates, shown as vertical bars, and 95 percent confidence intervals, shown as vertical lines, are based on the results of the difference-in-differences (DD) models reported in Table 2.

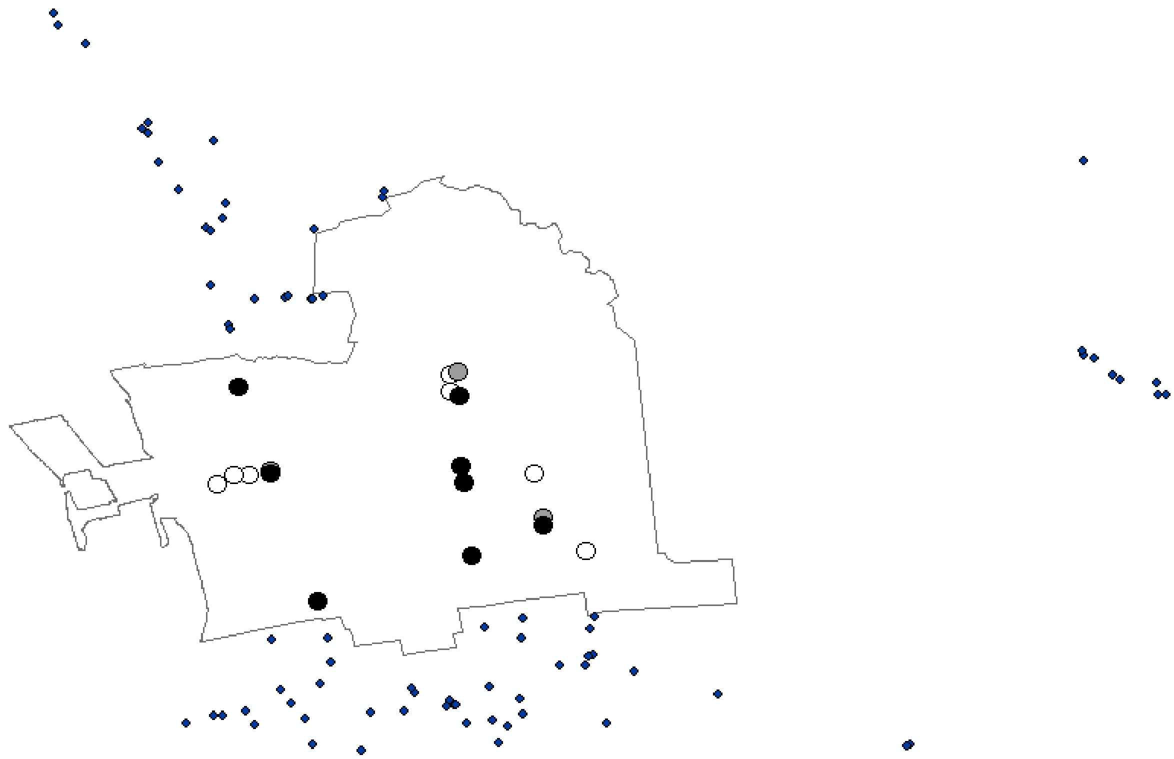
Figure 2A: Difference between the Post-Tax (June 2015) and Pre-Tax (December 2014) Prices of Full-Calorie Coke (20-oz Bottle), Berkeley



○ Difference in price 1 cent or more per ounce (N=7)
● Difference in price zero to 1 cent per ounce (N=5)
● Difference in price zero or negative (N=12)

Notes: Small black dots indicate the location of stores outside of Berkeley (where SSBs are not taxed). The lack of stores to the immediate west and east is due to the bay (to the west) and parkland (to the east).

Figure 2B: Difference between the Post-Tax (June 2015) and Pre-Tax (December 2014) Prices of Full-Calorie Pepsi (20-oz Bottle), Berkeley



○ Difference in price 1 cent or more per ounce (N=7)
● Difference in price zero to 1 cent per ounce (N=4)
● Difference in price zero or negative (N=8)

Notes: Small black dots indicate the location of stores outside of Berkeley (where SSBs are not taxed). The lack of stores to the immediate west and east is due to the bay (to the west) and parkland (to the east).

Table 3: Difference-in-Difference Models Controlling for Distance to Closest Store Outside of Berkeley (and Thus Not Subject to Tax)

		20 oz.	2 Liter	12 Pack 12 oz.	All Sizes
Coke	Treatment	0.760**	-0.158	-0.294	0.252
		(0.368)	(0.269)	(0.406)	(0.273)
		[0.025, 1.495]	[-0.705, 0.389]	[-1.137, 0.548]	[-0.286, 0.79]
	Treatment* Distance	-0.338	0.539**	0.5	0.154
		(0.325)	(0.244)	(0.314)	(0.244)
		[-0.988, 0.311]	[0.045, 1.034]	[-0.151, 1.151]	[-0.328, 0.636]
		N=138	N=82	N=56	N=276
Pepsi	Treatment	0.153	0.253	0.214	0.198
		(0.335)	(0.277)	(0.316)	(0.249)
		[-0.522, 0.8280]	[-0.308, 0.8130]	[-0.443, 0.871]	[-0.292, 0.688]
	Treatment* Distance	0.289	0.211	0.11	0.219
		(0.291)	(0.256)	(0.273)	(0.221)
		[-0.297, 0.875]	[-0.307, 0.73]	[-0.457, 0.677]	[-0.218, 0.655]
		N=102	N=86	N=54	N=242
Mt Dew	Treatment	0.880*	0.272	0.335	0.421*
		(0.455)	(0.324)	(0.355)	(0.239)
		[-0.038, 1.799]	[-0.392, 0.9350]	[-0.432, 1.103]	[-0.051, 0.894]
	Treatment* Distance	-0.367	0.249	0.102	0.042
		(0.384)	(0.301)	(0.312)	(0.21)
		[-1.143, 0.409]	[-0.369, 0.866]	[-0.573, 0.776]	[-0.374, 0.458]
		N=96	N=68	N=38	N=202
Gatorade	Treatment	0.768			
		(0.468)			
		[-0.186, 1.721]			
	Treatment* Distance	-0.316			
		(0.437)			
		[-1.206, 0.574]			
		N=76			
All Products	Treatment	0.615**	0.128	0.095	0.332*
		(0.287)	(0.151)	(0.178)	(0.175)
		[0.051, 1.18]	[-0.171, 0.426]	[-0.258, 0.449]	[-0.012, 0.675]
	Treatment* Distance	-0.146	0.333**	0.258*	0.112
		(0.251)	(0.139)	(0.152)	(0.156)
		[-0.641, 0.348]	[0.058, 0.608]	[-0.043, 0.560]	[-0.195, 0.418]
		N=412	N=236	N=148	N=796

Notes: *p<0.10, **p<0.05, ***p<0.01
Standard errors are shown in parentheses and 95% confidence intervals are shown in brackets. Each cell contains the results of separate regressions based on equation (1) and are difference-in-differences estimates of the change in prices per ounce from after to before the tax in Berkeley

relative to San Francisco for each product. Mean (SD) of distance to nearest store outside of Berkeley is 5,442 (1,879) feet.

Table 4: Robustness Checks:
DD Model Estimates for All Brands Pooled, by Size

All Brands Pooled	20 oz.	2 Liter	12 Pack 12 oz.	All Sizes
Base Model (Table 2, Final Row)	0.450***	0.436***	0.330***	0.431***
	(0.114)	(0.072)	(0.103)	(0.078)
	[0.226, 0.674]	[0.294, 0.579]	[0.125, 0.534]	[0.277, 0.584]
	N=416	N=238	N=150	N=804
Convenience Stores Only	0.329**	0.428***	0.374***	0.367***
	(0.158)	(0.0818)	(0.109)	(0.0973)
	[0.0184, 0.641]	[0.266, 0.590]	[0.158, 0.591]	[0.176, 0.558]
	N=294	N=156	N=106	N=556
Chain Stores Only	0.445***	0.547***	0.440***	0.470***
	(0.149)	(0.0810)	(0.108)	(0.0901)
	[0.152, 0.739]	[0.387, 0.707]	[0.226, 0.655]	[0.293, 0.647]
	N=300	N=184	N=134	N=618
Control for Whether Item On Sale	0.437***	0.467***	0.254***	0.424***
	(0.133)	(0.0713)	(0.0926)	(0.0844)
	[0.175, 0.698]	[0.326, 0.608]	[.0702, 0.437]	[0.258, 0.589]
	N=414	N=236	N=150	N=800

Notes: *p<0.10, **p<0.05, ***p<0.01
Standard errors are shown in parentheses and 95% confidence intervals are shown in brackets. Each cell contains the results of separate regressions based on equation (1) and are difference-in-differences estimates of the change in prices per ounce from after to before the tax in Berkeley relative to San Francisco for each size (all brands pooled).