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The Effects of E-Cigarette Taxes on E-Cigarette Prices and Tobacco Product Sales: Evidence from Retail Panel Data

Chad Cotti
University of Wisconsin-Oshkosh, cottic@uwosh.edu

Charles J. Courtemanche
University of Kentucky, courtemanche@uky.edu

Joanna Catherine Maclean
Temple University, catherine.maclean@temple.edu

Erik Nesson
Ball State University, etnesson@bsu.edu

Michael F. Pesko
Georgia State University, mpesko@gsu.edu

See next page for additional authors

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Nathan Tefft

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University of Kentucky
244 Gatton College of Business and Economics
Lexington, KY 40506-0034
http://isfe.uky.edu/

Gatton College of Business and Economics

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Chad Cotti
Department of Economics
College of Business
University of Wisconsin-Oshkosh
Oshkosh, WI 54901
cottic@uwosh.edu

Charles Courtemanche
Department of Economics
Gatton College of Business and Economics
University of Kentucky
Lexington, KY 40506
and NBER, IZA
courtemanche@uky.edu

Joanna Catherine Maclean
Department of Economics
Temple University
Ritter Annex 869
Philadelphia, PA 19122
and NBER, IZA
catherine.maclean@temple.edu

Erik Nesson
Department of Economics
Miller College of Business
Ball State University
Muncie, IN 47306
and NBER
etnesson@bsu.edu

Michael Pesko
Department of Economics
Andrew Young School of Policy Studies
PO Box 3992
Atlanta, GA 30302-3992
mpesko@gsu.edu

Nathan Tefft
Department of Economics
Bates College
Lewiston, ME 04240
and Montana State University
ntefft@bates.edu

Abstract

We explore the effect of e-cigarette taxes enacted through 2017 in eight states and two large counties on e-cigarette prices, e-cigarette sales, and sales of other tobacco products. We use the Nielsen Retail Scanner data for the years 2011 to 2017, comprising approximately 35,000 retailers nationally. We calculate a Herfindahl–Hirschman Index of 0.251 for retail-based purchases of e-cigarettes, indicating high market concentration. We estimate a tax-to-price pass-through of 1.55 (p<0.01) and an e-cigarette own-price elasticity of -2.6 (p<0.01) for the average e-cigarette tax. We also estimate a positive cross-price elasticity of demand for e-cigarettes and traditional cigarettes of roughly 1.1 for the average tax, suggesting that e-cigarettes and traditional cigarettes are economic substitutes. Our results suggest that higher e-cigarette taxes would increase e-cigarette prices and reduce e-cigarette sales, with an unintended effect of increasing traditional cigarette sales. We simulate that for every one standard e-cigarette pod (a device that contains liquid nicotine in e-cigarettes) of 0.7 ml no longer purchased as a result of an e-cigarette tax, the same tax increases traditional cigarettes purchased by 6.2 extra packs.

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responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

1. Introduction

According to the Centers for Disease Control and Prevention (CDC), nearly 3% of adults in the United States used electronic cigarettes ('e-cigarettes') in 2017 (Centers for Disease Control and Prevention 2018). Use of e-cigarettes ('vaping') among adolescents has grown even more rapidly, with nearly 27.5% of high school students using e-cigarettes in 2019 (U.S. Food & Drug Administration 2019). The rapid rise in vaping has led to concerns among public health officials and a focus on tobacco control policies aimed at curbing e-cigarette use. As of June 15, 2019, 15 states had enacted an e-cigarette tax (Public Health Law Center 2019). Despite the rapid increase in e-cigarette use, very little is known about the effects of these policies on the use of e-cigarettes or other tobacco products.

In this paper, we provide evidence of the effects of e-cigarette taxes on the prices and sales of e-cigarettes and other tobacco products using the Nielsen Retail Scanner Data (NRSD) over the years 2011 to 2017. The NRSD tracks weekly sales of a national panel of approximately 35,000 retailers and covers a large percentage of total sales among drug stores, mass merchandisers, food stores, dollar stores, and club stores.[1]

We identify purchases and sales of e-cigarettes and other tobacco products in the NRSD, and we match 93.5% of e-cigarette product sales to detailed product characteristics, including product type, liquid volume, and nicotine content. These additional characteristics allow for a detailed investigation of the impacts of taxation on ingredient consumption as well as a more

[1] We use the NRSD instead of the Nielsen Consumer Panel Data because the NRSD provides approximately a 4.8% sample of national e-cigarette sales, whereas the Nielsen Consumer Panel data covers only a 0.05% sample of e-cigarette sales (Allcott and Rafkin 2019).

accurate standardization of the e-cigarette taxes themselves, which are often levied based on the quantity of liquid or nicotine contained in the products.

We first estimate the pass-through of e-cigarette and traditional cigarette taxes to the prices of these goods, finding that e-cigarette taxes are more than fully passed through to e-cigarette prices. We then estimate how sales of e-cigarettes and other tobacco products respond to changes in e-cigarette taxes. We find that the demand for e-cigarettes is elastic, with an estimated price elasticity of demand of -2.6. We also estimate that traditional cigarette sales increase following a rise in e-cigarette taxes, suggesting that e-cigarettes and traditional cigarettes are economic substitutes with a cross-price elasticity of demand of 1.1. We estimate a price-elasticity of demand for traditional cigarettes of -0.6, which is in line with previous estimates (for reviews, see Chaloupka & Warner 2000, and DeCicca et al. 2018).

This study addresses many limitations in the literature examining the market for e-cigarettes. First, our paper is among the first to estimate the pass-through rate for e-cigarette taxes. In part, this dearth in the literature is due to the fact that examination of the intensive margin requires standardizing different forms of e-cigarette taxes to measure the magnitude of the tax. This standardization is complicated give the heterogeneous ways in which localities have elected to tax e-cigarettes. Many e-cigarette taxes are not levied per-unit as are traditional cigarette taxes, but rather are ad valorem taxes or excise taxes levied on the liquid amount of each e-cigarette product. The resulting difficulty in measurement has led the few papers that examine the effects of e-cigarette taxes to focus primarily on the extensive margin of the presence of a tax, rather than try to estimate the effect of changes/differences in taxes on the intensive margin of taxation (e.g.

Abouk et al. 2019).[2] Exploration of the intensive taxation margin is an important limitation of previous work, as the standardized magnitudes of existing e-cigarette taxes vary widely, from $0.05 per milliliter (ml) of nicotine in Kansas and Louisiana to $1.85 per ml in Minnesota. Since the smaller tax rates (generally from excise taxes) are much closer to zero than to the larger tax rates (generally from ad valorem taxes), combining the taxes in a single indicator (tax vs. no tax) creates an issue akin to treatment misclassification and could lead researchers to underestimate the potential impacts of higher levels of taxation.

To estimate the pass-through of e-cigarette taxes to prices and estimate a price elasticity of demand, we match e-cigarette Universal Product Codes (UPCs) in the NRSD to the product type, volume of liquid, and nicotine content of these e-cigarettes using internet searches, correspondences with companies, and visits to retailers. Although the database of characteristics was developed by Cotti et al. (2018), we are the first study to use it to study the effects of any e-cigarette-related policies. These additional product characteristics allow us to move beyond simply measuring the presence of an e-cigarette tax and instead incorporate the magnitude of the e-cigarette tax. Thus, we are among the first research groups in the economics literature to estimate the dollar-to-dollar pass-through rate of e-cigarette taxes to e-cigarette prices and the price elasticity of demand for e-cigarettes.

Using the NRSD allows us to examine e-cigarette purchases much earlier than is possible with other datasets of adults, which is another contribution of our paper. In particular, we track e-cigarette purchases beginning in 2011 in the NRSD, while adult survey datasets did not begin asking about e-cigarette use until several years later (e.g., 2016 in the Behavioral Risk Factor

[2] In binary specifications, localities with excise and ad valorem taxes are treated the same, even though the typical excise tax is so small that those localities are effectively much closer to the comparison group of non-tax adopting localities than to the ad valorem tax group.

Surveillance Survey and 2014 in the National Health Interview Survey). Use of this early time period enables us to leverage additional policy variation and a more rigorous investigation of pre-treatment trends between localities that adopted and did not adopt an e-cigarette tax.

Finally, we provide the first estimate of e-cigarette market concentration available in the literature by calculating a Herfindahl–Hirschman Index for the e-cigarette retail-based market. We find a high degree of market concentration, which is in line with over-shifted taxes.

The rest of this paper is organized as follows. Section 2 provides background and a review of the literature surrounding e-cigarette use, Section 3 summarizes our data sources, Section 4 describes our methodology, Section 5 reviews the results, and Section 6 concludes.

2. Literature Review and Background

In a perfectly competitive market, the rate at which a tax change impacts the after-tax price (i.e., the 'pass-through') is a function of the elasticities of both supply and demand and ranges from zero and one. The pass-through will be zero if consumers have perfectly elastic demand (suggesting that suppliers pay the full incidence of the tax) or one if consumers have perfectly inelastic demand (consumers pay all of the tax). However, over-shifting – when the pass-through is greater than one – is possible in imperfectly competitive markets (e.g. Stern 1987, Besley 1989, Hamilton 1999) and has been observed in the traditional cigarette market. For example, one study uses American Chamber of Commerce Research Association data and differences-in-differences (DD) modeling to examine the effect of sales taxes on after-tax prices of 12 common consumer products. The authors find negative pass-through estimates for two of 12 products, pass-through estimates between zero and one for five of 12 products, and pass-through estimates of >1 for five of 12 products. Bread has the highest pass-through of 2.42 (Besley and Rosen 1999).

Several recent studies use national-level data and DD modeling to evaluate the effect of traditional cigarette tax increases on traditional cigarette prices. Lillard and Sfekas (2013) use state-level prices from the Tax Burden on Tobacco from 1995 to 2007 and estimate a pass-through of 1.03 when including state and year fixed effects. DeCicca, Kenkel, and Liu (2013) use consumer-reported prices from the 2003 and 2006 to 2007 Current Population Survey Tobacco Use Supplements (TUS) to estimate the pass-through of excise taxes to consumer prices ranging from 0.91 to 1.18, with some evidence that pass-through is lower for higher intensity smokers. Rozema and Ziebarth (2017) use individual-level data on prices paid for traditional cigarettes from 2001 to 2012 in a sample of low-income, food stamp eligible households and estimate a pass-through of 0.80. Hanson and Sullivan (2009) use micro-level data on traditional cigarette prices from retail locations in Wisconsin and border states to evaluate the effects of large increases in traditional cigarette taxes, estimating a pass-through between 1.08 and 1.17. Finally, Harding, Leibtag, and Lovenheim (2012) use Nielsen Homescan data for 2006 and 2007 to estimate a UPC-level traditional cigarette tax pass-through of 0.85. The authors use a UPC-level rather than a state-level model to hold product quality constant. Overall, their findings provide a series of pass-through estimates ranging from 0.80 to 1.18 when studying traditional cigarette taxes.

Researchers have also estimated pass-through rates for other ‘sin goods:’ alcohol and sugar-sweetened beverages. At least two studies find that alcohol taxes are more than fully passed through to prices (Kenkel 2005, Shrestha and Markowitz 2016). Recently, Cawley et al. (2019) reviewed 15 studies on pass-through for sugar-sweetened beverages, concluding that trends in prices after nationwide tax implementations are in line with the hypothesis that prices rise by the full amount of the tax; however, local taxes generally have lower estimated pass-through, potentially due to tax evasion opportunities created by cross-border shopping.

Relatedly, a growing literature examines the relationship between e-cigarettes and traditional cigarettes. Because variation in e-cigarette policies, particularly e-cigarette taxes, is recent and data on e-cigarettes have not been readily available, much of the research to date on the relationship between e-cigarettes and traditional cigarettes has examined the effects of e-cigarette restrictions (rather than taxes) on the demand for traditional cigarettes (rather than e-cigarettes). For example, Friedman (2015) uses the National Survey on Drug Use and Health and finds that states implementing restrictions on youth access to e-cigarette products see increases in youth smoking rates as measured by traditional cigarette smoking in the past 30 days, suggesting that e-cigarettes and traditional cigarettes are substitutes among adolescents. Similarly, Pesko, Hughes, and Faisal (2016) and Dave, Feng, and Pesko (2019) use the Youth Risk Behavior Surveillance System data and restrictions on youth access to e-cigarettes, finding evidence that the two products are substitutes for this population. Pesko and Currie (2019) have comparable findings for pregnant adolescents using birth record data. Contrary to these findings, Abouk and Adams (2017) use the same restrictions on youth access to e-cigarettes and individual-level data for underage high school seniors from Monitoring the Future Survey (MTF) to find that the products are economic complements. Finally, Dave et al. (2019) finds that exposure to e-cigarette advertising helps adult smokers quit smoking.

Few studies estimate the effect of tobacco control policies on e-cigarette use itself. One exception is Cotti, Nesson, and Tefft (2018). The authors examine the effects of traditional cigarette taxes and other tobacco control policies, including indoor vaping restrictions (IVRs) and indoor smoking restrictions (ISRs), on adult households' purchases of e-cigarettes and other tobacco products using the Nielsen Consumer Panel data. The authors document that traditional cigarette tax increases induce households to purchase fewer e-cigarette products, suggesting a complementary relationship between e-cigarettes and traditional cigarettes. Both Abouk and Adams (2017) and Dave, Feng, and Pesko (2019) provide evidence from a single wave of data that age purchasing restrictions reduce e-cigarette use.

Recently, however, increasingly available data and the presence of new e-cigarette policies have led to additional examinations of e-cigarette tax effects. One working paper finds that e-cigarette tax adoption leads to a 6.3% increase in prenatal smoking (Abouk et al. 2019), a second study provides some evidence that the e-cigarette tax increase in Minnesota in 2013 reduces e-cigarette use and increases traditional cigarette use among teenagers (Pesko and Warman 2019), and a third study documents that e-cigarette tax adoption reduces current vaping by 13.9% among adult men (Pesko, Courtemanche, and Maclean 2019). The final study also documents that traditional cigarette taxes increase e-cigarette use. One limitation of these studies is that they use the presence of a tax (i.e., extensive margin) rather than the magnitude (i.e., intensive margin) of the tax as in the current paper. Additionally, these studies do not use as long a time period or as much policy variation as we use in our work.

A new working paper by Saffer et al. (2019) also uses survey data, the TUS from 1992 to 2015, in conjunction with e-cigarette taxes in Minnesota (which increased from 35% to 95% in 2013) and synthetic control methods to assess how e-cigarette taxes impact adult smokers in a case study analysis. Estimates suggest that the e-cigarette tax rate increases adult smoking and reduces smoking cessation in Minnesota, relative to the synthetic control group, and imply a cross elasticity of current smoking participation with respect to e-cigarette prices of 0.13. Assuming a retailer markup of 33% over the wholesale costs, the authors estimate a tax-pass-through to price in

Minnesota of 1.33. Relative to this paper, we utilize substantially more policy variation, as we leverage the experiences of all e-cigarette tax adopting localities to date rather than a single state, and explore outcomes beyond traditional cigarette smoking.

Other studies estimate the effect of e-cigarette prices, rather than taxes, on e-cigarette demand. The NRSD is used in two studies to study the effect of e-cigarette prices on e-cigarette and traditional cigarette sales. Huang et al. (2018) use data from 2007 to 2014 to document e-cigarette own-price elasticities for rechargeable e-cigarette sales of –1.4 and for disposable e-cigarette sales of –1.6. Using data over the period 2009 to 2013 Zheng et al. (2017) estimate an e-cigarette own-price elasticity of demand of –2.1, a cross-price elasticity of traditional cigarette prices on e-cigarettes sales of 1.9, and a cross-price elasticity of e-cigarette prices on traditional cigarette sales of 0.004. Using European data over the period 2011 to 2014, Stoklosa, Drope, and Chaloupka (2016) document an e-cigarette own-price elasticity of demand of –0.8 and a cross-price elasticity of traditional cigarette prices on e-cigarette sales of 4.6. Pesko et al. (2016), using a discrete choice experiment, estimate e-cigarette own-price elasticity among current adult smokers of 1.8.

Survey data are used in four studies to estimate the effect of e-cigarette prices on e-cigarette *use* rather than sales. Saffer et al. (2018) use data on adults from the 2014 to 2015 TUS to estimate an e-cigarette price elasticity of vaping participation of –1.2. Pesko et al. (2018) use two years of the MTF data on middle and high school students and find a –1.8 own price elasticity of days vaping. Finally, Cantrell et al. (2019) use national longitudinal cohort data on a sample of 15- to 21-year-olds from 2014 to 2016 and find no effect of e-cigarette prices on vaping, but a traditional cigarette cross-price elasticity of 0.9. Of course, the endogeneity of prices is an obvious potential limitation of these papers, and we aim to overcome this challenge by using plausibly exogenous variation from the implementation of taxes.

Lastly, a new working paper, Allcott and Rafkin (2019), use a different identification strategy to estimate whether e-cigarettes and traditional cigarettes are economic substitutes or complements. Using all known available survey data for the U.S., the authors use the pre-2013 smoking propensities for 800 adult demographic cells and 56 youth demographic cells to implement a 'shift-share' strategy to examine what impact wide use of e-cigarettes starting in the year 2013 had on smoking trends. Point estimates suggest that e-cigarettes cause a 4% reduction in smoking for adults and a 24% reduction for youth.

Allcott and Rafkin's paper was written concurrently to and independently from ours and, while their primary objectives and ours are notably different, there is some overlap in the contributions, such as using NRSD, standardizing e-cigarette tax sizes, examining the relationship between e-cigarette taxes and prices, and estimating the price elasticity of e-cigarettes. However, there are important differences in the nature of these contributions. First, their interest in the relationship between taxes and prices is as a first stage in an instrumental variable (IV) model estimating the price elasticity of demand for use in welfare calculation, rather than as an attempt to measure the pass-through rate. Accordingly, Allcott and Rafkin use a logarithmic, rather than linear, functional form for both taxes and prices, which implies that their estimate relates percentage changes in taxes to percentage changes in prices, which is not informative about over- versus under-shifting. Second, they use the 2013 to 2017 NRSD whereas we use data over the period 2011 to 2017, allowing us to examine longer pre-treatment trends. Third, Allcott and Rafkin standardize e-cigarette taxes as ad valorem taxes, whereas we standardize the e-cigarette taxes as specific excise taxes by taking advantage of Washington D.C.'s ad valorem tax that is set to parity with the traditional cigarette tax. Finally, Allcott and Rafkin estimate the own-price elasticity of e-cigarettes but do not examine the cross-price elasticity between e-cigarettes and traditional cigarettes. Instead, their primary evidence for substitutability comes from the shift-share approach described above. Our paper and theirs, therefore, complement each other in that both find evidence that e-cigarettes and traditional cigarettes are substitutes using very different approaches.

3. Data

a. Nielsen Retail Scanner Data (NRSD)

Our main data source is the NRSD between 2011 and 2017. The NRSD comprises a sample of approximately 30,000 to 35,000 retailers, including grocery stores, drug stores, mass merchandise retailers, and other types of stores. In 2017, the NRSD included between 15% and 26% of all food store, mass merchandiser, dollar store, and club store sales, and over 50% of drug store sales. The NRSD contains a smaller percentage of sales in convenience stores and liquor stores (approximately 2% each). The volume of each UPC purchased at each store is recorded weekly, as well as the average price paid, including all taxes except sales taxes. We construct a sales-weighted e-cigarette price at both the UPC-locality-quarter level and locality-quarter level, where a locality is defined as a state or county (depending on the geographical location of a tax) and a quarter refers to a quarter-by-year.

We analyze sales data on five tobacco product categories: e-cigarettes, traditional cigarettes, cigars, chewing tobacco, and loose tobacco. Measuring e-cigarette sales in the NRSD presents some challenges. First, e-cigarette products in the NRSD are heterogeneous. Some are disposable e-cigarettes, while others are starter kits or refill cartridges. Further, the quantity of cartridges, liquid, and nicotine varies widely within products of the same type. Second, many e-cigarette taxes are levied in proportion to the liquid volume in each e-cigarette product, while others are levied as ad valorem taxes. This regulatory pattern is distinct from traditional cigarette taxes, which are nearly all levied in terms of dollars per traditional cigarette. Finally, previous research suggests that measuring traditional cigarette consumption only through the number of products used provides an incomplete picture of smokers' behavior in response to policy changes. In particular, smokers may respond to traditional cigarette taxes by altering the type of traditional cigarette they smoke or how they smoke the product (Cotti, Nesson, and Tefft 2016, Nesson 2017a, b, Adda and Cornaglia 2006, Evans and Farrelly 1998). None of these behavioral responses are captured by the number of products consumed but all are important for evaluating the overall effect of a tax adoption. Vapers may plausibly display comparable behavioral responses to e-cigarette policies and we wish to capture such responses.

To address these challenges, we estimate our main models of e-cigarette sales using the liquid volume in each e-cigarette, as in Cotti et al. (2018). We match UPCs in the NRSD to three additional product characteristics using correspondences with e-cigarette companies, internet searches, and in-person visits to retailers conducted by members of the research team. We first record the type of e-cigarette product for each UPC, classifying products into disposable e-cigarettes, starter kits, and cartridge refills.[3] Second, we calculate the milliliters (mls) of fluid in each e-cigarette UPC and the amount of nicotine in milligrams for each UPC.[4] We are able to match 93.5% of the e-cigarette products by the value of sales in the NRSD to tobacco product characteristics in this way.

[3] Starter kits include a reusable battery and atomizer along with a selection of disposable cartridges.

[4] There are no regulations for labeling nicotine in e-cigarettes. While nearly all the products we identified label the nicotine content of their e-cigarettes, some brands directly label the nicotine content in milligrams while others label the nicotine content as a percent of the total liquid volume. Hence, for products where nicotine content is only provided as a concentration of nicotine by liquid volume, we convert from liquid volume to milligrams as nicotine by using the following calculation: (mg)= (%nicotine)*(10)*(liquid volume in ml).

For the other tobacco products, we create variables counting the sales for each product in terms of the units provided by Nielsen. We thus count the number of traditional cigarettes sold, which we aggregate into packs, the number of cigars, and the ounces of chewing tobacco and loose tobacco sold.

b. Tobacco Control Policies

We use three policy data sources to construct our e-cigarette tax variable. State-level e-cigarette tax data is drawn from the Public Health Law Center (Public Health Law Center 2019) and the CDC State Tobacco Activities Tracking and Evaluation (STATE) System (Centers for Disease Control and Prevention 2019b). We reconcile discrepancies by directly consulting the original statutes. We collect sub-state e-cigarette tax data from the Vapor Products Tax website (Tax Data Center 2019). To date, e-cigarette taxes are primarily levied through an excise tax on per ml liquid volume or through an ad valorem tax that is paid by the wholesaler or retailer. In our sample period, Kansas, Louisiana, North Carolina, West Virginia, Cook County, and Chicago levy an excise tax on liquid volume. California, Minnesota, Montgomery County, Pennsylvania, and Washington DC use an ad valorem tax. Chicago uses an excise tax on both liquid volume and the number of disposable or refill units sold. Several Alaskan counties also levy e-cigarette taxes, but Alaska is not included in the NRSD and is therefore not included in our standardization procedure. Appendix Table 1 provides information on the effective dates, unit taxed, tax amount, and relative tax value for each e-cigarette tax law implemented during the time frame of NRSD data utilized in this study.

Washington DC's tax is unique in that it set its ad valorem tax rate to match 100% of the traditional cigarette excise tax, suggesting that each one percentage point of ad valorem tax is 4.3 cents. We use this relationship to convert e-cigarette ad valorem taxes into excise tax equivalents for each relevant locality. Please see the appendix for a discussion of our conversion. We convert all e-cigarette taxes to 2017 dollars using the Consumer Price Index-Urban Consumers [CPI].

Between the end of our study period (end of 2017) and June 15, 2019, eight additional states enacted new e-cigarette laws: Connecticut, Delaware, Illinois, New Jersey, New Mexico, New York, Vermont, and Washington (Public Health Law Center 2019). We utilize these additional taxes when we incorporate future policies into our event study specification following Ghimire and Maclean (2020).

We collect data on traditional cigarette excise taxes from the CDC STATE System and transform these into the traditional cigarette excise taxes measured in real 2017 dollars (using CPI) in each state and quarter (Centers for Disease Control and Prevention 2019b). Two states (California and New Jersey) enacted Tobacco 21 laws by the end of 2017 and we include an indicator for this policy (Campaign for Tobacco-Free Kids 2019b).[5]

Additionally, we collect data on indoor air laws from the American Non-Smokers' Rights Foundation (ANR). ANR tracks when municipalities, counties, and states pass indoor air laws for vaping or smoking in different venues. We use this information to create two separate measures for the share of the population in each county living with IVRs and ISRs for private workplaces, restaurants, or bars. For both IVRs and ISRs, we weight laws applying to bars, restaurants, and private workplaces equally. For ISRs, we also consider laws applying to only part of the establishment (but not the full establishment) with ½ weight.[6]

4. Methods

[5] Hawaii also enacted a Tobacco 21 law before the end of 2017; however, the Nielsen data is limited to the contiguous 48 states and so Hawaii is not included.
[6] These partial laws were uncommon for IVRs.

We implement a standard DD identification strategy that connects variation in retailers' e-cigarette prices to changes in tobacco control policies. That is, we leverage variation in locality-level tobacco control policies that occur between 2011 and 2017 to identify treatment effects. Specifically, we estimate:

(1) $$Y_{i,l,t} = \beta_0 + \beta_E Etax_{l,t} + \beta_T Ttax_{l,t} + W_{l,t}\beta_W + X_{l,t}\beta_X + \sigma_{l,i} + \tau_q + \varepsilon_{i,l,t},$$

where $Y_{i,l,t}$ the price for e-cigarette product (i.e., UPC Code) *i* in locality *l* and quarter *t*. We use 51 localities, one for each state and Washington DC (minus Alaska and Hawaii as these states are not in the NRSD), but separating Cook County from Illinois and Montgomery County from Maryland since these localities also adopt e-cigarette taxes during our study period. We aggregate $Y_{i,l,t}$ to the product-by-locality-by-quarter level by creating an average price for each UPC-locality-quarter, using each UPC's sales volume in localities that have not enacted an e-cigarette tax by June 15, 2019 as the weight.[7] We measure both e-cigarette taxes ($Etax_{l,t}$) and traditional cigarette excise taxes ($Ttax_{l,t}$). $Etax_{l,t}$ is a continuous variable measuring the magnitude of e-cigarette taxes as described in Section 3.b and the online appendix. An exception to this approach is in our event-study in which we use an indicator for any e-cigarette tax to allow testing of the parallel trends assumption required for DD models to recover causal estimates of treatment effects. $Ttax_{l,t}$ is a continuous variable measuring the locality-level traditional cigarette excise tax per pack.

We include additional tobacco control policies in $W_{l,t}$, a vector of ISR and IVR laws (measured as the percent of the locality's population living under an ISR, and separately as the percent of the locality's population living under an IVR). We also include locality-level characteristics in $X_{l,t}$: beer tax (dollars per gallon converted to 2017 dollar using the CPI), the

[7] Non-adopting localities are used for the weights to avoid the weights being endogenously impacted by the taxes.

Affordable Care Act's Medicaid expansions,[8] the Bureau of Labor Statistics' unemployment rate, and Current Population Survey demographics (e.g., age, sex, and race/ethnicity). We also include UPC-by-locality and quarter fixed effects in our regression models, represented by $\sigma_{i,l}$ and τ_y, respectively, following Harding et al. (2013). The product fixed effects hold product availability, and other attributes such as quality, constant, thus allowing us to study pass-through independent of manufacturers changing their mix of products offered for sale in response to e-cigarette taxes. We cluster our standard errors at the locality level in all specifications (Bertrand et al., 2004), and we weight the data by the share of e-cigarette sales in localities that do not adopt an e-cigarette tax by 2017. We demonstrate that our main models are robust to a number of alternative specifications, as well as different analytical samples and aggregations.

After examining the pass-through of e-cigarette taxes to e-cigarette prices, we next examine whether e-cigarette prices and traditional cigarette prices affect sales of tobacco products. In these models, we aggregate our data to the locality-by-quarter level for each category of tobacco products, which is different from the product-by-locality-by-quarter aggregation in equation (1) to permit new product offerings to affect overall sales. We examine five categories of tobacco products: e-cigarettes, traditional cigarettes, cigars, chewing tobacco, and loose tobacco. For e-cigarette products, our unit of measure is mls of liquid purchased to match our standardized tax variable that is also per mls of e-cigarette liquid. We examine counts of the products purchased for the other tobacco product categories. We estimate a similar model to that in equation (1), but at the locality-by-quarter level:

(2) $$Y_{l,t} = \gamma_0 + \gamma_E Etax_{l,t} + \gamma_T Ttax_{l,t} + W_{l,t}\gamma_W + X_{l,t}\alpha_X + \delta_l + \chi_q + \mu_{l,t},$$

[8] https://www.kff.org/health-reform/state-indicator/state-activity-around-expanding-medicaid-under-the-affordable-care-act

Here, $Y_{l,t}$ represents the sales of a tobacco product in locality c and time t, and the other variables are the same as in equation (1). We weight equation (2) regressions using the population in that locality and cluster our standard errors at the locality level.

We are also interested in studying the impact of prices on tobacco product purchases. An obvious problem with estimating this relationship however is that e-cigarette and traditional cigarette prices are endogenously determined. Therefore, we simultaneously instrument for e-cigarette and traditional cigarette prices with e-cigarette and traditional cigarette taxes in a two-stage least squares (IV) regression:

$$(3) \qquad Y_{l,t} = \alpha_0 + \alpha_E \widehat{EP}_{l,t} + \alpha_T \widehat{TP}_{l,t} + W_{l,t}\alpha_W + X_{l,t}\alpha_X + \delta_l + \chi_q + \epsilon_{l,t},$$

where $EP_{l,t}$ and $TP_{l,t}$ are now replaced with their predicted values, $\widehat{EP}_{l,t}$ and $\widehat{TP}_{l,t}$, from first stage regressions. Our identifying assumption in the IV model is that e-cigarette and traditional cigarette taxes affect demand only through their effects on e-cigarette and traditional cigarette prices. Thus, we assume that there are no other channels though which taxes can influence sales (e.g., signaling of product risk). We acknowledge that assuming no non-price effects is a strong supposition.

5. Results

a. Summary Statistics

We begin by showing summary statistics and the variation in e-cigarette excise taxes. Table 1 shows summary statistics at the UPC-locality-quarter level. Overall, our sample has 90,730 UPC-locality-quarter observations, of which 10,248 are subject to an e-cigarette tax. The average e-cigarette price per ml of liquid is \$4.40, and the average price is slightly higher in localities that adopt an e-cigarette tax (measured before the tax) than in localities that did not adopt a tax by the end of our timeframe. The conditional (non-zero) mean e-cigarette tax is \$0.68 per fluid ml. The unconditional mean is \$0.044 per fluid ml. The unconditional mean is markedly lower than the conditional mean as many localities do not adopt a tax during our study period, and those localities that adopt a tax implement this policy during the latter portion of our study period. Excise taxes are generally much smaller in magnitude than ad valorem taxes, with the conditional mean value of excise taxes being $0.17 and ad valorem taxes being $1.06 during the study period. These differences underscore the importance of accounting for the size of the tax rather than simply using a dummy variable for any tax. In a binary specification, localities with excise and ad valorem taxes are treated the same, even though the typical excise tax is so small that those localities are effectively much closer to the comparison group of non-tax adopting localities than to the ad valorem tax group.

Table 2 shows summary statistics for our sample when aggregated to the locality-by-quarter level. This sample includes 1,428 locality-by-quarter observations, of which 186 are subject to an e-cigarette tax. On average, 3,608 mls of e-cigarette liquid; 80,732 packs of traditional cigarettes; 5,566 cigars; 5,985 ounces of chewing tobacco; and 712 ounces of loose tobacco are purchased within each locality-quarter by every 100,000 residents. For e-cigarettes, purchases are much lower in localities that adopt an e-cigarette tax, and this is true for traditional cigarettes, cigars and loose tobacco as well (but not for chewing tobacco). These descriptive statistics also show that through 2017 indoor vaping bans were still fairly rare, with only 14% of locality-quarter observations covered, while traditional cigarette indoor smoking bans were much more prevalent (80%).

Figure 1 displays the geographic and dollar variation in our standardized e-cigarette tax measure at the end of our sample period in the 4th quarter of 2017 (additional details are also provided in Appendix Table 1). Kansas, Louisiana, North Carolina, and West Virginia have excise tax values of between $0.05 to $0.075 per fluid ml and California, Minnesota, Pennsylvania have ad valorem tax rates of between 40% to 95%; thus the higher standardized tax values in the ad valorem tax states reflect the larger magnitude of these taxes.

b. Herfindahl–Hirschman Index

Since the pass-through of taxes to prices in part depends on market concentration, we provide supportive evidence by calculating the sample Herfindahl–Hirschman Index (HHI). We use 100% of the e-cigarette products identified in the NRSD[9] to calculate a unit-specific HHI for 70 unique e-cigarette brands[10] in the NRSD between 2011 and 2017. The annual HHI values are 0.294 (2011), 0.357 (2012 and 2013), 0.218 (2014), 0.164 (2015), 0.180 (2016), and 0.188 (2017), and the HHI over the full time period is 0.251. An HHI value of over 0.25 is classified as a highly concentrated industry and an HHI value between 0.15 and 0.25 is a moderately concentrated industry (U.S. Department of Justice 2010), indicating that e-cigarettes were sold by a moderately to highly concentrated industry during our study timeframe. This finding suggests an imperfect level of market competition, which is highly relevant to our main results, as imperfect competition has been theoretically linked to over-shifting of taxes to prices (Besley and Rosen 1999).

c. Estimates of Pass-through of E-Cigarette Taxes

We first present results estimating the effects of e-cigarette taxes on e-cigarette prices. Table 3 presents results estimating equation (1), where the unit of analysis is a UPC-locality-quarter and the independent variable is e-cigarette price. Moving from left to right in the table, we begin with a parsimonious specification that only includes e-cigarette taxes, then we add locality and quarter fixed effects, then we add time-varying controls, then finally we replace the locality

[9] Nielsen began to categorize specific UPC codes as e-cigarettes in 2013. We identify e-cigarettes in 2011 and 2012 as those categorized by Nielsen as e-cigarettes in 2013 and after. For our calculation of the HHI we use all e-cigarettes categorized by Nielsen rather than the 93.5% matched to additional characteristics.

[10] We group obvious brands produced by the same company together. For example, BLU is listed as 'BLU CIGS,' 'BLU ECIGS,' and 'BLU ECIGS PLUS+' etc.

fixed effects with UPC-by-locality fixed effects in the last column. We find that every \$1.00 increase in e-cigarette taxes raises e-cigarette prices by over \$1.31 in all regressions and over \$1.55 in the specifications with fixed effects. These estimates are all statistically significantly different from zero (and from one) at the 1% level. We therefore find robust evidence that e-cigarette taxes are over-shifted to consumers. Examining the last two columns, we do not see that changes in traditional cigarette taxes lead to statistically significant changes in e-cigarette prices, and the point estimates are small in magnitude.

Our estimated pass-through is in line with previous work on other 'sin goods,' which suggests that taxes are passed through at a higher than 100% level, for example, alcohol, traditional cigarettes, and sugar-sweetened beverages (Kenkel 2005, Cawley et al. 2019). A number of possible mechanisms for a higher than 100% pass-through exist within the e-cigarette market. For example, our HHI calculation suggests a high degree of market concentration, supporting the notion that the retail-based e-cigarette industry is imperfectly competitive, a market environment susceptible to over-shifting of taxes to prices. Further, given the wide dispersion of e-cigarette taxes throughout the country (see Figure 1), the existence of cross-border purchases by consumers may not be as common in the market for e-cigarettes as in the case of other similar tobacco products, such as traditional cigarettes.

Next, in order to test the parallel trends assumption of the DD model and to examine whether there were any anticipatory price increases, we estimate an event study. In particular, we treat the e-cigarette tax effective quarter as the event and construct 16 quarter leads (i.e., interactions between an indicator variable for being a tax adopting states and time-to-event) and four quarter lags around this event. Periods (quarter-years) more than 16 (four) quarters in advance (after) the effective date are included in the -16 (+4) bin. All non-adopting localities are coded as zero for event-time bins. The omitted category is the period (quarter-year) prior to the event.

Figure 2 shows the results, displaying the dynamics of e-cigarette prices in the quarters before and after an e-cigarette tax increase. As the event study illustrates, there is no evidence of a differential trend in e-cigarette prices in adopting and non-adopting localities prior to the tax increase. In the quarter after the tax increase, the coefficient estimate increases and stabilizes between 0.4 and 0.5, suggesting that the *implementation* of an e-cigarette tax (without consideration of the tax magnitude) raises prices by \$0.40 to \$0.50, on average. E-cigarette tax rates vary substantially, so the smaller implementation-based estimates (vs. the effects estimated using a DD model and the standardized tax variable, see Table 3) are not surprising. In particular, as we note in Section 1, an attenuation of the tax coefficient estimate when using a simple indictor, rather than our preferred standardized measure, is what one would expect.

We also test the robustness of our results in a number of ways. Table 4 lists results from a number of specification tests. We exclude U.S. Census divisions[11] that do not include any localities with an e-cigarette tax by the end of our study period, exclude time-varying controls, include U.S. Census division-by-quarter fixed effects, include UPC-by-quarter fixed effects, use different weighting methodologies, drop Illinois and Maryland (these states have e-cigarette taxes levied for counties within their borders), examine an alternative strategy for constructing the e-cigarette tax variable, and estimate models for which we impute missing e-cigarette prices (due to no sales in that locality-by-quarter)[12] using the last available price. Our results remain broadly stable and coefficient estimates suggest an over-shifting of e-cigarette taxes to prices in all specifications.

[11] We use the U.S. Census nine division classification.
[12] E-cigarette pries may be missing for three reasons: (1) the product has not yet been introduced into that locality, (2) the product has been introduced in that locality but not sold in that particular quarter, or (3) the product has been discontinued in that locality. Observations from scenario (1) are not relevant to pass-through estimates and therefore

Next, we further explore whether there is heterogeneity in the estimates between state vs. local and ad valorem vs. excise tax variation. One potential issue is the geographic overlap between excise taxes and the levels at which taxes are levied. A second issue is that ad valorem taxes are standardized to be equated as excise taxes. To address these issues, in the second-to-last panel of Table 4 we interact the e-cigarette tax with indicators for an excise (vs. ad valorem) tax and a county-level (vs. state-level) tax. Our results suggest that, once we control for the geographic level of the tax and the tax level, excise taxes and ad valorem taxes are passed through to prices at similar rates. This pattern of results suggests there are no differences in pass-through *rates* due to the standardization process, although overall pass-through *amounts* for ad valorem taxes would be higher on account of the larger size of these taxes. County-level taxes are passed on at lower rates than state taxes, supporting the hypothesis that tax evasion is more likely for smaller localities.

Finally, in the last panel of Table 4 we control for the tax law enactment period by including a variable that accounts for the impact of the interval between signing an e-cigarette tax into law and subsequently implementing it. Results of this investigation are also highly robust.

Next, we systematically drop treatment localities to examine whether any single treated locality has an outsized impact on our coefficients. These results, shown in Appendix Table 2, suggest that our results are stable when removing individual treatment localities. Finally, in Appendix Table 3, we aggregate the data to the locality-by-quarter level to examine pass-through at a higher level of aggregation that does not hold constant product availability/quality. This specification also allows us to examine whether e-cigarette taxes lead to changes in e-cigarette products and/or characteristics. To this end, we examine whether e-cigarette taxes are related to

are appropriately not included in the analysis. Observations from (2) and (3) could be important in estimating pass-through if the tax passes through at such a high rate that it causes products to not be purchased in that quarter (scenario 2), or ever again (scenario 3). Our results are virtually unchanged when using the last available price, thus helping to alleviate these concerns.

the number of new e-cigarette products in each quarter and locality and whether they are related to the average ounces of liquid per unit sold. In this case, we find a somewhat smaller pass-through estimate ($1.107), but the 95% confidence interval includes our estimate from Table 3. We do not find that e-cigarette taxes led to changes in the number of e-cigarette products sold for the first time in a given locality or in the liquid per unit sold, suggesting that manufacturers are not changing their offering of products in response to the taxes.

d. Estimates of Effects of E-Cigarette Taxes on Tobacco Product Sales

Next, we examine the effects of e-cigarette and traditional cigarette prices on the sales of e-cigarettes and other tobacco products. For these analyses, we examine sales at the locality-by-quarter level with equation (3), an IV regression where we instrument for e-cigarette prices and traditional cigarette prices with e-cigarette taxes and traditional cigarette taxes. Relative to the reduced form models estimated thus far, these IV analyses require the additional assumption that taxes only influence sales via prices (i.e., the exclusion restriction). We cannot rule out the possibility that taxes could exert part of their influence through mechanisms besides prices, such as signaling about health risks, in which case the IV estimates could be overstated.

Table 5 shows the results of these models across five tobacco products: e-cigarettes, traditional cigarettes, cigars, chewing tobacco, and loose tobacco. In the first column, every $1.00 increase in e-cigarette prices reduces e-cigarette sales by 1,255 ml of liquid, statistically significant at the 1% level. The e-cigarette results provide an estimated price elasticity of demand for e-cigarettes of -2.6.[13] This estimate suggests that a 10% increase in e-cigarette prices leads to a 26% decrease in e-cigarette sales. Note that, since the magnitude of the estimate is far greater than one,

[13] We multiply the coefficient from Table 5 by the average pre-tax e-cigarette price (5.03 from Appendix Table 3) and divide by average pre-tax e-cigarette sales (2,425 from Table 5): -1,255* (5.03/2,425) = -2.6.

we consider it unlikely that our finding that e-cigarettes are price elastic can be attributed to the potential presence of small secondary mechanisms noted above.

We also find that e-cigarettes and traditional cigarettes are economic substitutes, evident in the positive and statistically significant effect of e-cigarette prices on traditional cigarette sales (and vice versa). In particular, a 1% increase in the price of traditional cigarettes increases e-cigarette sales by 1.19% while a 1% increase in the price of e-cigarettes increases traditional cigarette sales by 0.97%.[14] We estimate a traditional cigarette own price elasticity of -0.63, which is in line with many previous estimates of the price elasticity of demand for traditional cigarettes.[15] We do not find any statistically or economically significant effects of e-cigarette price changes or traditional cigarette price changes on the sales of the other categories of tobacco products.

Comparable elasticities can be computed using back-of-the-envelope calculations based on reduced-form regressions of the sales of tobacco products on cigarette and e-cigarette taxes using equation (2). Appendix Table 4 shows results from these specifications. We find that every $1.00 increase in e-cigarette taxes reduces e-cigarette sales by -1,486 ml and increases traditional cigarette sales by 13,361 cigarettes. These coefficient estimates translate into own and cross-price elasticities of -2.78 and 1.02, respectively, which are very similar to the own and cross-price elasticities we estimate in Table 5. The own and cross-price elasticities estimated from traditional cigarette taxes are -0.65 and 1.24, which are again very similar to the elasticities calculated in Table 5.

[14] Here, we take the traditional cigarette price coefficient from the first column of Table 5 multiplied by the average cigarette price, pre-tax (5.37 from Appendix Table 3) and divide by the average e-cigarette sales pre-tax (2,425 from Table 5). 538*(5.37/2,425) = 1.19. The second number is calculated in a similar way, except we use the average e-cigarette price, pre-tax (5.37 from Appendix Table 3) and the average traditional cigarette sales pre-tax (59,798 from Table 5). Thus, 11,489*(5.03/59,798) = 0.97.

[15] Here, -7,057*(5.37/59,798) = -0.63.

Next, we re-estimate our IV model in equation (3) systematically dropping treatment localities to examine whether any single treated locality has an outsized impact on our coefficient estimates. These results shown in Appendix Table 5 suggest that our results are stable when removing individual treatment localities.[16]

6. Conclusion

In this paper, we examine the effects of e-cigarette taxes on e-cigarette prices, purchases, and other tobacco-related outcomes. We use UPC-level data on retail sales of e-cigarettes and other tobacco products from the NRSD. Importantly, we link the vast majority of e-cigarette UPCs (93.5%) in the NRSD to supplemental product characteristics collected by our research team, including the liquid amount, nicotine levels, and product types.

We find that e-cigarette taxes are passed through to e-cigarette prices at more than a 100% rate, consistent with our HHI calculation suggesting moderate to high market concentration. Our estimate of over pass-through is also similar to an estimate from the literature for the state of Minnesota (Saffer et al. 2019). We also provide the first estimates of e-cigarette market concentration, calculating an HHI of 0.25, which indicates a moderately to highly concentrated market as classified by the U.S. Department of Justice (U.S. Department of Justice 2010). We also find that e-cigarettes are an elastic good, with an estimated price elasticity of demand of -2.6. We estimate that e-cigarettes and traditional cigarettes are economic substitutes, as e-cigarette sales increase with traditional cigarette tax increases and traditional cigarette sales increase with e-cigarette tax increases.

[16] According to NRSD documentation and our conversation with data administrators, in 2017 the composition of stores tracked within the NRSD shifted from grocery stores to dollar stores and club stores. We also explore the sensitivity of our estimates to dropping 2017 data that incorporated this compositional shift. Point estimates remained of the same sign and were not statistically different from estimates using 2017 data.

A limitation of our study is the reliance on e-cigarettes sold through retail stores, ignoring e-cigarettes sold through specialty vape shops and online. Additionally, the NRSD does not include a large percent of sales from convenience and liquor stores. However, this limitation is balanced by the ability to observe UPC-level purchases in the NRSD. As more survey data on e-cigarette use become available, an important area of future research will be to examine how pass-through and elasticity results using self-reported datasets compare with results using scanner data.

Between the end of our study period in 2017 and June 15, 2019, eight additional states have enacted new e-cigarette laws (Connecticut, Delaware, Illinois, New Jersey, New Mexico, New York, Vermont, and Washington) (Public Health Law Center 2019). In late October, 2019, the United States House Ways and Means Committee approved an e-cigarette tax with bipartisan support that set a national e-cigarette tax proportional to the federal traditional cigarette tax (Bloomberg News 2019). Additionally, in 2019 eight states have imposed temporary bans on the sale of all e-cigarettes or flavored e-cigarettes (Campaign for Tobacco-Free Kids 2019a), which is equivalent to an infinite price increase for the banned products, absent likely black market activity.

Our study suggests that, as intended, e-cigarette taxes raise e-cigarette prices and reduce e-cigarette sales. However, an unintended effect is an increase in cigarette sales. The current House bill specifies a tax rate of $50.33 per 1,810 milligrams of nicotine (or $0.028 per milligram). Juul pods today contain 59 milligrams/ml (at 5% nicotine volume). Assuming this conversion, we simulate that if this bill were to become law, the tax would raise e-cigarette prices by $2.54 per ml ($0.0278 x 59 x 1.55 from Table 3). This price increase would reduce e-cigarette purchases by 3,188 ml per 100,000 adults ($2.54 x 1,255 from Table 5), but would increase traditional cigarette purchases by 29,182 packs per 100,000 adults ($2.54 x 11,489 from Table 5). Therefore, a national e-cigarette tax will increase traditional cigarettes purchased by 6.2 extra packs for every one standard e-cigarette pod of 0.7 ml no longer purchased.

Although vaping-related illnesses are a public health concern, traditional cigarettes continue to kill nearly 480,000 Americans each year (Centers for Disease Control and Prevention 2019a), and several reviews support the conclusion that e-cigarettes contain fewer toxicants (National Academies of Sciences Engineering and Medicine 2018, Royal College of Physicians 2019) and are safer for non-pregnant adults (Royal College of Physicians 2019) than traditional cigarettes. Thus, balancing e-cigarette and traditional cigarette use will continue to be an important issue for policymakers to consider as they develop e-cigarette related tobacco control policies.

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Appendix: Standardizing the E-cigarette Taxes

E-cigarette taxes have been levied using either specific excise taxes or ad valorem taxes through 2017. Kansas, Louisiana, North Carolina, West Virginia, Cook County, and Chicago use an excise tax on liquid volume. California, Minnesota, Montgomery County, Pennsylvania, and Washington DC use an ad valorem tax. Chicago uses an excise tax on both liquid volume and the number of disposable or refill units sold. Several Alaskan counties also have e-cigarette taxes, but Alaska is not included in the NRSD and is therefore not included in our standardization exercise. Between the end of our study period in 2017 and June 15, 2019, eight additional states enacted new e-cigarette laws (Connecticut, Delaware, Illinois, New Jersey, New Mexico, New York, Vermont, and Washington).

Ad Valorem Tax: Washington DC's ad valorem tax is conveniently benchmarked to be 100% of the cigarette excise tax, suggesting that each one percentage point of ad valorem tax had a value of approximately \$0.043. We multiply this value by the ratio of sales volume in units to sales volume in ml of fluid (calculated for each tax jurisdiction s on a year-by-quarter basis t) to obtain a measure of tax per ml of fluid.

$$ad\ valorem\ rate_{st} * 0.043 * \frac{sales\ volume\ in\ retail\ units_{st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} = \frac{tax\ revenue_{st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} = tax\ per\ ml\ of\ fluid_{st}$$

One concern with our equation is that the ratio of sales volume in units to ml of fluid may be endogenous to the e-cigarette tax adoption. Therefore, our primary standardized tax measure uses the ratio for all locations that have not adopted e-cigarette taxes by January 2020. As a sensitivity analysis, we use the ratio specific to each jurisdiction. Results are similar regardless of which measure is used.

For **Cook County**, we do not have the ability to separate Chicago from the rest of Cook County in the Nielsen data. For the Chicago portion of the tax, Chicago uses a \$0.55 tax per ml of fluid and a \$0.80 tax per 'container' of products containing liquid nicotine (e.g., cartridge, disposable, bottle of liquid nicotine). We, therefore, calculated tax per ml of fluid in the following way:

$$0.55 + \frac{sales\ volume\ in\ containers_{\ st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} * 0.80 = tax\ per\ ml\ of\ fluid_{st}$$

For the Cook County tax, similar to the approach mentioned earlier to address potential concerns of endogeneity, we used the ratio of sales volume in containers to sale volume in ml of fluid for all locations that have not adopted e-cigarette taxes by January 2020 for our primary standardized e-cigarette tax measure. As a sensitivity analysis, we use the ratio specific to Chicago. Results are similar regardless of which measure is used.

Since Chicago makes up approximately 52.1% of the population of Cook County in 2017, we weighted the Chicago tax by this share of the population to approximate the Cook County tax. Cook County later passed its own tax per fluid ml of fluid that we added in whole to the weighted tax from Chicago.

Figure 1. Map of e-Cigarette taxes per ml of vaping liquid in 4Q 2017

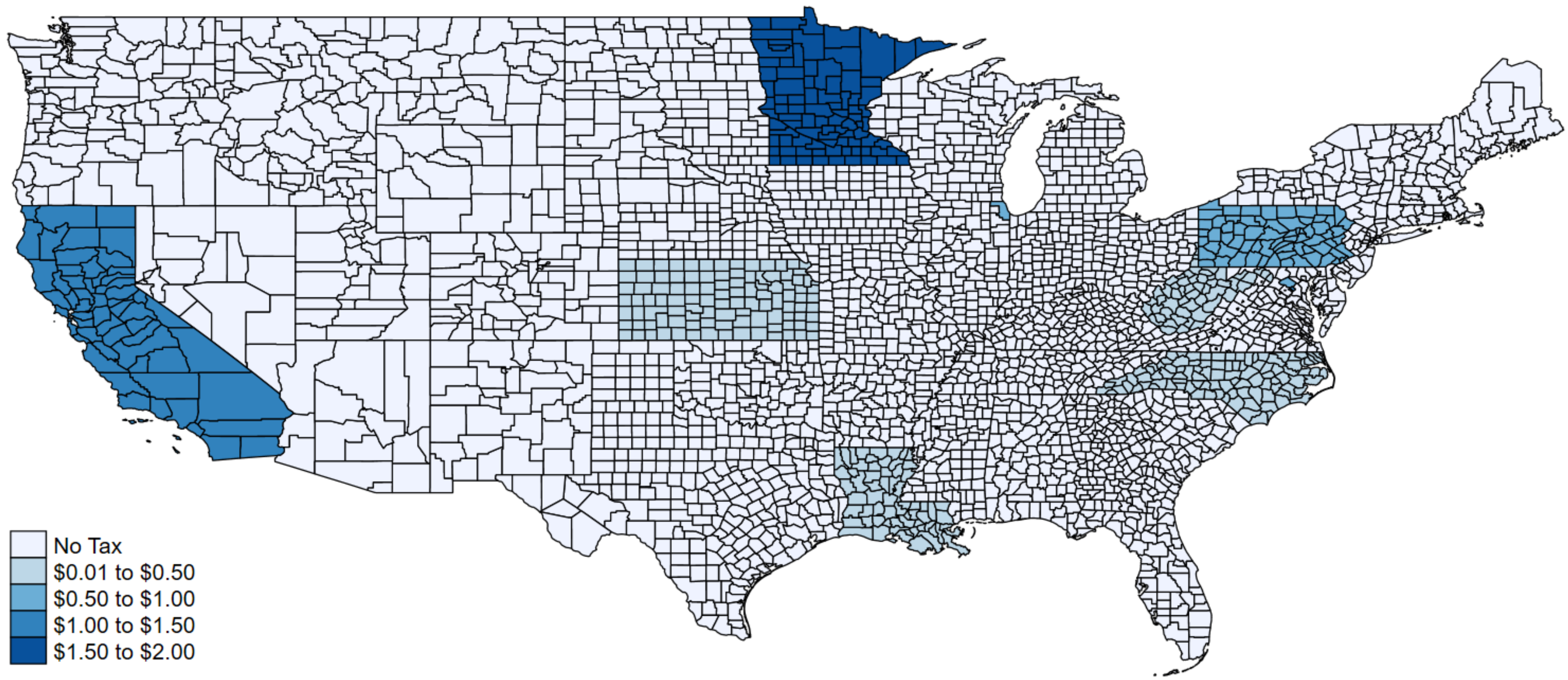
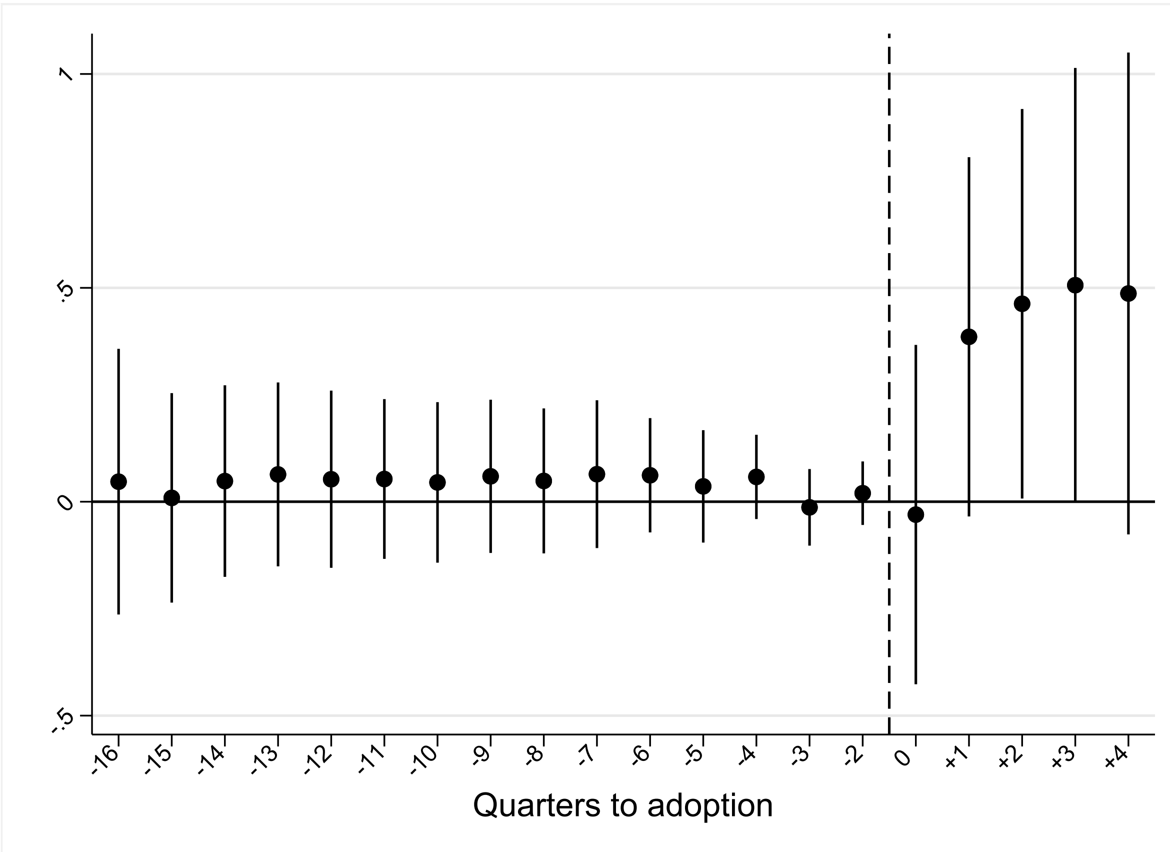


Figure 2. Effect of e-cigarette taxes on e-cigarette prices using an event study: Nielsen retail sales UPC-level data 2011-2017



Notes: The unit of observation is a UPC-code in a locality (state or county) in a quarter (quarter-by-year). The model estimated by equation (1) except using lags and leads from the first available e-cigarette tax in a given locality. The model is estimated with least squares and controls for time-varying locality characteristics, UPC-by-locality fixed effects, and period (quarter-by-year) fixed effects. Circles reflect the beta coefficient estimate and vertical solid lines reflect 95% confidence intervals. The omitted category is the quarter prior to policy adoption.

Table 1. Summary statistics: Nielsen retail sales UPC-level data 2011-2017

Sample:	**All localities**	**Localities that adopt a tax by 2017, pre-tax**	**Localities that do not adopt a tax by 2017**
Prices			
E-cigarette ($ per ML)	4.40	4.49	4.34
E-cigarette taxes			
E-cigarette standardized tax ($)	0.044	--	--
Conditional e-cigarette standardized tax ($)	0.68	--	--
Conditional e-cigarette standardized tax ($) - ad valorem	0.17	--	--
Conditional e-cigarette standardized tax ($) - excise	1.06	--	--
Policies and Demographics			
Traditional cigarette tax ($)	1.57	1.19	1.60
% covered by indoor vaping ban	0.14	0.086	0.13
% covered by indoor smoking ban	0.81	0.86	0.79
Tobacco 21 law	0.01	0.02	0.00
Beer tax ($)	0.26	0.19	0.28
ACA Medicaid expansion	0.34	0.28	0.33
Unemployment rate	6.00	7.14	5.91
Age	38.4	38.1	38.4
Male	0.49	0.48	0.49
Female	0.51	0.52	0.51
White	0.80	0.76	0.82
African American	0.12	0.16	0.11
Other race	0.08	0.08	0.08
Hispanic	0.11	0.12	0.12
Born outside the U.S.	0.10	0.12	0.10
Less than high school	0.15	0.16	0.15
High school	0.29	0.29	0.29
Some college	0.27	0.25	0.28
College	0.28	0.29	0.28
Population (millions)	6.43	10.2	5.85
Observations	90730	10248	73693

Notes: The unit of observation is a UPC-code in a locality (state or county) in a quarter (quarter-by-year). Data are weighted by the share of e-cigarette sales in localities that do not adopt an e-cigarette tax.

Table 2. Summary statistics: Nielsen retail sales locality-level data 2011-2017

Sample:	**All localities**	**Localities that adopt a tax by 2017, pre-tax**	**Localities that do not adopt a tax by 2017**
Sales per 100,000 state adult residents			
E-cigarette (ML)	3,608	2,425	3,962
Tobacco cigarette (packs)	80,732	59,798	88,508
Cigar (units)	5,566	3,425	6,119
Chewing tobacco (ounces)	5,985	6,132	5,894
Loose tobacco (ounces)	712	598	723
E-cigarette taxes			
E-cigarette standardized tax ($)	0.047	--	--
Conditional e-cigarette standardized tax ($)	0.73	.	.
Conditional e-cigarette standardized tax ($) - ad valorem	0.16	.	.
Conditional e-cigarette standardized tax ($) - excise	1.06	.	.
Policies and Demographics			
Traditional cigarette tax ($)	1.64	1.04	1.77
% covered by indoor vaping ban	0.14	0.14	0.12
% covered by indoor smoking ban	0.80	0.86	0.77
Tobacco 21 law	0.03	0.07	0
Beer tax ($)	0.26	0.19	0.28
ACA Medicaid expansion	0.34	0.37	0.30
Unemployment rate	6.45	7.74	6.24
Age	38.2	37.6	38.3
Male	0.49	0.49	0.49
Female	0.51	0.51	0.51
White	0.78	0.76	0.79
African American	0.13	0.11	0.13
Other race	0.09	0.13	0.08
Hispanic	0.17	0.24	0.16
Born outside the U.S.	0.14	0.19	0.13
Less than high school	0.16	0.18	0.16
High school	0.28	0.27	0.29
Some college	0.27	0.27	0.27
College	0.28	0.28	0.28
Population (millions)	14.0	24.9	11.0
Observations	1428	186	1148

Notes: The unit of observation is a locality (state or county) in a period (quarter-by-year). Data are weighted by the locality population.

Table 3. Effect of e-cigarette taxes on e-cigarette prices using a two-way fixed effects model: Nielsen retail sales UPC-level data 2011-2017

Outcome:	**E-cigarette price ($)**			
Mean in e-cigarette tax adopting localities, pre-tax┼	4.49	4.49	4.49	4.49
E-cigarette standardized tax ($)	1.314*** [1.103,1.525]	1.573*** [1.158,1.988]	1.568*** [1.206,1.931]	1.554*** [1.322,1.786]
Traditional cigarette tax per pack ($)	--	--	0.025 [-0.142,0.191]	0.052 [-0.196,0.300]
Locality fixed effects	N	Y	Y	n/a
Period (quarter-by-year) fixed effects	N	Y	Y	Y
Time-varying controls	N	N	Y	Y
UPC-by-locality fixed effects	N	N	N	Y
Observations	90730	90730	90730	90730

Notes: The unit of observation is a UPC-code in a locality (state or county) in a quarter (quarter-by-year). All models estimated with least squares. Data are weighted by the share of e-cigarette sales in localities that do not adopt an e-cigarette tax. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

Table 4. Effect of e-cigarette taxes on e-cigarette prices using a two-way fixed effects model, alternative specifications and samples: Nielsen retail sales UPC-level data 2011-2017

Outcome:	**E-cigarette price ($)**
Mean in e-cigarette tax adopting localities, pre-tax┼	4.49
Exclude divisions with no adopting localities by 2017 (New England, East South Central, and Mountain)	
E-cigarette standardized tax ($)	1.483***
	[1.280,1.686]
Observations	59475
Exclude time-varying locality-level controls	
E-cigarette standardized tax ($)	1.667***
	[1.319,2.016]
Observations	90730
Include division-by-quarter fixed effects	
E-cigarette standardized tax ($)	1.589***
	[1.383,1.795]
Observations	90730
Include UPC-by-quarter fixed effects	
E-cigarette standardized tax ($)	1.653***
	[1.265,2.041]
Observations	90730
Unweighted	
E-cigarette standardized tax ($)	1.575***
	[1.244,1.907]
Observations	90730
Weight by population	
E-cigarette standardized tax ($)	1.445***
	[1.221,1.668]
Observations	90730
Weight by quarterly e-cigarette sales in 2013	
E-cigarette standardized tax ($)	1.334***
	[1.091,1.578]
Observations	90730
Drop Illinois and Maryland (localities with sub-state taxes)	
E-cigarette standardized tax ($)	1.701***
	[1.492,1.909]
Observations	84247
Population-weighted e-cigarette tax for Illinois and Maryland (localities with sub-state taxes)	
E-cigarette standardized tax ($)	1.681***
	[1.473,1.890]
Observations	90730
Use alternative e-cigarette tax variable[1]	
E-cigarette standardized tax ($)	1.284***
	[0.827,1.740]
Observations	90730
Impute missing e-cigarette prices[2]	
E-cigarette standardized tax ($)	1.489***
	[1.299,1.680]
Observations	116018

Table 4. (continued)

Interact e-cigarette tax with indicators for an excise (vs. ad valorem) tax and a county-level (vs. state-level) tax	
E-cigarette standardized tax ($)	1.683***
	[1.469,1.896]
E-cigarette standardized tax ($) * excise tax	0.131
	[-0.374,0.636]
E-cigarette standardized tax ($) * county-level tax	-0.698***
	[-1.154,-0.243]
Observations	90730
Control for the enactment period	
E-cigarette standardized tax ($)	1.540***
	[1.285,1.795]
Enactment period	-0.050
	[-0.255,0.156]
Observations	90730

Notes: The unit of observation is a UPC-code in a locality (state or county) in a quarter (quarter-by-year). All models estimated with least squares and control for time-varying locality characteristics, UPC-by-locality fixed effects, and period (quarter-by-year) fixed effects unless otherwise noted. Data are weighted by the share of e-cigarette sales in localities that do not adopt an e-cigarette tax unless otherwise noted. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ┼Mean values are based on the full sample of e-cigarette adopting localities, pre-tax. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

[1] See the appendix for additional details.

[2] For localities with zero sales for a given UPC code (and hence no available prices), we forward impute with the last available price if a sale had previously been made for that UPC in that locality.

Table 5. Effect of e-cigarette prices on sales per 100,000 adults simultaneously instrumenting e-cigarette and traditional cigarette prices with e-cigarette and traditional cigarette taxes: Neilson state-level sales data 2011-2017

Outcome:	**E-cigarettes**	**Traditional cigarettes**	**Cigars**	**Chewing tobacco**	**Loose tobacco**
Mean sales in adopting localities, pre adoption	2,425	59,798	3,425	6,132	598
E-cigarette price ($)	-1,255***	11,489***	-651	105	-194
	[-2,133,-377]	[3,322,19,657]	[-2,039,736]	[-1,369,1,580]	[-526,137]
Traditional cigarette price ($)	538*	-7,057**	609	-92	112
	[-72,1,149]	[-12,622,-1,492]	[-362,1,581]	[-981,798]	[-74,298]
Observations	1428	1428	1428	1428	1428

Notes: All models estimated with two-stage least squares and control for time-varying area characteristics, area fixed effects, and period (quarter-by-year) fixed effects. 1st stage *F*-statistics are 14.95 for e-cigarette prices and 408.74 for traditional cigarette prices. 95% confidence intervals that account for within-state clustering are reported in square brackets. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

APPENDIX TABLES

Appendix Table 1. E-cigarette tax adoption through the end of 2017

Locality	Effective date	Unit taxed	Tax amount	Tax value Q4 2017 ($)
State				
California	4/2017, 7/2017	Wholesale price	27.3%, 65.1%	1.272
District of Columbia	10/2015, 10/2016	Wholesale price	67%, 65%	1.272
Kansas	1/2017, 7/2017	Per fluid milliliter	$0.20, $0.05	0.050
Louisiana	7/2015	Per fluid milliliter	$0.05	0.050
Minnesota	8/2010, 7/2013	Wholesale price	35%, 95%	1.849
North Carolina	6/2015	Per fluid milliliter	$0.05	0.050
Pennsylvania	7/2016	Wholesale price	40%	0.775
West Virginia	7/2016	Per fluid milliliter	$0.075	0.075
County/City				
Chicago, Illinois	1/2016	Per unit / per fluid milliliter	$0.80 / $0.55	0.606^
Cook County, Illinois	5/2016	Per fluid milliliter	$0.20	0.606^
Montgomery County, Maryland	8/2015	Wholesale price	30%	0.586

Notes: See text for full details. Minnesota is a treated control for our study period. ^ The Chicago tax is added to the Cook County tax based on the share of the population residing in Chicago, see the appendix for further details.

Appendix Table 2. Effect of e-cigarette taxes on e-cigarette prices using a two-way fixed effects model excluding treated localities one at a time: Nielsen retail sales UPC-level data 2011-2017

Outcome:	**E-cigarette price ($)**
Mean in e-cigarette tax adopting localities, pre-tax┼	4.49
Exclude California	
E-cigarette standardized tax ($)	1.540***
	[1.278,1.803]
Observations	88559
Exclude Cook County, IL	
E-cigarette standardized tax ($)	1.614***
	[1.383,1.846]
Observations	89182
Exclude DC	
E-cigarette standardized tax ($)	1.478***
	[1.149,1.807]
Observations	89651
Exclude Kansas	
E-cigarette standardized tax ($)	1.560***
	[1.328,1.793]
Observations	89155
Exclude Louisiana	
E-cigarette standardized tax ($)	1.544***
	[1.314,1.773]
Observations	88729
Exclude Minnesota	
E-cigarette standardized tax ($)	1.457***
	[1.246,1.669]
Observations	89263
Exclude Montgomery County, MD	
E-cigarette standardized tax ($)	1.624***
	[1.400,1.847]
Observations	89467
Exclude North Carolina	
E-cigarette standardized tax ($)	1.555***
	[1.323,1.788]
Observations	88656
Exclude Pennsylvania	
E-cigarette standardized tax ($)	1.601***
	[1.346,1.857]
Observations	88667
Exclude West Virginia	
E-cigarette standardized tax ($)	1.550***
	[1.318,1.781]
Observations	88934

Notes: The unit of observation is a UPC-code in a locality (state or county) in a quarter (quarter/year). All models estimated with least squares and control for time-varying locality characteristics, UPC-by-locality fixed effects, and period (quarter-by-year) fixed effects. Data are weighted by the share of e-cigarette sales in localities that do not adopt an e-cigarette tax. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ┼Mean values are based on the full sample of e-cigarette adopting localities, pre-tax. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

Appendix Table 3. Effect of e-cigarette and traditional cigarette taxes on the prices, number of new e-cigarette products, and liquid per unit using a two-way fixed effects model: Nielsen retail sales state-level data 2011-2017

Outcome:	**Traditional cigarette price ($)**	**E-cigarette price ($)**	**Number of new e-cigarette products**	**Liquid per unit**
Mean in e-cigarette tax adopting localities, pre-tax	5.37	5.03	14.3	1.47
E-cigarette standardized tax ($)	0.123 [-0.062,0.309]	1.107** [0.248,1.966]	-2.016 [-5.084,1.052]	0.029 [-0.216,0.273]
Traditional cigarette tax per pack ($)	1.064*** [0.961,1.168]	-0.059 [-0.470,0.353]	-0.259 [-1.381,0.864]	0.061 [-0.109,0.231]
Observations	1428	1428	1428	1428

Notes: The unit of observation is a locality (state or county) in a quarter (quarter/year). All models estimated with least squares and control for time-varying locality characteristics, locality fixed effects, and period (quarter-by-year) fixed effects. Data are weighted by the average quarterly traditional cigarette sales in 2011 in the traditional cigarette pass-through regression; by the average quarterly e-cigarette sales in 2013 in the e-cigarette pass-through regression; and the average quarterly e-cigarette sales in 2013 for the new product and liquid per unit regressions. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

Appendix Table 4. Effect of e-cigarette taxes on e-cigarette and tobacco product sales per 100,000 state adult residents using a two-way fixed effects model: Nielsen retail sales locality-level data 2011-2017

Outcome:	E-cigarettes	Traditional cigarettes	Cigars	Chewing tobacco	Loose tobacco
Mean in e-cigarette tax adopting localities, pre-tax	2,425	59,798	3,425	6,132	598
E-cigarette standardized tax ($)	-1,486***	13,361**	-734	119	-227
	[-2,307,-666]	[3,324,23,398]	[-2,338,871]	[-1,783,2,022]	[-597,144]
Traditional cigarette tax per pack ($)	595**	-7,724*	662	-100	123
	[132,1,058]	[-15,568,121]	[-406,1,731]	[-1,146,946]	[-92,338]
Observations	1428	1428	1428	1428	1428

Notes: The unit of observation is a locality (state or county) in a quarter (quarter-by-year). All models estimated with least squares and control for time-varying locality characteristics, locality fixed effects, and period (quarter-by-year) fixed effects. Data are weighted by the locality population. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ***,**, and * = statistically different from zero at the 1%, 5%, and 10% level.

Appendix Table 5. Effect of e-cigarette prices on sales per 100,000 adults instrumenting the e-cigarette price with the e-cigarette tax and instrumenting the traditional cigarette price with the traditional cigarette tax (*leave one out analysis)*: Neilson state-level sales data 2011-2017

Outcome:	**E-cigarettes**	**Traditional cigarettes**	**Cigars**	**Chew tobacco**	**Loose tobacco**
Mean sales in adopting localities, pre adoption┼	2,425	59,798	3,425	6,132	598
Exclude California					
E-cigarette price ($)	-1,881***	14,263***	-895	-762	-320
	[-3,216,-547]	[3,834,24,693]	[-2,872,1,082]	[-3,041,1,517]	[-828,188]
Traditional cigarette price ($)	185	-9,029***	426	-508	94
	[-572,941]	[-14,457,-3,601]	[-675,1,528]	[-1,657,642]	[-120,308]
Observations	1400	1400	1400	1400	1400
Exclude Cook Co, IL					
E-cigarette price ($)	-965***	9,834***	-647	-52	-109
	[-1,515,-415]	[3,130,16,539]	[-2,032,737]	[-1,488,1,384]	[-372,154]
Traditional cigarette price ($)	346	-6,501**	721	-25	90
	[-164,857]	[-12,234,-768]	[-292,1,734]	[-962,913]	[-95,275]
Observations	1400	1400	1400	1400	1400
Exclude DC					
E-cigarette price ($)	-1,211***	10,967***	-568	24	-183
	[-2,063,-359]	[2,748,19,185]	[-1,944,809]	[-1,504,1,551]	[-512,146]
Traditional cigarette price ($)	516*	-6,804**	572	-62	107
	[-92,1,124]	[-12,484,-1,123]	[-392,1,537]	[-970,845]	[-78,292]
Observations	1400	1400	1400	1400	1400
Exclude Kansas					
E-cigarette price ($)	-1,287***	10,478***	-701	138	-203
	[-2,166,-408]	[2,663,18,294]	[-2,117,715]	[-1,329,1,605]	[-541,135]
Traditional cigarette price ($)	563*	-6,261**	648	-114	119
	[-69,1,194]	[-11,538,-984]	[-346,1,641]	[-1,008,779]	[-71,309]
Observations	1400	1400	1400	1400	1400
Exclude Louisiana					
E-cigarette price ($)	-1,333***	12,627***	-312	-15	-182
	[-2,277,-390]	[3,908,21,345]	[-1,468,844]	[-1,642,1,612]	[-539,174]
Traditional cigarette price ($)	595*	-7,903***	370	-9	105
	[-61,1,251]	[-13,704,-2,103]	[-451,1,191]	[-951,933]	[-96,306]
Observations	1400	1400	1400	1400	1400
Exclude Minnesota					
E-cigarette price ($)	-1,036**	12,412**	-753	401	-216
	[-1,981,-91]	[2,904,21,921]	[-2,346,841]	[-1,272,2,074]	[-632,199]
Traditional cigarette price ($)	704***	-7,522**	674	-66	122
	[194,1,215]	[-13,711,-1,332]	[-450,1,799]	[-1,022,889]	[-95,338]
Observations	1400	1400	1400	1400	1400
Exclude Montgomery Co, MD					
E-cigarette price ($)	-1,269***	10,841***	-674	162	-248
	[-2,143,-395]	[2,703,18,978]	[-2,090,741]	[-1,323,1,647]	[-589,93]
Traditional	544*	-6,714**	623	-122	141

cigarette price ($)	[-82,1,170]	[-12,423,-1,004]	[-367,1,614]	[-1,041,798]	[-52,333]
Observations	1400	1400	1400	1400	1400
Exclude North Carolina					
E-cigarette price	-1,280***	12,030***	-680	407	-211
($)	[-2,161,-400]	[3,526,20,535]	[-2,058,698]	[-632,1,446]	[-537,116]
Traditional	540*	-6,977**	621	-98	116
cigarette price ($)	[-74,1,153]	[-12,620,-1,334]	[-349,1,590]	[-872,675]	[-72,303]
Observations	1400	1400	1400	1400	1400
Exclude Pennsylvania					
E-cigarette price	-1,161**	12,654***	-587	378	-144
($)	[-2,173,-150]	[3,792,21,517]	[-1,900,726]	[-1,203,1,960]	[-480,192]
Traditional	520*	-7,254**	604	-159	102
cigarette price ($)	[-64,1,104]	[-12,919,-1,589]	[-358,1,566]	[-1,040,721]	[-89,292]
Observations	1400	1400	1400	1400	1400
Exclude West Virginia					
E-cigarette price	-1,266***	11,313***	-648	-6	-149
($)	[-2,158,-374]	[2,955,19,671]	[-2,060,764]	[-1,546,1,534]	[-458,160]
Traditional	549*	-6,889**	618	-23	81
cigarette price ($)	[-68,1,166]	[-12,522,-1,257]	[-369,1,605]	[-929,883]	[-91,253]
Observations	1400	1400	1400	1400	1400

Notes: All models estimated with two-stage least squares and control for time-varying locality characteristics, locality fixed effects, and period (quarter-by-year) fixed effects. 95% confidence intervals that account for within-locality clustering are reported in square brackets. ┼Mean values are based on the full sample of e-cigarette adopting localities, pre-tax. ***, **, and * = statistically different from zero at the 1%, 5%, and 10% level.