Members of the Labor and Commerce Committee,

My name is Alex McDonald and I own Ice Fog Vapor in Fairbanks, AK. I am writing today to oppose HB110. This bill is highly flawed and will lead to increased costs to the state, leaving less money for communities, while increasing smoking rates as well. Vapor products help Alaskans across the state quit smoking. I smoked for 19 years and tried a variety of approved traditional methods to quit, with vapor products being the only thing that worked for me. My whole family has been smoke free for 8 years now. Please see the attached study published in the New England Journal of Medicine 2/14/19 that clearly shows these products have been found to be twice as effective as traditional cessation products.

This bill would cost the state money we do not have. If you look at the attached State Budget Solutions publication in table 4 page 6, it shows that in 2012 the State of Alaska brought in $67 million in tobacco taxes and $30 million in tobacco settlement payments. The cost to the state for Medicaid for smoking related illness was $202 million or 108% of what the state received. Keep in mind these figures are before Medicaid was expanded so the savings to the state now would likely be far greater than the 2012 figure. Less people smoking means more savings to the state budget for years to come, leaving more in the budget for communities like ours.

In the attached study from the National Bureau of Economic Research, they stated that "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." They also state that "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." The study also points out that "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." Policies like the ones contained in HB110 have been shown to increase smoking rates instead of decreasing the smoking rates. Smoking is the number one cause of preventable death in this country. We should be putting policies in place that help lower preventable deaths in our state instead of increasing that number.

The American Consumer Institute Center for Citizen Research published a report titled "Are E-Cigarette Regulations Jeopardizing Public Health?" They bring up some very good points and dispel many of the myths regarding vapor products. As far as the products safety they report that "In 2015, Public Health England conducted a systematic review of the evidence and concluded that e-cigarettes are at least 95 percent less harmful than conventional cigarettes. Other health organizations, including the Royal College of Physicians, National Academies of Science, Engineering, and Medicine, and American Cancer Society, have also acknowledged. that vaping is a safer alternative for adult cigarette smokers. One 2018 study written by a team of authors from the Georgetown University Medical Center estimated that 6.6 million lives could be saved in the U.S. over the next 10 years." They also point out the need for changes to the Premarket Tobacco Application that will need to be made by or these products will be possibly pulled from the market. "companies will still need to submit a "Premarket Tobacco Application" (PMTA) to the FDA… or else be forced to close shop, no easy task as suggested by the first company to submit the application." This application costs around $1million per flavor of liquid, with no standard of approval, and no small business can afford that cost.

The report also addresses youth use and the myth that it is leading to hooking a new generation. They state, "Indeed, among teens who use e-cigarettes regularly, almost all are (or were) smokers, suggesting that vaping may be an effective substitute for smoking among adolescents. The 2015 National Youth Tobacco Survey, for example, revealed that only 0.3 percent of non-smoking adolescents regularly vaped. A paper in the American Journal of Preventive Medicine found that non-smoking high school students are highly unlikely to use e-cigarettes; only six percent of 12th graders who had never smoked had used e-cigarettes in the past 30 days, and less than one percent used e-cigarettes regularly." Everyone I know does the best they can to keep products intended to help adults out of the hand of our youth. Brick and mortar stores are the first line of defense to card and ensure these products are sold to adults of age.

The report also finds taxing vapor products counter to public health interests and states, "More than a dozen states have implemented special taxes on e-cigarettes, typically in order to bring them in line with taxes on combustible tobacco products. But while tax parity might seem fair, proposals to jack up prices on e-cigarettes threaten to undermine policymakers' broader goals of improving public health." They also report "Imposing similar taxes on e-cigarettes runs counter to this logic, since the aggregate public health impact of e-cigarettes, compared to smoking, is positive. For example, a recent study found that, even under pessimistic assumptions, e-cigarettes will deliver significant public health benefits over the next half-century, extending the aggregate longevity of the U.S. population by 580,000 years."

The issue of taxation of vapor products was brought up during the Walker Administration and rejected as bad policy. The legislature found it to be a highly regressive tax hitting lower income Alaskans the hardest. The attached Vaping, e-cigarettes and public policy toward alternatives illustrates this in their finding that "2010 to 2011, smokers earning less than $30,000 per year spent 14.2 percent of their household income on cigarettes, compared to 4.3 percent for smokers earning between $30,000 and $59,999 and 2 percent for smokers earning more than $60,000." The legislature also stated that the money would be better left for families to spend on their kids while others simply saw it as a money grab that would push people back to smoking.

It was also found to be a job killer and would close small businesses across the state. The issue was recently brought up for the City of Fairbanks and the Fairbanks North Star Borough and was rejected as well. Kodiak also voted against a similar tax measure as shops could not survive the added costs. Steam Trunk in Kodiak closed last fall and Arctic Vapor in Fairbanks closed its doors last spring as well even without burdensome taxes in place. This tax would close small businesses and restrict consumer choice of safer alternatives to smoking traditional cigarettes further increasing the smoking rates for the state.

Thank you for your consideration of this matter. I hope we can all work together to make Alaska, and our community a better healthier place.

Alex McDonald

Are E-Cigarette Regulations Jeopardizing the Public Health?

A Review of the Evidence and Policy Missteps

March 9, 2020

The American Consumer Institute
Center for Citizen Research

Are E-Cigarette Regulations Jeopardizing the Public Health?

A Review of the Evidence and Policy Missteps[1]

Summary

In merely a decade, e-cigarettes have gone from fringe novelties to mainstream products used by millions of Americans. In response to rising teen use, policymakers in many jurisdictions have responded with burdensome taxes and regulations meant to mitigate this perceived public health threat. Yet, the reality is more nuanced. E-cigarettes are far less harmful than combustible cigarettes and constitute one of the most common -- and effective -- smoking cessation aids. Overzealous or poorly designed restrictions on vaping, combined with misleading information about e-cigarettes' true health risks, are deterring smokers from pursuing a potentially life-saving alternative. This report debunks common misunderstandings about e-cigarettes and highlights e-cigarettes' untapped potential to mitigate the harm done by combustible tobacco products.

Introduction

Electronic cigarettes (e-cigarettes) are devices – often resembling cigarettes, cigars or pipes -- designed to deliver nicotine to users in the form of a vapor. A mere decade ago, e-cigarettes were a peripheral phenomenon in the U.S. that attracted little attention from policymakers. Since 2014, however, e-cigarettes have experienced a boom in popularity, and their growing impact on public health has generated intense debate.

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[1] Liam Sigaud, Dr. Krisztina Pusok, Janson Q. Prieb and Steve Pociask *are with the American Consumer Institute, Center for Citizen Research, a nonprofit educational and research organization. A special thanks to Guy Bentley, Director of Consumer Freedom Research at the Reason Foundation, for his helpful comments. For more information about the Institute, visit* www.TheAmericanConsumer.Org *or follow us on Tweeter @ConsumerPal.*

Lawmakers and regulators around the U.S. must decide where e-cigarettes fit into a broader tobacco harm reduction strategy, and what policies are appropriate to protect the public while encouraging smokers to use e-cigarettes as healthier substitutes. In some countries, particularly the United Kingdom, public health officials have embraced e-cigarettes as effective smoking cessation aids. So far, policymakers in the U.S. have adopted a far more skeptical, even hostile, stance toward e-cigarettes.

The stakes are high. In 2017, 2.8% of U.S. adults (6.9 million) were current e-cigarette users.[2] In addition, last year, more than 3.6 million U.S. middle and high school students reported using e-cigarettes in the past 30 days, including 4.9% of middle school students and 20.8% of high school students.[3]

The Centers for Disease Control and Prevention (CDC) reports that more than 480,000 people in the U.S. die each year of smoking-related illnesses, and more than 16 million Americans are living with a disease caused by smoking.[4] If e-cigarettes can reduce smoking rates, the public health gains -- particularly when compounded over long time spans -- could be substantial. On the other hand, some fear that vaping's surging popularity among teens could entice more young people to take up cigarette smoking.

The attack against e-cigarettes is going full steam ahead. Earlier this year, the Trump administration announced a ban on all flavored e-cigarette cartridges, excluding tobacco and menthol.[5] Meanwhile, disposable and open-system e-cigarettes avoided the flavor ban, but that could change at any time, as the House recently passed legislation that would end all

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[2] Teresa W. Wang, Kat Asman, Andrea S. Gentzke, et al., "Tobacco Product Use Among Adults — United States, 2017," Centers for Disease Control and Prevention, November 9, 2018, https://www.cdc.gov/mmwr/volumes/67/wr/mm6744a2.htm?s_cid=mm6744a2_w.

[3] Karen A. Cullen, Bridget K. Ambrose, Andrea S. Gentzke et al., "Notes from the Field: Use of Electronic Cigarettes and Any Tobacco Product Among Middle and High School Students — United States, 2011–2018," Centers for Disease Control and Prevention, November 16, 2018, https://www.cdc.gov/mmwr/volumes/67/wr/mm6745a5.htm?s_cid=mm6745a5_w.

[4] "Smoking & Tobacco Use: Fast Facts," Centers for Disease Control and Prevention, February 6, 2019, https://www.cdc.gov/tobacco/data_statistics/fact_sheets/fast_facts/index.htm.

[5] Jamie Ducharme, "Trump Administration Announces Stripped-Down Regulations on Flavored Vaping Products," *Time*, January 2, 2020, https://time.com/5758004/flavored-vape-ban/.

flavored e-cigarettes, including menthol flavors, regardless of device.[6] The bill also includes various other restrictions and an excise tax on nicotine.[7]

Progress on enacting regulations does not seem to stop, as mounting pressure from the Food and Drug Administration (FDA) is forcing manufacturers like Juul to implement age locks on their products.[8] Making matters even worse, companies will still need to submit a "Premarket Tobacco Application" (PMTA) to the FDA by May 12th or else be forced to close shop, no easy task as suggested by the first company to submit the application.[9]

Yet, the attack on e-cigarettes is not limited to the federal level. New Jersey, for instance, is set to ban all flavored e-cigarettes sales by April, 2020, forcing some 270 shops across the state to either move or close shop entirely.[10] Meanwhile, Massachusetts passed a bill that would impose a 75 percent tax on e-cigarettes and banned all flavors (except those smoked on-site), thereby limiting access "puff shops."[11] And in Colorado, a bill is being proposed that would do away with flavored e-cigarettes completely.[12] A number of municipalities and counties are also following suit.

An important shortfall of these legislative efforts is that they fail to address the illicit e-cigarettes market that caused this "vaping epidemic" in the first place. According to Public

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[6] H.R.2339 - Reversing the Youth Tobacco Epidemic Act of 2019, https://www.congress.gov/bill/116th-congress/house-bill/2339 .

[7] Spencer Platt, "House Passes Bill to Ban the Sale of Flavored e-cigarettes and Tobacco Products," NBC News, February 28, 2020, https://www.nbcnews.com/politics/politics-news/house-passes-bill-ban-sale-flavored-e-cigarettes-n1145186.

[8] Audrey Concklin, "Juul, facing FDA pressure, plans age lock," Fox Business, February 25, 2020, https://www.foxbusiness.com/technology/juul-age-lock-21.

[9] Jim McDonald, "The First Vape PMTA Has Been Submitted to the FDA," October 14, 2019, https://vaping360.com/vape-news/85364/the-first-vape-pmta-has-been-submitted-to-the-fda/.

[10] Tracy Tully, "Vape Shops Face a Choice: Close or Rebrand?" New York Times, February 19, 2020, https://www.nytimes.com/2020/02/19/nyregion/new-jersey-vape-stores.html.

[11] Vanessa Romo, "Massachusetts Governor Signs Law Severely Restricting Flavored Tobacco, Vape Products," NPR, November 27, 2019, https://www.npr.org/2019/11/27/783400051/massachusetts-governor-signs-law-severely-restricting-flavored-tobacco-vape-prod.

[12] John Daley, "A New Bill Would Ban The Sale of All Flavored Nicotine Products," February 21, 2020, CPR News, https://www.cpr.org/2020/02/21/a-new-bill-would-ban-the-sale-of-all-flavored-nicotine-and-tobacco/.

Health England, the risks of vaping are around 95 percent safer than smoking.[13] Meanwhile, the vast majority of all illnesses and deaths have been linked to chemicals such as vitamin E acetate that is found in cartridges containing tetrahydrocannabinol (THC). This was not initially acknowledged by the CDC, which failed to release this information to the public for months. Despite CDC's recent correction, it seems the damage has already been considerable, as 66 percent of people now believe that legal vapes have caused these illnesses, a figure 10 points higher than compared to last September.[14]

Health Consequences of E-cigarette Use

Compared to non-smoking, e-cigarettes are by no means safe. In addition to nicotine, e-cigarette vapor can potentially contain heavy metals, toxic flavorings, and carcinogens. Studies of e-cigarette users have documented increased levels of oxidative stress, impaired respiratory function, and light-headedness, among other effects.[15]

While e-cigarettes are not without risk, experts agree that they pose a considerably lower threat to health than regular cigarettes. Since e-cigarettes do not combust tobacco, they do not produce the dangerous tars and disease-causing gasses associated with regular cigarettes. The doses of toxins contained in e-cigarettes are typically hundreds or thousands of times lower than in regular cigarettes.

A 2011 study in the *Journal of Health Policy* reviewed more than a dozen scientific reports and found that, other than tobacco-specific nitrosamines (TSNAs) and diethylene glycol

[13] Public Health England, "E-cigarettes around 95% less harmful than tobacco estimates landmark review," August 19, 2015, https://www.gov.uk/government/news/e-cigarettes-around-95-less-harmful-than-tobacco-estimates-landmark-review.
[14] Sara Wilson, "E-Cigarettes Increasingly Blamed for Lung Illnesses, as Evidence Points Elsewhere," Morning Consult, February 5, 2020, https://morningconsult.com/2020/02/05/electronic-cigarettes-increasingly-blamed-by-public-for-lung-illnesses-even-as-evidence-points-elsewhere/.
[15] Charlotta Pisinger, "A systematic review of health effects of electronic cigarettes," World Health Organization, December 2015, https://www.who.int/tobacco/industry/product_regulation/BackgroundPapersENDS3_4November-.pdf.

(DEG) which were found in trace amounts in some products, "few, if any, chemicals at levels detected in electronic cigarettes raise serious health concerns."[16] The study goes on to state:

> "Although the existing research does not warrant a conclusion that electronic cigarettes are safe in absolute terms and further clinical studies are needed to comprehensively assess the safety of electronic cigarettes, a preponderance of the available evidence shows them to be much safer than tobacco cigarettes and comparable in toxicity to conventional nicotine replacement products."[17]

In 2015, Public Health England conducted a systematic review of the evidence and concluded that e-cigarettes are at least 95 percent less harmful than conventional cigarettes.[18] Other health organizations, including the Royal College of Physicians,[19] National Academies of Science, Engineering, and Medicine,[20] and American Cancer Society,[21] have also acknowledged that vaping is a safer alternative for adult cigarette smokers. One 2018 study written by a team of authors from the Georgetown University Medical Center estimated that $6.6 million lives could be saving in the U.S. over the next 10 years.[22] More empirical evidence will be provided later in this report.

So, while non-smokers would be ill-advised to take up vaping, smokers could reap significant health benefits from switching to e-cigarettes.

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[16] Zachary Cahn and Michael Siegel, "Electronic cigarettes as a harm reduction strategy for tobacco control: A step forward or a repeat of past mistakes?," *Journal of Public Health Policy*, February 2011, https://link.springer.com/article/10.1057/jphp.2010.41.

[17] Ibid.

[18] "E-cigarettes around 95% less harmful than tobacco estimates landmark review," Public Health England, August 19, 2015, https://www.gov.uk/government/news/e-cigarettes-around-95-less-harmful-than-tobacco-estimates-landmark-review.

[19] "Nicotine without smoke: Tobacco harm reduction," Royal College of Physicians, April 28, 2016, https://www.rcplondon.ac.uk/projects/outputs/nicotine-without-smoke-tobacco-harm-reduction-0.

[20] "Public Health Consequences of E-Cigarettes," National Academies of Sciences, Engineering, and Medicine, 2018, https://www.nap.edu/catalog/24952/public-health-consequences-of-e-cigarettes.

[21] "American Cancer Society Position Statement on Electronic Cigarettes," American Cancer Society, February 15, 2018, https://www.cancer.org/healthy/stay-away-from-tobacco/e-cigarette-position-statement.html.

[22] David T. Levy, Ron Borland, Eric N Lindblom, et al., "Potential deaths averted in USA by replacing cigarettes with e-cigarettes," *Tobacco Control*, 2018, https://tobaccocontrol.bmj.com/content/27/1/18.

Misinformation About E-cigarettes' Health Risks

Despite the findings of prominent scientific authorities, the public remains deeply skeptical of e-cigarettes, according to data from two multiyear cross-sectional nationally representative surveys—the Tobacco Products and Risk Perceptions Surveys (TPRPS) and the Health Information National Trends Surveys (HINTS).[23] In 2017, the TPRPS indicated that 36.4 percent of American adults believed e-cigarettes were as harmful as regular cigarettes, while 4.3 percent believed e-cigarettes were more harmful than regular cigarettes. The HINTS found that 55.6 percent of American adults in 2017 believed e-cigarettes were as harmful as regular cigarettes, and 9.9 percent believed e-cigarettes were more harmful.

Moreover, the proportion of U.S. adults who perceived e-cigarettes to be as harmful as or more harmful than cigarettes increased substantially from 2012 to 2017, even as countervailing scientific evidence grew.[24] These misperceptions were also observed in a March 2020 empirical study by Public Health England:

> "Perceptions of harm from vaping among smokers are increasingly out of line with the evidence. The proportion who thought vaping was less harmful than cigarettes declined from 45% in 2014 to 34% in 2019. These misperceptions are particularly common among smokers who do not vape. "[25]

The public can hardly be blamed for having erroneous views, however, given the barrage of misleading or incomplete information peddled by a host of public health organizations and even government agencies. The National Institute on Drug Abuse for Teens, for example, posts on its website, "Aren't E-Cigs Better Than Traditional Cigarettes? We don't

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[23] Jidong Huang, Bo Feng, Scott R. Weaver, et al., "Changing Perceptions of Harm of e-Cigarette vs Cigarette Use Among Adults in 2 US National Surveys From 2012 to 2017," *Journal of the American Medical Association*, March 29, 2019, https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2729471.
[24] Ibid.
[25] Ann McNeill, Leonie Brose, et al, "Vaping in England: An Evidence Update Including Metal Health and Pregnancy," Commissioned by Public Health England, March 2020, p. 13. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869401/Vaping_in_England_evidence_update_March_2020.pdf.

know."[26] Earlier this year, the Pennsylvania Department of Health tweeted, "E-cigarettes, e-cigs, e-hookahs, mods, vape pens or vapes—whatever you call them, they are NOT safer than other tobacco products."[27]

Similarly, the FDA states that "All tobacco products are harmful to your health, despite what they taste, smell, or look like," without making any distinction between the relative risks of different products.[28] "Scientists have been working hard to debunk the belief that e-cigarettes are less harmful than traditional cigarettes," the American Lung Association announced in a recent blog post, citing a study that found that nicotine from e-cigarettes can impair airway functions -- much like combustible cigarette smoking does.[29] The American Lung Association failed to point out e-cigarettes do not cause a host of other health issues associated with combustible cigarette smoking.

There is also some growing evidence that the ongoing release of advertisements exaggerating the dangers of e-cigarettes may be having adverse consequences on the public. Specifically, government-sponsored health advertisements targeting teenagers of the dangers of vaping may actually be heightening their curiosity and increasing the use of these products among youth.[30] Consumers deserve to have the right information to make decisions about their health.

The purveyors of this misinformation might argue that scare tactics are justified as a means of discouraging non-smokers, particularly among young people, from trying e-cigarettes in the first place. But while smoking initiation through e-cigarette use is a valid concern,

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[26] Sara Bellum, "E-Cig Popularity on the Rise," National Institute on Drug Abuse for Teens, November 7, 2013, https://teens.drugabuse.gov/blog/post/e-cig-popularity-rise.
[27] Michelle Minton, "Anti-E-Cigarette Puritans Put Lives at Risk," Competitive Enterprise Institute, March 6, 2019, https://cei.org/sites/default/files/Michelle_Minton_-_Anti-E-Cigarette_Puritans_Put_Lives_at_Risk.pdf.
[28] "Tobacco-Related Health Fraud," U.S. Food and Drug Administration, January 18, 2018, https://www.fda.gov/tobacco-products/health-information/health-fraud#reference.
[29] "Another Gross Reason to Put Down the E-Cigarettes," American Lung Association, June 27, 2019, https://www.lung.org/about-us/blog/2019/06/another-gross-reason.html.
[30] Michael McGrady, "Do Anti-Vaping Ads and Media Actually Encourage Youth Vaping? *Filter*, February 26, 2020, https://filtermag.org/ads-encourage-youth-vaping/; and Michelle Minton, "Blame Anti-Tobacco Advocates for Youth Vaping *Epidemic*," Competitive Enterprise Institute, December 20, 2019, https://cei.org/blog/blame-anti-tobacco-advocates-youth-vaping-epidemic.

spreading misleading information about e-cigarette risks also discourages smokers from trying safer alternatives. In a recent article, writer Cheantay Jensen explains how, after replacing her smoking habit with e-cigarettes a few years ago and ridding herself of her smoker's cough and unpleasant tobacco odors, she has transitioned back to regular cigarettes, partly motivated by the belief that the products were equally harmful. "E-cigarettes are supposedly safer for you," she says, "although in this case I may just be trading the risk of cancer for the peril of heart disease."[31]

Not only does the hysteria surrounding e-cigarettes' risks endanger smokers and jeopardize public health, it also undermines the credibility of health authorities on other important issues like the coronavirus and vaccines. The American public should be told the truth about e-cigarettes.

E-cigarettes, Teens, and Smoking Initiation

For years, many media outlets and public health organizations have been declaring an "epidemic" of e-cigarette use among adolescents. Politicians have often repeated these claims to justify numerous restrictions on e-cigarettes. But, while the surge in e-cigarette use among American teens is troubling, defenders of e-cigarette alarmism too often omit key contextual facts.

The headline figure is jarring: E-cigarette use among teens has increased more than ten-fold since 2011. Moreover, research indicates that the use of e-cigarettes, particularly among young people, increases the risk of subsequent combustible cigarette smoking.[32] Yet this research is fraught with methodological caveats. Without conducting a controlled experiment, it is exceedingly difficult to know with confidence that an individual would not have taken up cigarette smoking in the absence of e-cigarettes.

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[31] Cheantay Jensen, "I'm smoking cigarettes to quit my vaping habit… Yeah, I know," The Hi-lo, July 7, 2019, https://lbpost.com/hi-lo/im-smoking-cigarettes-to-quit-my-vaping-habit-yeah-i-know/.

[32] Kaitlyn M. Berry, Jessica L. Fetterman, Emelia J. Benjamin, et al., "Association of Electronic Cigarette Use With Subsequent Initiation of Tobacco Cigarettes in US Youths," *Journal of the American Medical Association*, February 1, 2019, https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2723425.

It is also crucial to distinguish between teens for whom e-cigarettes may be the first step toward combustible tobacco products and teens for whom e-cigarettes replace a pre-existing propensity for combustible products. In attempting to prevent the former, policymakers may be impeding the latter, and doing more harm than good. Indeed, among teens who use e-cigarettes regularly, almost all are (or were) smokers, suggesting that vaping may be an effective substitute for smoking among adolescents. The 2015 National Youth Tobacco Survey, for example, revealed that only 0.3 percent of non-smoking adolescents regularly vaped.[33] A paper in the *American Journal of Preventive Medicine* found that non-smoking high school students are highly unlikely to use e-cigarettes; only six percent of 12th graders who had never smoked had used e-cigarettes in the past 30 days, and less than one percent used e-cigarettes regularly.[34]

The vast majority of habitual teen vapers are current or former smokers for whom e-cigarettes are a safer alternative to the products they currently or previously used. The substantial increase in e-cigarette use among middle- and high-schoolers over the last decade has coincided with a steep decline in cigarette smoking among students, as the Center Against Government Waste reports:

> "...from 2011 to 2017, cigarette smoking declined by almost 50 percent among middle and high school students. For middle school students it was 2.1 percent in 2017, down from 4.3 percent in 2011. For high school students, it was 7.6 percent in 2017, down from 15.8 percent in 2011. It appears some students that used to engage in the risky behavior of smoking cigarettes are moving to using less risky [vaping] products."[35]

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[33] Konstantinos Farsalinos, Venera Tomaselli, and Riccardo Polosa, "Frequency of Use and Smoking Status of U.S. Adolescent E-Cigarette Users in 2015," *American Journal of Preventive Medicine*, June 2018, https://www.ajpmonline.org/article/S0749-3797(18)31626-X/fulltext.

[34] Kenneth E. Warner, "Frequency of E-Cigarette Use and Cigarette Smoking by American Students in 2014," *American Journal of Preventive Medicine*, August 2016, https://www.ajpmonline.org/article/S0749-3797%2815%2900782-5/abstract.

[35] Tom Schatz, "Comment on FDA's Proposed Rule Regarding Tobacco Product Flavors," Citizens Against Government Waste, July 11, 2018, https://www.cagw.org/legislative-affairs/agency-comments/comment-fdas-proposed-rule-regarding-tobacco-product-flavors.

This finding was bolstered with a March 2020 study released by the Public Health of England, an executive agency of England's Department of Health and Social Care.[36] The empirically-based study concluded that underage vaping by nonsmokers was rare, which supports the correlation that the rise in vaping leads to a decline in smoking among teens. Debunking the teen vaping myth, the Public Health of England report states:

> "Current vaping is mainly concentrated in young people who have experience of smoking. Less than 1% of young people who have never smoked are current vapers."[37]

A paper published last year bolsters this view. It analyzed several national datasets on smoking behavior and found that, after controlling for previous trends, the downward trajectory in both current use and more established cigarette use substantially accelerated among youth and young adults in the U.S. once vaping became popular in 2014.[38]

To the extent that e-cigarettes are being used by teens as a substitute for smoking, these products are having a decidedly positive effect on youth. Further, since children whose parents smoke are far more likely to smoke themselves, lowering the smoking rate among adults will likely reduce smoking among teens, helping to break this generational cycle.[39]

Preventing non-smoking youth from using e-cigarettes is a worthy goal, but poorly designed policies may also make it harder for teen smokers to access a safer alternative. For

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[36] Ann McNeill, Leonie Brose, et al, "Vaping in England: An Evidence Update Including Metal Health and Pregnancy," Commissioned by Public Health England, March 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869401/Vaping_in_England_evidence_update_March_2020.pdf.

[37] Ibid, p. 11.

[38] David T. Levy, Kenneth E. Warner, K. Michael Cummings, et al., "Examining the relationship of vaping to smoking initiation among US youth and young adults: a reality check," *Tobacco Control*, November 20, 2018, https://tobaccocontrol.bmj.com/content/early/2018/10/31/tobaccocontrol-2018-054446.

[39] Denise B. Kandel, Pamela C. Griesler, and Mei-Chen Hu, "Intergenerational Patterns of Smoking and Nicotine Dependence Among US Adolescents," *American Journal of Public Health*, November 2015, https://ajph.aphapublications.org/doi/full/10.2105/AJPH.2015.302775.

those smokers should transitioned from combustible products to vaping, bans and taxes will likely send them "back to the pack."[40]

Smoking Cessation: The Role of E-cigarettes

While many public health organizations remain hostile to e-cigarettes, others have begun to acknowledge that vaping can be an effective smoking cessation method. The CDC acknowledges: "E-cigarettes have the potential to benefit adult smokers who are not pregnant if used as a complete substitute for regular cigarettes and other smoked tobacco products."[41]

Indeed, though e-cigarettes are not FDA-approved as smoking cessation devices, vaping is widely used by smokers in the U.S. in their efforts to quit. According to a survey conducted from 2014 to 2016, substituting some or all combustible cigarettes with e-cigarettes was used by a greater percentage of smokers than the nicotine patch, nicotine gum, or any other cessation aids approved by the FDA.[42]

Smokers are turning to e-cigarettes in record numbers seeking a safer source of nicotine. A peer-reviewed study in 2016 found that one-third of U.S. smokers used e-cigarettes in their last quit attempt, and that vaping has contributed to a 50% increase in the rate of smokers using cessation aids.[43]

Although few scientific studies of e-cigarettes' efficacy as smoking cessation aids have been conducted, the evidence so far is promising. In a recent randomized trial, the gold standard in scientific research, British researchers recruited about 900 smokers who expressed an interest in quitting and randomly assigned half to use e-cigarettes and the other half to use

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[40] Liam Sigaud and Steve Pociask, "A Vaping Ban Will Send Smokers Back to the Pack," Wall Street Journal, September 12, 2019, https://www.wsj.com/articles/a-vaping-ban-will-send-smokers-back-to-the-pack-11568325386.

[41] "Electronic Cigarettes," Centers for Disease Control and Prevention, March 11, 2019, https://www.cdc.gov/tobacco/basic_information/e-cigarettes/.

[42] Ralph S. Caraballo, Paul R. Shafer, Deesha Patel, et al., "Quit Methods Used by US Adult Cigarette Smokers, 2014–2016," Centers for Disease Control and Prevention, April 2017, https://www.cdc.gov/pcd/issues/2017/pdf/16_0600.pdf.

[43] Yue-Lin Zhuang, Sharon E Cummins, Jessica Y Sun, et al., "Long-term e-cigarette use and smoking cessation: a longitudinal study with US population," *Tobacco Control*, July 3, 2016, https://pdfs.semanticscholar.org/f22e/666734b20d102e29a2f743bcac39d5f83fe4.pdf.

traditional nicotine replacement products. All of the participants received weekly individual counseling for four weeks, and smoking cessation was assessed after one year. Among those using e-cigarettes, 18% had stopped smoking after a year, while only 9.9% of those using nicotine replacement therapy had quit -- making e-cigarettes nearly twice as effective as FDA-approved smoking cessation aids.[44]

In another U.K. study last year, researchers interviewed 40 participants who had previously smoked. After being introduced to e-cigarettes, three were no longer using either tobacco or e-cigarettes, 31 had switched entirely to vaping, five were using both tobacco and e-cigarettes, and only one was exclusively smoking. "E-cigarettes meet the needs of some ex-smokers by substituting physical, psychological, social, cultural and identity-related aspects of tobacco addiction. Some vapers reported that they found vaping pleasurable and enjoyable—being more than a substitute but actually preferred, over time, to tobacco smoking," wrote the study's authors.[45]

This month, a report by a government agency, the Public Health of England, an agency of England's Department of Health and Social Care, reported that most consumers who vape do so in order to stop smoking.[46]

In 2014, researchers in Belgium introduced e-cigarettes to 48 smokers who had never vaped and were unwilling to quit smoking. The results showed that vaping was as effective as smoking a cigarette in reducing nicotine cravings. Eight months after the start of the study, 21%

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[44] Peter Hajek, Anna Phillips-Waller, Dunja Przulj, et al., "A Randomized Trial of E-Cigarettes versus Nicotine-Replacement Therapy," *New England Journal of Medicine*, February 14, 2019, https://www.nejm.org/doi/full/10.1056/NEJMoa1808779?query=TOC.

[45] Caitlin Notley, Emma Ward, Lynne Dawkins, et al., "The unique contribution of e-cigarettes for tobacco harm reduction in supporting smoking relapse prevention," *Harm Reduction Journal*, June 20, 2018, https://harmreductionjournal.biomedcentral.com/articles/10.1186/s12954-018-0237-7.

[46] Ann McNeill, Leonie Brose, et al, "Vaping in England: An Evidence Update Including Metal Health and Pregnancy," Commissioned by Public Health England, March 2020, p. 13. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869401/Vaping_in_England_evidence_update_March_2020.pdf.

of all participants were completely abstinent from conventional cigarettes, while 23% had dramatically cut down on their smoking.[47]

In addition to these academic studies, public health surveys also indicate that e-cigarettes serve as a healthier substitute to a deadly habit. U.S. government surveys show that 2.6 million former smokers were vapers in 2016, nearly 90 percent of whom had quit smoking in the previous five years.[48] In addition, current smoking rates in the U.S. are at record lows for both adolescents and adults, the culmination of a sustained, decade-long decline which closely mirrors the rise in popularity of e-cigarettes.[49]

Taxpayers stand to benefit as e-cigarettes replace combustible tobacco products. One estimate found that if all smokers on Medicaid, the federal/state health program for low-income Americans, had switched to e-cigarettes in 2012, Medicaid would have saved $48 billion – more than 10 percent of total Medicaid spending for that year – in smoking-related medical treatment.[50] Another analysis calculated that if just 1 percent of smokers permanently switched to e-cigarettes, Medicaid would save $2.8 billion over 25 years.[51]

Public Policy Implications

The rise of e-cigarette use in the U.S. has attracted regulations from all levels of government. While well-intentioned, many of these laws may be doing more harm than good.

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[47] Karolien Adriaens, Dinska Van Gucht, Paul Declerck, et al., "Effectiveness of the Electronic Cigarette: An Eight-Week Flemish Study with Six-Month Follow-up on Smoking Reduction, Craving and Experienced Benefits and Complaints," *International Journal of Environmental Research and Public Health*, November 2014, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4245610/.

[48] Brad Rodu, "2016 CDC Data Shows E-Cigarette Use Declines Again," *Tobacco Truth*, September 27, 2017, https://rodutobaccotruth.blogspot.com/2017/09/2016-cdc-data-shows-e-cigarette-use.html.

[49] William T. Godshall, Comments to the Food and Drug Administration Center for Tobacco Products, Consumer Advocates for Smoke-free Alternatives Association, December 2015, http://www.casaa.org/wp-content/uploads/GodshallFDAcomment-December-2015.pdf.

[50] J. Scott Moody, "E-Cigarettes Poised to Save Medicaid Billions," Heartland Institute, March 31, 2015, https://www.heartland.org/_template-assets/documents/publications/20150331_sbsmediciadecigarettes033115.pdf.

[51] Richard B. Belzer, "Expected Savings to Medicaid for Substituting Electronic for Tobacco Cigarettes," R Street Institute, December 2017, http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2018/01/124-6.pdf.

1. Limits on E-liquid Flavors and Teen Use

Some policymakers worry that the proliferation and aggressive marketing of flavored e-cigarettes may attract young non-smokers. There is some mixed evidence to support this concern. One study documented that flavors entice youth to initiate and continue using e-cigarettes.[52] As a result, efforts to ban or restrict flavored e-liquids have gained momentum. However, restricting the availability of e-liquid flavors -- by limiting flavors to tobacco/menthol, for example -- could have unintended consequences.

A survey of non-smoking teens in 2015 found that they had very low interest in e-cigarettes (0.4 on a 0-10 scale, on average), and the availability of different flavors had no impact on their level of interest. The study also found that interest in e-cigarettes among adult smokers did vary by flavor, suggesting that sweeping measures to reduce the availability of flavored e-cigarettes might impose high costs on adult smokers and deliver few benefits to teen non-smokers.[53]

Meanwhile, a survey of young adults who use both e-cigarettes and combustible cigarettes indicated that bans on e-liquid flavors would lead to reductions in e-cigarette use and simultaneous increases in combustible cigarette use.[54]

Another study published in the *Journal of Harm Reduction* in 2018 found: "Adult frequent e-cigarette users in the USA who have completely switched from smoking cigarettes to using e-cigarettes are increasingly likely to have initiated e-cigarette use with non-tobacco flavors and to have transitioned from tobacco to non-tobacco flavors over time. Restricting

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[52] "E-Cigarette Use Among Youth and Young Adults," Office of the Surgeon General, 2016, https://www.cdc.gov/tobacco/data_statistics/sgr/e-cigarettes/pdfs/2016_sgr_entire_report_508.pdf.

[53] Shiffman S., Sembower M.A., Pillitteri J.L., et al., "The Impact of Flavor Descriptors on Nonsmoking Teens' and Adult Smokers' Interest in Electronic Cigarettes," Society for Research on Nicotine and Tobacco, October 2015, https://www.ncbi.nlm.nih.gov/pubmed/25566782.

[54] Lauren R. Pacek, "What Would You Do If…?: Analysis of Young Adult Dual User's Anticipated Responses to Hypothetical E-cigarette Market Restrictions," Duke University, 2017, https://www.rti.org/sites/default/files/related-content-files/pacek_ppt.pdf.

access to non-tobacco e-cigarette flavors may discourage smokers from attempting to switch to e-cigarettes."[55]

2. Taxes

More than a dozen states have implemented special taxes on e-cigarettes, typically in order to bring them in line with taxes on combustible tobacco products.[56] But while tax parity might seem fair, proposals to jack up prices on e-cigarettes threaten to undermine policymakers' broader goals of improving public health.

The primary objective of high taxes on tobacco products is to reduce consumer demand and curb the significant costs, including nearly $170 billion in direct medical care and more than $156 billion in lost productivity, associated with smoking.[57] Cigarette taxes, like other "sin taxes," aim to change consumer behavior and mitigate the spillover effects of harmful habits.

Imposing similar taxes on e-cigarettes runs counter to this logic, since the aggregate public health impact of e-cigarettes, compared to smoking, is positive. For example, a recent study found that, even under pessimistic assumptions, e-cigarettes will deliver significant public health benefits over the next half-century, extending the aggregate longevity of the U.S. population by 580,000 years.[58]

Consumers are sensitive to price. Economists estimate that a 10% increase in price reduces sales of disposable e-cigarettes by approximately 12%, and by about 19% for reusable

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[55] Mitchell Nides, Tiffany Dickson, Neil McKeganey, et al., "Changing Patterns of First E-Cigarette Flavor Used and Current Flavors Used by 20,836 Adult Frequent E-Cig Users," *Harm Reduction Journal*, June 28, 2018, https://harmreductionjournal.biomedcentral.com/articles/10.1186/s12954-018-0238-6.
[56] "States with Laws Taxing E-Cigarettes," June 15, 2019, Mitchell Hamline School of Law: Public Health Law Center, https://www.publichealthlawcenter.org/sites/default/files/States-with-Laws-Taxing-ECigarettes-June152019.pdf.
[57] "Economic Trends in Tobacco," Centers for Disease Control and Prevention, July 23, 2019, https://www.cdc.gov/tobacco/data_statistics/fact_sheets/economics/econ_facts/index.htm.
[58] Warner K.E. and Mendez D., "E-cigarettes: Comparing the Possible Risks of Increasing Smoking Initiation with the Potential Benefits of Increasing Smoking Cessation," *Nicotine and Tobacco Research*, 2019, https://www.ncbi.nlm.nih.gov/pubmed/29617887.

e-cigarettes.[59] High taxes on e-cigarettes have the beneficial effect of discouraging some non-smoking teens from vaping, but also deter cigarette smokers from switching to these safer alternatives.

Conclusion

In many U.S. jurisdictions, policymakers have been openly hostile to e-cigarettes, casting them as dangerous gateways to tobacco smoking. Laws to discourage e-cigarette use have cropped up everywhere, from restrictions on retailers to higher taxes and flavor bans. In June 2019, San Francisco went even further, effectively banning e-cigarettes entirely.[60]

While some targeted regulatory actions -- to discourage non-smoking teens from taking up vaping, for example -- are justified, the demonization of e-cigarettes in the U.S. is counterproductive. As part of a tobacco harm reduction strategy, the potential public health benefits from e-cigarettes are substantial. As noted earlier, a 2018 study in the journal *Tobacco Control* projected that if cigarette use were largely replaced by vaping over a 10-year period in the U.S., it would prevent as many as 6.6 million premature deaths.[61]

Too often, policymakers have acted without carefully weighing the costs and benefits of their actions. Knee-jerk opposition to e-cigarettes, often fueled by misleading information, curbs their use as a smoking cessation aid by millions of adults.

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[59] Frank J. Chaloupka, "Taxing E-Cigarettes–Options & Potential Impact," Council of State Governments Policy Workshop, December 12, 2015, https://knowledgecenter.csg.org/kc/system/files/Chaloupka.pdf.

[60] Michael Nedelman, "San Francisco passes ban on e-cigarette sales, a US first," CNN, June 25, 2019, https://www.cnn.com/2019/06/25/health/san-francisco-e-cigarette-ban-sales-bn/index.html.

[61] David T. Levy, Ron Borland, Eric N Lindblom, et al., "Potential deaths averted in USA by replacing cigarettes with e-cigarettes," *Tobacco Control*, 2018, https://tobaccocontrol.bmj.com/content/27/1/18.

NBER WORKING PAPER SERIES

THE EFFECTS OF E-CIGARETTE TAXES ON E-CIGARETTE PRICES AND TOBACCO PRODUCT SALES: EVIDENCE FROM RETAIL PANEL DATA

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The Effects of E-Cigarette Taxes on E-Cigarette Prices and Tobacco Product Sales: Evidence from Retail Panel Data
Chad D. Cotti, Charles J. Courtemanche, Johanna Catherine Maclean, Erik T. Nesson, Michael F. Pesko, and Nathan Tefft
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ABSTRACT

We explore the effect of e-cigarette taxes enacted 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 from 2011 to 2017, comprising approximately 35,000 retailers nationally. We calculate a Herfindahl–Hirschman Index of 0.251 for e-cigarette retail purchases, indicating high market concentration, and a tax-to-price pass-through of 1.6. We then calculate an e-cigarette own-price elasticity of -2.6 and a positive cross-price elasticity of demand between e-cigarettes and traditional cigarettes of 1.1, suggesting that e-cigarettes and traditional cigarettes are economic substitutes. 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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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 accurate standardization of the e-cigarette taxes themselves, which are often levied based on the quantity of liquid or nicotine contained in the products.

[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).

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

[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.

$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 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.

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.

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[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).

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

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

[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.

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 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

[7] Non-adopting localities are used for the weights to avoid the weights being endogenously impacted by the taxes.
[8] https://www.kff.org/health-reform/state-indicator/state-activity-around-expanding-medicaid-under-the-affordable-care-act. Web. 1 Jan. 2020.

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

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

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 \$0.04 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 4^{th} 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 $0.08 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 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

[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.

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.

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

[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 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.

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 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 ($1.11), 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, 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

[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.

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.

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]

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[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.

[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.

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.

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

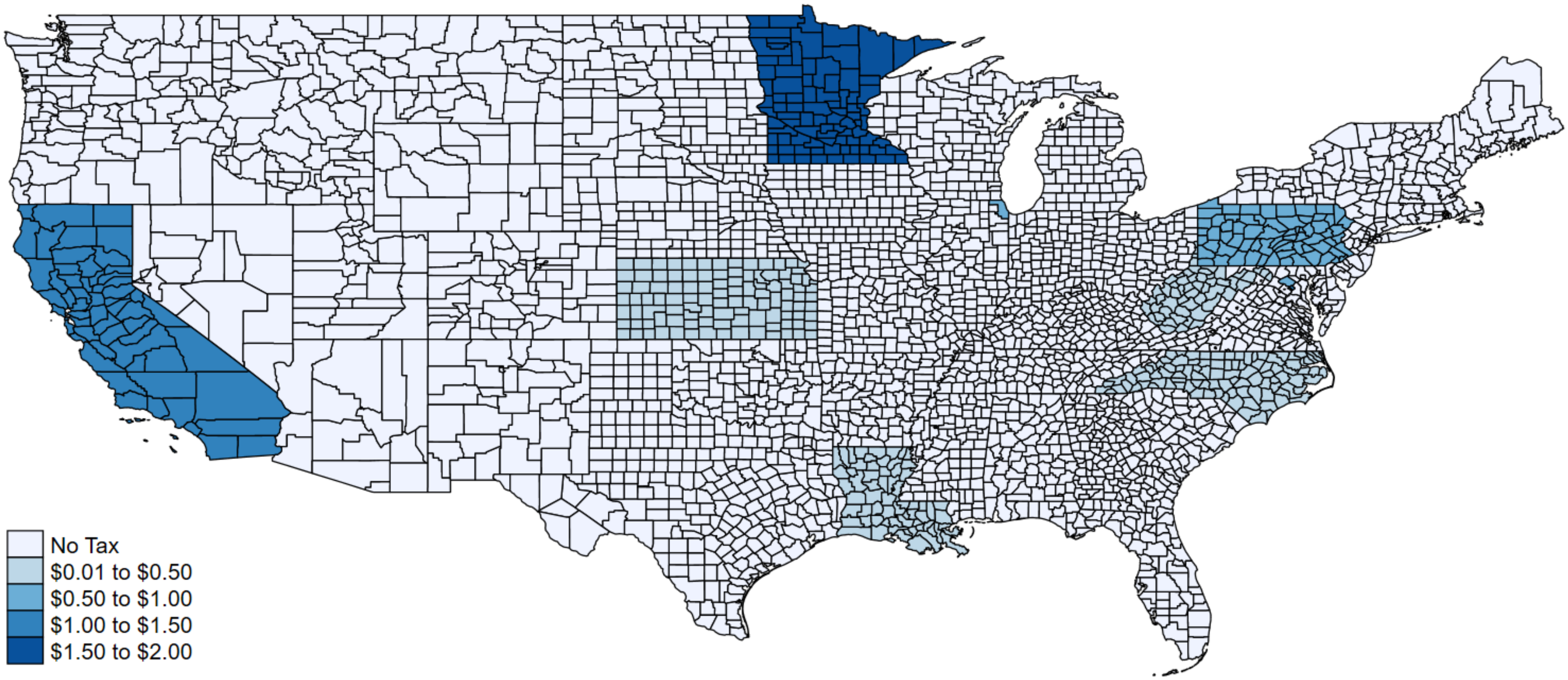
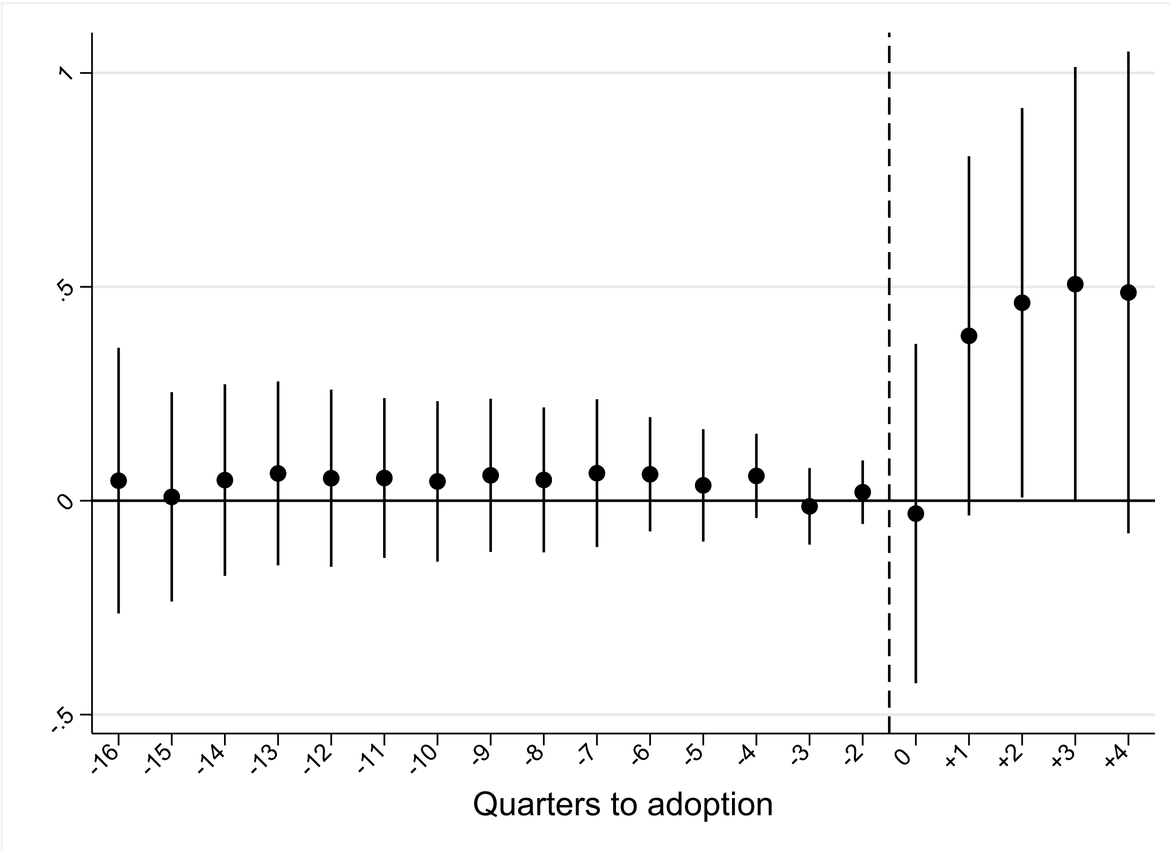


Figure 2. Effect of e-cigarette taxes on e-cigarette prices using an event study: Nielsen retail sales UPC-level data 2011-2017



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 ($)	-1,255*** [-2,133,-377]	11,489*** [3,322,19,657]	-651 [-2,039,736]	105 [-1,369,1,580]	-194 [-526,137]
Traditional cigarette price ($)	538* [-72,1,149]	-7,057** [-12,622,-1,492]	609 [-362,1,581]	-92 [-981,798]	112 [-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 ($)	1.614*** [1.383,1.846]
Observations	89182
Exclude Washington, DC	
E-cigarette standardized tax ($)	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 Washington, 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 cigarette price ($)	544* [-82,1,170]	-6,714** [-12,423,-1,004]	623 [-367,1,614]	-122 [-1,041,798]	141 [-52,333]
Observations	1400	1400	1400	1400	1400
Exclude North Carolina					
E-cigarette price ($)	-1,280*** [-2,161,-400]	12,030*** [3,526,20,535]	-680 [-2,058,698]	407 [-632,1,446]	-211 [-537,116]
Traditional cigarette price ($)	540* [-74,1,153]	-6,977** [-12,620,-1,334]	621 [-349,1,590]	-98 [-872,675]	116 [-72,303]
Observations	1400	1400	1400	1400	1400
Exclude Pennsylvania					
E-cigarette price ($)	-1,161** [-2,173,-150]	12,654*** [3,792,21,517]	-587 [-1,900,726]	378 [-1,203,1,960]	-144 [-480,192]
Traditional cigarette price ($)	520* [-64,1,104]	-7,254** [-12,919,-1,589]	604 [-358,1,566]	-159 [-1,040,721]	102 [-89,292]
Observations	1400	1400	1400	1400	1400
Exclude West Virginia					
E-cigarette price ($)	-1,266*** [-2,158,-374]	11,313*** [2,955,19,671]	-648 [-2,060,764]	-6 [-1,546,1,534]	-149 [-458,160]
Traditional cigarette price ($)	549* [-68,1,166]	-6,889** [-12,522,-1,257]	618 [-369,1,605]	-23 [-929,883]	81 [-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.

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ORIGINAL ARTICLE

A Randomized Trial of E-Cigarettes versus Nicotine-Replacement Therapy

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Article

Figures/Media

Metrics

Abstract

BACKGROUND

E-cigarettes are commonly used in attempts to stop smoking, but evidence is limited regarding their effectiveness as compared with that of nicotine products approved as smoking-cessation treatments.

METHODS

We randomly assigned adults attending U.K. National Health Service stop-smoking services to either nicotine-replacement products of their choice, including product combinations, provided for up to 3 months, or an e-cigarette starter pack (a second-generation refillable e-cigarette with one bottle of nicotine e-liquid [18 mg per milliliter]), with a recommendation to purchase further e-liquids of the flavor and strength of their choice. Treatment included weekly behavioral support for at least 4 weeks. The primary outcome was sustained abstinence for 1 year, which was validated biochemically at the final visit. Participants who were lost to follow-up or did not provide biochemical validation were considered to not be abstinent. Secondary outcomes included participant-reported treatment usage and respiratory symptoms.

RESULTS

A total of 886 participants underwent randomization. The 1-year abstinence rate was 18.0% in the e-cigarette group, as compared with 9.9% in the nicotine-replacement group (relative risk, 1.83; 95% confidence interval [CI], 1.30 to 2.58; P<0.001). Among participants with 1-year abstinence, those in the e-cigarette group were more likely than those in the nicotine-replacement group to use their assigned product at 52 weeks (80% [63 of 79 participants] vs. 9% [4 of 44 participants]). Overall, throat or mouth irritation was reported more frequently in the e-cigarette group (65.3%, vs. 51.2% in the nicotine-replacement group) and nausea more frequently in the nicotine-replacement group (37.9%, vs. 31.3% in the e-cigarette group). The e-cigarette group reported greater declines in the incidence of cough and phlegm production from baseline to 52 weeks than did the nicotine-replacement group (relative risk for cough, 0.8; 95% CI, 0.6 to 0.9; relative risk for phlegm, 0.7; 95% CI, 0.6 to 0.9). There were no significant between-group differences in the incidence of wheezing or shortness of breath.

CONCLUSIONS

E-cigarettes were more effective for smoking cessation than nicotine-replacement therapy, when both products were accompanied by behavioral support. (Funded by the National Institute for Health Research and Cancer Research UK; Current Controlled Trials number, ISRCTN60477608.)

Introduction

SWITCHING COMPLETELY FROM CIGARETTE SMOKING TO E-cigarette use would be expected to reduce risks to health.[1-3] There are questions about risks and benefits of use of e-cigarettes for different purposes, but an important clinical issue is whether e-cigarette use in a quit attempt facilitates success, particularly as compared with the use of nicotine-replacement therapy.

A Cochrane review showed that e-cigarettes with nicotine were more effective for smoking cessation than nicotine-free e-cigarettes.[4] A trial that compared e-cigarettes with nicotine patches for smoking cessation used cartridge e-cigarettes with low nicotine delivery and no face-to-face contact. It showed similar low efficacy for both treatments.[5] (For further details of previous trials, see the Supplementary Appendix, available with the full text of this article at NEJM.org.) Our trial evaluated the 1-year efficacy of refillable e-cigarettes as compared with nicotine replacement when provided to adults seeking help to quit smoking and combined with face-to-face behavioral support.

Methods

DESIGN AND OVERSIGHT

We conducted a two-group, pragmatic, multicenter, individually randomized, controlled trial. National Health Service (NHS) stop-smoking services are available free across the United Kingdom.[6] This trial was conducted in three service sites from May 2015 through February 2018. The Health and Lifestyle Research Unit that delivers the service for two London boroughs (Tower Hamlets and City of London), along with the Leicester and East Sussex services, recruited participants and delivered the interventions. Participating services included trial information in their advertising. Participants were also recruited through social media. Adult smokers were invited to participate if they were not pregnant or breast-feeding, had no strong preference to use or not to use nicotine replacement or e-cigarettes, and were currently not using either type of product.

The trial was approved by the National Research Ethics Service (reference number, 14/LO/2235). Collective unblinded data were seen only for the purposes of the meetings of the data monitoring and ethics committee. Data analyses were conducted with blinding to treatment assignments. All the authors contributed to the trial design, participated in the interpretation of the data, vouch for their completeness and accuracy, and made the decision to submit the manuscript for publication. All the authors vouch for the fidelity of the trial to the protocol, available at NEJM.org.

PROCEDURES

Smokers were provided with trial information, prescreened for eligibility, and, if eligible, invited to a baseline session. There, eligibility was confirmed, written informed consent and baseline data were obtained, and participants set up their quit date (normally the following week).[7]

Randomization took place on the quit date to limit differential dropout. Randomization sequences (1:1 ratio in permuted blocks of 20, stratified according to trial site) were generated with the use of a pseudorandom number generator in Stata software and were embedded into an application that only revealed the next treatment assignment once a participant had been entered into the database.

Product use started immediately after randomization. All the participants received the same multisession behavioral support as per U.K. stop-smoking service practice.[7,8] This support involved weekly one-on-one sessions with local clinicians, who also monitored expired carbon monoxide levels for at least 4 weeks after the quit date.

Participants were contacted by telephone at 26 and 52 weeks. Interviewers asked about product use and thus were aware of the treatment assignments. Participants who reported abstinence or a reduction in smoking of at least 50% at 52 weeks were invited back to provide a carbon monoxide reading. Participants were compensated £20 ($26 U.S.) for their travel and time at the 52-week validation visit.

Nicotine-Replacement Group

Participants were informed about the range of nicotine-replacement products (patch, gum, lozenge, nasal spray, inhalator, mouth spray, mouth strip, and microtabs) and selected their preferred product. Use of combinations was encouraged, typically the patch and a faster-acting oral product. Participants were also free to switch products. The way that nicotine replacement was provided differed slightly among trial sites (see the Supplementary Appendix). Supplies were provided for up to 3 months, as per standard practice. The cost to the NHS of a 3-month supply of a single nicotine-replacement product is currently approximately £120 ($159 U.S.).

E-Cigarette Group

A starter pack, called One Kit (Aspire, U.K. Ecig Store), was provided to facilitate initial use and teach participants how to use refillable e-cigarette products, along with one 30-ml bottle of Tobacco Royale flavor e-liquid purchased from U.K. Ecig Store, containing nicotine at a concentration of 18 mg per milliliter. The kit had a 2.1-ohm atomizer and 650-mAh battery. During the trial, the company discontinued this kit, so One Kit 2016 (Innokin, U.K. Ecig Store), with a 1.5-ohm atomizer and 1000-mAh battery, was used for 42 participants. Participants were asked to purchase their future e-liquid online or from local vape shops and to buy a different e-cigarette device if the one supplied did not meet their needs. They were encouraged to experiment with e-liquids of different strengths and flavors. Those who were unable to obtain their own supply were provided with one further 10-ml bottle, but this was not offered proactively. Participants received oral and written information on how to operate the e-cigarette.

The original One Kit, including five atomizers, U.K. adapter, spare battery, and e-liquid, was purchased wholesale for £19.40 ($26 U.S.). The cost of One Kit 2016, including the same extras, was £30.25 ($40 U.S.).

Participants in the e-cigarette group and those in the nicotine-replacement group were asked to sign a commitment to not use the nonassigned treatment for at least 4 weeks after their quit date. This was to minimize contamination between the trial groups.

MEASURES

At trial visits, the following data were recorded: smoking status, expired carbon monoxide level (at baseline, 4 weeks, and 52 weeks), use and ratings of trial products, ratings of withdrawal symptoms (weeks 1 through 6), adverse reactions (presence or absence of nausea, sleep disturbance, and throat or mouth irritation), and respiratory symptoms (presence or absence of shortness of breath, wheezing, cough, and phlegm). The Supplementary Appendix provides further details of trial measures.

The primary outcome was 1-year sustained abstinence, calculated in accordance with the Russell Standard[9] as a self-report of smoking no more than five cigarettes from 2 weeks after the target quit date, validated biochemically by an expired carbon monoxide level of less than 8 ppm at 1-year follow-up and not contradicted by any previous self-report or validation result. Carbon monoxide validation is the standard measure in trials assessing nicotine-containing products (see the Supplementary Appendix). Participants who died (one in each group) were excluded. Participants who were lost to follow-up or did not provide biochemical validation were classified as not being abstinent in the primary analysis.

Secondary abstinence outcomes included sustained abstinence from 26 to 52 weeks, at 4 weeks, and at 26 weeks and the percentage of participants without sustained abstinence from 26 to 52 weeks who reduced their cigarette consumption by at least 50%. We also assessed 7-day abstinence at 4, 26, and 52 weeks. In addition, we compared the trial groups with respect to relapse rate and time to relapse and with respect to the measures listed above.

STATISTICAL ANALYSIS

We calculated that a sample of 886 participants would provide the trial with 95% power (at a two-sided alpha level of 0.05) if the true percentages of 1-year abstinence were 23.8% in the e-cigarette group and 14.0% in the nicotine-replacement group (relative risk, 1.7). Since trial setup, the abstinence rate in stop-smoking service clinics declined to 10%, but the sample of 886 participants would provide 85% power if the percentages were 17.0% and 10.0% in the respective groups.

The primary and secondary abstinence outcomes were analyzed by regression of smoking status at each time point onto trial group. Primary analyses were adjusted for trial center to account for the stratification factor. In sensitivity analyses, each model was further adjusted for baseline covariates selected with the use of stepwise regression. Binary regressions were conducted by means of the generalized linear model with binomial distribution and logarithmic link to estimate the relative risk for e-cigarettes as compared with nicotine-replacement therapy.

To assess the effect of missing data on the primary outcome, we conducted four prespecified sensitivity analyses, which excluded participants who did not attend at least one behavioral-support session, excluded participants who used the nonassigned product for at least 5 consecutive days, excluded participants who did not complete the 52-week follow-up, and imputed missing information with the use of multiple imputation by chained equations.[10] Missing data were imputed for 136 participants in each group, and 50 data sets were imputed.

We also estimated mean differences and 95% confidence intervals between trial groups in product ratings and in change scores between baseline and follow-up time points in withdrawal symptoms, as well as between-group differences in the percentage of participants who had adverse reactions or respiratory symptoms, using binomial regression with adjustment for trial center (see the statistical analysis plan, available with the protocol at NEJM.org). Analyses were conducted with the use of Stata software, version 15 (StataCorp).

Results

PARTICIPANTS

Figure 1.

Screening, Randomization, and Follow-up.

Table 1.

Characteristics of the Participants at Baseline.

A total of 2045 clients of stop-smoking services were screened, and 886 underwent randomization (439 to the e-cigarette group and 447 to the nicotine-replacement group). Of the randomly assigned participants, 78.8% completed the 52-week follow-up (Figure 1). The sample was composed largely of middle-aged smokers, with 40.7% entitled to free prescriptions (a marker of social disadvantage or poor health)

(Table 1, and Table S1 in the Supplementary Appendix).

EFFECTS OF TREATMENT ON ABSTINENCE

Table 2.

Abstinence Rates at Different Time Points and Smoking Reduction at 52 Weeks.

The rate of sustained 1-year abstinence was 18.0% in the e-cigarette group and 9.9% in the nicotine-replacement group (relative risk, 1.83; 95% confidence interval [CI], 1.30 to 2.58; P<0.001) (Table 2). The absolute difference in the 1-year abstinence rate between the two groups was 8.1 percentage points, resulting in a number needed to treat for one additional person to have sustained abstinence of 12 (95% CI, 8 to 27). The result did not change substantially in the four sensitivity analyses (relative risk, 1.75 to 1.85; P≤0.001 for all comparisons) (Table S2 in the Supplementary Appendix). Abstinence rates were higher in the e-cigarette group than in the nicotine-replacement group at all time points (Table 2, and Table S3 in the Supplementary Appendix).

We conducted a post hoc analysis, in which participants with 1-year abstinence who used nonassigned products (see the Supplementary Appendix) were removed from the sample (3% [2 of 79] in the e-cigarette group were using nicotine replacement and 20% [9 of 44] in the nicotine-replacement group were using e-cigarettes). This resulted in a 1-year abstinence rate of 17.7% in the e-cigarette group, as compared with 8.0% in the nicotine-replacement group (relative risk, 2.21; 95% CI, 1.52 to 3.22).

Among participants in whom full abstinence was not achieved, more had a carbon monoxide–validated reduction of smoking by at least 50% in the e-cigarette group than in the nicotine-replacement group (Table 2). Time to relapse and relapse rates at 52 weeks among participants with sustained abstinence at 4 weeks did not differ substantially between the two trial groups (hazard ratio for time to relapse, 1.14; 95%

CI, 0.96 to 1.34; relative risk of relapse at 52 weeks, 1.27; 95% CI, 0.93 to 1.73).

TREATMENT ADHERENCE AND RATINGS AND EFFECTS ON WITHDRAWAL SYMPTOMS

Table 3.

Attendance and Treatment Adherence.

Overall adherence was similar in the two groups, but e-cigarettes were used more frequently and for longer than nicotine replacement (Table 3). In the nicotine-replacement group, 88.1% of participants used nicotine-replacement combinations. In the e-cigarette group, practically all participants used refillable e-cigarettes (Table S4 in the Supplementary Appendix).

Among participants with 1-year abstinence, 80% (63 of 79) were using e-cigarettes at 52 weeks in the e-cigarette group and 9% (4 of 44) were using nicotine replacement in the nicotine-replacement group. Further details of product use (including the use of nonassigned products) are provided in the Supplementary Appendix, including Tables S4 and S5.

Both e-cigarettes and nicotine-replacement products were perceived to be less satisfying than cigarettes. However, e-cigarettes provided greater satisfaction and were rated as more helpful to refrain from smoking than nicotine-replacement products (Table S6 in the Supplementary Appendix).

Table 4.

Urges to Smoke in Participants with Abstinence at 1 Week or 4 Weeks after Quit Date.

Among participants with abstinence at 1 week after their quit date as well as participants with abstinence at 4 weeks, those in the e-cigarette group had less severe urges to smoke than did those in the nicotine-replacement group (Table 4). They also reported a smaller increase from baseline in irritability, restlessness, and inability to concentrate than those in the nicotine-replacement group during the first week of abstinence. Between-group differences in hunger and depression were in the same direction but less substantial. By week 4, participants in either group who were abstinent reported little withdrawal discomfort (Table S7 in the Supplementary Appendix).

SAFETY EVALUATION

Two participants died during the trial. One died from ischemic heart disease in the e-cigarette group and one from traumatic spine injury in the nicotine-replacement group.

There were 27 serious adverse events in the e-cigarette group and 22 in the nicotine-replacement group (Table S8 in the Supplementary Appendix). No serious adverse event in either group was classified by the trial clinician as being related to product use, but we noted 1 respiratory event in the nicotine-replacement group and 5 in the e-cigarette group (2 in participants who were smoking and not vaping, 2 in participants who were smoking and vaping, and 1 in a participant whose status with respect to smoking and vaping was not known) (see the Supplementary Appendix).

Of the prespecified adverse reactions of interest, nausea was reported more frequently in the nicotine-replacement group (37.9%, vs. 31.3% in the e-cigarette group) and throat or mouth irritation more frequently in the e-cigarette group (65.3%, vs. 51.2% in the nicotine-replacement group). There was little difference between the two groups in the percentage of participants reporting severe nausea (6.6% in the e-cigarette group and 6.5% in the nicotine-replacement group) or severe throat or mouth irritation (5.9% and 3.9%, respectively) (Tables S9 and S10 in the Supplementary Appendix).

Table 5.

Respiratory Symptoms at Baseline and at 52 Weeks.

Regarding the prespecified respiratory symptoms of interest, the incidence of cough and phlegm production declined in both trial groups from baseline to 52 weeks. However, among participants who reported cough or phlegm at baseline, significantly more were symptom-free at the 52-week follow-up in the e-cigarette group than in the nicotine-replacement group (Table 5). To determine whether this was due to the higher abstinence rate in the e-cigarette group, we ran an exploratory analysis that controlled for abstinence status at 52 weeks. This did not change the results (relative risk for cough, 0.8; 95% CI, 0.6 to 0.9; relative risk for phlegm, 0.7; 95% CI, 0.6 to 0.9).

Discussion

E-cigarettes were more effective for smoking cessation than nicotine-replacement therapy in this randomized trial. This is particularly noteworthy given that nicotine replacement was used under expert guidance, with access to the full range of nicotine-replacement products and with 88.1% of participants using combination treatments.[11]

Our trial showed a stronger effect of e-cigarettes than previous trials.[5,12,13] This could be due to the inclusion of smokers seeking help in quitting, the provision of face-to-face support, and the use of refillable e-cigarettes with free choice of e-liquids. Previous trials provided limited or no face-to-face support and used first-generation cartridge products. Refillable devices are generally more efficient at nicotine delivery.[14]

The trial provides some indications of why e-cigarettes had better results than nicotine-replacement treatments. As in previous studies,[5,15] e-cigarettes were more effective in alleviating tobacco withdrawal symptoms and received better ratings than nicotine-replacement therapy. They may also have allowed better tailoring of nicotine dose to individual needs.

The rate of continuing e-cigarette use was fairly high. This can be seen as problematic if e-cigarette use for a year signals ongoing long-term use, which may pose as-yet-unknown health risks. On the positive side, ongoing e-cigarette use may ameliorate withdrawal symptoms, such as constipation,[16] mouth ulcers,[17] and weight gain,[18] and continue to provide some of the positive subjective effects previously derived from smoking.[19] Provided that ongoing e-cigarette use has similar effects to long-term nicotine-replacement use, for heavy smokers with a high risk of relapse, long-term e-cigarette use may also assist with preventing relapse.[20] Among participants in our trial in whom full abstinence was not achieved, those in the e-cigarette group were more likely to reduce their smoke intake than those in the nicotine-replacement group, but it is unclear whether this affects future abstinence.

E-cigarettes caused more throat or mouth irritation, and nicotine replacement caused more nausea; these effects were mostly mild. There were mixed signals regarding the effects of e-cigarettes on the respiratory system. More participants in the e-cigarette group than in the nicotine-replacement group reported respiratory serious adverse events, although the difference was not significant and some of the affected participants were not vaping. Meanwhile, we detected positive effects of e-cigarette use on some respiratory outcomes. Similar positive effects were reported previously. A switch to e-cigarettes was accompanied by a reduction in respiratory infections in an online survey,[21] and two case studies described nonsmokers with chronic throat and nose infections that resolved after they started to vape. Antibacterial effects of propylene glycol and glycerin were suggested as possible explanations.[22,23] (For more on e-cigarettes and the respiratory system, see the Supplementary Appendix.)

The trial had several limitations. Product assignments could not be blinded. Positive expectations have limited effects on long-term abstinence, but if nicotine replacement was seen as an inferior option, participants in the nicotine-replacement group could have put less effort into their quit attempt than those in the e-cigarette group. We tried to limit expectation effects by recruiting only participants with no strong product preference. Abstinence rates in the nicotine-replacement group were also at least as high as in usual practice[24] (see the Supplementary Appendix). Nevertheless, lack of blinding could affect the results. Carbon monoxide validation detects smoking only over the past 24 hours, so there may have been some false negative results. Several participants in the nicotine-replacement group used e-cigarettes during the trial, but this would dilute rather than amplify any effects of e-cigarettes. The 1-year follow-up rate of 79% was similar to the rates of 78%,[19] 79%,[5] and 75%[20] observed in other studies involving the same general population and setting. Achieving higher follow-up rates among smokers engaged in face-to-face treatment is difficult, because they tend to feel embarrassed if they do not quit, and some avoid further contact. Multiple imputation showed consistent results; nevertheless, incomplete follow-up represents another limitation of the trial.

The findings are likely to be valid for dependent smokers who seek help but may not be generalizable to smokers who are less dependent or who try e-cigarettes for reasons other than quitting smoking. In addition, they may not be generalizable to less effective first-generation e-cigarettes. Moreover, not all service clients want e-cigarettes. In a previous study, 69% accepted the offer of an e-cigarette starter pack.[25] (For comparison, 57% of service clients opt for nicotine replacement and 25% for varenicline.[26])

Further trials are needed to determine whether our results generalize outside the U.K. services. In addition, e-cigarette studies are needed that compare different levels of support. This is important for focusing public health messages on either encouraging smokers to switch to e-cigarette use within support services or recommending use with less intensive or no support.

In our trial, refillable e-cigarettes had greater efficacy than nicotine-replacement therapy, even though nicotine replacement was provided in combinations and under expert guidance.

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Supplementary Material

Protocol	PDF	1415KB
Supplementary Appendix	PDF	787KB
Disclosure Forms	PDF	188KB
Data Sharing Statement	PDF	57KB

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MARCH 31, 2015

E-Cigarettes Poised to Save Medicaid Billions

J. Scott Moody, Chief Executive Officer and Chief Economist

Electronic cigarettes (e-cigs) have only been around since 2006, yet their potential to dramatically reduce the damaging health impacts of traditional cigarettes has garnered significant attention and credibility. Numerous scientific studies show that e-cigs not only reduce the harm from smoking, but can also be a part of the successful path to smoking cessation.

The term "e-cig" is misleading because there is no tobacco in an e-cig, unlike a traditional, combustible cigarette. The e-cig uses a battery-powered vaporizer to deliver nicotine via a propylene-glycol solution—which is why "smoking" an e-cig is called "vaping." The vapor is inhaled like a smoke from a cigarette, but does not contain the carcinogens found in tobacco smoke.

Unlike traditional nicotine replacement therapy (NRT), such as gum or patches, e-cigs mimic the physical routine of smoking a cigarette. As such, e-cigs fulfill both the chemical need for nicotine and physical stimuli of smoking. This powerful combination has led to the increasing demand for e-cigs—8.2% use among nondaily smokers and 6.2% use among daily smokers in 2011.[1]

The game-changing potential for dramatic harm reduction by current smokers using e-cigs will flow directly into lower healthcare costs dealing with the morbidity and mortality stemming from smoking combustible cigarettes. These benefits will particularly impact the Medicaid system where the prevalence of cigarette smoking is twice that of the general public (51% versus 21%, respectively).

Based on the findings of a rigorous and comprehensive study on the impact of cigarette smoking on Medicaid spending, the potential savings of e-cig adoption, and the resulting tobacco smoking cessation and harm reduction, could have been up to $48 billion in Fiscal Year (FY) 2012.[2] This savings is 87% higher than all state cigarette tax collections and tobacco settlement collections ($24.4 billion) collected in that same year.

Unfortunately, the tantalizing benefits stemming from e-cigs may not come to fruition if artificial barriers slow their adoption among current smokers. These threats range from the Food and Drug Administration regulating e-cigs as a pharmaceutical to states extending their cigarette tax to e-cigs. To be sure, e-cigs are still a new product and should be closely monitored for long-term health effects. However, given the long-term fiscal challenges facing Medicaid, the prospect of large e-cigs cost savings is worth a non-interventionist approach until hard evidence proves otherwise.

Prevalence of Smoking in the Medicaid Population

According to the Centers for Disease Control and Prevention, in 2011, 21.2% of Americans smoked combustible cigarettes. However, as shown in Table 1, the smoking rate varies considerably across states with the top three states being Kentucky (29%), West Virginia (28.6%), and Arkansas (27%) and the three lowest states being Utah (11.8%), California (13.7%), and New Jersey (16.8%).[3]

Additionally, the smoking rate varies dramatically by income level. Nearly 28% of people living below the poverty line smoke while 17% of people living at or above the poverty line smoke.[4]

As a consequence, the level of smoking prevalence among Medicaid recipients is more than twice that of the general public, 51% versus 21%, respectively. However, this too varies considerably across states with the top three states being New Hampshire (80%), Montana (70%), and Pennsylvania (70%) and the three lowest states being Mississippi (35%), New Jersey (36%), and South Carolina (41%).[5]

In absolute terms, the U.S. Medicaid system includes 36 million smokers out of a total Medicaid enrollment of over 68 million. As such, this places much of the health burden and related financial cost of smoking on the Medicaid system which strains the system and takes away scarce resources from the truly needy.

Economic Benefit of Smoking Cessation and Harm Reduction

Smoking creates large negative externalities due to adverse health impacts. Table 2 shows the results of a comprehensive study that quantified the two major costs of smoking in 2009—lost productivity and healthcare costs.[6]

Lost productivity occurs when a person dies prematurely due to smoking or misses time from work due to smoking. This cost the economy $185 billion in lost output in 2009.

Table 1
Smokers Represent Significantly Larger Proportion of Medicaid Recipients than General Population
2011

State	Percent Smokers		Medicaid Enrollment	Number of Smokers on Medicaid
	Medicaid	General Population		
United States	51%	21.2% (median)	68,372,045	36,461,209
Alabama	52%	24.3%	938,313	487,923
Alaska	68%	22.9%	135,059	91,840
Arizona	49%	19.2%	1,989,470	974,840
Arkansas	54%	27.0%	777,833	420,030
California	45%	13.7%	11,500,583	5,175,262
Colorado	61%	18.3%	733,347	447,342
Connecticut	49%	17.1%	729,294	357,354
Delaware	58%	21.7%	223,225	129,471
Florida	46%	19.3%	3,829,173	1,761,420
Georgia	42%	21.2%	1,925,269	808,613
Hawaii	62%	16.8%	313,629	194,450
Idaho	62%	17.2%	409,456	253,863
Illinois	58%	20.9%	2,900,614	1,682,356
Indiana	68%	25.6%	1,208,207	821,581
Iowa	61%	20.4%	544,620	332,218
Kansas	54%	22.0%	363,755	196,428
Kentucky	65%	29.0%	1,065,840	692,796
Louisiana	43%	25.7%	1,293,869	556,364
Maine	63%	22.8%	327,524	206,340
Maryland	51%	19.1%	1,003,548	511,809
Massachusetts	53%	18.2%	1,504,611	797,444
Michigan	64%	23.3%	2,265,277	1,449,777
Minnesota	54%	19.1%	989,600	534,384
Mississippi	35%	26.0%	775,314	271,360
Missouri	66%	25.0%	1,126,505	743,493
Montana	70%	22.1%	136,442	95,509
Nebraska	64%	20.0%	284,000	181,760
Nevada	62%	22.9%	363,357	225,281
New Hampshire	80%	19.4%	152,182	121,746
New Jersey	36%	16.8%	1,304,257	469,533
New Mexico	50%	21.5%	571,621	285,811
New York	54%	18.1%	5,421,232	2,927,465
North Carolina	63%	21.8%	1,892,541	1,192,301
North Dakota	63%	21.9%	85,094	53,609
Ohio	65%	25.1%	2,526,533	1,642,246
Oklahoma	58%	26.1%	852,603	494,510
Oregon	67%	19.7%	690,364	462,544
Pennsylvania	70%	22.4%	2,443,909	1,710,736
Rhode Island	48%	20.0%	221,041	106,100
South Carolina	41%	23.1%	978,732	401,280
South Dakota	69%	23.0%	134,798	93,011
Tennessee	58%	23.0%	1,488,267	863,195
Texas	43%	19.2%	4,996,318	2,148,417
Utah	54%	11.8%	366,271	197,786
Vermont	67%	19.1%	184,088	123,339
Virginia	58%	20.9%	1,016,419	589,523
Washington	67%	17.5%	1,371,987	919,231
West Virginia	67%	28.6%	411,218	275,516
Wisconsin	63%	20.9%	1,292,799	814,463
Wyoming	62%	23.0%	76,372	47,351
District of Columbia	51%	20.8%	235,665	120,189

Source: Centers for Disease Control and Prevention, Centers for Medicare and Medicaid Services, and State Budget Solutions

Smokers incur higher healthcare costs when those individuals require medical services such as ambulatory care, hospital care, prescriptions, and neonatal care for conditions caused by smoking. This cost the economy $116 billion in extra medical treatments.

Overall, in 2009 alone, the negative externalities of smoking cost the U.S. economy $301 billion in lost productivity and higher healthcare costs. Not surprisingly, these costs were centered in high population states such as California ($26.9 billion), New York ($20.6 billion), and Texas ($20.4 billion).

Literature Review On E-cig Impact On Harm Reduction Through Reduced Toxic Exposure and Smoking Cessation

E-cigs have only been around since 2006, yet their potential to dramatically reduce the damaging health impacts of traditional combustible cigarettes has garnered significant attention and credibility. Numerous scientific studies are showing that e-cigs not only reduce the harm from smoking, but is also a successful path to smoking cessation.

In perhaps the most comprehensive e-cig literature review to date, Neil Benowitz et al. (2014) identified eighty-one studies with original data and evidence from which to judge e-cig effectiveness for harm reduction.[7] They concluded:

"Allowing EC (electronic cigarettes) to compete with cigarettes in the market-place might decrease smoking-related morbidity and mortality. Regulating EC as strictly as cigarettes, or even more strictly as some regulators propose, is not warranted on current evidence. Health professionals may consider advising smokers unable or unwilling to quit through other routes to switch to EC as a safer alternative to smoking and a possible pathway to complete cessation of nicotine use."

There are two ways that e-cigs benefit current smokers. First, there is harm reduction for the smoker by removing exposure to the toxicity

Table 2
Comprehensive Costs of Smoking
(Billions of Dollars)
2009

State	Lost Productivity			Healthcare Costs	Total Smoking Costs
	Premature Death	Workplace	Total		
United States	117.1	67.5	184.6	116.4	301.0
Alabama	2.7	1.2	3.9	1.7	5.6
Alaska	0.2	0.2	0.4	0.3	0.7
Arizona	1.9	1.3	3.2	1.9	5.1
Arkansas	1.7	0.7	2.4	1.1	3.4
California	9.6	5.7	15.2	11.6	26.9
Colorado	1.3	1.2	2.5	1.6	4.1
Connecticut	1.2	0.7	1.8	1.7	3.6
Delaware	0.4	0.2	0.6	0.4	1.1
District of Columbia	0.3	0.1	0.4	0.5	0.9
Florida	7.9	4.4	12.3	7.3	19.6
Georgia	3.7	2.4	6.2	2.9	9.0
Hawaii	0.4	0.2	0.7	0.4	1.1
Idaho	0.4	0.3	0.7	0.4	1.1
Illinois	5.0	2.9	7.9	4.8	12.7
Indiana	3.0	2.1	5.1	2.6	7.7
Iowa	1.2	0.7	1.9	1.1	3.0
Kansas	1.0	0.6	1.6	1.0	2.6
Kentucky	2.6	1.3	3.9	1.8	5.7
Louisiana	2.4	0.9	3.3	1.8	5.1
Maine	0.6	0.3	0.9	0.7	1.6
Maryland	2.1	1.3	3.4	2.2	5.6
Massachusetts	2.2	1.3	3.4	3.7	7.1
Michigan	4.5	2.4	7.0	4.0	11.0
Minnesota	1.5	1.5	3.0	2.3	5.4
Mississippi	1.8	0.7	2.4	1.0	3.5
Missouri	3.0	1.5	4.5	2.7	7.2
Montana	0.3	0.2	0.6	0.4	0.9
Nebraska	0.6	0.5	1.1	0.7	1.8
Nevada	1.1	0.7	1.7	0.9	2.6
New Hampshire	0.5	0.3	0.8	0.6	1.4
New Jersey	2.9	1.8	4.7	3.6	8.3
New Mexico	0.5	0.4	0.9	0.6	1.5
New York	6.9	3.9	10.8	9.8	20.6
North Carolina	4.1	2.2	6.3	3.4	9.7
North Dakota	0.2	0.2	0.4	0.3	0.7
Ohio	5.7	2.9	8.6	5.2	13.9
Oklahoma	2.1	0.9	3.0	1.3	4.3
Oregon	1.3	0.8	2.1	1.3	3.4
Pennsylvania	5.4	3.2	8.5	5.7	14.2
Rhode Island	0.4	0.2	0.7	0.6	1.3
South Carolina	2.3	1.0	3.3	1.6	4.9
South Dakota	0.3	0.2	0.5	0.3	0.8
Tennessee	3.6	1.7	5.3	2.6	7.9
Texas	7.9	4.9	12.8	7.6	20.4
Utah	0.4	0.3	0.7	0.4	1.1
Vermont	0.2	0.1	0.4	0.3	0.7
Virginia	2.9	2.0	4.8	2.7	7.5
Washington	2.1	1.3	3.4	2.4	5.7
West Virginia	1.1	0.5	1.6	0.9	2.5
Wisconsin	2.0	1.4	3.4	2.4	5.8
Wyoming	0.2	0.2	0.4	0.2	0.6

Source: See Endnote 6 and State Budget Solutions

associated with the thousands of compounds, many carcinogenic, found in the burning of tobacco and the resulting smoke. Second, smoking cessation efforts by the smoker are enhanced by simultaneously fulfilling both the chemical need for nicotine and physical stimuli of smoking.

In the last few years the academic literature has exploded with articles on these two topics. The following is a selection of some of the most recent studies and their conclusions.

Reduced Toxic Exposure

Igor Burstyn (2014) concludes, "Current state of knowledge about chemistry of liquids and aerosols associated with electronic cigarettes indicates that there is no evidence that vaping produces inhalable exposures to contaminants of the aerosol that would warrant health concerns by the standards that are used to ensure safety of workplaces . . . Exposures of bystanders are likely to be orders of magnitude less, and thus pose no apparent concern."[8]

Neal Benowitz, et al. (2013) concludes, "The vapour generated from e-cigarettes contains potentially toxic compounds. However, the levels of potentially toxic compounds in e-cigarette vapour are 9—450-fold lower than those in the smoke from conventional cigarettes, and in many cases comparable with the trace amounts present in pharmaceutical preparation. Our findings support the idea that substituting tobacco cigarettes with electronic cigarettes may substantially reduce exposure to tobacco-specific toxicants. The use of e-cigarettes as a harm reduction strategy among cigarette smokers who are unable to quit, warrants further study."[9]

Kostantinos E Farsalinos et al. (2014) concludes, "Although acute smoking inhalation caused a delay in LV (Left Ventricular) myocardial relaxation in smokers, electronic cigarette use was found to have no such immediate effects in daily users of the device. This short-term beneficial profile of electronic cigarettes compared to smoking, although not conclusive about its overall health-effects as a tobacco harm reduction product, provides the first evidence about the cardiovascular effects of this device."[10]

Smoking Cessation

Emma Beard et al. (2014) concludes, "Among smokers who have attempted to stop without professional support, those who use e-cigarettes are more likely to report continued abstinence than those who used a licensed NRT [Nicotine Replacement Therapy] product bought over-the-counter or no aid to cessation. This difference persists after adjusting for a range of smoker characteristics such as nicotine dependence."[11]

Christopher Bullen et al. (2013) concludes, "E-cigarettes, with or without nicotine, were modestly effective at helping smokers to quit, with similar achievement of abstinence as with nicotine patches, and few adverse events . . . Furthermore, because they have far greater reach and higher acceptability among smokers than NRT [Nicotine Replacement Therapy], and seem to have no greater risk of adverse effects, e-cigarettes also have potential for improving population health."[12]

Pasquale Caponnetto et al. (2013) concludes, "The results of this study demonstrate that e-cigarettes hold promise in serving as a means for reducing the number of cigarettes smoked, and can lead to enduring tobacco abstinence as has also been shown with the use of FDA-approved smoking cessation medication. In view of the fact that subjects in this study had no immediate intention of quitting, the reported overall abstinence rate of 8.7% at 52-weeks was remarkable."[13]

Konstantinos E. Farsalinos et al. (2013) concludes, "Participants in this study used liquids with high levels of nicotine in order to achieve complete smoking abstinence. They reported few side effects, which were mostly temporary; no subject reported any sustained adverse health implications or needed medical treatment. Several of the side effects may not be attributed to nicotine. In addition, almost every vaper reported significant benefits from switching to the EC [e-cigarette]. These observations are consistent with findings of Internet surveys and are supported by studies showing that nicotine is not cytotoxic, is not classified as a carcinogen, and has minimal effects on the initiation or propagation of atherosclerosis . . . Public health authorities should consider this and other studies that ECs are used as long-term substitutes to smoking by motivated exsmokers and should adjust their regulatory decisions in a way that would not restrict the availability of nicotine-containing liquids for this population."[14]

Potential E-cig Medicaid Cost Savings

To date, the academic literature strongly suggests that e-cigs hold the promise of dramatic harm reduction for smokers simply by switching from combustible tobacco cigarettes to e-cigs. This harm reduction is due to both its positive impact on smoking cessation and reduced exposure to toxic compounds in cigarette smoke.

As a result, we can expect the healthcare costs of smoking to decline over time as the adoption of e-cigs by smokers continues to grow. Additionally, we can expect greater rates of adoption as e-cigs continue to evolve and improve based on market feedback—a dynamic that has never existed with other nicotine replacement therapies.

As discussed earlier, the potential savings to the economy are very large. In terms of healthcare alone, most of that cost is currently borne by the Medicaid system where the prevalence of cigarette smoking is twice that of the general public, 51% versus 21%, respectively. So what are the potential healthcare savings to Medicaid?

Brian S. Armour et al. (2009) created an impressive economic model to estimate how much smoking costs Medicaid based on data from the Medical Expenditure Panel Survey and the Behavioral Risk Factor Surveillance System.[15]

Overall, their model ". . . included 16,201 adults with weighting variables that allowed us to generate state representative estimates of the

Table 3
Smoking Costs on Medicaid by State
(Millions of Dollars)
Fiscal Year 2012

State	Medicaid Spending	Smoking Costs as Percent of Medicaid Spending	Smoking Costs on Medicaid
United States	415,154	11%	45,667
Alabama	5,027	9%	452
Alaska	1,348	15%	202
Arizona	7,905	18%	1,423
Arkansas	4,160	11%	458
California	50,165	11%	5,518
Colorado	4,724	17%	803
Connecticut	6,759	7%	473
Delaware	1,485	10%	148
District of Columbia	2,111	11%	232
Florida	17,907	11%	1,970
Georgia	8,526	10%	853
Hawaii	1,493	11%	164
Idaho	1,452	14%	203
Illinois	13,393	11%	1,473
Indiana	7,486	15%	1,123
Iowa	3,495	10%	350
Kansas	2,667	12%	320
Kentucky	5,702	12%	684
Louisiana	7,358	12%	883
Maine	2,413	14%	338
Maryland	7,687	12%	922
Massachusetts	12,926	11%	1,422
Michigan	12,460	13%	1,620
Minnesota	8,894	11%	978
Mississippi	4,466	9%	402
Missouri	8,727	14%	1,222
Montana	973	15%	146
Nebraska	1,722	15%	258
Nevada	1,739	11%	191
New Hampshire	1,187	15%	178
New Jersey	10,389	6%	623
New Mexico	3,430	12%	412
New York	53,306	11%	5,864
North Carolina	12,282	11%	1,351
North Dakota	744	12%	89
Ohio	16,352	13%	2,126
Oklahoma	4,642	12%	557
Oregon	4,587	15%	688
Pennsylvania	20,393	11%	2,243
Rhode Island	1,856	8%	148
South Carolina	4,848	11%	533
South Dakota	749	16%	120
Tennessee	8,798	11%	968
Texas	28,286	11%	3,111
Utah	1,903	14%	266
Vermont	1,353	15%	203
Virginia	6,906	11%	760
Washington	7,560	18%	1,361
West Virginia	2,790	11%	307
Wisconsin	7,096	13%	923
Wyoming	528	16%	85

Note: States do not sum to Total due to rounding.
Source: See Endnote 15 and State Budget Solutions

adult, noninstitutionalized Medicaid population."

The study concluded that 11% of all Medicaid expenditures can be attributed to smoking. Additionally, among the states these costs ranged from a high of 18% (Arizona and Washington) to a low of 6% (New Jersey).

This study uses their percentage of Medicaid spending due to smoking and applies it to the latest year of available state-by-state Medicaid spending. As shown in Table 3, in FY 2012, smoking cost the Medicaid system $45.7 billion. Of course, the largest states bear the brunt of these costs such as New York ($5.9 billion), California ($5.5 billion), and Texas ($3.1 billion).

To put this potential savings to Medicaid into perspective, in FY 2012, state governments and the District of Columbia combined collected $24.4 billion in cigarette excise taxes and tobacco settlement payments. As shown in Table 4, the potential Medicaid savings exceeds cigarette excise tax collections and tobacco settlement payments by 87%.

However, this varies greatly by state with high ratios in the South Carolina (435%), Missouri (409%), and New Mexico (260%), Arizona (238%), and California (238%) and low ratios in New Jersey (-39%), New Hampshire (-31%), Rhode Island (-17%), Connecticut (-13%), and Hawaii (-4%). Overall, 45 states and D.C. stand to gain more from potential Medicaid savings than through lost cigarette tax collections and tobacco settlement payments.

Note that many of the five states with negative ratios are distorted because excise tax collections are based on where the initial sale occurred and not where the cigarettes were ultimately consumed. This can vary greatly because of cigarette smuggling and cross-border shopping created by state-level differentials in cigarette excise taxes.[16]

For instance, New Hampshire has long been a source for out-of-state cigarette purchase from shoppers living in Massachusetts, Maine, and Vermont because of its lower cigarette excise

Table 4
Smoking Costs on Medicaid Exceeds State Cigarette Tax Collections and Tobacco Settlement Payments
(Millions of Dollars)
Fiscal Year 2012

State	State Cigarette Tax Collections (a)	Tobacco Settlement Payments (b)	Smoking Costs on Medicaid	Smoking Costs on Medicaid as a Percent of State Cigarette Tax Collections and Tobacco Settlement Payments
United States	17,226	7,190	45,667	87%
Alabama	126	94	452	106%
Alaska	67	30	202	108%
Arizona	319	101	1,423	238%
Arkansas	247	51	458	54%
California	896	736	5,518	238%
Colorado	203	91	803	173%
Connecticut	418	124	473	-13%
Delaware	121	27	148	1%
District of Columbia	36	38	232	214%
Florida	381	365	1,970	164%
Georgia	227	141	853	132%
Hawaii	122	49	164	-4%
Idaho	48	25	203	177%
Illinois	606	274	1,473	67%
Indiana	465	130	1,123	89%
Iowa	225	66	350	20%
Kansas	104	58	320	98%
Kentucky	277	102	684	81%
Louisiana	133	141	883	222%
Maine	140	51	338	77%
Maryland	411	146	922	66%
Massachusetts	574	254	1,422	72%
Michigan	965	256	1,620	33%
Minnesota	422	167	978	66%
Mississippi	157	110	402	50%
Missouri	105	135	1,222	409%
Montana	87	30	146	24%
Nebraska	68	38	258	145%
Nevada	103	40	191	34%
New Hampshire	215	43	178	-31%
New Jersey	792	231	623	-39%
New Mexico	75	39	412	260%
New York	1,632	738	5,864	147%
North Carolina	295	141	1,351	210%
North Dakota	28	32	89	49%
Ohio	843	295	2,126	87%
Oklahoma	293	77	557	50%
Oregon	256	79	688	106%
Pennsylvania	1,119	337	2,243	54%
Rhode Island	132	47	148	-17%
South Carolina	26	73	533	435%
South Dakota	60	24	120	42%
Tennessee	279	139	968	131%
Texas	1,470	475	3,111	60%
Utah	124	36	266	66%
Vermont	80	35	203	77%
Virginia	192	117	760	145%
Washington	471	151	1,361	119%
West Virginia	110	64	307	77%
Wisconsin	653	131	923	18%
Wyoming	26	19	85	90%

(a) Includes all forms of tobacco taxes.
(b) Includes Master Settlement Agreement and individual state payments.
Source: Department of Commerce: Census Bureau, Internal Revenue Service, and State Budget Solutions

tax. As such, the ratio is too high for Massachusetts, Maine, and Vermont and too low for New Hampshire. The same applies to New Jersey and Connecticut vis-à-vis New York and, more specifically, New York City, which levies its own cigarette tax on top of the state tax.

Hawaii is an exception due to its physical isolation which creates monopoly rents. Rhode Island levies a very high cigarette excise tax, but not relatively high enough compared to neighboring Connecticut and Massachusetts to drive a lot of cross-border shopping.

Other Potential E-cig Cost Savings

Another area of cost savings from greater e-cig adoption is the reduction in smoke and fire dangers in subsidized and public housing. According to a recent study, smoking imposes three major costs:

1. Increased healthcare costs from exposure to second hand smoke within and between housing units.
2. Increased renovation costs of smoking-permitted housing units.
3. Fires attributed to cigarettes.

As shown in Table 5, the study estimates that smoking imposes a nationwide cost of nearly $500 million.[17] The top three states facing the greatest expenses are New York ($125 million), California ($72 million), and Texas ($24 million) while the top three states with the lowest expenses are Wyoming ($0.6 million), Idaho ($0.8 million), and Montana ($1 million).

Applying Cigarette Taxes to E-cigs?

Many policymakers around the country have suggested applying the existing cigarette tax, wholly or in part, to e-cigs. This is bad public policy and is based on a fundamental misunderstanding of the cigarette tax.

The cigarette tax is what economists call a "Pigovian Tax" which is designed to mitigate

Table 5
Smoking Costs on Subsidized and Public Housing
(Millions of Dollars)
2012

State	Smoking Costs
United States	496.8
New York	124.7
California	72.4
Texas	28.3
Massachusetts	24.0
Florida	23.2
Ohio	21.7
Pennsylvania	17.7
New Jersey	15.8
Louisiana	14.4
North Carolina	13.9
Illinois	13.3
Tennessee	12.9
Michigan	12.8
Alabama	12.4
Georgia	11.6
Connecticut	10.7
Missouri	9.4
Indiana	8.3
Virginia	7.8
Mississippi	7.2
Kentucky	7.1
Minnesota	7.1
South Carolina	7.0
Maryland	7.0
Arkansas	6.8
Oklahoma	6.8
Wisconsin	6.5
Washington	5.0
Arizona	4.9
Colorado	4.5
West Virginia	4.3
Oregon	4.3
Maine	4.2
Rhode Island	4.0
Hawaii	3.8
Iowa	3.8
New Mexico	3.0
Kansas	2.9
Nebraska	2.1
Nevada	1.9
Vermont	1.9
New Hampshire	1.9
Utah	1.4
Delaware	1.3
North Dakota	1.2
South Dakota	1.1
Montana	1.0
Idaho	0.8
Wyoming	0.6
Alaska	N.A.
District of Columbia	N.A.

Source: See Endnote 17 and State Budget Solutions

negative externalities of certain actions. Cigarette smoking creates many negative externalities such as harmful health consequences to the user or to those in near proximity (second-hand smoke).

As detailed in this study, the negative externalities associated with traditional smoking are all but eliminated by e-cigs. Without evidence of actual negative externalities, applying the existing cigarette tax to e-cigs is simply bad public policy.

Conclusion

Policymakers have long sought to reduce the economic damage due to the negative health impact of smoking. They have used tactics ranging from cigarette excise taxes to subsidizing nicotine replacement therapies. To be sure, smoking prevalence has fallen over time, but there is more that can be done, especially given the fact that so much of the healthcare burden of smoking falls on the already strained Medicaid system.

As with any innovation, no one could have predicted the sudden arrival into the marketplace of the e-cig in 2006. Since e-cigs fulfill both the chemical need for nicotine and physical stimuli of smoking the demand for e-cigs has grown dramatically. The promise of a relatively safe way to smoke has the potential to yield enormous healthcare savings. The most current academic research verifies the harm reduction potential of e-cigs.

As shown in this study, the potential savings to Medicaid significantly exceeds the state revenue raised from the cigarette excise tax and tobacco settlement payments by 87%. As such, the rational policy decision is to adopt a non-interventionist stance toward the evolution and adoption of the e-cig until hard evidence proves otherwise. While cigarette tax collections will fall as a result, Medicaid spending will fall even faster. This is a win-win for policymakers and taxpayers.

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