VAPING AWARENESS PUBLIC EDUCATION SOCIETY

SPEARHEADING THE FIGHT TO BREAK CIGARETTE ADDICTION

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OPPOSITION TO HOUSE BILL 732

February 18, 2020

Respectfully Submitted To:

MD House Committee on Ways And Means
Hon. Anne Kaiser, Chair

ORAL TESTIMONY

SUPPORTING EXHIBITS

1. New York Times Article: *What If A Vaping Tax Encouraged Smoking?*
2. Minnesota Study Showing 95% Vaping Tax Increased Smoking By 8.1%
3. Truth Initiative Fact Sheet – Minnesota
4. Truth Initiative Fact Sheet – Maryland
5. Tax Foundation Report On Vaping Taxes
6. New England Journal Of Medicine Article, *Differential Taxes*
7. Public Health England Study, E-Cigarettes Are About 95% Safer Than Smoking
8. Public Health England Study – Evidence Update 2019
9. 2nd Hand Vapor Analysis
10. Public Health Consequences of E-Cigarettes
11. Tobacco Harm Reduction Statistics For Maryland
12. Journal of Nature Article: Health Impact Of E-Cigarettes
13. Vaping Industry Economics In Maryland

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TESTIMONY OF SCOTT WEBBER IN OPPOSITION TO HB732

February 18, 2020

Good Afternoon Madam Chair and fellow members of the Ways & Means Committee.

My name is Scott Webber, proud MD citizen since 1986, currently living in Bethesda.

I am the Founder, along with my son, of the Vaping Awareness Public Education [V.A.P.E.] Society, a Non-Profit research and political advocacy organization formed to address the scourge of smoking, focused on the benefits - and risks - of vaping.

On the topic of vaping, I do consider myself an expert. I have been intensely researching the vaping universe since 2013. I have read hundreds of articles, reports, and studies on the topic, compiling multiple thousands of hours of combined time in this space. I probably know as much about vaping as anybody in the entire State. I tell you this, not to brag, but rather, to simply convey that I know what I am talking about because I have done my homework, and unlike many you have heard from today, I've studied both sides of the issue.

Accordingly, I can comfortably say HB732, as currently written - most notably its draconian 86% tax rate, even on all existing vaping products - will have VERY bad outcomes for the State and its citizens, both from a public health perspective, and certainly from a fiscal perspective. It is based on extremely bad science, is flagrantly dishonest, will likely result in the closing of well over 100 small businesses, actually reducing State revenues by the hundreds of millions of dollars over the next decade, while simply moving vaping sales out-of-state, to the Internet, and with all probability, to the black market. At the same time, current research shows that invoking tax parity among vaping and smoking products, as this bill proposes, actually leads to higher smoking rates, as cigarettes become both easier to obtain, and relatively less costly, while doing nothing at all to curb youth vaping.

I have submitted supporting documentation in my testimony packet that highlights what happened in MN after they imposed a similar 95% vaping tax and intentionally decimated their vaping industry. Smoking rates actually ROSE more than 8%, and their youth vaping rate is 50% higher than in MD. That is the proven wisdom of parity taxation of a less harmful product.

HB732 will create a situation, just like in MN, where you will be intentionally destroying small business vape shops and forcing users to either go black market, or the internet. As a result, the State will lose the sales tax, employment tax, income tax, and real estate revenues, AND the ability to monitor, regulate, and enforce these laws because the Comptroller can't walk in on the internet to test compliance. There is NOTHING smart about this legislation, and everything destructive and counterproductive to the intended outcome that we equally desire.

As evidenced in my packet, Vaping is known to be 95-99% less harmful than smoking, so to give the two parity, taxing a dangerous and deadly product equally to a much, much, MUCH healthier alternative, is nothing short of misguided Legislative malpractice.

In my packet is an article that discusses the applicable concept of 'differentiated taxation' that I hope you will read and absorb.

I'm not ignoring there are risks, but the benefits SOOO outweigh the risks, that no intelligent, or compassionate, or reasonable person – who has done their research - can logically deny the overwhelming superiority of vaping over smoking.

I would like to help put together a better bill, but one based on honesty, science, responsibility, fairness, and reality. I am offering myself as a resource to you and your staff to that end, but first, we need to stop this misguided legislation from inadvertently killing thousands of Maryland citizens while costing the taxpayers of this state, hundreds of millions of dollars.

Thank you for your consideration and discernment.

~Scott Webber

1. New York Times Article, *What If A Vaping Tax Encouraged Smoking?*

The New York Times | https://nyti.ms/2SWRS6p

What if a Vaping Tax Encouraged Cigarette Smoking?

Policies aimed at youth vaping may have negative effects on adult smokers.

By Margot Sanger-Katz

Jan. 6, 2020

Christian Bruna/EPA, via Shutterstock

The surging popularity of vaping among young Americans is driving lawmakers to use one of their favorite tools to discourage unwanted behavior: taxes.

In December, the Massachusetts legislature passed a 75 percent tax on all e-cigarettes. Twenty states have already done so, along with the District of Columbia, and several more are considering similar policies. The House Ways and Means Committee passed a bill last year that would make federal tobacco taxes apply equally to cigarettes and vaping products that deliver nicotine, the addictive drug in tobacco.

Taxes have proved effective in reducing cigarette smoking. But what if a vaping tax actually encouraged smoking instead of reducing it?

A new study suggests that these new taxes have the potential to do just that — by discouraging adult smokers from considering nicotine vaping, a safer way to ingest nicotine, or encouraging vapers to switch to cigarettes instead. The study, published by the National Bureau of Economic Research, examined what happened in Minnesota, one of the first states to impose a steep vaping tax (95 percent). The effect was that declines in smoking there leveled off, while they continued to fall in similar states that hadn't imposed such taxes.

"By decreasing the extent to which people use e-cigarettes, you decrease quitting of conventional cigarettes," said W. Kip Viscusi, a professor of law, economics and management at Vanderbilt University, who was not involved in the research but has studied tobacco policy extensively.

The research was conducted by Henry Saffer, Michael Grossman, Daniel L. Dench and Dhaval M. Dave, who used data from a detailed census survey about tobacco use to measure what happened to the smoking rate. Their goal was to find out whether e-cigarettes helped adult smokers quit smoking cigarettes, which are linked to a wide range of illnesses and are estimated to contribute to one in five deaths in the United States.

It's possible, they figured, that vaping might encourage more people to smoke, by providing a new way to try nicotine for the first time. It might also cause people who might have quit to just keep smoking, by providing a second way to get nicotine where smoking is restricted. The natural experiment of the Minnesota tax helped them measure what some overall effects really were.

When Minnesota made vaping more expensive, they found, smokers kept smoking instead of switching to e-cigarettes. A longstanding decline in adult smoking in the state slowed way down, while smoking in states that hadn't imposed big vaping taxes continued to fall. The researchers concluded that making e-cigarettes more expensive discouraged Minnesota smokers from trying them and caused fewer of them to switch away from smoking. By measuring the difference in the trends, the researchers estimated that Minnesota caused around 32,000 more adults to keep smoking cigarettes.

The paper didn't include close measures of whether people who stopped smoking completely quit nicotine, the most healthful possible outcome for smokers. While it is clear that most vaping products are safer than cigarettes, it is not yet clear by how much. New research is emerging that vaping products may cause some long-term lung and heart disease. And a recent poisoning outbreak associated mainly with THC, in which 55 people died, suggests that there can be acute health risks for some users.

But in general, nearly all public health researchers agree that it's better to switch to regulated e-cigarettes than to continue smoking cigarettes. They tend to describe a move from smoking to vaping as a form of "harm reduction," a more safe choice, even if it is not totally safe.

Some tobacco opponents were skeptical of the study's findings. Matthew L. Myers, the president at the Campaign for Tobacco-Free Kids, which endorses high vaping taxes, said the Minnesota results could be explained by unmeasured differences between that state and the states the researchers used for comparison. He pointed to other research that shows that only a fraction of adult smokers who start vaping ever switch over entirely.

"One has to be skeptical that e-cigarette use, including taxes on e-cigarettes, have been powerful enough in Minnesota or anywhere to actually have a meaningful measurable effect on adult cessation rates," he said.

Mr. Myers supports high taxes on e-cigarettes primarily because he sees them as a good way to discourage young people from starting to use nicotine in the first place. Since vaping products have entered the market in the United States, youth use of them has increased rapidly, outpacing a simultaneous decline in cigarette smoking among young people. Federal officials have described the development as a public health crisis.

The result has been a flurry of policy action to regulate vaping. In December, Congress passed a law that raises the legal age to purchase any tobacco product to 21. On Thursday, the Food and Drug Administration said it would crack down on the manufacturers of a subset of nicotine vaping devices that are sold in flavors other than tobacco or menthol. These measures are also intended to prevent youth vaping.

Strong evidence from states suggests that raising the tobacco purchasing age reduces smoking among both young adults and younger teenagers, who are less likely to have friends who can buy them cigarettes. Flavored products are particularly popular among younger vapers, according to surveys.

But Mr. Saffer, one of the Minnesota paper's authors, says his results suggest that a tax may be a blunt tool that reduces youth vaping at the expense of decreasing the number of adults who quit smoking.

"The research shows that e-cigarette taxes would be bad for adult smokers," he said. "To stop youth use, we know there are other alternatives."

Teen vaping rates have risen sharply in Minnesota, too, despite the large tax on the products.

Abigail Friedman, an assistant professor of health policy at Yale, and an author of two studies on state Tobacco 21 laws, said policymakers needed to strike a delicate balance in regulating e-cigarettes. Regulations need to deter teen vaping, she said, but also do as much as possible to help adult smokers switch to safer alternatives.

"We need to make it attractive as an alternative, and we need to make it unattractive otherwise," she said.

After reading the Minnesota paper, she concluded that broad vaping taxes had failed the first test.

2. Minnesota Study Showing 95% Vaping Tax Increased Smoking By 8.1%

NBER WORKING PAPER SERIES

E-CIGARETTES AND ADULT SMOKING: EVIDENCE FROM MINNESOTA

Henry Saffer
Daniel L. Dench
Michael Grossman
Dhaval M. Dave

Working Paper 26589
http://www.nber.org/papers/w26589

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
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E-Cigarettes and Adult Smoking: Evidence from Minnesota
Henry Saffer, Daniel L. Dench, Michael Grossman, and Dhaval M. Dave
NBER Working Paper No. 26589
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ABSTRACT

E-cigarettes use a battery powered heater to turn a liquid containing nicotine into a vapor. The vapor is inhaled by the user and is generally considered to be less harmful than the smoke from combustible cigarettes because the vapor does not contain the toxins that are found in tobacco smoke. Because e-cigarettes provide an experience that is very similar to smoking, they may be effective in helping smokers to quit, and thus the availability of e-cigarettes could increase quit rates. Alternatively, e-cigarettes may provide smokers with a method of bypassing smoking restrictions and prolong the smoking habit. There is very little causal evidence to date on how e-cigarette use impacts smoking cessation among adults. Although there is no federal tax on e-cigarettes, a few states have recently imposed heavy taxes on them. We provide some of the first evidence on how e-cigarette taxes impact adult smokers, exploiting the large tax increase in Minnesota. That state was the first to impose a tax on e-cigarettes by extending the definition of tobacco products to include e-cigarettes. This tax, which is 95% of the wholesale price, provides a plausibly exogenous deterrent to e-cigarette use. We utilize data from the Current Population Survey Tobacco Use Supplements from 1992 to 2015, in conjunction with a synthetic control difference-in-differences approach. We assess how this large tax increase impacted smoking cessation among adult smokers. Estimates suggest that the e-cigarette tax increased adult smoking and reduced smoking cessation in Minnesota, relative to the control group, and imply a cross elasticity of current smoking participation with respect to e-cigarette prices of 0.13. Our results suggest that in the sample period about 32,400 additional adult smokers would have quit smoking in Minnesota in the absence of the tax. If this tax were imposed on a national level about 1.8 million smokers would be deterred from quitting in a ten year period. The taxation of e-cigarettes at the same rate as cigarettes could deter more than 2.75 million smokers nationally from quitting in the same period. The public health benefits of not taxing e-cigarettes, however, must be weighed against effects of this decision on efforts to reduce vaping by youth.

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1. Introduction

A number of battery-powered devices on the market today deliver nicotine to the user in an aerosol or vapor form and are referred to as electronic cigarettes (e-cigs). Use of e-cigs is often called vaping in contrast to smoking conventional combustible cigarettes.[1] Because e-cigs are a relatively new product, there is no research on the long-term health effects of use. Nevertheless, e-cigs are generally considered to be less harmful than combustible cigarettes because the vapor produced by them does not contain the toxins and nitrosamines that are found in tobacco smoke (Goniewicz et al. 2013; Czogala et al. 2014). The U.S. National Institute on Drug Abuse states that because e-cigs deliver nicotine without burning tobacco, they appear to be a safer, less toxic alternative to conventional cigarettes.[2] Public Health England, a public health agency within the U.K.'s Department of Health and Social Care, has taken a more definitive position and stated that e-cigs are significantly less harmful to health and are about 95 percent safer than smoking (McNeil et al. 2015).

The public health debate surrounding the regulation of e-cigs has centered on harms to non-smoking adolescents and harm reduction for adults who smoke. For adolescents the concern is that e-cig use may have negative effects on cognitive development, result in long term nicotine addiction, and may lead to conventional cigarette use. For those adolescents who wish to experiment with nicotine, e-cigs may be a safer option than cigarettes and may have contributed to the decline in adolescent smoking. E-cigs may be effective in helping adult smokers to quit the habit. Currently between 14-19 percent of adults continue to use cigarettes (2017, National Health Interview Survey, NHIS and National Survey of Drug Use and Health, NSDUH), and interest in quitting smoking remains high. Almost two-thirds of current smokers report that they want to quit smoking completely, and among those who expressed such an intent about 60 percent follow-up with an actual cessation attempt (NHIS 2015). However, most

[1] All e-cigs have certain components in common, including a power source or battery that heats a liquid (usually propylene glycol) containing nicotine into an aerosol that is then inhaled by the user.
[2] See https://www.drugabuse.gov/publications/drugfacts/electronic-cigarettes-e-cigs.

attempts end in relapse, and less than one in ten smokers overall successfully quit in the past year (Babb et al. 2017).[3] E-cigs may be an effective substitute for smoking, particularly for smokers who have had a difficult time quitting in the past through other methods. Thus, the accessibility of e-cigs might enhance smoking cessation rates. On the other hand, it is also possible, as some contend, that e-cig use may adversely impact smoking cessation by undermining smoking restrictions and providing smokers with an alternative nicotine source for situations where smoking is not permitted.

This paper focuses on the potential for harm reduction for adults. There is very little causal evidence to date on how e-cig use impacts smoking cessation among adults. Acknowledging the potential for e-cigs to help smokers quit along with limited empirical evidence on this issue, the Food and Drug Administration (FDA) has thus far refrained from regulating their access for adults. For instance, unlike conventional cigarettes, e-cig manufacturers continue to be able to advertise in broadcast media, and the FDA has resisted banning or restricting such advertising. The FDA has also postponed for now the requirement that e-cig manufacturers submit marketing applications, a condition which would otherwise have effectively banned all e-cig products from the market until the FDA reviewed and approved the applications.[4]

In contrast to the FDA's relatively more accommodative stance at least with respect to adult access, a growing number of state and local governments have taken steps to more forcefully regulate the sale, marketing, and use of e-cigs. Attorneys General for 29 states signed a letter in 2014 urging the FDA to regulate the sale of e-cigs and restrict its advertising and marketing.[5] By the time the federal e-cig minimum legal sale age law of 18 went into effect in August of 2016, all states but two had a similar law in place. As of June 2019, 15 states

[3] In general, less than one in four cessation attempts is successful. For the average smoker, the expected number of quit attempts before quitting smoking successfully has been estimated as ranging from 6 to 30 attempts (Chaiton et al. 2016).
[4] While the FDA continues to make e-cigs available and accessible in the market for adults, it has taken a more aggressive approach towards regulating access for youth and educating them about the dangers of e-cigs.
[5] See https://ag.ny.gov/pdfs/FINAL_AG_FDA_Comment_Re_Deeming_Regulations.pdf.

raised their e-cig minimum purchase age to 21. An increasing number of states are also requiring licenses for retail sales of e-cigs and are expanding their smoking bans and clean indoor air laws to include vaping. Several states have also banned sales of flavored e-cigs and Walmart has announced that it will end sales of all e-cigs.

There is no federal tax on e-cigs, unlike on cigarettes and other tobacco products. With e-cigs being relatively new, states have struggled to determine whether and how to tax them. As of the end of 2018, ten states (in addition to several cities and counties) had started to levy taxes on e-cigs or the liquid nicotine used with e-cigs. Nine additional states began to do so in 2019 and two more will follow suit in 2020 (Campaign for Tobacco-Free Kids 2019). Given that one aspect of tobacco taxes is to improve public health and reduce tobacco-related health expenditures, there exists a key knowledge gap in the literature to inform policymakers contemplating taxes on e-cigs. It remains unclear how e-cig taxes impact smoking cessation. If higher e-cig taxes dissuade adult smokers from shifting to vapor products and from quitting smoking in the process, the forgone harm reduction must be taken into account; this would provide justification for taxing e-cigs less than traditional tobacco products, if at all. Similarly, if e-cig taxes promote smoking cessation, by making it more difficult for smokers to circumvent smoking restrictions and by reducing the overall addictive stock of nicotine, then this would provide additional rationale for levying taxes on e-cigs at the federal and state levels.

Our study directly addresses this knowledge gap, and makes several contributions in the process. We provide some of the first rigorous evidence on how taxing e-cigs impacts smoking cessation among adults. The empirical analysis exploits the large e-cig tax hike in Minnesota (MN), the first state to tax e-cigs, in conjunction with a synthetic control difference-in-differences approach to identify plausibly causal effects of e-cig use on adult smoking. In addition to providing direct estimates of the cross-effects of e-cig taxation, we also add to the very limited evidence base on the substitution and complementarity between e-cigs and cigarettes. We find consistent evidence that higher e-cig taxes increase adult smoking rates and reduce quits, implying that e-cigs are a likely substitute for conventional cigarettes among current smokers.

The remainder of the paper proceeds as follows. The next section briefly provides some background on the previous literature. Section 3 details the data and the empirical methods that we apply to this question, following by a discussion of the results. The concluding section summarizes our findings and places them in context along with some policy implications.

2. Background

Much of the literature that has considered the relationship between e-cig use and smoking among adults has relied on correlational evidence and not addressed the endogeneity between both behaviors.[6] The evidence from these sets of studies should be interpreted as descriptive and is fairly mixed. Several studies find that e-cig use is associated with reduced smoking. Zhu et al. (2017) analyze data from the Tobacco Use Supplements of the Current Population Surveys. They find that the population smoking cessation rate for 2014-2015 was significantly higher than for 2010-2011, coinciding with an increase in e-cig use. Exploiting information on e-cig use from the 2014-2015 wave, they also find that e-cig users were more likely than non-users to attempt to quit and more likely to succeed in quitting (defined as abstinence for 3 months or longer). Zhuang et al. (2016) conduct a two-year follow up of 2097 adult smokers, who were initially sampled using GfK's Knowledge Panel in 2012. Comparing short-term e-cig users (used in 2012 but not 2014) vs. long-term e-cig users (used e-cigs in both 2012 and 2014) vs. non-users, they find that long-term e-cig users had a higher quit attempt rate as well as a higher successful quit rate relative to both non-users and short-term e-cig users. A common pattern in tobacco consumption is dual cigarette and e-cig use, and there is some concern that prolonged dual use might impede or postpone the attempt to quit smoking. Zhuang et al. (2016) do not find, however, that dual use is associated with a lower smoking cessation rate.

[6] In this case, the endogeneity can reflect both reverse causality with e-cig use affecting smoking and vice versa as well as selection on unobserved factors (for instance, a propensity for addictive behaviors, risk tolerance, time preference) that may affect participation in both behaviors.

Brown et al. (2014) assessed the effectiveness of e-cigs when used to aid smoking cessation, in comparison with nicotine replacement therapy (NRT) and with unaided quitting. They rely on a cross-sectional survey of the English population that includes 5863 adults who had smoked within the previous 12 months and made at least one quit attempt during that period with either e-cigs, NRT or no aid. Their results show that e-cig users were more likely to report smoking abstinence (defined as non-smoking status at time of survey) than either those who used NRT or no aid.

Grana, Benowitz, and Glantz (2014) contend that although e-cig use may reduce smoking, it also may inhibit complete smoking cessation. They note that while some smokers cite a desire to quit smoking through the use of e-cigs, other common reasons given by smokers who also vape are to circumvent smoke-free laws and to cut down on conventional cigarettes. This may reinforce dual use patterns and delay or deter quitting. Kalkhoran and Glantz (2016) provide a review of papers that attempt to assess the relationship between e-cig use and smoking cessation by adult smokers. The question they are interested in is whether cigarette smokers who report e-cig use have a higher or lower probability of quitting smoking. Summarizing evidence from 38 studies, and performing a meta-analysis of 20 studies with control groups (most of these are cross-sectional or cohort studies), they conclude that the odds of quitting cigarettes were about 28 percent lower among e-cig users compared with non-users. Weaver et al. (2018) conduct a prospective cohort study, recruiting 1284 U.S. adult smokers in mid-2015 and following up with them about one year later. The odds of quitting smoking were found to be significantly lower among smokers who used e-cigs at baseline compared to smokers who did not vape. Smokers who had used e-cigs at some point during the study period were also less likely to quit smoking (defined as abstinence for at least 30 days prior to follow-up) relative to non-users. These studies are correlational rather than causal and cannot account for unmeasured confounders.

Huang et al. (2014), Zheng et al. (2016, 2017), and Tuchman (2019) provide evidence of causal effects of e-cigarette use on cigarette smoking in a reduced form setting. They do so by examining the impact of changes in the price of one good on the use of the other one. If, for example, the two goods are substitutes (a reduction in the price of one leads to a reduction in use of the other) that would suggest that an increase in e-cigarette use causes a reduction in smoking. All four studies employ Nielsen ScanTrack, which contains store scanner data at the point of sales, from 2009 or 2010 through 2012, 2013, or 2015 depending on the study. Except for Zheng et al. (2016), these studies find that the two goods are substitutes.

Several problems arise in this line of research. Price is computed by dividing sales revenue by sales in physical units. This introduces bias in the regression models because price and sales are not measured independently. Indeed, the own-price elasticity of demand for cigarettes in these studies usually is larger than one in absolute value, which is much larger than any of those in the previous literature reviewed by Cawley and Ruhm (2012). This problem aside, the demand functions may be subject to simultaneity bias due to the presence of an upward-sloping supply function in a competitive model or due to the behavior of firms in oligopolistic markets. Moreover, given that e-cigs are a new product, retailers may have incentives to begin to sell the product in areas where demand for it is expected to be substantial. Finally, e-cig sales in 2009, 2010, and 2011 were very limited. Consequently the price data for e-cigs in those years may be inaccurate.

Cotti, Nesson, and Teft (2018) overcome some of the issues just discussed by exploiting within-state variation in cigarette excise taxes to measure effects on e-cig and cigarette use from the Nielsen Homescan Panel, which contains actual purchases made by households, from 2011 through 2015. Cigarette taxes are not subject to measurement error and can reasonably be assumed to be exogenous in cigarette and e-cig demand functions. They find that higher cigarette taxes decrease both cigarette and e-cig purchases, suggesting that cigarettes and e-cigs are complements. Because e-cigs are a relatively new product, the sample period is short, which limits the identifying variation in cigarette taxes. This may have contributed to their finding of very large elasticity estimates (-1.9 to -2.6) of purchases of e-cig refills and starter kits with respect to the cigarette excise tax. Furthermore, because these are tax elasticities, the implied elasticities with respect to cigarette price are higher in magnitude. This study does not directly consider effects of e-cig taxes.

Pesko, Courtemanche and Maclean (2019) extend the previous study by examining the effects of e-cigarette taxes as well as those of cigarette taxes on smoking and vaping participation by adults. They employ a dichotomous variable for the adoption of any type of tax on e-cigs, which conflates very different tax schemes (ad valorem vs. excise; very small and relatively large taxes). These different approaches to state e-cig taxation policy have resulted in a trivial effect on price in some states and a large effect on price in other states. Pesko et al. (2019) use data from the Behavioral Risk Factor Surveillance System and the National Health Interview Surveys between 2011 and 2017 in conjunction with a difference-in-differences model. This sample period excludes Minnesota, which had the largest e-cig tax, from the within-state identifying variation because the state had a tax on e-cig in place for the entire sample period. Moreover, it ignores the extremely large e-cig excise tax hike that occurred in that state in 2013 (see the next section for details). The study adds two more years to the data used by Cotti, Nesson, and Teft (2018). Unlike Cotti, Nesson, and Teft (2018), Pesko et al. (2019) find that higher cigarette taxes increase adult e-cig use but find no effects of their-cig tax measure.

Abouk et al. (2019) use US birth records 2013 to 2017 to examine the effect of e-cig taxes on pre-pregnancy smoking and prenatal smoking. They find that e-cig taxes increase pre-pregnancy and prenatal smoking, implying that e-cigs and traditional cigarettes are substitutes among pregnant women. The e-cigarette tax measures are more refined than those in the one by Pesko et al. (2019). Abouk et al. (2019) do not, however, capitalize on the potential evidence contained in the quasi-natural experiment contained in the Minnesota experience and focus on a small segment of the population.[7]

[7] Abouk et al. (2019) exclude Minnesota from most of their analysis because it enacted an e-cigarette tax prior to the beginning of their sample year. When they start the study period in 2011 and include Minnesota, the state provides no within-state variation in one of their two wholesale tax measures: the presence of a tax. They do account for the Minnesota tax hike in 2013 (see the next section for details) but assume that Minnesota can be treated in the same manner as the seven other places (the District of

A few studies have conducted randomized control trials (RCT) to test the effectiveness of e-cigs vs. other modes in promoting smoking cessation. Bullen et al. (2013) conducted an RCT that included 657 smokers who wanted to quit. They were randomized into groups which were given e-cigs, placebo e-cigs (without any nicotine), and NRT. The trial lasted for 12 weeks, and the participants were also given limited counseling. Abstinence rates, verified chemically at six months, were 7.3% for the e-cig are, 4.1% for the placebo e-cig arm, and 5.8% for the NRT arm. Thus, e-cigs resulted in a greater likelihood of quitting, and were more effective than both placebo e-cigs and NRT, though the differences were not statistically significant. For those who failed to quit, the median time to relapse was twice as long for participants using e-cigs relative to both placebo e-cigs and NRT. Hajek et al. (2019) conducted an RCT with 886 participants who had sought assistance from the National Health Service in the U.K. to quit smoking. The 1-year abstinence rate was 18.0% for the e-cig group, as compared with 9.9% in the nicotine-replacement group. They concluded that e-cigs were more effective for smoking cessation than nicotine replacement therapy, when both products were accompanied with behavioral support. While RCTs can provide more definitive causal evidence, they are limited in their capability of assessing population-level effects under patterns of real-world use and conditions. Furthermore, they do not provide any information on the effects of policies such as e-cig taxation.

Our study provides some of the first evidence of the effects of e-cig taxes on smoking cessation among adults. We also provide the first estimate of the price elasticity of smoking participation with respect to the price of e-cigs implied by the impact of the first imposition of and subsequent large increase in an excise tax on e-cigs in the U.S. in the literature. This estimate is an important input towards evaluating the costs and benefits of e-cig taxation and the harm reduction debate. In the process, we add to the limited literature on how e-cig use is impacting

Columbia; Montgomery County, Maryland; and five counties in Alaska) that imposed e-cigarette taxes as a percent of wholesale prices during their sample period. All of these places did so for the first time in 2015 or 2016, which was much later than Minnesota. Moreover, none of them is a state.

adult smokers, drawing on the Minnesota tax hike as a natural experiment to drive exogenous variation in e-cig use.

3. Approach

The objective of this study is to provide plausibly causal evidence of the effects of e-cig use on adult smoking. In the empirical work, e-cig taxes serve as a lever that affects e-cig use. E-cig prices are less suitable because of their potentially endogeneity with use. The policy chosen must also have sufficient statistical power to change e-cig use in order to be able to identify downstream effects on smoking. We therefore rely on the large e-cig tax imposed in Minnesota (MN). Nicotine taxes are arguably exogenous to use because they are typically employed by states to raise revenue from products that are seen as harmful and thus face less resistance than taxes on other consumer goods.

MN was the first state to impose a tax on e-cigs by expanding its definition of "tobacco products" to include electronic cigarettes. The taxation began on August 1st 2010 (Public Law Health Center) with a tax rate of 35 percent. This tax was raised by another 60 percentage points to a total tax rate of 95 percent of the wholesale price on July 1st. 2013. This large tax hike on e-cigs had a substantial impact on prices. Based on retail sales from the Nielsen Scanner Data, e-cig retail prices of replacement pods in 2012 were $3.25 in MN (Figure 1).[8] Dave and Saffer (2013) and studies they cite indicate that tobacco product retailers apply a markup of approximately 1.33 to the wholesale price in setting the retail price. That estimate implies a 2012 wholesale price inclusive of tax of a replacement pod of about $2.44 inclusive of tax and exclusive of tax about $1.80. The 95 percent tax on $1.80 would equal a wholesale price of $3.52 and a retail price of $4.69. The actual retail price in MN in 2015 was $4.76, which suggests that our estimate is a close first-order approximation.[9]

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[8] E-cig sales in 2010 and 2011 were very limited and consequently the price data for e-cigs in these years may be inaccurate.

[9] We assume that the retail market for e-cigarettes can be characterized by the pure version of the Cournot model of oligopoly (Tirole 1988; Scherer and Ross 1990). Hence the retail price of e-cigarettes

The timing of the MN e-cig tax is also important for our analysis. In 2010 e-cigs were virtually unknown and sales were still relatively low in 2013. A new product needs to be heavily advertised and moderately priced to attract potential consumers. Thus, the MN tax impacted e-cigs at a particularly vulnerable time and probably had a greater impact than a similar tax imposed on a mature product. The timing of the MN e-cig tax hike further permits a sufficient time window to be able to observe any changes in smoking rates. A period of two or more years following the tax increase may be necessary because the addictive nature of smoking can lead to dynamics in the consumer response to new incentives and new potential substitutes. In the presence of such lagged effects and given the delay in data availability on smoking, we are necessarily limited to analyzing tax changes that were enacted prior to 2016. The states that had levied taxes on e-cigs prior to 2016 are North Carolina (6/2015), Louisiana (7/2015) and Minnesota.[10] The taxes in North Carolina and Louisiana are only five cents per milliliter of e-liquid. To put these taxes into perspective, a replacement pod which supplies roughly the nicotine equivalent of a pack of cigarettes cost about $3.47 in a state with no tax in 2015. The five cents per milliliter tax adds about four cents to the retail price which is trivial, leaving the North Carolina and Louisiana taxes under-powered to detect changes in smoking rates and thus empirically irrelevant. After the tax hike in MN in 2013, which raised its total tax rate to 95

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is given by $P = [\varepsilon(/\varepsilon - h)]C$, where ε is the market price elasticity of demand, h s the Herfindahl index, C is the sales-share weighted average of each retailer's average cost (assumed to be independent of pods sold) of selling e-cigarettes, and $\varepsilon > h$. Define m as $\varepsilon/\varepsilon - h$; assume that ε and h are constant; and note that $m > 1$. Average cost is given by $C = W^*(1 + r) + T$, where W^* is wholesale price exclusive of tax, r is the wholesale tax rate and T denotes other costs incurred by the retailer per unit of sales. Hence $P = m[W^*(1 + r) + T]$. Given these assumptions, the tax pass-through (the increase in P due to an increase in r with W^* held constant) exceeds one: $\partial P/\partial rW^* = m$. Let W be the wholesale price inclusive of tax. Then $P/W = k$, $k = m([1 + (mT/W)]$. We use a value of k of 1.33 in the computations above. We realize that T/W will change as W increases due to an increase in r, but assume that this effect is small enough to be ignored. Since our estimate of the retail price in Minnesota in 2015 differs from the actual price by only 7 cents, our assumption is very reasonable. Put differently, the tax pass-through to the retail price is approximately 1.33.

[10] See https://www.publichealthlawcenter.org/sites/default/files/States-with-Laws-Taxing-ECigarettes-September152019.pdf. More recently Pennsylvania and California have enacted large e-cig taxes, which can be evaluated as additional waves of data become available. D.C. imposed a tax on e-cigs in late 2015 after the 2015 CPS-TUS data were collected. We limit our data to waves prior to 2018 to draw a sharp contrast between the first state to enact an e-cig tax and all other states and to have a long-enough post period for potential effects to develop.

percent of the wholesale price, the MN tax remains the highest tax on e-cigs imposed by any U.S. state.

Our aim in this paper is to evaluate the effect of the imposition of a large excise tax on electronic cigarettes by the state of Minnesota on responses by adult smokers ages 18 years and older. We do so by examining its impacts on participation in electronic cigarettes and combustible cigarettes in that state and in a comparison group of states. Few people begin to smoke after that age, causing variations in smoking participation to be governed by decisions to start smoking e-cigarettes and to quit smoking combustible cigarettes. As pointed out above, the imposition of the e-cig excise tax raised the price of e-cigs by a substantial amount. Below, we show that the price of e-cigs relative to that of combustible cigarettes also rose in MN, while it fell in the comparison states. Therefore, to get insights into their impacts on smoking participation, we focus on price effects in equations determining the probability of starting to vape and stopping to smoke.

Decisions to start vaping by current vapers depends on a comparison between the money price of vaping and its reservation price. The latter is defined as the monetary value of the marginal utility of vaping, at the point at which no e-cigarettes are purchased. A smoker will not vape if the reservation price is less than the money price, while she will begin to vape if the reverse holds. An increase in the money price will cause some smokers to decide not to begin to vape. Given that consumers who are just at the margin of beginning to vape at the initial price incur fixed costs in the decision-making process, this negative effect can be quite large. These include the cost of the starter kit if a rechargeable device is employed. They also include the need to allocate resources to the acquisition of information about a new product that in part can be characterized as an experience good in the sense that smokers need to try it to decide whether or not they like it. Given the fixed cost, the entry decision also involves comparing the level of utility from two different baskets: one in which no e-cigs are vaped and the other at which a positive number are vaped. There will be one unique relative price at which these two baskets are on the same indifference curve. Hence, the relative price that induces entry must be smaller than the one that induces entry in the absence of fixed costs. If there are a large number of consumers with the same utility function, the demand function for starting to vape will be infinitely elastic at the relative price at which this occurs.

Another point to note is that under reasonable assumption about the utility function, vaping is less likely if its effect on the marginal utility of smoking is negative rather than positive. Moreover, the larger in absolute value is this cross-utility effect, the more elastic is the demand function for vaping. Smokers who do not vape at the initial money price are more likely to have a negative cross-utility term than those who do vape. The upshot is that fixed costs combined with negative cross-utility terms are likely to cause a significant number of current smokers to begin to vape and to cause some of them to quit smoking altogether when the price of e-cigs falls. The reverse occurs when the price rises.

For current vapers (dual users of e-cigs and combustible cigs) an increase in its price generates an income effect as well as a substitution effect. The latter involves more smoking and less vaping provided that the two goods are net (utility-constant) substitutes while both smoking and vaping fall if the goods are net complements. The income effect causes the consumption of both to fall provided each one has a positive income elasticity. If they are gross (money income-constant) substitutes, smoking will rise and vaping will fall, while both will fall if they are gross complements.

In summary, this analysis suggests that an increase in the price of vaping will reduce starts and quits and raise smoking participation. This prediction becomes somewhat ambiguous if cigs and e-cigs are gross complements. Moreover, it is possible that the price increase induces some smokers who began to vape because they wanted to quit but were not successful to resort to another method that results in successful quits.

The primary data come from the Current Population Survey Tobacco Use Supplements (CPS-TUS), which are sponsored by the National Cancer Institute and administered periodically as part of the Census Bureau's CPS since 1992. The CPS-TUS offers several advantages for our analyses, including large samples and consistent information on smoking behaviors over time, and measures of smoking on the intensive margin. We use eight available waves of the CPS-TUS, which were fielded in 1992-1993, 1995-1996, 1998-1999, 2001-2002, 2003, 2006-2007, 2010-2011 and 2014-2015. The CPS-TUS is nationally-representative and contains information on about 240,000 individuals within a given wave; it provides a key source of national, state, and sub-state level data regarding smoking and the use of other tobacco products among adults ages 18 and older. This yields a sample of approximately two million adults drawn from repeated cross-sections spanning 1992 to 2015. We rely on aggregate data at the state-level from each wave, and use smoking participation and cigarette consumption as outcome measures.[11]

The first e-cig tax (35 percent of wholesale price) went into effect in August 2010 in MN, and the subsequent tax hike (to 95 percent) went into effect in July 2013. We consider all waves up to 2010-2011 as the pre-treatment periods. Given that the prevalence of e-cig use in 2010 and 2011 remained quite low (less than 1 percent; see Dave et al. 2019) and given that it may take some time to change smoking habits, any effect of the e-cig tax in 2010 is unlikely to materialize until after 2010. In addition, the 2010-2011 TUS was conducted in May, 2010, August 2010, and January 2011. Data from the 2014-2015 wave of the CPS-TUS are considered the post-treatment period, allowing us to observe any potential effects on adult smokers that may have materialized 2-3 years post MN's e-cig tax.

We employ a difference-in-differences (DD) model to estimate how the e-cig tax hike in MN impacted adult smoking behaviors. The key assumption necessary for the DD estimate to signify an unbiased causal effect is that the control group of states represents a valid counterfactual for MN in the absence of the e-cig tax. Figure 4 plots the trend in the smoking rate in MN and the rest of the U.S. (excluding MA and IL as they substantially increased their cigarette excise in the post-treatment period). Smoking rates in MN and the rest of the U.S., while trending downward over the past two decades, do not appear to be doing so in a lockstep

[11] More information on the CPS-TUS can be found at: https://cancercontrol.cancer.gov/brp/tcrb/tus-cps/questionnaires.html.

parallel manner. Particularly, the difference in the pre-treatment smoking rate between the two groups is widening over most of the 1990s, then narrows until about 2007, before widening again. Hence, the rest of the U.S. may not be a good counterfactual for what would have happened in MN in the absence of the e-cig tax. Since any downstream effects from e-cig taxes to e-cig use to smoking cessation may be small, they risk being confounded from even relatively small deviations from pre-treatment parallel trends.

We therefore undertake a synthetic control design, following Abadie, Diamond, and Hainmueller (2010), to ensure that the treatment (MN) and control states share common pre-treatment trends in adult smoking outcomes. The algorithm underlying this method assigns weights to each donor state so that any pre-treatment differences in outcomes between MN and the synthetically matched "state" (SMN) are minimized. Hence, by expressly forcing the e-cig tax counterfactuals to have more similar pre-treatment trends, a synthetic control DD design raises the likelihood of satisfying the "parallel trends" assumption.[12]

One challenge in this framework relates to the computation of the correct standard errors, given that there is only a single treatment group and a single control group. Donald and Lang (2007) show that standard significance tests cannot be applied in this case. They refer to Moulton (1990) who shows that in regression models with individual data, the failure to account for the presence of common group errors results in standard errors that are biased downward and consequently overstate significance levels. Clustering the standard errors is not an option with only two groups or clusters. We follow the approach in Donald and Lang (2007), who suggest first computing group means to eliminate the common group error and then computing the difference between the treatment and control group for each period. We then estimate a regression of these differences on an indicator for the post-tax period.

The standard errors may still need to be adjusted for serial correlation of the group difference over time, which can be done by taking adjacent period differences in the outcome

[12] Lagged values of the dependent variable were used as matching variables.

difference between the treated and control groups for each period. This adjustment for serial correlation proposed by Donald and Lang (2007) assumes that the disturbance term follows a random walk. It also assumes time spacing between the data points, which is not the case with the CPS-TUS waves. One option is to drop the 2001-2002 wave, which creates a time series with two three-year gaps and four four-year gaps. In this case, the correlation in the error terms across three-year intervals and four-year intervals is assumed to be approximately similar. We refer to these data as Wave Differences in the presentation of the results and tables.

Changes in cigarette prices during the post-treatment period are relevant because they can affect smoking rates in the potential donor pool and in MN outside of any effects due to the e-cig tax. The post-treatment period spans 2011 through mid-2015 as the TUS in 2015 was last collected in May. Minnesota increased its cigarette excise tax by $1.60 to $2.83 in July 2013 and by another $0.07 in January 2015. Massachusetts and Illinois both increased their cigarette excise tax by $1.00 during the post-treatment period and were therefore dropped from the pool of potential donor states. They were the only states other than MN that enacted large cigarette tax hikes during this period. The range of small cigarette tax increases in the included states during the post-period is from $0.10 in New Hampshire to $0.40 in Connecticut.

To understand the effects of these tax changes on e-cig prices and cigarette prices, trends in both and in the relative price are presented in Figures 1-3 for MN and its synthetic control.[13] Price measures from the Nielsen Retail Scanner data indicate that the average price of a pack of cigarettes in MN in 2011 was $5.41 and fairly similar at $5.89 in the synthetic control group (SMN). By 2015 these prices had increase in MN to $7.83 and $6.07 in SMN (Figure 2). Figure 3 shows the relative price of e-cigs versus cigarettes in MN and SMN. In 2012, relative prices for both MN and the control group were virtually the same, 0.55 and 0.56 respectively. By 2015, following the tax increase, the relative price in MN had risen to 0.61 and

[13] SMN is the synthetic control group formed by applying the synthetic weights generated from the smoking participation model. We do not generate new weights specifically for matching prices, since we want to analyze the tax pass-through and effects of the tax on prices based on the same control group for which we analyze smoking outcomes.

fallen in SMN to 0.52. That is, in MN the price of e-cigs rose by 17 percent relative to cigarettes, when compared to SMN.

As predicted by the theory, this increase in the relative price of vaping would lead to a decrease in participation and use of e-cigs. Given the lack of information on e-cig consumption in the pre-treatment period, we focus on what happens to smoking participation. Our focus on cigarette use is also salient in that it directly addresses the harm reduction debate surrounding adult smokers. The increase in the price of e-cigs, and in the relative price of e-cigs is predicted to increase smoking rates given that smoking and vaping are substitutes. This conclusion depends on the relationship between e-cigs and cigarettes and is ultimately an empirical question.

4. Results

As a point of comparison, we start by presenting standard DD estimates utilizing the rest of the U.S. (excluding MN, and MA and IL) as a control group, in Table 1. An alternate specification, following Donald and Lang (2007), is estimated to generate appropriate standard errors that adjust for within-group correlated errors when there is only a single treatment and control group. The model denoted DL1 is based on the difference in the aggregated outcome across the treated group (MN) and the control group, which adjust for within-group and year correlated errors. The model denoted DL2 further corrects for serial correlation (thus adjusting for any correlated errors over time) by further differencing the DL1 data across adjacent waves. These estimates do not indicate any significant effects of the large e-cig tax in MN on smoking rates. The effects however may be biased due to differential pre-treatment trends between MN and the rest of the U.S. (Figure 4), and we therefore rely on the synthetic control approach to generate a more suitable counterfactual for MN.

Tables 2-4 present estimates from synthetic control DD models for three smoking outcomes. In Table 2, we report estimates of the effects on current smoking prevalence, which is the percentage of adults who reported ever smoking at least 100 cigarettes and who currently smoke every day or some days. The corresponding event study graph comparing MN with synthetic MN is in Figure 5. It is evident from the figure that the control group here matches MN virtually lockstep with respect to changes in the smoking rate in all of the pre-treatment periods, with a divergence observed only after the imposition of the large e-cig tax. Estimates in Table 2 confirm the graphical evidence that the e-cig tax in MN is associated with a significant increase in the prevalence of smoking among adults. Estimates from the first two specifications indicate an increase in smoking prevalence by almost one percentage point (0.8 to 0.9 percentage points), representing about a 5.4 percent increase relative to the immediate pre-treatment mean in MN. Ideally the time-differenced data used in the DL2 model should be based on the same spacing between adjacent periods. However, given the staggered nature of the CPS-TUS surveys, the spacing is somewhat uneven.[14]

We alternately tested for statistical significance based on a permutation of placebo tests, in the spirit of Abadie, Diamond and Hainmueller (2010) as modified by Bedard and Kuhn (2012) and Stearns (2015). This placebo test alternatively assumes that each state is the treatment state and finds a synthetic control group for that placebo. Then we estimate the DL2 specification for all placebo states. This provides a p-value for the treatment effect for each placebo state, generating a distribution of p-values. Finally, we compare the actual treatment state's (MN) position in this distribution of p-values in order to gauge whether the results could be generated due to chance. For example, if 49 states are used and MN has the highest p-value of all states, then the test statistic would be 1/49 = 0.02. This would be interpreted as a 2 percent probability that the outcome for MN was due to chance. This placebo p-value is presented in the graphs for each outcome.

For the model for current smoking prevalence, the placebo test found that MN had the second smallest p-value out of 49 states, implying about a 4 percent probability of a Type 1 error. Figure 5 and the treatment effects in Table 2 show that smoking increased in MN relative

[14] Note that a relatively large t-statistic is needed to achieve statistical significance due to the small sample sizes with group-period aggregated data.

to the control group following the e-cigarette tax. Because the relative price of e-cigs increased in MN compared to SMN (Figure 3), these results imply that cigarettes and e-cigs are substitutes among current smokers.

For adults, any changes in smoking prevalence are very unlikely to reflect the initiation margin (given that most current smokers have initiated by age 19 or 20). Changes in smoking prevalence then reflects mostly the cessation margin or possibly the relapse margin from former to current smoking. In Figure 6, with corresponding DD estimates in Table 3, we report effects on smoking cessation, by defining the ratio of the number of individuals who smoked but recently quit (former smokers) divided by the number of ever smokers. Trends in this outcome are virtually identical between MN and the control group. The placebo test indicated that MN had the third smallest p-value out of 49 iterative state tests, implying about a 6% probability of a Type I error. Estimates in Table 3 indicate that the e-cig tax in MN led to a decrease in quitting by about 1.14 percentage points, which is the same order of magnitude as in the models for smoking prevalence. This suggests that virtually all of the increase in current smoking prevalence in MN, associated with the e-cig tax, is driven by a decrease in successful quits.

Finally, we also consider whether the e-cig tax led to any changes in cigarette consumption at the intensive margin. That is, even if smokers in MN may not have quit, did they reduce their consumption of combustible cigarettes? Cigarettes per day may decline, for instance, as smokers may be trying to cut down as a progressive step toward cessation. Figure 7, and the corresponding estimates in Table 4, indicate that this is not the case. Cigarettes per day are not reported for 2003 and thus, for this variable, the 2002 data are used. We do not find any significant change in the number of cigarettes consumed among current everyday smokers in MN relative to the control group following the e-cig tax.

As a robustness check, we also tested data on current smoking prevalence from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a cross-sectional telephone survey that state health departments conduct by phone with a standardized questionnaire and technical assistance from CDC. The BRFSS is based on between 355,000 to

506,000 interviews each year between 2006 and 2017. The sample period begins in 2006 because in that year the CDC introduced a new weighting method to insure a representative sample at the state level. Another issue with the BRFSS is that it changed its survey design in 2011, which is also the first period of the treatment. The 2011 BRFSS data reflects a change in weighting methodology and the addition of cell phone only respondents. This change is evident in figure 8 as a jump in the smoking rate in 2011. However, because this change affected all states it should not lead to any systematic differential between MN and the control states. Again, MA and IL are dropped from the control pool because of large increases in the cigarette tax in the post-period. Figure 8 presents the graph comparing MN and its synthetic control group from the BRFSS. While the smoking rates in the BRFSS are noisier than those in the TUS, pre-treatment trends are well-balanced between the treatment and the control. There is a small apparent effect in 2011 which was not seen in the TUS data. The reason for this is likely because the 2011 TUS data is for 2010-2011 and primarily reflects 2010. The BRFSS effect size gets larger with the exception of 2013, which might be due to a transitory effect of the 2013 cigarette tax increase in MN. The placebo test resulted in a value of $p < .13$.

The DL1 results in table 5 suggest that smoking prevalence increased in MN following the e-cig tax relative to the control group. Effect magnitude for the entire post period is similar to the effect estimated from the TUS and suggests an increase in smoking prevalence of about 1 percentage point. The serial correlation adjustment used in DL2 is not useful with the BRFSS data because it measures only the effect in the first post period rather than the average effect over the entire post period (see the second regression in table 5). As an alternative we specify a model with lagged effects of the e-cig tax for each post-policy period, which is a post period event history study. All the post dummies are equal to 0 in 2006-2010. Then, post0 = 1 in 2011 and equals 0 in all other post years. Post1 = 0 in 2011, equals 1 in 2012 and 0 in all other post years, etc. This is a model in level form. We then define the time difference specification to account for serial correlation. This regression provides the correct standard errors and 95 percent confidence intervals for each of the 7 post-year differences. These data are presented in figure 9. The average effect over the seven years is 1.0084 with a standard error = 0.5488 and p-value < 0.14. This average value is slightly smaller than the value of 1.0404 in the level model (DL1). Also, the confidence intervals for all post periods includes the numeric value 1. Confidence in the conclusions are enhanced because both the BRFSS models and the TUS models predict about a 1 percentage point increase in smoking participation due to the tax.

5. Conclusions

The results presented in this study provide some of the first evidence on whether, and the extent to which, e-cig taxation affect adult smoking behaviors. We exploit the natural experiment provided by MN, the first state to impose a tax on e-cigs. Because the cross effects of a tax on e-cigs on smoking outcomes may be small, a large tax change is necessary to reliably detect such effects in population surveys. Also, because quitting smoking takes time, MN's early adoption of the large e-cig tax makes it possible to study effects on cessation that may take time to materialize. We find consistent and robust evidence that the e-cig tax in MN increased adult smoking relative to what it would have been in the absence of this tax. MN included e-cigs with other non-cigarette tobacco products when increasing the tax on these goods. This inclusion was based on the assumption that e-cigs are a hazard and not a cessation aid such as nicotine replacement products, which are not similarly taxed. It is not known at this time whether these results are generalizable to other states. Higher e-cig taxes are predicted to reduce e-cig consumption, and if the results from MN carry over to other states that have imposed taxes very recently, then they suggest that these taxes will also reduce quit rates in these states among adult smokers.

The results from the TUS and the BRFSS allow us to estimate the cross-price elasticity of current smoking participation with respect to e-cig prices. The e-cig price data prior to 2012 is based on a limited sample of observations, which may introduce bias. Thus, we estimate the changes in price using data from 2012 onward. As shown in figure 1, the price of e-cigs in MN and SMN were about the same in 2012. The e-cig tax increase of 60 percent (change from 35 percent to 95 percent) of the wholesale price in 2013 led to about a 50 percent increase in the price of e-cigs in MN in 2015 relative to the synthetic control. Given the large percentage increase in price, we estimate the arc price elasticity, which allows for the possibility that the elasticity may not be constant over the entire range of the smoking participation equation. The DD estimates indicate that this change is associated with about a 0.8 percentage point increase in current smoking prevalence, which is about a 5.4 percent increase in MN relative to its control. Division of the increase in price of $1.61 by the average of the SMN and MN price in 2015 of $3.96 yields a 40.7 percent increase in price and an arc cross-price elasticity of 0.13.

This estimate is a lower bound because the simultaneous increase in cigarette prices would have decreased smoking.[15] It is notable that the much more modest 17 percent increase in the relative price of e-cigarettes was accompanied by an approximate 5 percent increase in smoking participation. That suggests that if states raise cigarette and e-cigarette taxes by substantial amounts at the same time, smoking will rise if the relative price of e-cigarettes rises.

In 2014 there were about 600,000 adult smokers in Minnesota. Our estimates indicate that the e-cig tax deterred about 32,400 adult smokers from quitting. Currently there are approximately 34 million adult smokers. If the Minnesota tax had been a national one, we estimate that it would have deterred around 1.83 million smokers from quitting.[16] Some have suggested that e-cigs should be taxed at the same rate as cigarettes. Implementation of that policy would raise the price of e-cigs by approximately 62 percent, increase smoking participation by 8.1 percent, and deter approximately 2.75 million smokers from quitting.[17]

[15] The simultaneous increase in other non-cigarette tobacco prices would probably have had a small positive effect on cigarette smoking offsetting some of the effects of higher cigarette taxes.

[16] This figure is obtained by multiplying 600,000 by the percentage increase in smoking participation divided by 100 (600,000X0.054 = 32,400). If MN data apply to the entire US, 0.054 X 34 million = 1.83 million.

[17] A JUUL pod contains the nicotine equivalent of a pack of cigarettes and costs about $4.00. The combined federal cigarette tax and state average cigarette tax is $2.73 per pack. A tax of $2.73 with a pass-through of 1.33 (see note 8) would raise the price by of e-cigs by $3.63, which is an increase of 62 percent relative to an average of the initial and the final price. Divide that figure by 100 and then multiply the result by the arc cross-price elasticity of 0.13 to get an increase in smoking participation of 0.081 or 8.1 percent. Multiplication of the former number by 34 million gives 2.75 million.

While these increases may appear to be large, they are likely to be realized over a period as long as a decade. That is the short-run impact of the price hikes are likely to be much smaller than the long-run impacts. To put this in a somewhat different perspective, a projection of current trends in the number of smokers who quit over the next decade suggests that around 11 million smokers will quit by the end of that decade.[18] Our computations imply a reduction in that number by around 25 percent.

Our study addresses how e-cig use impacts adult smoking, which represents one side of the policy debate surrounding e-cigs. For adolescents, nicotine addiction, the potential progression from vaping to smoking, and the growing percentage of using e-cigs are also important considerations in this policy debate. E-cigs are considered to be harmful to youth due to the effect of nicotine on the developing brain and due to the potential for vaping to lead to nicotine addiction (regardless of whether or not the youth transitions to smoking). While the results from this study indicate that e-cigs may help adult smokers to quit smoking and thus lead to a decrease in smoking-related harms, this needs to be balanced against the goal of reducing vaping and nicotine use among youth. Deterrents to adolescent use include raising the national minimum purchase age to 21, allocating resources to enforcing that law, enacting stiff fines for violating it, and banning flavors and marketing targeted at youth. The public health benefits of not taxing e-cigarettes must be weighed against effects of this decision on efforts to reduce vaping by youth.

[18] Currently, approximately 1.3 million smokers quit each year, which implies a quit rate of 0.038 (3.8 percent). If there are no starters or relapsers, there would be $(0.962)^{10}$X34 million = 23 million remaining smokers ten years hence and 11 million quitters over that period. If the net percentage reduction in the number of smokers is less than 3.8 percent, we overestimate the number quitters.

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Figure 1
E-cig Prices

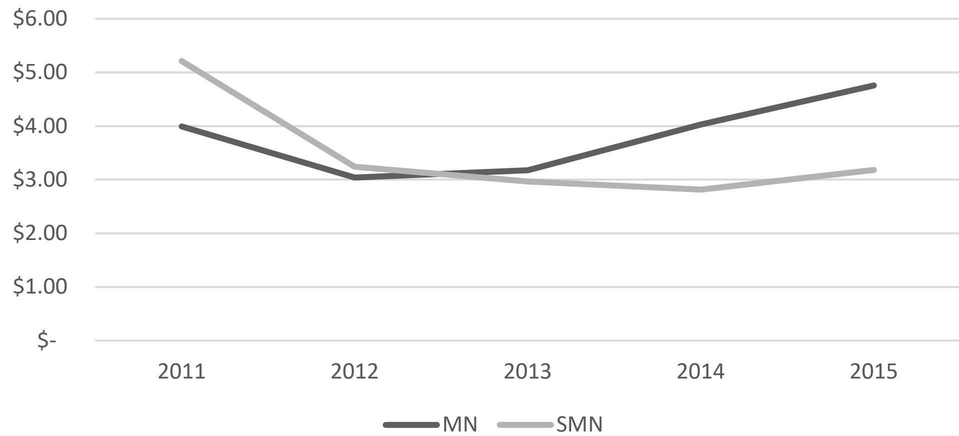


Figure 2
Cigarette Prices

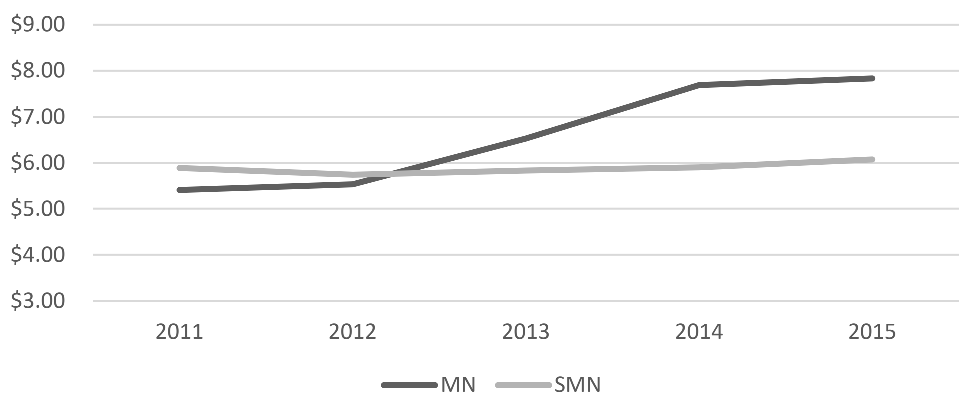
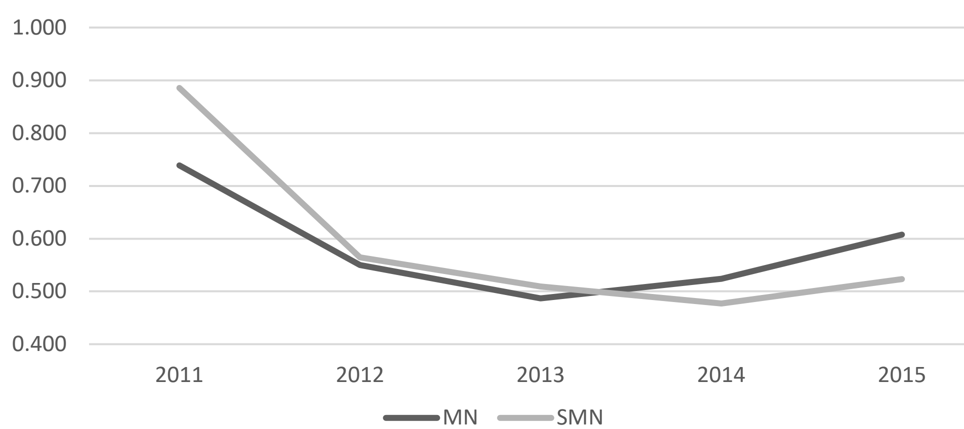
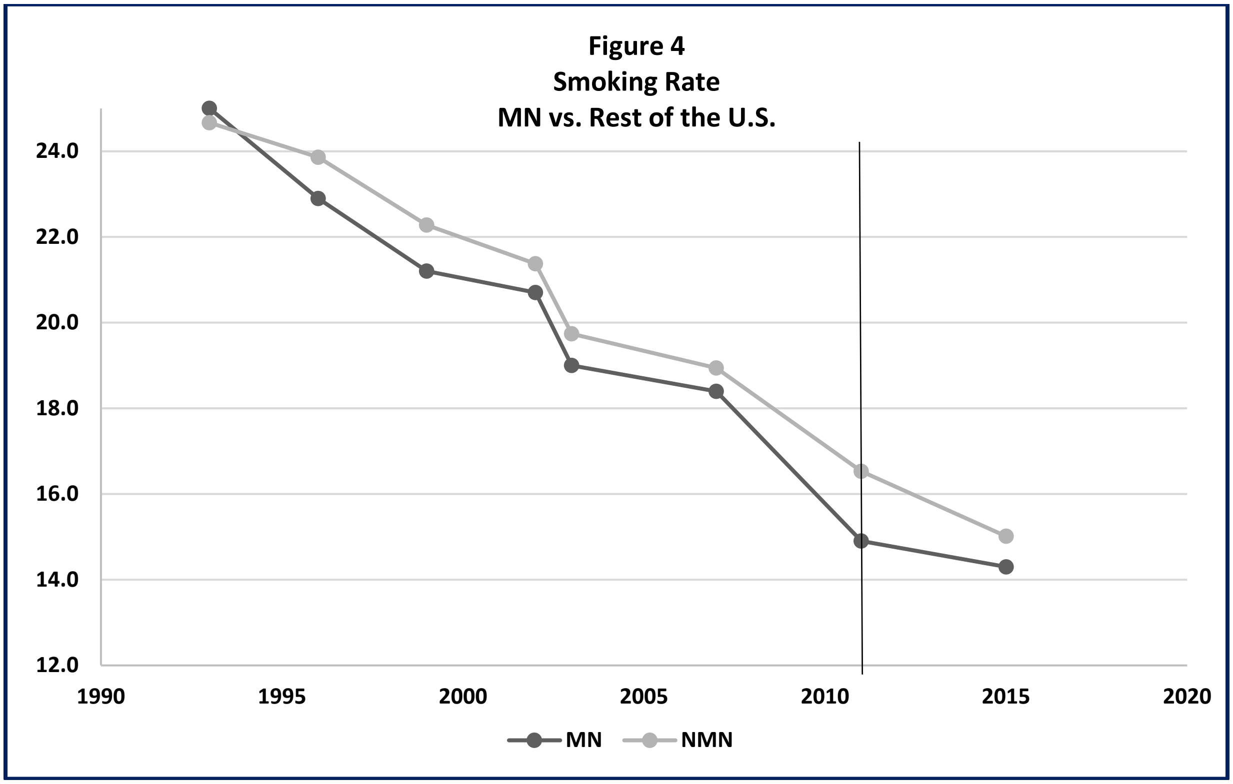


Figure 3
Relative Price of E-cigs vs. Cigarettes



Note: Price computations are based on the Nielsen Scanner Data for MN and synthetic MN.



Note: NMN is the population-weighted average smoking rate for the rest of the U.S. excluding MN. IL and MA are excluded from the rest of the U.S. (see text).

Table 1
Donald and Lang Models of the Smoking Rate
DD: MN vs. Rest of the U.S.

Model type	Data	Treatment Effect	Standard Error	t-value	P-value
DL1	Levels	-0.0289	0.6416	-0.04	0.966
DL2	Wave Differences	0.9200	0.6320	1.46	0.196

Figure 5
Smoking Rate
MN vs. Synthetic MN

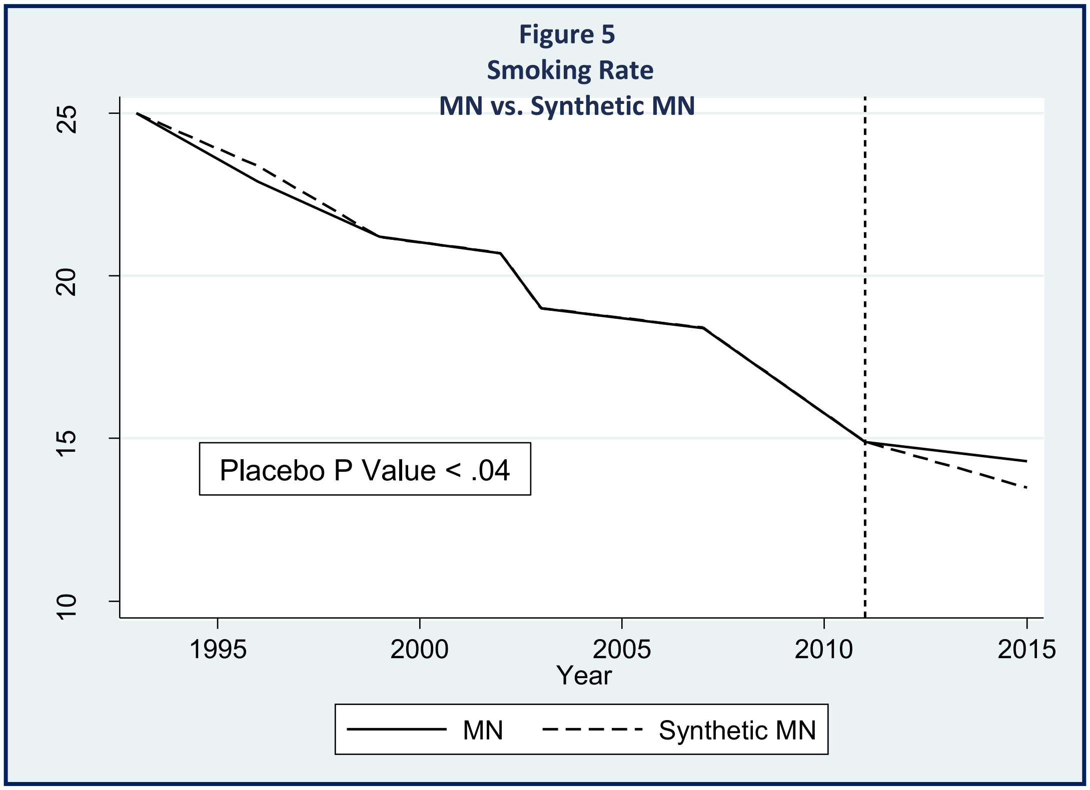


Table 2
Effect of the MN E-cigarette Tax on Smoking
DD: MN vs. Synthetic MN

Model type	Data	Coefficient of the treatment variable	Standard Error	t-value	P-value
DL1	Levels	0.9264***	0.2094	4.42	0.004
DL2	Wave Differences	0.8449**	0.3250	2.60	0.048

Note: 2002 data are not used in the model for Wave Differences. Asterisks denote significance as follows: *** p-value ≤ 0.01, ** 0.01 < p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

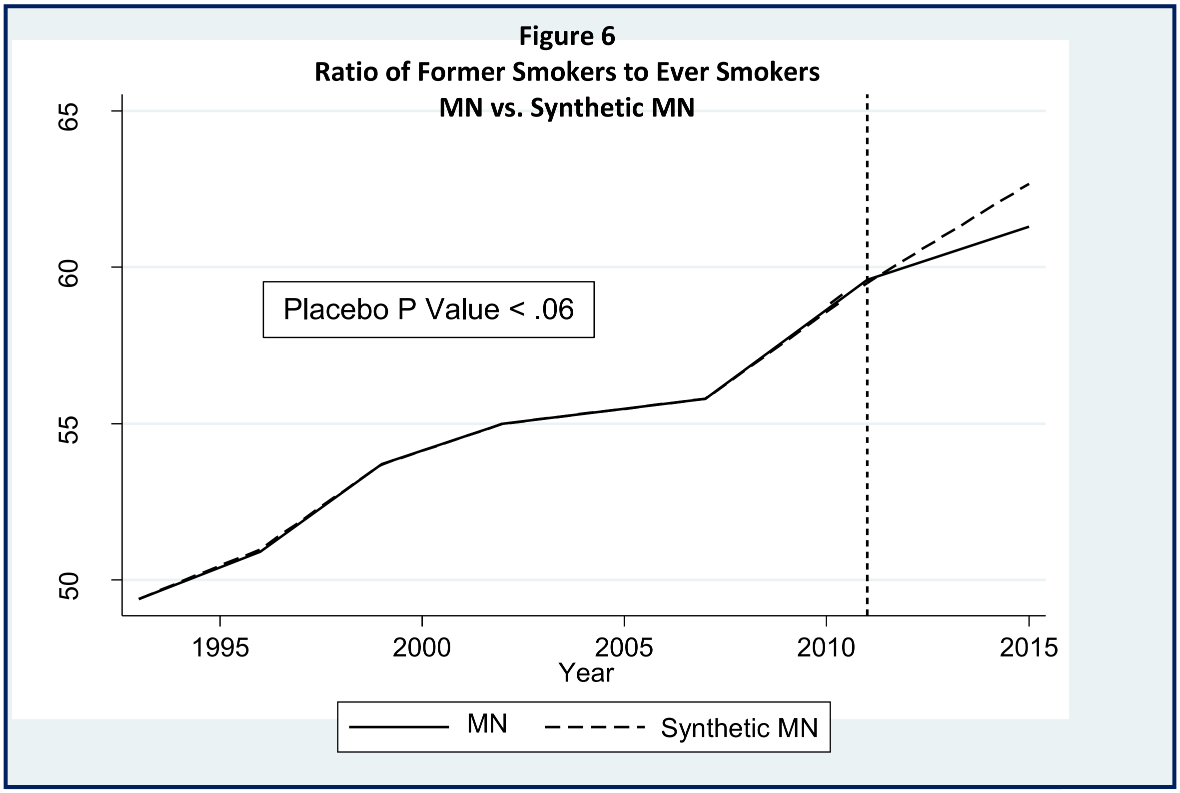


Table 3
Effect of the MN E-cigarette Tax on Ratio of Former Smokers
DD: MN vs. Synthetic MN

Model type	Data	Coefficient of the treatment variable	Standard Error	t-value	P-value
DL1	Levels	-0.9526***	0.1870	5.09	0.002
DL2	Wave Differences	-1.2326***	0.2425	5.08	0.004

Note: 2002 data are not used in the model for Wave Differences. Asterisks denote significance as follows: *** p-value ≤ 0.01, ** 0.01 < p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Figure 7
Cigarettes per Day Consumed by Everyday Smokers
MN vs. Synthetic MN

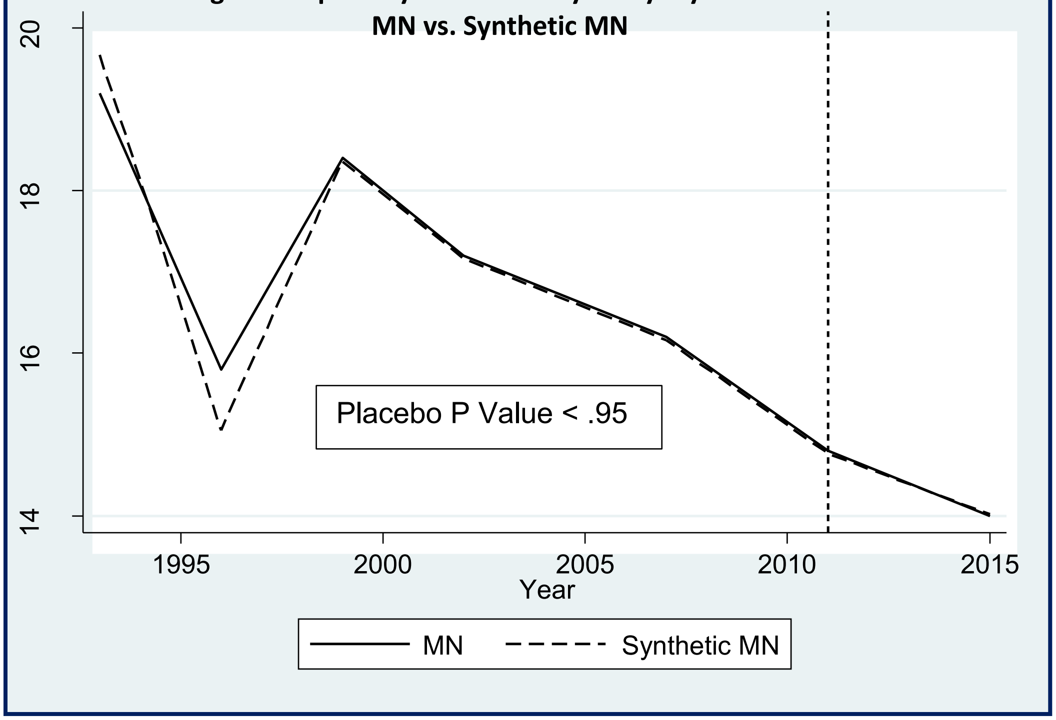


Table 4 **Effect of the MN E-cigarette Tax on Daily Cigarette Consumption (Intensive Margin)** **DD: MN vs. Synthetic MN**					
Model type	Data	Coefficient of the treatment variable	Standard Error	t-value	P-value
DL1	Levels	0.0885	0.4195	0.21	0.841
DL2	Wave Differences	0.0517	0.6298	0.08	0.938

Note: Data on cigarettes consumed are not available for 2003. Asterisks denote significance as follows: *** p-value ≤ 0.01, ** 0.01 < p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

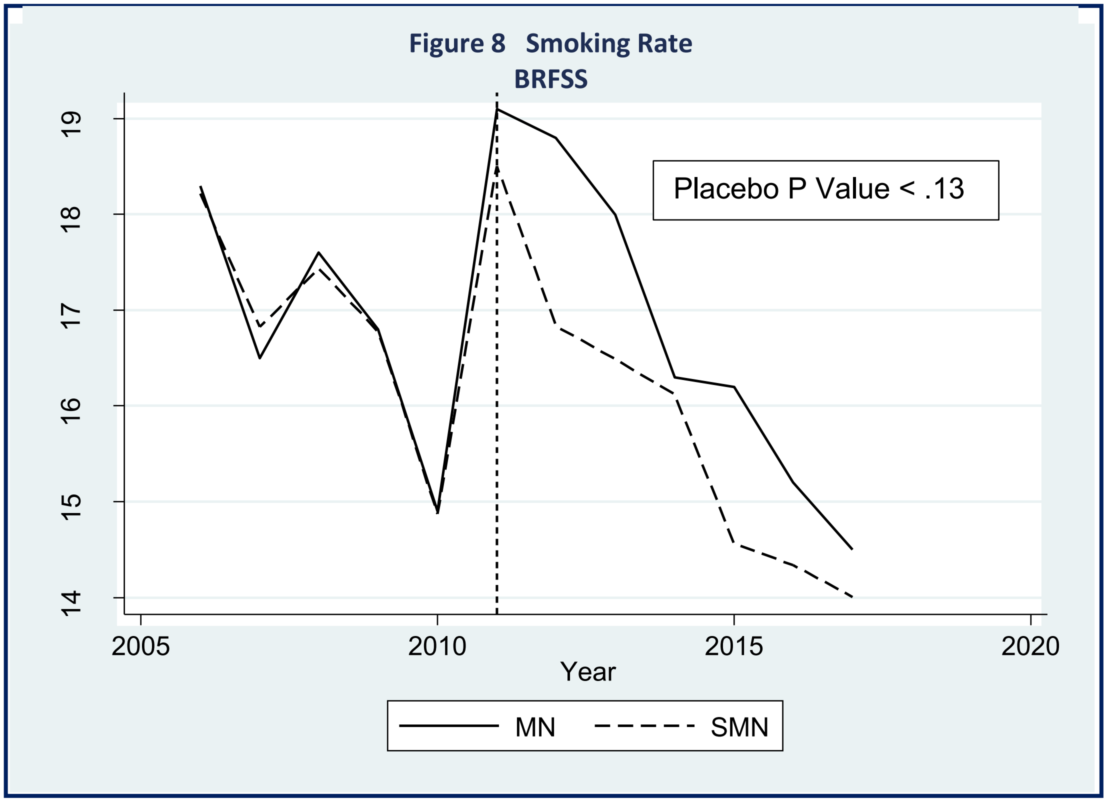
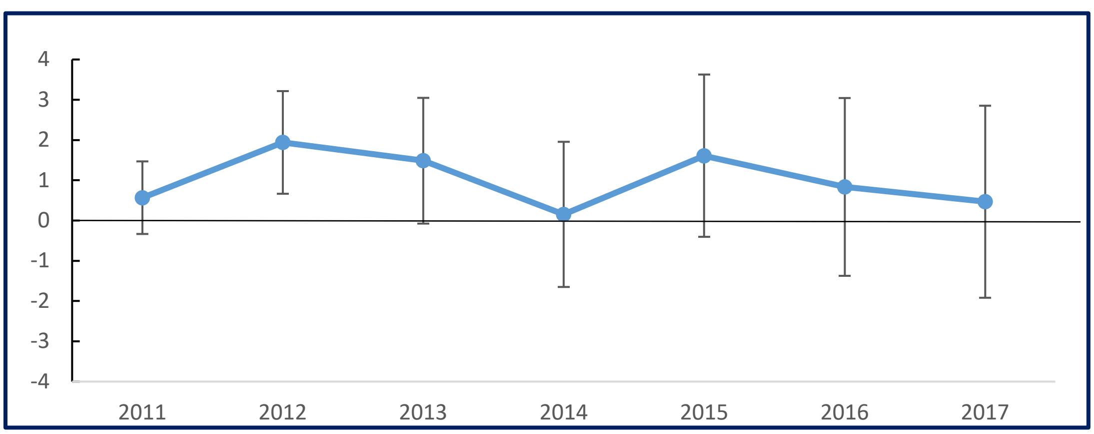


Table 5 Effect of the MN E-cigarette Tax on Smoking Rate from the BRFSS DD: MN vs. Synthetic MN					
Model type	Data	Coefficient of the treatment variable	Standard Error	t-value	P-value
DL1	Levels	1.0404***	0.3124	3.33	0.008
DL2	Year Differences	0.5677	0.8457	0.67	0.517

Figure 9

BRFSS Effects of Lagged Treatment Variables with 95% confidence intervals



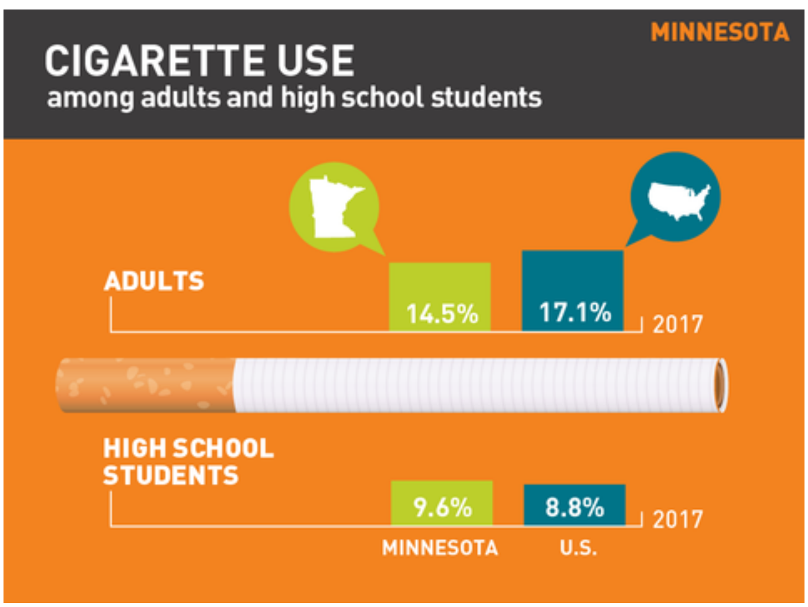
3. Truth Initiative Fact Sheet – Minnesota

Tobacco use in Minnesota 2019

Jun. 28, **2019** | **3 min** read

Cigarette use: Minnesota

- In 2017, 14.5% of adults smoked. Nationally, the rate was 17.1%.[1]
- In 2017, 9.6% of high school students in Minnesota smoked cigarettes on at least one day in the past 30 days. Nationally, the rate was 8.8%.[2,3]



Other tobacco product use: Minnesota

- In 2017, 3.6% of adults used e-cigarettes and 4.8% used

TOPIC

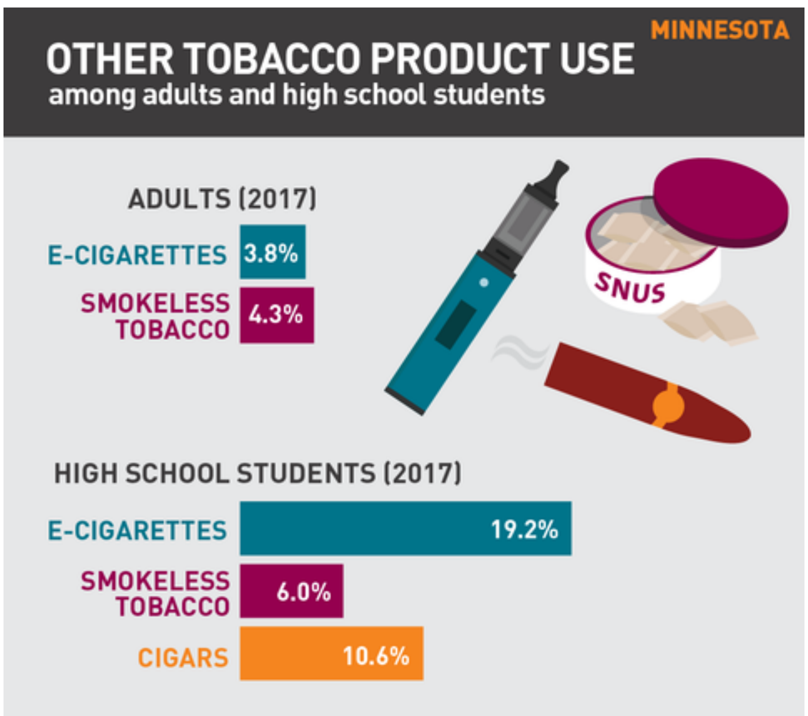
Smoking by Region

SUBTOPIC

State Facts

smokeless tobacco.[4]

- In 2017, 19.2% of high school students in Minnesota used electronic vapor products on at least one day in the past 30 days.[2]
- In 2017, 6.0% of high school students in Minnesota used chewing tobacco, snuff or dip on at least one day in the past 30 days.[2]
- In 2017, 10.6% of high school students in Minnesota smoke cigars, cigarillos or little cigars on at least one day in the past 30 days.[2]



Economics of tobacco use and tobacco control

- Minnesota received $703.6 million (estimated) in revenue from tobacco settlement payments and taxes in fiscal year 2019.[3]
- Of this, the state allocated $17.3 million in state funds to tobacco prevention in fiscal year 2019, 32.7% of the Centers

for Disease Control and Prevention's annual spending target.[3]

- Smoking-caused health care costs: $2.51 billion per year.[5]
- Smoking-caused losses in productivity: $1.54 billion per year.[6]

Minnesota tobacco laws

Tobacco taxes

- Minnesota is ranked 8th in the U.S. for its cigarette tax of $3.04 per pack (enacted January 2018), compared to the national average of $1.81. (The District of Columbia has the highest tax at $4.50 and Missouri has the lowest at 17 cents.)[5-7]
- Moist snuff containers weighing less than 1.2 ounces are taxed at the greater of 95% of the wholesale price or a minimum price equal to the cigarette tax at each container. Moist snuff containers weighing more than 1.2 ounces are taxed at the greater of 95% of the wholesale price or a minimum tax equal to the cigarette tax on each container multiplied by the number of ounces of moist snuff in the container, divided by 1.2 (container = smallest consumer-size can, package or other container that is marketed or packaged by an entity for separate sale to a retail

purchaser).

- Premium cigars are taxed at 95% of the wholesale or 50 cents per cigar, whichever is less.
- All other tobacco products, including e-cigarettes, are taxed at 95% of the wholesale sales price.[7,8]

Clean indoor air ordinances

- Smoking is prohibited in all government workplaces (workplaces with two or fewer employees are exempt), private workplaces (workplaces with two or fewer employees are exempt), schools, childcare facilities, restaurants, bars, casinos/gaming establishments (tribal establishments are exempt), retail stores and recreational/cultural facilities.[6]
- The use of e-cigarettes is prohibited in day care and health facilities, government owned or operated buildings, facilities owed by Minnesota state colleges and universities, the University of Minnesota, facilities licensed by the commissioner of human services, and in public and charter schools and any facility or vehicle owned, rented or leased by a school district.[9]

Youth access laws

- The minimum age to purchase tobacco products in Minnesota is 21. In December 2019, the United States adopted a law raising the federal minimum age of sale of all tobacco products to 21, effective immediately.
- Minors are prohibited from buying nicotine delivery products, including e-cigarettes.[5]
- Self-service sales are prohibited, except in adult-only facilties.[7,8]

Local tobacco laws

- Minneapolis and 33 other localities in the state raised their minimum age requirement for the purchase of tobacco products to 21.[10]

- In Minneapolis and St. Paul, the sale of flavored tobacco products is restricted to tobacco product shops. The sale of menthol flavored tobacco products is prohibited except in adult-only tobacco shops and liquor stores.[11,12]
- In Duluth, Falcon Heights and Lauderdale, the sale of flavored tobacco products, including menthol, is prohibited except in adult-only tobacco stores.[13-15]
- In Mendota Heights, Robbinsdale, Shoreview and St. Louis Park, the sale of flavored tobacco products is prohibited except in adult-only tobacco stores. Menthol, mint and wintergreen flavors are exempt from the restriction.[16-19]
- In Arden Hills, the sale of all flavored tobacco products is prohibited.[20]
- In Minneapolis, Robbinsdale and St. Paul, the minimum price for cigars (after coupons and discounts have been applied and before sales tax) is $2.60 for a single cigar, $5.20 for a 2-pack or “double” pack, $7.80 for a 3-pack and $10.40 for packs with four or more cigars.[12,17,21]
- Rock County prohibits pharmacies from selling tobacco products.[22]

Quitting statistics and benefits

- The CDC estimates 46% of daily adult smokers in Minnesota quit smoking for one or more days in 2017.[4]
- In 2014, the Affordable Care Act required that Medicaid programs cover all tobacco cessation medications.[8**]
- Minnesota’s state quit line invests $13.18 per smoker, compared to the national average of $2.21.[8]
- Minnesota does not have a private insurance mandate provision for cessation.[8]

Notes and references

Updated April 2019

*National and state-level prevalence numbers reflect the most recent data available. This may differ across state fact sheets.

**The seven recommended cessation medications are NRT gum, NRT patch, NRT nasal spray, NRT inhaler, NRT lozenge, Varenicline (Chantix) and Bupropion (Zyban).
Fiore MC, et al. Treating Tobacco Use and Dependence: 2008 Update. Clinical Practice Guideline. Rockville, MD: US Department of Health and Human Services. Public Health Service: May 2008.

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2. Minnesota Youth Tobacco Survey, 2017.

3. CDC, Youth Risk Behavior Surveillance System, 2017.

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votes to restrict flavored tobacco. November 29, 2016.

19. City of St. Louis Park. St. Louis Park City Council bans flavored tobacco sales in St. Louis Park. 2017; https://www.stlouispark.org/Home/Components/News/News/130/18.

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4. Truth Initiative Fact Sheet – Maryland

Tobacco use in Maryland 2019

Jun. 28, **2019** | **3 min** read

TOPIC

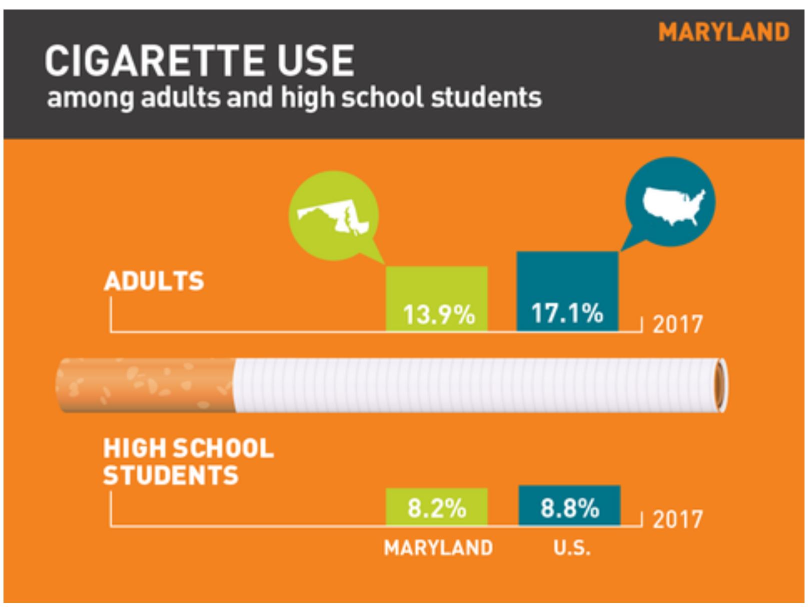
Smoking by Region

SUBTOPIC

State Facts

Cigarette use: Maryland

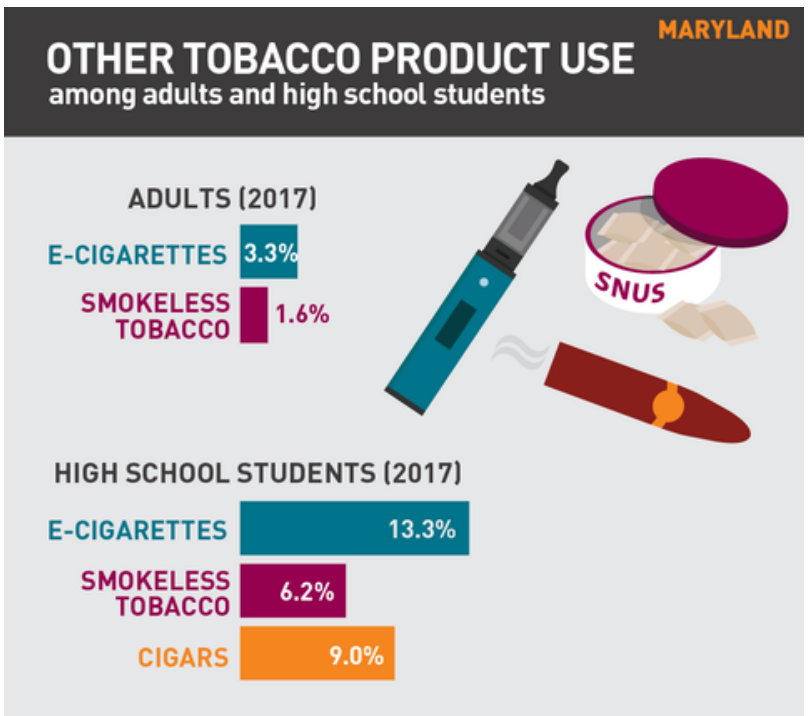
- In 2017, 13.9% of adults smoked. Nationally, the rate was 17.1%.[1]
- In 2017, 8.2% of high school students in Maryland smoked cigarettes on at least one day in the past 30 days. Nationally, the rate was 8.8%.[2]



Other tobacco product use: Maryland

- In 2017, 3.3% of adults used e-cigarettes and 1.6% used smokeless tobacco.[3]

- In 2017, 13.3% of high school students in Maryland used electronic vapor products on at least one day in the past 30 days. Nationally, the rate was 13.2%.[2]
- In 2017, 6.2% of high school students in Maryland used chewing tobacco, snuff or dip on at least one day in the past 30 days. Nationally, the rate was 5.5%.[2]
- In 2017, 9.0% of high school students in Maryland smoked cigars, cigarillos or little cigars on at least one day in the past 30 days. Nationally, the rate was 8.0%.[2]



Economics of tobacco use and tobacco control

- Maryland received $525 million (estimated) in revenue from tobacco settlement payments and taxes in fiscal year 2019.[4]
- Of this, the state allocated $10.5 million in state funds to tobacco prevention in fiscal year 2019, 21.8% of the Centers for Disease Control and Prevention's annual spending

target.[4]

- Smoking-related health care costs: $2.71 billion per year.[4]
- Smoking-related losses in productivity: $2.22 billion per year.[5]

Maryland tobacco laws

Tobacco taxes

- Maryland is ranked 17th in the U.S. for its cigarette tax of $2 per pack (enacted January 2008), compared with the national average of $1.81. (The District of Columbia has the highest tax at $4.50 and Missouri has the lowest at 17 cents.)[6-8]
- Cigars are taxed at 70% of the wholesale price and premium cigars are taxed at 15% of the wholesale price. All other tobacco products are taxed at 30% of the manufacturer's list price.[6,7]

Clean indoor air ordinances

- Smoking is prohibited in all government and private workplaces, schools, childcare facilities, restaurants, bars, casinos/gaming establishments, retail stores and recreational/cultural facilities.[7]

- No smoke-free restrictions exist for e-cigarette use.[9]

Youth access laws

- The minimum age to purchase tobacco products in Maryland is 21. In December 2019, the United States adopted a law raising the federal minimum age of sale of all tobacco products to 21, effective immediately.
- Minors are prohibited from buying electronic smoking devices, including e-cigarettes.[6,7]

Quitting statistics and benefits

- The CDC estimates that 50.4% of daily adult smokers in Maryland quit smoking for one or more days in 2017.[3]
- In 2014, the Affordable Care Act required that Medicaid programs cover all quit medications.[7]**
- Maryland's state quit line invests $3.39 per smoker, compared with the national average investment per smoker of $2.21.[7]
- Maryland does have a private insurance mandate provision for cessation.[7]

Notes and references

Updated April 2019

*National and state-level prevalence numbers reflect the most recent data available. This may differ across state fact sheets.

**The seven recommended quitting medications are NRT gum, NRT patch, NRT nasal spray, NRT inhaler, NRT lozenge, Varenicline (Chantix) and Bupropion (Zyban).
Fiore MC, et al. Treating Tobacco Use and Dependence: 2008 Update. Clinical Practice Guideline. Rockville, MD: US

Department of Health and Human Services. Public Health Service: May 2008.

1. CDC, Behavioral Risk Factor Surveillance System, 2017.

2. CDC, Youth Risk Behavior Surveillance System, 2017.

3. CDC, Behavioral Risk Factor Surveillance System, State Tobacco Activities Tracking and Evaluation System, 2017.

4. Campaign for Tobacco-Free Kids, Broken Promises to Our Children: a State-by-State Look at the 1998 State Tobacco Settlement 20 Years Later FY2019, 2018.

5. Campaign for Tobacco-Free Kids, Toll of Tobacco in the United States.

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5. Tax Foundation Report On Vaping Taxes

TAX FOUNDATION

Vaping Taxes Should Be Carefully Designed

September 12, 2019

Ulrik Boesen

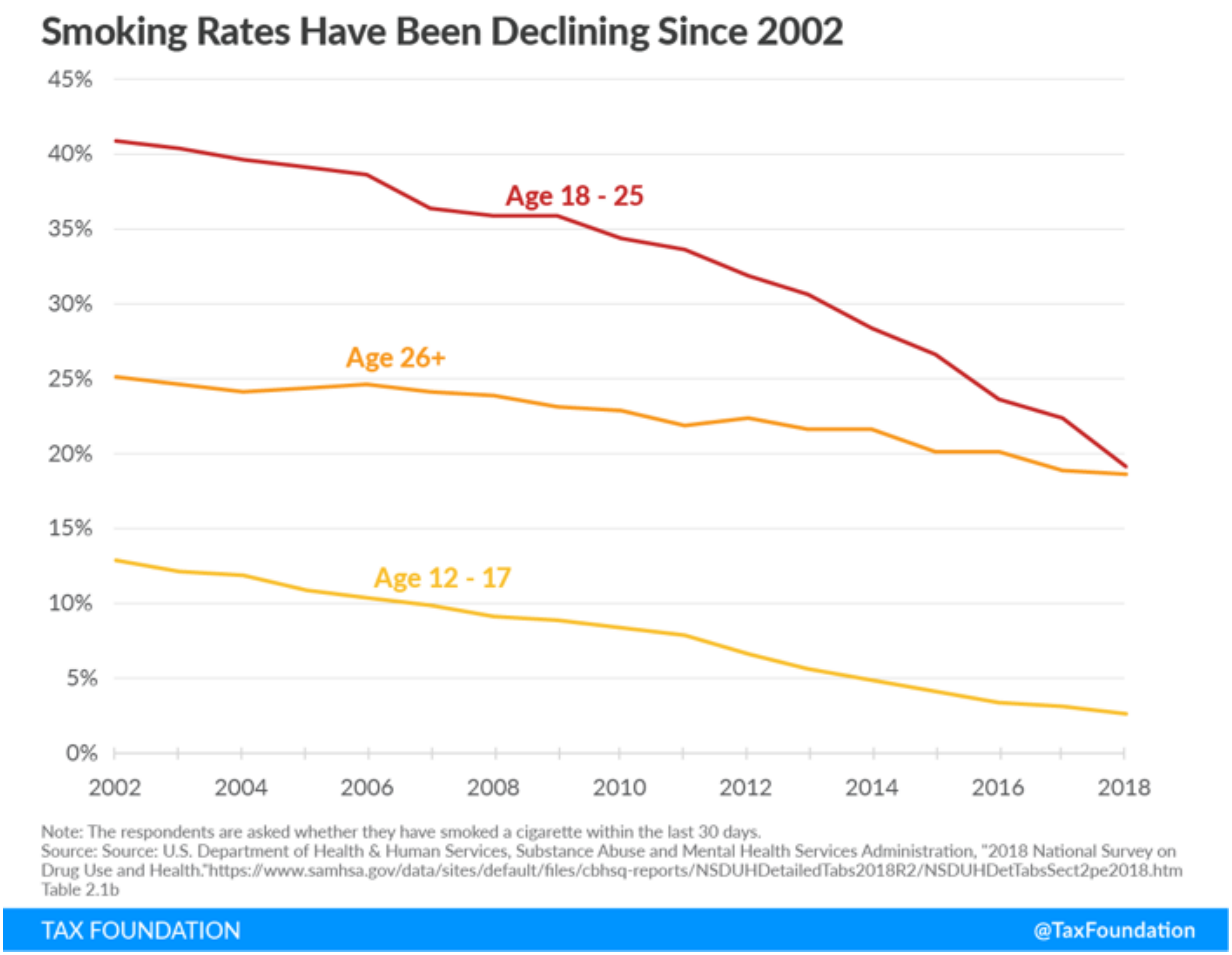
The incidence of increased vaping among teens as well as a recent uptick in lung disease has captured the attention of everyone from President Trump, who Wednesday called for a ban on flavored nicotine liquids used for vapor products, to Senate Finance Committee Ranking Member Ron Wyden (D-OR), who followed by proposing legislation to levy an excise tax on vapor products. Wyden's proposal suggests excise levels similar to that for traditional combustible tobacco products. Many states also are discussing whether and how to tax these vaping products.

With all good intentions to reduce the underage use of a product designed for adults, the question remains: Is increasing excise taxes to punitive levels the best way to achieve this honorable target? Punitive excise levels not only impact minors but also limit the availability of vapor products to adults, who are trying to quit smoking.

It is a principle of good taxation policy that taxes remain as neutral as possible. That means taxes should neither encourage nor discourage personal or business decisions. Legislators should pass regulations rather than adopt taxes to achieve regulatory goals. Furthermore, they should make sure that current regulations are enforced. This is currently not the case for most states. For instance, 19.2 percent of high school students use vaping products in Minnesota, where minors are prohibited from purchasing them.

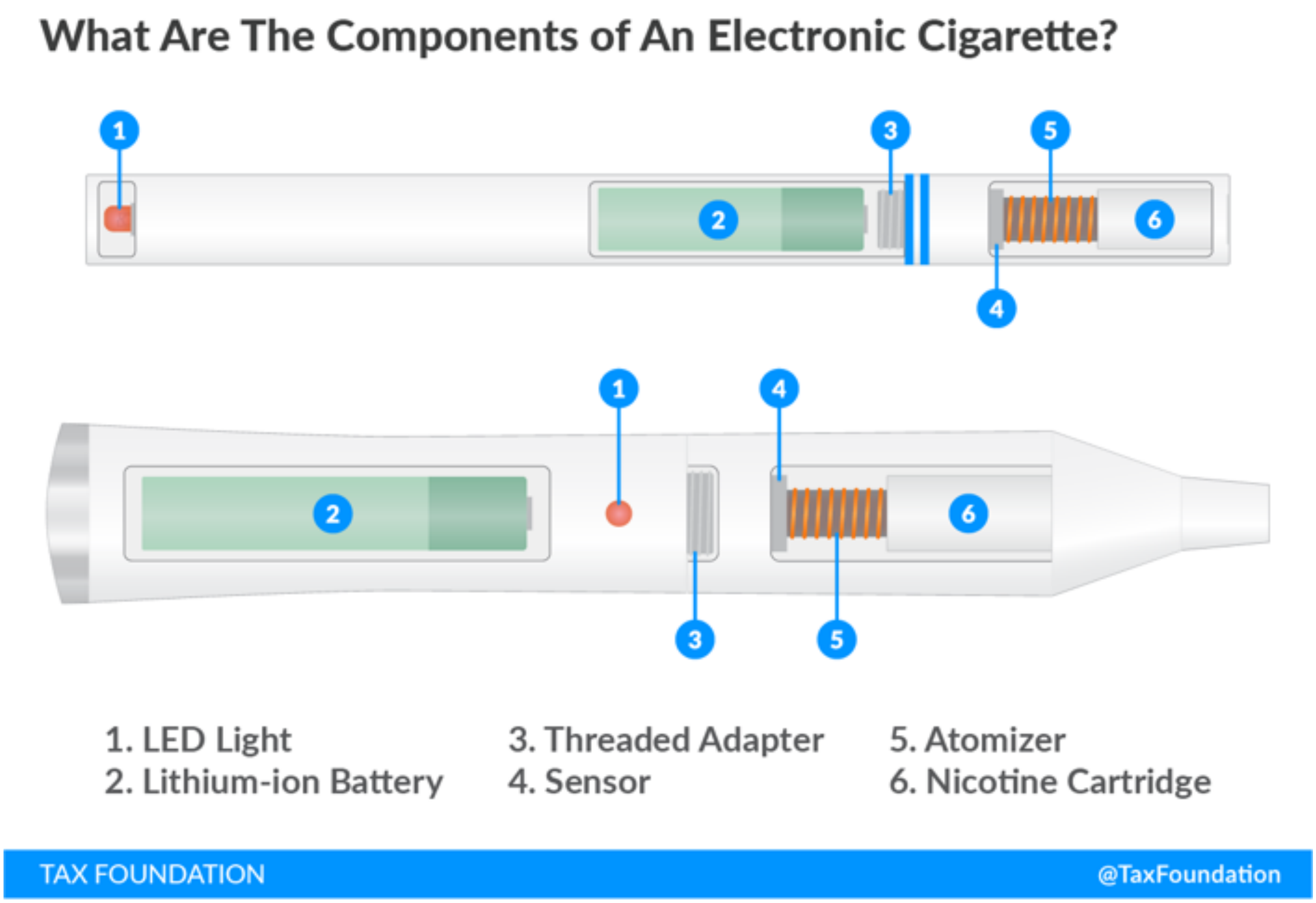
There is some debate over the societal health benefits of vaping, but generally it is believed beneficial for society every time a smoker becomes a vaper. Public Health England, an agency of the English Ministry for Health, recommends smokers switch to vaping, and the American Cancer Society concludes that, based on current available information, vaping is less harmful than smoking. In other words, vapor products could be a key tool in the fight against tobacco-related morbidity and mortality.

There seems to be some correlation among growth in the vapor market and a declining cigarette market. While vaping has been growing in many states, the decline in smoking has accelerated—among teens and adults.



What Comprises an E-Cigarette?

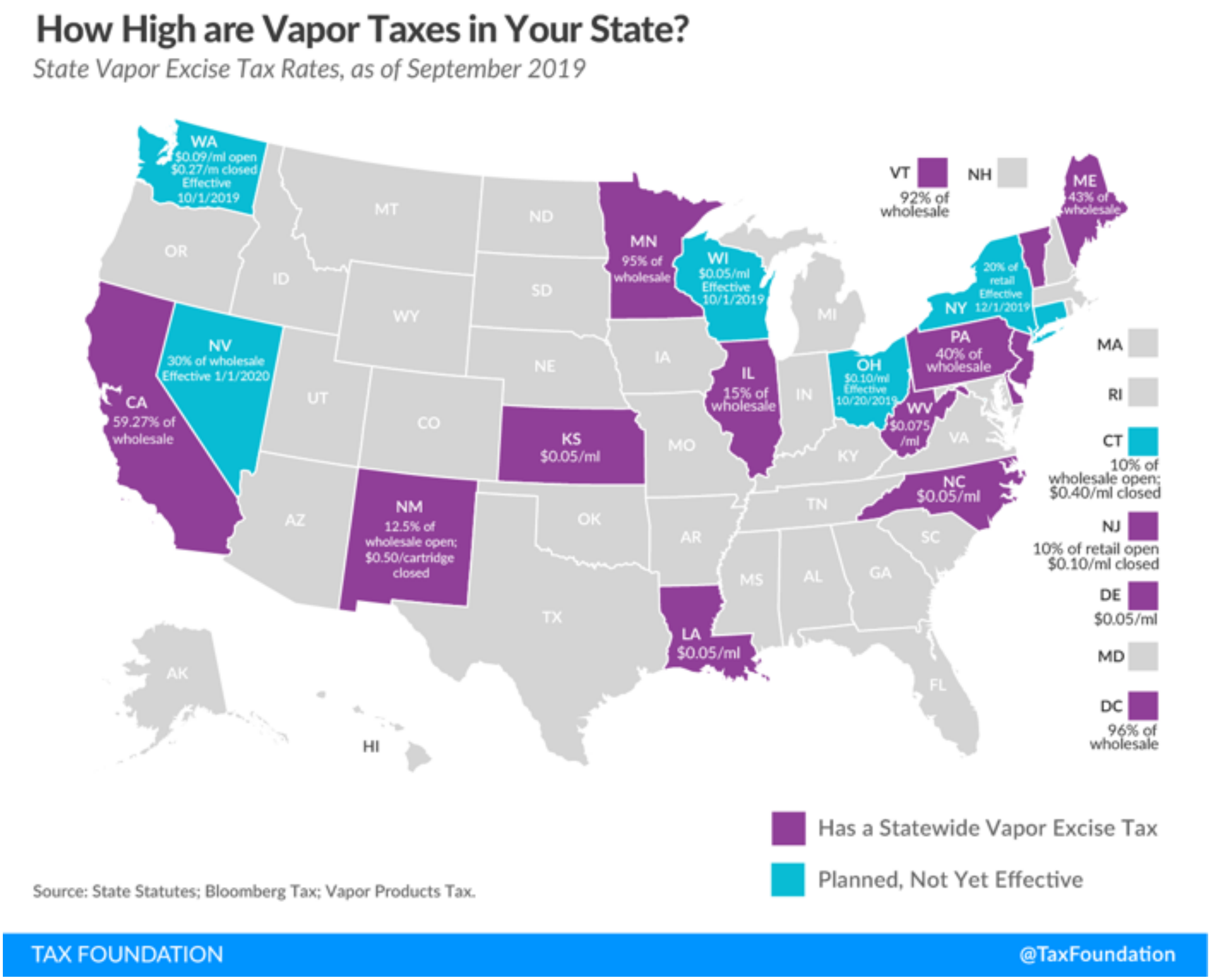
E-cigarettes generally come in two varieties: an open system, where the nicotine liquid is filled manually, and closed systems, which are prefilled with nicotine liquid in cartridges. The systems offer different user experiences as they are designed to be consumed in different ways. Closed tank systems normally have higher nicotine levels per milliliter to allow for consuming the desired amount of nicotine in shorter sessions. Due to these design differences lawmakers might look into differentiated excise levels for open and closed systems to achieve a product-neutral outcome.



How Are They Currently Taxed?

Vapor products debuted in the United States in 2007, but states have generally been slow to act on taxation. Currently, 12 states and the District of Columbia tax vaping products. Seven other states have passed legislation to begin taxing. The current focus on vaping gives states an opportune chance to modernize their excise taxes to reflect the actual nicotine market. Virginia has already done this and passed amendments to its definitions to reflect market developments. The new definitions include heated tobacco products, alternative nicotine products, nicotine vapor products, and liquid nicotine.

This exercise can help states design correct and simple ways to levy excise taxes on these novel products.



Minnesota is the state with the longest-running tax regime for e-cigarettes. It taxes the product at 95 percent of the wholesale value as it considers it a non-cigarette smoking tobacco product. In 2016 Minnesota raised $5.7 million from vapor products and expects to collect around $600 million in total tobacco excise taxes in 2019.

North Carolina, another state with a history of taxing vapor products, collected $4.5 million on vapor products and estimates $260 million in total tobacco tax revenue in 2018.

How to Tax Vapor Products

To the extent that legislators choose to tax vapor products, they should design a principled excise regime. Legislators should focus on raising revenue in a simple, neutral, transparent, and stable manner. Levying taxes based on these principles limits the adverse effects on the economy and the individual.

The tax should be specific, based on quantity. In terms of vapor products, the obvious choice is to tax the liquid based on volume (e.g., a certain amount per ml). It is the administratively simplest and most straightforward way for governments to tax a good as it doesn't require valuation and as such doesn't require expensive tax administration. Volume-based taxation also avoids discriminating between disposable and reusable products. In Minnesota for instance, the tax is levied differently when the nicotine solution is mixed in-state versus products imported in their final consumable form. During the 2017 legislative session, a bill was proposed that would have modified the tobacco tax statute to standardize how e-cigarette products are taxed in Minnesota. However, the proposal did not advance.

Taxing the value of a good (*ad valorem*) hurts consumer choice and product quality as it incentivizes manufacturers and retailers to reduce prices to limit tax liability. It also incentivizes downtrading, which is when consumers move from premium products to cheaper alternatives. Downtrading effects do not reduce harm and have no relation to any externality the tax is seeking to capture. Taxing based on quantity rather than value makes it easier for governments to forecast revenue as it is not affected by changes in consumer brand preference or retail prices.

The level (dollar amount) of the excise should reflect the harm of vapor products relative to traditional tobacco products and should be equal regardless of price, as potential harm caused by a vapor product is theoretically equal regardless of the price of the brand. More research relating to the potential harm-reduction qualities of vapor products is needed, but there is certainly consensus that vapor products are significantly less harmful than traditional combustible tobacco products. Public Health England reports vapor products are 95 percent less harmful than cigarettes.

When determining tax levels, it is important to keep in mind that excise taxes are regressive in nature. As smoking is more common among low-income Americans, lawmakers should take care to protect this group's ability to switch from cigarettes to vapor products.

Revenue collected through excise taxes on vapor products should not be considered stable—excise revenues seldomly are—and the market is both young and volatile. Keep in mind that cigarette tax revenue is notoriously difficult to predict, and the cigarette market is, contrary to the vaping market, a mature market. Legislators and state revenue forecasters should be aware of this when calculating the revenue expectations and appropriating funds.

Given the regressivity of these taxes and their inherent instability, policymakers are well-advised to avoid relying on this revenue to fund broad-based government programs. The revenue should instead be used to cover the externalities associated with the excised good.

Finally, if a specific excise tax is set at a relatively low rate reflecting the relative harm-reduction compared to traditional combustible tobacco products, it may make sense to inflation-adjust the rate to avoid needing to do so later. Resistance to inflation-adjusting tobacco excise taxes has often centered around the concern that rates are already quite high, promoting smuggling and heavily taxing lower-income consumers; the argument is the result may be counterproductive. If policymakers get the rate right in the first place, though, as they have an opportunity to do with vapor products, inflation adjustments could form a part of a well-structured tax regime.

6. New England Journal Of Medicine Article, *Differential Taxes*

Differential Taxes for Differential Risks — Toward Reduced Harm from Nicotine-Yielding Products

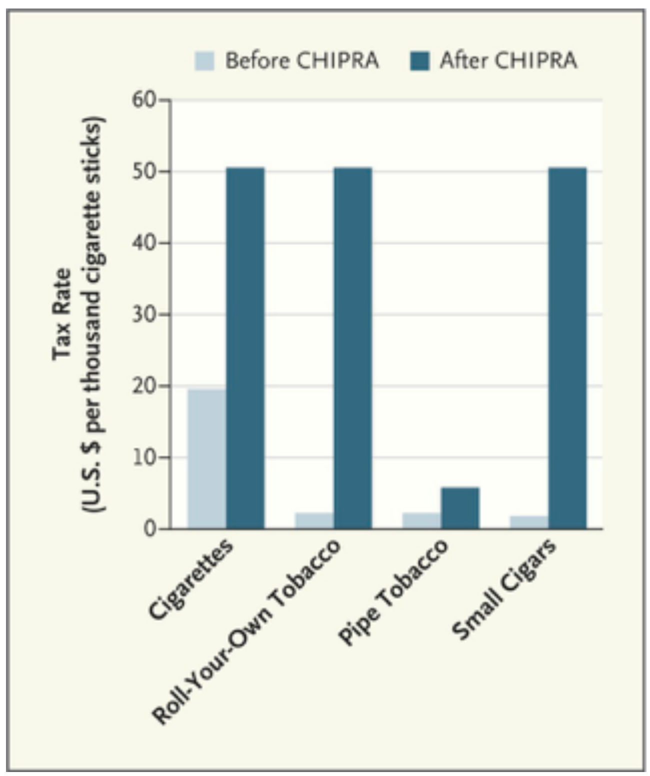
Frank J. Chaloupka, Ph.D.,
David Sweanor, J.D.,
and Kenneth E. Warner, Ph.D.

In a January 2014 report that marked the 50th anniversary of the first Surgeon General's Report on Smoking and Health, acting U.S. Surgeon General Boris Lushniak concluded that the enormous toll of tobacco-induced disease and death is overwhelmingly the result of combustible tobacco use, specifically cigarette smoking. He called for a rapid reduction in the use of combustible products to reduce the related burden of illness.[1] We believe this goal could be achieved by imposing differential taxes on nicotine products — including sharply increased taxes on combustible products.

Today's nicotine consumer has a remarkable array of options, ranging from extremely low-risk products (nicotine-replacement products approved by the Food and Drug Administration [FDA]) to extraordinarily risky ones (cigarettes, which kill half of long-term users). Elsewhere on the spectrum are other lower-risk products, including low-nitrosamine smokeless tobacco products and electronic nicotine-delivery systems (ENDS, which include e-cigarettes), and higher-risk products, including combustible tobacco products other than cigarettes (such as cigars, cigarillos, and hookah tobacco). Although no one has precisely characterized the relative risk associated with each of these products, research suggests that low-nitrosamine smokeless tobacco products pose no more than one tenth the risk of cigarettes, whereas the risk associated with other combustible-tobacco products may approach that of cigarettes.[1] Because ENDS products are so new and varied, the risk associated with them remains to be established, although early evidence suggests they are substantially less harmful than combustibles.[2]

Extensive research demonstrates that higher tobacco taxes can help promote quitting among current users, deter initiation among potential users, and reduce tobacco use among continuing users.[3] Studies have also shown that changes in the relative prices of tobacco products lead some tobacco users to switch to less expensive products.[3] Given the belief that all tobacco products are seriously deleterious to health, conventional wisdom in the tobacco-control world has long been that all products should be taxed similarly. For example, the World Health Organization states that adopting "comparable taxes and tax increases on all tobacco products" is a best practice for tobacco taxation.[4]

To some extent, the 2009 U.S. federal tobacco-tax increases reflected this strategy: taxes on historically lower-taxed products were increased by much more than taxes on products that had previously been taxed at higher rates (see). Whereas the cigarette tax rose from $0.39 to $1.0067 per pack (a 158% increase), taxes on roll-your-own tobacco rose from $1.0969 to $24.78 per pound (a 2159% increase) and taxes on small cigars rose from $1.828 to $50.33 per 1000



Changes in Federal Excise Tax Rates for Tobacco

Products as a Result of the Children's Health Insurance Program Reauthorization Act (CHIPRA) of 2009.

(a 2653% increase). The snuff tax rose by the same 158% as the cigarette tax. Many states have taken a similar approach, increasing taxes on noncigarette tobacco products by a greater amount than taxes on cigarettes in order to achieve greater parity between products.

As sales of ENDS have skyrocketed, interest in taxing them has grown as well. As of early 2015, Minnesota and North Carolina were the only states that had adopted taxes on ENDS. Minnesota taxes ENDS as tobacco products, levying the same tax of 95% of wholesale price that it applies to snuff and chewing and smoking tobacco. In contrast, North Carolina created a new, very low, ENDS-specific tax of $0.05 per milliliter of consumable solution. Several other states, counties, and cities are considering legislation to impose a tax on ENDS.

The rapid evolution of the nicotine-product marketplace suggests that it's time to rethink the idea that similar taxes are best practice. We believe that national, state, and local policymakers should consider an approach that differentially taxes nicotine products in order to maximize incentives for tobacco users to switch from the most harmful products to the least harmful ones. Sizable public health benefits could derive from current cigarette smokers' switching to ENDS and other noncombustible products, including nicotine-replacement therapies (as the one type of nicotine product demonstrated to be safe, nicotine-replacement therapy should not be subject to any excise tax).[1]

Sweden, which has Europe's lowest tobacco-attributable mortality among men, provides a good example of how this approach can succeed. There, lower taxes on snus — a form of smokeless tobacco — contributed to many male cigarette smokers switching to snus. Women, however, did not switch to the same extent, which illustrates that price differentials alone are not always sufficient to achieve public health goals.[5]

The manner in which a differential taxation system is implemented will determine how well it works as a harm-reduction strategy. To alleviate concerns that low prices on ENDS and lower-risk tobacco products might encourage uptake among young people, taxes on such products could be set high enough to discourage initiation. At the same time, taxes on combustible products could be further increased in order to raise their prices relative to less harmful noncombustible products. Such a strategy would maximize the likelihood of current smokers switching to lower-risk products while deterring users of lower-risk products from switching to more harmful ones. Higher prices for combustible products would have the added benefit of further reducing the likelihood that young people would take up smoking.

The current approach of imposing taxes on ENDS or raising taxes on cigarettes and other combustible products by the same amount as taxes on snus and other smokeless products has the opposite effect: it discourages tobacco users from switching to reduced-risk products, encourages dual use, and increases the likelihood that young people who initiate nicotine use will start with the most dangerous products.

A differential taxation strategy is not without potential problems. Decades ago, proposals were floated to tax cigarettes at different rates on the basis of tar and nicotine content. The United Kingdom and New York City adopted this approach, briefly levying special taxes on high-tar cigarettes. As evidence grew that cigarettes with lower tar and nicotine levels were no less dangerous, however, public health authorities realized that a differential taxation strategy was undesirable. Yet today the science supporting a difference in risk between combustible and noncombustible tobacco products is well established.

Given the FDA's regulatory authority over the manufacture, distribution, and marketing of tobacco products, a differential taxation strategy could be complemented by other policies, such as restrictions on ENDS marketing and strong product standards, to maximize public health benefit. Perhaps most important, as proposed in the FDA's recent “deeming” rule, the agency's authority over tobacco products could be extended to cover additional products including ENDS, opening up such items to new regulation. Policymakers could then make a product's eligibility for a lower tax rate dependent on the FDA's determination that it poses substantially reduced risk.

We believe that implementing differential taxes on nicotine-yielding products on the basis of degree of risk could substantially expedite the move away from cigarette smoking that has occurred during the past half-century, especially now that there are nicotine-yielding products that pose dramatically less danger than combustible tobacco products. Nearly a fifth of U.S. adults are cigarette smokers, and smoking accounts for one of every five deaths in the United States. Failure to seriously entertain a differential taxation approach may contribute to the prolongation of the epidemic of disease and death caused by smoking.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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Supplementary Material

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Google Scholar

7. Public Health England Study, E-Cigarettes Are About 95% Safer Than Smoking

E-cigarettes around 95% less harmful than tobacco estimates landmark review

Expert independent review concludes that e-cigarettes have potential to help smokers quit.

Public Health England

An expert independent evidence review published today by Public Health England (PHE) concludes that e-cigarettes are significantly less harmful to health than tobacco and have the potential to help smokers quit smoking.

Key findings of the review include:

- the current best estimate is that e-cigarettes are around 95% less harmful than smoking
- nearly half the population (44.8%) don't realise e-cigarettes are much less harmful than smoking
- there is no evidence so far that e-cigarettes are acting as a route into smoking for children or non-smokers

The review, commissioned by PHE and led by Professor Ann McNeill (King's College London) and Professor Peter Hajek (Queen Mary University of London), suggests that e-cigarettes may be contributing to falling smoking rates among adults and young people. Following the review PHE has published a paper on the implications of the evidence for policy and practice.

The comprehensive review of the evidence finds that almost all of the 2.6 million adults using e-cigarettes in Great Britain are current or ex-smokers, most of whom are using the devices to help them quit smoking or to prevent them going back to cigarettes. It also provides reassurance that very few adults and young people who have never smoked are becoming regular e-cigarette users (less than 1% in each group).

However, the review raises concerns that increasing numbers of people think e-cigarettes are equally or more harmful than smoking (22.1% in 2015, up from 8.1% in 2013: ASH Smokefree GB survey) or don't know (22.7% in 2015, ASH Smokefree GB survey).

Despite this trend all current evidence finds that e-cigarettes carry a fraction of the risk of smoking.

Emerging evidence suggests some of the highest successful quit rates are now seen among smokers who use an e-cigarette and also receive additional support from their local stop smoking services.

Professor Kevin Fenton, Director of Health and Wellbeing at Public Health England said:

> Smoking remains England's number one killer and the best thing a smoker can do is to quit completely, now and forever.
>
> E-cigarettes are not completely risk free but when compared to smoking, evidence shows they carry just a fraction of the harm. The problem is people increasingly think they are at least as harmful and this may be keeping millions of smokers from quitting. Local stop smoking services should look to support e-cigarette users in their journey to quitting completely.

Professor Ann McNeill, King's College London and independent author of the review, said:

> There is no evidence that e-cigarettes are undermining England's falling smoking rates. Instead the evidence consistently finds that e-cigarettes are another tool for stopping smoking and in my view smokers should try vaping and vapers should stop smoking entirely.
>
> E-cigarettes could be a game changer in public health in particular by reducing the enormous health inequalities caused by smoking.

Professor Peter Hajek, Queen Mary University London and independent author of the review said:

> My reading of the evidence is that smokers who switch to vaping remove almost all the risks smoking poses to their health. Smokers differ in their needs and I would advise them not to give up on e-cigarettes if they do not like the first one they try. It may take some experimentation with different products and e-liquids to find the right one.

Professor Linda Bauld, Cancer Research UK's expert in cancer prevention, said:

> Fears that e-cigarettes have made smoking seem normal again or even led to people taking up tobacco smoking are not so far being realised based on the evidence assessed by this important independent review. In fact, the overall evidence points to e-cigarettes actually helping people to give up smoking tobacco.

> Free Stop Smoking Services remain the most effective way for people to quit but we recognise the potential benefits for e-cigarettes in helping large numbers of people move away from tobacco.
>
> Cancer Research UK is funding more research to deal with the unanswered questions around these products including the longer-term

> impact.

Lisa Surtees, acting director at Fresh Smoke Free North East, the first region where all local stop smoking services are actively promoted as e-cigarette friendly, said:

> Despite making great strides to reduce smoking, tobacco is still our biggest killer. Our region has always kept an open mind towards using electronic cigarettes as we can see the massive potential health benefits from switching.
>
> All of our local NHS Stop Smoking Services now proactively welcome anyone who wants to use these devices as part of their quit attempt and increase their chance of success.

Background

PHE's remit letter for 2014 to 2015 requested an update of the evidence around e-cigarettes. PHE commissioned Professors Ann McNeill and Peter Hajek to review the available evidence. The review builds on previous evidence summaries published by PHE in 2014.

The full list of authors of the report are:

- McNeill A, Brose LS, Calder R, Hitchman SC: Institute of Psychiatry, Psychology & Neuroscience, National Addiction Centre, King's College London and UK Centre for Tobacco & Alcohol Studies

- Hajek P, McRobbie H (Chapters 9 and 10): Wolfson Institute of Preventive Medicine, Barts and The London School of Medicine and Dentistry Queen Mary, University of London and UK Centre for Tobacco & Alcohol Studies

Implications of the evidence for policy and practice: Based on the findings of the evidence review PHE advises that:

- e-cigarettes have the potential to help smokers quit smoking, and the evidence indicates they carry a fraction of the risk of smoking cigarettes but are not risk free
- e-cigarettes potentially offer a wide reach, low-cost intervention to reduce smoking in more deprived groups in society where smoking is elevated, and we want to see this potential fully realised
- there is an opportunity for e-cigarettes to help tackle the high smoking rates among people with mental health problems, particularly in the context of creating smokefree mental health units
- the potential of e-cigarettes to help improve public health depends on the extent to which they can act as a route out of smoking for the country's eight million tobacco users, without providing a route into smoking for children and non-smokers. Appropriate and proportionate regulation is essential if this goal is to be achieved
- local stop smoking services provide smokers with the best chance of quitting successfully and we want to see them engaging actively with smokers who want to quit with the help of e-cigarettes
- we want to see all health and social care professionals providing accurate advice on the relative risks of smoking and e-cigarette use, and providing effective referral routes into stop smoking services
- the best thing smokers can do for their health is to quit smoking completely and to quit for good. PHE is committed to ensure that smokers have a range of evidence-based, effective tools to help them to

quit. We encourage smokers who want to use e-cigarettes as an aid to quit smoking to seek the support of local stop smoking services

- given the potential benefits as quitting aids, PHE looks forward to the arrival on the market of a choice of medicinally regulated products that can be made available to smokers by the NHS on prescription. This will provide assurance on the safety, quality and effectiveness to consumers who want to use these products as quitting aids

- the latest evidence will be considered in the development of the next Tobacco Control Plan for England with a view to maximising the potential of e-cigarettes as a route out of smoking and minimising the risk of their acting as a route into smoking

From October this year it will be an offence to sell e-cigarettes to anyone under the age of 18 or to buy e-cigarettes for them. The government is consulting on a comprehensive array of regulations under the European Tobacco Products Directive.

Photo by pixelblume, used under Flickr Creative Commons

Please contact PHE press office for:

- the full review E-cigarettes: an evidence update - A report commissioned by Public Health England

- interviews with PHE spokespeople or the review's independent authors

- case studies of stop smoking services who work with e-cigarette users and smokers who have quit completely with a combination of e-cigarettes and attending a service

Public Health England

Protecting and improving the nation's health

Underpinning evidence for the estimate that e-cigarette use is around 95% safer than smoking: authors' note

The estimate that e-cigarette use is around 95% safer than smoking is based on the facts that:

- the constituents of cigarette smoke that harm health – including carcinogens – are either absent in e-cigarette vapour or, if present, they are mostly at levels much below 5% of smoking doses (mostly below 1% and far below safety limits for occupational exposure)
- the main chemicals present in e-cigarettes only have not been associated with any serious risk

Our review[i] aimed to assess whether studies that have recently been widely reported as raising new alarming concerns on the risks of e-cigarettes changed the conclusions of the previous independent review (Britton and Bogdanovica, 2014) and other reassuring reviews.

We concluded that these new studies do not in fact demonstrate substantial new risks and that the previous estimate by an international expert panel (Nutt et al, 2014) endorsed in an expert review (West et al, 2014) that e-cigarette use is around 95% safer than smoking, remains valid as the current best estimate based on the peer-reviewed literature.

Some flavourings and constituents in e-cigarettes may pose risks over the long term. We consider the 5% residual risk to be a cautious estimate allowing for this uncertainty.

Ongoing monitoring is needed to ensure that if any new risks emerge, recommendations to smokers and regulatory requirements are revised accordingly.

On current evidence, there is no doubt that smokers who switch to vaping reduce the risks to their health dramatically.

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Institute of Psychiatry, Psychology & Neuroscience, National Addiction Centre, King's College London

PHE publications gateway: 2015260

Public Health England

Protecting and improving the nation's health

Professor Peter Hajek
Wolfson Institute of Preventive Medicine, Barts and The London School of Medicine and Dentistry Queen Mary, University of London

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PHE publications gateway: 2015260

8. Public Health England Study – Evidence Update 2019

GOV.UK

1. Home (https://www.gov.uk/)
2. Vaping in England: an evidence update February 2019 (https://www.gov.uk/government/publications/vaping-in-england-an-evidence-update-february-2019)

1. Public Health England (https://www.gov.uk/government/organisations/public-health-england)

Research and analysis

Vaping in England: evidence update summary February 2019

Published 27 February 2019

Contents

This publication is available at https://www.gov.uk/government/publications/vaping-in-england-an-evidence-update-february-2019/vaping-in-england-evidence-update-summary-february-2019

1. Introduction

This report was commissioned by Public Health England to summarise evidence to underpin policy and regulation of electronic cigarettes in England. It focuses mainly on the latest evidence on prevalence and characteristics of electronic cigarette use in young people and adults in England.

The context for the report is that smoking remains the leading preventable cause of illness and premature death and is one of the largest causes of health inequalities. So alternative nicotine delivery systems, such as electronic cigarettes or e-cigarettes, could play a major role in improving public health.

Terminology

E-cigarette is a term that was commonly used when the first devices became available. These devices resembled tobacco cigarettes, but there has since been a rapid evolution of the technology and products. The shape of the products now varies enormously.

This variation means that the term e-cigarettes is no longer appropriate, and we are aware of discussions going on in the UK and internationally to develop common terminology. For this report, we continue to use the term e-cigarettes (EC) but we hope to replace this terminology in future reports, when a consensus has been reached.

2. Recent policy and guidance developments

2.1 Main changes

The National Institute for Health and Care Excellence (NICE) published guidance for health and social care workers on how to have an informed discussion about EC (https://www.nice.org.uk/guidance/ng92). The House of Commons Science and Technology Committee published a report on EC (https://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/505/50502.htm) which included recommendations about harm reduction, smoking cessation, EC in mental health settings and regulation.

The Government responded with a command paper (https://www.gov.uk/government/publications/government-response-to-the-science-and-technology-select-committees-report-on-e-cigarettes) which broadly accepted the Science and Technology Committee's recommendations. The response said the government is firmly committed to more research in this area and to a proportionate regulation system.

Following a consultation, the Committee of Advertising Practice (CAP) and the Broadcast Committee of Advertising Practice (BCAP) announced that they were lifting the blanket ban on making health claims in non-broadcast advertising for EC (https://www.asa.org.uk/news/can-e-cigarettes-claim-to-be-healthy.html). It is currently unclear how the new guidance will be applied in practice.

New NHS guidance (https://www.health-ni.gov.uk/publications/niaic-estates-and-facilities-alerts-publications) has followed recommendations on fire risks from our previous evidence reviews and placed EC in the same category as mobile phones.

The NHS Long Term Plan for England (https://www.england.nhs.uk/long-term-plan/) recommended a new universal smoking cessation offer for long-term users of specialist mental health and learning disability services. This will include the option for smokers to switch to e-cigarettes while in inpatient settings.

Individual countries have amended their policies on EC to either further restrict their use or, in the case of Canada and New Zealand, promote their use as less harmful alternatives to tobacco smoking.

The US Food and Drug Administration announced actions (https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm620184.htm) to restrict the sale and marketing of EC to young people.

2.2 Implications

Overall, England continues to take small progressive steps towards ensuring vaping remains an accessible and appealing alternative to smoking.

If the House of Commons Science and Technology Committee's recommendations are fully carried out by government, they have the potential to broaden this accessibility and appeal further, particularly in mental health settings, where smoking rates are high.

However, there is still no medicinally licensed EC in England, or anywhere else in the world. It is possible that more smokers may be attracted to vaping if a licensed EC was made available. Barriers to licensing and the commercialising of licensed products need further exploration.

3. Methods

We have used data from several surveys in the UK which assessed young people and adult vaping prevalence. We also drew on peer-reviewed publications of these surveys including any awaiting publication, for which we are co-authors.

We reviewed the international literature on vaping prevalence from 1 January 2017 to 5 November 2018 and examined data collected from local authorities on stop smoking services by NHS Digital from 1 April 2017 to 30 June 2018.

4. Vaping in young people

4.1 Main findings

In England and in Great Britain as a whole, experimentation with EC has steadily increased in recent years. However, regular use remains low, with 1.7% of 11 to 18 year olds in Great Britain reporting at least weekly use in 2018 (it was 0.4% among 11 year olds and 2.6% among 18 year olds).

Vaping continues to be associated with smoking. The proportion of young people who have never smoked who use EC at least weekly remains very low (0.2% of 11 to 18 year olds in 2018).

The latest smoking data used for measuring progress in reaching the goals of the Tobacco Control Plan for England (https://www.gov.uk/government/publications/towards-a-smoke-free-generation-tobacco-control-plan-for-england) are from 2016. The data indicated that 7% of 15 year olds were regular (at least weekly) smokers in 2016 (8% in 2014). The 2018 data is not yet available.

The proportion who haven't smoked but have tried vaping is increasing. The extent to which these young people would have tried smoking if vaping had not been available is unclear.

The proportion of 13 and 15 year olds who have ever smoked declined steadily between 1998 and 2015, including after the introduction of EC. In this period, young people's attitudes became more negative towards smoking. Further analyses of the period beyond 2015 are underway.

Studies from outside of the UK suggest a similar picture, with increasing experimentation and use of EC over time among youth. There is evidence from the US that increasing vaping is happening against a backdrop of reducing cigarette smoking.

4.2 Implications

Trends in smoking and vaping should continue to be monitored, particularly in the light of concerns in North America about youth smoking and vaping.

Surveillance is needed on purchase sources of EC by young people, as recommended in our previous evidence review (https://www.gov.uk/government/publications/e-cigarettes-and-heated-tobacco-products-evidence-review).

More research is also needed on how young people move from EC to smoking and vice versa.

5. Vaping in adults

5.1 Main findings

Data from several representative surveys suggest that vaping prevalence among all adults in Great Britain has remained stable since 2015. In 2017 to 2018, estimates for prevalence were:

- 5.4% to 6.2% for all adults
- 14.9% to 18.5% for current smokers
- 0.4% to 0.8% for people who had never smoked
- 10.3% to 11.3% for ex-smokers (vaping prevalence declined as the time since they had stopped smoking increased)

Smoking prevalence ranged from 13.7% to 17.3% for the adult population but was substantially higher in lower socio-economic groups (for example, 35% in people living in social housing smoked).

Just over a third of all current smokers had never tried EC.

Use of EC in quit attempts is similar across socio-economic groups. Among long-term ex-smokers, EC use is higher in those from lower socio-economic groups. This suggests that those from higher socio-economic groups are using EC to quit smoking and then stop use, while those from more disadvantaged groups continue to use EC.

continue to use EC.

Overall, we found no clear association among past and current vapers between how long people use EC, the devices they used and socio-economic status.

There are possible associations between lower socio-economic groups and higher strength of nicotine, amount of liquid used and a greater variety of EC flavours used.

Over time, most vapers report either continuing to use the same nicotine strength (44.7% of participants in one survey, 54.4% in another) or reducing the nicotine strength (40.1% and 49.2% respectively in the same surveys).

One survey indicated that over time most vapers tend to stick to a single flavour type (tobacco, fruit, menthol were the most popular types).

Quitting smoking remains the main reason for vaping in all socio-economic groups. People from higher socio-economic groups were possibly more likely to vape for enjoyment than those from lower groups, who may be more likely to vape for financial reasons than those from higher groups.

Internationally, the US appears to have similar adult vaping prevalence as Great Britain. In other countries where information is available, prevalence is lower.

5.2 Implications

More research is needed to explore the use of EC by different social grades.

Trends need to be monitored, particularly of EC use by never smokers, use alongside smoking and in long-term ex-smokers.

Given the importance of stopping smoking completely, smokers using EC should be advised to quit smoking as soon as possible.

Smokers should be advised to stop smoking as soon as possible and explore all available options for support, including EC.

6. Use of e-cigarettes in English stop smoking services

6.1 Main findings

Monitoring data from stop smoking services have limitations, but such data suggest that using an EC as part of quit attempt continues to be helpful for people attending stop smoking services in England.

In stop smoking services, the proportion of quit attempts using an EC remains very small (4.1% of all quit attempts in stop smoking services).

There is inconclusive evidence to support suggestions that EC have contributed to the decline in demand for stop smoking services in England.

6.2 Implications

6.2 Implications

Combining EC (the most popular source of support used by smokers in the general population), with stop smoking service support (the most effective type of support), should be a recommended option available to all smokers. This proposal from our previous evidence review (https://www.gov.uk/government/publications/e-cigarettes-and-heated-tobacco-products-evidence-review) is still valid.

Stop smoking practitioners and health professionals should provide behavioural support to smokers who want to use an EC to help them quit smoking.

Stop smoking practitioners and health professionals supporting smokers to quit should receive education and training on using EC in quit attempts. Online training is available from the National Centre for Smoking Cessation and Training (NCSCT) (http://www.ncsct.co.uk/).

Local authorities should continue to fund and provide stop smoking services, in line with the evidence base.

7. Authors and citation

7.1 Suggested citation

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9. 2nd Hand Vapor Analysis

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Article

An Assessment of Indoor Air Quality before, during and after Unrestricted Use of E-Cigarettes in a Small Room

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Abstract: Airborne chemicals in the indoor environment arise from a wide variety of sources such as burning fuels and cooking, construction materials and furniture, environmental tobacco smoke as well as outdoor sources. To understand the contribution of exhaled e-cigarette aerosol to the pre-existing chemicals in the ambient air, an indoor air quality study was conducted to measure volatile organic compounds (including nicotine and low molecular weight carbonyls), polycyclic aromatic hydrocarbons, tobacco-specific nitrosamines and trace metal levels in the air before, during and after e-cigarette use in a typical small office meeting room. Measurements were compared with human Health Criteria Values, such as indoor air quality guidelines or workplace exposure limits where established, to provide a context for potential bystander exposures. In this study, the data suggest that any additional chemicals present in indoor air from the exhaled e-cigarette aerosol, are unlikely to present an air quality issue to bystanders at the levels measured when compared to the regulatory standards that are used for workplaces or general indoor air quality.

Keywords: e-cigarette; indoor air quality; bystander exposure; exhaled aerosol; ambient air

1. Introduction

In recent years, the use of electronic cigarettes (also termed "vaping") has increased significantly worldwide with such products gaining acceptance with consumers as an alternative to traditional tobacco products. A report published in July 2014 by Action on Smoking and Health estimated as many as 2.1 million adults in the UK currently use electronic cigarettes (e-cigarettes) [1]. E-cigarettes are battery-powered devices that deliver vaporized nicotine, propylene glycol and/or glycerol and flavorings to users from an "e-liquid" [2,3]. They do not contain tobacco or require combustion [2,3]. E-cigarettes are available in many different configurations; the two principal distinctions being "open" systems which can be refilled by the consumer (e.g., tank systems) or "closed" systems (e.g., replaceable cartridges pre-filled by manufacturers) [3]. When the user takes a puff on the product, a heating element is activated converting the e-liquid in the cartridge into an aerosol that the user holds in the mouth or inhales.

With the increasing prevalence of e-cigarettes, there is growing discussion amongst public health organizations and the scientific community as to whether the aerosol exhaled following use of such products has implications for the quality of air breathed by bystanders through so-called "passive vaping", akin to that reported for environmental tobacco smoke from combusted tobacco products [2–6]. In recent years, there has been conflicting and, at times, confusing information presented to the public regarding the potential risks to bystanders from exhaled e-cigarette aerosol [5,7]. There are calls, including by some government bodies, to prohibit the use of e-cigarettes in workplaces and enclosed public spaces [5,7]. Equally, other organizations and researchers have stated that any regulation on using such products in enclosed public spaces requires an established evidence base, which is limited at this time [2,8].

Airborne chemicals in the ambient air which can impact indoor air quality arise from a wide variety of sources such as those infiltrating from outdoor sources (e.g., vehicle fumes), cooking, burning fuels and tobacco, and (scented) candles [9]. Other sources include emissions from construction materials and furniture, use of air fresheners and cleaning products as well as other consumer goods products like personal care products [9]. To date, there is limited data on the impact of exhaled e-cigarette aerosol on indoor air quality.

Of the few studies that have been undertaken to investigate the impact of e-cigarette emissions on indoor air quality, it has been reported that nicotine, propylene glycol, glycerol (the components of e-liquids), amongst other chemical compounds including volatile organic compounds, low molecular weight carbonyls, polycyclic aromatic hydrocarbons and trace metals, may be released into the air during use of e-cigarettes [10–15]. As no validated, standardized protocol is available for measuring exhaled e-cigarette emissions, the limited number of analytical investigations published above differ in environmental conditions and experimental set-up making it difficult to compare their findings and to determine the impact of e-cigarette use on the indoor ambient air. It is also questionable to compare results from smoking machine generated aerosol released into a room [12] with aerosol generated from human subjects [13] due to the changed chemistry and physical properties of the aerosol upon exhalation. Other factors include differences in the type of e-cigarette device used ("closed" *vs*. "open" system), the e-liquid composition, and the e-cigarette consumers' individual puffing topography, *i.e.*, number of puffs, interval between puffs, puff duration, inhalation volume and depth of inhalation.

It has been reported there is wide variations in the quality of e-cigarettes which may also impact measured emission values [16]. Taken as a whole, there is a clear need for studies evaluating indoor air quality before, during and after e-cigarette use to provide important information on the impact of e-cigarettes on indoor air quality and therefore bystander exposures under real-life conditions [17].

In this study, we performed an assessment of indoor air quality before, during and after *ad libitum* use of a disposable 'closed' system e-cigarette (Puritane™; manufacturer, Fontem Ventures B.V., Amsterdam, The Netherlands) by human subjects in a naturally ventilated meeting room. Within this study, we analyzed the airborne concentrations of volatile organic compounds (VOCs) including nicotine and low molecular weight carbonyls, polycyclic aromatic hydrocarbons (PAHs), tobacco-specific nitrosamines (TSNAs) and trace metals. To assess indoor air quality and to provide a context for potential bystander exposures, we compared these findings with Human Criteria Values including UK and other general indoor air quality guidelines or workplace exposure limits (WELs), where available. The experimental approach presented here may also be useful to compare the chemicals released into the ambient air from different e-cigarettes used in different indoor environments.

2. Experimental Section

2.1. Study Design

To assess indoor air quality in a real-life environment, a business meeting was conducted in a small meeting room (12.8 m^2) with five male adult volunteers (three experienced, regular e-cigarette users and two non-users) who had provided written, informed consent. The purpose of this was to create a realistic environment to encourage normal behavior by volunteers, without undue focus on vaping behavior. Smoking or vaping had not occurred in the room previously which was under natural ventilation conditions (*i.e.*, no air conditioning and all windows/doors were kept closed during the study). The air exchange rate of the office was confirmed using a standard tracer gas method as described previously by Upton and Kukadia [18]. The internal volume of the room was 38.5 m^3 and was furnished with a central table and five chairs; a video camera was placed in one corner of the room to record the study and number of puffs taken by the volunteers. Filter assemblies and sampling lines were suspended above the meeting table using metal struts; this served to reduce interference with volunteer behavior. To mitigate potential confounding from operators entering the test space, air samples were drawn using sampling lines into an adjacent room for collection onto tubes or sorbent cartridges specific for the respective chemical parameter being monitored. Samples for metals analysis were taken within the office using filter arrangements. A schematic representation of the room layout, with details of the two independent sampling locations and the positions of the e-cigarette users and non-users is shown in Figure 1. To investigate potential changes in indoor air quality, the ambient air was analyzed before, during and after a 165 min vaping session. Sampling times are shown in Figure 2. During the vaping session, three of the five participants used Puritane™ 16 mg/g disposable Original flavored e-cigarettes ("closed" system; battery capacity, 240 mAh) purchased over-the counter from a number of UK retail outlets. The base e-liquid (1 mL) used in the product consists of mixture of propylene glycol (67% (w/w)) and glycerol (30% (w/w)) in which pharmaceutical grade nicotine (1.6% (w/w); 16 mg/g per product) and small amounts of flavorings are dissolved; a typical e-liquid conformation in the UK. Products were consumed *ad libitum* (*i.e.*, with no restrictions on how to consume the product during the study period) with multiple products available to enable continual vaping during the study period as required; two participants did not use an e-cigarette during the meeting. The study was developed in collaboration with and conducted by an independent, leading UKAS accredited laboratory in the UK with expertise in indoor air quality.

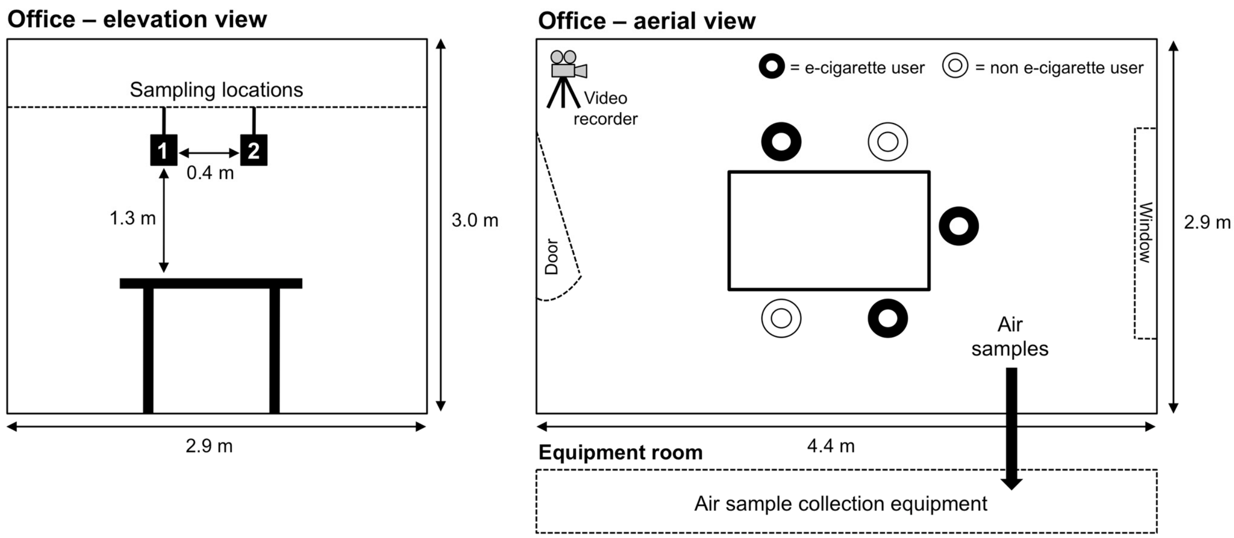

Figure 1. The layout of the meeting room used in this study (not drawn to scale). Sampling locations and positions of the e-cigarette users and non-users during the meeting are highlighted.

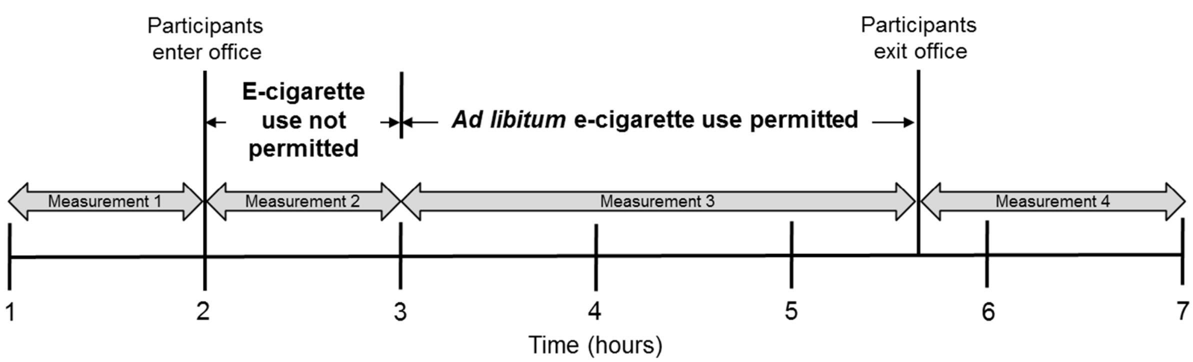

Figure 2. Timeline illustrating when participants entered and exited the office, when e-cigarettes were used and sampling times.

2.2. Analysis of Indoor Air Parameters

2.2.1. Indoor Climate

Carbon dioxide was measured continuously using a non-dispersive infrared detector (Q-Trak IAQ monitor, TSI Inc., Shoreview, MN, USA; limit of detection, 9 mg/m^3). Carbon monoxide was measured continuously using an electro-chemical sensor (Q-Trak IAQ monitor, TSI Inc.; LOD, 1.2 mg/m^3). Ozone was measured continuously using a UV based photometric analyzer (Ozone Analyzer Model 49C; LOD, 0.002 mg/m^3 Thermo Environmental Systems, Franklin, MA, USA). Nitric oxide and nitrogen dioxide were measured continuously using a NO_x Analyzer (Thermo Environmental Systems Model 42C; LOD, 1.25 mg/m^3 for nitric oxide and 1.9 mg/m^3 for nitrogen dioxide). Indoor humidity and temperature were continuously monitored (Q-Trak IAQ monitor, TSI Inc.).

2.2.2. Nicotine

Nicotine was measured in the air by pump sampling maintained at a flow rate of 1 L/min throughout the sampling period through PTFE tubing into XAD2 sorbent tubes (Ref. 226-30-06, SKC Ltd, Dorset, UK). Analysis of exposed tubes was performed by solvent extraction and GC-MS. The LOD for nicotine in air was 7.0 µg/m^3. Travel blanks were also collected and analyzed.

2.2.3. Volatile Organic Compounds (VOCs)

Sampling and analysis of VOCs was carried out according to the ISO 16000-6 international standard [19]. Pump sampling was maintained at a flow rate of 0.15 L/min throughout the sampling period through PTFE tubing. Travel blanks were also collected and analyzed. The total volatile organic compounds (TVOC) concentration, as used in many indoor air quality guidelines, was calculated as the area of all compounds eluting between, and including, hexane and hexadecane. This is quantified as toluene equivalents, and so the TVOC concentration may be less or more than the sum of the individual VOCs reported. The LODs for each individual VOC were in the range 0.5–1.0 µg/m^3.

2.2.4. Glycerol

Glycerol was measured in the air by pump sampling maintained at a flow rate of 1 L/min throughout the sampling period through PTFE tubing into XAD7 sorbent tubes (SKC Ltd Ref. 226-57). Analysis of exposed tubes was performed using a thermodesorption unit coupled to by solvent extraction and GC-MS. The LOD for glycerol in air was 150–350 µg/m^3; this range represents differences in sample durations and therefore sampling volumes. Travel blanks were also collected and analyzed.

2.2.5. Low Molecular Weight Carbonyls

Formaldehyde (methanal), acetaldehyde (ethanal) and acrolein (propenal) were measured in the air by pump sampling maintained at a flow rate of 1.5 L/min throughout the sampling period through PTFE tubing into commercially available purpose-built tubes which contained silica coated with 2,4-dinitrophenyl hydrazine (DNPH). Sampling and analysis of exposed tubes was performed according to ISO 16000-3 international standard [20]. The LOD for carbonyls in air was 2.0 µg/m^3. Travel blanks were also collected and analyzed.

2.2.6. Polycyclic Aromatic Hydrocarbons (PAHs)

The US Environmental Protection Agency (US EPA) ‘priority list’ of 16 PAHs [21] were measured in the air by pump sampling maintained at a flow rate of 2 L/min throughout the sampling period through PTFE tubing into XAD2 sorbent tubes (SKC Ltd Ref. 226-30-06). Analysis of exposed tubes was performed by solvent extraction and high resolution GC-MS. The LOD for each PAH in air was 1.25 µg/m^3. Travel blanks were also collected and analyzed.

2.2.7. Trace Metals

The US EPA "Method 29" metals [22], aluminium and phosphorus were measured in the air by pump sampling operating maintained at a flow rate of 6.5 L/min throughout the sampling period into pre-prepared 25 mm filter assemblies (using mixed cellulose ester "MCE" membrane filters). The filters were acid-extracted by digestion in boiling *aqua regia* and the extract analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The LOD for each metal in air ranged from 1.0 to 2.0 µg/m^3, depending on the metal analyzed. Travel blanks were also collected and analyzed.

2.2.8. Tobacco-Specific Nitrosamines (TSNAs)

TSNAs were measured in the air by pump sampling maintained at a flow rate of 1.5 L/min throughout the sampling period through PTFE tubing into Cambridge filter pads (44 mm diameter) impregnated with potassium bisulphate. Analysis of exposed tubes was performed by solvent extraction and HPLC-MS. The LOD for each TSNA in air was 0.5 µg/m^3. Travel blanks were also collected and analyzed.

2.3. Analysis of Outdoor Air Parameters

Temperature, relative humidity, and levels of ozone and NO_x were also monitored outside the building.

3. Results and Discussion

Across Europe and North America, consumer interest in electronic vapour (e-vapour) products, including e-cigarettes, continues to grow [1]. While there are some parallels between e-vapour products and conventional tobacco products in terms of product conformation and consumer behaviors, the products themselves are radically different in their design, composition, and the resultant inhaled and exhaled aerosol. As such, product standards and other regulatory measures must take account of this although as a comparatively recent product category, the evidence base on which to establish such regulation is still developing. While e-cigarettes do not combust or generate side-stream emissions, there is currently a debate on whether exhaled e-cigarette aerosols pose a potential exposure risk to bystanders akin to that reported for environmental tobacco smoke from conventional tobacco products [2–6]. In designing the present study, the key aims were to conduct a study under realistic conditions and to examine findings reported previously by other researchers.

3.1. Product Use: Puff Rate

From the video footage, the average puff rate across the three e-cigarette users during the 165 min vaping session was calculated to be 3.2 puffs per minute.

3.2. Indoor Climate Parameters

The measured room ventilation rate showed a low level of natural ventilation for the size of the office and number of occupants, with an average air exchange rate of 0.8 air changes per hour. The UK Chartered Institute of Building Services Engineers (CIBSE) recommends a ventilation rate of 1.0 air change per hour [23]. However, this level of ventilation is comparable to that previously reported for living rooms in residential properties [24].

The temperature and relative humidity (RH) in the office over the course of the study were in the ranges 22–28 °C and 43%–57% respectively, with both parameters showing a marked increase as a consequence of the room occupation, as would be expected in a small space with limited natural ventilation and no recourse to cooling. The temperature and RH nevertheless remained within the UK Health and Safety Executive (HSE) ranges for acceptable human comfort in an office space [25].

Carbon monoxide was not detected during any of the test periods (vaping or non-vaping). Carbon dioxide (CO_2) levels increased to a mean level of 5813 mg/m^3 from a background level of 969 mg/m^3 during the non-vaping session, with the concentration peaking at nearly 6800 mg/m^3 during the vaping session. With the windows and door closed, and continuous occupation by five people, this rise in CO_2 concentrations is to be expected from normal respiration. There were small differences in the concentrations of nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3) during the periods of vaping and non-vaping in the meeting room (data not shown). The small variations in the concentrations of these gases were considered to be as a result of the usual changes that occur in the outside atmosphere, which migrate into the building through infiltration.

3.3. Volatile Organic Compounds (VOCs; Including Nicotine, Propylene Glycol and Glycerol) and Low Molecular Weight Carbonyls

Table 1 summarizes the results for VOCs, including nicotine, propylene glycol and glycerol (the three principal components of e-cigarette base liquid) and low molecular weight carbonyls. Nicotine is present in most e-liquids and e-cigarettes, and several studies have investigated its presence in the ambient air following product use. After the generation and release of e-cigarette aerosol using a smoking machine into an exposure chamber, McAuley *et al.* [11] reported airborne nicotine concentrations ranging from 0.725 to 8.77 μg/m^3 following use of rechargeable e-cigarettes with refillable cartomisers containing 24 mg/mL or 26 mg/mL nicotine. Similarly, Czogala *et al.* [12] used three different e-cigarette products containing 16 mg/mL or 18 mg/mL nicotine and found airborne concentrations in an exposure chamber ranging from 0.82 to 6.23 μg/m^3. Both these studies (and others) used a machine approach to simulate the use of e-cigarettes for estimating potential bystander exposures to exhaled e-cigarette aerosol [11,12,26]. Such an approach does not account for consumer behavior nor the retention of nicotine by the e-cigarette user and so is likely to overestimate airborne nicotine concentrations and potential bystander exposures. In a volunteer study conducted by Schober *et al.* [13], it was found that the nicotine concentration in the ambient air ranged from 0.6 to 4.6 μg/m^3 during a 2 h vaping session using a rechargeable e-cigarette with refillable tank ("open" system).

Table 1. Average indoor air concentrations of VOCs (including nicotine, propylene glycol and glycerol (principle components of the e-liquid)) and low molecular weight carbonyls (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room) Measurement 1 (μg/m^3)	Room Occupied (No Vaping) Measurement 2 (μg/m^3)	Room Occupied (Vaping Permitted) Measurement 3 (μg/m^3)	Room Unoccupied (after Participants Leave Room) Measurement 4 (μg/m^3)	Air Quality Guidelines or UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m^3)	Air Quality Guidelines or UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m^3)
Propylene glycol	<0.5	<0.5	203.6	10.2	UK WEL: 474	474,000
Glycerol	<150	<225	<250	<200	UK WEL: 10	10,000
Nicotine	<7.0	<7.0	<7.0	<7.0	UK WEL: 0.5	500
Isoprene	<0.5	6.2	9.5	<0.5	Not established	Not established
Acetone	1.3	9.2	10.7	1.2	UK WEL: 1210	1,210,000
Propan-2-ol	55.3	13.6	8.0	29.2	UK WEL: 999	999,000
Hexamethylenecyclotri-siloxane	5.3	29.1	13.3	4.4	Not established	Not established
Octamethylcyclotetra-siloxane	<0.5	14.2	3.6	0.9	Not established	Not established
Limonene	2.2	2.1	2.9	1.5	Not established	Not established
Octanal	2.1	3.5	5.4	4.6	Not established	Not established
Decamethylcyclo-pentanesiloxane	6.3	307	460.8	107.5	Not established	Not established
Nonanal	6.3	7.9	10.6	11.0	Not established	Not established
Decanal	2.8	5.7	9.5	11.6	Not established	Not established
2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate	7.7	16.1	17.3	18.0	Not established	Not established

Table 1. *Cont.*

Chemical Compound	**Background (before Participants Enter Room)**	**Room Occupied (No Vaping)**	**Room Occupied (Vaping Permitted)**	**Room Unoccupied (after Participants Leave Room)**	**Air Quality Guidelines or UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m³)**	**Air Quality Guidelines or UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m³)**
	Measurement 1 (μg/m³)	**Measurement 2 (μg/m³)**	**Measurement 3 (μg/m³)**	**Measurement 4 (μg/m³)**		
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	<0.5	<0.5	1.5	2.2	Not established	Not established
Di-isobutyl phthalate	3.5	4.4	2.3	2.8	UK WEL: 5	5000
Formaldehyde	32.0	31.0	37.6	21.0	WHO: 0.1	100
Acetaldehyde	9.0	6.5	12.4	6.0	EU Indoor Air Quality: 0.2	200
Acrolein	<2.0	<2.0	<2.0	<2.0	UK WEL: 0.23	230
Total VOC	65.0	237.0	379.8	129.0	UK Building Regulations: 0.3 (8 h average)	300

* converted to μg/m³ to facilitate comparison with analytical findings in this study.

These levels are in general agreement with the theoretical maximum level determined in a recent publication which used a mathematical model to assess the concentration of nicotine in the indoor air following e-cigarette use [27]. However in our volunteer study presented here, there was no measurable increase in nicotine airborne concentrations with vaping when compared with either the no vaping control session or background measurements *i.e.*, all measurements were found to be <7.0 μg/m^3. By way of context, the published UK WEL for nicotine is 500 μg/m^3 [28]. The low level measured in this study may be attributable to the high retention rate of nicotine in the body, which has previously been reported following inhalation of tobacco smoke [29], as well as some potential loss by deposition [30]. Further research in these areas will be informative.

Propylene glycol and glycerol are principal components of e-liquids and their presence in exhaled e-cigarette aerosol is expected. Concentrations of propylene glycol in the range of 110–215 μg/m^3 and glycerol in the range of 59–81 μg/m^3 in the gas phase of emissions have been reported previously [13]. In other studies, McAuley *et al.* [11] observed airborne concentrations of propylene glycol that ranged from 2.25 to 120 μg/m^3 and Romagna *et al.* [15] reported airborne glycerol concentrations of 72 μg/m^3.

In our study, during *ad libitum* use of the 'closed' system e-cigarettes, propylene glycol in the air of the meeting room increased from <0.5 μg/m^3 during the no vaping control session to 203.6 μg/m^3 during vaping. At the end of the vaping session, there was a substantial and rapid decrease in the levels detected (down to 10.2 μg/m^3). The levels of propylene glycol determined within our study design were below the UK WEL of 474,000 μg/m^3 set for this chemical [28]. Glycerol, while also expected to be present in the indoor air during the vaping session, could not be detected with satisfactory precision due to the limit of detection (LOD) for this compound (<350 μg/m^3). Further methodological refinement is required in future work. Nonetheless, it can be established that glycerol in the indoor air did not exceed 350 μg/m^3 during consumption of the e-cigarettes which is below the UK WEL of 10,000 μg/m^3 set for this chemical [28].

Total volatile organic compounds (TVOCs) is an analytically based classification for a range of organic chemical compounds present in ambient air or emissions and is used for reporting purposes. In evaluating TVOCs, consideration of the individual compounds is also necessary (Table 1). The background concentration of TVOCs observed in the meeting room ambient air in our study rose from 65 μg/m^3 to 237 μg/m^3 upon occupation of the room. While not components of e-liquids, this increase was likely due to the contribution of siloxane compounds arising from the five volunteers. It is well known that siloxanes are widely used in toiletries, deodorants and other personal care products [31]; with increasing room temperature during the study session, release of these and other cosmetic components would likely to have increased. A number of other commonly used aroma compounds (e.g., octanal, nonanal) were also detected at lower levels during the study period. During the vaping phase the TVOC concentrations rose to 379.8 μg/m^3, conceivably due to further release of siloxanes and exhalation of propylene glycol from the active consumption of the e-cigarettes (see above). Following participant exit from the office, the TVOC concentrations returned to pre-vaping levels. While a WEL has not been established, UK Building Regulations recommend an 8 h average TVOC level of 300 μg/m^3 [32].

Previous studies have detected the presence of the low molecular weight carbonyls formaldehyde and acetaldehyde in exhaled e-cigarette aerosols [10,13]. It has been reported that potential sources of these compounds in e-cigarette aerosol may arise from the heating or pyrolysis of propylene glycol [33].

Schripp *et al.* [10] evaluated emissions from e-cigarettes after asking a volunteer user to consume three different refillable "open" e-cigarette devices in a closed 8 m^3 chamber. The authors reported formaldehyde and acetaldehyde in the air of the chamber albeit at significantly lower levels than emissions from a conventional cigarette. Schripp *et al.* [10] concluded that the presence of formaldehyde in the ambient air may be explained by human contamination and not from e-cigarette emissions; it has been previously reported that low amounts of both formaldehyde and acetaldehyde of endogenous origin can be detected in exhaled breath [34]. In addition, it is widely reported that formaldehyde is released from some furniture and fittings, an effect which increases with room temperature and humidity [35]. Taken as a whole, this highlights the importance of appropriate control sampling during air quality studies.

In our study, using a 38.5 m^3 environment, we observed slight changes in formaldehyde levels from an empty meeting room background value of 32.0 μg/m^3, to 31.0 μg/m^3 with occupancy, to 37.6 μg/m^3 during e-cigarette use. The level fell rapidly to 21.0 μg/m^3 following vacation of the office by study participants. The WHO has established a guideline indoor air value of 100 μg/m^3 for formaldehyde [36]. While indicated as a short-term (30 min) guideline to prevent sensitivity or sensitization in both adults and children, WHO has stated that this value is sufficient to prevent long-term health effects, including cancer, since two distinct long term risk assessment models in the review arrived at proposed guideline values of around 210 and 250 μg/m^3 [36]. The levels of formaldehyde determined within our study design were below WHO Indoor Air Quality guideline value of 100 μg/m^3 set for this chemical and comparable to range of values typically found in domestic or public spaces [36,37]. Schripp *et al.* [10] and Schober *et al.* [13] both reported formaldehyde levels below the WHO Indoor Air Quality Guideline.

When compared with the non-vaping session, we found acetaldehyde levels changed from a background of 9.0 μg/m^3 to 6.5 μg/m^3 after occupation to 12.4 μg/m^3 during the vaping session. These values and those reported by Schripp *et al.* [10] and Schober *et al.* [13] were well within the EU Indoor Air Quality guideline for acetaldehyde which is set at 200 μg/m^3 [38].

A further finding in our study was the absence of a measurable increase in acrolein, the pyrolysis product of glycerol [33], in the office air with use of e-cigarettes when compared to control measurements (<2.0 μg/m^3). This finding is consistent with those findings from Romagna *et al.* [15], who did not detect acrolein in air quality measurements in a 60 m^3 room during *ad libitum* use of e-cigarettes.

By way of context, it has been reported by the US Environmental Protection Agency (EPA) and others that the burning of candles indoors resulted in a measureable increase of benzene, toluene, formaldehyde, acetaldehyde and acrolein [39]. In air quality measurement studies following their use, formaldehyde levels in the air ranged from 1.0–323.5 μg/m^3 and acetaldehyde from 1.0 to 74.95 μg/m^3; reported levels of these two carbonyls measured in our study were substantially less than the maximal values in these studies [9].

For acetone and isoprene, both exhaled breath components [40], there was an increase from baseline during the occupied non-vaping session and active vaping sessions. Isoprene increased from a baseline measurement of <0.5 μg/m^3 to 6.2 μg/m^3 during room occupation to 9.5 μg/m^3 during active vaping.

Acetone increased from a baseline measurement of 1.3 µg/m^3 to 9.2 µg/m^3 during room occupation to 10.7 µg/m^3 during active vaping. Following participant exit from the room, the concentrations of both compounds returned to background levels. This indicates that the occupants were the primary source of isoprene and acetone. A UK WEL has not been established for isoprene; acetone levels in all measurements were substantially lower than the UK WEL which is currently 1,210,000 µg/m^3 [28].

3.4. Polycyclic Aromatic Hydrocarbons (PAHs)

Table 2 summarizes the results for the PAHs. Schober *et al.* [13] recently reported airborne concentrations of PAHs increased following e-cigarette use by volunteers, but were still substantially lower than the USA Occupational Safety and Health Administration's (OSHA) Permissible Exposure Level (PEL) for PAHs in the workplace of 200 µg/m^3 [41]. In a commentary on this work, Farsalinos and Voudris [42] noted several study limitations including measuring baseline values on different days from the vaping sessions thus changes in airborne PAHs levels may reflect variations in environmental PAH levels and not e-cigarette use. In our study, there was no measurable increase in the airborne concentration of any of the US EPA 'priority list' of 16 PAHs during the vaping period (all <1.25 µg/m^3), which includes seven PAHs classified as probable carcinogens by International Agency for Research on Cancer (IARC) [43,44]. Differences between the current work presented here and the low levels detected by Schober *et al.* [13] may reflect differences in the sensitivity of the methodologies employed, study design and/or differences between products used in the respective studies.

Table 2. Average indoor air concentrations of US EPA "priority list" of 16 PAHs (µg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room Occupied (Vaping Permitted)	Room Unoccupied (after Participants Leave Room)
	Measurement 1 (µg/m^3)	Measurement 2 (µg/m^3)	Measurement 3 (µg/m^3)	Measurement 4 (µg/m^3)
Acenaphthene	<1.25	<1.25	<1.25	<1.25
Acenaphthylene	<1.25	<1.25	<1.25	<1.25
Anthracene	<1.25	<1.25	<1.25	<1.25
Benz[a]anthracene	<1.25	<1.25	<1.25	<1.25
Benzo[b]fluoranthene	<1.25	<1.25	<1.25	<1.25
Benzo[k]fluoranthene	<1.25	<1.25	<1.25	<1.25
Benzo[ghi]perylene	<1.25	<1.25	<1.25	<1.25
Benzo[a]pyrene	<1.25	<1.25	<1.25	<1.25
Chrysene	<1.25	<1.25	<1.25	<1.25
Dibenz[ah]anthracene	<1.25	<1.25	<1.25	<1.25
Fluoranthene	<1.25	<1.25	<1.25	<1.25
Fluorene	<1.25	<1.25	<1.25	<1.25
Indeno[1,2,3-cd]pyrene	<1.25	<1.25	<1.25	<1.25
Naphthalene	<1.25	<1.25	<1.25	<1.25
Phenanthrene	<1.25	<1.25	<1.25	<1.25
Pyrene	<1.25	<1.25	<1.25	<1.25

3.5. Trace Metals

Table 3 summarizes the results for trace metals. It has been previously reported in the literature that e-cigarette use may result in the release of metal particles into the ambient air [13,45]. Schober *et al.* [13] reported that levels of aluminium in the ambient air increased 2.4-fold following e-cigarette use. Under the conditions employed in our study, there was no measurable increase in any of the USA "EPA Method 29" metals [22] as well as aluminium and phosphorus during the vaping period compared with the no-vaping control session and background levels. Measurements were all <1.0 μg/m^3 for antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc; <2.0 μg/m^3 for aluminium, beryllium, silver and thallium, and <10 μg/m^3 for phosphorus. Where established for those metals analyzed, all were below UK WELs as shown in Table 4 [28]. Again, the differences in these findings compared to the Schober *et al.* [13] study may be due to differences in the methods employed and/or the design and manufacture processes of the e-cigarette devices used in the respective studies.

Table 3. Average indoor air concentrations of US "EPA Method 29" metals (plus aluminium and phosphorous) (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room occupied (Vaping Permitted)	Room unoccupied (after Participants Leave Room)	UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m^3)	UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m^3)
	Measurement 1 (μg/m^3)	Measurement 2 (μg/m^3)	Measurement 3 (μg/m^3)	Measurement 4 (μg/m^3)		
Aluminium	<2.0	<2.0	<2.0	<2.0	10	10,000
Antimony	<1.0	<1.0	<1.0	<1.0	0.5	500
Arsenic	<1.0	<1.0	<1.0	<1.0	0.1	100
Barium	<1.0	<1.0	<1.0	<1.0	0.5	500
Beryllium	<2.0	<2.0	<2.0	<2.0	0.002	2.0
Cadmium	<1.0	<1.0	<1.0	<1.0	0.025	25
Chromium	<1.0	<1.0	<1.0	<1.0	0.5	500
Cobalt	<1.0	<1.0	<1.0	<1.0	0.1	100
Copper	<1.0	<1.0	<1.0	<1.0	1	1000
Lead	<1.0	<1.0	<1.0	<1.0	Not established	Not established
Manganese	<1.0	<1.0	<1.0	<1.0	0.5	500
Mercury	<1.0	<1.0	<1.0	<1.0	0.02	20
Nickel	<1.0	<1.0	<1.0	<1.0	0.1	100
Phosphorus	<10.0	<10.0	<10.0	<10.0	Not established	Not established
Selenium	<1.0	<1.0	<1.0	<1.0	0.1	100
Silver	<2.0	<2.0	<2.0	<2.0	0.1	100
Thallium	<2.0	<2.0	<2.0	<2.0	0.1	100
Zinc	<1.0	<1.0	<1.0	<1.0	Not established	Not established

* converted to μg/m^3 to facilitate comparison with analytical findings in this study.

3.6. Tobacco-Specific Nitrosamines (TSNAs)

Table 4 summarizes the results for TSNAs. Previous studies have reported the presence of TSNAs in the e-liquid or mainstream e-cigarette aerosols [46]. In our study, we sampled the ambient air for the presence of *N*'-nitrosonornicotine (NNN), 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK), *N*'-nitrosoanatabine (NAT) and *N*'-nitrosoanabasine (NAB). There was no measurable increase in the airborne concentrations of the four TSNAs analysed during active consumption of e-cigarettes when compared to control measurements (all < 0.5 μg/m^3).

Table 4. Average indoor air concentrations of TSNAs (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	**Background (before Participants Enter Room)**	**Room Occupied (No Vaping)**	**Room Occupied (Vaping Permitted)**	**Room Unoccupied (after Participants Leave Room)**
	Measurement 1 (μg/m^3)	**Measurement 2 (μg/m^3)**	**Measurement 3 (μg/m^3)**	**Measurement 4 (μg/m^3)**
N'-Nitrosonornicotine (NNN)	<0.5	<0.5	<0.5	<0.5
4-(Methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)	<0.5	<0.5	<0.5	<0.5
N'-Nitrosoanatabine (NAT)	<0.5	<0.5	<0.5	<0.5
N'-Nitrosoanabasine (NAB)	<0.5	<0.5	<0.5	<0.5

3.7. Study Limitations and Strengths

The key aim of our study design was to replicate a real-life scenario with unrestricted use of a disposable "closed" system product by the vaping volunteers. In doing so, overhead sampling of the ambient air was chosen rather than personal dosimetry approaches to reduce potential confounding of vaping behaviors from intrusive sampling.

Our use of volunteers in conditions designed to replicate those in a real-world situation limited the sample duration and therefore the sensitivity of the some of the methods employed, which were not as sensitive as in some other studies which used a machine generated aerosol. Arguably, if the presence of certain chemicals can only be detected by employment of artificial or atypical conditions, it is reasonable to question the appropriateness of such data. The use of consumers within the study removed many of the issues associated with the use of smoking machine generated aerosols, for example questions around the potential retention of chemicals in the body or that of different machine protocols not replicating product consumption profiles. With regards to the method to measure glycerol in our study, sensitivity was not as low as anticipated. While there could be some scope for reducing the LODs for these and other chemicals further by increasing sampling duration, this would be difficult without introducing other potential confounding factors such as opening and closing meeting doors for refreshment breaks. By excluding opening and closing doors in this study, and by limiting the air exchange to natural room ventilations, the levels reported in our study are likely to represent an overestimate of normal conditions. The measurement of air exchange and other environmental parameter measurements in the methodology are supportive of this.

Another limitation in this study was the use of a single product; as noted above, other research groups have reported findings that were not replicated in this present study. Such studies used different products which may reflect variations in e-liquid or device quality, sufficient details of which are often not reported. Additionally, given the focus on ambient air, the primary emissions of the analyzed product were not determined in this study, which may be of interest in future work focusing on consumer rather than bystander exposures. Further air quality studies could also investigate other product types as well as different settings and volunteer groups.

The potential issue of cross contamination with cigarette smoke has been noted previously [2]. Given the sensitivity of the methods employed in this study, potential confounding from recent tobacco smoking was minimized. A strength of this study was that the rooms used here had never been smoked in nor were they used for any prior tobacco research.

4. Conclusions

The present study offers an indoor air quality assessment by an independent, UKAS accredited laboratory following use of a disposable 'closed' system e-cigarette in a real life setting. Since this was not a long-term repeated exposure study; in providing a context, findings were related to indoor air quality guidelines, where available. Our data indicate that exposure of bystanders to the chemicals in the exhaled e-cigarette aerosol, at the levels measured within our study, are below current regulatory standards that are used for workplaces or general indoor air quality. This finding supports the conclusions of other researchers that have stated there is no apparent risk to bystanders from exhaled e-cigarette aerosols [6,11,47].

There has been conflicting and at times confusing information reported regarding the potential risks of bystanders and non-e-cigarette users to exhaled e-cigarette aerosol. The regulatory outlook from a public health perspective currently remains undetermined; there is a clear need for further research in this area to support the development of appropriate product standards and other science-based regulatory measures.

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Author Contributions

All authors conceived and designed the experiment. All authors analyzed and interpreted the data. Grant O'Connell and John D. Pritchard wrote the manuscript. All authors contributed to the manuscript and approved the final version.

Conflicts of Interest

All authors are employees of Imperial Tobacco Group. The work in this manuscript was supported by Imperial Tobacco Group. Imperial Tobacco Group is the parent company of Fontem Ventures B.V., the manufacturer of the e-cigarette products used in this study.

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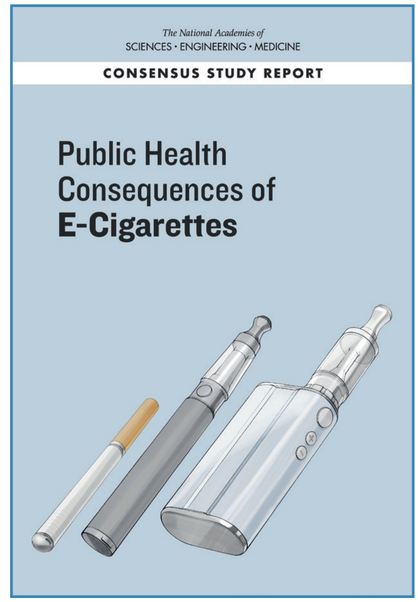
Consensus Study Report

January 2018

HIGHLIGHTS

Public Health Consequences of E-Cigarettes



Millions of Americans use electronic cigarettes (e-cigarettes). Young people especially, age 17 and under, have quickly taken up their use: Substantially more young people use e-cigarettes than any other tobacco product, including traditional combustible tobacco cigarettes.

Despite their popularity, little is known about the health effects of e-cigarettes. Perceptions of potential risks and benefits of e-cigarette use vary widely among the public, users of the products, health care providers, and the public health community.

With support from the Center for Tobacco Products of the Food and Drug Administration (FDA), the National Academies of Sciences, Engineering, and Medicine convened an expert committee to conduct a critical, objective review of the scientific evidence about e-cigarettes and health. The resulting report, *Public Health Consequences of E-Cigarettes,* provides an overview of the evidence, recommends ways to improve the research, and highlights gaps that are priority focus areas for future work.

As part of its work, the committee conducted a comprehensive, in-depth review of the scientific literature around e-cigarettes, including key constituents in e-cigarettes, human health effects, initiation and cessation of combustible tobacco cigarette use, and harm reduction. The committee considered the quality of individual studies and the totality of the evidence to provide 47 structured, consistent conclusions on the strength of the evidence (categorized as conclusive, substantial, moderate, limited, insufficient, and no evidence—all defined on the next page).

CONSTITUENTS OF E-CIGARETTES

E-cigarettes contain liquids (called e-liquids), which typically contain nicotine, flavorings, and humectants (to retain moisture).

With respect to nicotine, conclusive evidence shows that exposure to nicotine from e-cigarettes is highly variable. It depends on characteristics of the products, including those of the device and e-liquids, as well as how the device is operated. Substantial evidence also shows that among experienced adult e-cigarette users, exposure to nicotine can be comparable to that from combustible tobacco cigarettes.

Most of the flavorings used in e-cigarettes are generally regarded as safe by the FDA, although these designations relate to oral consumption (flavorings used in food), and most have not been studied for safety when inhaled with an e-cigarette.

The primary humectants are propylene glycol and glycerol (also known as vegetable glycerin). Similar to flavorings, they are generally regarded as safe for ingestion, but less is known about their health effects when inhaled.

Overall, e-cigarette aerosol contains fewer numbers and lower levels of toxicants than smoke from combustible tobacco cigarettes. Nicotine exposure can mimic that found with use of combustible tobacco cigarettes, but it is highly variable. The exposure to nicotine and toxicants from the aerosolization of flavorings and humectants depends on device characteristics and how the device is used.

HEALTH EFFECTS OF E-CIGARETTES

Because e-cigarettes have only been on the U.S. market for a relatively brief time—first imported in 2006, most have entered the market much more recently—it is difficult to scientifically compare their health effects to those of combustible tobacco cigarettes, whose health effects were not fully apreciated until after decades of use. However, in contrast to long-term effects, research on short-term health effects of e-cigarettes is now available.

The committee evaluated the current state of knowledge on outcomes including dependence and abuse liability, cardiovascular diseases, cancers, respiratory diseases, oral diseases, reproductive and developmental effects, and injuries and poisonings.

Overall, the evidence reviewed by the committee suggests that e-cigarettes are not without biological effects in humans. For instance, use of e-cigarettes results in dependence on the devices, though with apparently less risk and severity than that of combustible tobacco cigarettes. Yet the implications for long-term effects on morbidity and mortality are not yet clear.

To see the full text of the committee's conclusions organized by levels of evidence and outcome, visit **nationalacademies.org/eCigHealthEffects.**

Levels of Evidence for Conclusions

Conclusive evidence: There are many supportive findings from good-quality controlled studies (including randomized and non-randomized controlled trials) with no credible opposing findings. A firm conclusion can be made, and the limitations to the evidence, including chance, bias, and confounding factors, can be ruled out with reasonable confidence.

Substantial evidence: There are several supportive findings from good-quality observational studies or controlled trials with few or no credible opposing findings. A firm conclusion can be made, but minor limitations, including chance, bias, and confounding factors, cannot be ruled out with reasonable confidence.

Moderate evidence: There are several supportive findings from fair-quality studies with few or no credible opposing findings. A general conclusion can be made, but limitations, including chance, bias, and confounding factors, cannot be ruled out with reasonable confidence.

Limited evidence: There are supportive findings from fair-quality studies or mixed findings with most favoring one conclusion. A conclusion can be made, but there is significant uncertainty due to chance, bias, and confounding factors.

Insufficient evidence: There are mixed findings or a single poor study. No conclusion can be made because of substantial uncertainty due to chance, bias, and confounding factors.

No available evidence: There are no available studies; health endpoint has not been studied at all. No conclusion can be made.

The net public health outcome of e-cigarette use depends on the balance between positive and negative consequences.

E-CIGARETTES AND HARM REDUCTION

FDA regulations require that tobacco products introduced to the U.S. market over the past decade must show a net public health benefit. In considering this public health effect, a product must pose less risk to users than combustible tobacco cigarettes. Additionally, if a product caused more people to start harmful tobacco use, or caused fewer people to quit tobacco use, a product would be kept off the market. So separate from the health effects of e-cigarettes, the tobacco control field must pay close attention to the effects of e-cigarettes on starting and quitting combustible tobacco products.

For youth and young adults, there is substantial evidence that e-cigarette use increases the risk of ever using combustible tobacco cigarettes. For e-cigarette users who have also ever used combustible tobacco cigarettes, there is moderate evidence that e-cigarette use increases the frequency and intensity of subsequent combustible tobacco cigarette smoking.

There is insufficient evidence from randomized controlled trials about the effectiveness of e-cigarettes as cessation aids compared to no treatment or to FDA-approved smoking cessation treatments. While the overall evidence from observational trials is mixed, there is moderate evidence from observational studies that more frequent use of e-cigarettes is associated with increased likelihood of cessation.

Overall, the evidence suggests that while e-cigarettes might cause youth who use them to transition to use of combustible tobacco products, they might also increase adult cessation of combustible tobacco cigarettes.

Completely substituting e-cigarettes for combustible tobacco cigarettes conclusively reduces a person's exposure to many toxicants and carcinogens present in combustible tobacco cigarettes and may result in reduced adverse health outcomes in several organ systems. **Across a range of studies and outcomes, e-cigarettes appear to pose less risk to an individual than combustible tobacco cigarettes.**

To examine the possible effects of e-cigarette use at the population level, the committee used population dynamic modeling. Under the assumption that using e-cigarettes increases the net cessation rate of combustible tobacco cigarettes among adults, the modeling projects that in the short run, use of these products will generate a net public health benefit, despite the increased use of combustible tobacco products by young people. Yet in the long term (for instance, 50 years out), the public health benefit is substantially less and is even negative under some scenarios. If the products do not increase combustible tobacco cessation in adults, then with the range of assumptions the committee used, the model projects that there would be net public health harm in the short and long terms.

RESEARCH RECOMMENDATIONS

There is a great need for more evidence around the new field of e-cigarettes; research with both long- and short-term horizons is required.

The committee identified gaps in the literature in every aspect in its work and provides overarching categories of research needs and specific research suggestions within the final chapters of each of the three major sections of the report. These overarching categories include: (1) addressing gaps in substantive knowledge and (2) improving research methods and quality through protocol and methods validation and development, including the use of appropriate study design.

To download a copy of the report and read the full text of the committee's recommendations, please visit **nationalacademies.org/eCigHealthEffects.**

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CONCLUSION

Although e-cigarettes are not without risk, compared to combustible tobacco cigarettes they contain fewer toxicants; can deliver nicotine in a similar manner; show significantly less biological activity in most, but not all, in vitro, animal, and human systems; and might be useful as a cessation aid in smokers who use e-cigarettes exclusively. However, young people who begin with e-cigarettes are more likely to transition to combustible cigarette use and become smokers who are at risk to suffer the known health burdens of combustible tobacco cigarettes. The net public health outcome of e-cigarette use depends on the balance between positive and negative consequences.

More and better research is needed to help clarify whether e-cigarettes will prove to reduce harm—or induce harm—at the individual and the population levels. The approach taken by the committee to evaluate the health effects of e-cigarettes in this report is anticipated to provide a generalizable template for future evaluations of the evidence.

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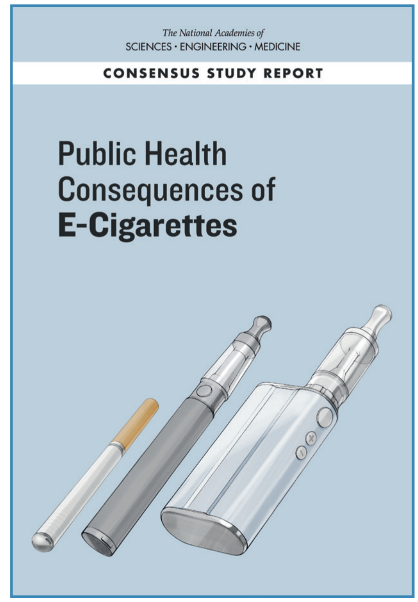
10. Public Health Consequences of E-Cigarettes

Consensus Study Report

HIGHLIGHTS

January 2018

Public Health Consequences of E-Cigarettes



Millions of Americans use electronic cigarettes (e-cigarettes). Young people especially, age 17 and under, have quickly taken up their use: Substantially more young people use e-cigarettes than any other tobacco product, including traditional combustible tobacco cigarettes.

Despite their popularity, little is known about the health effects of e-cigarettes. Perceptions of potential risks and benefits of e-cigarette use vary widely among the public, users of the products, health care providers, and the public health community.

With support from the Center for Tobacco Products of the Food and Drug Administration (FDA), the National Academies of Sciences, Engineering, and Medicine convened an expert committee to conduct a critical, objective review of the scientific evidence about e-cigarettes and health. The resulting report, *Public Health Consequences of E-Cigarettes,* provides an overview of the evidence, recommends ways to improve the research, and highlights gaps that are priority focus areas for future work.

As part of its work, the committee conducted a comprehensive, in-depth review of the scientific literature around e-cigarettes, including key constituents in e-cigarettes, human health effects, initiation and cessation of combustible tobacco cigarette use, and harm reduction. The committee considered the quality of individual studies and the totality of the evidence to provide 47 structured, consistent conclusions on the strength of the evidence (categorized as conclusive, substantial, moderate, limited, insufficient, and no evidence—all defined on the next page).

CONSTITUENTS OF E-CIGARETTES

E-cigarettes contain liquids (called e-liquids), which typically contain nicotine, flavorings, and humectants (to retain moisture).

With respect to nicotine, conclusive evidence shows that exposure to nicotine from e-cigarettes is highly variable. It depends on characteristics of the products, including those of the device and e-liquids, as well as how the device is operated. Substantial evidence also shows that among experienced adult e-cigarette users, exposure to nicotine can be comparable to that from combustible tobacco cigarettes.

Most of the flavorings used in e-cigarettes are generally regarded as safe by the FDA, although these designations relate to oral consumption (flavorings used in food), and most have not been studied for safety when inhaled with an e-cigarette.

The primary humectants are propylene glycol and glycerol (also known as vegetable glycerin). Similar to flavorings, they are generally regarded as safe for ingestion, but less is known about their health effects when inhaled.

Overall, e-cigarette aerosol contains fewer numbers and lower levels of toxicants than smoke from combustible tobacco cigarettes. Nicotine exposure can mimic that found with use of combustible tobacco cigarettes, but it is highly variable. The exposure to nicotine and toxicants from the aerosolization of flavorings and humectants depends on device characteristics and how the device is used.

HEALTH EFFECTS OF E-CIGARETTES

Because e-cigarettes have only been on the U.S. market for a relatively brief time—first imported in 2006, most have entered the market much more recently—it is difficult to scientifically compare their health effects to those of combustible tobacco cigarettes, whose health effects were not fully apreciated until after decades of use. However, in contrast to long-term effects, research on short-term health effects of e-cigarettes is now available.

The committee evaluated the current state of knowledge on outcomes including dependence and abuse liability, cardiovascular diseases, cancers, respiratory diseases, oral diseases, reproductive and developmental effects, and injuries and poisonings.

Overall, the evidence reviewed by the committee suggests that e-cigarettes are not without biological effects in humans. For instance, use of e-cigarettes results in dependence on the devices, though with apparently less risk and severity than that of combustible tobacco cigarettes. Yet the implications for long-term effects on morbidity and mortality are not yet clear.

To see the full text of the committee's conclusions organized by levels of evidence and outcome, visit **nationalacademies.org/eCigHealthEffects.**

Levels of Evidence for Conclusions

Conclusive evidence: There are many supportive findings from good-quality controlled studies (including randomized and non-randomized controlled trials) with no credible opposing findings. A firm conclusion can be made, and the limitations to the evidence, including chance, bias, and confounding factors, can be ruled out with reasonable confidence.

Substantial evidence: There are several supportive findings from good-quality observational studies or controlled trials with few or no credible opposing findings. A firm conclusion can be made, but minor limitations, including chance, bias, and confounding factors, cannot be ruled out with reasonable confidence.

Moderate evidence: There are several supportive findings from fair-quality studies with few or no credible opposing findings. A general conclusion can be made, but limitations, including chance, bias, and confounding factors, cannot be ruled out with reasonable confidence.

Limited evidence: There are supportive findings from fair-quality studies or mixed findings with most favoring one conclusion. A conclusion can be made, but there is significant uncertainty due to chance, bias, and confounding factors.

Insufficient evidence: There are mixed findings or a single poor study. No conclusion can be made because of substantial uncertainty due to chance, bias, and confounding factors.

No available evidence: There are no available studies; health endpoint has not been studied at all. No conclusion can be made.

The net public health outcome of e-cigarette use depends on the balance between positive and negative consequences.

E-CIGARETTES AND HARM REDUCTION

FDA regulations require that tobacco products introduced to the U.S. market over the past decade must show a net public health benefit. In considering this public health effect, a product must pose less risk to users than combustible tobacco cigarettes. Additionally, if a product caused more people to start harmful tobacco use, or caused fewer people to quit tobacco use, a product would be kept off the market. So separate from the health effects of e-cigarettes, the tobacco control field must pay close attention to the effects of e-cigarettes on starting and quitting combustible tobacco products.

For youth and young adults, there is substantial evidence that e-cigarette use increases the risk of ever using combustible tobacco cigarettes. For e-cigarette users who have also ever used combustible tobacco cigarettes, there is moderate evidence that e-cigarette use increases the frequency and intensity of subsequent combustible tobacco cigarette smoking.

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11. Tobacco Harm Reduction Maryland Profile

Policy Tip Sheet

POLICY ANALYSIS FROM THE HEARTLAND INSTITUTE

Tobacco Harm Reduction 101: Maryland

Since their introduction to the U.S. market in 2007, e-cigarettes and vaping devices—tobacco harm reduction products that are 95 percent safer than combustible cigarettes—have helped more than three million American adults quit smoking.

1. Economic Impact

According to the Vapor Technology Association, in 2018, the industry created 1,243 direct vaping-related jobs, including manufacturing, retail, and wholesale jobs in Maryland, which generated $54 million in wages alone.[1] Moreover, the industry has created hundreds of secondary jobs in the Old Line State, bringing the total economic impact in 2018 to $389,390,600. In the same year, Maryland received more than $31 million in state taxes attributable to the vaping industry. These figures do not include sales in convenience stores, which sell vapor products including disposables and prefilled cartridges. In 2016, sales of these products in Maryland eclipsed $10 million.[2]

2. State Health Department Data

As of December 24, 2019, the Maryland Department of Health (MDH) has reported 57 cases of vaping-related lung illnesses. Although other state health departments have provided additional patient information—including age, gender, and substances vaped—MDH has only reported the total number of cases, but did note that vitamin E acetate had been found in the lung fluid of three Maryland patients. Vitamin E acetate has been linked to vaping products containing tetrahydrocannabinol (THC). ***The Heartland Institute gives MDH a grade of D for information available on vaping-related lung illnesses.***

3. More Information Needed

The most recent report on youth e-cigarette use in Maryland is from the 2017 Maryland Youth Risk Behavior Survey.[3] In 2017, 35.3 percent of Maryland high school students reported using a vapor product on at least one occasion in the 30 days prior to the survey. Only 1.5 percent of Maryland high school students reported daily e-cigarette use. More data is needed to understand the effects of public health campaigns on youth e-cigarette use.

4. Youth Sales Miniscule

From January 1, 2018 to September 30, 2019, the U.S. Food and Drug Administration (FDA) administered 4,063 tobacco age compliance inspections in Maryland, in which the agency used a minor in an attempt to purchase tobacco products.[4] Of those, 782, or 19 percent, resulted in a sale to a minor. Of the violations, 182 (23 percent of violations and 4 percent of all compliance checks) involved the sale of e-cigarettes or vaping devices. The number of violations involving sales of cigars and cigarettes were 217 and 375, respectively, during the same period.

5. Misspent Money

In 2019, Maryland received an estimated $525 million in tobacco taxes and tobacco settlement payments. In the same year, the state spent only $10.5 million, or 2 percent, on funding tobacco control programs, including education and prevention.[5]

Policy Solution

Electronic cigarettes and vaping devices have proven to be tremendous tobacco harm reduction tools, helping many smokers transition away from combustible cigarettes. Despite recent fearmongering, their use is significantly safer than traditional cigarettes, as noted by numerous public health groups including the Royal College of Physicians,[6] Public Health England,[7] and the American Cancer Society.[8] Rather than restricting their use, and undoubtedly reducing public health gains and millions of dollars in economic output, lawmakers should dedicate existing tobacco funds on programs that actually reduce youth use.

Key Points

1. Maryland's vaping industry provided more than $389 million in economic activity in 2018 while generating 1,243 direct vaping-related jobs. Sales of disposables and prefilled cartridges in Maryland exceeded $10 million in 2016.
2. As of December 24, 2019, MDH has reported 57 cases of vaping-related lung illness. MDH reports do not offer details on age, gender, or substances vaped. MDH earns a **D** for its reporting on vaping-related lung illnesses.
3. In 2017, only 1.5 percent of Maryland high school students reported using vapor products daily. More data is needed.
4. Only 4 percent of FDA retail compliance checks in Maryland resulted in sales of e-cigarettes to minors from January 1, 2018 to September 30, 2019.
5. Maryland spends very little on tobacco prevention. In 2019, Maryland dedicated only $10.5 million on tobacco control, or 2 percent of what the state received in tobacco settlement payments and taxes.

Notes

Tobacco Harm Reduction 101: Maryland

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For More Information, please refer to:

Tobacco Harm Reduction 101: A Guidebook for Policymakers
https://www.heartland.org/publications-resources/publications/latest-heartland-policy-booklet-addresses-vaping-myths
This booklet from The Heartland Institute aims to inform key stakeholders on the much-needed information on the benefits of electronic cigarettes and vaping devices. *Tobacco Harm Reduction 101* details the history of e-cigarettes, including regulatory actions on these products. The booklet also explains the role of nicotine, addresses tax policy and debunks many of the myths associated with e-cigarettes, including assertions about "popcorn lung," formaldehyde, and the so-called youth vaping epidemic.

12. Health Impact Of E-Cigarettes

SCIENTIFIC REPORTS

OPEN

Health impact of E-cigarettes: a prospective 3.5-year study of regular daily users who have never smoked

Received: 16 June 2017
Accepted: 3 October 2017
Published online: 17 November 2017

Riccardo Polosa[1,2,3], Fabio Cibella[4], Pasquale Caponnetto[1,3], Marilena Maglia[1,3], Umberto Prosperini[5], Cristina Russo[6] & Donald Tashkin[7]

Although electronic cigarettes (ECs) are a much less harmful alternative to tobacco cigarettes, there is concern as to whether long-term ECs use may cause risks to human health. We report health outcomes (blood pressure, heart rate, body weight, lung function, respiratory symptoms, exhaled breath nitric oxide [eNO], exhaled carbon monoxide [eCO], and high-resolution computed tomography [HRCT] of the lungs) from a prospective 3.5-year observational study of a cohort of nine daily EC users (mean age 29.7 (±6.1) years) who have never smoked and a reference group of twelve never smokers. No significant changes could be detected over the observation period from baseline in the EC users or between EC users and control subjects in any of the health outcomes investigated. Moreover, no pathological findings could be identified on HRCT of the lungs and no respiratory symptoms were consistently reported in the EC user group. Although it cannot be excluded that some harm may occur at later stages, this study did not demonstrate any health concerns associated with long-term use of EC in relatively young users who did not also smoke tobacco.

Electronic cigarettes (ECs) are battery powered electronic devices. Puffing on an EC heats up an element (most commonly, a metal coil) that vaporizes a solution (e-liquid) mainly consisting of propylene glycol, vegetable glycerin, distilled water, and flavorings that may or may not contain liquid nicotine. The user inhales the aerosol generated by vaporizing the e-liquid in a process commonly referred to as "vaping". ECs do not contain tobacco, do not create smoke and do not rely on combustion to operate. These consumer products have been rapidly gaining ground on conventional cigarettes among smokers due to the expectation of reducing/quitting smoking[1–4], the perception of being a less harmful alternative to cigarettes[1–6], competitive price[7–9] and because they allow the smoker to continue having a "smoking experience without smoking"[9–11].

Although vapour toxicology under normal condition of use is less problematic than tobacco smoke[12–14] and e-vapour products are estimated to be less harmful than combustible cigarettes[15–17], there is concern as to whether chronic exposure to their residual toxicological load may nevertheless carry a risk for lung health[18–20]. Therefore, investigating the health impact of long term EC use is warranted.

Considering that inhalation is the exposure mechanism for EC use, the respiratory system is the primary target of any potential harmful effects of constituents in ECs aerosol emissions. No deterioration in lung function, airway responses, and respiratory symptoms could be observed in a 1-year prospective RCT of "healthy" smokers who were invited to quit or reduce their tobacco consumption by switching to ECs[20,21]. Of note, FEF25–75% (a sensitive measure of obstruction in the more peripheral airways)[20], nitric oxide (a non-invasive biomarker of airway inflammation in airways disease, as well as in studies of environmental and occupational exposure)[21] and

[1]Centro per la Prevenzione e Cura del Tabagismo (CPCT), Azienda Ospedaliero-Universitaria "Policlinico-V. Emanuele", Università di Catania, Catania, Italy. [2]Institute of Internal and Emergency Medicine, Azienda Ospedaliero-Universitaria "Policlinico-V. Emanuele", Università di Catania, Catania, Italy. [3]Dipartimento di Medicina Clinica e Sperimentale, University of Catania, Catania, Italy. [4]National Research Council of Italy, Institute of Biomedicine and Molecular Immunology, Palermo, Italy. [5]Ospedale "San Vincenzo" - ASP Messina, Taormina, ME, Italy. [6]MCAU ARNAS Garibaldi, Catania, Italy. [7]David Geffen School of Medicine at the University of California, Los Angeles (UCLA), Los Angeles, California, USA. Correspondence and requests for materials should be addressed to R.P. (email: polosa@unict.it)

13. Vaping Economics In Maryland

VAPOR TECHNOLOGY ASSOCIATION

The Economic Impact of the Vapor Industry 2018
MARYLAND

DIRECT ECONOMIC IMPACT	Jobs	Wages	Output
Vape Store Retail Jobs	1,243	$ 29,412,400	$ 52,573,800
All Other Retail Jobs	244	$ 8,760,100	$ 18,488,400
Wholesale Jobs	122	$ 10,680,800	$ 30,044,200
E-Liquid Manufacturing Jobs	121	$ 5,417,900	$ 69,188,800
Component Manufacturing Jobs	0	$ 0	$ 0
Total	1,730	$ 54,271,200	$ 170,295,200

SUPPLIER ECONOMIC IMPACT	Jobs	Wages	Output
Agriculture	3	$ 87,400	$ 284,300
Mining	2	$ 29,500	$ 477,600
Construction	10	$ 602,200	$ 1,528,500
Manufacturing	22	$ 1,597,800	$ 10,916,500
Wholesale	31	$ 2,736,700	$ 7,596,800
Retail	7	$ 275,300	$ 621,700
Transportation & Communication	79	$ 7,532,800	$ 23,411,100
Finance, Insurance & Real Estate	74	$ 4,392,000	$ 20,627,200
Business & Personal. Services	213	$ 16,463,500	$ 31,271,700
Travel & Entertainment	25	$ 778,000	$ 1,810,400
Government	9	$ 896,800	$ 1,218,600
Other	0	$ 0	$ 0
Total	475	$ 35,392,000	$ 99,764,400

INDUCED ECONOMIC IMPACT	Jobs	Wages	Output
Agriculture	6	$ 134,000	$ 654,300
Mining	1	$ 11,700	$ 154,700
Construction	9	$ 535,900	$ 1,403,300
Manufacturing	20	$ 1,390,600	$ 9,221,300
Wholesale	22	$ 1,934,600	$ 5,425,300
Retail	103	$ 3,520,800	$ 8,874,400
Transportation & Communication	42	$ 3,764,700	$ 15,006,100
Finance, Insurance & Real Estate	87	$ 6,206,800	$ 35,045,700
Business & Personal Services	320	$ 18,196,800	$ 32,921,800
Travel & Entertainment	115	$ 3,267,200	$ 8,811,300
Government	7	$ 770,800	$ 1,173,200
Other	21	$ 948,200	$ 639,600
Total	753	$ 40,682,100	$ 119,331,000

	Jobs	Wages	Output
TOTAL ECONOMIC IMPACT	2,958	$ 130,345,300	$ 389,390,600

TAX IMPACT	TAXES GENERATED
Business Taxes Generated	$ 62,906,100
Federal	$ 31,811,400
State	$ 31,094,700
Consumption Taxes Generated	$ 17,122,000
Total Taxes	$ 80,028,000