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The Impact of Electronic Cigarettes on Cigarette Smoking By Americans and Its Health and Economic Implications

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Contents

Executive Summary

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Cigarette smoking by Americans declined steadily from the mid-1960s to around 2005, when this progress began to slow. From 2013 to 2017, however, cigarette smoking rates fell sharply, during a period in which the use of electronic cigarettes or e-cigarettes increased sharply. This study examines the connection between these two developments and the implications.

- Among adults, cigarette smoking rates fell from 18.0% in 2013 to 14.0% in 2017, while the use of e-cigarettes increased from 1.9% to 2.8%.
- Over the same years, cigarette smoking rates among high school students fell from 12.7% to 7.6% while their rates of e-cigarette use increased from 4.5% to 11.7%. Among adolescents, the association between declining smoking rates and rising e-cigarette use was even stronger than among adults.
- Statistical analysis of the changes in smoking rates and e-cigarette use by age, gender, race and ethnicity suggests that about 70 percent of the increased decline in cigarette smoking from 2013 to 2017 was associated with the rising use of e-cigarettes. The remaining 30 percent was associated with higher cigarette taxes, bans on cigarette sales by the CVS pharmacy chain, and increased use of anti-smoking prescription drugs.
- Statistical analysis also strongly suggests that e-cigarettes are not a gateway to smoking cigarettes.

- Rather, statistical analysis and numerous studies establish that e-cigarettes are an effective tool to help people stop smoking or avoid starting to smoke cigarettes.

Based on these analyses, we estimate that pre-existing trends and factors other than e-cigarettes can explain a decline in smoking rates by people ages 18 to 44 from 20.2% in 2014 to 17.9% in 2017. However, the rate fell from 20.2% to 14.6% in 2017, and the rising use of e-cigarettes can explain the additional 3.3 percentage-point decline in cigarette smoking rates.

- By this account, e-cigarette use is closely linked to a reduction in cigarette smoking from 2014 to 2017 by 922,301 people ages 18 to 24 and 2,922,540 people users ages 25 to 44, or a total of 3,844,840 people.

We also calculated the healthcare savings and costs and the productivity benefits associated with the reductions in cigarette smoking and the increased use of e-cigarettes from 2014 to 2017 by those 3,844,840 people ages 18 to 44. These calculations are based on healthcare costs, life expectancy, and the differences in the incidence of illnesses that interfere with work for smokers, ex-smokers, nonsmokers and e-cigarette users.

- E-cigarette use lowers people's annual *per capita* healthcare costs, compared to cigarette smokers and ex-smokers, for all age groups up to age 75.
  - For people ages 25 to 44, the annual *per capita* healthcare costs of cigarette smokers are 9.8 percent greater than those of e-cigarette users, and the average annual *per capita* healthcare costs for ex-smokers are 19.8 percent greater than for e-cigarette users.
  - For people ages 45 to 64, annual *per capita* healthcare spending for cigarette smokers is 8.8 percent greater than for e-cigarette users, and average *per capita* healthcare costs for ex-smokers are 34.4 percent greater than for e-cigarette users.
  - Treating cigarette-smoking-related diseases accounts for an estimated 8.7 percent of annual healthcare spending, or $303.8 billion in 2017.
- By reducing the number of people who smoke cigarettes, e-cigarette use also extends the lifespans of millions of people, raising their lifetime medical costs across all age groups except those 18 to 24.
  - We calculate that the use of e-cigarettes by the 922,301 people ages 18 to 24 in 2017, who otherwise would have started smoking cigarettes, should reduce their lifetime healthcare costs by $11.3 billion.
  - However, the use of e-cigarettes by the 2,922,540 people ages 25 to 44 in 2017, who otherwise would have started smoking cigarettes, increases their lifetime healthcare costs by $284.5 billion.
- Those higher lifetime healthcare costs reflect spending for 330,489 people whom we would expect to have died before their mid-to-late 60s if they started smoking cigarettes in 2014-2017, and for 500,865 people whom we would expect to have died before their mid-to-late 80s if they had started smoking instead of using e-cigarettes.
- E-cigarette users (and nonsmokers) also are more productive than smokers, because smokers miss more work due to illness, come to work still impaired by illness more often, and take smoking breaks. We found that e-cigarette

users are on average $820 more productive per-year than ex-cigarette smokers and $2,371 more productive per-year than current smokers, and that ex-smokers who shifted to e-cigarettes are on average $1,554 more productive per-year than current smokers.

- Based on the above estimates and the share of people ages 18 to 64 who work, we estimate that compared to smokers and ex-smokers,
  - The additional productivity of the share of the 922,301 e-cigarette users ages 18 to 24 in 2017 who worked from 2017 on, and who otherwise would have become smokers in 2014-2017, would be worth $14.7 billion over the 10 years from 2017 to 2027;
  - The additional productivity of the share of the 2,922,540 e-cigarette users ages 25 to 44 in 2017 who worked from 2017 on, and who otherwise would have continued to smoke in 2014-2017, would be worth $29.2 billion over the years from 2017 to 2027.

The Impact of Electronic Cigarettes on Cigarette Smoking By Americans and Its Health and Economic Implications

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I. INTRODUCTION AND MAJOR FINDINGS

In 1964, U.S. Surgeon General Luther Terry issued the landmark report on the health dangers of cigarette smoking. Drawing on more than 7,000 studies, the report found that cigarette smoking was a cause of lung cancer among men, a likely cause of lung cancer among women, and the leading cause of chronic bronchitis for both men and women.[2]

The following year, Congress passed the "Federal Labeling and Advertising Act of 1965" directing cigarette manufacturers to post health warning labels on all cigarette packaging. Since then, the federal government, American Cancer Society, the American Heart Association, the American Lung Association and other organizations have conducted continuing, large scale public education campaigns encouraging Americans to quit smoking or resist taking up the habit.

These efforts have been very successful. The share of American adults using tobacco products fell steadily from 42.4 percent in 1965 and 30.1 percent in 1985 to 20.9 percent in 2005.[3] This progress slowed from 2005 to 2011, when 18.0 percent of adults still smoked, and then accelerated again from 2013 to 2017,at by which time the share of American adults still smoking cigarettes had fallen to 14.0 percent. In fact, all forms of smoking fell markedly from 2011 to 2017 with one exception: From 2011 to 2017, while cigarette smokers fell from 19.0 percent of adults to 14.0 percent, the use of

electronic or e-cigarettes more than doubled from 1.3 percent to 2.8 percent. Larger declines in cigarette smoking and greater increases in e-cigarette use occurred among young Americans. From 2011 to 2017, the share of high school students who smoked cigarettes dropped from 15.8 percent to 7.6 percent, while their use of e-cigarettes jumped from 1.5 percent to 11.7 percent.

These rapid increases in e-cigarette use have stimulated heated public debate over whether these developments should be welcomed or condemned. Since wide use of e-cigarettes is a recent occurrence, we cannot know yet whether long-term e-cigarette use carries any of the adverse health effects of cigarette smoking. Researchers have established that the vapors inhaled from e-cigarettes do not contain many of the carcinogens produced from burning tobacco and inhaling its smoke. Skeptics of e-cigarettes note that those vapors contain nicotine, which scientists have long established is addictive but not carcinogenic.[4] Since nicotine addiction is a serious hurdle for most people trying to quit smoking, some public health advocates view the nicotine in e-cigarette vapors as a positive tool to help people quit smoking.. In this view, e-cigarettes offer a much less harmful addiction than regular cigarettes for people already addicted to nicotine. In response, some skeptics claim that e-cigarette use, especially by young people, may be a gateway to smoking regular cigarettes.

This report analyzes the data on cigarette smoking and e-cigarette use to answer these and other questions. We analyze the recent sharp decline in cigarette smoking rates that occurred while e-cigarette use sharply increased, across virtually all groups. From 2013 to 2017, cigarette smoking fell sharply and e-cigarette use rose sharply among men, women, whites, blacks, Hispanics, middle-school students, high school students, young adults ages 18 to 24, and older adults ages 25 to 44 and ages 45 to 64. In every group, the rates at which e-cigarette use rose and cigarette smoking declined accelerated substantially from 2013 to 2017, compared to the preceding five years. The only exception were people ages 65 and over, among whom smoking rates and e-cigarette use were stable. For all other groups, statistical analysis shows that increased e-cigarette use explains most of the unusually sharp decline in cigarette smoking in 2013 to 2017. This finding is also supported by regression analysis, which shows that among white, black and Hispanics adolescents, every one percent decline in their cigarette smoking was accompanied by a 0.87 percent increase in their e-cigarette use.

We also use statistical analysis to test the proposition that e-cigarettes are a “gateway drug” to smoking regular cigarettes, especially for middle school and high school students. Fundamentally, the gateway proposition appears inconsistent with basic data on smoking rates: The young adults ages 18 to 24 whose use of cigarettes declined sharply from 2013 to 2017 included millions of people who began using e-cigarettes as adolescents in the preceding years. If e-cigarettes were a gateway to cigarette smoking, their large increases in e-cigarette use as adolescents should have been followed by rising cigarette smoking rates as they aged into the 18 to 24-year-old group. These data and our analysis of other data on adolescents appear to refute the gateway proposition, a conclusion also consistent with findings by other researchers.

We also reviewed the literature and data to evaluate how effective e-cigarettes are in helping

people stop smoking cigarettes. We identified three meta-reviews in leading peer-reviewed journals that analyze scores of studies on how e-cigarette use affects cigarette smoking rates. One of these reviews found that cigarette smokers were 28 percent more likely to stop smoking if they used e-cigarettes, and another found that e-cigarette users were 2.3 times more likely to stop smoking than those trying to stop using no aid. The third meta-analysis reported that people using e-cigarettes containing nicotine were more than twice as likely to stop smoking as people using placebo e-cigarettes without nicotine. Lastly, a new study found that the short-term success rate of people trying to stop smoking using e-cigarettes was twice as high as those using nicotine patches, gum or lozenges.

To better isolate the impact of e-cigarette use on smoking rates, we also evaluate how other factors affect those rates, including rising cigarette taxes, smoke-free air laws, bans on cigarette sales in pharmacies, anti-smoking public education campaigns, restrictions of marketing for cigarettes, and the use of pharmaceuticals to help people stop smoking. The issue here is not whether these factors affect cigarette smoking – they do. The question is which factors can help explain why the decline in cigarette smoking rates accelerated abruptly from 2014 to 2017. To meet that criterion, we should see some increase or intensification in these factors over those years, as clearly occurred with the use of e-cigarettes.

Our review found that smoke-free air laws, anti-smoking public education campaigns, and marketing restrictions all operated from 2014 to 2017 as they did over the preceding five years. They likely helped maintain the declining trend in cigarette smoking, but they cannot explain why that declining trend accelerated. However, cigarette taxes increased, the CVS pharmacy chain banned cigarette sales in its stores, and the use of anti-smoking drugs such as Zyban and Chantix increased. Our statistical analysis found that rising taxes and the CVS sales ban contributed to about 15 percent of the additional decline in cigarette smoking rates from 2014 to 2017, and the increased use of anti-smoking drugs – Zyban, Chantix and their generics – could explain another 10 percent of the additional decline in cigarette smoking.

With 75 percent of the additional decline in cigarette smoking rates unexplained by factors other than the increased use of e-cigarettes, we rely on the estimate by a leading medical researcher in this area that the sudden increase in e-cigarette use can explain 60 percent to 80 percent of the additional decline in smoking rates from 2014 to 2017. We use the midpoint of that estimate and posit that up to 70 percent of the additional decline can be associated with the remaining major anti-smoking factor, the sharp increase in e-cigarette use over the same years. On this basis, we created a model to estimate more precisely how much the increased use of e-cigarettes reduced cigarette smoking from 2014 to 2017 among Americans ages 18 to 24 and ages 25 to 44. We projected how much cigarette smoking would have declined if the trend from 2010 to 2014 had simply continued. Next, we adjusted those results for the impact of the higher cigarette taxes, the CVS ban on selling cigarettes, and the increased use of anti-smoking drugs. Based on our previous analyses, we can attribute the difference between that adjusted rate and actual cigarette smoking rates in 2017 to the increased use of e-cigarettes.

From 2014 to 2017, the cigarette smoking rate of the two age groups (18 to 24 and 25 to 44) fell

from 20.2 percent to 14.6 percent. The rate of decline from 2010 to 2014 and the impact of the three factors noted above can explain a decline from 20.2 percent to 17.9 percent. A reasonable explanation consistent with the data is that the remaining 3.3 percentage-points decline in cigarette smoking from 2014 to 2017 was largely or entirely the result of increased use of e-cigarettes. By this account, we estimate that the sharp increase in e-cigarette use from 2014 to 2017 was closely linked to the success of 3,844,840 Americans ages 18 to 24 and ages 25 to 44 who from 2014 to 2017 otherwise would have taken up smoking or who quit smoking.

We also examine the impact of e-cigarettes on healthcare costs and the economy. The impact on healthcare costs is mixed. At every age up to 75, e-cigarette users spend substantially less per person for healthcare than cigarette smokers or ex-smokers. For example, at ages 25 to 44, the annual *per capita* healthcare costs of cigarette smokers are 9.8 percent higher than those of e-cigarette users, and average healthcare spending by ex-smokers is 19.8 percent greater than e-cigarette users. E-cigarette use also reduces the numbers of people who smoke cigarettes, whose lifetime medical costs are lower because they die younger, and so extends the lifespans of millions of people, raising their lifetime medical costs. Since e-cigarettes help smokers quit, they also raise healthcare spending because those costs are higher among ex-smokers than smokers.

To analyze healthcare costs, we use life expectancy data for smokers, ex-smokers and nonsmokers and Congressional Budget Office (CBO) estimates of per-person healthcare spending for smokers, ex-smokers and nonsmokers, adjusting the results for nonsmokers to reflect e-cigarette users. We found that use of e-cigarettes instead of regular cigarettes by the additional 3,844,480 people from 2014 to 2017 reduced the lifetime healthcare costs of those ages 18 to 24 in 2017 by $11.3 billion while increasing the lifetime healthcare costs of those ages 25 to 44 by $284.5 billion. Those increased costs reflect the healthcare required for 330,489 people who would be expected to have died by their mid-to-late sixties if they had started smoking cigarettes in 2017 instead of using e-cigarettes, and 500,865 people likely to have died by their mid-to-late 80s if they had begun smoking instead of using e-cigarettes. Using a conservative estimate for the value of an additional year of life, the life extension associated with the use of e-cigarettes instead of cigarette smoking by our two age groups can be valued at $2.8 trillion or more than 10 times the additional healthcare costs.

Finally, we estimate the impact of smoking compared to e-cigarettes on people's productivity over a 10-year period, based on our two groups' rates of illnesses and time lost to cigarette breaks. Researchers report that e-cigarette users are $820 more productive per-year than ex-cigarette smokers and $2,371 more productive per-year than current cigarette smokers. We found that over a 10-year period, the additional productivity of the 922,301 e-cigarette users ages 18 to 24 in 2017, relative to their productivity if they had started smoking, came to $12.7 billion. Similarly, the 10-year productivity benefits of using e-cigarettes instead of smoking for the 2,922,540 people ages 25 to 44 who made that choice in 2017 were worth $25.2 billion.

This study establishes that the increased use of e-cigarettes is closely associated with declining

rates of cigarette smoking, that e-cigarettes almost certainly are not a gateway to cigarette smoking, and e-cigarettes are highly effective in helping people stop smoking. We also found that using e-cigarettes instead of smoking often results in higher lifetime healthcare costs because people live longer, but the value of the extended lifespans far exceeds the additional healthcare costs. We also find that e-cigarette use is associated with large productivity benefits compared to smoking. Regulation of e-cigarettes should take account of these findings.

II. USE OF CIGARETTES, E-CIGARETTES AND OTHER TOBACCO PRODUCTS, 2011 TO 2018

Rates of cigarette smoking among Americans, defined by the CDC as smoking at least once over the previous 30 days, have declined for many years. Since the Surgeon General issued his landmark report on the health effects of smoking, the share of American adults who smoke cigarettes fell from 42 percent in 1965 to less than 20 percent in 2011.[5] Over the next three years, e-cigarettes were introduced and broadly adopted by the public. E-cigarettes are battery-powered devices that convert liquid nicotine into a vapor that its users inhale without any combustion. While the vapor contains nicotine, it does not contain many of the harmful chemicals in regular cigarettes linked to sharply increased risks of cancers, heart disease, and respiratory ailments.

The CDC has collected data on e-cigarettes since 2011, along with the data it has long collected on cigarette smoking and use of other combustible tobacco products such as cigars and hookahs. These data show that among adults, cigarette use continued to decline from 19 percent 2011 to 14 percent in 2017, and adult use of all combustible tobacco products fell from 19.2 percent in 2013 to 16.7 percent in 2017. (See Table 1, below). This pattern holds for males and females, although men use all forms of tobacco at much higher rates than women. This declining tobacco use also holds across races and Hispanic ethnicity for cigarettes. By contrast, adult use of e-cigarettes rose steadily from 1.3 percent in 2011 to 3.5 percent in 2015 and then dipped to 2.8 percent in 2017. Men use e-cigarettes at higher rates than women, and whites use them at higher rates than blacks, Hispanics, or Asians. The data also show that the increase in adult e-cigarette use has consistently accompanied declining use of regular cigarettes: All told, regular cigarette use by adults fell 5.0 percentage points or more than 26 percent from 2011 to 2017, while electronic cigarette use by adults increased 1.5 percentage points or more than 115 percent.

TABLE 1: RATE OF TOBACCO USE AMONG ADULTS (AGES 19 AND OLDER), 2011-2017[6]

PRODUCT	2011	2013	2014	2015	2017	2011-2017
OVERALL						
ALL TOBACCO	NA	21.3%	21.3%	20.1%	19.3%	**- 2.0 pts**
ANY COMBUSTIBLE	NA	19.2%	18.4%	17.6%	16.7%	**- 2.5 pts**
CIGARETTES	19.0%	18.0%	17.0%	15.1%	14.0%	**- 5.0 pts**
E-CIGARETTES	1.3%	1.9%	3.3%	3.5%	2.8%	**1.5 pts**
MALE						
ALL TOBACCO	NA	26.2%	26.3%	25.2%	24.8%	**- 1.4 pts**
ANY COMBUSTIBLE	NA	22.6%	21.5%	21.0%	20.8%	**- 1.8 pts**
CIGARETTES	21.6%	20.0%	19.3%	16.7%	15.8%	**- 5.8 pts**
E-CIGARETTES	1.1%	2.2%	4.0%	4.3%	3.3%	**2.2 pts**
FEMALE						
ALL TOBACCO	NA	15.4%	16.7%	15.4%	14.2%	**- 1.2 pts**
ANY COMBUSTIBLE	NA	14.9%	15.7%	14.4%	12.9%	**- 2.0 pts**
CIGARETTES	16.5%	14.5%	15.1%	13.6%	12.2%	**- 4.3 pts**
E-CIGARETTES	1.5%	1.6%	2.8%	2.6%	2.4%	**0.9 pts**
WHITE						
ALL TOBACCO	NA	20.7%	21.3%	22.6%	21.4%	**0.7 pts**
ANY COMBUSTIBLE	NA	18.2%	17.8%	19.3%	18.3%	**0.1 pts**
CIGARETTES	20.6%	17.2%	16.6%	16.6%	15.2%	**- 5.4 pts**
E-CIGARETTES	1.5%	2.1%	3.6%	4.1%	3.3%	**1.8 pts**
BLACK						
ALL TOBACCO	NA	22.5%	25.1%	20.8%	20.1%	**- 2.4 pts**
ANY COMBUSTIBLE	NA	21.6%	23.5%	19.9%	18.8%	**- 2.8 pts**
CIGARETTES	19.4%	19.7%	21.3%	16.7%	14.9%	**- 4.5 pts**
E-CIGARETTES	NA	0.8%	2.1%	1.9%	2.2%	**1.4 pts**
HISPANIC						
ALL TOBACCO	NA	15.9%	17.6%	12.9%	12.7%	**- 3.2 pts**
ANY COMBUSTIBLE	NA	15.4%	16.2%	11.8%	11.2%	**- 4.2 pts**
CIGARETTES	12.9%	14.6%	14.7%	10.1%	9.9%	**- 3.0 pts**
E-CIGARETTES	NA	1.1%	2.7%	2.0%	1.8%	**0.7 pts**

The CDC also collects data on tobacco use among younger Americans, middle school students (approximately ages 11 to 13) and high school students (approximately ages 14 to 18), using separate categories for cigarettes, cigars, hookahs, e-cigarettes and all tobacco products.

Among both groups of youths, the data show that from 2011 to 2018, rates of regular cigarette and cigar smoking fell sharply while rates of e-cigarette use rose sharply. This pattern holds for both men and women, and across whites, blacks, and Hispanics.[7]

TABLE 2: RATES OF TOBACCO USE, MIDDLE SCHOOL STUDENTS (AGES 11-13), 2011-2018 [8]

PRODUCT	2011	2012	2013	2014	2015	2016	2017	2018	2011-2018
OVERALL									
CIGARETTES	4.3%	3.5%	2.9%	2.5%	2.3%	2.2%	2.1%	1.8%	**-2.5 pts**
CIGARS	3.5%	2.8%	3.1%	1.9%	1.6%	2.2%	1.5%	1.6%	**-1.9 pts**
HOOKAH	1.0%	1.3%	1.1%	2.5%	2.0%	2.2%	1.9%	1.2%	**0.2 pts**
E-CIGARETTES	0.6%	1.1%	1.1%	3.9%	5.3%	4.3%	3.3%	4.9%	**4.3 pts**
ALL TOBACCO	7.5%	6.7%	6.5%	7.7%	7.4%	7.2%	5.6%	7.2%	**- 0.3 pts**
MALE									
CIGARETTES	4.5%	3.8%	3.0%	3.0%	2.3%	2.5%	2.0%	2.1%	**-2.4 pts**
CIGARS	4.3%	3.2%	3.3%	2.4%	1.8%	2.7%	1.6%	1.7%	**-2.6 pts**
HOOKAH	1.1%	1.5%	0.9%	2.4%	1.9%	3.0%	2.4%	1.5%	**0.4 pts**
E-CIGARETTES	0.7%	1.5%	1.4%	4.5%	5.9%	5.1%	3.7%	5.1%	**4.4 pts**
ALL TOBACCO	9.0%	7.8%	6.5%	8.8%	8.3%	8.3%	6.4%	8.0%	**-1.0 pts**
FEMALE									
CIGARETTES	4.0%	3.2%	2.8%	2.0%	2.2%	1.8%	2.2%	1.5%	**-2.5 pts**
CIGARS	2.5%	2.4%	2.9%	1.4%	1.4%	1.7%	1.4%	1.6%	**-0.9 pts**
HOOKAH	1.0%	1.0%	1.3%	2.6%	2.0%	1.5%	1.2%	1.0%	**0.0 pts**
E-CIGARETTES	0.4%	0.8%	0.9%	3.3%	4.8%	3.4%	2.9%	4.8%	**4.4 pts**
ALL TOBACCO	5.9%	5.6%	6.5%	6.6%	6.4%	5.9%	4.8%	6.3%	**0.4 pts**
WHITE									
CIGARETTES	3.8%	3.1%	2.6%	2.2%	2.1%	1.9%	1.7%	1.6%	**-2.2 pts**
CIGARS	2.3%	1.6%	2.2%	1.4%	1.2%	1.4%	1.1%	1.1%	**-1.2 pts**
HOOKAH	0.9%	0.8%	0.7%	1.4%	1.6%	2.1%	1.6%	0.8%	**-0.1 pts**
E-CIGARETTES	0.6%	0.9%	0.9%	3.1%	4.4%	3.7%	3.4%	4.9%	**4.3 pts**
ALL TOBACCO	6.2%	5.1%	5.6%	6.2%	6.3%	5.9%	5.1%	6.6%	**0.4 pts**

PRODUCT	2011	2012	2013	2014	2015	2016	2017	2018	2011-2018
BLACK									
CIGARETTES	3.6%	2.6%	1.7%	1.7%	1.0%	NA	2.1%	NA	**-1.5 pts**
CIGARS	5.7%	5.0%	4.5%	2.0%	2.0%	4.5%	1.9%	2.9%	**-2.8 pts**
HOOKAH	0.9%	0.9%	NA	NA	NA	NA	NA	NA	**N/A**
E-CIGARETTES	0.4%	1.1%	NA	3.8%	4.1%	4.0%	2.2%	3.0%	**2.6 pts**
ALL TOBACCO	8.5%	7.7%	6.8%	7.3%	6.6%	7.5%	4.9%	6.8%	**-1.7 pts**
HISPANIC									
CIGARETTES	6.7%	5.4%	5.1%	3.7%	2.8%	2.5%	3.5%	2.4%	**-4.3 pts**
CIGARS	6.1%	4.9%	4.7%	2.9%	2.2%	2.8%	2.4%	2.2%	**-3.9 pts**
HOOKAH	1.7%	3.0%	2.4%	5.6%	3.2%	3.0%	3.2%	2.2%	**0.5 pts**
E-CIGARETTES	0.6%	2.0%	1.8%	6.2%	8.3%	5.6%	4.0%	6.6%	**6.0 pts**
ALL TOBACCO	11.5%	10.5%	9.7%	11.8%	10.6%	9.5%	7.7%	9.5%	**-2.0 pts**

The data show that the overall smoking rate among American middle schoolers, ages 11 to 13, remained reasonably steady: In 2011, 7.5 percent of middle schoolers used some form of tobacco; and while the rate fluctuated over the next seven years, in 2018, 7.2 percent of middle schoolers used tobacco or just three-tenths of a percentage-point fewer than in 2011. (Table 2, above) Middle-schoolers in 2018 were nearly as likely to use some form of smoking product as children the same age were in 2011.

However, their choice of tobacco product changed. Their rates of regular cigarette use fell 53 percent, from 4.5 percent to 2.1 percent, and their cigar use fell 54 percent, from 3.5 percent to 1.6 percent. Over the same period, middle school students' use of e-cigarettes increased more than seven-fold, from 0.6 percent in 2011 to 4.9 percent in 2018. In 2011, cigarettes accounted for over 57 percent of all tobacco use by middle schoolers, and e-cigarettes accounted for 8 percent. By 2018, e-cigarettes accounted for 68 percent of all tobacco use by middle-school students, while regular cigarettes accounted for 25 percent.

Female middle schoolers use tobacco products at lower rates than males the same ages, but the decline in the use of cigarettes and cigars by male and female middle schoolers from 2011 to 2018 followed similar trajectories. The rising rates of e-cigarette use by male and female middle schoolers also closely parallel each other: The share of male middle schoolers using e-cigarettes increased from 0.7 percent in 2011 to 5.1 percent in 2018, while the share of female middle schoolers using e-cigarettes increased from 0.4 percent to 4.8 percent. By 2018, e-cigarettes accounted for almost 64 percent of all tobacco use by male middle schoolers and more than 76 percent of tobacco use by female middle schoolers.

Some differences in the patterns of tobacco use are evident across white, black and Hispanic middle schoolers. In all three cases, the rates of use of cigarettes and cigars declined, and

rates of use of e-cigarettes increased. However, cigarette and cigar use feel more sharply among Hispanics than among white or blacks, and Hispanics and whites adopted e-cigarettes at higher rates than blacks. By 2018, e-cigarettes accounted for 74 percent of all tobacco use by white middle schoolers and 70 percent of all tobacco use by Hispanic middle schoolers, but only 44 percent of tobacco use by black middle schoolers. By contrast, cigarette use in 2018 accounted for 24 percent of tobacco use by white middle schoolers, 25 percent by Hispanic middle schoolers, but 42 percent by black middle schoolers.

American high school students, ages 14 to 18, use tobacco at higher rates than middle school students, but their patterns of use changed in similar ways from 2011 to 2018. Overall, their use of tobacco products rose moderately from 24.3 percent to 27.1 percent. (See Table 3, below) Therefore, high school students were 11 percent more likely to use some form of tobacco in 2018 than in 2011. However, their use of cigarettes fell sharply while their use of e-cigarettes rose dramatically. In 2011, cigarettes accounted for 65 percent of all tobacco use among high school students, and e-cigarettes accounted for just over 6 percent. By 2018, their cigarette use fell by more than half, as cigarettes had come to account for just 30 percent of tobacco use among high schoolers. Over the same period, the rates at which high schoolers uses e-cigarettes jumped from 1.5 percent to 20.8 percent, almost a 14-fold increase, and e-cigarette use accounted for nearly 77 percent of all tobacco use by high school students. (The rates of use of different types of tobacco add up to more than 100 percent, because some high schoolers use more than one form of tobacco.)

TABLE 3: RATES OF TOBACCO USE, HIGH SCHOOL STUDENTS (AGES 14-18), 2011-2018[9]

PRODUCT	2011	2012	2013	2014	2015	2016	2017	2018	2011-2018
OVERALL									
CIGARETTES	15.8%	14.0%	12.7%	9.2%	9.3%	8.0%	7.6%	8.1%	**- 7.7 pts**
CIGARS	11.6%	12.6%	11.9%	8.2%	8.6%	7.7%	7.7%	7.6%	**- 4.0 pts**
HOOKAH	4.1%	5.4%	5.2%	9.4%	7.2%	5.8%	5.5%	4.1%	**0 pts**
E-CIGARETTES	1.5%	2.8%	4.5%	13.4%	16.0%	11.3%	11.7%	20.8%	**19.3 pts**
ALL TOBACCO	24.3%	23.3%	22.9%	24.6%	25.3%	20.2%	19.6%	27.1%	**2.8 pts**
MALE									
CIGARETTES	17.7%	16.3%	14.1%	10.6%	10.7%	9.1%	7.6%	8.8%	**- 8.9 pts**
CIGARS	15.7%	16.7%	15.4%	10.8%	11.5%	9.0%	9.0%	9.0%	**- 6.7 pts**
HOOKAH	4.8%	6.2%	5.6%	8.9%	7.4%	8.3%	7.7%	4.0%	**- 0.8 pts**
E-CIGARETTES	2.3%	3.7%	5.5%	15.0%	19.0%	13.1%	13.3%	22.6%	**20.3 pts**
ALL TOBACCO	29.4%	28.3%	27.2%	28.3%	30.0%	23.5%	21.5%	29.1%	**- 0.3 pts**

PRODUCT	2011	2012	2013	2014	2015	2016	2017	2018	2011-2018
FEMALE									
CIGARETTES	13.8%	11.7%	11.2%	7.9%	7.7%	6.9%	7.5%	7.3%	**- 6.5 pts**
CIGARS	7.4%	8.4%	8.3%	5.5%	5.6%	5.6%	6.3%	6.0%	**-1.4 pts**
HOOKAH	3.5%	4.5%	4.8%	9.8%	6.9%	3.3%	3.0%	4.1%	**0.6 pts**
E-CIGARETTES	0.7%	1.9%	3.5%	11.9%	12.8%	9.5%	9.9%	18.8%	**18.1 pts**
ALL TOBACCO	19.0%	18.1%	18.5%	20.9%	20.3%	17.0%	17.5%	24.9%	**5.9 pts**
WHITE									
CIGARETTES	17.6%	15.4%	14.0%	10.8%	10.2%	9.9%	9.5%	9.9%	**- 7.7 pts**
CIGARS	12.1%	12.2%	11.4%	8.3%	8.4%	7.9%	8.4%	7.8%	**- 4.3 pts**
HOOKAH	4.3%	6.1%	5.3%	9.4%	6.9%	7.4%	7.2%	3.3%	**- 1.0 pts**
E-CIGARETTES	1.8%	3.4%	4.8%	15.3%	17.2%	13.7%	14.2%	26.8%	**25.0 pts**
ALL TOBACCO	26.6%	24.6%	24.0%	26.5%	26.2%	23.0%	22.7%	32.4%	**5.8 pts**
BLACK									
CIGARETTES	10.6%	9.6%	9.0%	4.5%	5.7%	3.9%	2.8%	3.2%	**- 7.4 pts**
CIGARS	11.7%	16.7%	14.7%	8.8%	12.8%	9.5%	7.8%	9.2%	**- 2.5 pts**
HOOKAH	1.7%	2.1%	2.4%	5.6%	6.4%	2.1%	1.8%	3.7%	**2.0 pts**
E-CIGARETTES	0.8%	1.1%	2.7%	5.6%	8.9%	6.2%	4.9%	7.5%	**6.7 pts**
ALL TOBACCO	18.9%	22.6%	21.0%	17.2%	21.9%	16.4%	14.2%	17.4%	**- 1.5 pts**
HISPANIC									
CIGARETTES	15.8%	14.3%	13.4%	8.8%	9.0%	6.4%	6.2%	7.2%	**- 8.6 pts**
CIGARS	11.3%	12.4%	12.1%	8.0%	7.3%	7.2%	6.7%	7.3%	**- 4.0 pts**
HOOKAH	5.1%	6.6%	7.1%	13.0%	8.7%	4.4%	3.7%	6.0%	**0.9 pts**
E-CIGARETTES	1.3%	2.7%	5.3%	15.3%	16.4%	10.3%	10.1%	14.8%	**13.5 pts**
ALL TOBACCO	23.8%	22.5%	23.9%	26.7%	25.4%	18.3%	16.7%	21.7%	**-2.1 pts**

The patterns of tobacco use differed among male and female high school students over this period; but in both cases, the use of cigarettes fell substantially while the use of e-cigarettes increased sharply. The use of all tobacco products was reasonably unchanged among male high schoolers, declining very slightly from 29.4 percent to 29.1 percent. Tobacco use of all kinds by female high school students, however, increased substantially, from 19.0 percent in 2011 to 24.9 percent in 2018. In both cases, cigarette use fell sharply while e-cigarette use increased more sharply. Among male high schoolers, cigarette use fell by half from 2011 to 2018 (17.7 percent to 8.8 percent), and e-cigarette use jumped almost ten-fold (2.3

percent to 22.6 percent). Among their female counterparts, cigarette use fell 47 percent (13.8 percent to 7.3 percent), and e-cigarette use jumped almost 26-fold (0.7 percent to 18.8 percent).

The clearest way to state these developments is as follows: Among male high school students in 2011, cigarettes accounted for 60 percent of their tobacco use, and e-cigarettes for 8 percent; seven years later, cigarettes accounted for 30 percent of their total tobacco use, and e-cigarettes accounted for 78 percent. Among their female counterparts, cigarettes accounted for almost 73 percent of all tobacco use in 2011, and e-cigarettes for 10.5 percent. By 2018, cigarettes accounted for 29 percent of their tobacco use, and e-cigarettes for 75.5 percent.

The same pattern is evident across race and ethnicity. From 2011 to 2018, the percentage of white high school students who had smoked cigarettes in the preceding 30 days fell from 17.6 percent to 9.9 percent, while their use of e-cigarettes jumped from 1.8 percent to 26.8 percent. As a result, cigarettes as a share of all tobacco use by white high schoolers fell from 66 percent in 2011 to 30.5 percent in 2018, while e-cigarettes' share of their total tobacco use rose from barely 7 percent to 83 percent.

Black high school students use tobacco less than white or Hispanic high schoolers, but the patterns are familiar. Their rate of cigarette use dropped from 10.6 percent in 2011 to 3.2 percent, while their rate of e-cigarettes jumped from 0.8 percent to 7.5 percent. As a result, cigarettes accounted for 56 percent of all tobacco use by black high schoolers in 2011 and only 18 percent in 2018. Thus, cigarettes as a share of all tobacco use among black high schoolers fell from 56 percent to 18 percent, while e-cigarettes' share rose from 4 percent to 43 percent.

Similarly, from 2011 to 2018, the percentage of Hispanic high school students who smoked cigarettes fell from 15.8 percent to 7.2 percent, while their use of e-cigarettes jumped from 1.3 percent to 14.8 percent. As a result, cigarettes as a share of all tobacco use by Hispanic high schoolers fell from 66 percent in 2011 to 33 percent in 2011, while e-cigarette's share of their tobacco use jumped from 5 percent to 68 percent.

These data document a broad, large-scale shift from the use of cigarettes to e-cigarettes among middle school and high school students, overall and across gender, race and ethnicity. Next, we apply regression analysis to measure the extent of the association between the rising use of e-cigarettes and the declining use of cigarettes and cigars. We estimate our regression models using two data samples: one sample covers cigarette, cigar, and e-cigarette smoking rates by school level and race and ethnicity, and the second sample covers cigarette, cigar, and e-cigarette smoking rates by school level and gender.

This analysis focuses on the relationships between the use of e-cigarettes and the use of combustible tobacco products among adolescents; and to make our estimates more precise, our model also includes and controls for school level and for race/ethnicity or gender (depending on the sample). The first set of regressions uses the race/ethnicity sample to measure the relationship between the use of combustible cigarettes and e-cigarettes. Using this sample, we found that across whites, blacks and Hispanics, a one percentage point decline in cigarette smoking rates is associated, on

average, with a 0.87 percentage point increase in e-cigarette use, after controlling for school level. We use whites as our control group, to examine the differences in this association across race and ethnicity. The regression confirms what we reported in Tables 2 and 3 above: Relative to their declining cigarette smoking rates, adolescent Hispanics use e-cigarettes one percentage-point less than adolescent whites (an estimate not statistically significant) while adolescent blacks use e-cigarettes seven percentage-points less than adolescent whites (which is statistically significant). The results are shown in Table 4, below.

TABLE 4: REGRESSION ANALYSIS:
AVERAGE ASSOCIATION BETWEEN CHANGES IN CIGARETTE AND CIGAR SMOKING RATES AND CHANGES IN THE USE OF E-CIGARETTES AMONG MIDDLE SCHOOL AND HIGH SCHOOL STUDENTS, BY RACE-ETHNICITY AND GENDER, 2011-2018

RACE/ETHNICITY SAMPLE			GENDER SAMPLE		
	(1) CIGARETTES	(2) CIGARS		(3) CIGARETTES	(4) CIGARS
AVERAGE ASSOCIATION	-0.87***	-1.24***	AVERAGE ASSOCIATION	-1.63***	-1.28***
	(0.17)	(0.21)		(0.24)	(0.23)
E-CIGARETTE USE RELATIVE TO WHITES			E-CIGARETTE USE RELATIVE TO MALES		
BLACK	-0.07***	-0.02	FEMALE	-0.04**	-0.06***
	(0.02)	(0.02)		(0.01)	(0.02)
HISPANIC	-0.01	0.00			
	(0.02)	(0.01)			

*Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; coefficients by school level are not shown.*

We also use the race/ethnicity sample to measure the relationship between cigar smoking and the use of e-cigarettes. We found that on average across this sample, a one percentage-point decline in adolescents' use of cigars is associated with a 1.24 percentage-point increase in their use of e-cigarettes. Again, we use whites as the control group to examine the differences in this association across race and ethnicity: Relative to their declining cigarette smoking rates, blacks use e-cigarettes two percentage-points less than whites and Hispanics use e-cigarette at the same rate as whites. However, neither difference is statistically significant.

We also preformed parallel regressions using our gender sample, again controlling for school level and race/ethnicity. We found first that across both genders of adolescents, a one percentage-point decline in cigarette smoking rates is associated with a 1.63 percentage-point increase in e-cigarette use. We use adolescent males as the control group to examine the response of adolescent females relative to those males with regard to the association between cigarette smoking and e-cigarette use. Again, the results confirm the data reported in Tables 2 and 3, that relative to changes in cigarette smoking rates, adolescent females use e-cigarettes less than adolescent males: Taking account

of differences in declining rates of cigarette smoking, e-cigarette use among the females on average is four percentage points less than among the males.

Finally, we used the gender sample to measure the relationship between changes in cigar smoking rates and e-cigarette use. We found that across both genders of adolescents, a one percentage point decline in cigar smoking rates is associated with a 1.28 percentage point increase in e¬-cigarette use. Using adolescent males as the control group, we also found that after taking account for declining rates of cigar smoking, adolescent females use e-cigarettes six percentage-points less than those males.

All told, these results strongly suggest that e-cigarettes substitute for rather than merely complement cigarette and cigar smoking among adolescents.

III. THE EVIDENCE THAT E-CIGARETTES ARE NOT A "GATEWAY DRUG" TO CIGARETTE SMOKING

While a great deal of evidence suggests that e-cigarettes substitute for regular cigarettes among adults and young people, some observers and analysts are concerned about a "gateway effect." In this scenario, using e-cigarettes leads some people, especially young people, who otherwise would not smoke anything to develop a cigarette smoking habit. These skeptics of e-cigarettes have proposed a number of explanations for why a gateway effect might occur, including a view that smoking e-cigarettes mimics smoking regular cigarettes, that e-cigarettes lead to nicotine dependence, and that smoking e-cigarettes affects a person's cognitive judgement about smoking cigarette.

A few researchers claim to have found evidence of a gateway effect, although their studies have been critiqued for methodological shortcomings. One often-cited study analyzed youth and young adults ages 14 to 30 who had not smoked regular cigarettes during a baseline time period.[10] The authors reported that the likelihood that a new e-cigarette user would also smoke regular cigarettes at least occasionally by the study's conclusion was 3.5 times greater than among those who had not smoked e-cigarettes. Using a different sample of former smokers instead of non-smokers, they reported that the likelihood that e-cigarette use would lead to smoking regular cigarettes was 4.3 times greater than among nonsmokers who did not use e-cigarettes.

Scholars have noted a number of flaws in the study, starting with the researchers' failure to establish a causal link between the use of e-cigarettes and regular cigarette smoking.[11] Critics also note that the study did not distinguish between people who used e-cigarettes that contained no nicotine and people who used nicotine-based e-cigarettes.[12] Further, the study appears to claim, at once, that using e-cigarettes predicts cigarette smoking and that smoking cigarettes predicts using e-cigarettes. This suggests that an additional untested factor could be correlated with both smoking cigarettes and using e-cigarettes and be the cause of both. For example, people with a proclivity for risky, thrill-seeking behaviors may be more likely to both smoke cigarettes and use e-cigarettes, in either order.

This study and a number of other gateway analyses also measure smoking with no reference to the frequency of smoking, but instead only with reference to whether a person has smoked cigarettes or used e-cigarettes at least once in the previous 30 days. Smoking or using e-cigarettes once or twice over 30 days

does not signify a nicotine addiction and is generally not associated with adverse health effects. Only about one-quarter of the people counted as smokers in this study used tobacco products at least 20 times in the preceding 30 days, including 27.7 percent of e-cigarette users and 23.1 percent of regular cigarette smokers.[13]

Other experts also have been skeptical of a gateway effect. Dr. Adam Leventhal, professor of preventative medicine at University of Southern California, has said, "I wouldn't necessarily say that the results indicate one way or the other that vaping is influencing prevalence of smoking." Other researchers point to the contemporaneous increase in e-cigarette use and decline in cigarettes smoking, which we documented earlier, as evidence that e-cigarettes use reduces the incidence of cigarette smoking. A recent assessment by Dr. David Levy from Georgetown University, for example, estimates that e-cigarette use was responsible for 60 percent to 80 percent of the decline in cigarette smoking.[14] This would make e-cigarettes the opposite of a gateway drug.

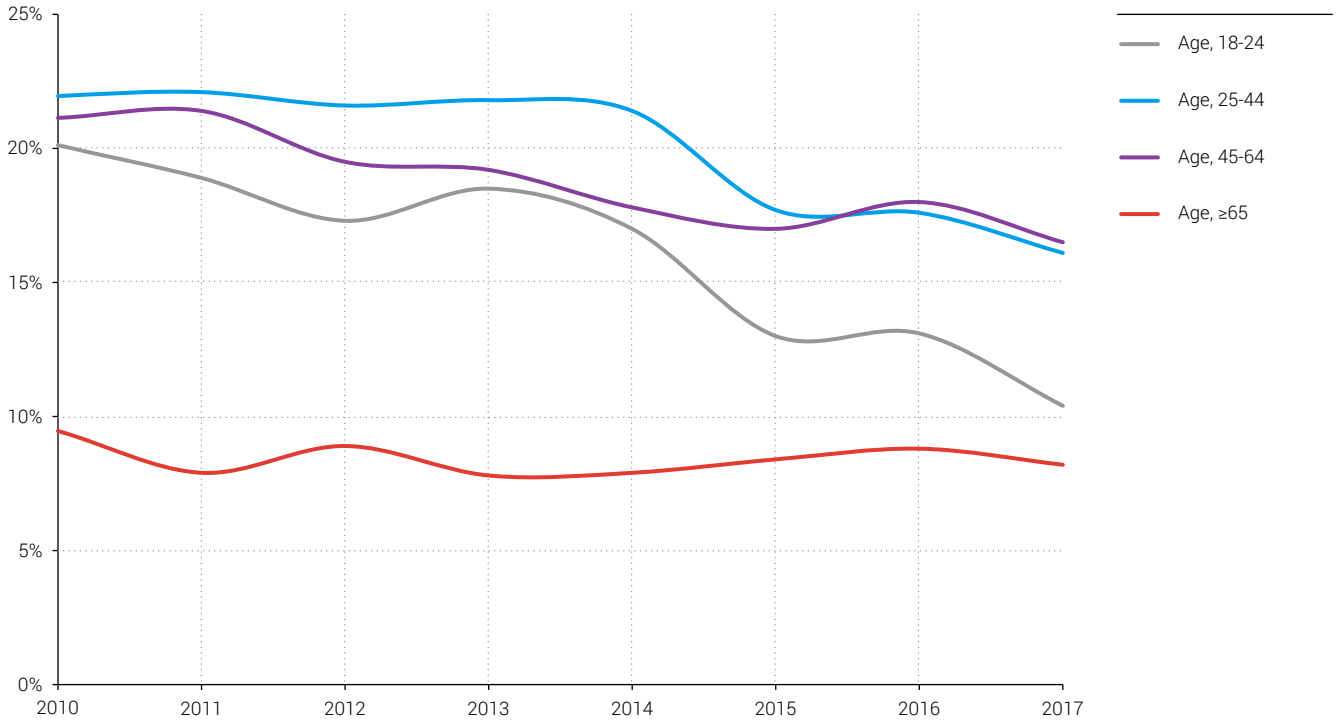
Our Empirical Evidence of the Impact of E-Cigarettes on Cigarette Smoking

Our analysis of the data presented earlier (Tables 1, 2 and 3, all above) bolsters the view of e-cigarettes as an effective smoking prevention or cessation tool and therefore the opposite of a gateway drug. The CDC data show substantial reductions in cigarette use among both adults and younger Americans from 2011 to 2018. The CDC also provides data by four age groups for 2010 to 2017. (Table 5, below) Those data show clearly that among all four adult age groups, smoking cessation rates decline with age.[15] (See also Figure 1, below) Among those ages 18 to 24, cigarette smoking rates fell from 20.1 percent to 10.4 percent or by more than 48 percent from 2010 to 2017. By comparison, cigarette smoking among 25 to 44 year olds, declined from 22.0 percent to 16.1 percent, or by nearly 27 percent; cigarette smoking among people ages 45 to 64 fell almost 22 percent, from 21.0 percent to 16.5 percent; and cigarette smoking among those ages 65 or older declined from 9.5 percent to 8.2 percent or nearly 14 percent.[16] We note here that the earlier dataset on total tobacco use by gender, race and ethnicity from 2011 to 2018 (Table 3, above) showed generally declining rates for all forms of tobacco except e-cigarettes from 2011 to 2017, followed by higher rates in 2018. This series ends in 2017, so it might well show slightly higher rates of cigarette use in 2018.

TABLE 5: CIGARETTE USE BY AGE, 2010 AND 2017

AGE	2010	2011	2012	2013	2014	2015	2016	2017	PERCENTAGE DECLINE
18-24	20.1%	18.9%	17.3%	19.2%	17.0%	13.0%	13.1%	10.4%	**48.3%**
25-44	22.0%	22.1%	21.6%	21.8%	21.4%	17.7%	17.6%	16.1%	**26.8%**
45-64	21.1%	21.4%	19.5%	19.2%	17.8%	17.0%	18.0%	16.5%	**21.8%**
65 +	9.5%	7.9%	8.9%	7.8%	7.9%	8.4%	8.8%	8.2%	**13.7%**

FIGURE 1: CIGARETTE USE BY AGE, 2010-2017[17]



The CDC also has issued data on e-cigarette use among adults by age, covering the years 2013, 2014, 2015 and 2017.[18] Again, the earlier dataset on total tobacco use by gender, race and ethnicity from 2011 to 2018 showed rising e-cigarette use from 2011 to 2017 followed by a very large increase in its use in 2018. This additional data series on e-cigarette also ends in 2017, and the 2017 data show lower e-cigarette use across every age group in 2017 than in 2016. If 2018 data were available, they might well show a substantial increase in e-cigarette use across the age groups.

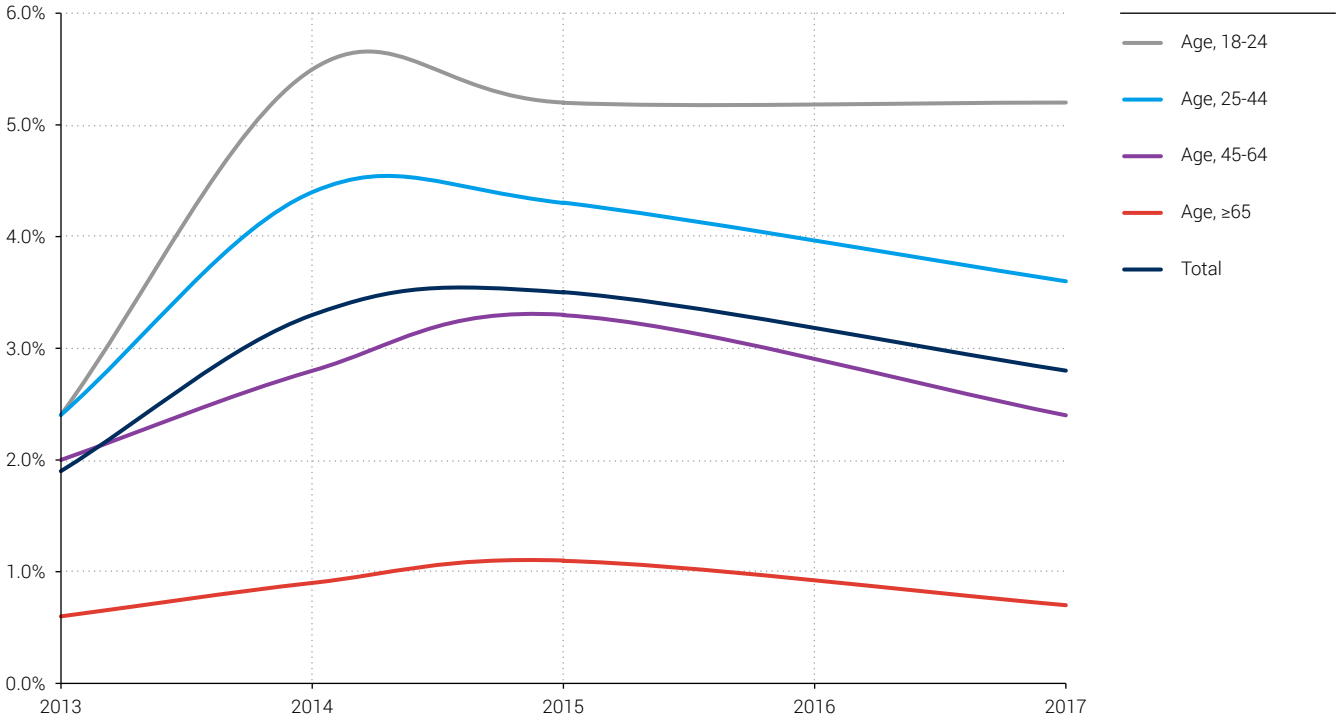
As it is, these data show substantial increases in e-cigarette use across the age groups and overall. (Table 6 and Figure 2, below) People ages 18 to 24 show the largest increase by far, as their rates of e-cigarette use jumped from 2.4 percent in 2013 to 5.2 percent in 2017 or more

than 112 percent. The other age groups all show more moderate increases in e-cigarette use, ranging from 20 percent among both those ages 25 to 44 and 45 to 65 to 16.7 percent among people ages 65 and older. Overall, the use of e-cigarette increased from 1.9 percent in 2013 to 2.8 percent in 2017, or gains of over 47 percent.

TABLE 6: E-CIGARETTE USE BY AGE, 2013, 2014, 2015 AND 2017

AGE	2013	2014	2015	2017	PERCENTAGE INCREASE
18-24	2.4%	5.5%	5.2%	5.2%	**112.5%**
25-44	2.4%	4.4%	4.3%	3.6%	**20.0%**
35-64	2.0%	2.8%	3.5%	2.4%	**20.0%**
65 +	0.6%	0.9%	1.1%	0.7%	**16.7%**
ALL	1.9%	3.3%	3.5%	2.8%	**47.4%**

FIGURE 2: E-CIGARETTE USE BY AGE, 2013, 2014, 2015 AND 2017



The CDC data provide additional empirical evidence that e-cigarettes are not a gateway mechanism to cigarette smoking. We saw earlier (Table 2, above) that high school students' use of e-cigarettes increased sharply in 2014, jumping from 4.5 percent in the 2013 to 13.4 percent in 2014. If smoking e-cigarettes led to regular cigarette smoking, we should observe rising cigarette smoking rates among those ages 18 to 24 in subsequent years, or at least an attenuated decline in their cigarette smoking. Instead, the CDC data above (Table 5) show the opposite: Rates of cigarette smoking among those ages 18 to 24 declined from 17.0 percent in 2014 to 10.4 percent in 2017.

Similarly, the use of e-cigarette by middle school students spiked in 2014 and generally continued to rise through 2018. (Table 2, above) If using e-cigarettes led to higher cigarette smoking rates, we should expect to find rising cigarette use among high school students in subsequent years. Again, the data show the opposite development: Cigarette smoking rates among middle school students fell steadily from 2014 through 2018, and the same pattern is evident among high school students. Their use of e-cigarettes jumped in 2014 and continued rising through 2018, and over the same period, cigarette smoking rates among high schoolers generally declined.

These population-level data appear to refute the proposition that e-cigarettes are a gateway to cigarette smoking among middle school students, high school students, or adults. Instead, these data suggest that the rising popularity of e-cigarettes has led to declining rates of cigarette smoking. In the following section, we further examine this proposition.

IV.THE IMPACT OF E-CIGARETTE USE ON EFFORTS TO STOP SMOKING CIGARETTES

Studies of the Impact of E-Cigarettes on Smoking

As yet, no study with a causal design and a sufficiently large sample has produced definitive evidence of how e-cigarette use affects cigarette smoking on a population-wide scale. However, most of the empirical evidence appears to support the view that e-cigarette use reduces the incidence of regular cigarette smoking. In 2016, three separate meta-reviews of this topic were published in *Lancet Respiratory Medicine*, *Database of Systematic Reviews* and *The International Journal of Public Health*. All three support that conclusion.

In the first review published in *Lancet Respiratory Medicine*, the researchers analyzed 21 separate studies and concluded that based on those data, cigarette smokers were 28 percent more likely to stop smoking if they used e-cigarettes.[19] This finding also was "robust" – that is, unaffected by alterations in its specifications with regard to definitions of e-cigarette use, whether individuals wanted to quit cigarette smoking or not, and whether the subjects were nicotine-dependent or not.[20]

The second major 2016 review study issued in the *Database of Systematic Reviews* updated a 2014 analysis that had been based on 13 separate empirical studies of the relationship between e-cigarette use and regular cigarette smoking.[21] For the update, the researchers included 24 studies which they deemed methodologically sound, including eight analyses that were also part the *Lancet* meta-review. These researchers analyzed two studies with randomized control trials for their empirical analysis and conducted qualitative analysis

on the other 22 studies. They concluded that the qualitative studies provided evidence short of a conclusive finding that e-cigarette use supported people's efforts to stop smoking regular cigarettes. They further found that their empirical analysis showed that e-cigarette users were 2.29 times more likely to succeed in stopping cigarette smoking than were those using no aid.[22]

The third 2016 meta-review published in *The International Journal of Public Health* drew on five studies that met these researchers' inclusion criteria.[23] Unlike the other two meta-reviews, this study included three analyses that focused on the short-term impact of e-cigarettes on cigarette smoking as well as the long-term effects. Their analysis of short-term effects found statistically significant evidence that e-cigarettes containing nicotine reduced people's desire to smoke regular cigarettes, compared to placebo e-cigarettes without nicotine. The authors also pooled the long-term analyses and found that people who used e-cigarettes with nicotine were 2.02 times more likely to stop smoking regular cigarettes than those using placebo e-cigarettes without nicotine. In addition, among those people who continued to smoke cigarettes, those who had used e-cigarettes with nicotine modestly reduced their regular cigarette smoking compared to those using the placebo e-cigarettes.

Since those three meta-reviews were issued, *The New England Journal of Medicine* published another major study in 2019 based on a randomized control trial. This recent analysis provides the strongest evidence thus far that e-cigarettes are a viable device for reducing cigarette smoking among those trying to stop smoking. The study is based on 886 participants in a British smoking cessation program, who were randomly assigned to use a traditional nicotine replacement product of their choice, such as a nicotine patch, nicotine gum or nicotine lozenge, or their choice of e-cigarettes. In all cases, the program supplemented the smoking cessation devices with supportive meetings. After one year, the rate of sustained cigarette abstinence was 9.9 percent among those using a traditional nicotine replacements product, compared to 18.0 percent for those using e-cigarettes: Among people who had wanted to stop smoking, those using e-cigarettes were 82 percent more likely to stay off cigarette smoking for at least one year than those using nicotine patches, gums or lozenges. This study showed clearly that e-cigarettes can be a valuable tool for public health officials trying to help people stop smoking.[24]

The View in Other Countries

The country that most aggressively promotes e-cigarettes as an effective tool to help people stop smoking is the United Kingdom. The U.K. government has urged organizations offering stop smoking and smoking prevention services to explicitly tell smokers that e-cigarettes are a viable way for them to quit smoking. Further, Public Health England has found that "the evidence does not support the concern that e-cigarettes are a route into smoking among young people"[25] and estimates that using e-cigarette is 95 percent safer than smoking regular cigarettes.[26]

While a number of developing countries ban e-cigarettes, including Argentina, Cambodia, the Philippines, and Saudi Arabia,[27] the regulatory approach in developed countries ranges from strongly supportive as in the U.K. to mildly supportive or agnostic.[28] In France, the High Council of Public Health publicly touts e-cigarettes as an effective smoking cessation

device.[29] The Canadian government also encourages people to switch from regular to e-cigarettes if they are unable to stop smoking without using a nicotine product.[30] And Norway strictly limits the use of all tobacco products and bars imports of any form of tobacco that does not have plain packaging – except e-cigarettes and other devices if they have been classified as "medicinal products" or "tobacco surrogates."[31]

Similarly, a number of other countries tax electronic cigarettes at lower rates than conventional cigarettes, including Italy, Portugal, Bulgaria and Croatia.[32] Their approach suggests that those governments believe that e-cigarettes entail less societal harm than regular tobacco products. In much the same way, Japan applies more lax restrictions to e-cigarettes than to regular cigarettes.[33] Finally, some nations, most prominently Germany, remain agnostic about e-cigarettes, taxing and regulating them as they do other tobacco products.[34]

Finally, the World Health Organization (WHO) reported in 2016 that e-cigarettes pose lower health risks than combustible cigarettes and cited suggestive evidence that use of e-cigarettes can help current smokers quit tobacco products.[35] The WHO also held that more evidence was needed to establish the full health effects of e-cigarettes and whether its' use by youth leads some to smoke regular cigarettes. As noted earlier, we used more recent data and found no evidence of a "gateway effect" among young Americans.

Our Empirical Evidence of the Impact of E-Cigarettes on Efforts to Stop Smoking

We earlier examined the CDC data showing clearly that the use of e-cigarettes jumped from 2013 to 2014 and continued to rise through 2017. Given those data, we begin our empirical analysis of e-cigarettes' impact on smoking cessation efforts by comparing actual cigarette smoking rates from 2014 to 2017 as the use of e-cigarettes increased, with a mathematical projection of cigarette smoking rates from 2014 to 2017 if the five-year declining trend in cigarette smoking from 2010 to 2014 had simply been sustained from 2014 to 2017. If the use of e-cigarettes increases the success of smoking cessation efforts or simply substitutes for cigarettes, we should see a larger decline in cigarette smoking from 2014 to 2017 than would be expected based on declining rates from 2010 to 2014. In fact, the results clearly show that cigarette cessation rates accelerated significantly with increasing use of e-cigarettes.

We earlier examined the association between e-cigarette use and cigarette smoking among middle school and high school students. Here, we focus on trends in smoking rates among adults ages 18 to 24 and 25 to 44 from 2013 to 2017, because their rates of e-cigarette use are the highest of any adult age group. We note that this approach may underestimate the impact of e-cigarettes on cigarette smoking, because the use of e-cigarettes may have reduced cigarette smoking rates before 2014.

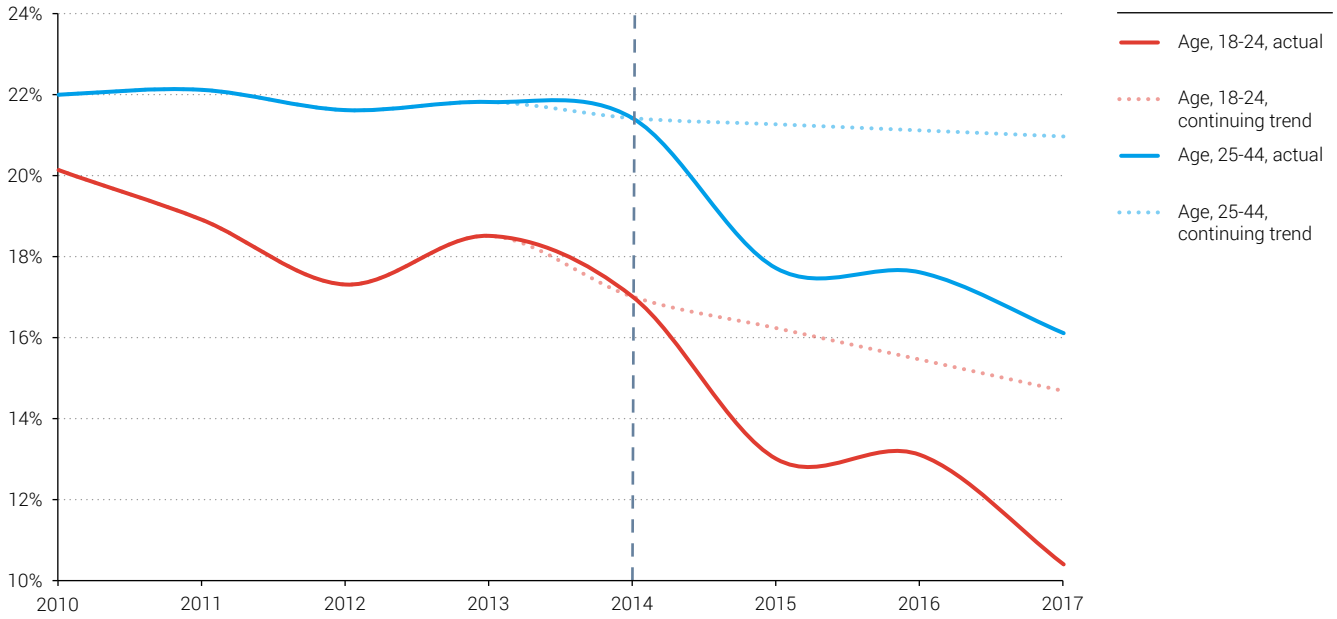
This analysis appears to demonstrate that the rising use of e-cigarettes has had a meaningful negative effect of cigarette smoking. The rate of cigarette smoking among people ages 18 to 24 declined from 20.1 percent in 2010 to 17.0 percent in 2014; and if that trend had continued, the rate of cigarette smoking among this group would have declined from 17.0 percent in 2014 to 14.7 percent in 2017 In fact, the data show that as the use of e-cigarettes by this age group increased, their rate of cigarette smoking declined from 17.0 percent in 2014 to 10.4

percent in 2017. If the 2010 to 2014 declining trend in cigarette use had continued through 2017, cigarette smoking among people ages 18 to 24 would have fallen nearly 14 percent from 2014 to 2017. The actual rate of decline from 2014 to 2017 was almost 39 percent. This clearly suggests that the rising use of e-cigarettes contributed, perhaps substantially, to a 4.3 percentage point reduction in cigarette smoking rates among this group over four years (10.4 – 14.7).

The results are similar among adults ages 25 to 44. The rate of cigarette smoking in this group declined from 22.0 percent in 2010 to 21.4 percent in 2014; and if that trend had continued for three more years, the group's rate of cigarette smoking would have fallen to 21.0 percent in 2017. In fact, the data show that as the group's use of e-cigarettes increased, their rate of cigarette smoking actually declined from 21.4 percent in 2014 to 16.0 percent in 2017. If the 2010 to 2014 trend had continued, cigarette smoking among people ages 25 to 44 would have fallen by less than 2 percent from 2014 to 2017; the actual rate of decline from 2014 to 2017 was more than 25 percent. This again suggests that the rising use of e-cigarettes, here among people ages 25 to 44, contributed substantially to a 5.0 percentage point reduction in cigarette smoking rates over four years.

These results are graphed in Figure 3, below: The dotted lines from 2014 to 2017 are the projected cigarette smoking rates based on the trends from 2010 to 2014, and the solid lines represent actual cigarette smoking rates from 2014 to 2017 as e-cigarettes use increased sharply.

FIGURE 3: CIGARETTE SMOKING RATES, 2010-2017, ACTUAL AND PROJECTED FROM FIVE-YEAR TRENDS FROM 2010 TO 2014, PEOPLE AGES 18 TO 24 AND 25 TO 44



The Role of E-Cigarettes, Cigarette Taxes, and Other Factors in Cigarette Smoking Rates

A number of factors could have contributed to the accelerating decline in cigarette smoking among these groups as well as among middle school and high school students over the same years that the use of e-cigarettes increased sharply. For example, cigarettes taxes increased in many places, the use of smoke free air laws and cigarette-free environments spread, and cigarettes and other tobacco products were withdrawn from many pharmacies.[36] It can be challenging to determine how much some factors affected cigarette smoking rates. However, it would be difficult to maintain that those factors that did not change from 2010 to 2017 helped drive the accelerating decline in cigarette smoking from 2014 to 2017.

One factor that did change was cigarette taxes: The average tax on a pack of cigarettes nationwide increased from $1.46 at the beginning of 2014 to $1.76 at the end of 2017 or by 20.5 percent.[37] Numerous academic analyses have studied the "price elasticity" for cigarette consumption – that is, how much a given price increase reduces consumption. The U.S. Public Health Service (USPHS) conducted a meta-review of the price elasticity literature and concluded that a 10 percent increase in the price of cigarettes should be expected to reduce cigarette consumption by 1.8 percent.[38] Using this finding, the 20.5 percent increase in cigarette taxes from January 2014 to December 2017 should be associated with an additional 3.7 percent decline in cigarette smoking by December 2017. For those ages 18 to 24, a group with a 17.0 percent smoking rate in 2014, we would expect that the cigarette tax increase reduced their smoking rate by 0.6 percentage-points to 16.4 percent. Similarly, among those ages 24 to 44, with a 21.4 percent smoking rate in 2014, the higher cigarette taxes should have reduced their smoking rate by 0.8 percentage points to 20.7 percent.

By contrast, smoke-free air laws and cigarette-free environments likely had little effect on the accelerating decline in cigarette smoking rates from 2014 to 2017. The USPHS has estimated that broad smoke free air laws banning cigarette smoking in worksites, restaurants and bars are associated with a 10 percent decline in cigarette use compared to areas with no smoke-free air laws. However, the USPHS also finds that those laws "have smaller effects if (other) smoke-free policies are already prominent."[39] Moreover, the laws addressing public cigarette smoking did not change in most states from 2013 to 2017. Some places such as Oklahoma had few restrictions throughout this period, while others such as California maintained strict policies before 2013 and through 2017.[40] Our review found that municipalities in 13 states adopted stronger restrictions on public smoking over this period, but many of those city-wide stricter policies occurred in states that already had strict smoke-free laws. On balance, there is no evidential basis to conclude that smoke free air laws and other policies promoting cigarette-free environments meaningfully affected the accelerating decline in cigarette smoking rates from 2014 to 2017.

Similarly, our analysis found that moves to ban cigarette sales in pharmacies during this period had at most a modest effect on smoking rates from 2014 to 2017. To be sure, researchers have found that banning cigarette sales in pharmacies can reduce cigarette smoking. One study estimated that the number of tobacco users in a municipality will decline 5.5 percent when a city bans all tobacco sales in pharmacies.[41] However, pharmacies in San

Francisco and Boston stopped selling cigarettes in 2008, and New York City pharmacies stopped selling cigarettes in 2019. While certain other municipalities in California and Massachusetts and one county in Minnesota banned pharmacy sales of cigarettes during the 2014-2017 period, their actions affected much too small a share of the nation's population to help explain the unusual decline in national smoking rates since 2014.

The most notable instance of banning cigarette sales in pharmacies during this period was the 2014 decision by CVS to stop selling cigarettes in all of its stores nationwide. Researchers who studied the impact of CVS's policy change found that among customers who purchased their cigarettes exclusively at CVS stores, their likelihood of giving up cigarettes after the CVS ban increased 38.2 percent in the following year.[42] Since the likelihood of quitting among all smokers is estimated at 2.8 percent per-year, CVS's policy raised the quit rate among CVS's exclusive cigarette customers to 3.91 percent. The researchers further found that 2.1 percent of U.S. smokers purchased their cigarettes exclusively from CVS. Therefore, we can estimate that the CVS ban on selling cigarettes in 2014 was associated with an additional 0.02 percentage point decline in cigarette smoking in 2015. We also should expect this effect to diminish in later years. If we posit that the effect declined by half each year, the CVS ban was associated with an additional 0.04 percentage-point decline in cigarette smoking from 2015 to 2017.

Researchers also have established that anti-tobacco media campaigns can contribute to declining cigarette use, although the USPHS has questioned the quality of some of those studies.[43] For its part, the USPHS estimates that a sustained high-intensity mass media campaign in places that had not been exposed to such a campaign before can reduce cigarette smoking by as much as 8 percent, However, since such campaigns were conducted for years prior to 2014 and then continued through the 2014 to 2017 period, there is no evidence that they contributed meaningfully to the accelerating decline in smoking rates from 2014 to 2017.

Bans on marketing cigarettes also have been associated with reductions in cigarette smoking rates. One study found that a complete ban on cigarette advertising reduces smoking rates by 4 percent, compared to no restrictions on cigarette ads.[44] The Truth Initiative, a nonprofit that promotes ending tobacco use in the United States, notes that most marketing bans have arisen from requirements under federal law and regulations; and the most recent major marketing restrictions went into effect in 2009 under the Family Smoking Prevention and Tobacco Act. Further, courts have found some recent state efforts to ban all forms of cigarette marketing violations of the First Amendment.[45] Again, there is no evidence to suggest that marketing bans played a role in the unusually rapid decline in cigarette use from 2014 to 2017.

Finally, we also consider the impact of Zyban, Chantix and their generics, FDA approved pharmacotherapies shown to decrease the incidence of cigarette smoking. The two medications have been available, respectively, since 1997 and 2006. While data on the number of Americans using these drugs or their generic counterparts are not publicly available, there is some evidence that their U.S. sales revenues increased. Pfizer reported that its U.S. sales of Chantix increased from $426 million in 2015 to $597 million in 2017.[46] However, Pfizer also more

than doubled the price of Chantix from 2013 to 2017, so sales revenues are not a reliable basis for estimating increased use.[47] All told, we will assume here that the use of anti-smoking pharmaceuticals increased sufficiently to explain at most 10 percent of the additional decline in smoking rates.[48]

All told, we estimate that the higher taxes on cigarettes and CVS's nationwide ban on cigarette sales reduced cigarette use from 2014 to 2017 by an additional 0.63 percentage points among Americans ages 18 to 24 and by 0.79 percentage-points among those ages 25 to 44. These findings suggest that the factors commonly-cited for the sharp drop in smoking rates from 2014 to 2017, apart from the sharp increase in the use of e-cigarettes, explain only a modest share of the decline in smoking rates from 2014 to 2017, relative to the trend from 2010 to 2014: 14.6 percent of the additional decline among 18-to-24 year-olds and 16.1 percent of the additional decline among 25-to- 44 year-olds. Finally, we estimate that increased use of anti-smoking pharmaceuticals may explain up to 10 percent of the additional decline in smoking pharmaceuticals. All told, other factors are required to explain roughly 75 percent of the additional decline in cigarette smoking from 2014 to 2017.

V. EMPIRICAL ANALYSIS OF THE IMPACT OF E-CIGARETTES ON SMOKING RATES, 2014 TO 2017

This analysis supports the assessment by Dr. David Levy, noted earlier, that the rising use of e-cigarettes over this period documented by the CDC was responsible for 60 percent to 80 percent of the accelerating decline in cigarette smoking from 2014 to 2017. For the purposes of this analysis, we can adopt the midpoint of Dr. Levy's estimate: Our analysis found that the other factors we identified can explain perhaps 25 percent of the additional decline in cigarette smoking, and we assume here that 70 percent of the additional decline in smoking rates from 2014 to 2017, beyond the declining trend in those rates from 2010 to 2014, is associated with the sharply rising use of e-cigarettes.

We acknowledge that factors not normally considered also may have affected smoking rates. For example, minorities and people without college degrees account for disproportionate shares of smokers, relative to their shares of the population. It is conceivable that employment, income or health dynamics affected these groups in particular ways that led them to quit smoking at higher rates than previously, a possibility that additional research could support or refute. For the purposes of this analysis, however, we cannot speculate further. Instead, we construct a thought experiment that assumes that 70 percent of the additional decline in cigarette smoking from 2014 to 2017, beyond its existing trend, was associated with the sharp increase in e-cigarette use. First, we project cigarette smoking rates from 2014 to 2017 if e-cigarettes had not been available and compare those rates to both smoking rates if the declining trend from 2010 to 2014 had continued and to the actual smoking rates. On this basis, we can estimate more precisely the impact of e-cigarettes on cigarette smoking rates. (Table 7 and Figure 4, below)

In 2014, 17.0 percent of Americans ages 18 to 24 smoked cigarettes. If the declining trend in their cigarette use from 2010 to 2014 had continued through 2017, plus the impact we found from rising cigarette taxes, the CVS sales ban, and the increased use of anti-smoking pharmaceuticals -- that is, in a world without e-cigarettes -- we estimate that the cigarette

smoking among this group would have fallen from 17.0 percent in 2014 to 13.4 percent by 2017. However, the CDC data show that the cigarette smoking rate of this group actually fell to 10.4 percent. Based on our analysis, it is reasonable to conclude that the rising use of e-cigarettes can help explain 3.0 percentage-points of the actual 6.6 percentage-point decline in cigarette smoking by this group, or 922,301 people.

Similarly, in 2014, 21.4 percent of Americans ages 25 to 44 smoked cigarettes. In a world without e-cigarettes, we estimate that based on the existing falling trend and the impact of higher taxes, the CVS ban and greater use of anti-smoking drugs, the cigarette smoking rate of this group would have fallen from 21.4 percent to 19.5 percent in 2017. Instead, CDC data show that this group's cigarette smoking rate actually fell to 16.1 percent.[49] Based on this analysis, we estimate that the rising use of e-cigarettes helps to explain 3.4 percentage-points of the actual 5.3 percentage-point decline in cigarette smoking among this group from 2014 to 2017.

Based on our analysis and this thought experiment, we estimate that the sharp increase in the use of e-cigarettes from 2014 to 2017 can help explain 3.3 percentage points of the actual 6.5 percentage-point decline in cigarette smoking from 2014 to 2017 among people ages 18 to 44. The total number of cigarette smokers ages 18 to 44 declined from 23,331,249 in 2014 to 17,064,789 in 2017, or by 6,266,460. Based on the declining trend in cigarette smoking from 2010 to 2014 plus the three additional factors identified earlier (higher cigarette taxes, the CVS sale ban, and increased use of anti-smoking pharmaceuticals), we should have expected the number of cigarette smokers to decline to 20,909,620 in 2017, or by 2,421,620. Therefore, we estimate that the rising use of e-cigarettes helps explain the additional 2,922,540 decline in cigarette smokers from 2014 to 2017. (See Table 7B and Figure 4, below)

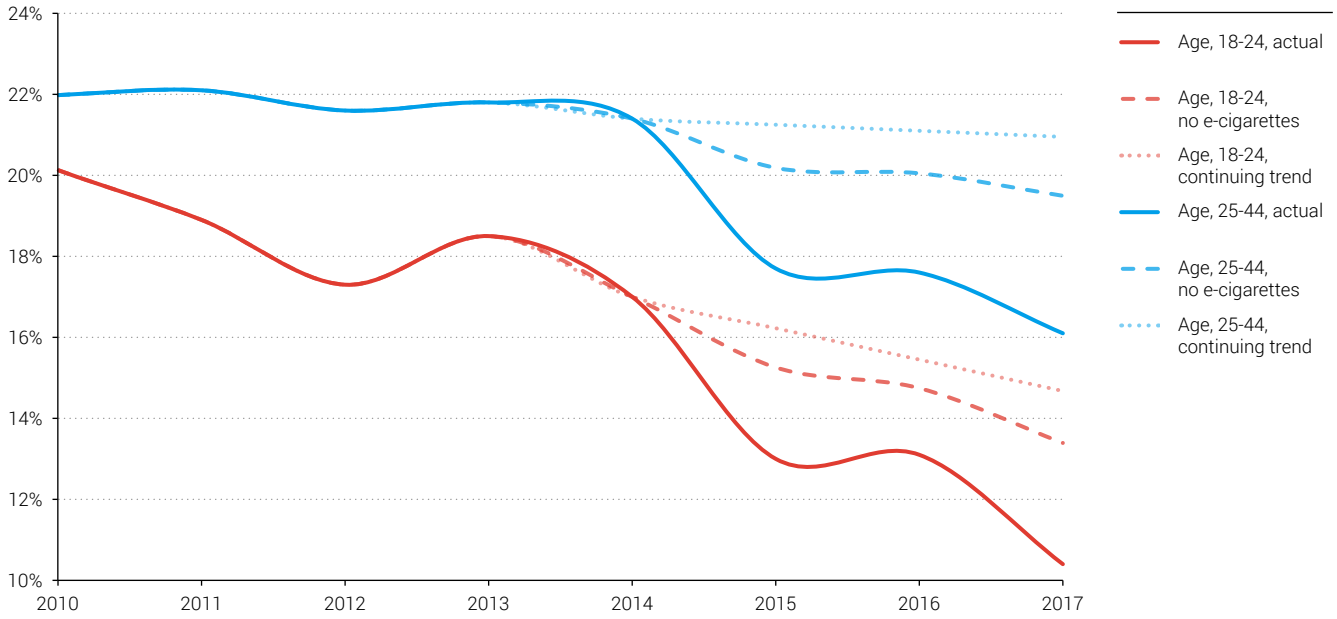
TABLE 7A: IMPACT OF E-CIGARETTE USE ON CIGARETTE SMOKING RATES, AGES 18-24 AND 25-44:
THE CIGARETTE SMOKING RATE IN 2014; PROJECTED 2017 SMOKING RATE BASED ON THE DECLINING TREND IN SMOKING FROM 2010 TO 2014; PROJECTED 2017 SMOKING RATE BASED ON THE PREVIOUS TREND AND OTHER ANTI-SMOKING FACTORS; AND THE 2017 SMOKING RATE INCLUDING THE IMPACT OF E-CIGARETTES

AGE	SMOKING RATES, 2014	SMOKING RATES 2017 BASED ONLY ON 2010-2014 TREND	SMOKING RATES 2017 BASED ON 2010-2014 TREND + OTHER FACTORS	SMOKING RATES, 2017, WITH ALSO E-CIGARETTES	IMPACT OF E-CIGARETTES ON 2017 SMOKING RATES
18-24	17.0%	14.7%	13.4%	10.4%	**3.0 pts.**
25-44	21.4%	21.0%	19.5%	16.1%	**3.4 pts.**
TOTAL	20.2%	19.3%	17.9%	14.6%	**3.3 pts.**

TABLE 7B: IMPACT OF E-CIGARETTE USE ON NUMBERS OF CIGARETTE SMOKERS, AGES 18-24 AND 25-44: THE NUMBER OF CIGARETTE SMOKERS RATE IN 2014; PROJECTED 2017 SMOKERS RATE BASED ON THE DECLINING TREND IN SMOKING FROM 2010 TO 2014; PROJECTED 2017 SMOKERS BASED ON THE PREVIOUS TREND AND OTHER ANTI-SMOKING FACTORS; AND THE NUMBER OF CIGARETTE SMOKERS IN 2017, INCLUDING THE IMPACT OF E-CIGARETTES

AGE	NUMBER OF SMOKERS, 2014	SMOKERS, 2017, BASED ON 2010-2014 TREND	SMOKERS, 2017, BASED ON 2010-2014 TREND + OTHER FACTORS	SMOKERS, 2017, WITH ALSO E-CIGARETTES	IMPACT OF E-CIGARETTES ON NUMBER OF SMOKERS IN 2017
18-24	5,348,907	4,522,895	4,127,624	3,205,323	**- 922,301**
25-44	17,982,342	18,034,523	16,782,006	13,859,466	**- 2,922,540**
TOTAL	23,331,249	22,557,418	20,909,629	17,064,789	**- 3,844,840**

FIGURE 4: CIGARETTE SMOKING RATES, INCLUDING THE IMPACT OF E-CIGARETTES, BY AGE, 2010-2017: ACTUAL RATES; PROJECTED RATES FOR 2014-2017 BASED ON 2010-2014 TREND; AND PROJECTED RATES IF E-CIGARETTES HAD NOT BEEN AVAILABLE



These projections and estimates are highly consistent with the underlying data reported by the CDC: Cigarette smoking rates fell precipitously (the solid lines in Figure 4) over the same years that e-cigarette usage rates increased sharply. The decline was much greater than one could have expected based on the declining trend in cigarette smoking from 2010 to 2014, and significantly greater than could have been expected based on that trend plus additional factors other than e-cigarettes. The most reasonable explanation consistent with all of the data is that most or all of the remaining difference is the result of the sharply increased use of e-cigarettes.

VI. BENEFITS ASSOCIATED WITH REDUCTIONS IN CIGARETTE SMOKING TIED TO E-CIGARETTE USE

Skeptics of e-cigarettes often focus on the fact that like combustible cigarettes, e-cigarettes contain the addictive chemical nicotine. However, e-cigarette vapors do not contain acetaldehyde, a chemical produced from burning sugars added to cigarettes and which contributes to tobacco addiction.[50] Further, the nicotine in the vapors of e-cigarettes makes them an effective tool for some people trying to stop smoking, since it satisfies their existing nicotine cravings. More important, e-cigarette vapors do not contain numerous carcinogens found in cigarette smoke, including tar, hydrogen cyanide, formaldehyde, lead, arsenic, ammonia, benzene, carbon monoxide, nitrosamines, and polycyclic aromatic hydrocarbons (PAHS).[51] While the vapors from some e-cigarettes contain trace amounts of nickel, chromium and cadmium,[52] research on the health impact of inhaling vapors with those elements has not established the adverse health effects linked to cigarette smoking. To be sure, more research on the long-term health costs and benefits of e-cigarettes is needed to inform the growing public debate around their use.

Healthcare and Other Costs Associated with Cigarette Smoking

At this time, public health authorities in the United Kingdom have estimated that e-cigarettes eliminate 95 percent of the health dangers of regular cigarette smoking.[53] In this context and drawing on our findings that e-cigarettes played a role in as much as 70 percent of the additional decline in cigarette smoking by Americans from 2014 to 2017, we will estimate the health-related implications and savings or costs of that role.

CDC data show that cigarette smoking causes more than 480,000 deaths per-year among Americans, including more than 41,000 deaths associated with secondhand smoke exposure, and that another 16 million Americans live with smoking-related diseases.[54] The CDC also has estimated that smoking-related diseases generate nearly $170 billion in direct annual medical costs and another $156 billion in productivity-related costs.[55] The productivity losses reflect smokers' premature deaths and, at work, their heightened absenteeism and presenteeism as well as time lost to smoking breaks.

Researchers have analyzed smoking-related costs for several decades. A study issued in 1984 found that the average lifetime costs of lung cancer, coronary heart disease and emphysema for 40-year-olds were $20,000 higher among light smokers than nonsmokers and $56,00 higher among heavy smokers compared to nonsmokers (1982 dollars).[56] Twenty years later, researchers calculated that the lifetime social costs linked to a lifetime of smoking by a 24 year old were $220,000 for men and $106,000 for women (2000 dollars), with 82.5 percent of those costs borne by the smokers, 13.8 percent by smokers' relatives, and 3.8 percent by society.[57] In 2015, a major study found that the treatment of smoking related illnesses accounted for 8.7 percent of U.S. healthcare spending,[58] or an estimated $303.8 billion in 2017.[59] Finally, a 2019 analysis explored the "opportunity costs" of smoking – the costs from diverting resources from productive purposes such as investment to smoking-related uses. The authors found that the opportunity costs of a lifetime smoker ranged from $1.4 million to $2.9 million, depending on where the smoker lived.[60]

Other analysts have found that smokers' average lifetime healthcare costs are less than those costs for comparable nonsmokers, because nonsmokers live longer and therefore experience more later-in-life illnesses and injuries. Researchers for a 1990 study calculated the lifetime healthcare costs for people in five-year age cohorts ranging from 35 to 79 and different levels of smoking intensity, compared to comparable nonsmokers.[61] Their analysis divided both men and women into 27 discrete groups and found that all 27 groups of male smokers and 25 of 27 groups of female smokers had lower lifetime healthcare costs than their nonsmoking counterparts. These researchers also calculated the cost impact of quitting smoking at different ages and different smoking intensity levels and found that 24 of the 27 groups of men and 21 of the 27 groups of women had higher healthcare costs after quitting than comparable people who stopped smoking. Similarly, a study from the Netherlands found that the lifetime healthcare costs of nonsmokers were 15 percent greater among men and 18 percent greater among women than among otherwise comparable smokers.[62]

Calculations of the lifetime healthcare costs of smokers versus comparable nonsmokers are affected by medical advances that continue to extend life among both smokers and nonsmokers and the development of costly new treatments for conditions that predominantly affect older people. As a result, some studies that also take account of differences in average lifespans for smokers and nonsmokers reached an opposite conclusion. A study from 1992 analyzed data from the National Health Interview Survey and estimated that each one million new smokers increased national healthcare costs by $9 billion to $10 billion (1990 dollars).[63] Similarly, a more recent study from China found that smoking increased China's healthcare costs by $6.2 billion in 2008.[64]

The Healthcare Implications of E-Cigarette Use

If the use of e-cigarettes reduces the incidence of cigarette smoking, as we and others have found, the recent sharp increase in e-cigarette use carries significant implications for the health of Americans and the costs of their healthcare. Several recent studies have examined these issues.[65] One analysis used a dynamic model with a range of scenarios to estimate the health effects of e-cigarettes: Under a worst-case scenario, e-cigarettes increased the total years of life of Americans by 580,000 years by 2070, while the best-case scenario found that e-cigarettes led to 3.3 million additional years of life.[66] Another study estimated the number of lives saved by the year 2100 if all cigarette smokers shifted to e-cigarettes over the next decade. Under an optimistic scenario, the shift would prevent 6.6 million premature deaths and increase the population's combined lifespan by 86.7 million years, while the pessimistic scenario found that the change averted 1.6 million premature deaths and added 20.8 million years to the population's combined lifespan.[67]

We will use our findings of the impact of e-cigarettes on smoking rates to produce new estimates of their healthcare cost implications. To begin, we adopt the results of a recent analysis of the impact of cigarette smoking on *per-capita* healthcare costs by the Congressional Budget Office (CBO).[68] This study divides the U.S. population into the age groups used by the CDC and by smoking status. CBO's findings (2008 dollars) are summarized in Table 8, below.

TABLE 8: ANNUAL *PER CAPITA* HEALTHCARE SPENDING BY SMOKING STATUS AND AGE OVER THE PERSON'S EXPECTED LIFETIME, $2008[69]

SMOKING STATUS	AGE				
	18–24	25–44	45–64	65–74	75 OR OLDER
CURRENT SMOKER	$2,010	$2,850	$5,540	$7,940	$8,750
EX-SMOKER FOR LESS THAN 5 YEARS	$2,000	$3,090	$7,650	$11,250	$15,530
EX-SMOKER FOR 5 TO 14 YEARS	NA	$2,920	$6,580	$9,760	$12,280
EX-SMOKER FOR 15 YEARS OR MORE	NA	$3,330	$6,290	$9,330	$11,770
NONSMOKER	$1,870	$2,570	$5,040	$7,790	$9,810

For our analysis, we first adjust those results from 2008 dollars to 2017 dollars. We also assume here that in each age group, the healthcare costs are those of a person of median age in each group. For example, the healthcare costs of people ages 18 to 24 are taken to be those of a 21-year-old with the life expectancy of a 21-year old smoker, ex-smoker or nonsmoker. We also apply the estimate that 2.8 percent of smokers ages 18 and over quit smoking each year.

In addition, we re-designate the "nonsmoker" category to e-cigarette users, using an appropriate adjustment drawn in part from the conclusion by Public Health England that e-cigarette smoking is 95 percent safer than smoking combustible cigarettes.[70] We are more conservative and assume with other researchers that e-cigarette smoking is 90 percent safer than smoking combustible cigarettes.[71] Therefore, if CBO estimated the annual healthcare costs of nonsmokers at $100 and smokers at $200, we would estimate an annual healthcare costs for e-cigarette smokers at $110. Our adjusted healthcare cost estimates, in 2017 dollars, are presented below in Table 9.

TABLE 9: ANNUAL *PER CAPITA* HEALTHCARE SPENDING BY SMOKING STATUS AND AGE OVER THE PERSON'S EXPECTED LIFETIME, ADJUSTED FOR E-CIGARETTE USE AND $ 2017

SMOKING STATUS	AGE				
	18–24	25–44	45–64	65–74	75 OR OLDER
CIGARETTE SMOKER	$2,624	$3,721	$7,233	$10,366	$11,424
EX-SMOKER FOR LESS THAN 5 YEARS	$2,611	$4,034	$9,988	$14,688	$20,276
EX-SMOKER FOR 5 TO 14 YEARS	NA	$3,812	$8,591	$12,743	$16,033
EX-SMOKER FOR 15 YEARS OR MORE	NA	$4,348	$8,212	$12,181	$15,367
E-CIGARETTE USER	$2,460	$3,392	$6,645	$10,190	$12,808

Consistent with some of the studies noted earlier, CBO estimates that the *per capita* healthcare costs of former smokers are higher than those of continuing smokers. In addition to longer lifespans, costly medical issues persuade some smokers to finally quit smoking. As noted earlier, however, other researchers have found that lifetime healthcare costs are still lower among ex-smokers than among current smokers if those ex-smokers remain cigarette-free for several years.[72]

Our analysis of healthcare costs also takes account of the indisputable evidence that smokers on average have shorter lifespans and higher mortality rates than nonsmokers, or here e-cigarette users. In particular, we draw on a 2013 study published in the *New England Journal of Medicine*. The researchers estimated the survival probabilities for smokers and "never" smokers between the ages of 25 and 80 and compared the likelihood of death of never smokers and several categories of ex-smokers (those who quit before age 25, and those who between the ages of 25 and 34, 35 and 44, 45 and 54, and 55 and 64).[73] We also use CDC data to extend the probabilities of death of the different categories of smokers and ex-smokers beyond age 80 to age 95.[74]

Using all of these data, we estimate the likelihood of a person's death by his or her age and smoking status. Those results are presented below in Table 10:

TABLE 10: CIGARETTES AND LIFESPAN: LIKELIHOOD OF BEING ALIVE BY SMOKING STATUS AND AGE

AGE	NEVER SMOKED / E-CIGARETTE USER	QUIT SMOKING, AGES 35 TO 44	QUIT SMOKING, AGES 45 TO 54	QUIT SMOKING, AGES 55 TO 64	SMOKERS WHO NEVER QUIT
30	99.3%	99.1%	98.9%	98.8%	98.7%
35	98.9%	98.7%	98.4%	98.1%	98.0%
40	98.5%	98.2%	97.8%	97.4%	97.3%
45	97.3%	96.7%	95.9%	95.2%	95.0%
50	96.0%	95.2%	94.0%	93.0%	92.7%
55	94.8%	93.7%	92.2%	90.9%	86.6%
60	93.5%	92.2%	90.3%	88.7%	80.5%
65	88.8%	86.5%	83.2%	80.4%	70.6%
70	84.0%	80.8%	76.2%	72.2%	60.7%
75	74.8%	69.7%	62.4%	56.1%	45.9%
80	65.5%	58.6%	48.6%	40.0%	31.2%
85	47.6%	42.6%	35.3%	29.1%	22.7%
90	27.7%	24.8%	20.5%	16.9%	13.2%
95	11.1%	9.9%	8.2%	6.8%	5.3%

Using this matrix, we next estimated the average annual *per capita* healthcare costs for each year people in each group are expected to live, based on whether they are current smokers, ex-smokers who stopped within the previous four years, ex-smokers who stopped in the previous five to 14 years, ex-smokers who stopped more than 15 years prior, or are e-cigarette users (never smokers with the appropriate adjustment described earlier.).

We earlier estimated that 922,301 people ages 18 to 24 in 2017 used e-cigarettes and otherwise would likely have been cigarette smokers, but for the increase in e-cigarette use. (See Table 7, above, and accompanying analysis.). For that cohort, we estimated their associated healthcare savings or costs for each year of their expected lifespan. For example, to estimate their 2018 healthcare costs, we first take account of the number of people expected to die from 2017 to 2018: Based on mortality rates, 1,291 would be expected to die in that year, leaving a cohort of 921,010 e-cigarette users in 2018 who otherwise would have been cigarette smokers. Next, we take account of the pre-2014-2017 rate of smoking cessation: Based on those rates, 26,044 would have quit smoking in that year, leaving 894,966 e-cigarette users who otherwise would have been smokers in 2018.

Using CBO's healthcare cost estimates by age and smoking status, we can now estimate that but for e-cigarettes, the 2018 healthcare costs for this cohort would have totaled $2.42 billion: $2.35 billion (894,966 * $2,624) + $68.01 million (26,044 * $2,611) = $2.42 billion. However, since this cohort used e-cigarettes instead of smoking regular cigarettes, we estimate that only 728 would have died in that year, leaving 921,573 people alive in 2018; and their 2018 healthcare costs would have been $2.27 billion (921,573 * $2,460). Therefore, we can associate $149.6 million in 2018 healthcare savings for this group as well as 563 lives (1,291 – 728) to e-cigarettes. Table 11 below summarizes the results of these calculations.

TABLE 11: 2018 HEALTHCARE COSTS FOR E-CIGARETTE USERS, AGES 18 TO 24, WHO OTHERWISE WOULD HAVE SMOKED CIGARETTES, ($ 2017)

WITHOUT THE INCREASE IN E-CIGARETTE USE		E-CIGARETTES USERS INSTEAD OF CIGARETTE SMOKERS
CIGARETTE SMOKERS	NEW NONSMOKERS	
894,966	26,044	921,573
$2,624/person	$2,611/person	$2,460/person
$2,416 million		**$2,348 million**

We calculated the healthcare cost savings from the use of e-cigarettes by this age group for each year through their expected lifespans, based on whether or not they were or had been regular cigarette smokers. (The complete data sets tracing each year's savings are available on request.) Here are our calculations for two other years (2061 and 2081) over the expected lifespans of this cohort of people who were ages 18 to 24 in 2017.

This cohort of 922,301 people in 2017 who used e-cigarettes but otherwise would have been cigarette smokers would be ages 62 to 68 in 2061. If e-cigarettes never existed, by 2061, we would expect that 742,226 people in this cohort would be alive in 2061; and 460,594 of them would have quit smoking more than 15 years earlier, 74,529 would have quit smoking between five and 14 years earlier, another 22,725 would have quit smoking less than five years earlier, and 184,378 would still be cigarette smokers. The 2061 healthcare costs of this cohort, therefore, would total $8.81 billion (2017 dollars): $5,611 million (460,594 * $12,181) + $950 million (74,529 * $12,743) + $344 million (22,725 * $14,668) + $1,911 million (184,378 * $10,366). However, we designated this cohort of 18 to 24-year-olds in 2017 as e-cigarette users who otherwise would have become cigarette smokers. As a result, 818,542 of them would be alive in 2061, and their healthcare costs that year would total $8,341 million (818,542 * $10,190). Healthcare cost savings of $464 million for this cohort in 2061, as well as 76,316 additional people still living, can be closely associated with their e-cigarette use.

By 2081, this cohort would be in the twilight of their lives, ages 82 to 88. If this cohort had become cigarette smokers instead of e-cigarette users, we would expect 403,473 of them to be alive in 2081. Those people would include 270,029 who quit smoking more than 15 years prior to 2081, as well as 59,334 who quit smoking after age 65 or remained smokers throughout this long period. Their healthcare costs in 2081 would have totaled $4,827 million: $4,150 million (270,029 * $15,367) + $678 million (59,334 * $11,424). However, since this cohort used e-cigarettes instead of ever smoking regular cigarettes, we would expect 439,343 people to be living in 2081 with total healthcare costs in that year of $5,627 million (439,343 * $12,808). Additional healthcare costs for this cohort in 2081 that can be associated with e-cigarette use would total $1,478 million, principally because an additional 35,870 people would be alive in their eighties using healthcare resources.

All told, we estimate that the lifetime healthcare costs of this group of people ages 18 to 24 in 2017 who became e-cigarette users would total $382.0 billion (2017 dollars). If instead, they had become cigarette smokers at ages 18 to 24 – that is, if the additional decline in cigarette smoking rates from 2014 to 2017, as e-cigarette use increased sharply, had not occurred – we estimate that their lifetime healthcare costs would have totaled $393.7 billion. This calculation takes account of their expected rates of quitting smoking, healthcare costs for smokers and ex-smokers, and their expected mortality rates. For this group of 922,301 e-cigarette smokers ages 18 to 24 in 2017, the lifetime healthcare savings associated with their use of e-cigarettes 2017 is $11.31 billion.

We performed the same analysis for the larger cohort of 2,922,540 e-cigarette users ages 25 to 44 in 2017, who would have continued to smoke cigarettes in that period if the sharp increase in e-cigarette use from 2014 to 2017 had not occurred, and quitting smoking at average rates. Once again, we present here the healthcare cost calculations for three selected years. (Complete calculations are available on request.)

We start with the costs in 2018 for this cohort, as we did for the younger group. As we did for that younger cohort, we take account of the number of people in this older group who we would expect to die over that year, the number

we would expect to quit smoking cigarettes, and the healthcare costs by smoking status based on the CBO findings. We estimate that the additional 2018 healthcare costs for this older cohort associated with their e-cigarette use would total $896 million, principally because an additional 1,848 people would be alive and because CBO estimates that the healthcare costs of ex-smokers are greater than the costs of current smokers.

Next, we estimate the healthcare costs in 2048 for the older group who used e-cigarettes but otherwise would have remained cigarette smokers, when they would reach ages 62 to 68. Using the same model applied above for the younger cohort, we estimate that the additional healthcare costs for this group in 2048 that can be associated with the increased use of e-cigarettes in 2014-2017 would total $5,133 million. These additional costs largely reflect the healthcare costs for the additional 330,489 e-cigarette users in this group who would have died before reaching their mid-to-late sixties if they had begun smoking cigarettes in 2014-2017 instead of using e-cigarettes.

Finally, by the year 2068, this cohort would be in the twilight of their lives at ages 82 to 88. Applying our model, we estimate that the additional healthcare costs in 2068 associated with their e-cigarette use would total $8.79 billion, again reflecting the costs to care for the additional 500,865 people who likely would have died before reaching their mid-to-late eighties if they had started smoking cigarettes in 2014-2017 instead of using e-cigarettes.

All told, we estimate that the lifetime healthcare costs of this cohort of people, who were ages 25 to 44 in 2017 and who became e-cigarette users instead of cigarette smokers, would total $1,333.0 billion (2017 dollars). If instead they had remained cigarette smokers at ages 25 to 44 – that is, if the additional decline in cigarette smoking rates and the increased use of e-cigarettes from 2014 to 2017 had not occurred – we estimate that their lifetime healthcare costs would have totaled $1,048.5 billion. This calculation takes account of their expected rates of quitting smoking, healthcare costs for smokers and ex-smokers, and their expected mortality rates. For this group of 2,922,540 e-cigarette smokers ages 25 to 44 in 2017, the additional lifetime healthcare costs associated with their use of e-cigarettes 2017 is $284.5 billion.

Lastly, we take account of the value of the longer lives that e-cigarettes enjoy compared to cigarette smokers. We have estimated that their e-cigarette use would save 3.99 million years of life for the 18 to 24-year-old cohort and 17.09 million years of life for the 25 to 44 year-old-cohort. For the purposes of this analysis, we assign a reasonable economic value to each additional year of life associated here with using e-cigarettes instead of smoking cigarettes. According to a 2007 study, the Food and Drug Administration (FDA) applies values ranging from $100,000 to $500,000 for each year that a drug extend a person's life.[75] Using the lower end value of $100,000 in 2003 dollars, or $133,345 in 2017 dollars, we estimate that the value of the additional life-years associated with the increased use of e-cigarettes is $399.4 billion for the younger cohort and $1.71 trillion for the older group in 2003 dollars or, in 2017 dollars, $532.6 billion for the younger cohort and $2.8 trillion for the older group. (See Table 11, below.)

All told, the value of those additional years of life associated with our cohorts adopting e-cigarettes instead of smoking cigarettes

far exceeds the additional healthcare costs associated with their living longer: Among those ages 25 to 44 in 2017, the value of their additional years of life is some $2,279 million compared to the costs of their healthcare over those additional years of life, which comes to some $284.5 million. Across both age cohorts, the net health-associated lifetime gains from starting to use e-cigarettes in 2017 instead of smoking cigarettes exceed $2.5 trillion.

TABLE 12: LIFETIME HEALTHCARE SAVINGS OR COSTS FOR THE ADDITIONAL PEOPLE WHO TOOK UP E-CIGARETTES INSTEAD OF CIGARETTE SMOKING, 2014-2017, AND THE VALUE OF THEIR ADDITIONAL YEARS OF LIFE, BY AGE ($ MILLIONS, 2017 DOLLARS)

	18-24	25-44	TOTAL
HEALTHCARE SAVINGS/COSTS	$11,310.0	- $284,471.5	- $273,161.4
VALUE OF ADDITIONAL YEARS OF LIFE	$532,563.2	$2,278,899.1	$2,811,462.3
TOTAL	**$543,873.2**	**$1,994,427.6**	**$2,538,300.9**

Higher Productivity of E-Cigarette Users, Compared to Cigarette Smokers and Ex-Smokers

Economists have also found that smoking cigarettes affects a person's productivity. Research has shown that smokers are more susceptible to certain illnesses, so they miss work more often and are less productive if they come to work before they recover fully. They also take smoking breaks. A leading study of this issue, published in the *Journal of Occupational and Environmental Medicine*, analyzed a dataset of health conditions and their effects on people based on whether they were nonsmokers, ex-cigarette smokers or current smokers.[76] The researchers then estimated the annual productivity costs associated with those conditions for each group. They found that the conditions reduced an average person's annual productivity by $2,623 for nonsmokers, compared to $3,246 for ex-smokers and $4,430 for current smokers (2000 dollars). Therefore, ex-smokers were $623 less productive per-year than nonsmokers, current smokers were $1,807 less productive per-year than nonsmokers, and current smokers were $1,184 less productive per year than ex-smokers.

However, the use of e-cigarettes also may entail health-related costs. As noted earlier, Public Health England has estimated that e-cigarette use is 95 percent safer than cigarette smoking.[77] Since there are no studies yet of the long-term health effects of e-cigarettes, we again assume here that using e-cigarettes is 90 percent safer than smoking cigarettes, or twice the estimate from Public Health England. On that basis and adjusting the productivity estimates described above from 2000 dollars to 2017 dollars, we estimate that e-cigarette users are $820 more productive per-year than ex-cigarette smokers and $2,371 more productive per-year than current cigarette smokers, and that ex-smokers who shift to e-cigarettes are $1,554 more productive per-year than current smokers.

We will now apply these findings to our cohorts of people who took up e-cigarettes in 2014 to 2017 and otherwise would have become cigarette smokers: 922,301 people ages 18 to 24 in 2017 and 2,922,540 people ages 25 to 44. Based on the evidence disproving the gateway hypothesis, we assume here that e-cigarette users in the younger group never switched to cigarette smoking and so never suffered the harms from cigarettes that lower people's productivity, while the e-cigarette users in the older group quit smoking by taking up e-cigarettes. We also apply the current report by the Bureau of Labor Statistics that 73 percent of civilians ages 18 to 64 are employed.[78] Finally, for the younger group, we use their median age of 21, assume that they all work an additional 44 years,[79] and take account of CDC data showing that 2.8 percent of current smokers quit smoking annually.[80]

Using these assumptions and the findings from the 2006 study, we calculate that in 2018, the productivity savings associated with this younger cohort's use of e-cigarettes instead of cigarettes would total $1.57 billion. We also calculated the 10-year productivity implications of e-cigarette use, compared to cigarette smoking, for this group, for 2017 to 2027. Over those years, the productivity savings associated with their using e-cigarette instead of smoking cigarette (including those who smoked and then quit), would total $14.73 billion or an average of nearly $1.5 billion per-year.

We also calculated comparable estimates for the older group of 2,922,540 people ages 25 to 44 in 2017 who took up e-cigarettes but otherwise would have smoked cigarettes. We estimate that the productivity benefits in 2018 associated with their use of e-cigarettes instead of smoking came to total $3.22 billion. We further estimate that over the 10-year period, their productivity benefits would total $29.24 billion or an average of more than $2.9 billion per year.

Over the ten years from 2017 to 2027, therefore, we estimate that the use of e-cigarettes from 2017 to 2027 by these 3,844,841 people who otherwise would have been cigarette smokers will increase their collective productivity by $43.96 billion.

We can also calculate the healthcare savings and costs associated with the additional use of e-cigarettes instead of cigarette smoking over the 10-year period. The results show that the value of the additional productivity far exceeds the additional healthcare costs for the older group. (Table 12 below) All told, the 10-year productivity benefits of e-cigarette use by both groups who adopted e-cigarettes instead of smoking, net of any additional healthcare costs, total almost $17.4 billion for those ages 18 to 24 in 2017 and $13.6 billion for those ages 25 to 44 in 2017.

TABLE 13: 10-YEAR HEALTHCARE AND PRODUCTIVITY EFFECTS OF THE ADDITIONAL PEOPLE WHO TOOK UP E-CIGARETTES INSTEAD OF CIGARETTE SMOKING FROM 2014 TO 2017, BY AGE, 2017-2027 ($ MILLIONS, 2017 DOLLARS)

	AGES 18-24	AGES 25-44	TOTAL
HEALTHCARE SAVINGS/COSTS	$2,634.2	-$15,667.4	-$13,033.3
PRODUCTIVITY SAVINGS	$14,728.4	$29,235.6	$43,964.0
TOTAL	**$17,362.6**	**$13,568.1**	**$30,930.8**

VI. CONCLUSIONS

In this study, we examined the growing use of electronic cigarettes and its implications. The wide use of e-cigarettes is a very recent development, and issues regarding their long-term effects and significance cannot be fully analyzed at this time. Using CDC and other data covering the last decade, however, we examined the relationship between the recent sharp increase in e-cigarette use among Americans and the contemporaneous acceleration in the declining rate of cigarette smoking. We found that the sharp increase in e-cigarette use across many groups can explain as much as 70 percent of the accelerating decline in smoking rates. We also found no reasonable evidential basis for concerns that e-cigarettes are a gateway to cigarette smoking. We further found that e-cigarettes are highly effective in helping people stop smoking cigarettes.

Finally, we analyzed the impact of the sharp increase in e-cigarette use and the accelerating decline in cigarette smoking on healthcare costs and economic productivity. We found that while e-cigarette users incur lower healthcare costs than cigarette smokers or ex-smokers, the longer lifespans of e-cigarette users and ex-smokers who used e-cigarettes to quit smoking result in higher lifetime healthcare costs. However, we also found that the value of the additional years of life associated with using e-cigarettes instead of smoking is much greater than the additional healthcare costs. Lastly, we found that the increase in e-cigarette use and the associated reduction in smoking rates results in large productivity benefits, mainly from lower rates of illness.

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Endnotes

1 The authors gratefully acknowledge the support for this research provided by the Progressive Policy Institute. All of the analysis and views contained in this study are those solely of the authors.

2 Centers for Disease Control and Prevention-A (2018).

3 American Lung Association (2011).

4 Dana Farber Cancer Institute (2018).

5 Cummings and Proctor (2014).

6 Centers for Disease Control and Prevention-D (2019).

7 The rates of use of cigarettes, cigars, hookahs, and e-cigarettes sum to a larger total than "All Tobacco," because some people use more than one form of tobacco.

8 Centers for Disease Control and Prevention-B (2019).

9 Centers for Disease Control and Prevention-B (2019).

10 Soneji and Barrington-Trimis, et. al (2017).

11 Etter (2018).; Kozlowksi and Warner (2017).

12 Etter, (2018).

13 Frequent use is defined as having used the product at least 20 times in the past 30 days. Center for Disease Control and Prevention-C (2018).

14 Thompson (2018).

15 The CDC does not publish gross quit or cessation rates for cigarette smokers, and most researchers focus on cessation rates for particular groups, especially people trying to quit smoking. National Jewish Health-Denver, University of Colorado Hospital, a leading teaching hospital for respiratory illnesses and lung surgery, estimates that 2,8 percent of U.S. smokers successfully quit each year; and we rely on that estimate. See U.S. News & World Report – Health (2018).

16 Centers for Disease Control and Prevention-D (2019).

17 Ibid.

18 Ibid.

19 Kalkhoran and Glantz (2016). Twenty of the studies focused on adults, had smoking cessation as an outcome, and had a control group of smokers that did not use electronic cigarettes. Of those 20 studies, 15 were cohort analyses, three were cross-sectional studies, and two were clinical trials. Most of these studies focused on the United States, but several examined populations from the United Kingdom, New Zealand, Canada, Australia, and Italy.

20 Ibid.

21 Hartmann-Boyce. McRobbie et al (2016).

22 The authors could not conclusively determine whether e-cigarettes were more effective than nicotine patches.

23 Khoudigian, Devji, et al (2016).

24 Hajek and Phillips-Waller et al (2019).

25 Public Health England (2018).

26 Kmietowicz (2018).

27 McDonald, Jim (2019).

28 The exception is Singapore, where possession of regular or electronic cigarettes is a criminal offense.

29 Braillon (2018).

30 Government of Canada (2019).

31 Global Tobacco Control-A (2019).

32 Fruits (2018).

33 Global Tobacco Control-B (2019).

34 Global Tobacco Control-C (2019).

35 Conference of the Parties to the WHO Framework Convention on Tobacco Control (2016).

36 Thompson (2018).

37 Average statewide average for cigarette taxes was calculated by a weighted average where the weight was the number of cigarette smokers in a state in 2017. Data from Boon (2019).

38 Levy, Tam, et al (2018).

39 Ibid.

40 We use 2013 to account for any lag time from policy to impact.

41 Brennan, Shrank and Sussman (2014).

42 Polinski, Howell et al. (2017).

43 Levy, Tam, et al (2018).

44 Ibid.

45 Truth Initiative (2017).

46 Pfizer-A (2016) and Pfizer-B (2018).

47 Weintraub (2018).

48 In addition to Zyban and Chantix, the FDA has approved the use of nicotine replacement therapies such as gums, patches and lozenges. A meta-review of 267 studies found that nicotine replacement therapies increased short-term smoking cessation rates as much as 80 percent compared with a placebo, and the use of Zyban and Chantix had better results. The study also found that combining two NRT increased chance of cessation by the same amount that did varenicline. See Cahill, Stevens et al (2013).

49 71.4% is 1 minus the sum of pre-existing trends (13.7%) and non-e-cigarette abatement strategies (14.9%).

50 National Institute on Drug Abuse-A (2019).

51 American Cancer Society (2019).

52 National Institute on Drug Abuse-B (2019).

53 Kmietowicz, (2018).

54 Centers for Disease Control and Prevention -E (2019).

55 Centers for Disease Control and Prevention -F (2019).

56 Oster, Colditz and Kelly (1984).

57 Taylor (2011).

58 Xu, Bishop, Kennedy et. al. (2015).

59 Centers for Medicare and Medicaid Services (2019).

60 McCann (2019).

61 Lippiatt (1990).

62 Barendergt, Bonneux, and van der Maas (1997).

63 Hodgson, Thomas (1992).

64 Yang, Sung, et al. (2011).

65 We excluded one study, because it assumed an enormous gateway effect from e-cigarettes which our analysis rejects. The researchers posited that e-cigarettes would induce 2,070 adults to quit smoking per-year and lead 168,000 adolescents per-year who otherwise would not have smoked to become cigarette smokers. See Soneji, Sung et al (2018).

66 Warner and Mendez (2019).

67 Levy, Borland et al (2018).

68 Congressional Budget Office (2012).

69 The findings are expressed in 2008 dollars and regression-adjusted to control for as gender, race, education, marital status, and income.

70 Kmietowicz, (2018).

71 Warner and Mendez (2019).

72 For example, a study of HMO patients Washington, D.C. found that the healthcare costs of ex-smokers did exceed the costs for nonsmokers after they stopped smoking, but by the seventh year, healthcare costs were less among former smokers than current smokers. See Fishman, Kahn, et al (2003).

73 Jha, Ramasundarahettige, et al. (2013). Former smokers who quit before 35 were shown to have a lower mortality rate than never smokers, but the differences were not statistically significant. For our analysis, we assign the mortality rates of never smokers to those who quit before age 35. We also assume that smokers who quit after age 65 have the same health profiles as those who continue smoking throughout their lives

74 Centers for Disease Control and Prevention-G (2004).

75 Robinson, Lisa (2007).

76 Bunn, Stave et. al. (2006).

77 Kmietowicz (2018).

78 Bureau of Labor Statistics (2019).

79 Forty-four years assumes that everyone in the cohort was 21 (their median age) and worked until age 65.

80 We also assume here that no one in the cohort dies before age 55.

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