CENTER for BLACK EQUITY

THE MAJOR BENEFITS AND MODEST RISKS OF NICOTINE VAPING PRODUCTS

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FOREWORD

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In 1999, I founded the International Federation of Black Pride, known today as the Center for Black Equity (CBE).

At CBE, our mission is simple but important: to promote a multinational Black and LGBTQ+ network dedicated to improving health and wellness opportunities, economic empowerment, and equal rights while promoting individual and collective work, responsibility, and self-determination.

Over the years, the CBE has established a global network of Black and LGBTQ+ individuals, allies, and community-based organizations dedicated to achieving equality and social justice for our communities through economic, health, and social equity.

Today, the CBE takes another meaningful step towards this goal with the publication of a groundbreaking new study that will advance national health equity conversations on the critically important topic of tobacco harm reduction.

The study is authored by Dr. Robert J. Shapiro, noted economist and advisor to three Democratic presidential administrations.

Dr. Shapiro's first-of-its-kind analysis, detailed on the following pages, presents compelling new evidence that quantifies the economic benefits and improved health outcomes across demographic groups of switching from smoking to vaping. The study also examines and confirms existing research that e-cigarettes and other flavored vaping products are an effective tobacco harm reduction tool for adults looking to reduce or quit smoking.

Tobacco use is a critical topic for the CBE, as Black and LGBTQ+ communities smoke – and suffer the effects of smoking-induced cancer – at disproportionately high rates. Meanwhile, 90% of all lung cancer in the U.S. is caused by smoking cigarettes and is the No. 1 cause of preventable death in America.

The principal victims of smoking-related deaths are marginalized populations. That this is not more often discussed reflects the challenges marginalized communities face to ensure that conversations about health equity are measured against improved health outcomes.

More vaping means less smoking. And less smoking means less cancer, especially for Black and LGBTQ+ Americans.

Supporting access to a variety of tobacco harm-reduction products – including vaping products – is consistent with science-based harm reduction and health equity strategies that will lead to more adults quitting smoking, result in fewer cancer diagnoses, and will eliminate the most preventable and persistent cause of cancer in the United States.

Dr. Shapiro's research demonstrates that the risks of vaping are significantly lower than those of smoking. Because marginalized communities smoke at higher rates, the benefits of shifting from smoking to vaping will be felt most acutely among the communities most at-risk – Black and LGBTQ+ populations. This is the definition of health equity, and Americans deserve regulatory policies that allow choice rooted in science, not politics.

The CBE is calling on the U.S. Food and Drug Administration, including the Center for Tobacco Products, to reset its posture towards e-cigarette and vaping products by ensuring that adults have access to a variety of effective tobacco harm-reduction options, including flavored e-cigarette and vaping products. This is critical if the agency intends to effectively pursue both tobacco harm reduction and health equity, particularly for vulnerable populations.

The CBE will be submitting Dr. Shapiro's report to the FDA and CTP to inform the government's thinking as the agency prepares important updates to its tobacco regulatory strategy. Unfortunately, government agencies are allowing misinformation to perpetuate health equity disparities in regulatory policy. I am confident that the CBE's work with Dr. Shapiro will drive critical conversations that will lead to improved health outcomes for at-risk Black and LGBTQ+ communities.

EARL D. FOWLKES, JR.
President and CEO

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Executive Summary

Vaping rates in recent years have declined substantially among adolescents and remained modest among adults, and vaping by both groups was accompanied by falling smoking rates.

- In 2021 and 2022, 13 percent of high school students reported using vaping products in the previous month, down from 27 percent in 2018 and 2019, and less than 4 percent vaped daily. Over the same period, their smoking rates fell from 8 percent to 2 percent.
- The availability of non-tobacco flavors in e-cigarettes now plays a very modest role in adolescent vaping: In 2021 and 2022, 56 percent of adolescents who had vaped cited the influence of friends as their reason, versus 14 percent who cited flavors; and in 2022, barely 6 percent of current adolescent e-cigarette users said they vaped for the flavors.
- From 2018 to 2022, an average of 5 percent of adults used vaping products in the previous month and only 3 percent used them daily, and their use was closely related to the decline in adult smoking rates from 13.8 percent to 11.5 percent over the four years.

The acceleration in the downward trend in adult smoking rates over the past decade was closely associated with vaping.

- Based on the rate of decline in the adult cigarette smoking rate from 2002 to 2010, we would have expected that rate to fall to 16.2 percent by 2022—but with the rising use of e-cigarettes from 2010 onward, the adult smoking rate fell to 11.3 percent by 2022.
- We tested factors other than vaping and found that the accelerated decline in smoking rates since 2010 cannot be explained by rising cigarette taxes and price, the Food and Drug Administration (FDA) ban on flavored cigarettes, or use of nicotine gums and patches.
- Two factors did contribute moderately to the new trend: The CDC's Tips anti-smoking campaign and increased access to anti-smoking services under the Affordable Care Act.

All told, the shift from cigarette smoking to vaping from 2010 to 2022 generated nearly $180 billion in healthcare savings and additional economic growth.

- Using econometric analysis that accounted for those factors and other unknown causes, we found that the introduction and use of vaping from 2010 to 2022 reduced the number of adult smokers by 6.1 million or an average of 510,000 people annually.
- This finding is consistent with extensive research and numerous studies showing that vaping is a very useful tool for reducing or stopping smoking, more effective than nicotine gums or patches, and flavored e-cigarettes are more useful and effective than tobacco-flavored vaping products.

This shift from smoking to e-cigarettes has provided largescale benefits because nicotine vaping carries much fewer health risks than smoking cigarettes.

- E-cigarettes contain none of the toxic ingredients in cigarettes, and many studies have found no evidence that vaping and the nicotine in e-cigarettes pose significant health risks.
- Public Health England, an executive agency of Britain's Department of Health and Social Care, has estimated that vaping carries 5 percent of the health risks of smoking.
- According to the Centers for Disease Control and Prevention (CDC), no reported fatalities have occurred from using commercial vaping products compared to an estimated 480,000 premature deaths annually linked to smoking.
- And among adolescents, vaping is one of the most benign forms of common "risky adolescent behaviors:" Less than 4 percent of high schoolers vape daily versus 6 percent who report abusing opioids, 5 percent who used ecstasy or cocaine, 11 percent did binge drinking, 16 percent who used marijuana, and over 10 percent who attempted suicide.

The lower smoking rates linked to vaping have saved thousands of lives and billions of dollars.

- Our analysis found that the shift from smoking to vaping by adults from 2010 to 2022 saved 113,300 people from premature deaths and could save 334,200 people by 2030.
- The 113,300 adult smokers who lived longer by shifting to vaping continued to contribute to the economy, adding an estimated $66 billion to GDP from 2010 to 2022.
- The shift to vaping by the other 6 million former smokers from 2010 to 2022 also saved an estimated $39 billion in healthcare savings and added $71 billion to GDP.
- All told, the shift from cigarette smoking to vaping from 2010 to 2022 generated nearly $180 billion in healthcare savings and additional economic growth.

The lives saved and economic benefits related to smokers shifting to vaping would have been greater, but for the negative media coverage of e-cigarettes:

- Despite the scientific evidence, only 11 percent of Americans in 2020 considered vaping less harmful than smoking while 63 percent saw vaping as equally or more harmful.

The potential benefits from people shifting from smoking to vaping are greatest among certain minority groups, including LGBTQ+ people and Black and Hispanic adults.

- LGBTQ+ adults could benefit greatly from measures urging them to shift from smoking

to vaping, since 15.3 percent smoke versus 11.4 percent of heterosexual adults. LGBTQ+ adults also may be more open to shifting since because they also currently vape at much higher rates than heterosexual adults—13.2 percent versus 4.1 percent.

- Black adults also could benefit greatly from steps to induce smokers to shift to vaping as 13.5 percent smoke versus 12.4 percent of white adults and 7.7 percent of Latino adults.
- Such measures also could greatly benefit Black and Hispanic adult smokers since they vape at such low rates—4.4 percent and 4.0 percent, versus 6.7 percent for white adults.
- Such measures also could raise the low quit rates of minorities since 13.3 percent of adult Blacks and 13.6 percent of adult Hispanics are ex-smokers versus 26.7 percent of whites.

The lives saved and economic benefits associated with vaping also would have been greater if the Food and Drug Administration (FDA) acknowledged and promoted its benefits.

- Despite the FDA's legal directive to approve only those tobacco products "appropriate for the protection of the public health," FDA regulations in 2016 exempted existing cigarettes and future equivalents from approval requirements, but not vaping products.
- FDA also does not allow e-cigarette makers to advertise that vaping poses less risk than smoking, that e-cigarettes do not contain the toxic ingredients in cigarettes, or, with few exceptions, that e-cigarettes can help people reduce or stop smoking.
- The FDA also has severely restricted vaping sales by approving only 23 related products and devices out of 6.7 million applications filed and 1.2 million reviewed by FDA, and no flavored vaping products have been approved despite their utility for stopping smoking.
- The FDA also has not clearly informed Americans about the relative risks of vaping and smoking and instead consistently states in public advertising campaigns that "no tobacco product is safe" and that vaping is dangerous to people's health.

The FDA should adopt evidence-based reforms to encourage adult smokers to shift to vaping:

- Public education campaigns to inform Americans about the relative risks and harm of smoking versus vaping and how to use e-cigarettes to reduce or stop smoking.
- Public education about those relative risks and harms should also target groups with the highest smoking rates, such as Black and LGBTQ+ populations.
- New labeling and marketing requirements for cigarettes and vaping products should publicize the relative risks and benefits for smokers of stopping or shifting to vaping.

Sales of non-tobacco flavored e-cigarettes to adults should be widely permitted.

- The nicotine levels of cigarettes should be capped below the level for e-cigarettes, the toxic emissions in cigarette smoke also should be capped, and cigarettes should be taxed at higher rates than e-cigarettes.

Introduction and Summary of Findings

The advent of e-cigarettes and the spread of their use by adolescents as well as adults have generated extensive public discussion and hundreds of scientific studies. Yet, much of the public debate is distorted by misconceptions and claims refuted by the research.

To begin, the incidence of vaping, including among adolescents, is considerably less than often assumed and has recently declined sharply. In 2021 and 2022, less than 13 percent of high school students reported vaping at some time in the preceding 30 days, down from more than 27 percent in 2018 and 2019.[2] Despite concerns that flavored e-cigarettes attract adolescents, surveys also show that flavorings are a minor factor for young people who vape. Recent data further show that most adolescent vapers use e-cigarettes irregularly: In 2021 and 2022, more than 70 percent of high school e-cigarette users reported vaping on less than a daily basis in the preceding month, including more than 37 percent who vaped less than five days in that month.[3] All told, less than 4 percent of high school students used e-cigarettes daily.

As a result, researchers have found that most young e-cigarette users are not nicotine dependent.[4] Moreover, the use of e-cigarettes by adolescents has been accompanied by very low cigarette smoking rates: In 2022, 2 percent of high school students reported smoking cigarettes in the previous month compared to more than 8 percent in 2018. (Throughout this study, "adolescents" and "high school students" cover young people in grades 9 to 12, consistent with CDC data.) The sense of crisis around vaping by young Americans spurred by some critics of e-cigarettes is unfounded.

The sense of crisis around vaping by young Americans spurred by some critics of e-cigarettes is unfounded.

Vaping is even more uncommon among adults, with an average of about 5 percent of adults reporting using e-cigarettes in the preceding 30 days from 2018 to 2022.[5] Over the same years, the share of adults that smoked cigarettes fell from 13.8 percent to 11.5 percent though remaining nearly six times the smoking rate of adolescents. Adults who smoke or vape also do so more regularly than

young people: About 60 percent of the 5 percent of adults who use e-cigarettes vape daily, twice the share of high school vapers, and nearly 90 percent of adult cigarette users reported smoking daily.[6]

The health effects of e-cigarettes also are commonly misunderstood. Because vaping and smoking share the ingredient nicotine, many people assume that the health risks of smoking apply to vaping. However, e-cigarettes contain none of the toxic ingredients found in cigarettes and do not produce the carcinogenic compounds inhaled from burning tobacco.

Across hundreds of peer-reviewed studies of the physiological effects of vaping, little evidence has emerged that e-cigarettes pose any substantial health risks, especially compared to smoking cigarettes.

Using e-cigarettes does physiologically affect a person's pulmonary and circulatory systems, as do most things people inhale or ingest. Studies have found that some people report headaches, sore throats, cough, or nausea from vaping. However, no study has established that the short-term physiological changes associated with vaping pose any serious risk. This conclusion is supported by a recent scholarly metareview of 400 studies on vaping and health: Its "key finding" was the "general paucity of evidence for the effects of nicotine ... and e-cigarettes on many major clinical outcomes, including cancer, cardiovascular, metabolic, mental health, developmental, reproductive, and neurological outcomes."[7]

Since e-cigarettes were introduced less than 15 years ago, scientists cannot say with any certainty whether absorbing nicotine through vaping poses any long-term risks. However, the disparity between the risks of smoking and vaping is well-established. The CDC estimates that cigarette smoking causes the deaths of more than 480,00 Americans annually[8] compared to no reported fatalities from using commercial e-cigarettes. The CDC and private researchers also have found no health consequences related to secondhand exposure to vaping,[9] in contrast to the CDC's estimate that exposure to secondhand cigarette smoke is linked to 34,000 premature deaths per year from heart disease, 7,600 premature deaths from lung cancer, and increased incidence of sudden infant death syndrome and other respiratory conditions in children.[10]

Neuroscience also provides important insights into why many adolescents experiment with vaping. Scientists have found that physiological changes in the brain during puberty predispose adolescents to sensation-seeking activities and situations—and among those common behaviors, vaping is the most benign. In 2021, while some 4 percent of high school students reported vaping daily over the previous 30 days, 6 percent reported abusing opioids, 10.5 percent reported binge drinking, and nearly 16 percent reported using marijuana.[11] More than 5 percent of high schoolers also used ecstasy or cocaine over the preceding year, 14 percent reported being victims of dating violence and, most disturbing, 13 percent of female high school students and nearly 7 percent of male high schoolers reported having attempted suicide in the previous year.[12]

Without long-term data on people who vape regularly for many years, scientists cannot say that using e-cigarettes poses no long-term risks. But they can agree that the health risks of vaping are a small fraction of the risks from smoking. Public Health England, for example, estimated that vaping carries about 5 percent of the risk of smoking cigarettes, and other estimates range up to no more than 15 percent.[13]

E-cigarettes also can provide benefits: There is substantial scientific evidence that vaping can help people cut down or stop smoking. Dr. Eric Lindblom, former head of the Office of Policy for the FDA's Center on Tobacco, has noted that "research indicates that using e-cigarettes, either exclusively or through dual use, can help smokers to quit smoking, or even prompt some smokers not trying to quit to reduce their smoking or stop."[14]

There is substantial scientific evidence that vaping can help people cut down or stop smoking.

One review of 12 studies of people who vaped while trying to reduce their smoking found that more than 22 percent cut back their cigarette use by 50 to 80 percent after 12 weeks and nearly half of them maintained those reductions after one year.[15] Similarly, a CDC survey of 27,000 adults found that 15 percent of e-cigarette users succeeded in stopping smoking, compared to 3 percent who used other noncigarette tobacco products.[16] And a recent study of daily cigarette smokers not trying to quit found that 28 percent of those who shifted to daily vaping stopped smoking for 12 months, versus 6 percent of those who did not vape.[17]

Numerous studies also report that e-cigarettes with flavors such as mint, menthol, candy, fruit, and chocolate are more effective as smoking cessation tools than tobacco flavored vaping products.[18]

Similarly, researchers have found that dual users of cigarettes and sweet-flavored vaping products were more likely to smoke less or stop smoking entirely than those vaping tobacco-flavored products,[19] and that adults using sweet-flavored e-cigarettes to stop smoking were 41 percent more likely to succeed than those using tobacco-flavored products.[20]

Notably, the long-term downward trend in smoking rates began to accelerate around 2010, when e-cigarettes were introduced in the United States. To begin to estimate the role that vaping played in the unexpectedly fast decline in smoking rates from 2011 to 2022—if any—we constructed an econometric model to track the decline in smoking rates from 2002 to 2010 and project that trend forward to 2022. Based on the 1991 to 2010 trend, we would expect the adult smoking rate to fall to about 16.2 percent in 2022; yet the data show that the rate fell to 11.3 percent.

Next, we tested five factors other than the rising use of e-cigarettes that might explain the unexpected progress from 2011 to 2022—cigarette tax and price increases, the 2009 FDA ban on most flavored cigarettes, increased access under the Affordable Care Act (ACA) to programs to help people stop smoking, the availability of other nicotine-replacement products such as gums and patches, and the CDC's Tips anti-smoking campaign.

We found that these factors cannot explain most of the disparity between the long-term trend and actual smoking rates from 2011 to 2022. For example, average cigarette prices rose at faster rates from 1991 to 2010 than from 2010 to 2022, so while rising prices have reduced demand since at least 1991, they could not have played a meaningful role in accelerating the downward trend in smoking rates since 2010. Similarly, nicotine gums, patches, and lozenges were as widely available from 1986 to 2010 as from 2010 to 2022, and their sales declined from 2017 to 2020. The FDA ban on flavored cigarettes also had little if any effect on smoking rates independent of e-cigarettes since flavored vaping products remained available from 2010 to 2022. Studies of the effects of enhanced access to smoking cessation programs through the ACA and Medicaid expansion have produced mixed results, and we will attribute a marginal change in smoking rates to this factor, which makes our estimate of the impact of vaping conservative. One new factor clearly did affect smoking rates after 2010: The Tips anti-smoking campaign which the CDC found was responsible for an estimated 1 million smokers giving up cigarettes.[21]

Apart from Tips and the ACA, there is no nationwide factor other than the spread of vaping cited in the literature and recognized for helping people stop smoking that can explain the change in the long-

term trend of smoking rates. It seems reasonable to conclude, therefore, that the new availability of vaping products and people shifting from smoking to e-cigarettes or people choosing to vape who otherwise would have been smokers are directly associated with the intensified downward trend in smoking rates from 2010 to 2022, from the expected 16.2 percent to 11.3 percent. We built an econometric model to take account of the impact of the Tips campaign and the ACA, and we added a 25 percent "X' factor for unknown causes. The analysis found that the use of e-cigarettes in this period reduced the number of adult smokers by an estimated 6.1 million people or an average of nearly 510,000 people per year from 2011 to 2022.

We further found that the additional reduction in smoking rates associated with vaping has saved thousands of lives and billions of dollars. Based on the mortality rates for four major illnesses linked to smoking and the modest risks posed by e-cigarettes, the shift from smoking to vaping by adults from 2010 to 2022 saved some 113,300 people from smoking-related premature deaths from those diseases over those years and by 2030 will have saved 334,200 people from such premature deaths.

Living longer also enabled those vaping former smokers to continue to contribute to the economy, and based on their age distribution, their shift contributed $65.8 billion to GDP through additional productivity from 2010 to 2022. The shift from smoking to vaping also reduced the healthcare costs and productivity losses associated with smoking-related illnesses that force people to take off work and seek treatment. Based on those factors, and again taking account of the modest risks from e-cigarettes, we found that the shift among adults from smoking to vaping from 2010 to 2022 led to healthcare savings of $38.8 billion over those years and averted productivity losses totaling $71.2 billion. All told, smokers shifting to vaping from 2010 to 2022 generated economic benefits and savings that totaled $179.3 billion.

These benefits and savings could have been greater but for the predominantly negative popular image of vaping, particularly among groups with relatively high smoking rates and relatively low use of e-cigarettes including adult Black Americans and

> ...the new availability of vaping products and people shifting from smoking to e-cigarettes... are directly associated with the intensified downward trends in smoking rates from 2010 to 2022.

people aged 45 and older. A 2020 study of media coverage of e-cigarettes found that 70 percent of articles emphasized the risks of vaping, especially for young people, compared to 37 percent that noted any benefits for smokers.[22] This drumbeat of negative stories had the expected effect: The National Cancer Institute found that by 2020, only about 11 percent of respondents to its surveys believed that e-cigarettes were less harmful than smoking compared to nearly 63 percent who believed that vaping was more harmful or equally harmful than smoking.[23]

The benefits derived from smokers shifting to vaping also would have been greater but for the FDA's reticence about the benefits of e-cigarettes. Based on a review of FDA regulation and enforcement and the testimony of former FDA senior officials, the agency has regulated vaping much more strictly and extensively than cigarettes. Congress first authorized the FDA to regulate tobacco products in 2009 and directed the agency to approve only those products "appropriate for the protection of the public health." Cigarettes clearly could not meet that public health standard, but when the FDA's initial regulations took effect in August 2016, they exempted cigarettes that were already marketed at the time and any future cigarettes with "substantially equivalent" ingredients and formulation. However, the FDA did not also exempt e-cigarettes but rather held that manufacturers of those on the market in August 2016 had to apply for FDA approval by August 2020 (extended to September 2020 due to the pandemic)—and then denied such approval to nearly all of them. From

> Of the 1.2 million [vaping product] applications formally reviewed, FDA granted marketing authorization to a total of 23...products and devices.

2020 to 2023, producers of Electronic Nicotine Delivery Systems (ENDS)—mainly e-cigarette products and devices along with hookah pens, e-cigars, and e-pipes—filed 26.5 million applications, of which 6.7 million were accepted for review and 1.2 million of those accepted were formally filed. Of the 1.2 million applic X it does not contain the toxic ingredients in cigarettes. Despite the scientific evidence, the FDA has never granted any such approvals. FDA regulations also require the agency's approval before an e-cigarette maker can claim that its product can help people reduce or stop smoking—approval granted routinely to nicotine patches, nicotine gums, and nicotine lozenges. Despite all available evidence, such approvals were routinely denied until 2021, when the FDA for the first and only time acknowledged publicly the potential benefits of three new vaping products as smoking cessation aids.[24]

Based on the science, the FDA should adopt a new agenda of evidence-based reforms that will discourage smoking more aggressively and educate smokers about the benefits of switching to vaping.

Based on recommendations from former FDA officials and other tobacco experts, these reforms should include,

- Public education campaigns to provide accurate information about the relative risks of cigarettes and vaping and instruct smokers about how to use e-cigarettes to reduce or stop smoking.
- Develop and disseminate targeted messages on those relative risks and instructions for groups with the highest smoking rates including Black Americans and LGBTQ+ people.
- New cigarette label and marketing requirements warning about the relative risks and new label and marketing rules for e-cigarettes to promote the benefits of switching.
- Advertising rules that are less and burdensome for vaping products than for cigarettes.
- An expedited process for e-cigarette manufacturers to obtain FDA premarket product approval for new e-cigarettes.
- An expedited approval process for e-cigarette makers to advertise that their products entail less risk than cigarettes and can be used to help people reduce or stop smoking.
- Cap nicotine levels for cigarettes at levels that will not promote addiction and cap the maximum emissions of the most toxic substances in cigarettes.
- Apply higher taxes and minimum prices for cigarettes than for e-cigarettes so vaping becomes more appealing economically to smokers.
- Allow marketing of flavored e-cigarettes while continuing to bar non-tobacco flavors for cigarettes and limit sales of cigarettes and vaping products to adult-only retail stores.

The Extent and Character of E-Cigarette Use

E-cigarette Use by Adolescents

The use of e-cigarettes or vaping has been controversial mainly because vaping has been popular among young people.

However, the data show that adolescent vaping has declined substantially in recent years, and most young people who vape use e-cigarettes on an irregular or occasional basis without becoming dependent on nicotine.

The Surgeon General found in 2016 that the share of high school students who reported ever using e-cigarettes jumped from 10.0 percent in 2012 to 37.7 percent by 2015,[25] and CDC data showed that nearly 47 percent of high school students, grades 9 to 12, reported in 2019 that they had tried e-cigarettes at least once.[26] However, such high levels of experimentation fell to less than 29 percent by 2021 and 2022. (Table 1 below.) Its use also varied by demographic characteristics with young women more likely to have vaped than young men, white youth more likely than Hispanic or Black youth, and lesbian, gay, and bisexual youth (L/G/B) more likely than heterosexual young people.

CDC surveys also found that use of vaping products by high school students in the preceding 30 days declined by almost 50 percent from 2019 and 2018 to 2022: The share that vaped sometime in the preceding month was 27.1 percent in 2018[27] and 27.5 percent in 2019,[28] and then fell to 19.6 percent in 2020,[29] 11.3 percent in 2021,[30] and 14.3 percent in 2022.[31] The data on current users also showed patterns similar to those for young people who ever tried vaping. From 2018 to 2022, larger shares of white high schoolers used e-cigarettes in the preceding month than Hispanic youth, and larger shares of Hispanics adolescents had vaped recently compared to Black youth. Lesbian, gay,

and bisexual adolescents also were much more likely to have vaped than heterosexual youth. And while time series data on transgender adolescents are not available, a recent study also found that transgender teens were two to three times more likely to vape than cisgender teens, depending on race and ethnicity.[32]

Table 1. E-Cigarette Use by High School Students, 2018 to 2022

Lifetime Use								
	All	Male	Female	White	Black	Hispanic	Straight	L/G/B
2022	28.9%	27.3%	30.5%	32.3%	22.8%	27.6%	–	–
2021	28.9%	27.7%	30.2%	33.8%	16.9%	25.0%	22.8%	35.4%
2019	46.9%	46.2%	47.7%	52.2%	33.8%	44.9%	–	–

Current Use (At Least Once in the Preceding 30 Days)								
	All	Male	Female	White	Black	Hispanic	Straight	L/G/B
2022	14.3%	12.8%	15.4%	16.9%	11.1%	12.2%	9.7%	16.0%
2021	11.3%	10.7%	11.9%	14.5%	5.9%	7.6%	7.9%	14.2%
2020	19.6%	20.4%	18.7%	23.2%	9.1%	18.9%	12.3%	20.2%
2019	27.5%	27.4%	27.6%	32.4%	17.7%	23.2%	–	–
2018	27.1%	29.1%	24.9%	32.4%	17.4%	21.7%	–	–

CDC data also show that most high school students who vaped in the preceding 30 days used e-cigarettes on an irregular basis: Daily vapers accounted for 27.5 percent of high school students who vaped in the preceding 30 days in 2021[33] and 30.1 percent in 2022.[34] Since 11.3 percent and 14.1 percent of all high school students had vaped at all over the preceding 30 days in those years, the data show that 3.1 percent of all high school students were daily vapers in 2021 and 4.2 percent in 2022. Similarly, other CDC data show that 37.2 percent of high school vapers in 2022 used e-cigarettes only one-to-five days over the preceding 30 days and another 16.8 percent vaped on six to 19 days over the month.[35]

Such irregular use of e-cigarettes was also evident in earlier years when high school vaping was more common. Among high school vapers in 2018, non-daily users accounted for 70.2 percent of the 27.1 percent who vaped in the preceding month.[36] Another report using 2019 data found that daily vapers accounted for only 7.0 percent of the 27.5 percent of high school students who used e-cigarettes in the previous month, and overall current vapers used e-cigarettes an average of 3.7 days over the preceding month.[37]

Accordingly, several studies of the irregular use of e-cigarettes by adolescent vapers have concluded that most young e-cigarette users are not nicotine dependent. A 2018 study of youth vaping found that among those who used e-cigarettes on less than a daily basis, 77.7 percent had no or low dependence on nicotine.[38] A 2021 study also concluded that after accounting for the association between vaping and declining cigarette use, increase in

nicotine vaping by high-school students was not associated with an overall increase in nicotine dependence.[39] Another 2021 study found that many adolescent vapers dependent on nicotine were former or current smokers whose nicotine dependence was established before they began using e-cigarettes.[40] And an analysis of CDC data on high school students using e-cigarettes in 2017, 2018, and 2019 concluded,

> ... the evidence does not suggest it is addicting very large numbers [of adolescents] and do not provide support for claims of a new epidemic of nicotine addiction stemming from use of e-cigarettes.[41]

The data also show that contrary to claims by some analysts, non-tobacco flavorings for e-cigarettes including mint, fruit, candy, and chocolate played a modest role in decisions by adolescents to vape. In the earlier years of vaping, the National Youth Tobacco Survey (NYTS) found that nearly one-third of high schoolers who had vaped in 2016 cited such flavors as a reason, second to the influence of friends or family.[42] Since then, however, the importance of flavors declined sharply. In the 2019 NYTS, the share of adolescents who tried vaping and cited flavors as the attraction declined to 22.4 percent while 55.3 percent cited curiosity and 30.8 percent the influence of friends or family.[43] By 2021 and 2022, only 14.0 percent of adolescents who had vaped cited flavorings as the chief reason compared to 55.8 percent who pointed to friends vaping, 47.4 percent who cited curiosity, 25.3 percent who said vaping relieved feelings of anxiety, stress, or depression, and 20.6 percent who cited a family member's use.[44] And among adolescents who had vaped in the previous month in 2022, only 6.4 percent said they did so because of flavorings.[45]

E-Cigarette Use Among Adults

Adults vape at substantially lower rates than adolescents, a pattern common to most behaviors that adolescents consider taboo or risky. In 2021, 17.2 percent of adults reported having tried e-cigarettes at some time compared to 28.9 percent of high school students.[46] Moreover, from 2017 to 2022, an average of 5.1 percent of adults reported having vaped in the preceding month, ranging from 4.4 percent in 2017 to 5.9 percent in 2022.[47] (Table 2 below.) Over the same five-year period, an average of 20.0 percent of adolescents reported vaping in the preceding month, four times the rate of adults and ranging from 27.5 percent in 2018 to 11.3 percent in 2021. As we will see, this disparity is partly explained by adult smokers shifting to e-cigarettes: Among adults who vaped in 2021, 40.3 percent were former cigarette smokers,[48] and 13.1 percent of adult smokers in 2020 used e-cigarettes to quit smoking.[49] Notably, young adults who recently aged out of adolescence—those 18 to 24 years old—accounted for much of the decline in adult smokers from 2020 to 2021.[50]

Table 2. Current E-Cigarette use Among Adults, 2017-2022[51]

	All	Female	Male	White	Black	Hispanic	Straight	L/G/B	Daily
2017	4.4%	3.6%	5.5%	5.7%	3.2%	2.5%	4.4%	6.6%	1.5%
2018	5.5%	4.7%	7.4%	7.0%	3.7%	4.3%	5.8%	9.0%	2.1%
2020	5.1%	4.7%	6.6%	9.7%	3.7%	3.5%	5.2%	8.3%	2.2%
2021	4.5%	4.0%	5.1%	5.2%	2.4%	3.3%	4.1%	13.2%	NA
2022	5.9%	5.1%	6.7%	6.7%	4.4%	4.0%	NA	NA	–

Patterns of e-cigarette use by adolescents and adults also differ by gender: Male adults are more likely to vape than female adults while adolescent women were more likely to vape than adolescent men. But their patterns are the same in other respects: For both age groups, whites are more likely to vape than Hispanics, Hispanics are more likely to vape than Blacks, and gay, lesbian, and bisexual people are more likely to vape than heterosexuals.

Smoking and Vaping by Adults and Adolescents

By contrast, adults are more likely to smoke than vape while adolescents are more likely to vape than smoke. In 2022, 11.3 percent of adults smoked cigarettes in the preceding 30 days compared to 5.8 percent who vaped.

Table 3. Current Cigarette Use by Adults, by Gender, Race/Ethnicity, and Age, 2022[52]

	Population	Current	Daily	Some Days	Former	Never
Gender						
Female	131,108,202	9.8%	7.7%	2.1%	17.9%	69.5%
Male	124,236,500	12.9%	9.6%	3.2%	25.8%	58.6%
Race/Ethnicity						
Non-Hispanic Black	30,339,270	13.5%	9.5%	4.0%	13.3%	67.8%
Non-Hispanic White	158,495,296	12.4%	10.0%	2.4%	26.7%	58.7%
Hispanic	43,985,221	7.7%	4.8%	2.9%	13.6%	75.7%
Age						
18-24	29,348,311	4.7%	2.8%	1.9%	4.7%	87.8%
25-44	87,057,536	12.1%	8.9%	3.3%	18.0%	66.8%
45-64	82,047,389	14.7%	11.6%	3.1%	23.0%	59.9%
65+	56,918,726	8.4%	6.9%	1.4%	34.5%	54.4%

Table 4. Current E-Cigarette Use by Adults, by Gender, Race/Ethnicity, and Age, 2022[53]

	Population	Current	Daily	Some Days	Former	Never
Gender						
Female	131,108,202	5.1%	2.6%	2.5%	11.1%	81.1%
Male	124,236,500	6.7%	3.7%	3.0%	15.5%	75.2%
Race/Ethnicity						
Non-Hispanic Black	30,339,270	4.4%	1.8%	2.6%	10.6%	79.7%
Non-Hispanic White	158,495,296	6.7%	3.8%	2.9%	14.6%	76.6%
Hispanic	43,985,221	4.0%	1.8%	2.2%	11.2%	82.0%
Age						
18-24	29,348,311	14.9%	8.1%	6.8%	20.4%	62.2%
25-44	87,057,536	8.8%	4.7%	4.1%	19.4%	68.7%
45-64	82,047,389	3.0%	1.6%	1.4%	10.6%	84.1%
65+	56,918,726	1.0%	0.5%	0.5%	4.0%	92.5%

The data also show that in 2022, 8.6 percent of adults or 22.0 million Americans reported smoking daily in the preceding month versus 3.1 percent or 8.0 million adults who had vaped daily. The data also suggest that vaping is much less addictive than smoking: Of nearly 28.9 million adults who smoked in 2022, 22.0 million or 76.5 percent did so daily—while of the 15 million adults who had vaped some time in 2022, 53.6 percent did so daily. Further, adult women were more likely than adult men to have never smoked or vaped since adult men were more likely to smoke cigarettes, vape, and be former smokers or vapers than adult women. Also, Black adults were more likely to smoke than white adults, but white adults were more likely to smoke daily than Black adults, and Hispanics were least likely to smoke or smoke daily. And with respect to age, adults ages 25 to 44 and 45 to 64 were more likely to smoke than those 18 to 24 or 65 and older, while e-cigarette use by adults declined steadily with age.

Comparing smoking and vaping rates for adults and high school students in 2021, 11.5 percent of adults or 29.1 million people smoked cigarettes in the preceding 30 days compared to 4.5 percent or 11.4 million adults who had used e-cigarettes. (Table 5 below.) By contrast, among adolescents, only 320,000 high school students (1.9 percent) reported smoking cigarettes in the preceding month compared to 1.72 million (11.3 percent) who reported vaping. As a result, adults were about six times more likely to smoke than adolescents, and adolescents were 2.5 times more likely to vape than adults. These data suggest, therefore, that a substantial number of adolescents substitute vaping for smoking, an encouraging development since the CDC reports that nearly 90 percent of adult daily cigarette smokers started smoking before age 18.[54]

Table 5. Current Use of Cigarettes and E-Cigarettes, Adults and High School Students, By Gender, Race/Ethnicity, and Sexual Orientation, 2021 (millions)

	All	Female	Male	White	Black	Hispanic	Straight	L/G/B
Adults								
Cigarettes	29.1	13.2	16.1	24.7	4.0	3.7	27.2	1.7
	11.5%	10.1%	13.1%	12.9%	11.7%	7.7%	11.4%	15.3%
E-Cigs	11.4	5.1	6.4	10.0	0.83	1.6	9.8	1.4
	4.5%	4.0%	5.1%	5.2%	2.4%	3.3%	4.1%	13.2%
High School Students								
Cigarettes	0.32	0.15	0.17	0.17	NA	0.08	NA	NA
	1.9%	1.8%	2.0%	2.2%	NA	1.6%	NA	NA
E-Cigs	1.9	1.0	0.9	1.1	0.15	0.37	1.1	0.31
	11.3%	11.9%	10.7%	14.5%	5.9%	7.6%	7.9%	14.2%

Why Adolescents Vape

The debate around e-cigarettes does not explain why vaping became relatively common among adolescents over the past decade, whether because young people substitute e-cigarettes for smoking or young people who would never have smoked cigarettes started to vape. Advocates of measures to drastically restrict vaping often cite its disproportionate use by adolescents while stressing the alleged risks that vaping poses for adolescents.

As we will see, such advocates misconstrue those risks by overstating the health harms associated with vaping, exaggerate the likelihood of adolescents switching from vaping to smoking, ignore the substantial recent decline in adolescent vaping, and conflate the numbers of adolescents who use e-cigarettes irregularly with those who vape daily.

Recent neuroscientific research can help explain why vaping has been relatively common among adolescents, namely that the development of certain aspects of the brain during puberty results in adolescents attracted to activities and behaviors with uncertain outcomes,[55] especially those they can undertake with their peers. To the frustration of parents everywhere, these neurological developments make many adolescents prone to a wide range of activities perceived as risky. The sobering result is that millions of high school students experiment with substances and behaviors that, unlike vaping, can cause of death and injury, including drug and alcohol use and situations that lead to violence.

This neuroscience suggests that the high incidence of risky adolescent behaviors is natural and unavoidable as it is based substantially on biological changes in dopaminergic brain activity during puberty that for several years enhance the appeal of sensation-seeking acts.[56] In layman's terms, biological changes temporarily enhance the adolescent brain's responsiveness to stimuli that produce the pleasure-generating chemical dopamine, and risky behaviors generate those stimuli. In addition, vaping and smoking enhance these effects because nicotine acts as

a neurotransmitter that stimulates dopamine release.[57] These effects can be further enhanced by an increase in gonadal steroids during puberty that promotes social bonding, so young people also become more likely to commit risky acts with their peers.[58] For example, adolescents are more likely than adults to drive intoxicated with peers present and to commit crimes in groups.[59]

These neurological developments can overwhelm adolescents' reason and knowledge. Most young people are exposed to drug, alcohol, sex, and driver education in school; and studies have found that while they often recognize the risks involved in drug use, excessive drinking, unsafe sex, and reckless driving, that recognition has little effect on their behavior.[60] Perhaps more adolescents would engage in dangerous activities without such education. Nevertheless, a leading expert in this field has concluded that "heightened risk-taking during adolescence is likely to be normative, biologically driven, and, to some extent, inevitable."[61] Such risky activities also can have positive effects: Psychologists have noted that adolescents learn much about the world and their own capacities by exploring uncertain situations, especially ones with rewards, and since risky behavior produces chemical rewards, their willingness to take risks is "an Important and adaptive quality."[62]

In the context of the risky behaviors that impel many adolescents, vaping is perhaps the most benign, especially since the associated risk exists mainly in their minds and promoted by nicotine's effects on dopamine release. It is undeniable that the other common types of risky adolescent behavior carry much more serious consequences. The CDC surveys high school students on such behaviors every two years as a supplement to its Mortality and Morbidity Reports. The most recent report based on the 2021 survey found the substantial use of e-cigarettes on an occasional basis and that 5.0 percent of high school students reported vaping daily over the preceding 30 days—compared to 10.5 percent who reported binge drinking, 15.8 percent who reported using marijuana, and 22.7 percent who reported drinking alcohol.[63] (Table 4 below.) Fewer adolescents also vaped daily during the preceding month than the numbers of young people who reported abusing opioids or being victims of dating violence or bullying over the preceding year. And more male adolescents reported carrying firearms in the previous year than vaped daily in the preceding month.

In the context of risky behaviors that impel many adolescents, vaping is perhaps the most benign.... It is undeniable that the other common types of risky adolescent behavior carry much more serious consequences.

Table 4. Risky Behavior and Activities by High School Students in the Preceding 30 Days, 2021[64]

	All	Male	Female	White	Black	Hispanic	Straight	L/G/B
Vaping (30 days)	18.0%	14.9%	21.4%	21.3%	14.0%	17.8%	16.4%	14.8%
Daily Vaping (30 days)	5.0%	4.5%	5.6%	6.5%	3.1%	3.4%	4.4%	5.0%
Opioid Abuse (30 days)	6.0%	4.0%	8.0%	4.6%	8.6%	8.3%	4.3%	11.7%
Marijuana (30 days)	15.8%	13.6%	17.8%	14.8%	21.0%	16.7%	14.0%	25.6%
Alcohol (30 days)	22.7%	18.8%	26.8%	25.9%	13.2%	22.9%	21.6%	29.3%
Binge Drinking (30 days)	10.5%	9.0%	12.2%	13.3%	4.1%	10.1%	10.3%	13.6%
Dating Violence (12 months)	13.6%	8.2%	19.0%	14.9%	9.7%	13.2%	10.0%	17.0%
Victim of Violence (12 months)	9.7%	4.0%	15.3%	10.7%	5.3%	10.0%	6.6%	12.0%
Victim of Bullying (12 months)	22.0%	17.7%	26.2%	26.3%	13.4%	17.9%	17.9%	35.2%
Carried a Gun (12 months)	3.5%	5.0%	1.8%	3.0%	5.1%	5.1%	3.3%	2.9%

As with vaping and smoking, there also are significant disparities in adolescents' risky behaviors based on their gender, race or ethnicity, and sexual orientation. All types of risky adolescent behaviors except carrying firearms attracted larger shares of female high school students than male high schoolers and lager shares of gay or bisexual young people than heterosexual young people. The CDC data also showed that Black high school students were less likely than their white or Hispanic counterparts to drink alcohol, binge drink, or become victims of violence or bullying, as well as vaping; while white adolescents were less likely to abuse opioids, use marijuana, or carry firearms than their Black or Hispanic counterparts.

The CDC 2021 survey also examined very risky adolescent behaviors over longer periods. (Table 5 below). For example, 12.2 percent of high school students reported abusing opioids at some time in the past. Most disturbing, 13.3 percent of adolescent girls and 6.6 percent of adolescent boys reported having attempted suicide, including 17.8 percent of young Black high schoolers, 11.2 percent of young Black high schoolers, 15.2 percent of gay, lesbian, or bisexual female high school students (G/L/Bi), and 19.6 percent of male gay, lesbian, or bisexual students.

Table 5. Longer-Term Risky Behavior or Use of Risky Substances by High School Students, 2021[65]

	All	Male	Female	White	Black	Hispanic	Straight	L/G/B
Opioid Abuse (Ever)	12.2%	9.5%	14.8%	11.2%	13.6%	13.8%	9.4%	21.5%
Alcohol (Ever)	47.4%	42.0%	53.2%	50.0%	39.4%	50.4%	45.8%	58.0%
Marijuana (Ever)	27.8%	24.8%	30.9%	26.2%	33.3%	31.2%	25.8%	41.2%
Ecstasy/Cocaine (Last Year)	5.4%	5.5%	4.9%	5.3%	4.6%	5.6%	3.9%	10.4%
Vaping (Ever)	36.2%	32.1%	40.9%	36.7%	33.6%	40.4%	34.7%	34.4%
Unprotected Sex (3 months)	13.4%	11.3%	15.2%	9.5%	21.4%	19.0%	11.8%	–
Suicide Attempt (female)	–	–	13.3%	12.4%	17.8%	13.8%	8.1%	15.2%
Suicide Attempt (male)	–	6.6%	–	5.5%	11.2%	6.5%	5.0%	19.6%
Suicide Attempt /Med Treat (f)	–	–	3.9%	3.5%	5.5%	4.7%	2.1%	3.0%
Suicide Attempt /Med Treat (m)	–	1.7%	–	1.2%	3.3%	2.0%	0.9%	7.4%

While vaping is not linked to deaths or injuries among adolescents, other behaviors and activities can entail very serious consequences. Almost 23 percent of adolescents reported using alcohol in the preceding 30 days, including 10.5 percent who binge drank, that resulted in some cases in automobile crashes. Using National Highway Traffic Safety Administration (NHTSA) data on traffic deaths and injuries of young people ages 15 to 24 and the share of those accidents related to alcohol, we estimate that 2,209 young adults of those ages died and 128,472 were injured in 2021 in automobile accidents where a young driver was alcohol impaired.[66] In contrast to vaping, speeding and distracted driving by young people also involve significant risks of death or injury—for example, based on NHTSA data, an estimated 2,031 young adults died and 118,174 were injured in traffic crashes involving young adults driving at excessive speeds.[67]

Similarly, 12.2 percent of adolescents reported having abused opioids, and such abuse cost the lives of 1,156 adolescents in 2020.[68] Some 13.6 percent of adolescents report being victims of dating violence in the preceding year, and one-third to one-half of those incidents produced injuries.[69] Finally, half of all sexually transmitted diseases affect young adults ages 15 to 24, and 13.4 percent of high school students reported having unprotected sex over the preceding three months.[70] Based on CDC data on the incidence of STDs, this suggests that unprotected sex by young people in 2021 resulted in 88,357 adolescent cases of syphilis, 833,208 adolescent cases of chlamydia, and 355,076 adolescent cases of gonorrhea,[71] as well as 1,248 HIV infections of young people ages 15 to 19.[72]

The Effects of E-Cigarette Use on People's Health

While vaping is not associated with the serious consequences of other common adolescent or adult behaviors, many researchers have investigated potential health risks related to vaping, often as compared to those from cigarette smoking. Since e-cigarette use is a relatively recent phenomenon, the long-term health effects have been difficult to evaluate—apart from the absence of the hundreds of toxic substances released by smoking.

Based on hundreds of peer-reviewed scientific studies of the physiological effects of vaping, however, there is little evidence that e-cigarette use poses any substantial health risks on its own and as compared to cigarette smoking.

Vaping inevitably has physiological effects, as does virtually anything that people inhale or ingest. Whether those physiological effects are notable remains unsettled. For example, some studies report changes in blood pressure and/or heart rates from vaping, while others have found no such effects.[73] Similarly, some research suggests that vaping may affect lung functions again other studies also have found no such effects. For instance, some researchers report that vaping can affect mechanisms associated with asthma and bronchitis while others found that smokers with asthma or chronic obstructive lung disease improved after switching to e-cigarettes.[74] And while there is substantial evidence that vaping can be associated with mild to moderate mouth or throat irritation, none of them has reported related effects on those organs.[75] More generally, no study has established that any short-term physiological changes in people's lungs associated with vaping pose serious risks—including smokers' lung cancers, since it is well established that e-cigarettes contain "negligible concentrations of the carcinogens in cigarettes."[76]

More generally, no scientific study has established that the physiological effects associated with vaping lead to any serious, adverse health conditions. This conclusion is supported by a recent metareview of 400 studies on vaping and health, including broad reviews by eight national health authorities.[77] This broad review did find "moderate evidence" that vaping can cause headache, cough, throat

irritation, dizziness, and nausea but "limited or insufficient evidence" that nicotine vaping reduces lung function or other respiratory measures and "insufficient evidence" that nicotine e-cigarettes have any adverse effects on endocrine, olfactory, ocular, allergic, and hematological conditions, reproduction, wound healing, development in children and adolescents, and mental health. Overall, the study's "key finding" was,

> ... the general paucity of evidence for the effects of nicotine and non-nicotine e-cigarettes on many major clinical outcomes, including cancer, cardiovascular, metabolic, mental health, developmental, reproductive, and neurological outcomes (other than seizures)."[78]

Some of the widespread popular anxieties about the health effects of vaping are likely connected to the 2020 outbreak of a condition designated as EVALI or "E-cigarette or vaping product use associated lung injury." Over a short period in 2020, EVALI resulted in 68 deaths and the hospitalization of 2,800 people, raising serious new alarms about the health risks of vaping.[79] In the end, those concerns were misplaced as the CDC and other researchers established that EVALI was unrelated to commercial vaping products: The EVALI toxicant was identified as vitamin E acetate, a synthetic form of vitamin E introduced into black market cannabis vaping cartridges and not present in commercial vaping products.[80]

Some of the health concerns also equate vaping and cigarette smoking based on their common use of nicotine. As one research group noted, "the use of nicotine-containing electronic- or e-cigarettes divided the tobacco control community along a spectrum from fervent opponents to enthusiastic supporters."[81] Nicotine has well-established physiological effects: It is easily absorbed by the mucus membrane, skin, gastrointestinal tract and respiratory airways and acts as a neurotransmitter stimulating the release of dopamine that contributes to feelings of pleasure and satisfaction. This effect can make both smoking and vaping habit-forming.[82] While the nicotine content varies among cigarette brands, an average cigarette contains 10 to 12 mg of nicotine, and a typical smoker inhales 1.1 to 1.8 mg of nicotine per cigarette or 22 to 36 mg from a standard package of 20 cigarettes.[83] An early study of the nicotine in e-cigarettes estimated that 20 puffs delivered nicotine comparable to smoking a cigarette,[84] and a later study of 30 types of e-cigarettes found that it takes about 30 puffs on an e-cigarette to deliver the nicotine absorbed from smoking a typical cigarette.[85] In short, absorbing nicotine comparable to smoking a cigarette requires repeated, concentrated vaping.

At this time, the science regarding whether the physiological effects of absorbing nicotine in normal concentrations pose distinct health risks remains unsettled. However, the disparity between the overall health risks of smoking and vaping is

...the disparity between the overall health risks of smoking and vaping is enormous.

enormous. To begin, the carcinogenic aspects of cigarettes are unrelated to nicotine.[86] E-cigarettes contain a limited number of other ingredients, principally glycerol and propylene glycol, common additives in foods and recognized by the FDA as nonharmful, along with tobacco nitrosamines and flavorings that also have not been linked to illnesses. In contrast, the American Lung Association reports that the average unlit cigarette contains up to 600 different substances.[87] And while e-cigarettes do not entail combustion, the CDC reports that a burning cigarette produces some 7,000 chemicals including acetone, ammonia, butane, carbon monoxide, formaldehyde, lead, and tar, and 69 of those chemicals are linked to cancers.[88]

While the scientific evidence does not connect e-cigarettes with any serious medical condition or deaths, the CDC estimates that cigarette smoking causes the premature demise of more than 480,000 Americans annually.[89] Compared to nonsmokers, smoking also increases the risks of coronary disease and stroke by two-to-four times and the risk of lung cancer by 25 times—while vaping has no such effects. The CDC and private researchers also have found no health consequences related to secondhand exposure to vaping,[90] with one analysis calling it less dangerous than exposure to candles.[91] Again, by contrast, the CDC estimates that exposure to secondhand cigarette smoke is linked to 34,000 annual premature deaths from heart disease, 7,600 premature deaths from lung cancer, and increased incidence of sudden infant death syndrome and a range of other respiratory conditions in children.[92]

While the differences in health effects are vast between smoking and vaping, scientists cannot say with confidence that using e-cigarettes poses no risks over the long term. Public Health England has estimated that e-cigarette use carries about 5 percent of the risk of smoking cigarettes,[93] and other estimates range up to 15 percent.[94] Those relative risks are consequential, since vaping products can be alternatives to cigarettes. The Royal Society for Public Health in Britain evaluated the ingredients and products from vaping and smoking, including their common ingredient nicotine, and concluded,[95]

> … nicotine use itself can be usefully compared to caffeine consumption: dependence-producing but not a significant cause of disease. The substitution of far less harmful and less addictive alternatives can be ranked as among the really simple but really dramatic breakthroughs in public health history; comparable to things like vaccinations, citrus to prevent scurvy, sanitary food manufacturing …

Similarly, taking account of both the common use of nicotine and disparate health effects related to vaping and smoking, Dr. Eric Lindblom, former head of the Office of Policy for the FDA Center on Tobacco Products, concluded,

> "… public health gains are secured each time a smoker who would not otherwise quit all smoking switches entirely to using e-cigarettes instead. Moreover, available data shows that switches from smoking to exclusive e-cigarette use are possible and already occurring, at least to some extent."[96]

Public Misconceptions About the Risks of E-Cigarettes

Despite the evidence that the health risks associated with vaping are modest, many Americans remain convinced that e-cigarettes pose risks comparable to cigarettes or nearly so. If these misperceptions merely discourage nonsmokers from vaping, they have relatively benign effects. But these distortions damage public health when they discourage smokers from switching to e-cigarettes or convince vapers that smoking cigarettes will not increase their health risks.

The prevalence of these misconceptions reflects the media's treatment of vaping, which has been predominantly negative. One study of news coverage of e-cigarettes found that from 2015 to 2018, 70 percent of articles emphasized the risks of vaping, especially for young people, compared to 37.3 percent that noted the potential benefits for smokers.[97]

Similarly, a 2022 study reported that much of the media coverage of vaping emphasized claims that e-cigarette use leads to smoking or nicotine addiction and that the nicotine in e-cigarettes harms brain development in young people.[98] All of these claims are unsupported.

With more than two-thirds of adolescent vapers using e-cigarettes on an occasional rather than daily basis,[99] researchers have found that most young e-cigarette users do not become nicotine dependent.[100] There also is no credible evidence that vaping affects the developing brains of young people.[101] And as we will see, early claims of a so-called "gateway" effect in which vaping leads to smoking have been widely refuted.[102] Rather, studies suggest an opposite dynamic in which vaping diverts more adolescents from smoking cigarettes than encourages them to smoke.[103]

The media's negative drumbeat about e-cigarettes has shaped the public's broadly negative perceptions of e-cigarettes. One analysis found that public exposure to negative news stories about vaping increased from 18.0 percent in 2017 to 64.6 percent in early 2020; and while some of that increase was related to coverage of the EVALI outbreak in early 2020, the preponderance of negative new coverage changed little after scientists established that EVALI was not linked to commercial e-cigarettes. As a result, a 2022 study from the American Cancer Institute found that 28.3

...early claims of a so-called 'gateway' effect in which vaping leads to smoking have been widely refuted.

percent of Americans believed that e-cigarettes were *more harmful* than cigarettes, compared to 11.4 percent who saw e-cigarettes as less harmful.[104] Similarly, a survey by the National Cancer Institute found that from 2015 to 2020, the share of respondents who recognized that e-cigarettes were less harmful than cigarettes fell from 25.9 percent to 11.2 percent, compared to 27.7 percent in 2020 who believed that e-cigarettes were more harmful and 34.5 percent in 2020 who believed they were equally harmful.[105] In a follow-up survey in 2022, the Institute found that the share of Americans who believed that vaping was less harmful than cigarette smoking had fallen to 10.1 percent compared to 32.0 percent who saw the two alternatives as equally harmful.[106] On an encouraging note, the share who saw vaping as more dangerous than smoking in 2022 declined to 18.4 percent, while undecideds rose to 39.5 percent

It is also notable that negative coverage of vaping is less prominent in Great Britain where the National Health Service runs public education campaigns endorsing e-cigarettes as a tool to help people stop smoking: In 2020, negative stories accounted for 34.3 percent of English coverage or barely half the U.S. percentage.[107] Accordingly, about half of the British public in 2022 recognized that vaping is less harmful than smoking.[108]

The misconceptions among Americans about vaping have serious consequences. Two studies found that about half of adult American smokers say that they would be interested in tobacco products that are less harmful than cigarettes, without recognizing that such product are easily available.[109] The result, as the authors of a third such study noted, is that,

"... most adults, including most smokers, incorrectly consider use of e-cigarettes to be as dangerous as or more dangerous than cigarette smoking ... fewer people who smoke will attempt quitting smoking with e-cigarettes than would occur were the public (especially smokers) more knowledgeable about the health risks of e-cigarettes and nicotine ... Inadvertently, the nation's overwhelming focus on e-cigarettes' risks for adolescents may be harming the public's health."[110]

The FDA could promote public health, as Congress has directed, by countering these misconceptions. Dr. Brian King, director of its FDA Center for Tobacco Products, has acknowledged being "fully aware of the misperceptions that are out there and aren't consistent with the known science ... [and] that e-cigarettes—as a general class—have markedly less risk than a combustible cigarette product."[111] Yet, FDA public education campaigns never mention it.[112] Instead, the FDA requires that packaging and advertising for e-cigarettes—but not for cigarettes—include the warning, 'This product contains nicotine which is a highly addictive substance. According to recent research, this disparity,

... may inadvertently signal to people who smoke that e-cigarettes are more addictive than cigarettes, given that cigarettes are not required to have warning labels about addictiveness ... [people] shown warnings that emphasize addictiveness report being less willing to try e-cigarettes to help them quit smoking.[113]

The Links between Vaping and Quitting Smoking or Starting to Smoke

E-Cigarettes and Smoking Reductions or Cessation

While some early studies were skeptical of e-cigarettes usefulness to help reduce or stop smoking,[114] other early studies and the preponderance of recent research supports their utility. For example, a 2015 review of 12 studies of people who vaped while trying to reduce their smoking found that an average of 22.3 percent cut their smoking by 50 to 80 percent after 12 weeks and 10.3 percent maintained those reductions after 52 weeks.[115] Similarly, a 2014 European study of people using vaping to quit cigarettes found that 34 percent had stopped smoking after two months and 44 percent had stopped or reduced their smoking by an average of 60 percent after eight months.[116] And as early as 2015, Dr. Lindblom concluded,[117]

"... research indicates that using e-cigarettes, either exclusively or through dual use, can help smokers to quit smoking, or even prompt some smokers not trying to quit to reduce their smoking or stop. There is also some evidence that smokers who successfully use e-cigarettes to help them quit smoking are likely subsequently to stop using the e-cigarettes as well."

Subsequent studies have further established the effectiveness of e-cigarettes for smoking cessation, including as compared to other cessation tools recognized by the FDA. One study found that e-cigarettes were as effective as nicotine patches,[118] and a British study found that 18 percent of smokers using e-cigarettes stopped smoking at one year compared to 9.9 percent of the smokers who used nicotine replacement therapy.[119] Similarly, a 2020 CDC survey of 27,000 adults found that 15.1 percent of e-cigarette users succeeded in stopping smoking compared to 3.3 percent of smokers using other tobacco products and 6.6 percent using no non-cigarette tobacco products.[120] In this , another 2021 study found that e-cigarette use increased

the effectiveness of nicotine patches and other approved cessation aids.[121]

Further, a 2021 study of daily cigarette smokers who were *not* trying to quit found that 28 percent of those who shifted to daily vaping stopped smoking for 12 months versus 5.8 percent of those who did not vape.[122] And the largest U.S. clinical trial of e-cigarettes found recently that even the unguided use of e-cigarettes led to less smoking by individuals who expressed no intention of quitting smoking.[123] The lead investigator, Dr. Matthew Carpenter, noted, "No matter how we looked at it, those who got the e-cigarette product demonstrated greater abstinence and reduced harm as compared to those who didn't get it."[124]

A series of studies have also found that non-tobacco flavored vaping products such as mint, menthol, candy, fruit, and chocolate flavored e-cigarettes are more effective as smoking cessation tools than tobacco flavored e-cigarettes.

One analysis based on a large national sample found that among adults who used vaping to quit smoking, those using mint or menthol flavored e-cigarettes were more likely to succeed than those using tobacco flavored e-cigarettes.[125] That findings is also supported by two other subsequent studies.[126] Researchers have further found that frequent vapers were more likely to stop smoking than those who vaped less regularly and that those vapers using flavored e-cigarettes were more likely to stop than those using tobacco-flavored products.[127] Yet another study found that dual users of cigarettes and sweet-flavored vaping products were more likely to smoke less or stop smoking than those using tobacco-flavored vaping products.[128] Finally, a recent analysis reported that among adults using vaping products to quit smoking, those using sweet-flavored e-cigarettes were 41 percent more likely to succeed than those using tobacco-flavored e-cigarettes (13.8 percent versus 9.6 percent).[129]

The Purported "Gateway Effect"

Despite clear evidence that vaping can help many smokers stop or reduce their cigarette use, critics continue to claim that vaping is a "gateway" to cigarette smoking. This contention is based on a review of nine early cohort studies that found correlations between adolescents who vaped and those who started smoking.[130] Since the study's release, however, researchers have thoroughly critiqued its methodology, including two studies that found that the apparent correlation was explained by other variables that make some adolescents particularly susceptible to starting to smoke.[131] A third analysis of the original study further found that taking account of the adolescents' marijuana and alcohol use eliminated a link between vaping and subsequent smoking.[132]

Researchers have refuted the basic proposition of a net gateway effect. Three recent studies found that e-cigarettes divert more adolescents from smoking than encourage them to smoke,[133] and other researchers reported that less than one percent of high school students who started with vaping became established smokers.[134] Regarding flavorings, a recent study also refuted claims that youths who vaped non-tobacco flavored e-cigarettes were likely to start smoking.[135] All told, the most recent review of the evidence of a gateway effect concluded,

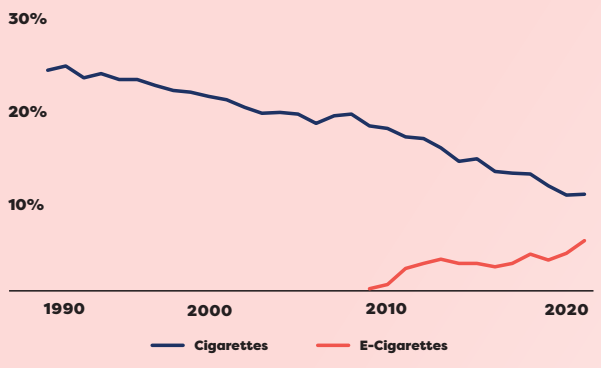
"Evidence from trends in smoking prevalence over a period where vaping increased, though limited by the difficulty of accounting for other factors ... suggest no material adverse effect due to vaping. Indeed, most publications suggest some benefit of e-cigarette introduction in the US and UK. The evidence strongly suggests that introducing e-cigarettes has benefited public health and reduced smoking prevalence." [136]

The Impact of Vaping on Smoking Rates

Next, we used counterfactual modeling to estimate how many Americans adults have stopped smoking since e-cigarettes became widely available. First, we tracked the trend line of smoking rates for adults, youth, and certain subgroups from 1991 to 2010, the first year that e-cigarettes were widely marketed in the United States.[137] We extended that trend to forecast the expected smoking rates from 2011 to 2022 and compared the results to actual smoking rates for those years. The results provide a baseline to examine the impact of e-cigarettes and other factors on smoking rates.

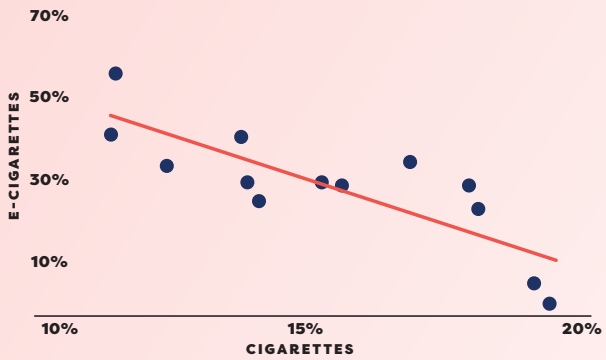
Tracking adult smoking rates since 1991 and vaping rates since 2010 showed, first, that cigarette smoking declined substantially over the whole period and that the decline accelerated after 2010 as the use of e-cigarettes increased. (See Figure 1 below.)

Figure 1: Rates of Cigarette and E-Cigarette use by American Adults, 1991-2022[138]



Next, we next established that the apparent correlation is statistically significant: Smoking rates declined more sharply as e-cigarette use increased. (See Figure 2 below.) To be sure, this correlation did not establish causality or account for other factors that could have caused smoking to decline at a faster rate since 2010.

Figure 2: Correlation Between Rates of Cigarette and E-Cigarette Use by American Adults, 1991-2022



The next step to assess the impact of e-cigarettes on smoking rates involved determining the precise breakpoints when the trend in declining smoking rates shifted downward, so we could better define the forecast periods for the impact of e-cigarettes.

In an advance over previous analyses, we applied an algorithm that can identify multiple structural breaks points in smoking rates and determined that the best fitting model incorporated structural breaks in 1997, 2002, 2010, 2014, and 2018.[139] Since e-cigarettes were introduced in 2010, we used the linear trend from the 2002 breakpoint to 2010 for the baseline of our forecast. On this basis, we estimated that the smoking rate in 2022 based on that trend line would be 16.21 percent, compared to the actual rate of 11.27 percent in that year. On this basis, we established that new factors including e-cigarettes had shifted the trend line downward from 2010 to 2022 and so reduced the number of adult American smokers by an additional 12.6 million people over the 2010-2022 period.

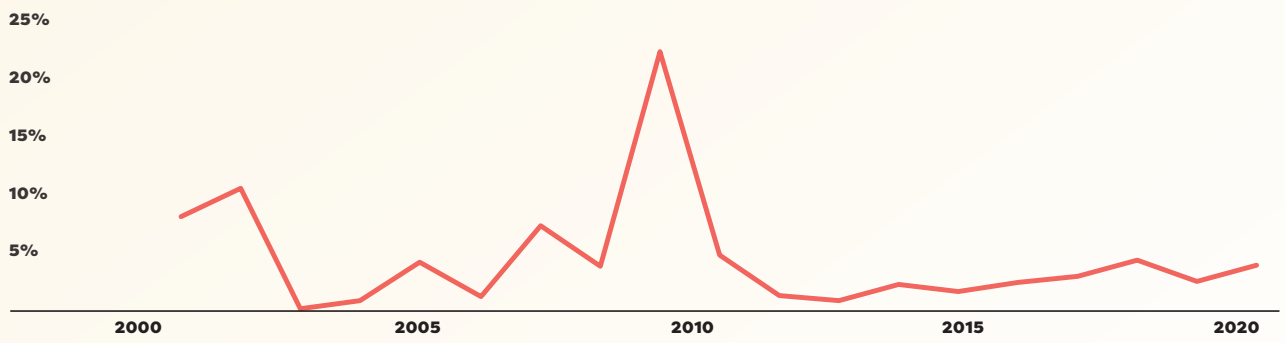
To assess potential other factors and better isolate the impact of e-cigarettes on adult smoking rates, we next analyzed the four policy initiatives or changes that occurred in the period from 2010 to 2022. First, we considered the impact of cigarette price increases including the increase in the federal excise tax on cigarettes in 2009. It is well documented that higher prices reduce smoking rates,[140] particularly among young adults.[141] To affect the acceleration in the downward trend in smoking rates after 2010, the price increases after 2010 should exceed those from earlier years. We analyzed data on the average national retail price for a pack of cigarettes[142] and calculated the average annual price increase. Figure 3, below, shows the average price increase per year was greater from 2000 to 2008 than post-2009.

This result strongly suggests that changes in cigarette prices did not contribute to the change in the trend of smoking rates from 2010 onward—in fact, they may have had the opposite effect. This conclusion is consistent with studies of the 2009 excise tax, which generally found that it did not have a statistically significant effect on the rate of smoking quits among adults, although it did appear to affect adolescents.[143]

Next, we considered other policy changes since 2010 that could have affected smoking rates, starting with the CDC "Tips" anti-smoking campaign launched in 2012. Tips used testimony from former smokers to publicize and dramatize the serious health costs from cigarette smoking. In 2020, the CDC issued a study evaluating the campaign: It estimated that Tips was responsible for 1,005,419 smokers permanently quitting from 2012 to 2018 who otherwise would not have been expected to stop smoking.[144] Over that period, the number of adult smokers declined by 9.7 million, so Tips can explain 10.3 percent of that reduction. Notably, other researchers found that the campaign was more effective among men than women, among Black people than white people, and its effectiveness declined as the age of smokers increased.[145]

Another policy change that might have affected the acceleration of smoking cessation rates after 2010 was passage of the Family Smoking Prevention and Tobacco Control Act in 2009 (TCA or Tobacco Control Act). The TCA and its associated regulations banned the sale of non-menthol flavored cigarettes, required graphic warning labels

Figure 3: Average Annual Increase in the Price of a Pack of Cigarettes, 2000-2019



on tobacco products, limited tobacco company advertising to minors, and directed the FDA to apply preapproval requirements for all tobacco products. (Later, we will examine in detail how the FDA has administered the TCA.) To estimate the TCA's impact on adult smoking rates, the most relevant provisions are the requirement for graphical cigarette warning labels for cigarettes and the ban on non-menthol flavored cigarettes.

The graphical warning requirement was met with court challenges and injunctions, and the FDA withdrew it in 2013.[146] Researchers have studied the other pertinent provision, the ban on non-menthol flavored cigarettes, and one prominent early analysis reported a significant effect on smoking rates based on breaks in the downward trend in smoking rates associated with the flavoring ban.[147] However, the study failed to fully consider the well-documented substitution effects.[148] (The Appendix provides a detailed account of the study's deficiencies.) Most notably, while the study acknowledged that the ban on non-menthol flavored cigarettes led to substitution effects, including shifts to flavored e-cigarettes not subject to the ban, it attributed those effects to the ban itself without taking account of the role of flavored vaping.[149] On balance, there is little evidence that the ban on non-menthol flavored cigarettes contributed in a meaningful way to the accelerated decline in smoking rates beginning around the 2010 breakpoint, independent of the impact of e-cigarettes.

A third factor that might have helped accelerate the downward trend in smoking rates was the availability of other nicotine replacement products, principally nicotine gum, patches, and lozenges. Such products were first introduced in 1986, and the gum and patches were widely available from 2010 to 2022, as they were from 1991 to 2010. These nicotine replacement tools could have affected the post-2010 downward trend if their use increased post-2010. However, the data suggest the opposite as their generally weakened, particularly from 2017 to 2020 when e-cigarette use peaked.[150] We conclude that while these tools continued to help people stop or reduce their smoking, their use did not contribute to the faster decline in smoking rates from 2010 to 2022 compared to 1991 to 2010.

The fourth potentially confounding factor was passage of the Patient Protection and Affordable Care Act of 2010 (ACA or Obamacare), that took effect in 2014. The ACA contained two provisions that could have affected smoking rates in this period—mandating access to smoking cessation medications and services for many health plans, and the state option to expand Medicaid coverage and thereby make those medications and services available to more households.[151] The evidence on the impact of these provisions is mixed. Some researchers found no impact on smoking rates despite the enhanced access.[152] Other analysts found evidence that smokers used the new coverage for smoking cessation programs at higher rates in states that expanded Medicaid and that those programs increased the rates at which participants stopped smoking.[153] Researchers also found that the ACA Medicaid expansion affected Blacks and Hispanics more than whites and women more than men.[154]

Unlike the CDC's study of the Tips program that provided methodologically sound estimates of its impact over a defined period that we could extrapolate forward, taking account of the ACA's impact in our modeling is more challenging. However, our approach for identifying breaks in the downward trend in smoking rates found a structural break beginning in 2014, when most ACA provisions were implemented, and we assume here that the 2014 structural break captures the impact of the ACA provisions. Therefore, we analyzed the changes in the downward trend in smoking rates from 2010 to 2014 and from 2014 to 2018;and by taking the difference in these linear trends from the pre-2010 trend beginning in 2014 and adjusting for the Tips program's effect, we can construct smoking rates for 2010 to 2022 that incorporate both effects.

Finally, we also include an "X" factor that represents other developments such as smoke-free policies or increased public concerns about damaging respiratory and circulatory conditions and alternative explanations that might have materially affected the changes in smoking trends from 2010 to 2022. In addition to the impact of Tips and the ACA anti-smoking provisions, therefore, we applied an additional 25 percent reduction to the decline in smoking rates to represent other unknown factors

that also could have affected the downward shift in smoking rates. The remaining difference between those rates and actual smoking rates is attributed to the availability and use of e-cigarettes.

The resulting counterfactual estimates are presented in graphical form in Figure 4 below.

In this figure, the top blue line represents the projected decline in adult smoking rates based on pre-2010 trends and the red line represents the actual decline in smoking rates since 2010. The purple line represents the projected trend from 2002 to 2010 adjusted for the impacts of the Tips campaign, the expanded access to smoking cessation assistance under the ACA, and the X factor. So, the light gray region between the blue and purple lines represents the total smoker-years avoided by the decline in smoking rates resulting from Tips, the ACA and X factors. And the pink area between the red line (actual smoking rates) and the purple line (factors other than e-cigarettes) represents the total smoking years avoided by e-cigarette use. Finally, the green line tracks the trend in vaping rates, and the light green area represents total e-cigarette user years.

Based on this analysis and the number of smokers and e-cigarette users each year from 2010 to 2022 as presented earlier in Tables 3 and 4, we estimate that rising e-cigarette use since 2010 was associated with a reduction in the number of smokers that totaled 6.1 adult smokers over the period from 2010 to 2022—an average of about 509,000 adults per year who shifted from smoking to vaping or who otherwise would have smoked cigarettes but vaped instead. Over this period, e-cigarette use totaled 101 million vaper-years and that use was responsible for a reduction of 44.5 million smoker-years, so each additional vaper-year resulted in a 0.44 reduction in smoker-years.

We also estimated the impact of e-cigarette use from 2010 to 2022 on the numbers of adult cigarette smokers in 2022 by gender, race or ethnicity, and age. (See Table 6A below.) Overall, 40.8 percent of vapers were former smokers or people who otherwise would have become smokers. Using this metric, the analysis found that e-cigarettes were most effective in reducing smoking rates among women, whites, and people ages 25 to 44 and 45 to 64.

Figure 4: Estimated Impact of E-Cigarettes, the Tips Campaign, and the ACA on Adult Smoking Rates

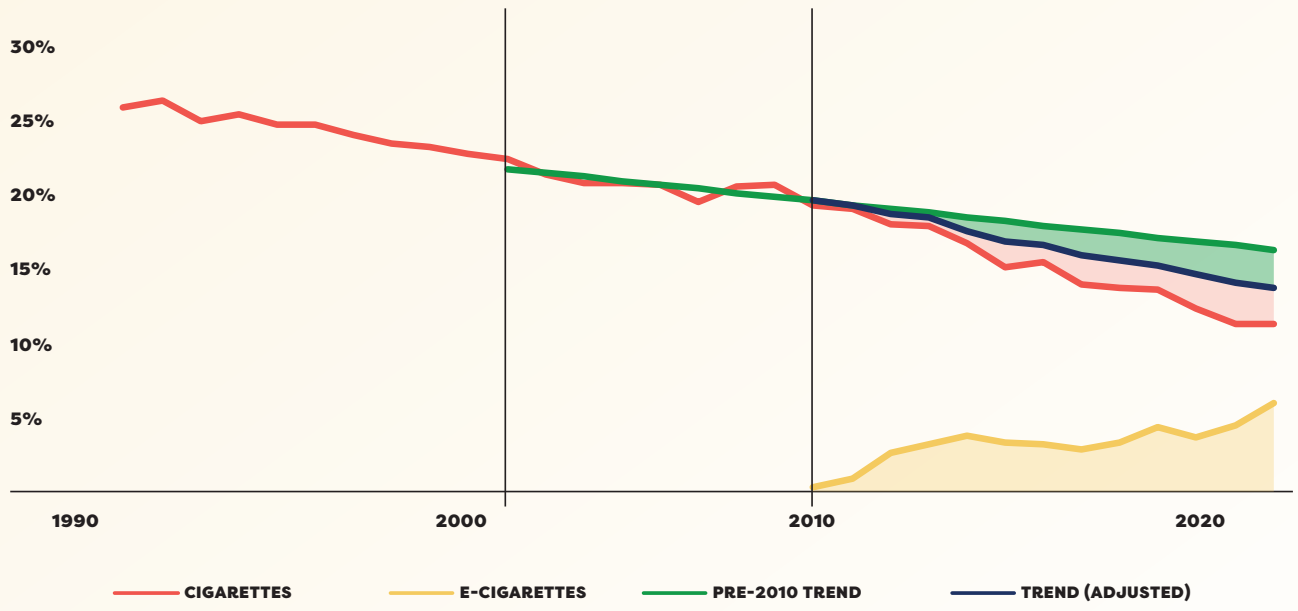


Table 6A: E-Cigarettes' Impact on Smoking Rates, 2010 to 2022, By Gender, Race/Ethnicity, and Age

	Smoking Rate, 2022	Impact of E-Cigarettes on Smoking Rate	E-Cigarette Users, 2022	Impact as a Share of E-Cigarette Users
Gender				
Male	12.9%	3,276,000	8,344,000	39.3%
Female	9.8%	3,184,000	6,629,000	48.0%
Race				
Non-Hispanic Black	13.5%	474,000	1,341,000	35.3%
Non-Hispanic White	12.4%	5,811,000	10,678,000	54.4%
Hispanic	7.7%	157,000	1,748,000	9.0%
Age				
18-24	4.7%	554,000	4,376,000	12.7%
25-44	12.1%	4,615,000	7,622,000	60.5%
45-64	14.7%	1,797,000	2,425,000	74.1%
65+	8.4%	20,000	549,000	3.6%
Total	11.3%	6,105,000	14,972,000	40.8%

We also used the metric of smoking years and vaping years and annual data that took account of when a smoker shifted to e-cigarettes from 2010 to 2022 to gauge the impact of e-cigarettes on smoking rates by gender, race or ethnicity, and age.

Table 6B: Effectiveness of E-Cigarettes in Reducing Smoking in Smoking Years and Vaping Years,2010 to 2022, by Gender, Race/Ethnicity, and Age

	Total Decline in Smoker-Years	Total Vaper-Years	E-Cigarette Based Smoking Reductions as a Share of E-Cigarette Use
Gender			
Male	23,800,000	56,200,000	42.4%
Female	21,7000,000	40,800,000	53.3%
Total	45,600,000	97,000,000	47.0%
Race			
Non-Hispanic Black	5,300,000	6,500,000	81.6%
Non-Hispanic White	40,000,000	71,300,000	56.1%
Hispanic	3,400,000	10,300,000	33.3%
Total	45,300,000	77,800,000	58.2%
Age			
18–24	4,100,000	23,300,000	17.7%
25–44	28,200,000	45,200,000	62.5%
45–64	14,300,000	22,500,000	63.4%
65+	600,000	4,900,000	12.8%
Total	47,300,000	95,900,000	49.3%

Using the metric of smoking years and vaping years, the shifts from smoking to e-cigarettes had a larger impact for women than men: Each year a female ex-smoker vaped from 2010 to 2022 was associated with a 0.53 reduction in smoking years, compared to a 0.42 reduction for male ex-smokers. By race and ethnicity, the greatest impact in smoking and vaping years occurred among Black ex-smokers with each Black vaping year associated with a 0.83 reduction in smoker years, while the smallest effect occurred among Hispanics with each Hispanic vaping year associated with a 0.33 reduction in smoker years.

By age, e-cigarettes had the largest marginal impact on smoking for people ages 25 to 44 and 45 to 64: Each vaping year by an ex-smoker of those ages was associated with a fall in smoker years of 0.625 and 0.63 respectively. The much more modest impact for those ages 18 to 24 reflects their low smoking and high vaping rates, and the even smaller effect for people ages 65 and over reflects their modest decline in smoking rates from 2010 to 2022 and low vaping rate.

Impact of E-Cigarettes on Smoking by Adolescents

We also analyzed the impact of e-cigarettes on cigarette smoking by adolescents using data from the National Youth Tobacco Survey (NYTS) for adolescents in grades 9 to 12. (See Table 7 below.)

Table 7: Adolescent Rates of Cigarette and E-Cigarette Use By Gender, Age, Race and Ethnicity, and Sexual Orientation, 2022[155]

	Cigarette Use			E-Cigarette Use		
	Current	Former	Never	Current	Former	Never
Gender						
Female	1.8%	8.3%	88.9%	15.3%	14.6%	69.3%
Male	2.3%	8.7%	87.6%	12.7%	14.1%	72.4%
Race/Ethnicity						
Hispanic	2.0%	7.5%	88.9%	12.2%	14.9%	72.1%
Non-Hispanic Black	0.9%	4.8%	93.1%	11.3%	11.2%	77.0%
Non-Hispanic White	2.4%	10.2%	86.4%	16.5%	15.4%	67.3%
Age by High School Grade						
Ninth	1.4%	5.0%	92.8%	8.7%	9.7%	80.8%
Tenth	1.3%	7.8%	89.4%	13.7%	13.2%	74.3%
Eleventh	2.4%	9.1%	87.2%	15.5%	15.9%	67.6%
Twelfth	3.1%	12.5%	82.7%	18.8%	19.1%	61.3%
Stated Sexual Orientation						
Straight	1.4%	7.6%	90.7%	12.1%	14.1%	73.4%
Gay/Lesbian	5.7%	10.9%	82.6%	17.4%	17.3%	64.7%
Bisexual	3.9%	13.3%	82.5%	17.6%	20.1%	61.1%

Young people's use of e-cigarettes surpassed their cigarette use in 2014 and remained more popular since that time. As noted earlier, the correlation between annual smoking and vaping rates by adolescents from 2010 to 2022 is statistically significant and negative—that is, adolescent smoking rates decline as e-cigarette use increases. However, the correlation is lower for young people than adults. The data also show differences based on gender, race and ethnicity, sexual orientation, and age. Young men were more likely to smoke than young women while young women were more likely to vape than young men. Black youth were much less likely to smoke and somewhat less likely to vape than Hispanic or white youth, and Hispanic youth were somewhat less likely to smoke and much less likely to vape than white youth. Gay, lesbian, and bisexual young people also were more likely to smoke and vape than straight young people. Finally, adolescent use of both cigarettes and e-cigarettes increased with grade level.

To estimate the impact of e-cigarettes on adolescent smoking rates from 2010 to 2022, we applied the same process used to analyze the impact of e-cigarette use on adult smoking rates. First, we analyzed the time series data for breakpoints and determined that such breaks occurred in 2003, 2013, and 2018. Youth vaping spiked in 2014, so we extrapolated the decline in adolescent smoking rates from 2004 to 2013 to the period from 2013 to 2022 and compared the results to actual smoking rates. We found a downward shift in the smoking prevalence of youth in 2014 and an acceleration in the decline in their cigarette use in 2019, corresponding with the two major spikes in youth vaping. (A detailed discussion of the process for estimating the impact of adolescent vaping on their smoking rates is provided in the Appendix.)

In contrast to adults, however, the difference between the projected smoking rates for adolescents and their actual rates was not statistically significant even without accounting for factors such as the increased funding for the Children's Health Insurance Program (CHIP) under the ACA.[156] One reason that adolescent vaping was not linked statistically to smoking cessation by young people is that the share of young people who smoked declined so sharply, reaching barely 2 percent by 2022. So, while adolescents have moved away from cigarette smoking and taken up vaping, the two developments are not closely related as they were for adults. This is consistent with the impact on adolescent vaping of neurophysiological changes that enhance their propensity to seek out sensations associated with behaviors seen as risky or taboo.

The NYTS surveys also provide additional confirmation of these dynamics. Since 2015, the survey has asked young people who use e-cigarettes why they vape. In 2015, about 14 percent of adolescent vapers said they used e-cigarettes to help stop smoking, and that response fell to 3.4 percent by 2022.[157] Similarly, the percentage who said they vape because it is less harmful than smoking declined sharply from nearly 37 percent in 2015 to 14.5 percent in 2022. In the initial surveys, young people often cited the flavors available in e-cigarettes as their reason for vaping, but the share citing flavorings also fell by half to less than 24 percent in 2022. By 2022, the reason cited most often was that their friends use them with 61 percent of current young e-cigarette users citing friends for why they started or continue to vape. Notably, the percentage of young vapers citing any reason related to tobacco products fell from 70 percent in 2015 to 41 percent in 2022: Increasingly, adolescents vape for social reasons or simply because they want to.

The Health and Economic Effects of Adult Smokers Shifting to E-Cigarettes

Smoking entails largescale economic and social costs through increased health expenditures related to smoking, the productivity losses of smokers being treated for smoking-related illnesses and of those who die from smoking-related conditions, and the healthcare costs associated with people's exposure to secondhand smoke. There also are costs associated with e-cigarette use, including those from smokers who shift to vaping, that offset a modest share of the cost savings linked to the declining smoking rates of American adults.

There is extensive literature on the harms related to smoking, but scientific research and analysis of the harms related to vaping is more limited. The most comprehensive study of the relative harm of various products that contain nicotine found that the harm associated with e-cigarettes is approximately 4 percent of the harm of smoking cigarettes,[158] and subsequent studies have adopted this estimate.[159] For our analysis, we follow the conservative approach used by the most recent rigorous study of those harms and adopt as our midpoint estimate that vaping entails about 5 percent of the harm of smoking with regard to associated healthcare costs and productivity losses,[160] which is also the estimate of British public health authorities.[161] Following the research literature and the CDC, we ascribe no harm from secondhand exposure to vaping compared to the substantial documented harm from secondhand cigarette smoke.[162]

Our counterfactual modeling results do not differentiate between whether the decline in smoking rates is driven by smokers quitting or fewer people starting to smoke, including those who vape instead of ever smoking. This affects the calculation of the healthcare and productivity benefits associated with declining smoking rates because former smokers experience more health effects than those who never smoked. So, we adopted the conservative assumption that former smokers account for all the e-cigarette related decline in smoking rates. This affects our estimates because, again, healthcare costs, productivity losses and mortality rates are much higher for former smokers than never-smokers. Overall, averting someone from becoming a smoker through e-cigarette use has 1.9 times the impact in reducing smoking-attributable deaths and 2.3 times the economic savings of someone shifting from smoking to vaping.

Our analysis did not disaggregate by race or ethnicity the premature deaths, healthcare and economic costs averted by people shifting from smoking to vaping from 2010 to 2022. Research on the incidence

of smoking-related illnesses and premature deaths by race and ethnicity is difficult to interpret, because other differences in lifestyle often tied to income and differences in access to healthcare and healthcare information vary by race and ethnic group. For example, one study found that Black smokers believe they are at less health risk from smoking than white smokers.[163] This is consistent with a 2013 study based on data from 1980 to 2005 that found that smoking-related mortalities reduced life expectancy in 2005 of Black males age 50 by 3.1 years compared to 2.2 years for white males age 50, and current smoking status explained about 20 percent of the Black male excess relative mortality risk without adjusting for socioeconomic differences.[164] The study also found, however, that smoking reduced the life expectancy of Black females age 50 in 2005 by 1.66 years or slightly less than the 1.72 years for white females. And more recent research found that rates of lung cancer, chronic obstructive pulmonary disease (COPD), and stroke were higher for white current and former smokers than Black current and former smokers.[165]

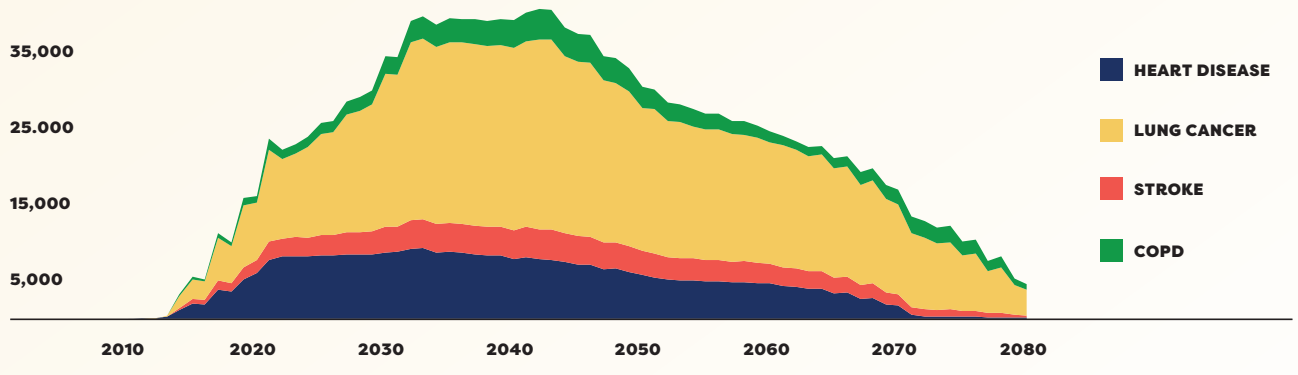
The Reduction in Premature Deaths from Smokers Switching Cigarettes to Vaping

As we will see, our analysis found that smokers shifting to vaping from 2010 to 2022 resulted in 113,300 fewer premature deaths from smoking-attributable diseases by 2022, averaging nearly 22 additional years alive per person, and 334,200 fewer premature deaths by 2030. Estimating the impact on life expectancy of former smokers who shifted to vaping from 2010 to 2022 began with estimates of 10-year mortality rates for lung cancer, heart disease, stroke, and COPD for current, former, and never-smokers by age group from 35 to 75.[166] We averaged the male and female values and determined the marginal increase in 10-year mortality rates for current smokers versus former smokers for each of the diseases. We limit our analysis to these diseases rather than using smokers' deaths from all causes because those diseases are directly linked to smoking. The analysis also takes account of the potential health impact from vaping by former smokers based on the estimate described earlier that e-cigarettes entail 5 percent of the health costs of smoking.

The estimates of the numbers of expected premature deaths averted by former smokers shifting to vaping are based on the marginal 10-year mortality risk of smokers compared to former smokers distributed across the following 10 years. For the eleventh year and thereafter, we use population data by age and each age's all-cause mortality rate to estimate the number of individuals who would still be alive 10 years later. We use the same process applying the new age category's marginal mortality risk and repeat the cycle through our age groups to age 75. We also assume no smoking-related mortality risk for people under age 35.

This analysis covered those ages 18 and older by 2022 and tracked their mortality rates to 2080, when the survivors in the youngest cohort would be 75 years old. Figure 5 below presents a graphical representation of our results of the numbers of premature deaths from the four smoking-related diseases averted by smokers shifting to

Figure 5: Reductions in Smoking-Attributed Deaths, 2011 to 2080, Related to Smokers Shifting from Cigarettes to E-Cigarettes from 2010 to 2022



e-cigarettes from 2010 to 2022. As expected, the averted deaths from smoking-related lung cancers comprise the bulk of the results, followed by deaths from smoking-related heart disease.

These results capture the deaths averted by smokers who shifted to vaping from 2010 to 2022 and thus do not include any estimates of smoking and vaping rates beyond 2022. As noted, we assumed that each reduction in smoking rates relative to the previous trend, corrected for the impact of the CDC Tips program, the ACA, and a 25 percent "X factor," represents a smoker shifting to vaping. Based on the limited period in which data on vaping are available, the results also cannot take account of any smokers who shifted to vaping resuming their smoking after 2022 or any smokers who did not shift quitting after 2022.[167] This second assumption is problematic for the longer periods up to 2060 or 2080, but it does not affect the estimates of deaths averted over the 2011 to 2022 period and should have marginal impact for the 2030 and other near-term estimates.

Table 8 below presents the number of smoking-related deaths from the four main smoking related diseases that were averted by adults shifting from smoking to e-cigarette use from 2010 to 2022. The analysis found that people shifting from smoking to vaping from 2010 to 2022 averted the premature deaths from the four smoking-attributable diseases of 113,300 Americans by 2022 and 334,200 people by 2030. Their numbers increase with time and age: Taking account of the assumptions noted above, the analysis suggests that premature deaths from smoking-related conditions averted by former smokers switching to vaping from 2010 to 2022 could total 1.1 million people by 2050 and 1.7 million people by 2080. [168]

Table 8: Cumulative Deaths from Four Smoking-Attributable Disease Averted by Smokers Shifting to Vaping from 2010 to 2022

	2022	2030	2050	2080
Lung Cancer	**55,200**	**173,100**	**630,800**	**1,010,000**
Heart Disease	**39,800**	**107,100**	**264,100**	**349,000**
Stroke	**12,100**	**34,500**	**108,300**	**163,300**
COPD	**6,2000**	**19,500**	**85,300**	**136,900**
Total	**113,300**	**334,200**	**1,088,500**	**1,664,300**

To better understand the impact of e-cigarettes on public health, we also estimated the years of life expectancy gained by those former smokers who averted premature deaths by shifting to vaping. We drew on data on the 10-year all-causes mortality rates for former smokers and the Social Security Administration's Actuarial Life Tables to estimate the life expectancy of a former smoker for each 5-year age bucket.[169] Using these values, we found that the 113,300 smoking-attributable deaths averted by 2022 would have resulted in a loss of 2.5 million life-years or an average of 21.9 years per person.

Economic Benefits from the Productivity of Smokers Who Averted Premature Deaths By Shifting to Vaping from 2010 to 2022

Averting those premature deaths for an average of nearly 22 years also produces economic benefits from those people of working age continuing to work and avoiding the economic costs from being too sick to work to their full effectiveness. To estimate the dimensions of those benefits, we used the imputed earnings estimates from the

NHIS dataset to calculate the average annual earnings of people in each five-year age bracket from 35 and 75 and the overall average for all earners ages 75 years and older. We applied this time series to our mortality calculations to estimate the expected lifetime earnings lost by an individual who would have passed away in each age bucket but for switching from smoking to vaping. These expected lifetime earnings ranged from $21,326 for working people ages 75 and older to $1,488,038 for workers ages 35 to 39. Using these values and the number of smoking-attributable deaths averted in each age group, we estimate that the mortality-related productivity losses averted by smokers shifting to vaping from 2010 to 2022 totaled $65.8 billion by 2022.

The medical treatment of smokers and former smokers related to their smoking also involves productivity losses for the time they would be absent from work. One recent study found that in 2018, the productivity costs for smokers and former smokers forced to take time off to treat smoking-related medical conditions averaged $2,830 per current smoker and $1,363 per former smokers.[170] Those findings suggest that quitting smoking, including those who switch to vaping, results in a $1,806 annual gain in illness-related productivity, in 2022 dollars, per former smoker.

The Healthcare Savings from Smokers Who Shifted to Vaping from 2010 to 2022

Shifting smokers to e-cigarettes also produces direct healthcare savings, since smokers seek and receive medical treatment for a range of smoking-related illnesses. A rigorous 2014 study found that smoking was responsible for 11.7 percent of U.S. healthcare spending from 2010 to 2014, including 6.0 percent of the spending for current smokers, 1.3 percent for former smokers who quit within the previous five years, and 4.4 percent for former smokers who quit more than five years ago.[171] The researchers further found that $226.7 billion in U.S. healthcare spending in 2014 was tied to smoking. Accounting for inflation, this finding suggests that in 2022, smoking-related healthcare costs averaged $3,795 per current smoker, $2,815 per former smokers who had quit within five years, and $2,781 for former smokers who quit more than five years ago. On this basis and accounting for the presumed 5 percent harm related to e-cigarettes, quitting smoking results in healthcare savings of $980 for each former smoker who quit in the preceding five years and $1,014 for each former smoker who stopped more than five years ago.

Estimating health costs related to secondhand exposure to cigarette smoke is challenging. Researchers found that healthcare spending in 2010 related to secondhand smoke exposure at home totaled $62.9 million for children ages 3 to 14 and $1.9 billion for adult non-smokers.[172] Another study found that 73 percent of secondhand smoke exposure was experienced by individuals living with anyone who smoked inside the home.[173] Assuming uniformity in healthcare costs associated with secondhand smoke across all exposed individuals and adjusting for inflation, these findings suggest that secondhand smoke leads to annual healthcare costs of $80 per smoker and quitting smoking results in $80 in healthcare savings per ex-smoker or $3.5 billion by 2022.

Based on our estimates of productivity losses from smoking-related premature deaths and lost time at work and healthcare costs associated with smoking and exposure to secondhand smoke, we estimate that the economic benefits derived from 2011 to 2022 from smokers shifting to e-cigarettes in those years totaled $179.3 billion or an average of nearly $15 billion per year. (See Table 9 below.) This analysis highlights the large economic benefits based on the productivity of people who switched from smoking to vaping from 2010 to 2022 and thereby reduced their likelihood of dying prematurely or taking time off from work because of smoking-related conditions. Over this period, the productivity benefits total $137 billion. In addition, shifting from smoking to vaping in this period reduced the costs of treating the four major smoking-related illnesses by $38.8 billion.

Table 9: Economic Benefits and Healthcare Savings Based on Smokers Shifting to E-Cigarettes from 2010 to 2022 (Billions, 2022 $)

	Productivity Losses Averted		Healthcare Costs Averted		Total
	Mortality	Morbidity	Smokers	Secondhand	
2011	$0.1	$0.7	$0.4	$0.0	$1.1
2012	$0.1	$2.5	$1.4	$0.1	$4.1
2013	$0.6	$1.9	$1.0	$0.1	$3.6
2014	$1.8	$2.6	$1.5	$0.2	$6.0
2015	$3.3	$6.7	$3.7	$0.3	$14.1
2016	$3.3	$4.3	$2.3	$0.2	$10.1
2017	$6.3	$8.1	$4.4	$0.4	$19.1
2018	$6.0	$7.4	$4.0	$0.4	$17.8
2019	$8.4	$6.2	$3.4	$0.3	$18.2
2020	$9.9	$9.6	$5.2	$0.5	$25.2
2021	$12.5	$11.6	$6.3	$0.6	$31.0
2022	$13.6	$9.7	$5.2	$0.5	$29.0
Total	$65.8	$71.2	$38.8	$3.5	$179.3

These estimates almost certainly understate the economic costs and related benefits and savings associated with vaping from 2010 to 2022 because we attributed all of the accelerated decline in smoking rates related to e-cigarettes to smokers shifting to vaping and not to any non-smokers choosing to vape instead of smoking. The productivity and healthcare cost benefits are much greater for never smokers than former smokers. As a result, if 25 percent of the accelerated decline in smoking rates associated with e-cigarette use was based on vapers who otherwise would have started smoking cigarettes, the economic benefits and healthcare savings would rise to about $240 billion for the 2011 to 2022 period.

FDA Regulation of E-Cigarettes Versus Combustible Cigarettes

The FDA was first authorized to regulate all tobacco products, including cigarettes and e-cigarettes, by the Tobacco Control Act in 2009. Yet despite the extensive evidence of the large personal and societal costs arising with cigarette smoking, the large benefits and significant savings associated with smokers shifting to vaping, and the growing recognition of those benefits by scientists and FDA officials, the agency has continued to tacitly discourage people from shifting from smoking to vaping by regulating e-cigarettes more strictly and extensively than cigarettes.[174]

Congress first addressed issues related to smoking in 1965 when, in response to public concerns around the Surgeon General's report on smoking and health, it directed cigarette manufacturers to post a warning on their packages that "Cigarettes Smoking May Be Hazardous to Your Health."[175] In 1970, under the Public Health Smoking Act, Congress strengthened the warning to "The Surgeon General has Determined that Cigarette Smoking is Hazardous to Your Health" and banned cigarette advertising on television and radio.[176]

For the next two decades, however, Congress protected the tobacco industry from further regulation by explicitly exempting tobacco products from its legal definitions of a "controlled substance" under the Controlled Substances Act of 1970, a "consumer product" under the Consumer Product Safety Act of 1972, a "hazardous substance" under the 1976 amendments to the Federal Hazardous Substances Labeling Act, and a "chemical substance" under the Toxic Substances Control Act of 1984.[177] The only additional federal regulation of tobacco products in this period were laws banning smoking on domestic airline flights and mandating four rotating warning labels on cigarette packages and advertising.

The FDA tried to step into the breach in 1995 by proposing to regulate cigarettes as drug delivery devices, following a CDC report that 3,000,000 American adolescents were cigarette smokers and one in three would die prematurely by proposing to regulate cigarettes as drug delivery devices.[178] Lawsuits delayed the proposal's implementation and the Supreme Court nullified it in 2000, declaring that "Congress has not given the FDA the authority to regulate tobacco products as customarily marketed."[179] It took Congress nine more years to authorize the FDA to regulate tobacco products under the Family Smoking Prevention and Tobacco Control Act of 2009 (TCA).[180] That law empowered the FDA to regulate tobacco products and reduce their use and harmful effects in ways "appropriate for the protection of the public health," thereby creating a broad public standard for tobacco regulation based on benefiting the health of Americans as a whole.[181]

E-cigarettes were introduced in the United States the year before Congress enacted the TCA.[182] Before the FDA proposed steps to regulate cigarettes under the new law, it moved in 2010 to regulate e-cigarettes as "adulterated, misbranded, or unapproved drug delivery devices" under its original authorizing legislation, the Federal Food, Drug, and Cosmetic Act of 1938.[183] By citing the 1938 Act instead of the TCA, the FDA proposed to regulate e-cigarettes without addressing cigarettes or other tobacco products. The ploy failed: The Supreme Court held that the FDA could regulate e-cigarettes only under the TCA's authorization covering all tobacco products.

The FDA finally took steps to regulate tobacco in 2014 under proposed regulations that deemed cigarettes, cigars, hookahs, pipe tobacco, and e-cigarettes or "electronic nicotine delivery systems" (ENDS) as tobacco products covered under the TCA and required that those products could not be legally marketed in the United States without the FDA's approval that doing so would be consistent with the provisions of the TCA.[184] These "Deeming Regulations" and premarket approval requirements were finalized and formally issued in August 2016.

The new regulation posed a dilemma for the FDA and serious problems for cigarette producers since approving the continuing sales of cigarettes would clearly violate the TCA's mandate to protect public health. The FDA finessed its dilemma and the industry's problem by creating a large loophole for cigarette producers: Cigarettes already on the market in August 2016 and new products "substantially equivalent" in ingredients and formulation to those 2016 products were "grandfathered"—that is, exempt from the TCA approval requirements based on the public health standard.[185] The FDA also declared, however, that this blanket exemption did not cover existing e-cigarettes and their substantial equivalents in the future, despite the growing scientific evidence that their use as an alternative to smoking aligned with the public health standard.

> The FDA...create[ed] a large loophole for cigarette producers...

Instead, the FDA directed that e-cigarettes on the market in August 2016 could continue to be sold only if their manufacturers applied for formal FDA premarket approval by August 2022, and later moved up the deadline to May 2020 and then extended it to September 2020 because of the pandemic.[186] The new regulations of e-cigarettes also obliged their manufacturers to register and make regular reports to the FDA, requirements also not applied to cigarette makers. The main restriction that did apply to both cigarettes and e-cigarettes was the federal ban on sales to anyone under age 18.[187]

> In practice, the FDA has rejected virtually all applications for vaping products and devices.

Under the premarket approval requirements, FDA data show that from 2020 to mid-2023, producers of "Electronic Nicotine Delivery Systems" (mainly covering e-cigarette products and devices but also hookah pens, e-cigars, and e-pipes) filed 26,497,293 Premarket Tobacco Product Applications (PMTA).[188] The FDA accepted 6,699,741 of those applications for review and formally evaluated 1,193,237 of those initially accepted, or 4.5 percent of the nearly 26.5 million PMTAs originally filed.[189] Despite the extensive benefits of e-cigarettes as alternatives to smoking, the FDA has thus far granted PMTAs to only 23 of the nearly 1.2 million vaping products and devices it evaluated.[190]

The FDA also has devoted substantial resources to enforcing e-cigarette restrictions, especially regarding sales to minors. From 2016 to 2018, for example, the FDA issued more than 8,000 warning letters to online and brick-and-mortar sellers of e-cigarettes, including a major enforcement exercise in September 2018 that involved more than 1,100 warning letters and 131 civil money penalty complaints.[191] In the same period, the FDA also conducted more than 1,200 inspections

of e-cigarette manufacturing facilities and vape shops that modify the products.

FDA regulations also bar e-cigarette makers from advertising that their products pose less risk or harm than cigarettes and other combustible tobacco products without securing a Modified Risk Tobacco Product (MRTP) order from the FDA. Without a MRTP order, an e-cigarette maker cannot even advertise that its products do not contain the toxic chemical ingredients in cigarettes or produce the toxic byproducts from combustion that are linked closely to serious and often fatal medical problems. In practice, the process for obtaining a MRTP order are so complicated, costly, and uncertain that applications have been rare, and the FDA has not approved any of them.[192]

Instead of focusing on the toxic substances absorbed by cigarette smokers and linked to cancers, heart disease, stroke and other serious conditions, and despite the lack of evidence linking nicotine to any of those conditions, the FDA has designated "nicotine and the issue of addiction, (as) the center of the agency's tobacco regulation effort."[193]

In so doing, the FDA has focused on the only ingredient common to cigarettes and vaping products while ignoring the absence in e-cigarettes of any of the toxic substances in cigarettes.

FDA regulations also bar e-cigarette makers from claiming any therapeutic benefits for their products in their labeling or marketing, including evidence that vaping can help people reduce or stop smoking, unless the e-cigarette producer secures the FDA's approval of the product as a "safe and effective" drug or medical device. The FDA has granted such approval for nicotine patches, nicotine gum, and nicotine lozenges as replacement therapies that can help smokers quit, but generally not for e-cigarettes—again, despite the preponderance of evidence that shifting smokers to e-cigarettes produces "a substantial mortality reduction."[194]

A 2018 study, for example, concluded that switching smokers to e-cigarettes from 1990 to 2040 would have reduced premature deaths from lung cancer, COPD, heart disease, and stroke by 760,000 to 2,525,000, depending on the share and pace of the switching.[195] Similarly, a 2022 study estimated that replacing cigarettes with vaping for 10 years would result in 1.6 million to 6.6 million fewer premature deaths from 2016 to 2100.[196] These studies are consistent with our analysis that much of the acceleration in declining smoking rates that began in 2010 was associated with some 6 million smokers shifting to vaping from 2010 to 2022, which in turn saved an estimated 113,300 people from premature deaths linked to smoking in those years and produced nearly $180 billion in economic benefits and cost savings.

While the FDA has been effectively barred e-cigarettes makers from advertising that their products do not contain the toxic ingredients in cigarettes or that using e-cigarettes can help people reduce or stop smoking, the agency has begun to acknowledge the weight of scientific evidence on these issues. In October 2021, the agency approved the marketing of three new e-cigarette products produced by RJ Reynolds under the brand name VUSE as "appropriate for the protection of public health."[197] In so doing, the FDA for the first time acknowledged the potential benefits of vaping products as smoking cessation aids for adult smokers and found that those benefits outweighed the "risk" of youths using the products. The Director of the FDA Center for Tobacco, Mitch Zeller, wrote at the time,

"Today's authorizations are an important step toward ensuring all new tobacco products undergo the FDA's robust, scientific premarket evaluation. The manufacturer's data demonstrates its tobacco-flavored products could benefit addicted adult

smokers who switch to these products – either completely or with a significant reduction in cigarette consumption – by reducing their exposure to harmful chemicals." [198]

Even so, the approval order for the three products imposed strict restrictions on their digital, radio, and television advertising and require that their manufacturer to report regularly to the FDA on any "ongoing and completed consumer research studies, advertising, marketing plans, sales data, information on current and new users, manufacturing changes, and adverse experiences."[199]

In one respect, the FDA has treated cigarette manufacturers more strictly than e-cigarette makers. It banned the sale of flavored cigarettes in 2009, covering fruit flavors, candy flavors, and dessert flavors or virtually everything except tobacco or menthol flavors, to curtail marketing cigarettes to children. The FDA did finally ban the sale of non-tobacco or non-menthol cartridge-based flavored e-cigarettes, by far the most popular type of vaping products, in 2020.[200]

And from 2016 to 2020, [the FDA] refused to approve the marketing of any new flavored vaping products, including new menthol e-cigarettes, despite the growing evidence that flavored e-cigarettes are particularly effective in helping smokers quit and play at most a modest role in adolescent decisions to vape.[201]

The ban of flavored e-cigarettes has proved to be self-defeating as recent evidence shows it induced more e-cigarette users to switch to smoking than to quit vaping.[202] Among vapers who had used flavored products before the ban, 14.1 percent shifted to cigarettes or other combustible tobacco products compared to 4.9 percent who quit vaping, while 59.5 percent simply switched to disposable flavored vaping products or to cartridge or pod based menthol or tobacco flavored products.[203]

Based on the FDA's public health standard and the weight of scientific evidence that e-cigarettes are much less harmful than cigarettes and that smokers can be persuaded to switch, it is reasonable to conclude that the FDA has an obligation to regulate cigarettes and e-cigarettes in ways that actively encourage people to switch from smoking to vaping.[204] In so doing, the FDA would join the British National Health Service. Instead, as Dr. Lindblom has noted, "the FDA has yet to implement a rule that would sharply reduce U.S. tobacco use harms."[205]

A New Policy Agenda for the FDA

Future FDA policy on tobacco products should draw on the well-established scientific evidence regarding the relative risks of e-cigarettes and cigarettes and the utility of people using e-cigarettes to stop or reduce their smoking, and proactively inform American smokers about the health benefits of shifting to vaping. A senior advisor on tobacco issues to the Canadian government, David Sweanor, wrote nearly a decade ago,

"The development of policies on vaping ... should be seen in the broader public health context of innovative alternative nicotine delivery systems playing a key role in ending the immense devastation of combustible cigarettes. Opposition to vaping based on inaccurate and incomplete information, or fear of unlikely and avoidable hypothetical unintended consequences, will invariably cause great harm to individuals, impede rather than assist the attainment of public health objectives, and unnecessarily prolong the epidemic of cigarette-caused diseases."[206]

This reorientation of FDA tobacco policy would represent a virtual reversal of current policies that have followed "a war on drugs orientation to nicotine, focusing on risks rather than public health benefits."[207] This policy reboot could begin with a series of evidence-based reforms recommended by Dr. Lindblom based on the FDA's authority under the TCA to take steps "appropriate for the protection of the public health." The recommendations include,[208]

- Mount public education campaigns to encourage smokers to switch to e-cigarettes, including campaigns targeted to groups with the highest smoking rates such as Black and LGTBQ people. These campaigns would provide accurate information about the relative risks of cigarettes compared to vaping and instruct smokers on how to use e-cigarettes to stop smoking.
- Require that all labeling and marketing of cigarettes and other combustible tobacco products include a warning about those relative risks and the potential health benefits of switching to e-cigarettes.

- Apply less costly and burdensome restrictions and requirements to e-cigarettes and their advertising and marketing than those applied to cigarettes or other combustible tobacco products.
- Create an expedited pathway for e-cigarette manufacturers to secure FDA product approval orders for new types and brands of e-cigarettes with the potential to increase the numbers of smokers who switch to vaping.
- Also create an expedited pathway for e-cigarette manufacturers to obtain FDA Modified Risk Tobacco Product orders allowing them to advertise that their e-cigarette products entail less risk than cigarettes and other combustible tobacco products.
- Enable more smokers to quit or secure the nicotine they crave from e-cigarettes by capping nicotine levels for cigarettes at no more than 0.4 mg nicotine per gram or 0.6 mg per cigarette, levels that should not promote addiction or compensating behavior such as inhaling more deeply.[209]
- Apply higher taxes and minimum prices for cigarettes and other smoked tobacco products than for e-cigarettes to make vaping more appealing economically to smokers. This recommendation is also supported by recent research findings that a Minnesota state tax on e-cigarettes aimed at discouraging vaping by young people induced some adults to switch from vaping to smoking and reduced the numbers of adults who stopped smoking.[210]

Experts at the University of Michigan's School of Public Health and Tobacco Research Network recently recommended many of the same measures, including higher taxes on cigarettes and other combustible tobacco products than on e-cigarettes and setting nicotine yields for cigarettes at levels unlikely to sustain addiction.[211] They also urged the FDA to cap the maximum emissions of the toxic substances in cigarettes and limit e-cigarette sales to adults-only retail outlets.

Some commentators who support vaping to help people reduce or stop smoking have a mixed view about flavored e-cigarettes. Despite extensive research showing that flavored e-cigarettes are more effective than tobacco flavored vaping products in helping smokers reduce or stop their cigarette use, and despite survey evidence showing that flavors play a very modest role in attracting some adolescents to vaping, some experts remain concerned that flavored vaping products attract adolescent non-smokers. As a result, the University of Michigan experts and some others recommend that the FDA allow a limited variety of adult-oriented flavors for e-cigarettes including menthol but not candy and other sweet flavors,

The FDA and Congress should consider more proactive measures to persuade Americans to stop smoking by shifting to vaping.

while barring all non-tobacco flavors in cigarettes and restricting the sales of flavored e-cigarettes to adult-only retail outlets.[212] This approach ignores research findings that the lack of appealing flavors in e-cigarettes reduced smokers' use of vaping to help quit smoking.[213] Moreover, the Michigan recommendations were published before the most recent studies on the anti-smoking effectiveness of flavored vaping products on a broader basis.

The FDA and Congress also should consider more proactive measures to persuade Americans to stop smoking by shifting to vaping.

For example, this year the British government introduced its "Swap to Stop" initiative that includes aggressive policies to accelerate the switch from cigarettes to vaping.[214] Under the program, the government will provide at least one million Britons or one in five English smokers with free "vaping starter kits" and behavioral supports to help them switch. Swap to Stop also will provide direct payments to pregnant smokers who shift to vaping or stop smoking entirely.

These policy changes are all based on the scientific evidence that, as Dr. Lindblom has written,

"... e-cigarettes are uniquely positioned to serve as less-harmful alternatives to smoking because they enable users to inhale nicotine into their lungs, as smokers do, but without using any combustion or tobacco. By delivering nicotine from a liquid solution in aerosol form without combustion, e-cigarettes can sharply reduce user and non-user exposure to many carcinogens and other harmful or potentially harmful constituents." [215]

As a result, "public health gains are secured each time a smoker who would not otherwise quit all smoking switches entirely to using e-cigarettes instead."[216]

Conclusions

This study examined the risks and benefits of e-cigarette use in the United States by reviewing the scientific literature and through new econometric analysis. First, we found that Americans use e-cigarettes more moderately and irregularly than often assumed. In 2022, about 13 percent of adolescents or high school students reported vaping in the previous month, with only 4 percent doing so daily. Among adults, 5 percent vaped in the previous month with 3 percent vaping daily. The National Youth Tobacco Survey also has found that flavorings in e-cigarettes are now a minor factor in decisions by adolescents to use vaping products.

Contrary to a common popular view, there is little evidence in the scientific literature that vaping poses any substantial health risks, and especially as compared to smoking.

Public Health England, the British agency that was responsible for protecting and improving the health and wellbeing of Britons, assigned e-cigarettes 5 percent of the health risks of smoking. Nicotine is the only ingredient common to cigarettes and e-cigarettes, and it can be addictive. However, studies have not found that absorbing nicotine is harmful in itself. Nicotine vaping does have some physiological effects, and some users report headaches and sore throats. However, those physiological responses are not linked to any serious health issues. Crucially, e-cigarettes do not contain any of the toxic ingredients that make smoking a major cause of cancers, heart disease, stroke, and pulmonary diseases.

E-cigarettes can also provide significant benefits. CDC surveys and many scientific studies have found that vaping can help people reduce or quit smoking, especially by using flavored vaping products. While smoking rates have been declining in the United States since the early 1970s, we found that the downward trend from 2002 to 2010 began to accelerate coincident with the introduction and rising use of e-cigarettes. Moreover, the increasing use of e-cigarettes from 2010 to 2022 is correlated strongly with falling smoking rates.

Since correlation does not necessarily imply causation, we further tested whether the new alternative of e-cigarettes played a significant role in the historically large drop in smoking rates since 2010. First, we examined five other possible factors and established that three of them—cigarette tax and price increases, the FDA ban on most flavored cigarettes, and the availability of other nicotine replacement packages such as gums and patches—did not affect the downward shift since 2010 in the long-term decline in smoking rates. We also found that two other factors—the CDC Tips anti-smoking campaign and expanded access to anti-smoking services under the ACA—did contribute modestly to the recent downward shift. However, most of that downward shift remained unexplained, and the literature does not cite other factors to explain it apart from the rising use of vaping products. Nevertheless, to be conservative we attributed 25 percent of the unexplained acceleration in declining smoking rates to "X factors" for unknown causes.

On this basis, we conclude that the remaining decline can most reasonably be attributed to the availability and spread of vaping products. We estimate that the use of e-cigarettes from 2010 to 2022 reduced the number of adult smokers by more than 6 million or an average of nearly 510,000 smokers per year. We further find that the additional reduction in adult smoking rates associated with vaping from 2010 to 2022 saved more than 113,000 people from smoking related premature deaths over those years and can be expected to save some 334,000 people by 2030.

Living longer also enabled those former smokers to continue contributing to the economy, and we calculated that their doing so added nearly $66 billion to GDP from 2010 to 2022. The shift from smoking to vaping also reduced the healthcare costs and productivity losses associated with smoking-related illnesses that as yet have not caused premature deaths. We estimate that the shift from smoking to vaping in this period produced $39 billion in healthcare savings and averted $71 billion in productivity losses by people who shifted from cigarettes to vaping and otherwise would have suffered smoking-related health problems. All told, smokers shifting to vaping from 2010 to 2022 have generated economic benefits and savings totaling $180 billion.

These benefits would have been larger but for the predominantly negative media coverage of vaping that convinced most Americans that e-cigarettes are not a healthier alternative to smoking. A recent National Cancer Institute survey, for example, found that only 11 percent of Americans believe that vaping is less harmful than smoking while 63 percent see it as more harmful or equally harmful.

The benefits of e-cigarettes also would have been greater but for the FDA's reluctance to acknowledge the anti-smoking benefits of vaping and regulate cigarettes and e-cigarettes on that basis.

Instead, when the FDA first applied broad regulation to tobacco products in 2016, it exempted existing cigarettes and their future equivalents, but *not* e-cigarettes, from new legal requirements that approved tobacco products must be "appropriate for the protection of public health." As a result, only 23 vaping products and devices have been approved from 6.7 million applications from vaping manufacturers accepted for the FDA's review and the 1.2 million applications formally evaluated by the FDA. The FDA also has refused to allow producers of e-cigarette makers to advertise that their products do less harm than cigarettes or even that their products do not contain the specific toxic ingredients found in cigarettes.

In July 2022, FDA Commissioner Robert Califf asked the Reagan-Udall Foundation to convene an independent panel of experts to evaluate the performance of the Center for Tobacco Products.

In December 2022, the Foundation issued its report urging the FDA to develop a new strategic plan that will strengthen its regulatory processes and operations to better carry out its public health mandate.[217] In response, Commissioner Califf announced in February 2023 that the FDA would develop and release a five-year plan and policy agenda on all forms of tobacco use by the end of 2023.[218]

We urge the FDA to include in its new agenda specific reforms to promote vaping as a desirable alternative to smoking, based on the scientific evidence and recommendations from former FDA officials and other tobacco experts.

Under this agenda, the FDA would proactively educate Americans about the disparate risks of smoking and vaping and how people can use e-cigarettes to reduce or stop smoking. The FDA also should apply new labeling, advertising, and marketing regulations to cigarettes and vaping products that acknowledge their disparate risks and vaping's utility in helping people stop smoking. In addition, the FDA should approve the sale of flavored vaping products and cap the nicotine levels in cigarettes to induce more smokers to quit or seek the nicotine they crave from vaping products. Finally, Congress and state legislatures can do their part by giving smokers economic incentives to quit or shift to vaping through higher taxes and minimum prices for cigarettes than for e-cigarettes.

...the FDA should approve the sale of flavored vaping products and cap the nicotine levels in cigarettes to induce more smokers to quit or seek the nicotine they crave from vaping products.

Technical Appendix

Basic Approach and Contributions to the Literature

Following the work of previous analysts, we adopted a counterfactual forecasting approach to determine the impact of e-cigarettes on cigarette use.[219] This approach is preferred due to the complicated nature of constructively estimating population-level impacts using available data. Estimates of transition rates between different categories of cigarette and e-cigarette use vary greatly and can produce narrow results that obfuscate the impacts that are relevant for tobacco policy.[220] Moreover, our methodology advances previous instances of this approach in five ways:

1. We consider data on adults and youths from both the CDC National Health Information Survey (NHIS) and National Youth Tobacco Survey (NYTS). As previous researchers have found, e-cigarette use and its impact on smoking rates vary by age in the adult population reported in the NHIS, so we expanded our analysis by including the NYTS data, which enabled us to broaden the conclusions. Since e-cigarette use by youths is a salient issue, determining whether the impact on adult smoking rates identified in previous studies applies to younger people is relevant for policy purposes.
2. The timeframe for our study covers data through 2022 so the analysis includes the pandemic and immediate post-pandemic period, enabling us to draw conclusions about the future with greater confidence.
3. For the adult population, we supplemented the NHIS dataset with estimates from a separate mixed-mode survey of rates of e-cigarette use in 2010–2012,[221] rather than imputing them, so we only had to impute the 2013 value.[222] We also aligned our age groups with the groups used by the mixed-mode survey which facilitated our subgroup analyses and avoided imputing several years of data within subsamples.
4. We examined multiple structural breakpoints in the cigarette prevalence time series, so our analysis avoids bias from the accelerated decline in cigarette prevalence in the 1990s and early 2000s. Including multiple breakpoints substantially improves the model.
5. We considered five potential alternative mechanisms for the accelerated decline in smoking rates after 2011—cigarette tax and price changes, the CDC Tips campaign, certain provisions of the Tobacco Control Act, use of other nicotine replacement products, and the ACA—to produce more accurate final estimates.

Data Source for the Adult Use Model

Our analysis of adult tobacco behavior used data from the CDC's NHIS for 1991–2022. Data for 1991 to 2021 was retrieved from the Integrated Public Use Microdata Series (IPUMS) website, and the 2022 data was retrieved directly from the CDC. The NHIS dataset includes annual representative information on smoking behavior as well as demographic information including gender, race, ethnicity, age, and income. Consistent with NHIS methodology, "never-smokers" are defined as those who had smoked fewer than 100 cigarettes in their lifetime. Among those who had smoked at least 100 lifetime cigarettes, "current smokers" are 'now' smokers who smoked 'some days' or 'every day,' while former smokers are those who no longer smoke. The survey does not include cumulative lifetimes measures for e-cigarettes, and the definition of e-cigarettes varied slightly from year to year.[223] The 2020 the data could have been affected by the COVID-19 pandemic, both in its effects on smoking and vaping rates as well as the NHIS's use of interviews by telephone instead of in-person. However, our breakpoint detection methods did not identify 2020 as a potential breakpoint, limiting our concerns about pandemic-related data effects.

Breakpoint Detection

The initial step of our analysis focused on determining a breakpoint in the cigarette prevalence time series from which to begin a forecast period. Earlier researchers[224] used the Kneedle algorithm to identify "knees" or inflection points in a trend[225] and identified 2010 as the "knee" in the cigarette prevalence time series. Using

2010 as an inflection point is also consistent with other previous studies.[226] To further investigate this modeling decision, however, we applied the Bai and Perron's algorithm for multiple structural breaks,[227] which is designed to identify the structural break(s) that result in the lowest sum of squared residuals in a linear trend model. Further, to avoid overfitting by identifying too many structural breaks, we also applied the LWZ criterion for model selection which is more conservative regarding the total number of structural breaks than the Bayesian information criterion employed by Bai and Perron.[228]

Alternative Explanations that Resulted in Model Adjustments

In 2020, the CDC published an evaluation of its Tips campaign and found that it resulted in 1,005,419 sustained quits in the period from 2012 to 2018 or an average of 143,631 quits per year.[229] The evaluation did not indicate the campaign's effectiveness varied over time in a significant way, so we extrapolated the results to the years 2019 to 2022 and assumed that from 2012 to 2022, 143,631 quits per year are attributable to the Tips campaign.

Unlike the Tips campaign that the CDC evaluated and reported a methodologically sound estimate of its effects over a defined period that we could extrapolate forward, the ACA's effects were more challenging to incorporate constructively into our model. However, our test for structural breaks in the smoking prevalence time series identified a break downwards in 2014, lending credence to the proposition that the ACA had a population level effects on smoking rates based on two key provisions that took effect fully in that year (the mandatory smoking cessation coverage requirements and the Medicaid expansion). In the interest of a more conservative estimate of the impact of e-cigarettes, we attributed the 2014 downward shift or break in the level and trend of smoking prevalence to the ACA. Therefore, we took the difference between the change in trend and level for two additional linear segments, 2010 to 2014 and 2014 to 2018, and applied those changes in trend and level to the Tips-adjusted trend line beginning in 2014. In this way, we could construct a counterfactual estimate of smoking prevalence that incorporated the effects of both the Tips campaign and the ACA increased smoking cessation coverage and Medicaid expansion.

Potential Alternative Explanations that Did Not Affect the Model

We analyzed three other alternative factors that we found did not meaningfully affect the smoking rates. The first is the 2009 ban on non-menthol-flavored cigarettes. An early analysis (Rossheim, 2020) that identified such an effect did not sufficiently demonstrate its claim for three principal reasons.[230]

First, the analysis used large national surveillance data and only analyzed only one break in trend and levels for four age groups, immediately following the ban. Without additional sensitivity analyses or comparisons to trial-level results of effects, it is impossible to disentangle the long-term effect of the ban from the effect of e-cigarette use that became increasingly popular starting around the same time. This is why our analysis includes additional subgroup analysis as well as comparisons to non-population-level studies to corroborate our findings.

Second, the study found a strong effect among youths ages 12 to 17, a much more attenuated effect among young adults ages 18 to 25, and very small or no effect among adults ages 26 to 49 and older adults ages 50 and over. By contrast, our subgroup analysis shows the largest departure from the pre-2010 trend among those ages 25 to 44, and the analysis of NYTS data found little change in the trend of youth smoking. Rather, our subgroup analysis strongly suggests that e-cigarette use was the primary explanatory factor for the change in trend, based on comparisons of e-cigarette prevalence to the change from trend within demographic groups. Subgroup analysis of the Rossheim study's findings further reduces confidence in its proposed explanatory factor: Before the ban, only 1 percent of the population age 55 and older used flavored cigarettes; yet the change in slope estimates and total effect estimates for Older and Adults in the Rossheim study are very similar. (Table A1 below).

Table A1: Estimated Effect of Flavor Ban on Cigarette Use, By Age, from Rossheim Study[231]

	Odds Ratio (95% CI)	
	Change in slope	Total Effect
Adults	**.994 (.992,.997)**	**.883 (.785, .994)**
Older Adults	**.995 (.990, 1.000)**	**.854 (.702, 1.039)**

It is unreasonable to attribute a 15 percent reduction in cigarette use to a flavored smoking ban for a group in which less than 1 percent used flavored cigarettes prior to the ban, as if that 1 percent of all older adults could represent more than 15 percent of the smokers. While the authors do not claim that the effect on older adults was statistically significant, the similarity of the change in slope estimate and confidence interval among the adult population to the clearly incorrect estimate for older adults raises serious questions about how much of this decline can be attributable to the flavored cigarette ban. It is much more likely that the advent of e-cigarette use very soon after the initial ban confounded the study's results. By contrast, our age-based sensitivity testing is consistent with our overall findings and the broader research about e-cigarette and smoking rates by age.

Third, later analyses as well as the original study found evidence that the ban on flavored cigarettes led to a substitution effect towards other flavored tobacco products.[232] With the overall use data, it is very likely that some of the decrease in cigarette use attributed by the study to the ban reflected smokers shifting to flavored e-cigarettes rather than menthol cigarettes, which were not subject to the ban. This suggests that even if the ban on flavored cigarettes had some effect on the decline in overall cigarette use, much of that decline was attributable to the increasing availability and use of e-cigarettes as an alternative.

Overall, analysis does not support the proposition that the ban on flavored cigarettes in itself contributed in a meaningful way to the decline in smoking beginning around the 2010 breakpoint, and we did not adjust our estimate on the basis of this provision of the Tobacco Control Act. Any effect was at most modest, and we can account for our 25 percent X factor encompassing any unknown factors affecting the smoking rate.

We also considered the proposition that rising cigarette prices and specifically the 2009 increase in the federal excise tax on cigarettes affected the rate of decline in smoking prevalence. Using data from the CDC's comprehensive dataset on state-level historical cigarette tax rates and retail prices, we calculated an aggregate national average retail price of a pack of cigarettes.[233] The average 2.44 percent price increase per year was lower after 2009 than the 2.66 percent average annual increase from 2002 to 2008. On this basis, any price effect for our counterfactual forecasting approach would result in a slower decline in smoking rates post 2010 rather than the acceleration that occurred. While there was a large one-time spike from the 2009 tax increase, the 2010 breakpoint shows a change in trend rather than level. Certainly, the 2009 excise tax increase could not have created conditions resulting in declining smoking rates for more than a decade. As for a potential break in level (rather than trend), overall smoking prevalence increased in 2010.

We conclude, therefore, that changes in cigarette prices did not contribute to changes in the trend of cigarette smoking rates among adults in the post 2010 period. This conclusion is consistent with prior research on the 2009 excise tax that broadly found that while the policy helped reduce youth smoking rates, it did not have a statistically significant effect on adult quits.[234] Table A2 provides the year-by-year data on e-cigarette use and total e-cigarette users and the contemporaneous changes in those measures for cigarettes.

Table A2: E-Cigarette Use and Its Impact on Cigarette Use, 2011 to 2022

	E-Cigarette Use		Effect on Cigarette Use	
	Prevalence	Users	Prevalence	Users
2011	0.8%	1.9 M	- 0.2%	- 0.5 M
2012	2.6%	6.1 M	- 0.7%	- 1.7 M
2013	3.2%	7.5 M	- 0.6%	- 1.4 M
2014	3.7%	8.9 M	- 0.8%	-1.9 M
2015	3.2%	7.9 M	- 1.7%	- 4.1 M
2016	3.2%	7.8 M	- 1.1%	- 2.8 M
2017	2.8%	6.9 M	- 1.9%	- 4.8 M
2018	3.2%	8.1 M	- 1.8%	- 4.5 M
2019	4.3%	10.9 M	- 1.6%	- 4.0 M
2020	3.6%	9.1 M	- 2.3%	- 5.8 M
2021	4.4%	11.1 M	- 2.8%	- 7.0 M
2022	5.9%	15.0 M	- 2.4%	- 6.1 M
Total	—	101.0 M	—	- 44.5M

NHIS Data Subgroup Analysis

We conducted subgroup analysis for the three demographic groups by gender, age and race and ethnicity. For race and ethnicity, we considered only Hispanic, non-Hispanic Black, and non-Hispanic white because the data over time for other race categories had comparability problems and small samples.[235] For each subgroup, we followed the same procedures as the overall population.

First, we conduct breakpoint testing to determine years of interest. The most salient results of this test are displayed in Table A3, including the breakpoints for the impact of the ACA by subgroup.

Table A3: Breakpoints by Gender, Age, and Race and Ethnicity

	Baseline Period Begins	Projection Period Begins	ACA Impact Period Begins
Gender			
Male	1999	2010	2015
Female	2003	2011	2015
Race and Ethnicity			
Non-Hispanic Black	2002	2011	2017
Non-Hispanic White	2002	2011	2015
Hispanic	2001	2009	2014
Age			
18-24	2002	2010	2014
25-44	2004	2010	2015
45-64	2002	2012	2014
65+	2002	2011	–

The results for each subgroup align with breakpoint structure of the data for the overall population, providing additional credence or support for our population-level estimates. Notably, seven of the nine subgroups had breakpoints in 2010 or 2011, and the exceptions were very close to those years—2012 for the 45 to 64 age group, and 2009 for Hispanics. In addition, every group except the age group 65 and older and non-Hispanic Blacks had breakpoints in 2014 or 2015 followed by a breakpoint in 2018 or 2019. This pattern is well aligned with both the population-level breakpoints and data on increases in Medicaid enrollments during that time period, given one or two additional years for the new ACA benefits to affect smoking rates. The fact that the population age 65 and over did not have a breakpoint beyond 2011 corroborates the proposition that the 2014 and 2015 breakpoints are related to the ACA, since Medicaid expansion had a much smaller impact on the population 65 and over compared to the other subgroups. The non-Hispanic Black population is an outlier here with the only breakpoint post-2011 occurring in 2017. The most significant variation, as expected, occurs with the start of the baseline periods, which range from 1999 for Males to 2004 for the age group 25 to 44.

It is well-documented that the effects of the CDC Tips campaign and the ACA were not uniform across demographic groups.[236] To distribute the effects of Tips across our demographic groups, we applied the point estimates from a study that calculated the influence of a variety of smoker characteristics on the perceived effectiveness of the Tips advertisements and the odds ratios for associations between perceived effectiveness and quit attempts.[237] The campaign was more effective among men than women and among Black individuals than white individuals, and decreased in effectiveness as age increased.[238]

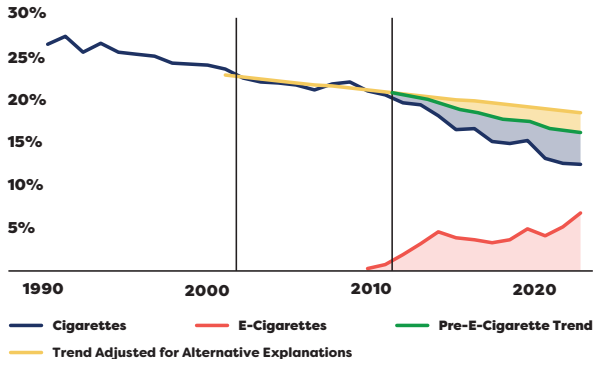
To account for demographic variations in the impact of the ACA Medicaid expansion, we used

data on Medicaid enrollments provide in the Census Bureau's Current Population Survey Annual Social and Economic Supplement from IPUMS.[239] To help isolate the effect of the Medicaid expansion, we analyzed the difference in Medicaid enrollees in each subgroup in 2013 and 2015 and calculated a share of ACA benefit for each subgroup. Next, we multiplied this share by the population-level break in level and trend for smoking prevalence in 2014, to determine the ACA effect that could reasonably be attributed to each subgroup. We also applied our 25 percent reduction in e-cigarette benefits to account for unknown potential effects beyond the five factors that we examined (CDC Tips, the ACA, the Tobacco Control Act, use of other nicotine-replacement products, and cigarette price changes). The 2022 results and the cumulative effects are similar for all demographic groups except non-Hispanic Black individuals and Hispanic individuals. This may be a result of the volatility in smoking rates in the baseline period for these groups which limited the precision of our approach.

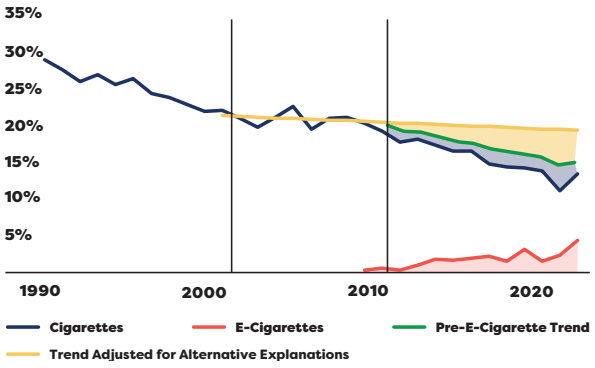
Figures with the smoking rate trend line extrapolated from the 2002-2009 period (blue line), the actual smoking rate trend (red line), our estimates of the effect of Tips, the ACA and the 25 percent X factor (the shaded grey area), the trend of e-cigarette use (the green line), and the estimated impact of rising e-cigarette use on the smoking rates (the pink shaded area) are provided below for each subgroup.

Figures A1-A9: Counterfactual Forecasts of the Impact of E-Cigarette Use on Adult Smoking Rates

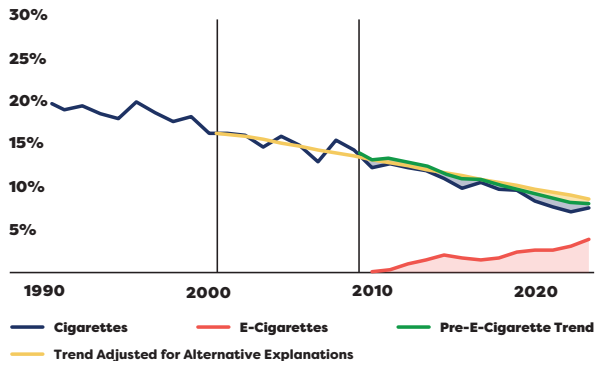
Race and Ethnicity: White



Race and Ethnicity: Black

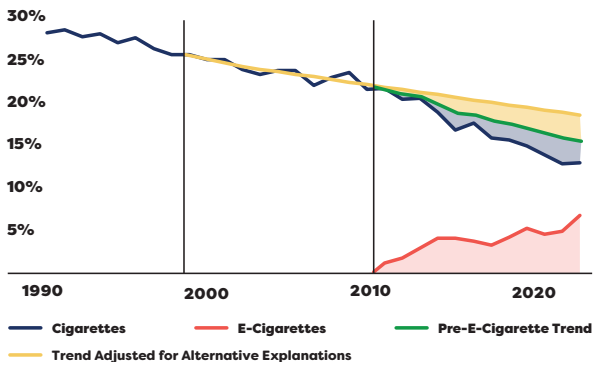


Race and Ethnicity: Hispanic

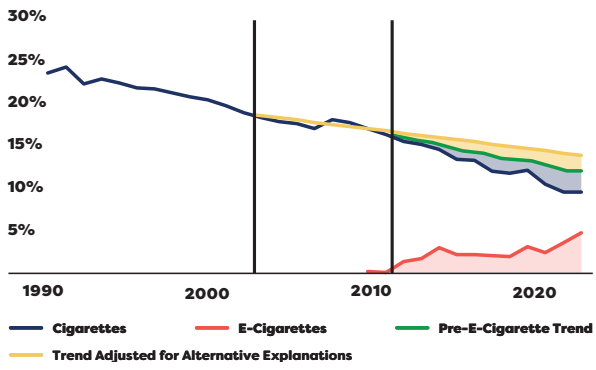


Figures A1-A9: Counterfactual Forecasts of the Impact of E-Cigarette Use on Adult Smoking Rates (cont.)

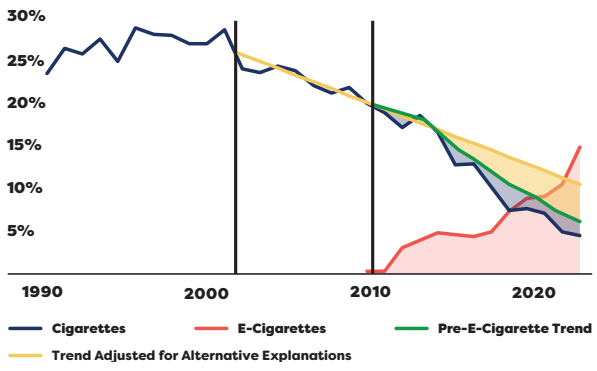
Gender: Male



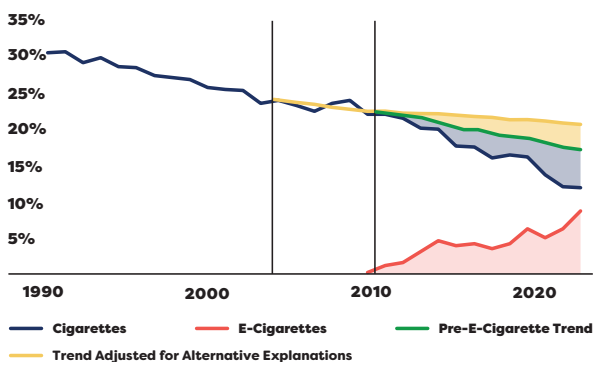
Gender: Female



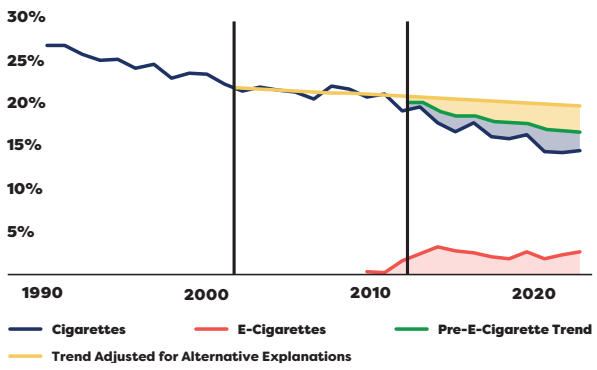
Age: 18-24



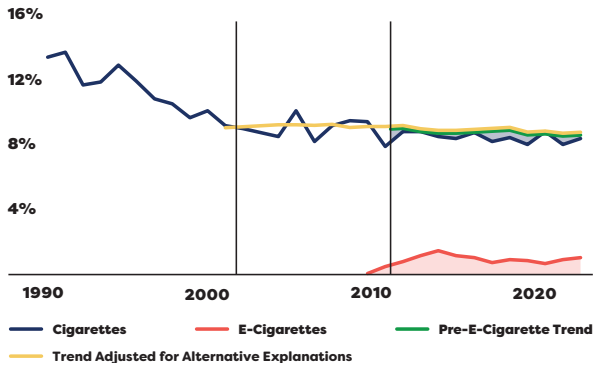
Age: 25-44



Age: 45-64



Age: 65+



Breakpoint Variation Sensitivity Tests

We performed additional tests using alternative designations of the structural breaks in the smoking prevalence trend to ensure that our results are robust to the break-detecting algorithm. The Bai and Perron test identified 2011 for a single structural break, and the Kneedle test identified 2009 as the singular break in trend. To test the sensitivity of our model to the selection of the beginning of the forecast period, we ran two alternative models with breaks in 2011 and 2009 in place of a 2010 break. The test using a 2011 break produced a total reduction of 53.0 million smoker-years instead of the 44.5 million in our 2010 break scenario. Moving the break back to 2009 produced a forecast reduction of 65.9 million smoker-years resulting from e-cigarette use. This suggests that our initial analysis may underestimate the impact of e-cigarettes on the use of cigarettes.

We also ran the model removing the 2002 break point and using only the 2010 structural break. This specification was used in a recent notable analysis as the Kneedle break-detecting algorithm used in the study does not allow for multiple breaks.[240] As expected, our analysis without the 2022 break found that e-cigarette use was associated with a considerably smaller impact, accounting for only 33.9 million fewer smoker-years. This specification, however, did not account properly for the substantial decline in smoking prevalence from 1997 to 2002, resulting in a historical trend that does not match the years preceding the 2010 breakpoint. Therefore, this confirms the importance of including the 2002 breakpoint and explains why our estimated reduction in cigarette use exceeds that of prior analyses.

Investigating the Impact of Vaping on Cigarette Use for Youths

We also examined the effects of e-cigarettes on cigarette smoking by youth using data from the CDC's National Youth Tobacco Survey (NYTS). The NYTS provides nationally representative data covering middle school and high school students' use of cigarettes and e-cigarettes with demographic breakdowns. The COVID-19 pandemic forced the CDC to administer the NYTS online in 2021 instead of in person on school campuses, and the survey continued to be conducted online in 2022. As with NHIS data, this shift may limit the comparability of the time series data but should not substantially affect our analysis.

As we did for the adult analysis of NHIS data, we created a counterfactual forecast by first analyzing structural breaks in the trends of the data on smoking prevalence by adolescents. We applied the Bai and Perron algorithm which identified structural breaks in 2004, 2013, and 2018.[241] (See Figures A10 and A11 below.) These breaks are somewhat analogous to the adult case, and the trend lines in each time segment aligned closely with the data.

Figure A10: Trends in Cigarette and E-cigarette Use by Youth, 1999 to 2022

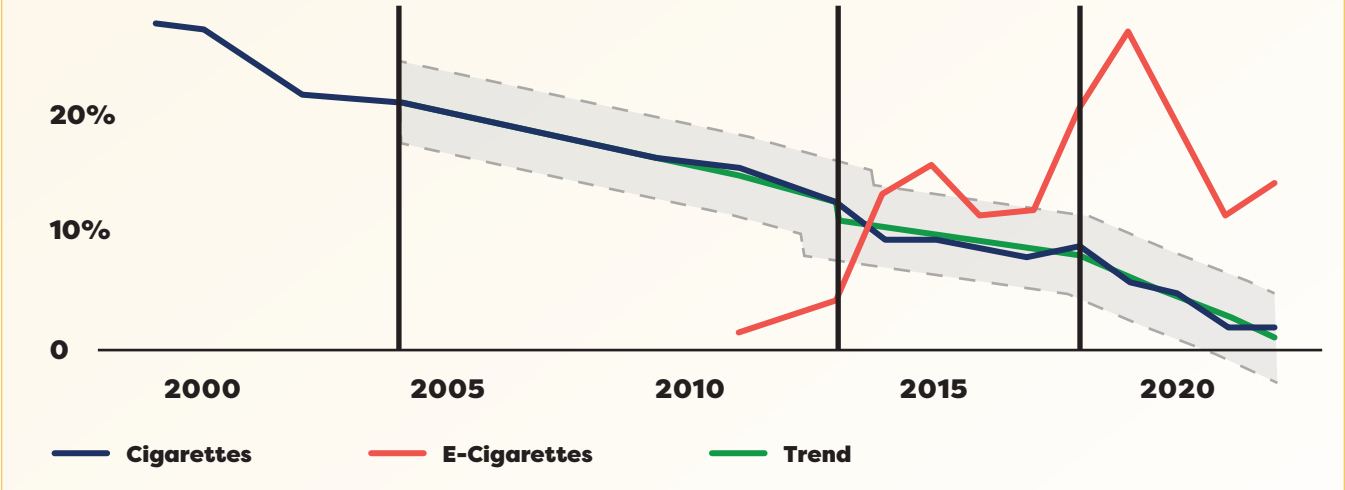
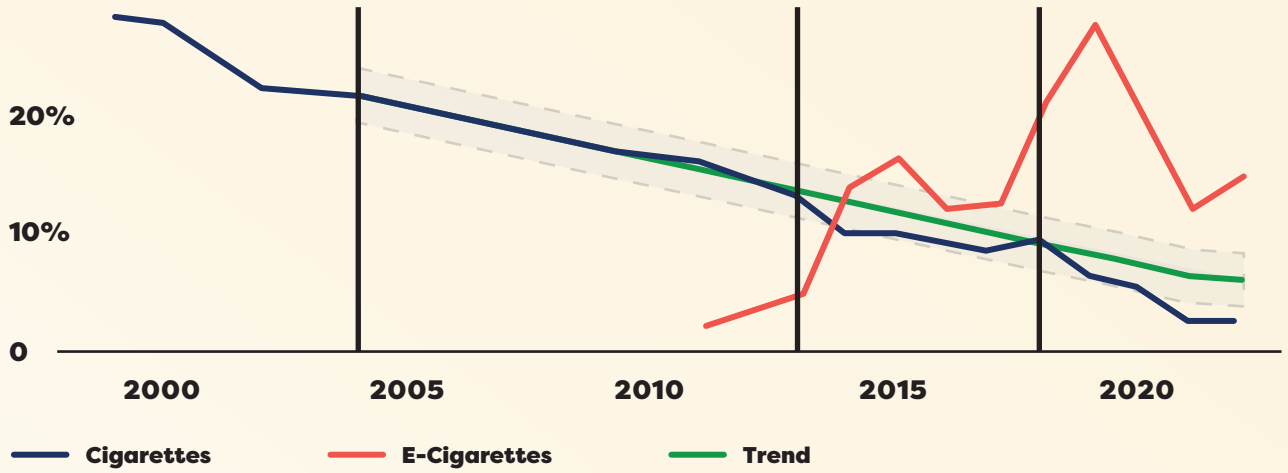


Figure A11: Counterfactural Forecast Breakpoints for Adolescents, 2004 and 2013



The forecasts for the pre-2004 and post-2013 periods had the worst fits as those data proved to be less linear. However, this issue did not present a problem for our counterfactual forecasting as we can use the 2004 to 2013 period to train our forecast. This period follows a very consistent linear trend over the entire decade. As with the NHIS adult data, the smoking prevalence by adolescents declined substantially in the late 1990s and early 2000s, but that trend did not persist through the latter half of the decade from 2000 to 2009. The later breakpoints in 2013 and 2018 immediately preceded large spikes in e-cigarette use in 2014 and 2019, suggesting a relationship between rising e-cigarette use and declining cigarette use.

Figure 11A presents a counterfactual forecast for the youth population based on extrapolating the pre-2013 trend line through 2022. This exercise produces a pattern very different from the analogous adult analysis. While the smoking prevalence trendline generally tracks beneath the forecasted trendline, it remains close to or within a 95 percent confidence interval and exceeds the forecasted trend in 2018. The hypothesized impact of the Tobacco Control Act of 2009 (TCA), cigarette price changes, and the 2011 CDC Tips campaign on cigarette use do not appear to affect the youth population, as there is no statistically significant departure from the pre-2009 trajectory until the decline that begins in 2014, three years after the Tips campaign started and five years after passage of the TCA and the cigarette excise tax increase.

By contrast, previous studies have found that the Medicaid expansion under the ACA that began in 2014 and the additional financing for the Children's Health Insurance Program (CHIP) increased significantly the access of young people to anti-smoking services.[242] In conjunction with the ACA requirements for smoking cessation coverage in ACA-covered healthcare plans, the number of youths that gained access to better healthcare and specifically to smoking cessation assistance grew dramatically directly following the 2013 breakpoint. While Medicaid already provided coverage for children in low income families, lowering the income eligibility threshold in the ACA Medicaid expansion states resulted in more than 700,000 young people under age 18 gaining insurance coverage between 2013 and 2015.[243]

Despite these effects, the fact that a second breakpoint identified in 2018 corresponds to the second spike in e-cigarette use by youths suggests that such e-cigarette use had some negative effect on their cigarette prevalence rate. However, based on the entanglement with the ACA implementation timeline, the absence of a statistically significant difference from the pre-2013 trendline for most of the 2014 to 2022 forecast period, and the very low ratio of lower smoker-years to increased e-cigarette user-years over that time period, we concluded that among young people, e-cigarettes have only modest effects on reducing their smoking rate.

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End Notes

Endnotes

1 We gratefully acknowledge the support for our research from the Center for Black Equity. All the analyses and conclusions are those of Dr. Shapiro and Mr. Stuttgen.

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[113] Arshad, Jackson, Kock, Ide-Walters, Tattan-Birch (2023).

[114] See, for example, Vickerman, Carpenter, Altman, Nash, and Zbikowski (2013).

[115] Gualano, Passi, Bert, La Torre, Scaioli, and Siliquini (2015).

[116] Adriaens, Van Gucht, Declerck, and Baeyens (2014).

[117] Lindblom (2015).

[118] Bullen, Howe, Laugesen, McRobbie, Parag, Williman, and Walker (2013).

[119] Hajek, Phillips-Waller, Przuli, Pesola, Myers Smith, Bisal, Li, Parrott, Sasieni, Dawkins, Ross, Goniewicz, Wu, and McRobbie (2019).

[120] Walton, Wang, Prutzman, Jamal, and Babb (2020).

[121] Balfour, Benowitz, Colby, Hatsukami, Lando, Leischow, Lerman, Mermelstein, Niaura, Perkins, Pomerleau, Rigotti, Swan, Warner, and West (2021).

[122] Kasza, Edwards, Kimmel, Anesetti-Rothermel, Cummings, Niaura, Sharma, Ellis, Jackson, Blanco, Silveira, Hatsukami, and Hyland (2021).

[123] Carpenter, Wahlquist, Dahna, Gray, Cummings, Warren, Wagener, Goniewicz, and Smith (2023).

[124] Cantu (2023).

[125] Mok, Jeon, Levy, and Meza (2023).

[126] Fetterman, Ross, Robertson, Bhatnagar, and Benjamin (2022) and Friedman and Xu (2020).

[127] Glasser, Vojjala, Cantrell, Levy, Giovenco, Abrams, and Niaura (2021).

[128] Rest, Eva, Kristin Brikmanis, and Robin Mermelstein (2022).

[129] Li, Borland, Cummings, Fong, Gravely, Smith, Goniewicz, O'Conner, Thompson, and McNeil. (2021

[130] Soneji, Thomas Wills, Leventhal, Unger, Gibson, Yang, Primack, Andrews, Miech, Spindle, Dick, Eissenberg, Hornik, Dang, and Sargent (2017).

[131] Lee, Coombs and Afolalu (2019); and Lee and Fry (2020).

[132] Balfour, Benowitz, Colby, Hatsukami, Lando, Leischow, Lerman, Mermelstein, Niaura, Perkins, Pomerleau, Rigotti, Swan, Warner, and West (2021).

[133] Foxon and Selya (2020); Selya and Foxon (2021); and Sokol and Feldman (2021).

[134] Shahab, Beard, and Brown. (2021).

[135] Friedman and Xu (2020).

[136] Lee, Fry, Gilliland, Campbell, and Joyce (2022).

[137] Blewett, Drew, King, Williams, Chen, Richards, and Westberry. (2023).. Data for 2022 data came from the CDC, and pre-2014 e-cigarette data from surveys conducted by McMillen, Gottlieb, Shaefer, Winikoff, and Klein (2105).

[138] *Ibid.*

[139] The algorithm is described in Bai and Perron (1998). We also applied the Liu, Wui, and Zidek (1997) criteria for model selection to avoid overfitting by identifying too many structural breaks, a more conservative approach than the Bayesian information criteria used by Bai and Perron.

[140] Marynak, Xu, Wang, Holmes, Tynan, and Pechacek (2016); Le and Jaffri (2022).

[141] Parks, Patrick, Levy, Thrasher, Elliott, and Fleischer (2022).

[142] Centers for Disease Control and Prevention (2023-H).

[143] Bush, Zbikowski, Mahoney, Deprey, Mowery, and Magnusson (2012), and Huang and Chaloupka (2012).

[144] Centers for Disease Control and Prevention (2023-G); Murphy-Hoefer, Davis, King, Beistle, Rodes, and Graffunder (2020).

[145] Davis, Duke, Shafer, Patel, Rodes, and Beistle (2016).

[146] Kraemer and Baig (2013).

[147] Rossheim, Livingston, Krall, Barnett, Thombs, McDonald and Gimm (2020).

[148] Courtemanche, Palmer, and Pesko (2017).

[149] *Ibid.* The Rossheim analysis also found these substitution effects but attributed the related impact on smoking rates to the flavor ban, ignoring the switching to e-cigarettes.

[150] Trigger, Xu, Malarcher, Salazar, Shin, and Babb (2023).

[151] McAfee, Babb, McNabb and Fiore (2015).

[152] Donahoe, Norton, Elliott, Titus, Kalousová, and Fleischer (2019); and Bailey, Voss, Angier, Huguet, Marino, Valenzuela, Chung-Bridges, and DeVoe (2022).

[153] Ku, Bruen, Steinmetz, and Bysshe (2016); and Bailey, Hoopes, Marino, Heintzman, O'Malley, Hatch, Angier, Fortmann, and DeVoe (2016).

[154] Guth, Artiga, and Pham (2020).

[155] Centers for Disease Control and Prevention (2023-I).

[156] Rudowitz, Artega, and Arguello (2014); and Schubel (2021).

[157] Centers for Disease Control and Prevention (2023-I).

[158] Nutt, Phillips, Balfour, Curran, Dockrell, Foulds, Fagerstrom, Letlape, Milton, Polosa, Ramsey, and Sweanor (2014).

[159] Lee, Fry, Gilliland III, Campbell, and Joyce (2022); and Abrams, Glasser, Pearson, Villanti, Collins, and Niaura (2018).

[160] Lee, Fry, Gilliland III, Campbell, and Joyce (2022).

[161] McNeill, Brose, Calder, and Hitman (2015).

[162] Levy, Borland, Lindblom, Goniewicz, Meza, Holford, Yuan, Luo, O'Connor, Niaura, and Abrams (2018).

[163] Perez, Gareen, Sicks, Lathan, Carr, Kumar, Ponzani, Hyland, and Park (2019).

[164] Ho and Elo (2013).

[165] Jeon, Inoue-Choi, Mok, Tam, Freedman, and Meza (2023).

[166] Woloshin, Schwartz, and Welch (2008).

[167] It would be possible to model the probability of smokers shifting to e-cigarettes after 2022 if we had more extended longitudinal data, but such data are not available since e-cigarettes have been used for only a short period.

[168] We also cannot take account of future medical advances that could reduce mortality rates from the four diseases.

[169] Woloshin, Steven, Lisa Schwartz, and H. Gilbert Welch (2008-A); and Office of the Chief Actuary (2023).

170 Shrestha, Ghimire, Wang, Trivers, Homa, and Armour (2022).

171 Xu, Bishop, Bishop, Simpson, Pechacek (2014).

172 Yao, Sung, Wang, Lightwood, and Max (2018); and Yao, Sung, Wang, Lightwood, and Max (2018-A). The authors did not consider children under three or children aged 15–17 in order to isolate the effect of secondhand smoke by avoiding misattribution of smoking during pregnancy and the teens themselves smoking, respectively.

173 Tsai, Homa, Gentzke, Mahoney, Sharapova, Sosnoff, Caron, Wang, Melstrom and Trivers (2018).

174 This conclusion is shared by the former head of the office of Policy at the FDA Center on Tobacco, Dr Erik Lindblom. See Lindblom (2018).

175 The Federal Cigarette Labeling and Advertising Act of 1965; also see Brumage (2017).

176 Centers for Disease Control (2022-C).

177 *Ibid.*

178 Fulmer (2021).

179 Food and Drug Administration *versus* Brown & Williamson Tobacco Corp, 529 U.S. 120 (2000).

180 Fulmer (2021); Bhatnagar, **Whitsel**, **Blaha**, **Huffman**, **Krishan-Sarin**, **Maa**, **Rigotti**, **Robertson**, and **Warner** (2019).

181 Lindblom, Erik (2019).

182 Gottlieb (2019).

183 Fulmer (2021).

184 *Ibid.*

185 Food and Drug Administration (2016). The Federal Trade Commission (FTC) has adopted a similar laissez-faire attitude towards cigarettes, dropping its requirement that its' manufacturers test their products annually and submit tar yield data for every cigarette variety they produce. With no requirement to test their products, the manufacturers are asked to submit only the data "in their possession or control." (Federal Trade Commission (2023).

186 Bhatnagar, **Whitsel**, **Blaha**, **Huffman**, **Krishan-Sarin**, **Maa**, **Rigotti**, **Robertson**, and **Warner** (2019). Also, Gottlieb (2019), and Federal Trade Commission (2021).

187 The minimum age was raised to 21 in 2019.

188 Food and Drug Administration (2023-C).

189 *Ibid.*

190 *Ibid.*

191 *Shapeless (2019).*

192 Lindblom (2018-A).

193 Food and Drug Administration (2017). The FDA also has announced an intention to regulate a maximum nicotine level for combustible tobacco products and banned new synthetic nicotine products without premarket approval. Food and Drug Administration (2022).; Harvard University T.H. Chan School of Public Health (2022).

194 Levy, Borland, Lindblom, Goniewicz, Meza, Holford, Yuan, Luo, O'Connor, Niaura, and Abrams (2018).

195 *Ibid.*

196 Lee, Fry, Gilliland III, Campbell, and Joyce (2022).

197 Food and Drug Administration (2021).

198 *Ibid.*

199 *Ibid.*

200 FDA (2020-A).

201 Food and Drug Administration (2022-A) and (2022-B). The ban on menthol e-cigarettes was controversial inside the FDA: According to memos released in court proceedings, the Office of Policy for the Center for Tobacco found that "menthol smokers preferred menthol vaping to menthol cigarettes, so as long as menthol-flavored cigarettes remain on the market, menthol-flavored ENDS could be a direct substitute (and) a less harmful alternative for menthol cigarette smokers ..." The Center director overruled the recommendation to allow menthol vaping products. See Apelberg (2022); and King and Mital (2022).

202 Li, Ossip, Bansal-Travers, and Xie (2022).

203 *Ibid.*

204 Lindblom (2018).

205 Lindblom (2019).

206 Sweanor (2015).

207 *Ibid.*

208 Lindblom (2018).

209 *Ibid.*

210 Saffer, Dench, Grossman, and Dave (2020).

211 Warner, Kiessling, Douglas, and Liber (2022). Many of the same measures were also recommended in Balfour, Benowitz, Colby, Hatsukami, Lando, Leischow, Lerman, Mermelstein, Niaura, Perkins, Pomerleau, Rigotti, Swan, Warner, and West (2021).

212 Warner, Kiessling, Douglas, and Liber (2022); and Balfour, Benowitz, Colby, Hatsukami, Lando, Leischow, Lerman, Mermelstein, Niaura, Perkins, Pomerleau, Rigotti, Swan, Warner, and West (2021).

213 Friedman and Xu (2020).

214 *O'Brien and the Department of Health and Social Care (2023).*

215 Lindblom (2018).

216 Lindblom (2015).

217 Silvis, Axelrad, Flanagan, Frizzera, and Gutierrez (2022).

218 Califf (2023).

219 Foxon, Selya, Glitchell and Shiffman (2022)

220 See Levy, Borland, Lindblom, Goniewicz Meza, Holford, Yuan, Luo, O'Connor, Niaura and Abrams (2018) for a discussion of this effect in the context of a very flawed 2018 study from the National Academies of Sciences, Engineering, and Medicine.

221 McMillen, Gottlieb, Shaefer, Winikoff, and Klein (2015).

222 McMillen, Gottlieb, Shaefer, Winikoff and Klein also conducted a survey and published the results for 2013. However, their reported e-cigarette prevalence rates were dramatically

higher than any other estimates and for most demographic groups would have been the all-time high prevalence rate for the 2010-2022 period. Instead, we use mean imputation, so the 2013 value is the average of the 2012 and 2014 values for each demographic group as well as for the total population. Our approach does not rely on statistical testing relating to the e-cigarette prevalence series, so this does not substantially bias the results.

223 Foxon, Selya, Glitchell and Shiffman (2022)

224 *Ibid;*

225 Satopää, Albrecht, Irwin, and Raghavan (2011)

226 See, for example, Wagner and Clifton (2021); Foxon and Selya (2020); and Selya and Foxon (2021).

227 Bai and Perron (2003)

228 Liu, Wu, and Zidek (1997)

229 Murphy-Hoefer, Davis, King, Beistle, Rodes, Graffunder (2020)

230 Rossheim, Livingston, Krall, Barnett, Thombs, McDonald, and Gimm (2020).

231 Rossheim, Livingston, Krall, Barnett, Thombs, McDonald, and Gimm (2020).

232 Courtemanche, Palmer, and Pesko (2017)

233 Centers for Disease Control and Prevention (2023-H)

234 Huang and Chalouopka (2012); and Bush, Zbikowski, Mahoney, Deprey, Mowery, and Magnusson (2012).

235 Our external vaping prevalence source included only the race-specific rates for "White" and "Black." We use those values for non-Hispanic White and non-Hispanic Black prior to 2014 and the more accurate NHIS values for 2014 to 2022. We performed a linear regression of Hispanic prevalence on non-Hispanic White and non-Hispanic Black prevalence for the 2014–2022 period and used the external source's values for 2010 to 2013 to impute corresponding values for the Hispanic population.

236 Guth, Artiga, and Pham (2020)

237 Davis, Duke, Shafer, Patel, Rodes, and Beistle (2016).

238 The age groups in the prior study do not align precisely with our age groups. We used their estimates for ages 25 to 39 for our age group 25 to 44 age group and their estimates for ages 40 to 64 for our 45 to 64 age group.

239 Flood, King, Rodgers, Ruggles, Warren, and Westberry (2022).

240 Foxon, Selya, Glitchell and Shiffman (2022).

241 We set the minimum segment length at three to avoid overidentifying structural breaks given the higher volatility of the dataset.

242 Rudowitz, Artiga, and Arguello (2014) and Schubel (2021).

243 Schubel (2021).

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