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Examining the relationship of vaping to smoking initiation among US youth and young adults: a reality check

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ABSTRACT

Background The 2018 National Academies of Sciences, Engineering, and Medicine Report found substantial evidence that electronic cigarette use (vaping) by youth is strongly associated with an increased risk of ever using cigarettes (smoking) and moderately associated with progressing to more established smoking. However, the Report also noted that recent increases in vaping have been associated with declining rates of youth smoking. This paper examines the temporal relationship between vaping and youth smoking using multiple data sets to explore the question of whether vaping promotes smoking initiation in the USA.

Methods Using publicly available, nationally representative data on smoking and vaping among youth and young adults, we conducted a trend line analysis of deviations from long-term trends in smoking starting from when vaping became more prevalent.

Results There was a substantial increase in youth vaping prevalence beginning in about 2014. Time trend analyses showed that the decline in past 30-day smoking prevalence accelerated by two to four times after 2014. Indicators of more established smoking rates, including the proportion of daily smokers among past 30-day smokers, also decreased more rapidly as vaping became more prevalent.

Conclusions The inverse relationship between vaping and smoking was robust across different data sets for both youth and young adults and for current and more established smoking. While trying electronic cigarettes may causally increase smoking among some youth, the aggregate effect at the population level appears to be negligible given the reduction in smoking initiation during the period of vaping's ascendance.

INTRODUCTION

Considerable attention has been devoted to the public health implications of electronic cigarette use ('vaping') and cigarette smoking ('smoking').[1–3] While a growing literature[4–7] indicates that vaping may increase smoking cessation among established smokers, there is concern that any such benefits may be offset by an increase in smoking initiation among youth and young adults.[8–10] This concern arises from a potential 'gateway effect' in which vaping leads non-smoking youth to take up cigarette smoking.

A growing literature indicates that vaping is associated with future smoking initiation. The 2018

National Academies of Sciences, Engineering, and Medicine (NASEM) Report[2] concluded: 'There is substantial evidence that e-cigarette use increases risk of ever using combustible tobacco cigarettes among youth and young adults'. The analysis is supported by a meta-analysis[11] as well as more recent studies with generally consistent findings.[12–16] The NASEM Report[2] also considered studies examining the relationship of vaping to smoking frequency and intensity,[17–20] and concluded that 'Among youth and young adult e-cigarette users who ever use combustible tobacco cigarettes, there is moderate evidence that e-cigarette use increases the frequency and intensity of subsequent combustible tobacco cigarette smoking'. These conclusions are consistent with the gateway hypothesis, which the NASEM Report calls the catalyst hypothesis.

The NASEM Report[2] also refers to an alternative explanation for the observed positive association between vaping and subsequent smoking initiation. The joint susceptibility hypothesis, also known as the common liability hypothesis, suggests that vaping is more likely to occur within a population with a propensity to use cigarettes due to shared common risk factors. The reviewed studies showing an association between vaping and smoking may reflect a failure to adequately control for risk factors common to both vaping and smoking.[21]

The NASEM Report reaches its conclusions based primarily on the results of short-term cohort studies that examine the association of vaping with future smoking. However, the NASEM Report also examines population trends. A population-level study[22] concluded that there was no significant change in the overall linear trend of smoking prevalence among youths after e-cigarettes first became available. However, from their own examination of population trends in vaping and smoking, the Report commented, 'the population-based data broadly show opposing trends in e-cigarette and cigarette use', noting that these results 'are more consistent with the diversion hypothesis than the catalyst hypothesis'. According to the diversion hypothesis, vaping partially replaces and/or substitutes completely for cigarette smoking, thus explaining the decline in smoking as vaping rates in the population increase. The apparent inconsistency between the findings from cohort studies and population trends in smoking and vaping merits a more rigorous examination of the temporal

relationship between vaping and youth smoking at the population level.

In examining population-level trends in youth smoking, the NASEM Report was limited by its reliance on a single data source, its failure to incorporate past trends in smoking before vaping became popular, and failure to examine trends in established smoking among young adults where the progression to more established smoking is likely to be more apparent.[23 24] This study attempts to overcome all three of these limitations by reconsidering whether vaping rates in the USA are associated with changes in population-level youth and young adult smoking prevalence. We conduct time series analyses to examine trends in vaping and smoking patterns across national surveys that reported on current and established cigarette use among US youth and young adults.

METHODS

To examine trends in population vaping and smoking, we first determined trends in vaping, and then examined the association between these trends and those for cigarette smoking.

Trends in vaping

To estimate youth and young adult vaping prevalence, we conducted a search of the literature through December 2017 using PubMed to find nationally representative surveys on youth and young adult vaping, particularly studies of trends. The search strategy consisted of the following keywords: ('e-cigarette' OR 'electronic cigarette' OR 'vaporized nicotine' OR 'vaping') AND ('youth' OR 'young adult' OR 'adolescent' OR 'student') AND ('prevalence' OR 'use'). We also considered US surveys that collected information on tobacco use for either youth or young adults. We restrict the analyses to results from nationally representative surveys for youth and young adults aged 15 through 25, where smoking initiation and the progression to more established smoking generally occur.[23 24]

The relationship of vaping to trends in smoking

US data on youth and young adult cigarette use were obtained from five different publicly available surveys: (1) the Monitoring the Future (MTF) survey; (2) the National Youth Tobacco Survey (NYTS); (3) the Youth Risk Behavior Survey (YRBS); (4) the National Survey of Drug Use and Health (NSDUH); and (5) the National Health Interview Survey (NHIS) for young adults. When information was available, we examined both past 30-day smoking prevalence and more established smoking. For established smoking, we considered daily and half-pack-a-day smoking prevalence using the MTF and NSDUH surveys, and the prevalence of current smokers who had smoked more than 100 cigarettes lifetime using the NHIS. The survey questions are provided as online supplementary 1.

Using the five surveys, our goal was to apply a uniform, straightforward analysis of the relationship between vaping and smoking trends. Our analysis of this relationship involved the estimation of long-term cigarette smoking trends and testing whether those trends changed once vaping became more prominent. Specifically, we estimated the following equation for each of our measures of smoking prevalence:

Log (Smoking Prevalence$_t$)=α + $\beta1$ Long-term Trend$_t$ + $\beta2$ VapingTrend$_t$, t=1,...,T

where Long-term Trend is a time trend taking the values 1,...,T, with the value of t corresponding to each sample year beginning with the first year and continuing to the last sample year. VapingTrend takes the value 0 until the first year that vaping becomes prominent, followed by a time trend from that year forward (eg, for vaping beginning in 2014, VapingTrend=1 in 2014, 2 in 2015, 3 in 2016, and 0 before 2014). With the dependent variable measured in log form and the VapingTrend overlapping with the Long-term Trend, the coefficient $\beta1$ corresponds to the average annual long-term relative reduction in smoking each year and $\beta2$ corresponds to the annual relative change from that long-term trend once vaping becomes prominent (ie, $\beta1$ + $\beta2$ corresponds to the trend after vaping become prominent). Because the NYTS was limited to six observations and was available on a biennial basis, the vaping period was modelled as a step function (ie, a simple indicator variable) rather than as a trend deviation.

We employed the log form of the dependent variable based on goodness of fit and the a priori expectation that the size of change is likely to depend on the initial level, but we also conducted sensitivity analysis employing the linear form. Based on a graphic examination of the stability of trends prior to vaping over the period 2004 through 2012 (see online supplementary 2), we included data starting in 2004 (or the earliest year available after 2004), but the choice of start year did not substantively affect the results. The choice of the initial tipping point year of vaping was based on our analysis of the vaping data, but we also considered the overall explanatory power of the equations as measured by the adjusted R-squared, and whether the equation was subject to first-order autocorrelation of the error terms, as indicated by the Durbin-Watson statistics.[25] We conducted sensitivity analysis on other start points for increased vaping. Finally, where the Durbin-Watson statistics indicated a potential for autocorrelation, we transformed the data using the Cochrane-Orcutt method[25] and considered the sensitivity of results to that correction.
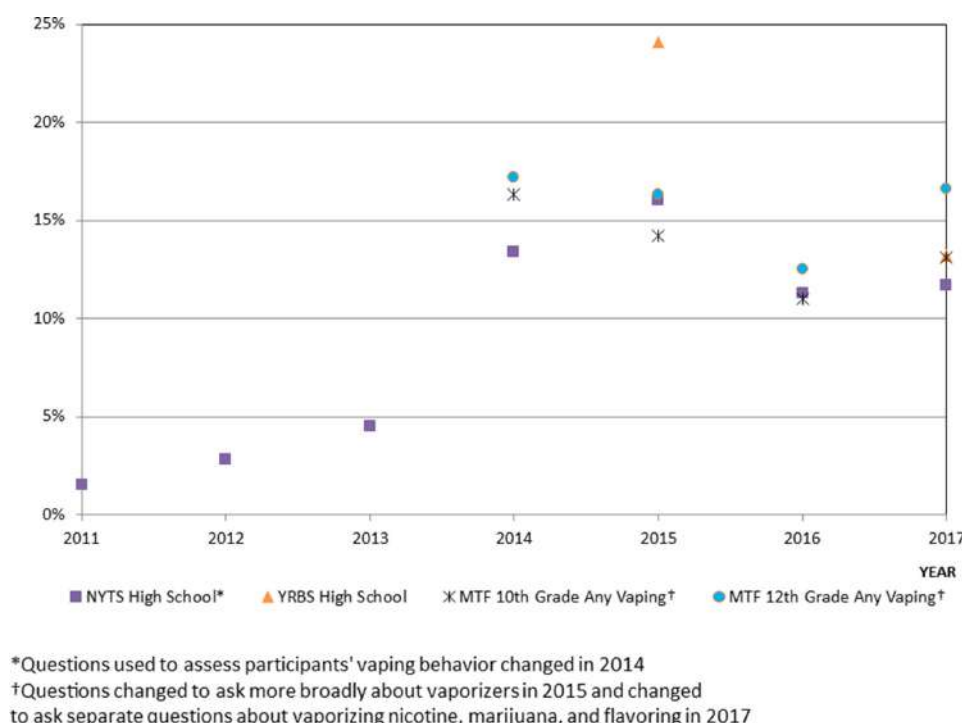
RESULTS

Trends in vaping

The NYTS was the first youth survey to include questions on vaping, starting in 2011. Past 30-day vaping among high school students increased from 1.5% in 2011 to 4.5% in 2013 and to 13.4% in 2014.[26] Vaping increased slightly to 16.0% in 2015, declined to 11.3% in 2016, and then rose slightly to 11.7% in 2017. However, reported use between 2013 and 2014 may have increased in the 2014 NYTS at least partially due to a change in the questions used to assess participants' vaping behaviour.[27]

The MTF survey began asking about vaping in 2014,[28] when past 30-day use was reported at 16.3% for 10th graders (usually ages 15–16)[29] and 17.2% for 12th graders (usually ages 17–18). With questions changed in 2015 to ask more broadly about vapourisers,[30] rates fell between 2015 and 2016 from 14.2% to 11.0% for 10th graders and from 16.3% to 12.5% for 12th graders.[31] With separate questions asked about vapourising nicotine and marijuana in 2017,[32] any vaping was 13.1% (10th grade) and 16.6% (12th grade). MTF estimates are roughly consistent with recent NYTS youth estimates, but YRBS estimated high schoolers' 2015 last 30-day vaping prevalence at a higher rate of 24.1%, although that prevalence fell to 13.2% in 2017.[33]

A longitudinal follow-up of the young adults in the MTF[34] survey had 2016 past 30-day vaping at 7.5% for those aged 19–21 years old and 7% for those aged 22–24 years old. The 2013–2014 National Adult Tobacco Survey reported everyday or someday vaping prevalence among those aged 18–24 years old at 5.5% in 2013–2014,[35] compared with 2.2% in 2012–2013.[36] Data from the 2013–2014 Population Assessment of Tobacco

*Questions used to assess participants' vaping behavior changed in 2014
†Questions changed to ask more broadly about vaporizers in 2015 and changed
to ask separate questions about vaporizing nicotine, marijuana, and flavoring in 2017

Figure 1   Youth vaping prevalence various surveys, 2011–2017. MTF, Monitoring the Future survey; NYTS, National Youth Tobacco Survey; YRBS, Youth Risk Behavior Survey.

and Health (PATH) Survey indicated that 12.5% of those aged 18–24 years old vaped in the past 30 days, with 1.3% being daily users.[37] NHIS[38 39] data had 5.1% of adults aged 18–24 vaping every day or some days in 2014, declining slightly to 4.7% in 2016.

Thus, while information on youth and young adult vaping before 2014 is limited and diverges for the different surveys, the data for youth, as shown in figure 1, indicate that vaping occurred at relatively low levels from 2011 to 2013, but reached much higher levels by 2014. We therefore identified 2014 as the tipping point year when vaping became popular among youth and young adults. However, we considered earlier years as the tipping point in our analyses of trends in cigarette use.

Trends in cigarette use

Table 1 presents the results for trend analysis as distinguished by (1) any past 30-day smoking; (2) established smoking; and (3) proportion of daily smoking among past 30-day smokers. Figure 2A–D shows trends in smoking for 10th graders, 12th graders, ages 18–21 and ages 22–24 using the MTF survey. Trends for other measures and other surveys can be found in online supplementary 2.

Past 30-day use

Using MTF data for 12th graders, figure 2B distinguishes cigarette use once vaping became prominent relative to a trend line estimated over the period of 2002–2013. Actual smoking prevalence from MTF is below the predicted smoking rates for 2014 (13.6% vs 15.5%), with the discrepancy increasing in 2017 (9.7% vs 12.9%). Thus, actual rates are below the prevaping trend predicted rates by 12% in 2014 increasing to 25% in 2017. Trend analysis (table 1) indicates a long-term annual relative reduction in smoking prevalence of 4.6% with an additional 9.5% annual reduction during the later vaping period, yielding a total annual relative reduction of 14.1% during the vaping period. Thus, the

downward trend was more than three times greater in the vaping period (14.1%) than the long-term trend (4.6%). MTF showed consistent results for 10th-grader past 30-day smoking, with large reductions seen in figure 2B, and more than three times the relative reduction in the vaping period (19.8%=5.8%+14.0%) than the preceding period (5.8%) using the trend analysis (table 1).

With the vaping period modelled as a simple reduction in smoking for the YRBS and NYTS analyses, we obtained a 52% lower past 30-day smoking rate in the vaping period for YRBS and a 22% reduction for NYTS.

We aggregated combined male and female MTF estimates by single age into age groups 18–21 and 22–24, and estimated the trend line over the period 2000–2016. Graphical analysis (figure 2C,D) did not show clear variations in trend beginning in 2014, but trend analysis showed approximately three times the relative reduction in past 30-day smoking for ages 18–21 and twice the reduction for ages 22–24 in the vaping period compared with the long-term trend. Estimates from the NSDUH indicated about four times the annual relative reduction in the vaping period compared with prior trend.

For both the 10th-grader and 12th-grader and ages 22–24 equations, the Durbin-Watson statistics was in the indeterminate region, indicating potentially autocorrelated error terms. When we corrected for autocorrelation, we obtained substantively similar results in terms of the relative reductions (see online supplementary 3, table 1). We also examined linear rather than log forms of the dependent variable and obtained consistent, although slightly weaker results (online supplementary 3, table 2). In addition, we considered different starting points for the vaping period (see online supplementary 3, table 3). We obtained improved results using the 2013 instead of the 2014 start date in terms of the adjusted Durbin-Watson statistics for the 10th-grade and improved adjusted R-squared for the 12th-grade MTF equations, but in other cases obtained weaker results in terms of the adjusted R-squared using the 2013 and 2012 start dates.

Table 1 Trend line analysis of smoking rates with deviations from long-term trend with vaping, various surveys

Survey	Measure	Years	Long-term trend	P values	Vaping trend	P values	Durbin-Watson statistics	Adjusted R-squared
Last 30-day use								
MTF	10th grade, M and F*	2004–2017	−0.058	<0.001	−0.14	.0002	1.27*	0.954
MTF	12th grade, M and F*	2004–2017	−0.046	<0.001	−0.095	<0.001	1.14*	0.985
NYTS	High school, M and F	2010–2017	−0.082	0.005	−0.22	0.02	3.01*	0.980
YRBS	High school, M and F	2003–2017	−0.062	0.04	−0.52	0.004	3.18*	0.969
MTF	Ages 18–21, M and F	2004–2016	−0.048	<0.001	−0.091	<0.001	2.23	0.973
MTF	Ages 22–24, M and F	2004–2016	−0.047	<0.001	−0.041	0.01	2.92*	0.979
NSDUH	Last 30 days, ages 18–25, M and F	2004–2016	−0.027	<0.0002	−0.092	<0.001	2.20	0.988
Established smoking								
MTF	Daily, 10th grade, M and F	2004–2017	−0.070	<0.001	−0.15	0.0002	2.23	0.959
MTF	Daily, 12th grade, M and F	2004–2017	−0.061	<0.001	−0.13	<0.001	1.19*	0.986
MTF	Daily, ages 18–21, M and F	2004–2016	−0.063	<0.001	−0.15	<0.001	2.09	0.977
MTF	Daily, ages 22–24, M and F	2004–2016	−0.062	<0.001	−0.050	0.01	2.65*	0.982
NSDUH	Daily, ages 18–25, M and F	2004–2016	−0.044	<0.001	−0.083	<0.001	2.36	0.992
MTF	Half pack per day, 10th grade, M and F	2004–2017	−0.088	<0.001	−0.200	0.002	2.06	0.948
MTF	Half pack per day, 12th grade, M and F	2004–2017	−0.086	<0.001	−0.150	<0.001	1.97	0.989
MTF	Half pack per day, ages 18–25, M and F	2004–2016	−0.073	<0.001	−0.041	0.029	2.76*	0.986
NHIS	Current smoker, ages 18–24, M	2004–2016	−0.033	0.002	−0.10	0.01	1.54	0.864
NHIS	Current smoker, ages 18–24, F	2004–2016	−0.04	<0.001	−0.059	0.06	2.99*	0.889
Daily use/last 30-day use								
MTF	10th grade, M and F	2004–2017	−0.013	0.030	−0.013	0.46	3.16*	0.954
MTF	12th grade, M and F	2004–2017	−0.015	<0.001	−0.037	0.0002	2.01	0.963
MTF	Ages 18–21, M and F	2004–2016	−0.013	<0.001	−0.058	0.0002	2.33	0.941
MTF	Ages 22–24, M and F	2004–2016	−0.015	<0.001	−0.008	0.39	2.62*	0.891
NSDUH	Ages 18–25, M and F	2004–2016	−0.017	<0.0002	−0.0053	0.51	2.29	0.943

Durbin-Watson statistics (k=2, n=13: dl=0.86, du=1.56; k=2, n=14, dl=0.91, du=1.55).
*Indeterminate region.
F, female; M, male; MTF, Monitoring the Future survey; NHIS, National Health Interview Survey; NSDUH, National Survey of Drug Use and Health; NYTS, National Youth Tobacco Survey; YRBS, Youth Risk Behavior Survey.

Established cigarette use

Trend line analysis of MTF 10th-grader and 12th-grader daily cigarette use showed about three times the annual relative reduction for both in the vaping period compared with the long-term trend. Trend analysis of MTF data also indicated more than three times the relative reductions for ages 18–21 and nearly twice the relative reductions for ages 22–24 during the vaping period. Using NSDUH, trend analysis again indicated about three times the annual relative reduction in daily smoking with vaping compared with previous trends.
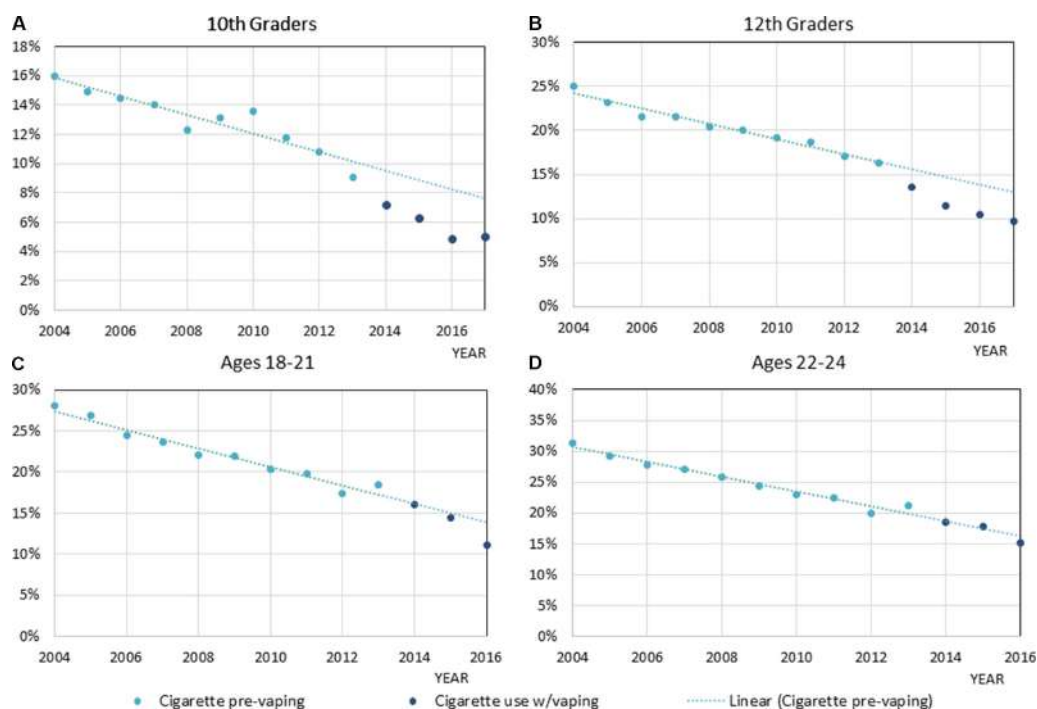
Figure 2 Monitoring the Future survey, prevaping (2004–2013) and postvaping (2014–2017), and last 30 days cigarette prevalence with linear trend for prevaping period. (A) 10th graders, (B) 12th graders, (C) ages 18–21 and (D) ages 22–24.

Among other measures of established use, MTF data on having smoked half-pack a day among last 30-day smokers yielded results consistent with those for daily smoking for the 10th and the 12th graders and for ages 18–25. Trend analysis of the NHIS data indicated a 10.0% higher relative reduction in the male smoking rate with vaping, translating to four times the relative reduction prior to vaping. A weaker indication (p=0.06) of reduced smoking was found for women, but was subject to potential autocorrelation.

On correcting for autocorrelation, the vaping term in the female NHIS equation was significant at the 0.02 level, and the associated annual relative reduction increased from 6% to 8% and the adjusted R-squared improved in the MTF 12th-grade equation, but otherwise similar results were obtained (online supplementary 3, table 1). We also obtained similar, although generally weaker results when using the linear instead of log models. The equation for MTF 12th graders showed less autocorrelation using a 2013 vape start date, but the 2014 equations otherwise performed marginally better than the 2013 equations in terms of the adjusted R-squared.

Smoking intensity

To more specifically consider trends towards more established smoking, we also examined the number of daily smokers as a proportion of the number of past 30-day smokers.[40 41] Trend line analysis yielded twice the annual relative reduction in the proportion of daily use during the vaping period for 12th graders than prior trends, but no change for 10th graders using MTF. Trend analysis of MTF data also indicated an increased annual relative reduction of 6.0% in the vaping period for ages 18–21 in addition to the prior trend of a 1.3% reduction. While the vaping trend coefficient was negative and significant or nearly significant in all cases for current and established smoking, negative but insignificant reductions were found in the analyses of smoking intensity for young adults aged 22–24 years old in the MTF survey and for those aged 18–25 years old in NSDUH.

On correcting for autocorrelation, the vaping trend became significant (p=0.05), showing twice the downward trend for 10th graders. Similar, although generally weaker, results were obtained using the linear rather than log form of smoking prevalence. As shown in online supplementary 3, table 3c, the MTF equations with the 2013 instead of 2014 vaping start date performed better in terms of the adjusted R-squared for 10th graders and those ages 18–21.

DISCUSSION

A long-term decline in smoking prevalence among US youth accelerated after 2013 when vaping became more widespread. These findings were also observed for US young adults, especially those ages 18–21. We also found that the decline in more established smoking, as measured by daily smoking, smoking half pack a day or having smoked at least 100 cigarettes and currently smoking some days or every day, markedly accelerated when vaping increased. Like previous analyses,[40 41] the proportion of daily to past 30-day smoking decreased slowly through 2012, but the extent of the decline in this measure of smoking intensity increased once vaping became popular. The results were consistent across different surveys, suggesting that the results are robust across different methods of data collection. The results remained consistent after correcting for potentially autocorrelated error terms and using linear instead of log forms of the dependent variable.

We chose the year 2014 as the first year when vaping became a more popular behaviour among youth and young adults in the USA. The selection of 2014 as a tipping point is supported by retail sales data, where growth was relatively slow through 2013, but more than doubled in 2014.[3 42] In addition, the percentage of adults who switched from cigarettes to e-cigarettes doubled between 2012–2013 and 2013–2014.[43] Our examination of the 2013 tipping points generally yielded smaller, although consistent results but did not otherwise affect the analysis. Nevertheless, our review indicates considerable variation in vaping prevalence estimates across the various surveys. In addition, the question wording in the surveys appears to make a difference in estimated vaping rates.[27 44] These differences will need to be considered in developing useful measures to assess the public health implications of vaping.

To date, only one other study has examined the temporal relationship between vaping and smoking among US youth. Dutra and Glantz[22] found no change in the linear downward trend between 2004 and 2014. They used 2009 as the tipping point for vaping when youth vaping was minimal and only considered through 2014, before most change occurred. The divergent findings between individual-level cohort studies, which show a possible causal relationship between vaping and smoking, and those of population trends showing a negative association between vaping and smoking are not necessarily inconsistent. Rather, it is possible that trying e-cigarettes is causally related to smoking for some youth, but the aggregate effect of this relationship at the population level may be small enough that its effects are swamped by other factors that influence smoking behaviour. A recent simulation analysis[45] concluded that, even if estimates from the cohort literature are accepted as causal, they would account for only a 2% increase in smoking initiation rates. Potentially, other forces reducing smoking among young people are much larger than the postulated effect of vaping on otherwise never-smoking youth. Some of the reduction in youth smoking may be due to vaping substituting for smoking among a subset of youth or being used by smokers to quit both vaping and smoking.

While the accelerated rate of decline in smoking observed after 2013 coincides with the increase in vaping, it could also reflect the influence of tobacco control interventions. For example, the FDA implemented the Real Cost media campaign directed at youth from 2014 through 2016. A recent study[46] found that this campaign reduced the risk for smoking initiation. However, the projected number of youth ages 11–18 prevented from initiating smoking was about 350 000, or about 1% of those ages 11–18, suggesting that only a small portion of the reduction in youth smoking prevalence could be explained by this policy. In addition, previous research indicates much smaller effects on smoking prevalence for media campaigns than observed during the vaping period.[47] While our analysis did not specifically control for the effect of other policies, we have considered effects from tobacco policies and interventions as predicted by the SimSmoke tobacco control policy simulation model.[48] Incorporating the minimal changes in cigarette prices and smoke-free air laws that occurred between 2012 and 2017, as well as state-level and national-level media campaign spending (including the Tips from Former Smokers (TIPS), Truth #FinishIT and Real Cost campaigns), SimSmoke predicted a slow, relatively stable downward trend for those aged 15–17 and 18–24 since 2010. These results suggest that policies and media campaigns would not have been responsible for much of an accelerated decline in youth and adult smoking in recent years. In addition, trends projected by Holford et al[49] using data from the 1965–2012

NHIS showed no major changes from 2010 onward. These analyses suggest that tobacco control policies are at most responsible for a small part of the accelerated reductions in youth and adult smoking.

Our purpose was to present a straightforward approach to examining recent trends in order to encourage research using more sophisticated techniques that adequately capture population trends. While our results indicate that rapid reductions in youth and young adult smoking have been associated with the uptake of e-cigarette use, further analysis is needed to distinguish the temporal effects of e-cigarette use and the specific role of tobacco control policies. In conducting that research, it will be important to allow for the possibility that the effects of cigarette-oriented policies in recent years may be impacted by the availability of e-cigarettes. In particular, stricter cigarette-oriented policies may have greater effects on smoking prevalence if consumers switch completely to e-cigarettes, but could instead have reduced effects if smokers turn to dual use with e-cigarettes rather than quitting smoking. Further analysis is also warranted to examine differences in smoking and vaping trends by region, where patterns of vaping may differ, and by sociodemographic status, given evidence of increasing concentration of smoking in disadvantaged groups.[50] In conducting further analyses, more sophisticated techniques, such as generalised linear models and generalised additive models,[51 52] could be applied to longer time series while incorporating individual-level characteristics and environmental factors.

The analyses were all conducted using US data, and the relationships may not hold for other countries with different cultures and regulatory regimes. It would be instructive to consider other countries, such as Canada[53] and the UK,[54] which have also experienced rapid declines in smoking prevalence in recent years, especially among young adults.

In summary, while caution is warranted in interpreting our findings, they paint a consistent picture of accelerated reductions in youth and young adult smoking prevalence as vaping became more widespread. Even if there is some validity to the catalyst hypothesis, its impact is dwarfed by other factors. In our view, it is premature to conclude that the observed increased rate of decline in smoking is due to vaping diverting youth from smoking, although it is a plausible explanation. Working out the contribution, if any, that diversion might be playing, along with attempting to understand the roles of the major public education campaigns and perhaps other activities, is critical for making the appropriate policy choices to facilitate the highly encouraging recent trends in youth and young adult cigarette use. If our primary concern is population-level trends in youth and young adult smoking, which we believe is appropriate, then vaping has not shown to be a serious cause for concern, even if the catalyst hypothesis is correct, and it is possible that vaping may be playing a contributing role to the recent steep declines in youth and young adult smoking.

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Supplement 1: Questions asked on Surveys to estimate cigarette and E-cigarette Prevalence

To Accompany "Examining the Relationship of Vaping to Smoking Initiation Among U.S. Youth and Young Adults: A Reality Check" by Levy et al.

1)   Monitoring Future (MTF) survey

Current smokers: those reporting any smoking in the past 30 days. Intensity measured by daily use and half-pack a day use.

Current vapers: those reporting any vaping in the past 30 days

For smokers (2010-2016):

SOURCE for 2010: http://www.monitoringthefuture.org/datavolumes/2010/2010dv.pdf

SOURCE for 2012: http://www.monitoringthefuture.org/datavolumes/2012/2012dv.pdf

SOURCE for 2016 (only B002): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6125759/

B001: Have you ever smoked cigarettes?

1. Never—GO TO Q.B006

2. Once or twice

3. Occasionally but not regularly

4. Regularly in the past

5. Regularly now

B002: How frequently have you smoked cigarettes during the past 30 days?

1. Not at all

2. Less than one cigarette per day

3. One to five cigarettes per day

4. About one-half pack per day

5. About one pack per day

6. About one and one-half packs per day

7. Two packs or more per day

B003: "To be more precise, during the past 30 days about how many cigarettes have you smoked per day?"

For e-cigarettes (2014-2017):

SOURCE: https://onlinelibrary.wiley.com/doi/full/10.1111/add.14119

SOURCE (search e-cigarette): https://www.icpsr.umich.edu/icpsrweb/NAHDAP/search/variables

The following questions were asked in 2015 and 2016. In 2014, the questions referred only to e-cigarettes. In 2017, separate questions were asked about vaporizing nicotine and vaporizing marijuana.

Electronic vaporizers make a mist that is inhaled and have the feel of cigarette smoking. Examples include e-cigarettes and e-pens. Have you ever used an electronic vaporizer such as an e-cigarette?

1="Never"

2="Once or twice"

3="Occasionally but not regularly"

4="Regularly in the past"

5="Regularly now"

(Two variations for the questions below were found for MTF in the same year)

Variation 1: During the LAST 30 DAYS, on how many occasions (if any) have you used electronic cigarettes (e-cigarettes)?

Variation 2: During the LAST 30 DAYS, on how many days (if any) have you used electronic cigarettes (e-cigarettes)?

1="None"

2="1-2 days"

3="3-5 days"

4="6-9 days"

5="10-19 days"

6="20-30 days"

2)   National Youth Tobacco Survey (NYTS)

Current smokers: smoked in past 30 days.

Current e-cigarette users: used e-cigarettes 1 or more days in past 30 days.

Source for all years:

https://www.cdc.gov/tobacco/data_statistics/surveys/nyts/data/index.html

For smokers (2009, 2011, 2012, 2013, 2014, 2015, 2016, and 2017; no questionnaire for 2010):

9. Have you ever tried cigarette smoking, even one or two puffs?

A. Yes

B. No

14. About how many cigarettes have you smoked in your entire life?

A. I have never smoked cigarettes, not even one or two puffs

B. 1 or more puffs but never a whole cigarette

C. 1 cigarette

D. 2 to 5 cigarettes

E. 6 to 15 cigarettes (about 1/2 a pack total)

F. 16 to 25 cigarettes (about 1 pack total)

G. 26 to 99 cigarettes (more than 1 pack, but less than 5 packs)

H. 100 or more cigarettes (5 or more packs)

15. During the past 30 days, on how many days did you smoke cigarettes?

A. 0 days

B. 1 or 2 days

C. 3 to 5 days

D. 6 to 9 days

E. 10 to 19 days

F. 20 to 29 days

G. All 30 days

16. During the past 30 days, on the days you smoked, about how many cigarettes did you smoke per day?

> A. I did not smoke cigarettes during the past 30 days
>
> B. Less than 1 cigarette per day
>
> C. 1 cigarette per day
>
> D. 2 to 5 cigarettes per day
>
> E. 6 to 10 cigarettes per day
>
> F. 11 to 20 cigarettes per day
>
> G. More than 20 cigarettes per day

17. When was the last time you smoked a cigarette, even one or two puffs? (PLEASE CHOOSE THE FIRST ANSWER THAT FITS)

> A. I have never smoked cigarettes, not even one or two puffs
>
> B. Earlier today
>
> C. Not today but sometime during the past 7 days
>
> D. Not during the past 7 days but sometime during the past 30 days
>
> E. Not during the past 30 days but sometime during the past 6 months
>
> F. Not during the past 6 months but sometime during the past year
>
> G. 1 to 4 years ago
>
> H. 5 or more years ago

For e-cigarettes (2011, 2012, 2013):

35. Which of the following tobacco products have you ever heard of? (You can CHOOSE ONE ANSWER or MORE THAN ONE ANSWER)

> A. Roll-your-own cigarettes
>
> B. Flavored cigarettes, such as Camel Crush
>
> C. Bidis (small brown cigarettes wrapped in a leaf)
>
> D. Clove cigars (kreteks)

E. Flavored little cigars (such as mint, clove, spice, alcohol (wine, cognac), candy, fruit, chocolate, or other sweets)

F. Smoking tobacco from a hookah or a waterpipe

G. Snus, such as Camel or Marlboro Snus

H. Dissolvable tobacco products, such as Ariva, Stonewall, Camel orbs, Camel sticks, or Camel strips

I. Electronic Cigarettes or E-cigarettes, such as Ruyan or NJOY

J. Some other new tobacco products not listed here

K. I have never heard of any of the products listed above or any new tobacco product

36. Which of the following tobacco products have you ever tried, even just one time? (You can CHOOSE ONE ANSWER or MORE THAN ONE ANSWER)

A. Roll-your-own cigarettes

B. Flavored cigarettes, such as Camel Crush

C. Bidis (small brown cigarettes wrapped in a leaf)

D. Clove cigars (kreteks)

E. Flavored little cigars (such as mint, clove, spice, alcohol (wine, cognac), candy, fruit, chocolate, or other sweets)

F. Smoking tobacco from a hookah or a waterpipe

G. Snus, such as Camel or Marlboro Snus

H. Dissolvable tobacco products, such as Ariva, Stonewall, Camel orbs, Camel sticks, or Camel strips

I. Electronic Cigarettes or E-cigarettes, such as Ruyan or NJOY

J. Some other new tobacco products not listed here

K. I have never tried any of the products listed above or any new tobacco product

37. In the past 30 days, which of the following products have you used on at least one day? (You can CHOOSE ONE ANSWER or MORE THAN ONE ANSWER)

A. Roll-your-own cigarettes

B. Flavored cigarettes, such as Camel Crush

C. Bidis (small brown cigarettes wrapped in a leaf)

D. Clove cigars (kreteks)

E. Flavored little cigars (such as mint, clove, spice, alcohol (wine, cognac), candy, fruit, chocolate, or other sweets)

F. Smoking tobacco from a hookah or a waterpipe

G. Snus, such as Camel or Marlboro Snus

H. Dissolvable tobacco products, such as Ariva, Stonewall, Camel orbs, Camel sticks, or Camel strips

I. Electronic Cigarettes or E-cigarettes, such as Ruyan or NJOY

J. Some other new tobacco products not listed here

K. I have not used any of the products listed above or any new tobacco product in the past 30 days

For e-cigarettes (2014, 2015, 2016, and 2017):

31. Have you ever tried an electronic cigarette or e-cigarette such as blu, 21st Century Smoke or NJOY?

a. Yes

b. No

During the past 30 days, on how many days did you use electronic cigarettes or e-cigarettes such as blu, 21st Century Smoke, or NJOY?

a. 0 days

b. 1 or 2 days

c. 3 to 5 days

d. 6 to 9 days

e. 10 to 19 days

f. 20 to 29 days

g. All 30 days

3) Youth Risk Behavior Survey (YRBS);

Current smokers: those reporting any smoking in the past 30 days.

Current vapers: those reporting any vaping in the past 30 days

Source for all odd years:

https://www.cdc.gov/healthyyouth/data/yrbs/pdf/2017/YRBS_questionnaire_content_1991-2017.pdf

For smokers (available in odd years since 1991):

Have you ever tried cigarette smoking, even one or two puffs?

    A.   Yes

    B.   No

Have you ever smoked cigarettes regularly, that is, at least one cigarette every day for 30 days?

    A. Yes

    B. No

During the past 30 days, on how many days did you smoke cigarettes?

    A.   0 days

    B.   1 or 2 days

    C.   3 to 5 days

    D.   6 to 9 days

    E.   10 to 19 days

    F.   20 to 29 days

    G.   All 30 days

During the past 30 days, on the days you smoked, how many cigarettes did you smoke per day?

    A. I did not smoke cigarettes during the past 30 days

    B. Less than 1 cigarette per day

    C. 1 cigarette per day

    D. 2 to 5 cigarettes per day

    E. 6 to 10 cigarettes per day

    F. 11 to 20 cigarettes per day

    G. More than 20 cigarettes per day

For e-cigarette users (available in 2015 and 2017):

[only asked in 2017] During the past 12 months, did you ever try to quit using all tobacco products, including cigarettes, cigars, smokeless tobacco, shisha or hookah tobacco, and electronic vapor products?

> A. I did not use any tobacco products during the past 12 months

> B. Yes

> C. No

Have you ever used an electronic vapor product?

> A. Yes

> B. No

During the past 30 days, on how many days did you use an electronic vapor product?

> A. 0 days

> B. 1 or 2 days

> C. 3 to 5 days

> D. 6 to 9 days

> E. 10 to 19 days

> F. 20 to 29 days

> G. All 30 days

---

4)   **National Survey of Drug Use and Health (NSDUH)**

Current smokers: those reporting any smoking in the past 30 days. Intensity measured by daily use.

Current vapers: those reporting any vaping in the past 30 days

Sources for 2010-2016:

> https://www.samhsa.gov/data/sites/default/files/NSDUH2010MRB/NSDUH2010MRB/2k10Q.pdf

> https://www.samhsa.gov/data/sites/default/files/NSDUH2013MRB/NSDUH2013MRB/NSDUHmrbCAIquex2013.pdf

https://samhda.s3-us-gov-west-1.amazonaws.com/s3fs-public/field-uploads-protected/studies/NSDUH-2014/NSDUH-2014-datasets/NSDUH-2014-DS0001/NSDUH-2014-DS0001-info/NSDUH-2014-DS0001-info-questionnaire-specs.pdf

https://samhda.s3-us-gov-west-1.amazonaws.com/s3fs-public/field-uploads-protected/studies/NSDUH-2015/NSDUH-2015-datasets/NSDUH-2015-DS0001/NSDUH-2015-DS0001-info/NSDUH-2015-DS0001-info-questionnaire-specs.pdf

https://www.samhsa.gov/data/sites/default/files/NSDUHmrbCAIquex2016v2.pdf

For smokers:

CG01 Have you ever smoked part or all of a cigarette?

    1 Yes

    2 No

    DK/REF

CGREF1 [IF CG01 = REF] The answers that people give us about their cigarette smoking are important to this study's success. We know that this information is personal, but remember your answers will be kept confidential. Please think again about answering this question: Have you ever smoked part or all of a cigarette?

    1 Yes

    2 No

    DK/REF

CG05 [IF CG01 = 1 OR CGREF1 = 1] Now think about the past 30 days, that is, from [DATEFILL] up to and including today. During the past 30 days, have you smoked part or all of a cigarette?

    1 Yes

    2 No

    DK/REF

CG06 [IF CG05 = 2] How long has it been since you last smoked part or all of a cigarette?

    1 More than 30 days ago but within the past 12 months

    2 More than 12 months ago but within the past 3 years

    3 More than 3 years ago

DK/REF

CG07 [IF CG05 = 1] During the past 30 days, that is, since [DATEFILL], on how many days did you smoke part or all of a cigarette?

OF DAYS: [RANGE: 1 - 30]

DK/REF

CG07DKRE [IF CG07 = DK/REF] What is your best estimate of the number of days you smoked part or all of a cigarette during the past 30 days?

1 1 or 2 days

2 3 to 5 days

3 6 to 9 days

4 10 to 19 days

5 20 to 29 days

6 All 30 days

DK/REF

CG08 [IF CG07 > 1 OR CG07DKRE = 1 - 6]) On the [CG07 days / CIGDKRE] you smoked cigarettes during the past 30 days, how many cigarettes did you smoke per day, on average?

1 Less than one cigarette per day

2 1 cigarette per day

3 2 to 5 cigarettes per day

4 6 to 15 cigarettes per day (about ½ pack)

5 16 to 25 cigarettes per day (about 1 pack)

6 26 to 35 cigarettes per day (about 1 ½ packs)

7 More than 35 cigarettes per day (about 2 packs or more)

DK/REF

CG10 [IF CG07 = 1] On the one day you smoked cigarettes during the past 30 days, how many cigarettes did you smoke?

1 Less than one cigarette

2 1 cigarette

3 2 to 5 cigarettes

4 6 to 15 cigarettes (about ½ pack)

5 16 to 25 cigarettes (about 1 pack)

6 26 to 35 cigarettes (about 1 ½ packs)

7 More than 35 cigarettes (about 2 packs or more)

DK/REF

CG16a [IF (CG05 = 2 OR DK/REF) OR ((CG08 < 4) OR (CG08 = 4 AND CG07 <17) OR (CG08 = 5 AND CG07 <7) OR (CG08 = 6 AND CG07 <4) OR (CG08 = 7 AND CG07 <3 AND CG07DKRE NE BLANK)) Have you smoked at least 100 cigarettes in your entire life?

1 Yes

2 No

DK/REF

For e-cigarette users: NOT ASKED

**5)	National Health Interview Survey (NHIS) [only for adults aged 18+]**

Current smokers: those reporting currently smoking every day or somedays.

Current vapers: those reporting currently smoking every day or somedays.

Source for 2010-2016:

ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2010/english/qadult.pdf

ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2013/english/qadult.pdf

ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2014/english/qadult.pdf

ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2015/english/qadult.pdf

ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2016/english/qadult.pdf

For smokers:

Have you smoked at least 100 cigarettes in your ENTIRE LIFE?

    1 Yes

    2 No

    7 Refused

    9 Don't know

Do you NOW smoke cigarettes every day, some days or not at all?

    1 Every day

    2 Some days

    3 Not at all

    7 Refused

    9 Don't know

On how many of the PAST 30 DAYS did you smoke a cigarette?

    *Enter '0' for None.

    00   None

    01-30   1-30 days

    97   Refused

    99   Don't know

On the average, when you smoked during the PAST 30 DAYS, about how many cigarettes did you smoke a day?

    * Enter '1' if less than 1.

    * Enter '95' if 95 or more cigarettes.

    01-94   1-94 cigarettes

    95   95+ cigarettes

    97   Refused

    99   Don't know

For e-cigarette users (starting in 2016):

Have you EVER used an e-cigarette EVEN ONE TIME? *Read if necessary: E-cigarettes and similar products can be bought as one-time, disposable products, as re-usable kits with a cartridge, or with refillable chambers. These usually contain a liquid, often called an "e-liquid" or "e-juice." Popular brands include NJOY, BLU, LOGIC, and VUSE.

     1 Yes

     2 No

     7 Refused

     9 Don't know

Do you now use e-cigarettes every day, some days, or not at all?

     1 Every day

     2 Some days

     3 Not at all

     7 Refused

     9 Don't know

On how many of the PAST 30 DAYS have you used e-cigarettes?

     00-30 0-30

     97   Refused

     99   Don't know

Supplement 2.

Supplement Figure 1. Monitoring the Future, 10th Grade Students, Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2017)
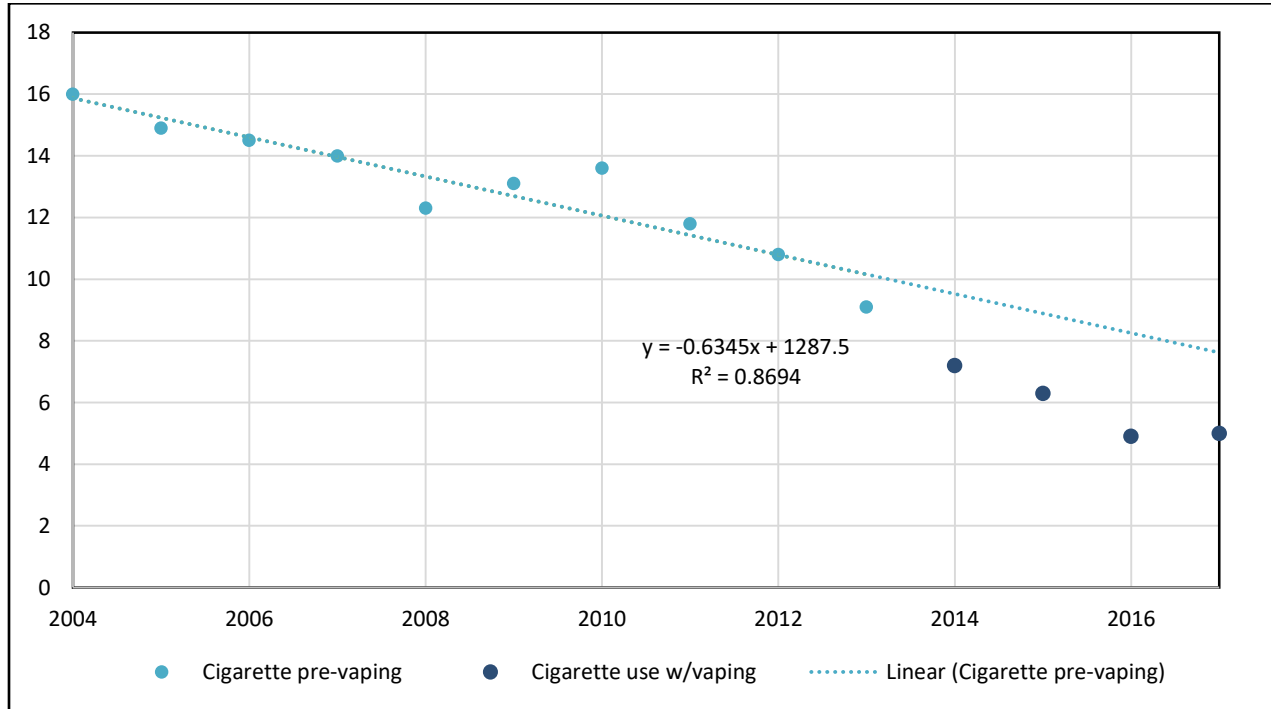
Supplement Figure 2. Monitoring the Future, 12th Grade Students, Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2017)

Supplement Figure 3. National Youth Tobacco Survey, High Schoolers, Last 30-Day Cigarette Use, Trends Pre-Vaping (2011-2013) and Post-Vaping Estimates (2014-2017)

$y = -1.55x + 3132.8$
$R^2 = 0.9914$

Legend: ● Cigarette pre-vaping ● Cigarette use w/vaping ⋯⋯ Linear (Cigarette pre-vaping)

Supplement Figure 4. Youth Risk Behavior Survey, High Schoolers, Last 30-Day Cigarette Use, Trends Pre-Vaping (2005-2013) and Post-Vaping Estimates (2015-2017)

$y = -0.825x + 1676.7$
$R^2 = 0.9515$

Legend: ● Cigarette pre-vaping ● Cigarette use w/vaping ⋯⋯ Linear (Cigarette pre-vaping)

Supplement Figure 5. Monitoring the Future, Ages 18-21, Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

y = -1.1286x + 2289.2
R² = 0.9592

● Cigarette pre-vaping   ● Cigarette pre-vaping   ⋯⋯ Linear (Cigarette pre-vaping)

Supplement Figure 6. Monitoring the Future, Ages 22-24, Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

y = -1.2026x + 2440.7
R² = 0.9652

● Cigarette pre-vaping   ● Cigarette use w/vaping   ⋯⋯ Linear (Cigarette pre-vaping)
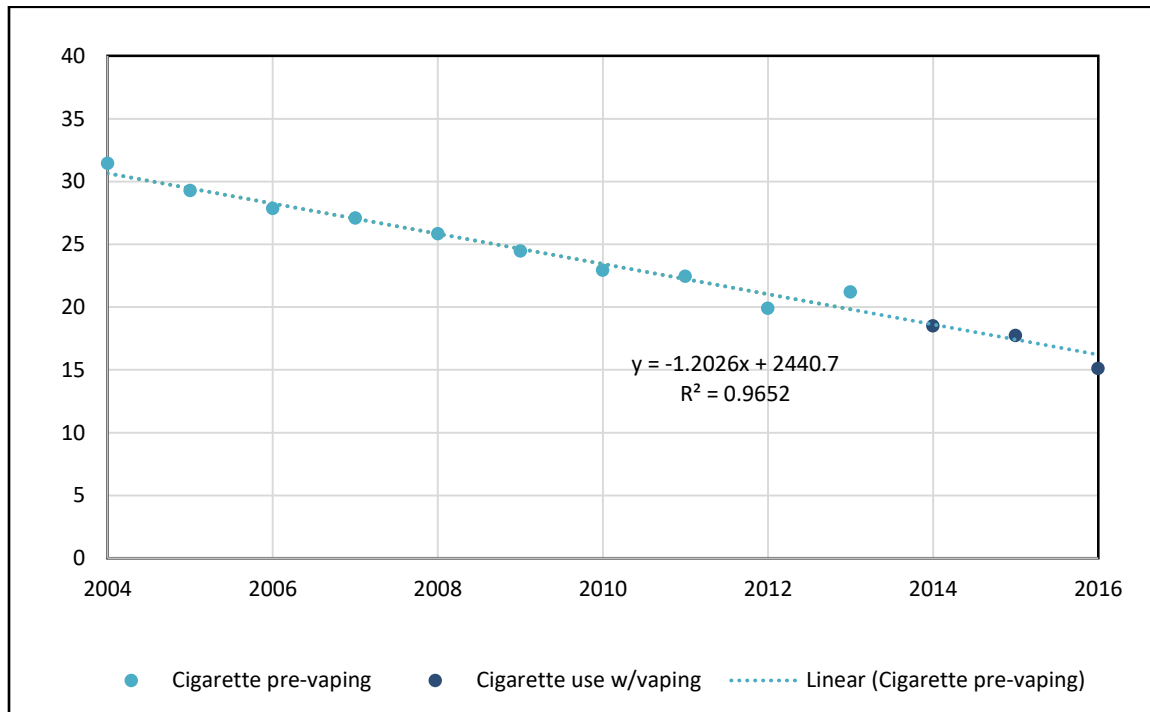
Supplement Figure 7. National Survey of Drug Use and Health, Ages 18-25, Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

y = -0.9764x + 1996.5
R² = 0.9708

● Cigarette pre-vaping ● Cigarette use w/vaping ⋯⋯ Linear (Cigarette pre-vaping)
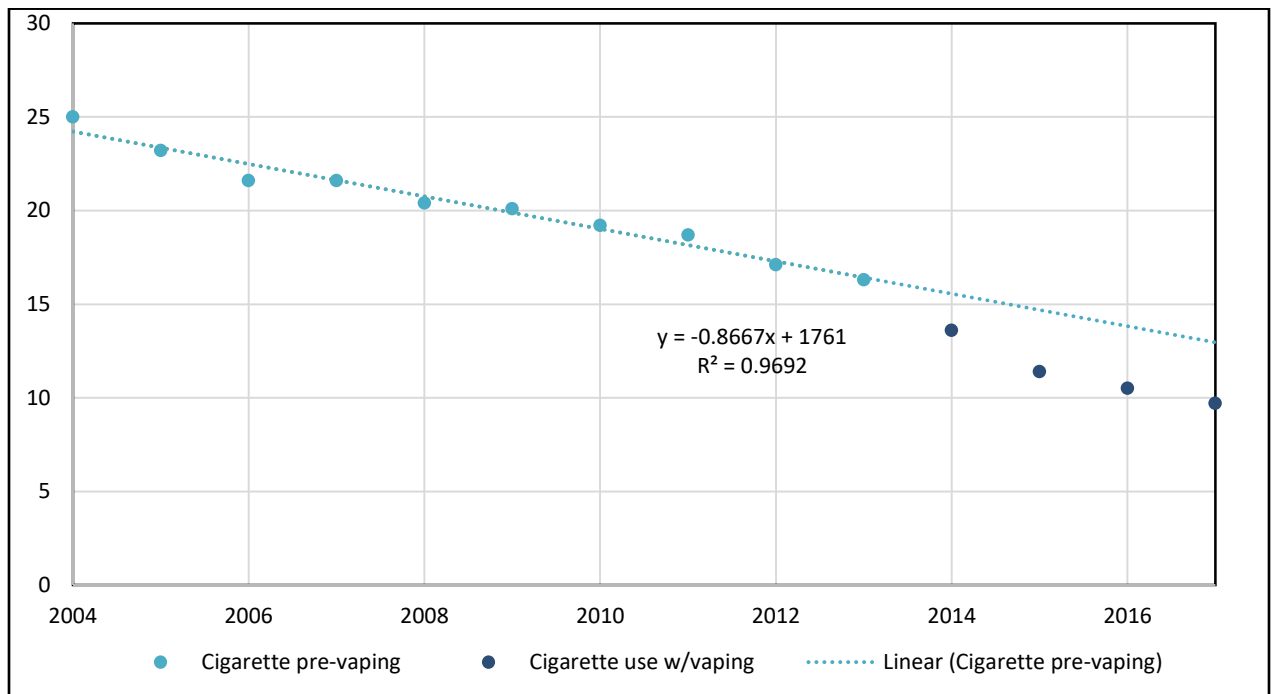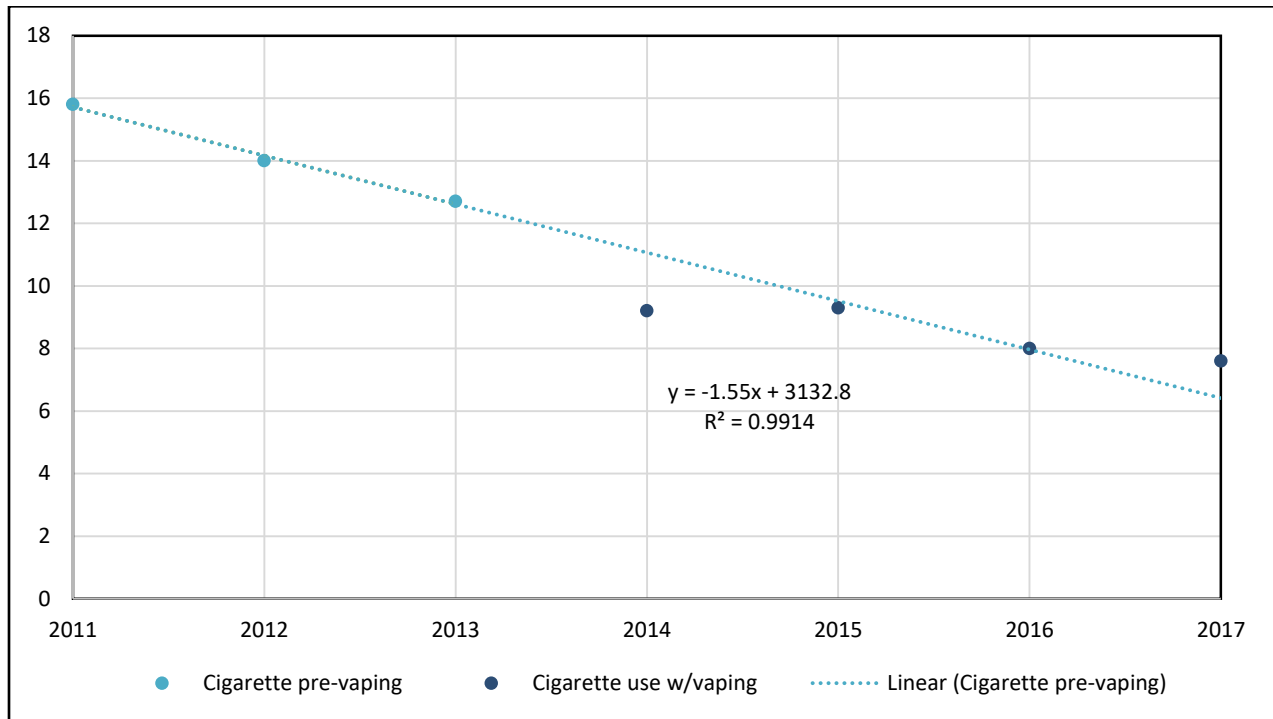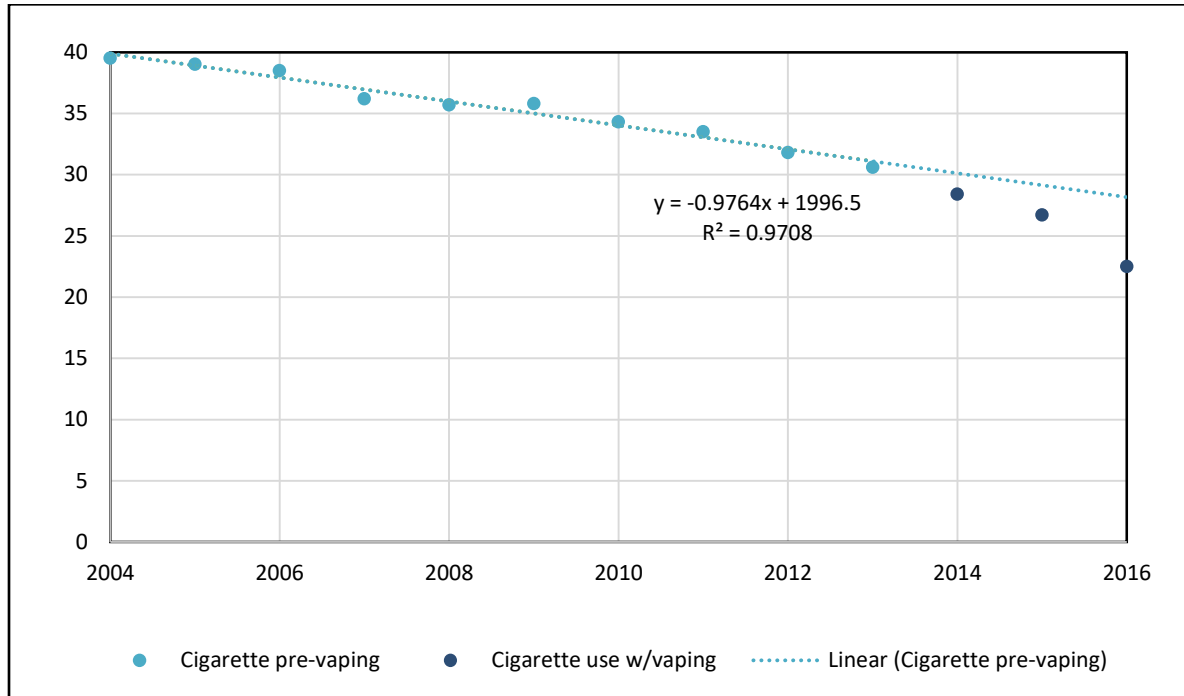
Supplement Figure 8. Monitoring the Future, 10th Grade Students, Daily Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2017)
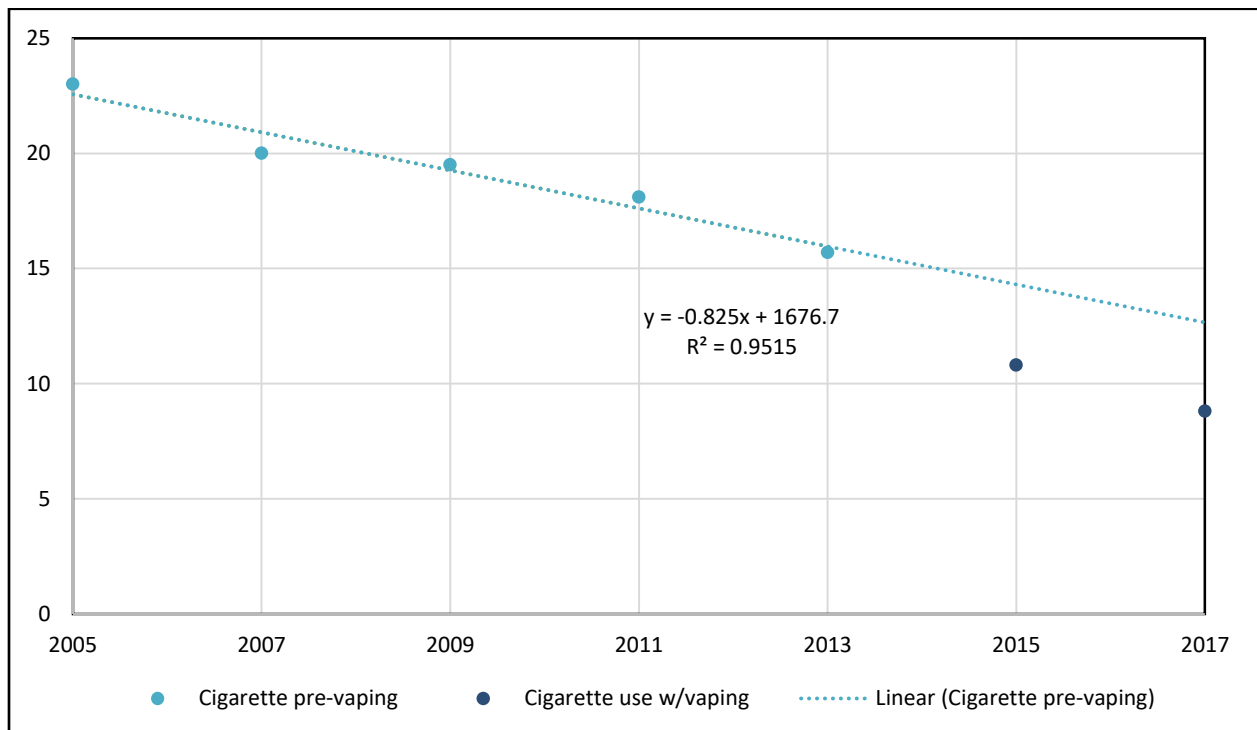

y = -0.3909x + 791.57
R² = 0.903

● Cigarette pre-vaping ● Cigarette use w/vaping ⋯⋯ Linear (Cigarette pre-vaping)
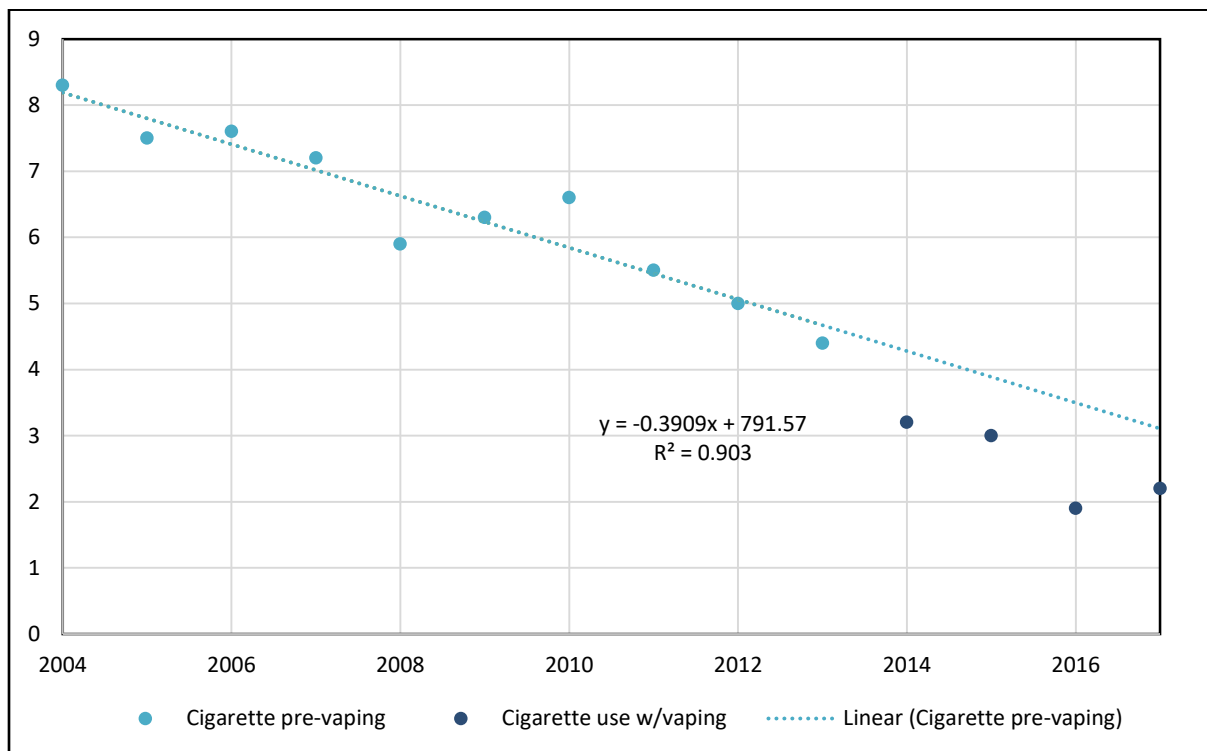
Supplement Figure 9. Monitoring the Future High School 12th Grade Students, Daily Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2017)
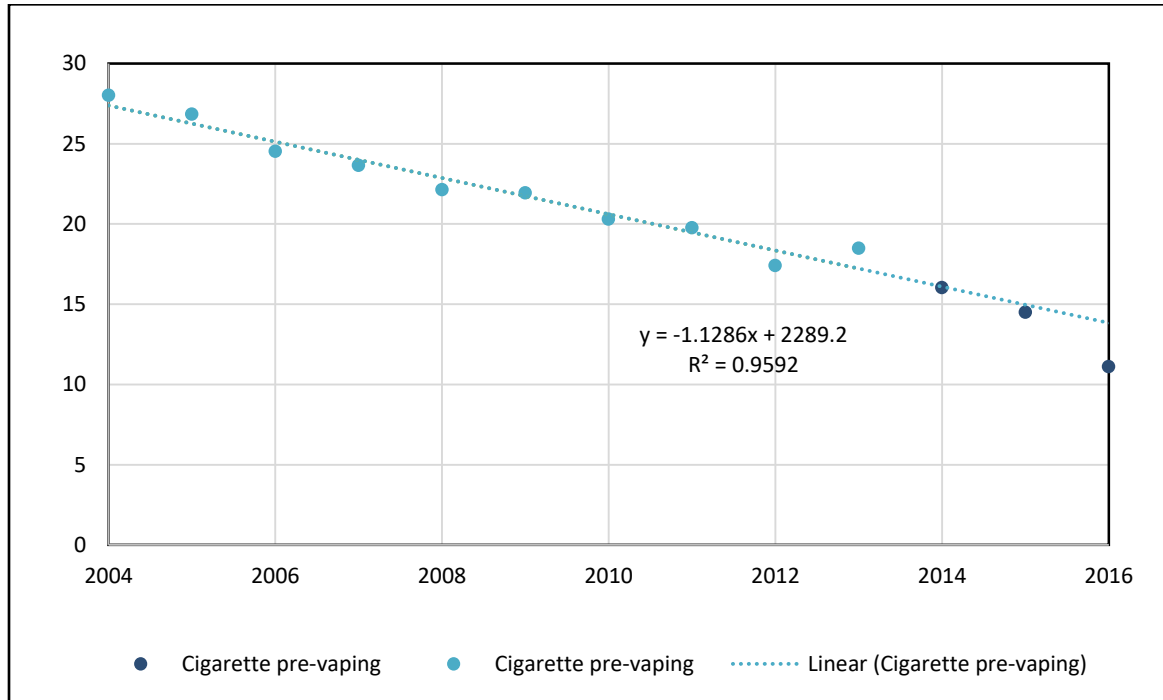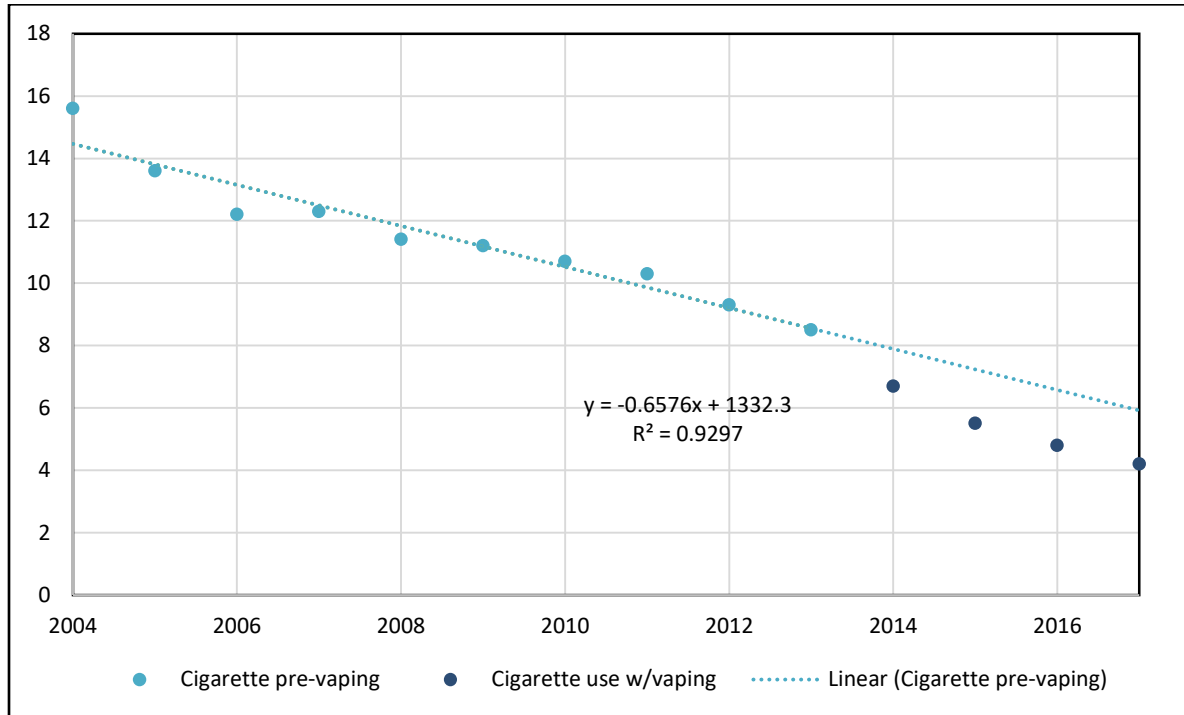

Supplement Figure 10. Monitoring the Future, Ages 18-21, Daily Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)
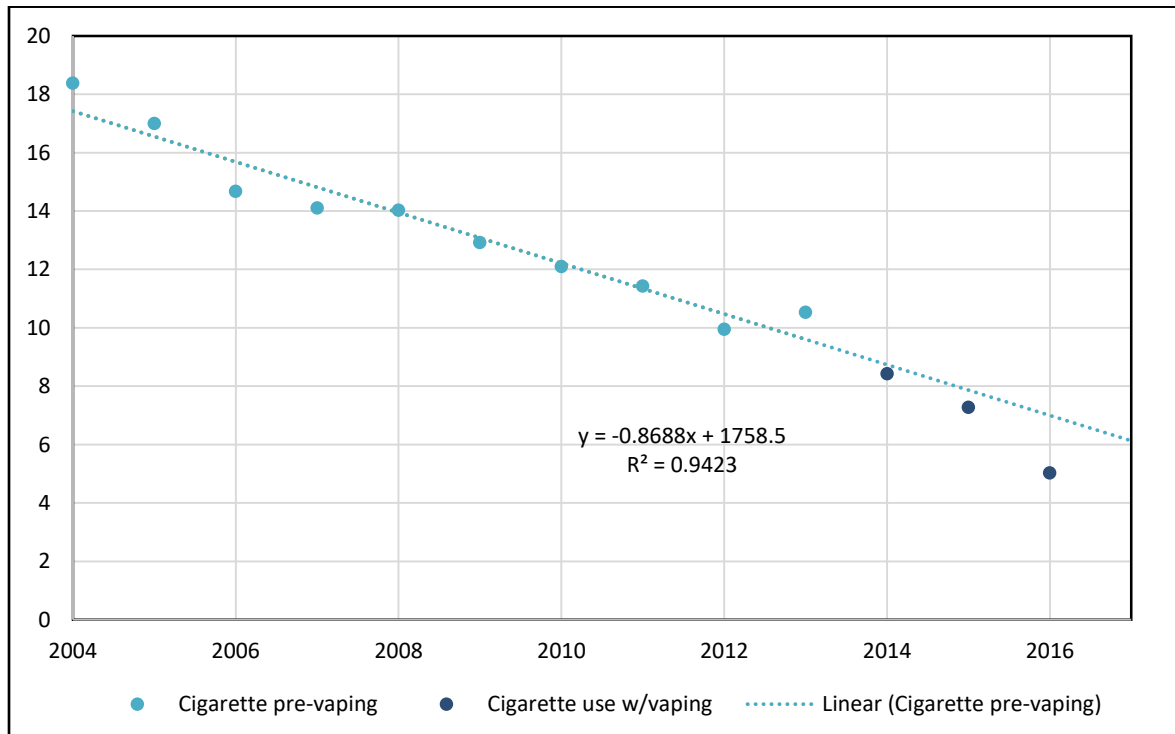
Supplement Figure 11. Monitoring the Future, Ages 22-24, Daily Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$$y = -1.0564x + 2138.4$$
$$R^2 = 0.9662$$

Legend: Cigarette pre-vaping • Cigarette use w/vaping • .... Linear (Cigarette pre-vaping)
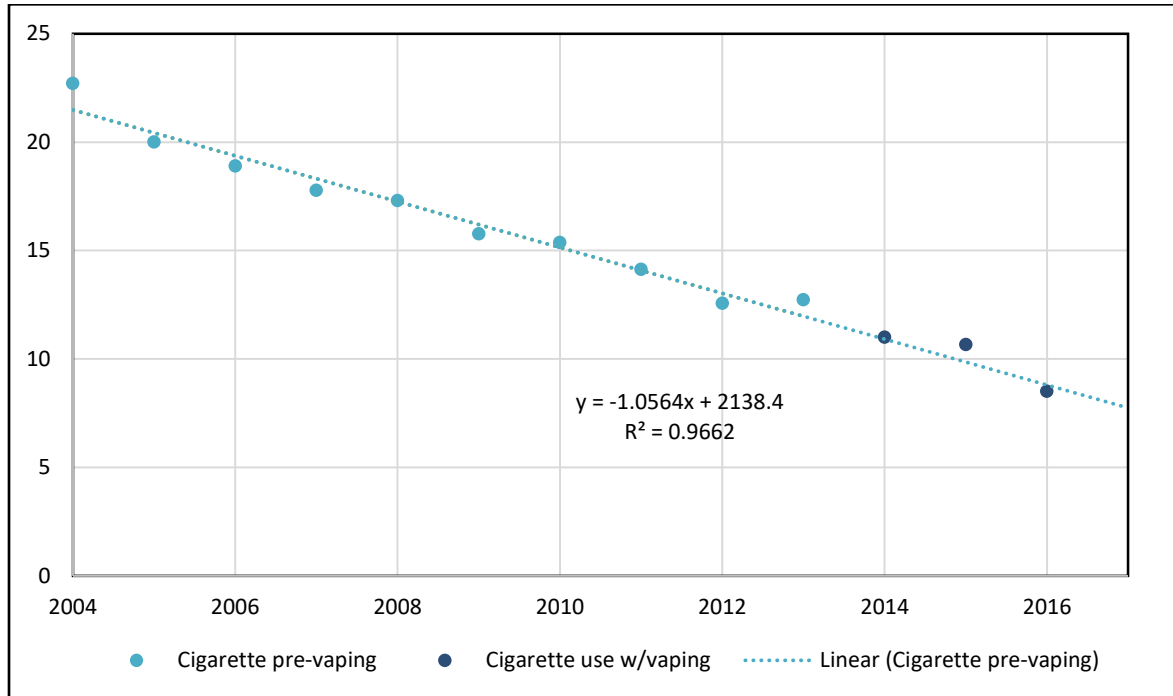
Supplement Figure 12. National Survey of Drug Use and Health, Ages 18-25, Daily Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$$y = -0.7657x + 1554.6$$
$$R^2 = 0.9947$$

Legend: Cigarette pre-vaping • Cigarette use w/vaping • .... Linear (Cigarette pre-vaping)
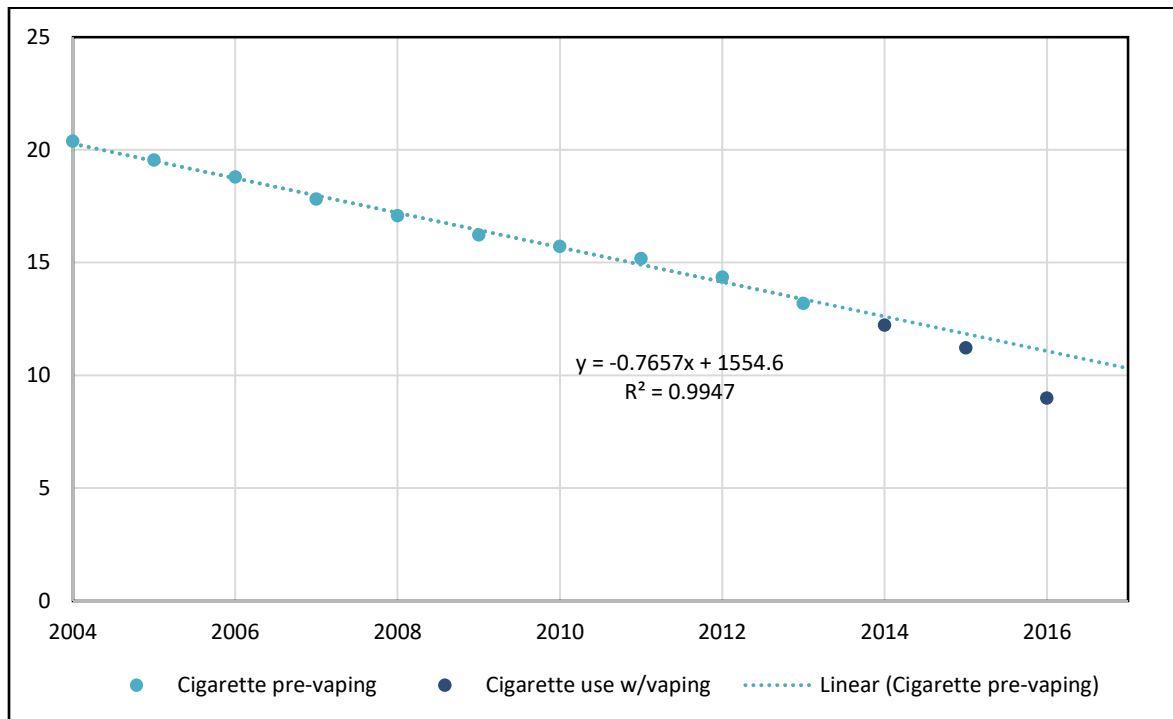
Supplement Figure 13. National Health Interview Survey Male, Ages 18-24, 100 Cigarettes per Lifetime, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$y = -0.7758x + 1582.6$
$R^2 = 0.6012$

Legend: Cigarette pre-vaping | Cigarette use w/ vaping | ········· Linear (Cigarette pre-vaping)
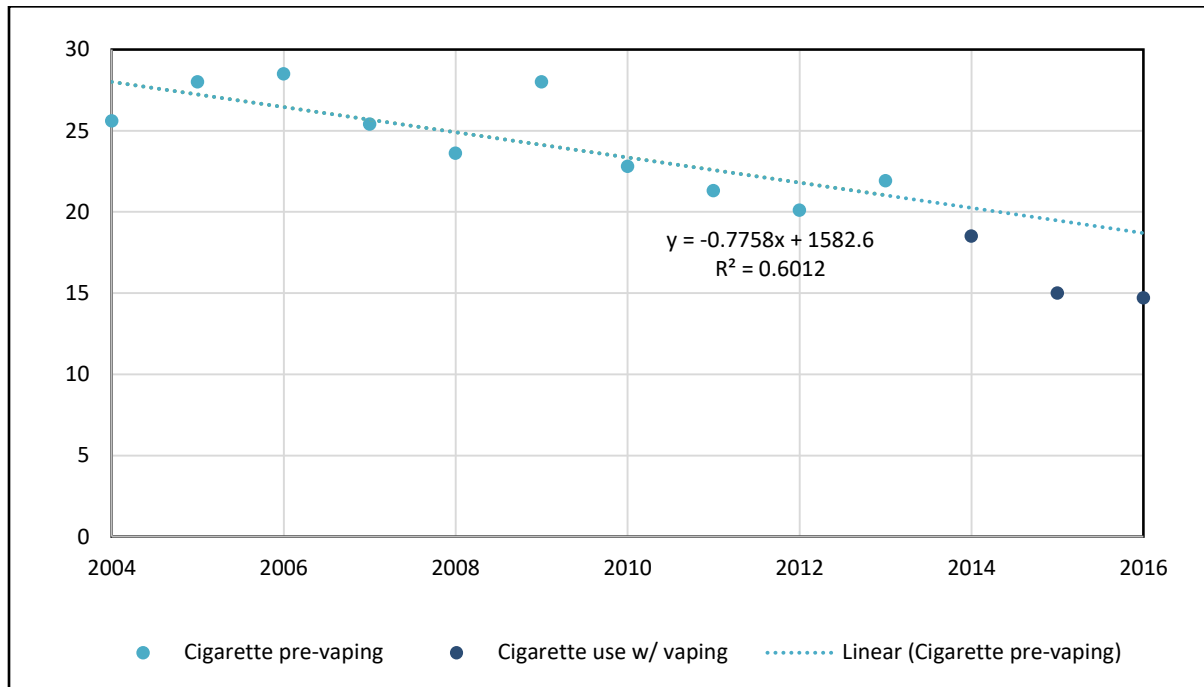
Supplement Figure 14. National Health Interview Survey Female, Ages 18-24, 100 Cigarettes per Lifetime, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$y = -0.7352x + 1494.4$
$R^2 = 0.8741$

Legend: Cigarette pre-vaping | Cigarette use w/vaping | ········· Linear (Cigarette pre-vaping)
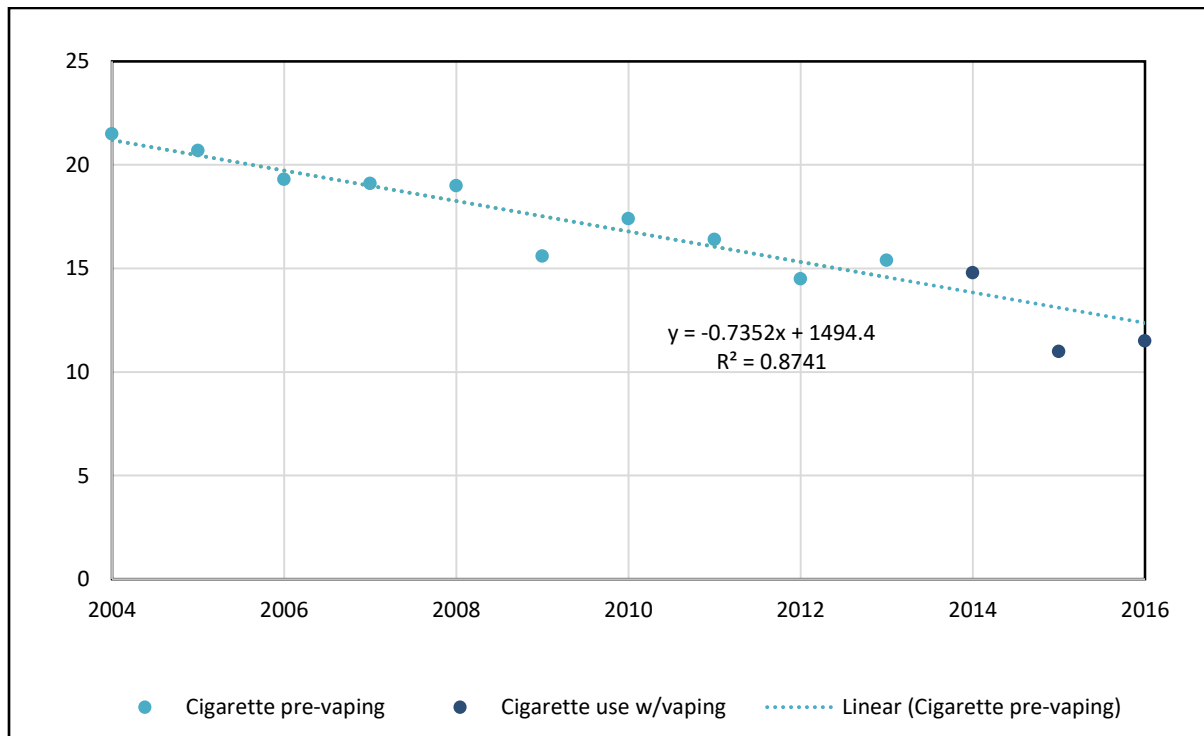
Supplement Figure 15. Monitoring the Future, 12th Grade Students, Ratio of Daily Cigarette Use to Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2017)

$y = -0.008x + 16.72$
$R^2 = 0.8057$

Legend: ● Cigarette pre-vaping   ● Cigarette use w/vaping   ⋯⋯ Linear (Cigarette pre-vaping)
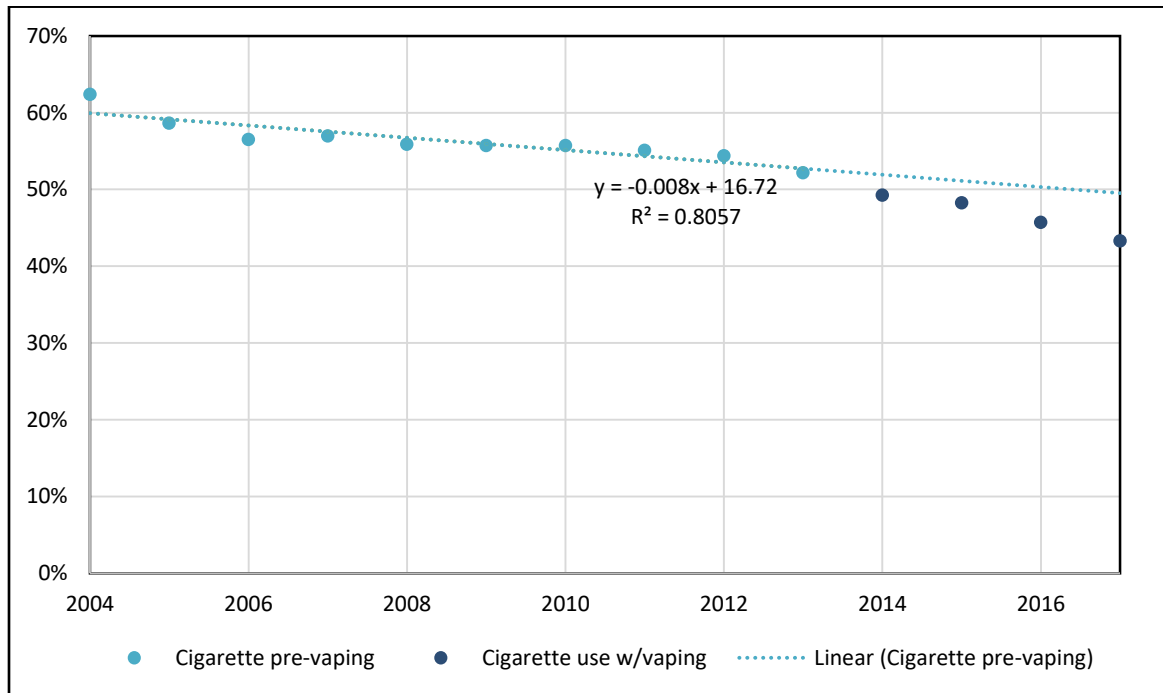
Supplement Figure 16. Monitoring the Future, Ages 18-21, Ratio of Daily Cigarette Use to Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$y = -0.0082x + 17.001$
$R^2 = 0.7225$

Legend: ● Cigarette pre-vaping   ● Cigarette use w/vaping   ⋯⋯ Linear (Cigarette pre-vaping)
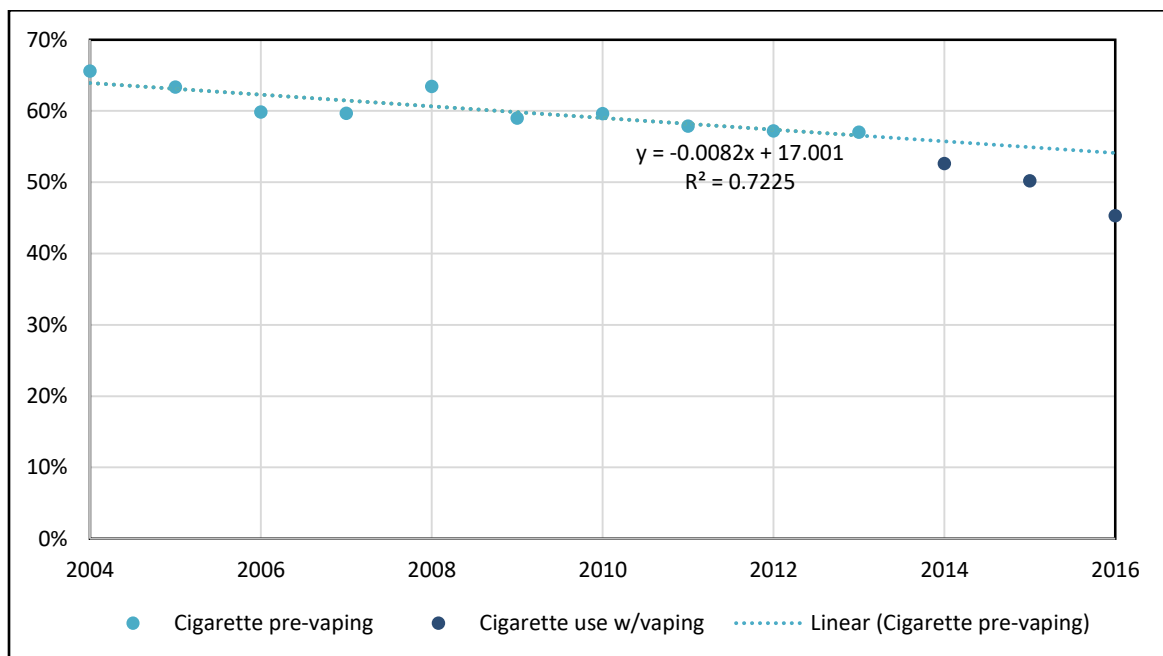
Supplement Figure 17. Monitoring the Future, Ages 22-24, Ratio of Daily Cigarette Use to Last 30-Day Cigarette Use, Trends Pre-Vaping (2004-2013) and Post-Vaping Estimates (2014-2016)

$y = -0.0102x + 21.187$
$R^2 = 0.8251$

Legend: ● Cigarette pre-vaping ● Cigarette use w/vaping ········· Linear (Cigarette pre-vaping)
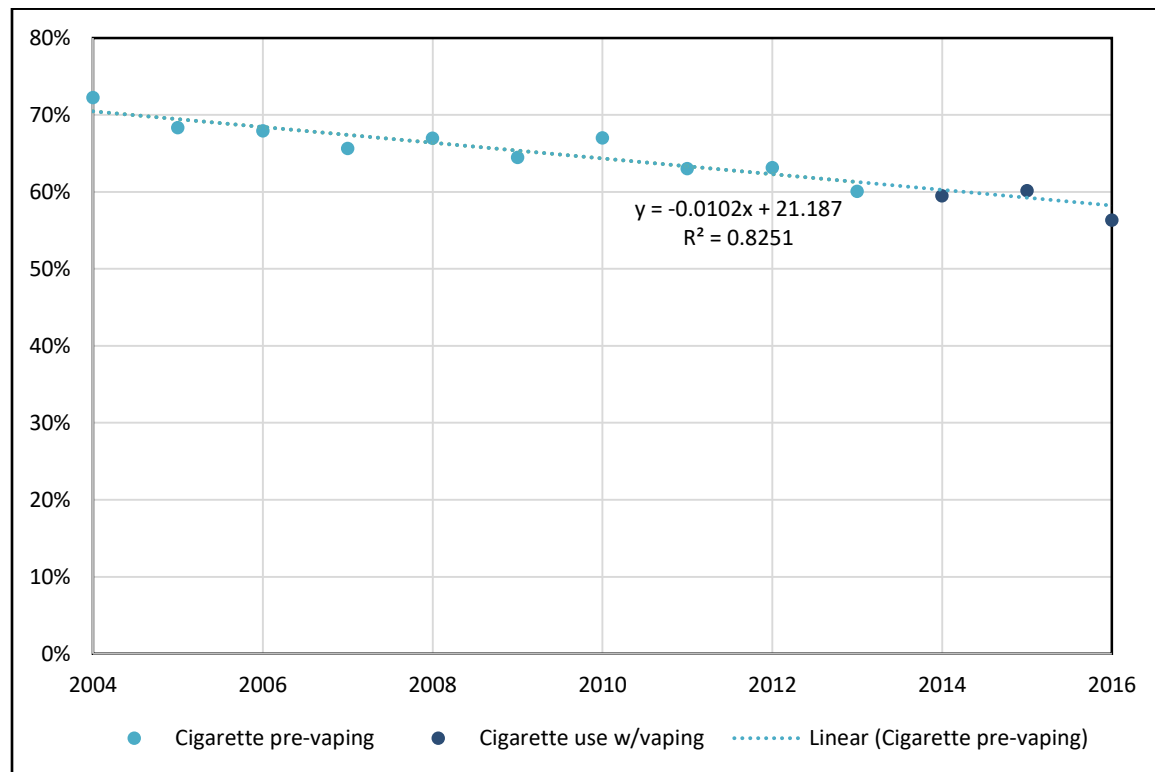
Supplement 3.

Supplement 3: Table 1. Trend Line Analysis with Vaping-Related Deviations from Long-Term Trend, Log Form of Dependent Variable, Various Surveys, with Corrections for Autocorrelation (only for Equations w Durbin Watson Statistics in the Indeterminate Region)

Survey	Measure	Years Included	Long-term trend	P-value	Vaping trend	P-value	Adj. R-squared
MTF	10th-grade, M & F	2004-2017	-0.043	<0.001	-0.086	0.01	0.911
MTF	12th-grade, M & F	2004-2017	-0.03	<0.001	-0.056	0.002	0.958
MTF	Ages 22-24, M & F	2004-2016	-0.08	<0.001	-0.059	<0.001	0.970
MTF	12th-grade, Daily, M & F	2004-2017	-0.039	<0.001	-0.08	0.03	0.962
MTF	Ages 22-24, Daily, M & F	2004-2016	-0.090	<0.001	-0.058	0.05	0.994
MTF	Ages 18-25, Half Pack, M & F	2004-2016	-0.065	<0.001	-0.048	0.05	0.989
NHIS	Current Smoker, 18-24, F	2004-2016	-0.054	<0.001	-0.078	0.02	0.945
MTF	10th-grade, M & F	2004-2017	-0.020	<0.001	-0.025	0.05	0.922
MTF	Ages 22-24, M & F	2004-2016	-0.022	0.002	-0.012	0.17	0.888

Notes: MTF= Monitoring the Future survey, NHIS = National Health Interview Survey, M= Male, F=Female

Equations were corrected for autocorrelation by first estimating the correlation of the error term, $e_t = a + \rho e_{t-1}$, then adjusting the dependent variable y as $(y_t - \rho y_{t-1})$

Supplement 3: Table 2. Trend Line Analysis with Vaping-Related Deviations from Long-Term Trend, Various Surveys, with the Dependent Variable in Linear Form

Survey	Measure	Years Included	Long-term trend	P-value	Vaping trend	P-value	Durbin Watson Stat.	Adj. R-squared
Last 30-day Cigarette Use								
MTF	10th grade, M & F	2004-2017	-0.089	<0.001	-0.72	0.03	1.21*	0.954
MTF	12th grade, M & F	2004-2017	-0.92	<0.001	-0.86	0.002	1.28*	0.982
MTF	Ages 18-21, M & F	2004-2016	-1.09	<0.001	-0.77	0.04	1.23	0.975
MTF	Ages 22-24, M & F	2004-2016	-1.18	<0.001	-0.267	0.85	3.03*	0.970
NSDUH	Last 30 day Ages 18-25	2004-2016	-0.96	<0.001	-1.73	<0.001	2.23	0.981
Established Cigarette Use								
MTF	10th grade, Daily M & F	2004-2017	-0.43	<0.001	-0.27	0.09	1.97	0.960
MTF	12th grade, Daily, M & F	2004-2017	-0.69	<0.001	-0.45	0.03	1.19*	0.972
MTF	Ages 18-21, Daily, M & F	2004-2016	-0.85	<0.001	-0.58	0.06	1.62	0.970
MTF	Ages 22-24, Daily, M & F	2004-2016	-1.04	<0.001	-0.013	0.05	1.99	0.980
NSDUH	Ages 18-25, Daily M & F	2004-2016	-0.75	<0.001	-0.62	<0.001	2.04	0.994
NHIS	Current Smoker, 18-24, M	2004-2016	-0.79	0.002	-1.53	0.08	2.23	0.835
NHIS	Current Smoker, 18-24, F	2004-2016	-0.71	<0.001	-0.50	0.25	2.84*	0.781
Daily Use/Last 30 Day Use								
MTF	10th grade, M & F	2004-2017	-0.006	0.02	-0.005	0.48	3.11*	0.657
MTF	12th grade, M & F	2004-2017	-0.008	<0.001	-0.014	0.001	1.23*	0.953
MTF	Ages 18-21, M & F	2004-2016	-0.008	<0.001	-0.003	0.001	2.29	0.923
MTF	Ages 22-24, M & F	2004-2016	-0.010	<0.001	-0.004	-0.87	2.58*	0.888
NSDUH	Ages 18-25, M & F	2004-2016	-0.82	<0.001	-0.083	0.81	2.19	0.906

Notes: Durbin Watson Statistic (k=2, n= 13: dl=0.86, du= 1.56; k=2, n= 14, dl=0.91, du= 1.55), * = indeterminate region, MTF= Monitoring the Future survey, NSDUH =National Survey of Drug Use and Health, NHIS = National Health Interview Survey, M= Male, F=Female

Supplement 3: Table 3a. Trend Line Analysis of Last 30-day Use with Vaping-Related Deviations from Long-Term Trend, Log Form, Various Surveys, with Different Begin Dates for Vaping Trend: 2012, 2013, 2014

Survey	Measure	Years	Initial Year of Vaping trend	Long-term trend	P-value	Vaping trend	P-value	Durban-Watson Statistic	Adj R-squared
				Last 30-day Use					
MTF	10th grade, M & F*	2004-2017	2014	-0.340	<.0001	-0.130	<.0001	2.44*	0.980
MTF	10th grade, M & F*	2004-2017	2013	-0.046	<.0001	-0.133	<.0001	1.87	0.975
MTF	10th grade, M & F*	2004-2017	2012	-0.058	<.0001	-0.140	<.0001	1.28*	0.954
MTF	12th grade, M & F*	2004-2017	2014	-0.046	<.0001	-0.096	<.0001	1.16*	0.985
MTF	12th grade, M & F*	2004-2017	2013	-0.040	<.0001	-0.086	<.0001	2.45*	0.990
MTF	12th grade, M & F*	2004-2017	2012	-0.034	<.0001	-0.078	<.0001	1.69	0.988
MTF	Ages 18-21, M & F	2004-2016	2014	-0.048	<.0001	-0.091	0.0005	2.28	0.973
MTF	Ages 18-21, M & F	2004-2016	2013	-0.047	<.0001	-0.061	0.01	2.02	0.951
MTF	Ages 18-21, M & F	2004-2016	2012	-0.049	0.0200	-0.045	0.0008	1.63	0.943
MTF	Ages 22-24, M & F	2004-2016	2014	-0.047	<.0001	-0.041	0.0100	3.00*	0.979
MTF	Ages 22-24, M & F	2004-2016	2013	-0.470	<.0001	-0.025	0.0800	2.74*	0.969
MTF	Ages 22-24, M & F	2004-2016	2012	-0.021	<.0001	-0.046	<.0001	2.48	0.968
NSDUH	Ages 18-25, M&F	2004-2016	2014	-0.027	<.0001	-0.075	<.0001	2.21	0.982
NSDUH	Ages 18-25, M&F	2004-2016	2013	-0.024	<.0001	-0.059	<.0001	2.09	0.976
NSDUH	Ages 18-25, M&F	2004-2016	2012	-0.021	0.0006	-0.050	0.0003	1.59	0.967

Notes: Durbin Watson Statistic (k=2, n= 13: dl=0.86, du= 1.56; k=2, n= 14, dl=0.91, du= 1.55), * = indeterminate region, MTF= Monitoring the Future survey, NSDUH =National Survey of Drug Use and Health,

Supplement 3: Table 3b. Trend Line Analysis of Established Use with Vaping-Related Deviations from Long-Term Trend, Log Form, Various Surveys, with Different Begin Dates for Vaping Trend: 2012, 2013, 2014

Survey	Measure	Years	Initial Year of Vaping trend	Long-term trend	P-value	Vaping trend	P-value	Durban-Watson Statistic	Adj R-squared
			Daily Use						
MTF	Daily, 10th grade, M & F	2004-2017	2014	-0.070	<.0001	-0.15	0.0010	2.23	0.959
MTF	Daily, 10th grade, M & F	2004-2017	2013	-0.058	0.0003	-0.14	0.0003	2.81*	0.958
MTF	Daily, 10th grade, M & F	2004-2017	2012	-0.130	0.0002	-0.048	0.004	2.93*	0.959
MTF	Daily, 12th grade, M & F	2004-2017	2014	-0.061	<.0001	-0.13	<.0001	1.19*	0.986
MTF	Daily, 12th grade, M & F	2004-2017	2013	-0.053	<.0001	-0.12	<.0001	2.50*	0.989
MTF	Daily, 12th grade, M & F	2004-2017	2012	-0.061	<.0001	-0.13	<.0001	1.19*	0.986
MTF	Daily, Ages 18-21, M & F	2004-2016	2014	-0.063	<.0001	-0.15	<.0001	2.09	0.977
MTF	Daily, Ages 18-21, M & F	2004-2016	2013	-0.059	<.0001	-0.10	0.0020	1.95	0.974
MTF	Daily, Ages 18-21, M & F	2004-2016	2012	-0.055	<.0001	-0.085	0.0090	1.51*	0.940
MTF	Daily, Ages 22-24, M & F	2004-2016	2014	-0.062	<.0001	-0.050	0.0100	2.65*	0.982
MTF	Daily, Ages 22-24, M & F	2004-2016	2013	-0.062	<.0001	-0.034	0.0400	2.82*	0.977
MTF	Daily, Ages 22-24, M & F	2004-2016	2012	-0.029	<.0001	-0.020	0.0600	2.61*	0.976
NSDUH	Daily, Ages 18-25, M & F	2004-2016	2014	-0.044	<.0001	-0.083	<.0001	2.36*	0.988
NSDUH	Daily, Ages 18-25, M & F	2004-2016	2013	-0.041	<.0001	-0.065	<.0001	1.80*	0.984
NSDUH	Daily, Ages 18-25, M & F	2004-2016	2012	-0.038	<.0001	-0.054	0.0008	1.38*	0.976
NHIS	Current Smoker, Ages 18-24, M	2004-2016	2014	-0.033	0.002	-0.099	0.012	2.22	0.876
NHIS	Current Smoker, Ages 18-24, M	2004-2016	2013	-0.031	0.011	-0.073	0.028	2.27	0.857

NHIS	Current Smoker, Ages 18-24, M	2004-2016	2012	-0.038	0.0037	-0.032	0.18	2.59*	0.879
NHIS	Current Smoker, Ages 18-24, F	2004-2016	2014	-0.040	0.0002	-0.059	0.05	2.99*	0.899
NHIS	Current Smoker, Ages 18-24, F	2004-2016	2013	-0.039	0.0009	-0.039	0.14	2.78*	0.883
NHIS	Current Smoker, Ages 18-24, F	2004-2016	2012	-0.038	0.0037	-0.032	0.17	2.59*	0.879

Notes: Durbin Watson Statistic (k=2, n= 13: dl=0.86, du= 1.56; k=2, n= 14, dl=0.91, du= 1.55), * = indeterminate region, MTF= Monitoring the Future survey, NSDUH =National Survey of Drug Use and Health, NHIS = National Health Interview Study

Supplement 3: Table 3c. Trend Line Analysis of Daily/Last 30-day Use with Deviations from Long-Term Trend with Vaping, Log Form, Various Surveys, with Different Begin Dates for Vaping Trend: 2012, 2013, 2014

Survey	Measure	Years	Initial Year of Vaping trend	Long-term trend	P-value	Vaping trend	P-value	Durban-Watson Statistic	Adj R-squared
**Daily Use/Last 30-day Use**
MTF	10th grade, M & F	2004-2017	2014	-0.013	0.03	-0.013	0.46	3.16*	0.954
MTF	10th grade, M & F	2004-2017	2013	-0.013	0.05	-0.008	0.55	3.10*	0.974
MTF	10th grade, M & F	2004-2017	2012	-0.006	0.65	-0.012	0.08	3.05*	0.800
MTF	12th grade, M & F	2004-2017	2014	-0.015	<.0001	-0.037	0.0002	2.01	0.963
MTF	12th grade, M & F	2004-2017	2014	-0.015	<.0001	-0.034	0.0002	1.30*	0.963
MTF	12th grade, M & F	2004-2017	2013	-0.013	<.0001	-0.029	0.0001	2.45	0.958
MTF	12th grade, M & F	2004-2017	2012	-0.011	0.0030	-0.026	0.009	1.82	0.952
MTF	Ages 18-21, M & F	2004-2016	2014	-0.013	0.0004	-0.058	0.0002	2.33	0.941
MTF	Ages 18-21, M & F	2004-2016	2013	-0.013	0.0001	-0.029	0.0010	2.35	0.965
MTF	Ages 18-21, M & F	2004-2016	2012	-0.010	0.06	-0.035	0.0065	1.93	0.890
MTF	Ages 22-24, M & F	2004-2016	2014	-0.015	<.0001	-0.008	0.39	2.62*	0.891
MTF	Ages 22-24, M & F	2004-2016	2013	-0.014	0.0003	-0.009	0.26	3.10*	0.897
MTF	Ages 22-24, M & F	2004-2016	2012	-0.014	<.0001	-0.078	0.28	3.24*	0.896
NSDUH	Ages 18-25, M & F	2004-2016	2014	-0.017	<.0001	-0.05	0.51	2.29	0.937
NSDUH	Ages 18-25, M & F	2004-2016	2013	-0.017	<.0001	-0.04	0.55	2.22	0.936
NSDUH	Ages 18-25, M & F	2004-2016	2012	-0.017	<.0001	-0.0057	0.78	2.21	0.934

Notes: Durbin Watson Statistic (k=2, n= 13: dl=0.86, du= 1.56; k=2, n= 14, dl=0.91, du= 1.55), * = indeterminate region, MTF= Monitoring the Future survey, NSDUH =National Survey of Drug Use and Health, NHIS = National Health Interview Study

Pace of US smoking rate decline mirrors rapid rise in popularity of vaping

Little evidence that e-cigs prompting young people to start smoking, say researchers

The pace of the fall in smoking prevalence among teens and young adults in the US has mirrored the rapid rise in popularity of e-cigarettes, suggesting that the two may be linked, finds research published online in the journal **Tobacco Control.**

While trying e-cigarettes may prompt some young people to take up smoking at the individual level, there is little evidence that this is the case at the population level, conclude the researchers. And these findings are consistent over several years, they emphasise.

Earlier this year, the National Academies of Sciences, Engineering and Medicine published a report which concluded there was "substantial evidence" that vaping among young people is strongly associated with progression to smoking.

But the report also noted that recent increases in the popularity of e-cigarettes have been associated with falling smoking rates among this age group.

To try and explore these trends in more depth and settle the question of whether vaping might act as a gateway to smoking, the researchers carried out a time trend analysis, using publicly available data up to and including 2017.

They first drew on nationally representative surveys on vaping and tobacco use for 15-25 year olds, as this is the age group most likely to start and/or progress to regular smoking.

They then looked at smoking patterns among teens and young adults, going back as far as 2004, to gauge smoking trends before e-cigarette use became popular.

They used responses to five different national surveys. Where information was available, they included any cigarette use during the preceding 30 days as well as established use–defined as daily/half a pack a day/100 cigarettes smoked to date and currently smoking some days.

The responses revealed that vaping prevalence was low between 2011 and 2013, but reached much higher levels by 2014, so this was identified as the tipping point when vaping became popular among teens and young adults.

The choice of this date is backed up by retail sales data, which recorded a more than doubling in sales in 2014, and by the percentage of adults switching from cigarettes to e-cigarettes, which also doubled between 2012-13 and 2013-14.

The analysis showed that the downward trend in smoking prevalence among young people in the US sped up after 2013, just as vaping was becoming more widespread, and that this was particularly evident among 18-21 year olds.

The analysis also showed that the decline in more established smoking sped up sharply when vaping prevalence increased. And the proportion of those who said they had smoked within the past 30 days, which had fallen slowly throughout 2012, fell more steeply (two to four times) once vaping became popular.

The findings were consistent across different surveys, suggesting that the results were reliable despite different methods of data collection, and after correcting for data input anomalies.

The researchers suggest that the increase in smoking prevalence in tandem with vaping prevalence, found by other researchers, may nevertheless be consistent with their findings.

"It is possible that trying e-cigarettes is causally related to smoking for some youth, but the aggregate effect of this relationship at the population level may be small enough that its effects are swamped by other factors that influence smoking behaviour," they suggest.

These factors could include media campaigns and tobacco control policies: further research would be needed to distinguish between their potential role and the rise in popularity of vaping, they add.

This is an observational study, and as such, can't establish cause. And as the analyses were all done using US data, the findings may not be applicable elsewhere, caution the researchers.

"While caution is warranted in interpreting our findings, they paint a consistent picture of accelerated reductions in youth and young adult smoking prevalence as vaping became more widespread," they write.

And referring to the National Academies report, they add: "In our view, it is premature to conclude that the observed increased rate of decline in smoking is due to vaping diverting youth from smoking, although it is a plausible explanation."

They conclude: "If our primary concern is population level trends in youth and young adult smoking, which we believe is appropriate, then vaping has not shown to be a serious cause for concern….and may be playing a contributing role to the recent steep declines in youth and young adult smoking."