Examination of the association between state tobacco control spending and the demand for electronic cigarettes by high school students

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ABSTRACT

Background While much is known about the influence of tobacco control spending on the demand for conventional cigarettes, little is known about the effects of tobacco control spending on the demand for electronic cigarettes (e-cigarettes). This study provides the first evidence on the association between state tobacco control spending and high school student vaping in the USA.

Methods We used data from the 2015 through 2019 National Youth Risk Behavior Surveys to estimate vaping prevalence and vaping intensity demand equations. We employed logistic regressions to estimate the vaping prevalence equations and generalised linear models with log-link and gamma distribution to estimate the vaping intensity equations.

Results We found evidence that funding for state tobacco control programmes had a significant negative association with both vaping prevalence and vaping intensity among high school students in the USA. Our results indicate that a 50% increase in state spending on tobacco control during the time of the surveys would have been associated with a 7.46% lower high school student vaping prevalence rate than what was observed.

Conclusions There has been a dramatic increase in e-cigarette use by adolescents and young adults in the USA. The rapid rise in e-cigarette use has been a significant source of public policy concern for many states. The results of this study strongly suggest that increased spending on tobacco control programmes will reduce the number of high school students who vape and will decrease the number of days vaping products are used by high school students. These findings should be extremely valuable to policymakers interested in curbing the youth vaping epidemic in the USA.

INTRODUCTION

Over the past two decades, significant progress has been made in reducing cigarette smoking among adolescents in the USA. According to the Monitoring the Future Study, the prevalence of smoking by 12th grade students decreased from 36.5% in 1997 to 7.5% in 2020 and the prevalence of smoking among 8th graders decreased from 19.4% in 1997 to 2.2% in 2020.[1]

In 2007, electronic cigarettes (e-cigarettes) entered the US marketplace. Many adolescents began using e-cigarettes and prevalence rates significantly escalated. By 2014, e-cigarettes overtook cigarettes as the most commonly used tobacco product by youth in the USA.[2] From 2011 to 2019, current e-cigarette use by high school students increased 1733%, from 1.5% to 27.5%.[3 4] Moreover, from 2011 to 2019, current e-cigarette use by middle school students increased 1650%, from 0.6% to 10.5%.[3 4]

Early release data from the Centers for Disease Control and Prevention (CDC) suggest that the rate of e-cigarette smoking by high school students has dropped in 2020 to 19.6% and by middle school students has dropped to 4.7%.[5] Some of the recent drop in e-cigarette smoking is likely due to an outbreak of hospitalisations and deaths due to cases of e-cigarette, or vaping, product use-associated lung injury (EVALI). Between 31 March 2019 and 9 February 2020, a total of 2807 hospitalised EVALI cases or deaths had been reported to CDC (EVALI will not confound the estimates from this research as the 2019 Youth Risk Behavior Survey (YRBS) was completed during Spring 2019 and the outbreak in EVALI hospitalisations began in earnest in June 2019, after the YRBS data were already collected).[6] Some of the recent drop in e-cigarette smoking by high school students is also likely due to states prohibiting the sale of flavoured e-cigarettes. Between November 2019 and May 2020, four states (Massachusetts, New Jersey, New York and Rhode Island) permanently banned the sale of flavoured e-cigarettes. Moreover, in 2019, five additional states (Michigan, Montana, Oregon, Utah and Washington) issued emergency rules to temporarily ban the sale of flavoured cigarettes (state-flavour bans will not confound the estimates from this research as all the permanent and temporary bans were enacted after the 2019 YRBS data were already collected).

The dramatic increase in e-cigarette use rates by adolescents is troubling since e-cigarettes have been found to be a strong predictor of future combustible tobacco product use. The National Academies of Science Engineering and Medicine found 'substantial evidence that e-cigarette use increases the risk of ever using combustible tobacco cigarettes among youth and young adults'.[7]

The rise in e-cigarette use by youth is equally disconcerting given the health consequences associated with their use. According to the Surgeon General: 'E-cigarette use poses a significant—and avoidable—health risk to young people in the United States. Besides increasing the possibility of addiction and long-term harm to brain development and respiratory health, e-cigarette use is associated with the use of other tobacco products that can do even more damage to the body. Even breathing e-cigarette aerosol that someone else has exhaled poses potential health risks.'[8]

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The rapid rise in e-cigarette use among adolescents in conjunction with the health risks of use and the increased likelihood of transitioning to smoking combustible products later in life has been a significant source of public policy concern for many states. Over the past three decades, states and the federal government have funded a variety of programmes and policies in an effort to prevent initiation and promote cessation of combustible tobacco products. Following the rapid rise in e-cigarette use by youth, the federal government and numerous states have funded efforts to prevent e-cigarette use by youth and young adults as part of their tobacco control efforts. Tobacco control funds are typically used for health communication interventions, cessation interventions, state and community interventions, surveillance and evaluation, and administration and management. In fiscal year (FY) 2021, all 50 states and District of Columbia (DC) appropriated $656 million for established and emerging tobacco product prevention and cessation programmes.[9] These appropriations are significantly less than the combined total of $3.3 billion CDC recommends states spend to maintain comprehensive tobacco control programmes.[10] In FY 2021, no state reached the CDC recommended spending level and the average state-level tobacco control funding corresponds to just 19.9% of the CDC recommendations.

Numerous state-specific reports and several review studies have provided convincing evidence that state tobacco control programmes reduce conventional cigarette use.[11–21] Moreover, several nationally representative studies have found tobacco control spending at the state level to have a significant negative impact on conventional cigarette smoking. These nationally representative studies have observed state-level tobacco control spending to be inversely related to cigarette sales,[22–24] adult cigarette smoking prevalence,[25] and youth cigarette smoking prevalence and intensity.[26]

While much is known about the impact of tobacco control spending on conventional cigarette smoking, no published studies to date have examined the association between state tobacco control spending and e-cigarette use. This is an important omission from the literature given e-cigarettes are now the leading tobacco product used by youth in the USA. This paper provides the first evidence of the relationship between state-funded tobacco control efforts and youth e-cigarette use.

MATERIALS AND METHODS

Data

The data employed in this study are extracted from the National 2015–2019 YRBS conducted by the CDC (the 2019 wave of the YRBS is the latest wave currently available). The YRBS are conducted during spring semesters and provide data representative of 9th through 12th grade students in public and private schools in the USA. The YRBS monitor health behaviours that contribute to death, disability, and social problems among youth and young adults in the USA. In 2015, questions regarding high school student use of electronic vaping products were first added to the surveys.

Two dependent variables were created from the surveys: participation in vaping and number of days using vaping products. The first measure was a dichotomous indicator equal to one for respondents who indicated that they had used vaping products on at least 1 day in the past 30 days and equal to zero otherwise. The second dependent variable was a quasi-continuous measure of the number of days vapers used vaping products during the past 30 days. This variable is based on the midpoints of the categorical responses. The values and categorical responses (in parentheses) follow: 1.5 (1–2 days), 4 (3–5 days), 7.5 (6–9 days), 14.5 (10–19 days), 24.5 (20–29 days) and 30 (all 30 days).

Based on the survey data, a number of independent variables were constructed to control for factors thought likely to affect youth and young adult vaping. These factors included: the age of the respondent in years; gender (male and female—reference category); indicators of race/ethnicity (non-Hispanic black, non-Hispanic American Indian or Alaskan Native, non-Hispanic Asian, non-Hispanic native Hawaiian or Pacific Islander, non-Hispanic multiple races, Hispanic and non-Hispanic white—reference category); and indicators of grade level (grade 10, grade 11, grade 12 and grade 9—reference category).

We also created dichotomous indicators for each state in the survey and each year of the survey. The dichotomous state indicators capture all time-invariant state-level unobserved heterogeneity and the year indicators account for the overall trend in vaping over time. We employed a two-way fixed-effects regression technique in all the analyses. The fixed-effects approach amounts to including a dichotomous indicator for each state (less one) and each year (less one) as explanatory variables in the models.

Annual state-specific, inflation-adjusted, per-capita tobacco control expenditures were merged with the survey data using geo-identifiers. The tobacco control expenditure data are based on the American Lung Association's annual State of Tobacco Control report which included spending for each state from the following sources: tobacco excise tax revenues earmarked for tobacco control, Master Settlement Agreement and individual state settlements with the tobacco industry earmarked for tobacco control, other state funds specifically earmarked for tobacco control purposes and federal funding to states earmarked for tobacco control.[27] State-level per-capita tobacco control expenditures were created using total state population estimates from the US Census Bureau and were adjusted for inflation using the US Bureau of Labor Statistics Consumer Price Index.

Using state identifiers, we merged a dichotomous indicator equal to one if the student resided in a state that imposed a tax on vapour products at the time the student was surveyed, and was equal to zero otherwise. A dichotomous indicator was used for this tax rather than a tax rate given the variation in how vaping taxes are imposed by states. Unlike cigarettes, which are taxed by all states at a uniform rate per pack of cigarettes (ie, a specific excise tax), the taxing strategies of states are quite different from one another as it pertains to vaping products. Some states use an ad valorem tax (ie, a tax based on the value of the product) to tax vaping products, whereas other states use a specific excise tax to tax vaping products, and yet other states apply a two-tier tax that employs both an ad valorem and a specific component. Moreover, states that use an ad valorem tax differ in what constitutes a taxable vapour product. Finally, states that use a specific excise tax on vapour products differ on what constitutes a consumable product, with some states requiring the vapour liquid to contain nicotine and others not.

Using state-geocode data, we also merged a dichotomous indicator equal to one for states that banned vaping in private worksites at the time the student was surveyed, and was equal to zero for states that did not impose a vaping ban in private worksites. The vaping ban data were acquired from the CDC's State Tobacco Activities Tracking and Evaluation System.

Lastly, using data from the CDC's State Tobacco Activities Tracking and Evaluation System, we constructed a dichotomous indicator equal to one for states that imposed a minimum legal purchase age of 18 years or greater for vaping products, and was equal to zero otherwise.

Empirical methods

The cumulative distribution of vaping is a mixed distribution, one that is neither discrete nor continuous, but contains both discrete and continuous elements. In particular, there exists a large mass of zero outcomes corresponding to individuals who do not vape. There also exists a continuous distribution of the number of days vaped among current vapers. We used a modified two-part model of demand in which vaping prevalence and vaping intensity were estimated separately. In the first step, we used logistic regression to estimate a vaping prevalence equation. In the second step, we used a generalised linear model with log-link and gamma distribution to model the number of days vaped in the previous 30 days among current vapers.

A two-way fixed-effects approach is used to estimate the relationship between tobacco control spending and high school student vaping prevalence and intensity. The two-way fixed-effects regression technique controls for time-invariant unobserved state-level heterogeneity (through the use of dichotomous state indicators) and changes in the distribution of vaping by high school students over time (through the use of dichotomous year indicators). Controlling for unobserved state-level heterogeneity is critical in attempting to estimate a causal effect of state spending on tobacco control as state sentiment toward vaping may be simultaneously driving both changes in vaping behaviour by adolescents and changes in tobacco control spending and vaping policy enactment. The two-way fixed-effects approach is particularly appropriate for this research given that it is impractical to randomise persons to locations with different levels of tobacco control spending and vaping policies before they are adopted. Finally, we accounted for the complex sampling design of the national YRBS in all the regressions in order to obtain appropriate population estimates and SEs.

Estimates from the vaping prevalence and intensity equations are presented in table 1. We estimated two separate models for each of the dependent variables. The first model for each dependent variable contained estimates from a specification that includes real per-capita tobacco control expenditures, age, gender, grade in school, race and ethnicity, year fixed-effects and state fixed-effects. Model 2 is identical to model 1, but it adds additional vaping control measures. In particular, model 2 for each dependent variable adds: an indicator for whether or not the state bans vaping in private worksites at the time of the survey;

Table 1 Vaping prevalence and intensity equations among high school students

	Vaping prevalence equations		Vaping intensity equations	
Independent variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Tobacco control expenditure	0.895*** (0.838 to 0.955)	0.913** (0.839 to 0.994)	0.946*** (0.914 to 0.978)	0.909*** (0.862 to 0.959)
Vaping ban workplace		0.848 (0.630 to 1.140)		1.134 (0.942 to 1.366)
E-cigarette tax		1.052 (0.781 to 1.417)		1.107 (0.841 to 1.457)
E-cigarette MLPA		1.226 (0.830 to 1.813)		0.876 (0.680 to 1.129)
Age	1.121*** (1.045 to 1.202)	1.120*** (1.044 to 1.202)	1.029 (0.977 to 1.084)	1.029 (0.977 to 1.085)
Male	1.128*** (1.037 to 1.226)	1.128*** (1.037 to 1.227)	1.293*** (1.204 to 1.388)	1.291*** (1.203 to 1.386)
10th grade	1.148* (0.998 to 1.321)	1.151** (1.000 to 1.324)	1.035 (0.938 to 1.143)	1.037 (0.938 to 1.145)
11th grade	1.245** (1.033 to 1.501)	1.249** (1.036 to 1.506)	1.057 (0.921 to 1.212)	1.059 (0.921 to 1.217)
12th grade	1.364** (1.074 to 1.732)	1.370** (1.078 to 1.740)	1.088 (0.912 to 1.298)	1.086 (0.908 to 1.300)
Black	0.501*** (0.431 to 0.583)	0.503*** (0.431 to 0.587)	0.822*** (0.711 to 0.951)	0.825** (0.708 to 0.962)
American Indian/Alaskan Native	1.497** (1.060 to 2.114)	1.494** (1.058 to 2.111)	1.126 (0.918 to 1.380)	1.127 (0.920 to 1.381)
Hispanic	0.708*** (0.619 to 0.811)	0.711*** (0.622 to 0.813)	0.728*** (0.638 to 0.830)	0.723*** (0.633 to 0.825)
Asian	0.334*** (0.262 to 0.425)	0.333*** (0.261 to 0.425)	1.088 (0.853 to 1.389)	1.084 (0.851 to 1.381)
Native Hawaiian/Pacific Islander	0.823 (0.547 to 1.238)	0.831 (0.552 to 1.250)	1.164 (0.820 to 1.653)	1.174 (0.832 to 1.656)
Multiple race	0.876** (0.790 to 0.971)	0.880** (0.791 to 0.979)	0.932* (0.857 to 1.013)	0.931* (0.855 to 1.013)
2017	0.404*** (0.338 to 0.484)	0.401*** (0.313 to 0.513)	1.339*** (1.189 to 1.508)	1.318*** (1.161 to 1.497)
2019	1.491*** (1.255 to 1.770)	1.477*** (1.173 to 1.860)	1.771*** (1.600 to 1.960)	1.737*** (1.551 to 1.947)
Observations	39233	39233	9228	9228

All equations include an intercept and dichotomous indicators for each state in the sample minus one. For the vaping prevalence equations, ORs and 95% CIs (in brackets) are presented. For the vaping intensity equations, exponentiated coefficients and 95% CIs (in brackets) are presented.
*P<0.1, **p<0.05, ***p<0.01.
e-cigarette, electronic cigarette; MLPA, minimum legal purchase age.

an indicator for whether or not the state imposes a minimum legal purchase age of 18+ years for vaping products; and an indicator for whether or not the state imposes a tax on vaping products. Including only the real per-capita tobacco control expenditures in model 1 is designed to eliminate the possibility of collinearity resulting from the inclusion of a group of potentially highly correlated measures of vaping control policy. The potential correlation stems from the fact that when states implement or enhance tobacco control programmes, they often enact several new tobacco control initiatives simultaneously. Omitting measures of vaping control in model 1, however, may lead to biased estimates of the effects of real per-capita tobacco control expenditures on high school vaping—an omitted variables bias. The bias would occur if the vaping bans, taxes or minimum legal purchase age laws are determinants of the youth vaping and correlated with the included tobacco control spending variable. Fortunately, the inclusion and exclusion of other vaping control variables from our models had very little effect on the magnitude and significance of our findings with respect to the effect of tobacco control expenditures on vaping among high school students. This implies that parameter estimates in model 1 for both dependent variables do not suffer from an omitted variables bias.

RESULTS

We found inflation-adjusted tobacco control expenditures per capita to have a negative and statistically significant association with vaping prevalence and the number of days youth vape in every model that was estimated. These estimates imply that increasing tobacco control spending per capita is significantly associated with decreases in youth vaping prevalence and decreases in the number of days vaping among high schoolers who choose to use vaping products.

Because the relationship between the linear predictors and the mean of the distribution functions for both the logistic and generalised linear models is non-linear, we used the estimates from the regressions to conduct simulations to predict vaping prevalence rates and days vaped using alternate assumptions about the level of real per-capita tobacco control programme spending. Specifically, our simulation entails substituting a hypothetical value for the real per-capita tobacco control programme spending into the equations implied by the regression coefficients while holding all other covariates at their actual values. Table 2 presents predicted probabilities of vaping prevalence if each state would have increased its funding for tobacco control by 25%, 50%, 75% and 100% in years 2015–2019, holding all other covariates at their actual values. Table 2 also provides the predicted number of days vapers would have used vaping products if each state would have increased its funding for tobacco control by 25%, 50%, 75% and 100% in years 2015–2019, holding all other independent variables at their actual values.

Holding all covariates, including tobacco control expenditures, at their actual values, the predicted prevalence rates of vaping in models 1 and 2 are 23.29% and 23.25%, respectively. If states would have spent more on tobacco control during each year of the survey, the estimates imply that vaping prevalence among high school students would have been significantly lower than what was observed. For example, using the average effects across models 1 and 2, if states would have spent 25% more on tobacco control efforts, the estimates indicate that high school vaping prevalence would have been 0.885 percentage points lower than what was observed. Likewise, had states spent 50%, 75% and 100% more on tobacco control efforts, the estimates indicate that high school vaping prevalence would have been 1.74, 2.55 and 3.34 percentage points lower than what was observed.

Holding all covariates, including tobacco control expenditures, at their actual values, the predicted number of days vaped by high school vapers in models 1 and 2 are 10.12 days and 10.13 days, respectively. If states would have spent more on tobacco control during each year of the survey, the estimates imply that the number of days vaping among high school vapers would have been significantly lower than what was observed. For example, using the average effects across models 1 and 2, if states would have spent 25% more on tobacco control efforts, the estimates imply that the number of days vaped by high schoolers would have declined by 0.395 days. Likewise, had states spent 50%, 75% and 100% more on tobacco control efforts, the estimates imply that the number of days vaping by high school vapers would have declined by 0.77, 1.12 and 1.45 days, respectively, compared with what was actually observed.

We found bans on vaping in private worksites, minimum age requirements to purchase vaping products, and the existence of state vaping taxes to have a statistically insignificant effect on the prevalence of vaping and the number of days vaped by high school vapers.

CONCLUSIONS

Coinciding with the rapid rise in e-cigarette use by youth in the USA, the federal government and numerous states have funded efforts to prevent e-cigarette use by youth and young adults as part of their tobacco control efforts. The funds used for the prevention of e-cigarette use by youth are included in our measure of real per-capita tobacco control spending. The findings from this study provide the first evidence that state tobacco control spending is associated with reduced vaping among youth in the USA. The findings from this study should be very helpful for policymakers debating how states should allocate scarce public resources. If policymakers want to curb the vaping epidemic among youth, the findings from this study suggest that additional appropriations for tobacco control efforts will be needed.

Table 2 Predicted vaping prevalence and intensity based on alternative values for tobacco control spending

	Prevalence (per cent vaping)		Intensity (days vaped)	
	Model 1	Model 2	Model 1	Model 2
Average predicted vaping	23.29	23.25	10.12	10.13
Predicted vaping if states increase tobacco control spending by 25%	22.31	22.46	9.83	9.63
Predicted vaping if states increase tobacco control spending by 50%	21.38	21.69	9.54	9.17
Predicted vaping if states increase tobacco control spending by 75%	20.49	20.95	9.27	8.74
Predicted vaping if states double their tobacco control spending	19.64	20.23	9.01	8.34

Since 1999, the CDC has published its Best Practices for Comprehensive Tobacco Control Programs Report that provides advice to states on key components of comprehensive tobacco control programmes. The Best Practice Reports also include recommendations for funding these state programmes. Its most recent release recommends that states spend a total of $3.3 billion on comprehensive tobacco control programmes—a funding level that is ample to reduce tobacco use.[10] In FY 2021, all 50 states and DC combined appropriated $656 million for tobacco control purposes,[9] which is equivalent to approximately 19.9% of the CDC recommended level of funding. Results from this study indicate that a 50% increase in state spending on tobacco control during the time of the surveys would have been associated with a 7.46% (or 1.74 percentage points) lower high school student vaping prevalence rate than what was observed.

The finding of an inverse relationship between tobacco control spending and youth vaping is consistent with a study by Levy *et al* that found e-cigarette use among adult smokers was less in states with high levels of tobacco control spending.[28] The finding of an inverse relationship between tobacco control spending and youth vaping is also consistent with the findings from earlier studies on the effects of state tobacco control spending on the demand for combustible tobacco products. For example, Tauras *et al* found a strong inverse relationship between state tobacco control spending and youth cigarette smoking prevalence and intensity.[26] Other studies have focused on the effects of state tobacco control spending on adult cigarette consumption and tax paid cigarette sales. These studies have also concluded that higher tobacco control spending reduces adult cigarette smoking and tax paid cigarette sales.[23–25] Finally, our finding of an insignificant association between vape-free air laws and vaping taxes on youth vaping is consistent with insignificant vape-free air and tax results found by Levy *et al* on adult vaping.[28]

Our study has several limitations. First, no information is available on the types of interventions each state tobacco control programme used and the percentage of total funding that was spent on each type of intervention. Second, despite our statistical efforts to get at a causal effect of tobacco control spending on youth vaping, our study used cross-sectional data and causality cannot be established with certainty when using cross-sectional data. Third, we did not examine the economic relationship between e-cigarette and cigarette use among high school students. Comprehensive data on state-level prices of vaping products are not available and therefore we did not include cigarette prices in the regressions. It is possible that the omission of cigarette prices from our equations may result in a slight underestimate of the effects of tobacco control spending on vaping. The possible underestimate stems from the fact that increases in cigarette taxes may result in both increases in state tobacco control spending and increases in e-cigarette use. Indeed, increases in cigarette taxes result in increases in cigarette prices. Many state tobacco control programmes are funded from revenues generated by cigarette taxes, so there is likely to be a positive correlation between cigarette prices and state spending on tobacco control. Moreover, an increase in cigarette prices is likely to increase the use of e-cigarettes because e-cigarettes are a substitute form of nicotine.

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What this paper adds

- ► While much is known about the influence of tobacco control spending on the demand for conventional cigarettes, little is known about the effects of tobacco control spending on the demand for electronic cigarettes.
- ► This is the first paper to examine the association between state tobacco control spending and high school student vaping in the USA.
- ► We found evidence that funding for state tobacco control programmes had a significant negative relationship with both vaping prevalence and vaping intensity among high school students in the USA.
- ► By allocating more money for tobacco control purposes, states have the ability to reduce the number of high school students who vape and decrease the number of days high school students use vaping products.

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