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# Investigating the Impact of E-Cigarette Price and Tax on E-Cigarette Use Behavior

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**Introduction:** Although the relationship between tax and price and youth cigarette use is well established, little is known about these associations and youth e-cigarette use. This research examines U.S. youth sensitivity to changes in e-cigarette prices and tax using standardized measures of e-cigarette taxes and prices.

**Methods:** This analysis uses national data on past 30-day use and the number of days using e-cigarettes (i.e., the intensity of use) from the repeat cross-sectional 2015−2019 Youth Risk Behavior Survey, in combination with inflation-adjusted standardized e-cigarette price and tax data to understand whether changes in e-cigarette price and tax were associated with changes in e-cigarette use. Two-part demand regression models controlling for demographics and e-cigarette restriction policies were conducted to calculate price and tax elasticities of demand, in addition to $0.50 and $1.00 price and tax increase simulations.

**Results:** Increased e-cigarette prices and taxes were associated with significant reductions in past 30-day use. Prices were also significantly associated with decreases in the intensity of use. A $0.50 and $1.00 tax increase leads to a 6.3% and 12.2% decrease in past 30-day use and a 4.7% and 9.3% decrease in intensity, respectively. A $0.50 and $1.00 price increase leads to a 4.1% and 8.2% decrease in past 30-day use and a 4.2% and 8.3% decrease in intensity, respectively.

**Conclusions:** Higher prices and taxes reduce youth current e-cigarette use and days using e-cigarettes. Policies increasing e-cigarette prices, such as excise taxes, can reduce youth current e-cigarette use and days using e-cigarettes.
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## INTRODUCTION

Since the introduction of e-cigarettes in the early 2000s, the United States (U.S.) market has expanded dramatically, from the rise of pod-based e-cigarettes such as JUUL in 2018[1] to the expansion of disposable products in 2020.[2] E-cigarette use among high-school students rose from 1.5% in 2011 to 19.6% in 2020,[3] decreasing to 11.3% in 2021.[4] Today, e-cigarettes remain the most popular tobacco product among U.S. youth,[5] calling for research on effective ways to deter youth e-cigarette use, including raising e-cigarette prices.

Importantly, if young e-cigarette users are sensitive to changes in price, raising the price of e-cigarettes can deter product use.[6] For cigarettes, there is a large body of empirical evidence showing that excise tax−induced price increases are highly effective in deterring cigarette initiation and promoting cessation among young people.[7,8] However, there is limited and conflicting empirical evidence on the impact of prices and taxation

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on e-cigarette use among young people[1]. The most comprehensive working paper on this topic finds that e-cigarette demand is highly sensitive to changes in prices, finding an own-price elasticity of about −1.32.[9] However, price elasticity of demand estimates were not separated between adults and youth. Another 2 studies found that increasing the price of e-cigarette cartridges reduces youth use[10] and that youth are sensitive to changes in e-cigarette price,[11] whereas another found no relationship between e-cigarette price and product use.[12] Choi et al.[13] and Anderson et al.[14] used limited Youth Risk Behavior Surveillance System data to find that e-cigarette taxes reduce use, although they did not capture the magnitude of e-cigarette taxes. Finally, a paper by Abouk et al.[15] using Monitoring the Future data for 2014−2019 and the standardized e-cigarette tax rates as calculated by Cotti et al.[16] found own-price elasticities of demand of −0.38 to −1.31, implying a wide range of price sensitivity.

It is crucial to examine both tax and price in analysis because, depending on demand, not all increases in excise taxes are passed to the consumer as higher prices. For cigarettes, in high-income countries, overshifting is prevalent, where an increase in taxes leads to larger increases in prices.[8] However, the industry often temporarily reduces prices by offering price promotions and lowering manufacturing costs to undershift the effect of a tax increase.[17] This behavior causes variability in how much increasing excise taxes will increase the price of a product. For e-cigarettes, limited empirical evidence has shown that tax increases are both overshifted and undershifted to the consumer, creating a variable tax−price structure.[16,18] Similar to cigarettes, there is variation in the price of these products across retail markets regardless of whether or not e-cigarettes are subject to an excise tax, suggesting the need to examine the impact of both taxation and price when testing for price sensitivity.

As of June 2022, only 30 U.S. states and the District of Columbia have enacted e-cigarette taxes.[19] States that tax e-cigarettes use a range of taxation structures, and the definitions of what constitutes a taxable product vary,[20] causing variation in prices and differential impacts on consumer choices that have not been fully investigated among youth.

Given that e-cigarettes are now the most popularly used tobacco product among youth, examining the effect of prices and taxes on e-cigarette use could be key in preventing initiation and reducing sustained use. This research examines e-cigarette price and tax sensitivity among youth at the population level with an improved methodology standardizing average prices and taxes. Unlike cigarettes, where average prices and taxes can be easily compared across brands, products, and locations, e-cigarettes lack a unifying characteristic to compare average prices and taxes. To address these challenges, a novel measure of standardized price of e-cigarettes by volume of e-liquid sold and a novel standardized state e-cigarette tax rate were created. This study uses 2015−2019 national Youth Risk Behavior Survey (YRBS) data to model the effect of these standardized prices and taxes on past 30-day and intensity of e-cigarette use, simulate price and tax increases, and estimate price and tax elasticity of demand.

[1]The literature review excludes Friedman and Pesko because they analyze young adults aged 18−25 instead of youth in high school.

## METHODS

### Study Sample

For this study, data from the state-level 2015−2019 YRBS, a national school-based survey of 9th−12th-grade students in public and private schools conducted every spring by the Centers for Disease Control and Prevention (CDC) were used. In 2015, questions were added to assess the use of e-cigarettes. The sample characteristics of the publicly available 2015, 2017, and 2019 waves of the YRBS survey are described elsewhere.[21−23] CDC provided state identifiers for participants upon request.

### Measures

Two dependent variables from the YRBS were created. The first captured past 30-day use of e-cigarettes and was a dichotomous indicator equal to 1 for respondents who used e-cigarettes at least 1 day in the past 30 days and was equal to zero, otherwise. The second captured current e-cigarette use intensity, a quasi-continuous measure of the number of days participants used e-cigarettes during the past 30 days on the basis of the midpoints of the categorical responses to the question, *During the past 30 days, on how many days did you use an electronic vapor product?* as follows: 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).

Using other items from the survey, several independent variables believed to affect e-cigarette use among 9th−12th-grade students were constructed. These variables include sex (male and female [reference]), age, grade level (Grades 10, 11, 12, and 9 [reference]), and indicators for race and 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]).

Real state-level sales-weighted average price of 1 mL of e-liquid for the first 6 months of each year was merged with YRBS data. This variable was created using NielsenIQ Retail Scanner Sales data. NielsenIQ captures universal product code data from participating independent, chain, and gas-station convenience stores; food, drug, and mass merchandizers; discount and dollar stores; and military commissaries from 23 U.S. states that are commercially available: Alabama, Arizona, California, Colorado, Florida, Georgia, Illinois, Indiana, Louisiana, Kentucky, Massachusetts, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Virginia, and Washington. These states account for 78% of the population as of 2019 and approximately 79% of all e-cigarette sales dollars tracked by NielsenIQ. Any missing data from the remaining states were dropped. The sales-weighted average price per 1 mL of e-liquid was calculated by first identifying milliliters of e-liquid for each of the unique universal product codes in the data set. The analysis focused exclusively on products that contain e-liquid and excluded hardware, batteries, and starter kits with no e-liquid (6.5% of the data). The data were supplemented through online searches on e-liquid milliliters, finding information for 94% of all barcodes. To calculate the sales-weighted average price of 1 mL of e-liquid, total sales dollars were summed at the state level and averaged over the first 6 months to coincide with the timing of the survey and then divided by total milliliters sold and adjusted for inflation to January 2020 dollars using the U.S. Bureau of Labor Statistics Consumer Price Index. Price is inclusive of all taxes levied, with the exception of sales taxes.

Standardized state-level e-cigarette tax data were merged using publicly available e-cigarette tax data from Cotti et al.,[24] who used Nielsen retail scanner data and e-cigarette product characteristics to develop a method to standardize e-cigarette taxes as an equivalent average excise tax rate measured per milliliter of e-liquid fluid. This variable measures both the magnitude and structure of the various e-cigarette taxes across states. From CDC's State Tobacco Activities Tracking and Evaluation System, state-level policies on e-cigarette bans in private work sites and minimum legal purchase age laws for e-cigarettes were merged, creating dichotomous indicators of 1 for students living in U.S. states with these policies in place and zero for those living in states without such policies.

### Statistical Analysis

A 2-part demand model developed by Cragg was used.[25] First, a 2-way fixed-effects logit regression to estimate the effect of e-cigarette taxes or e-cigarette prices, private worksite bans, and minimum legal age requirements on past 30-day use of e-cigarettes was used ($n$=39,233). Second, a 2-way fixed-effects generalized linear model with log-link and gamma distribution to estimate the effects of the same covariates on e-cigarette use intensity was used ($n$=9,228). This 2-way fixed-effects approach used state-fixed effects to control for time-invariant unobserved state-level factors and year-fixed effects to control for changes in the distribution of e-cigarette use by high-school students over time. All models used robust standard errors clustered on the interaction of the primary sampling unit and year.

Table 1 contains estimates from past 30-day e-cigarette use equations, and Table 2 contains estimates from e-cigarette use intensity equations. Six models were estimated for each dependent variable. The first model included real standardized e-cigarette taxes, age, sex, grade level, race/ethnicity, year-fixed effects, and state-fixed effects. Model 2 was identical to Model 1 but included private worksite e-cigarette bans. Model 3 was identical to Model 2 but included the minimum legal purchase age of 18 years. Models 4−6 were identical to Models 1−3 but replaced the real standardized tax with the real price of 1 mL of e-liquid. Including only tax or price in Models 1 and 4 and no other e-cigarette restriction policies reduces collinearity from potentially correlated measures. When states enact policies on e-cigarettes, they often enact several initiatives simultaneously. This can also be true of states with anti−e-cigarette sentiment, where the statuses of policies are correlated to certain points in time. However, omitting e-cigarette policies in Model 1 may lead to biased estimates of the effects of taxes or prices on high school e-cigarette use.

Because the analytical methods were nonlinear, the estimated parameters do not provide effect magnitude. Therefore, tax and price elasticities of demand—a measure of price sensitivity—are in Table 3. Table 4 uses the estimates from the 2-part demand models to simulate past 30-day e-cigarette use and intensity rates under alternative assumptions where both tax and prices were to increase by $0.50 and $1.00 per milliliter of e-liquid.

Notably, traditional cigarette taxes are not included as determinants of e-cigarette demand in the models. In diagnosis models (not shown), the inclusion of traditional cigarette taxes, state-fixed effects,and year-fixed effects explained 94% of all within-state variation in e-cigarette taxes. Moreover, e-cigarette taxes, state-fixed effects, and year-fixed effects were regressed on state and federal traditional cigarette taxes (not shown). Variation in traditional cigarette taxes was fully explained (98%) by e-cigarette taxes, state-fixed effects, and year-fixed effects, indicating that there was not enough independent variation in traditional cigarette taxes after controlling for e-cigarette taxes. Finally, we regressed models (not shown) with no state-fixed effects, which yielded negative and significant effects of e-cigarette taxes on e-cigarette prevalence but insignificant effects of traditional cigarette taxes. These diagnosis models confirmed that the exclusion of traditional cigarette tax results in more robust models.

## RESULTS

Approximately 23% of the sample used e-cigarettes and on average vaped about 10 days of the past 30 days. Summary statistics are available in Appendix Table 1 (available online).

The 2-part demand model finds that inflation-adjusted standardized e-cigarette taxes were associated with statistically significant reductions in past 30-day use (Table 1). Model 3, the most conservative estimate, was significant at the 10% level ($p<0.10$). Increases in standardized e-cigarette price were associated with statistically significant reductions in past 30-day use in all models (Table 1). Both e-cigarette taxes and prices were associated with decreased intensity of use, but only e-cigarette prices were statistically significant ($p<0.05$) (Table 2).

Model results also show that high-school students living in U.S. states with comprehensive worksite e-cigarette bans are less likely to have used an e-cigarette in the past 30 days, and students living in states with minimum legal sales-age restrictions use e-cigarettes on fewer days. Other statistically significant findings indicate that age is positively related to 30-day use; males have a higher prevalence than females; sophomore, juniors, and seniors have a higher prevalence than freshmen; and Black, Hispanic, Asian, and multiracial students have a lower prevalence than White students;

however, American Indian and Alaska Natives have a higher prevalence. Males use e-cigarettes on more days than females, and Black, Hispanic, and multiracial students use e-cigarettes on fewer days than White students.

All simulations modeling $0.50 and $1.00 increases in e-cigarette taxes and prices predicted a decrease in both 30-day use and intensity of use (Table 4). The most conservative results from Model 3 find that a $0.50 and $1.00 tax increase leads to a 6.3% and 12.2% decrease in past 30-day use and a 4.7% and 9.3% decrease in the number of days using e-cigarettes, respectively. Similarly, the most conservative results show that a $0.50 and $1.00 price increase leads to a 4.1% and 8.2% decrease in past 30-day e-cigarette use and a 4.2% and 8.3% decrease in the number of days using e-cigarettes, respectively.

A 10% increase in the price of 1 mL of e-liquid decreases past 30-day e-cigarette use by 4.65%−7.99%, decreases the intensity of use by 3.57%−4.52%, and decreases total e-cigarette demand by 9.17%−11.55% (Table 3). In addition, a 10% increase in the standardized tax rate decreases past 30-day use by 0.28%−0.49%, decreases the intensity of use by 0.07%−0.15%, and

**Table 1.** Logistic Regression Model Predicting Past 30-Day E-Cigarette Use

| Independent variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| E-cigarette tax, per mL of E-liquid | **−0.311*****| **−0.189**** | **−0.178*** | | | |
| | **(−4.29)** | **(−1.96)** | **(−1.89)** | | | |
| E-cigarette price, per mL of E-liquid | | | | **−0.200*** ** | **−0.132**** | **−0.117**** |
| | | | | **(−4.17)** | **(−2.32)** | **(−2.08)** |
| Private workplace E-cigarette ban | | **−0.292**** | **−0.284*** | | **−0.272*** | **−0.247*** |
| | | **(−2.00)** | **(−1.92)** | | **(−1.89)** | **(−1.68)** |
| E-cigarette MLPA | | | 0.0975 | | | 0.247 |
| | | | (0.54) | | | (1.03) |
| Age, years | **0.0982***** | **0.0963***** | **0.0963***** | **0.0895***** | **0.0875***** | **0.0860***** |
| | **(4.28)** | **(4.20)** | **(4.20)** | **(2.89)** | **(2.82)** | **(2.80)** |
| Male | **0.166***** | **0.166***** | **0.166***** | **0.132***** | **0.132***** | **0.132***** |
| | **(4.75)** | **(4.74)** | **(4.74)** | **(3.00)** | **(2.98)** | **(2.99)** |
| Sophomore | **0.134***** | **0.137***** | **0.137***** | 0.0927 | 0.0960 | 0.0973 |
| | **(2.71)** | **(2.77)** | **(2.77)** | (1.48) | (1.53) | (1.54) |
| Junior | **0.175**** | **0.180***** | **0.180***** | 0.146 | 0.152 | 0.155 |
| | **(2.52)** | **(2.59)** | **(2.59)** | (1.51) | (1.57) | (1.59) |
| Senior | **0.282***** | **0.288***** | **0.288***** | **0.300**** | **0.307**** | **0.312**** |
| | **(3.10)** | **(3.17)** | **(3.17)** | **(2.40)** | **(2.45)** | **(2.50)** |
| Black | **−0.836***** | **−0.838***** | **−0.837***** | **−0.856***** | **−0.850***** | **−0.849***** |
| | **(−8.65)** | **(−8.69)** | **(−8.68)** | **(−9.36)** | **(−9.17)** | **(−9.29)** |
| American Indian/Alaska Native | **0.387***** | **0.385***** | **0.385***** | **0.364**** | **0.367***** | **0.366**** |
| | **(3.41)** | **(3.40)** | **(3.39)** | **(2.55)** | **(2.58)** | **(2.56)** |
| Hispanic | **−0.351***** | **−0.355***** | **−0.352***** | **−0.410***** | **−0.410***** | **−0.404***** |
| | **(−5.90)** | **(−5.96)** | **(−5.97)** | **(−7.35)** | **(−7.29)** | **(−7.38)** |
| Asian | **−1.004***** | **−1.007***** | **−1.006***** | **−1.017***** | **−1.015***** | **−1.013***** |
| | **(−8.87)** | **(−8.95)** | **(−8.94)** | **(−8.01)** | **(−8.01)** | **(−8.01)** |
| Native Hawaiian/Pacific Islander | −0.0607 | −0.0514 | −0.0508 | −0.237 | −0.222 | −0.224 |
| | (−0.38) | (−0.32) | (−0.32) | (−1.31) | (−1.22) | (−1.23) |
| Multiracial | **−0.175***** | **−0.174***** | **−0.172***** | **−0.238***** | **−0.234***** | **−0.229***** |
| | **(−3.46)** | **(−3.45)** | **(−3.37)** | **(−5.10)** | **(−4.96)** | **(−4.74)** |
| 2017 | **−0.839***** | **−0.812***** | **−0.832***** | **−0.994***** | **−0.971***** | **−1.026***** |
| | **(−7.06)** | **(−6.86)** | **(−6.25)** | **(−8.62)** | **(−8.46)** | **(−8.61)** |
| 2019 | **0.376***** | **0.401***** | **0.384***** | **0.674***** | **0.626***** | **0.554***** |
| | **(5.33)** | **(5.66)** | **(5.45)** | **(5.22)** | **(4.92)** | **(4.48)** |
| Observations | 39,233 | 39,233 | 39,233 | 26,490 | 26,490 | 26,490 |

*Note:* Boldface indicates statistical significance (*$p$<0.10, **$p$<0.05, and ***$p$<0.01).
All equations include an intercept and dichotomous indicators for each state in the sample minus one. *t*-statistics are presented in paratheses.
MLPA, minimum legal purchase age.

**Table 2.** Generalized Linear Regression Model Predicting Intensity of E-Cigarette Use

| Independent variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| E-cigarette tax, per mL of E-liquid | −0.0450 | −0.0874 | −0.0969 | | | |
| | (−0.93) | (−1.30) | (−1.46) | | | |
| E-cigarette price, per mL of E-liquid | | | | **−0.0682**** | **−0.0759**** | **−0.0863**** |
| | | | | **(−2.28)** | **(−1.97)** | **(−2.34)** |
| Private workplace E-cigarette ban | | 0.0959 | 0.0894 | | 0.0307 | 0.00528 |
| | | (0.97) | (0.90) | | (0.36) | (0.06) |
| E-cigarette MLPA | | | −0.0894 | | | **−0.205*** |
| | | | (−0.81) | | | **(−1.69)** |
| Age, years | 0.0252 | 0.0254 | 0.0254 | 0.0105 | 0.0107 | 0.0114 |
| | (1.40) | (1.41) | (1.42) | (0.42) | (0.43) | (0.46) |
| Male | **0.303***** | **0.303***** | **0.302***** | **0.304***** | **0.305***** | **0.303***** |
| | **(11.09)** | **(11.11)** | **(11.07)** | **(8.95)** | **(8.95)** | **(9.00)** |
| Sophomore | 0.0293 | 0.0291 | 0.0301 | 0.0482 | 0.0480 | 0.0496 |
| | (0.67) | (0.67) | (0.68) | (0.93) | (0.92) | (0.94) |
| Junior | 0.0609 | 0.0596 | 0.0609 | 0.0675 | 0.0666 | 0.0690 |
| | (1.19) | (1.16) | (1.17) | (0.95) | (0.94) | (0.97) |
| Senior | 0.0869 | 0.0851 | 0.0856 | 0.127 | 0.126 | 0.124 |
| | (1.31) | (1.27) | (1.28) | (1.37) | (1.35) | (1.32) |
| Black | **−0.327***** | **−0.330***** | **−0.329***** | **−0.271***** | **−0.273***** | **−0.267***** |
| | **(−4.21)** | **(−4.26)** | **(−4.25)** | **(−3.37)** | **(−3.35)** | **(−3.22)** |
| American Indian/Alaska Native | −0.0424 | −0.0446 | −0.0465 | **−0.209*** | **−0.211*** | **−0.218*** |
| | (−0.45) | (−0.47) | (−0.49) | **(−1.76)** | **(−1.78)** | **(−1.86)** |
| Hispanic | **-0.282***** | **−0.281***** | **−0.285***** | **-−0.265***** | **−0.265***** | **−0.274***** |
| | **(−5.87)** | **(−5.85)** | **(−5.84)** | **(−4.56)** | **(−4.56)** | **(−4.68)** |
| Asian | 0.0174 | 0.0188 | 0.0178 | −0.0868 | −0.0866 | −0.0878 |
| | (0.26) | (0.28) | (0.27) | (−1.14) | (−1.14) | (−1.15) |
| Native Hawaiian/Pacific Islander | 0.173 | 0.171 | 0.170 | 0.232 | 0.231 | 0.225 |
| | (1.26) | (1.25) | (1.24) | (1.47) | (1.46) | (1.44) |
| Multiracial | **−0.116***** | **−0.117***** | **−0.118***** | **−0.135***** | **−0.135***** | **−0.139***** |
| | **(−3.23)** | **(−3.25)** | **(−3.25)** | **(−3.44)** | **(−3.45)** | **(−3.54)** |
| 2017 | **0.176**** | **0.170**** | **0.188**** | **0.371***** | **0.369***** | **0.414***** |
| | **(2.50)** | **(2.47)** | **(2.31)** | **(5.14)** | **(5.15)** | **(5.57)** |
| 2019 | **0.485***** | **0.478***** | **0.493***** | **0.666***** | **0.671***** | **0.728***** |
| | **(8.58)** | **(8.43)** | **(7.45)** | **(8.60)** | **(8.82)** | **(9.22)** |
| Observations | 9,228 | 9,228 | 9,228 | 6,004 | 6,004 | 6,004 |

*Note:* Boldface indicates statistical significance (*$p$<0.10, **$p$<0.05, and ***$p$<0.01).
All equations include an intercept and dichotomous indicators for each state in the sample minus one. $t$-statistics are presented in paratheses.
MLPA, minimum legal purchase age.

**Table 3.** Tax and Price Elasticities of Demand

| Models | E-cigarette prevalence | E-cigarette intensity | Total elasticity of demand |
|---|---|---|---|
| Tax elasticities of demand | | | |
| Model 1 | −0.0497 | −0.0069 | −0.0566 |
| Model 2 | −0.0301 | −0.0135 | −0.0436 |
| Model 3 | −0.0285 | −0.0149 | −0.0434 |
| Price elasticities of demand | | | |
| Model 4 | −0.7986 | −0.3568 | −1.1554 |
| Model 5 | −0.5277 | −0.3974 | −0.9251 |
| Model 6 | −0.4652 | −0.4516 | −0.9168 |

**Table 4.** Simulations of Past 30-Day E-Cigarette Use and Intensity of Use Given $0.50 and $1.00 Increases in Tax and Price of E-Cigarette Products

| | Prevalence (percentage) | | | Intensity (days vaped) | | |
|---|---|---|---|---|---|---|
| Models | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Tax simulations | | | | | | |
| Average predicted E-cigarette use | 23.52 | 23.52 | 23.52 | 10.14 | 10.14 | 10.14 |
| $0.50 increase in tax | 21.01 | 21.97 | 22.05 | 9.91 | 9.70 | 9.66 |
| $1.00 increase in tax | 18.68 | 20.49 | 20.65 | 9.69 | 9.29 | 9.20 |
| Price simulations | | | | | | |
| Average predicted E-cigarette use | 22.67 | 22.67 | 22.67 | 10.04 | 10.04 | 10.04 |
| $0.50 increase in price | 21.07 | 21.60 | 21.73 | 9.70 | 9.67 | 9.62 |
| $1.00 increase in price | 19.55 | 20.56 | 20.81 | 9.38 | 9.31 | 9.21 |

decreases total e-cigarette demand by 0.43%−0.57% (Table 3).

To account for possible endogeneity in the price variable in Models 4−6, 2-stage least squares regressions for both vaping prevalence and intensity using the state's e-cigarette tax as an instrument for e-cigarette price were estimated (Appendix Table 2, available online). Tax is found to be a strong predictor of price in all regressions. A Wu−Hausman test to evaluate regressor endogeneity was conducted. The F-statistic on the Wu−Hausman test is not significant at the 5% level in any estimate, and the null hypothesis of price exogeneity cannot be rejected. The estimated price elasticities from the instrumental variables approach are slightly larger than the price elasticity estimates in Table 3.

## DISCUSSION

This analysis found that prices and taxes affect e-cigarette use behavior among high-school students. The 2-part demand model found that price was associated with statistically significant decreases in both past 30-day use and intensity of use, whereas taxes were associated only with decreases in past 30-day use. This study is the first to simulate price and tax increases, which indicate that both a $0.50 and a $1.00 increase in prices or taxes may lead to decreases in both 30-day use and e-cigarette intensity of use among youth.

As the e-cigarette market continues to evolve, future research must explore the influence of e-cigarette prices and taxes on behavior. The relatively conservative price elasticity estimates indicate that e-cigarette use may be less sensitive to price changes than previously estimated, possibly owing to the improved price and tax methodology.[6,11,12,26−28] Because the estimated cigarette elasticity of demand for youth ranges from −0.7 to −0.86,[6,26−28] the calculated total e-cigarette price elasticity of demand (−0.917) indicates that youth are still more sensitive to changes in e-cigarette prices than to changes in cigarette prices; however, the gap seems to be narrowing.

This study examined data from 2015 to 2019, a time period encompassing the rise of pod-based e-cigarettes containing nicotine salts that soared in popularity among youth after 2017.[29] This study is the first to examine youth using standardized price measures. Together with the standardized tax measure, this analysis provides more precise model estimates while making it easier to understand the relative magnitude of price and tax differences. This unique methodology shows that youth are sensitive to changes in the price of e-cigarettes and that increasing e-cigarette taxes is likely to have a measurable impact on youth use. Policymakers and regulators must tax products in ways that promote public health. In taxing e-cigarettes, this means evaluating the populations that are using e-cigarettes and balancing the trade-offs between the harms that youth vaping poses, their potential future addiction to high levels of nicotine, and the potential benefits that e-cigarettes afford to adults who completely transition from cigarettes to e-cigarettes. In addition, efforts to increase e-cigarette taxes should be considered in the context of how combustible tobacco and other tobacco products are taxed, to maximize public health impact.

### Limitations

This work has limitations. First, this price data only capture e-cigarette sales from participating retailers in 23 states and do not include vape stores or online sales, of which the latter are estimated to have about 30% market share.[30] Second, although these data improve on the price estimates previously used, prices may not reflect the actual price paid by YRBS respondents. Respondents may use coupons or pay a higher price because they are not legally able to buy these products and may resort to other means to obtain these products. Third, although the standardized taxation rate made publicly available by Cotti and colleagues[24] helped to quantify and unify the structure and magnitude of e-cigarette taxes, its construction is also limited by the availability of Nielsen retailer scanner data. Fourth, recent studies[31,32] suggest that the effects of heterogeneity and dynamic treatment effects could potentially bias 2-way fixed effects results. Potential bias is reduced because there are many never-treated units in this sample (states that do not impose a tax on e-cigarettes) and no always-treated units in this sample (states that have imposed a tax on e-cigarettes since the beginning of 2015). Nevertheless, as more states impose taxes on e-cigarettes and future studies are conducted, testing for the potential effects of heterogeneity and dynamic treatment effects may be warranted. Finally, this research only focused on e-cigarettes and did not assess the impact of price and tax on the use of other tobacco products, dual or poly use.

## CONCLUSIONS

These results suggest that increasing e-cigarette prices, specifically through higher taxes, can reduce 30-day e-cigarette use and intensity of use among high-school students. Therefore, policies that increase the price of e-cigarettes have the potential to reduce past 30-day e-cigarette use and intensity of use. As the e-cigarette market continues to evolve and rapidly change, understanding the impact of product price is critical when considering how to best craft policies that prevent e-cigarette use, protect youth, and optimize public health outcomes.

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## SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2023.01.015.

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