Can Cigarette Taxes Still Reduce Teen Smoking?

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Abstract

Several prior studies have documented that a higher cigarette tax reduces youth smoking, but Hansen, Sabia, and Rees (2017) found that this effect disappeared in recent years. We argue that this disappearance can be attributed to nonlinearities in the relationship. Continually rising tax rates over the past several decades have induced price-sensitive youth to quit smoking, leaving only those who are price-insensitive in the market, making further tax hikes less effective deterrents. Using data from the national and state Youth Risk Behavior Surveys, we present two pieces of evidence to support this hypothesis. First, using a semi-parametric model, controlling for state and year fixed effects as well as observable characteristics, we document a diminishing marginal impact of cigarette tax rate on youth smoking, with recent tax hikes in most states falling on the flat portion of the curve. Second, focusing on states where the baseline tax rates are low, we find that tax increases still reduce youth smoking even in the period during which Hansen, Sabia, and Rees find no effects on average. Both results are robust to allowing for state-specific linear time trends, which contrasts the sensitivity observed in prior work.

Keyword: cigarette tax, smoking, teen smoking, youth smoking

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I. Introduction

Cigarette smoking is the world's leading cause of preventable death, killing an estimated six million people per year (World Health Organization 2015). In the U.S., despite large reductions in the smoking rate over the past several decades, smoking still leads to an estimated 480,000 deaths and $289 billion in costs from medical care and lost productivity. Public policies on tobacco control include taxation, bans on smoking in public places, regulated dispensation, criminalization, and informational campaigns, with taxation still being touted as the most effective intervention in the public health community. Many tobacco control efforts focus on teenagers, as 90% of adult smokers started before age 18 (US Department of Health Human Services 2014). These efforts have largely been successful, as the percentage of U.S. teens who smoke fell to 16% in 2013 from a high of 36% (see Figure 1).

An extensive literature has examined the relationship between cigarette excise taxes and teen smoking.[2] Early studies relied on cross-sectional approaches and generally found that higher taxes were associated with lower cigarette consumption (Baltagi and Goel 1987, Chapman and Richardson 1990, Seldon and Boyd 1991, Peterson et al. 1992, Chaloupka and Saffer 1992, Sung, Hu, and Keeler 1994, Keeler et al. 1996). Results from such studies may not be causally interpretable, however, as states with stronger anti-smoking sentiments tend to levy higher taxes and stronger sentiments discourage smoking directly.[3] Some researchers showed that the negative association persisted after controlling for proxies for state anti-smoking sentiment, such as smoke-free air laws and tobacco control expenditures, but it is difficult to

[2] See Chaloupka and Warner (2000), Bader, Boisclair and Ferrence (2011), and Guindon (2013) for more detailed reviews of the literature than we provide here.

[3] For instance, the average state-level cigarette excise tax rates in New York are more than eightfold of that in North Carolina over the period 1991–2013 (Orzechowski & Walker 2014). Surveys seeking to understand individual perception of smoking (DeCicca et al. 2008) also find that anti-smoking sentiments are much stronger in New York than in North Carolina.

capture all possible unobserved confounders in a cross-sectional design (Wasserman et al. 1991, Chaloupka and Saffer 1992, Chaloupka and Grossman 1996, Chaloupka and Wechsler 1997, Lewit et al. 1997, Chaloupka and Pacula 1998, Tauras and Chaloupka 1999, Bardsley and Olekalns 1999).

More recent studies accounted for unobserved, time-invariant state characteristics by estimating state fixed effects models. Using data from the National Education Longitudinal Study (NELS), DeCicca, Kenkel, and Mathios (2002) found little to no evidence of an effect of cigarette taxes on youth smoking initiation after including state fixed effects. Carpenter and Cook (2008) (hereafter CC) also included state fixed effects but used data from the Youth Risk Behavior Surveys (YRBS), which allows for a much larger sample size spanning a longer period (1991 to 2005) than the NELS does.[4] They found that higher taxes decreased youth smoking participation and frequent smoking, though the magnitude of the effects were smaller than those found in the associational literature. Most recently, Hansen, Sabia, and Rees (2017) (hereinafter HSR) revisited CC's findings by extending the sample period to 2013.[5] Using state fixed effects models, they documented a negative relationship between cigarette taxes and youth smoking across the full sample period (1991-2013), but found no evidence of an effect in the most recent years (2007-2013). This is an important result, as it implies that further tax increases would not lead to further reductions in teen smoking. Additionally, they showed that the effect in the full sample period disappears if state-specific linear time trends are added. While including state trends helps account for time-varying unobservables that are correlated with tax changes and youth smoking, it does so at the cost of discarding potentially useful identifying variation in taxes. Accordingly, HSR are agnostic as to which model is preferable.

[4] CC use micro-level data from the national YRBS as well as aggregate-level data from the state and local YRBS.
[5] Unlike CC, HSR use the micro-level data from both the national and state YRBS, which is the same data source we will employ.

The goal of our paper is to shed light on two important unresolved questions from HSR's work. First, *why* has the effect of cigarette taxes on youth smoking disappeared in recent years? We argue that the diminished tax effect can be attributed to an inherently nonlinear relationship.[6] Price-sensitive youth are the most likely to be responsive initially as the cigarette tax begins to rise. After decades of tax increases, price-sensitive youth may have already been driven from the market, leaving only price-*insensitive* youth who are not responsive to continued increases. The result is a non-linear relationship between cigarette tax rate and youth smoking, with the marginal effect being strongest at low levels of taxation. The average baseline tax rate in 2007 may have been high enough to be in the flat portion of the curve, leading to HSR's finding of a null effect during the 2007-2013 period.

We provide two pieces of evidence to support this proposition. First, we estimate the relationship between cigarette tax rate and youth smoking semi-parametrically using Yatchew's difference estimator. This allows the data to choose the appropriate functional form, conditional on state and year fixed effects as well as observable characteristics. The results indeed document a diminishing marginal effect of cigarette taxes on youth smoking, with the average 2007 tax rate lying in the relatively flat portion of the curve. This finding is robust to the use of parametric non-linear models such as a quadratic specification in taxes. Second, our hypothesis implies that tax increases should still effectively deter youth smoking in states with low baseline tax rates, since they are not yet on the flat of the curve. Consistent with this prediction, we show that higher taxes lead to statistically significant and economically meaningful reductions in teen smoking in 2007-2013 in states with low 2007 tax rates. In other words, raising cigarette taxes *can* still reduce teen smoking in some states, even if there is little to no effect across the country on average.

[6] HSR mention this possibility in their conclusion.

The second unresolved question from HSR is whether, in light of the sensitivity of the full-sample-period results to the inclusion of state-specific time trends, there has ever actually been a true, causal effect of cigarette taxes on youth smoking in the first place. Interestingly, we find that the results using non-linear modeling approaches actually *are* robust to the inclusion of state trends. This means that conclusions on the relationship between cigarette taxes and youth smoking can be reached even without resolving the methodological debate about whether models with or without state trends are more appropriate.

II. Data

Following HSR, we use data from the national and state YRBS, spanning 1991 to 2013. The YRBS is one of the leading data sources on youth risky behaviors. Started in 1991, the YRBS has surveyed thousands of high school students around the country and has been implemented every other year. The national YRBS is conducted by Centers for Disease Control and Prevention (CDC) and the state YRBS, while coordinated by CDC, is usually administered by the participating state health departments or education agencies.[7] The advantage of pooling the national and state YRBS is sample size, as this leads to about six times more observations than the national YRBS alone. The YRBS' smoking question is, "*During the past 30 days, on how many days did you smoke cigarettes*?" Following CDC's benchmark, we define youth as current smokers if any day of smoking is reported and as frequent smokers if cigarettes are used more than 20 days over the past month.

[7] Many states have authorized CDC to distribute their data for secondary analyses and for states that have not, we received their permissions to use the data. In addition, we have obtained permission from CDC to use state identifiers in the national YRBS dataset. The states included in both the national and state YRBS vary somewhat each year, though our inclusion of state fixed effects should mitigate any resulting bias in the econometric estimates. See HSR for state-by-year observation counts; our sample is nearly identical to theirs.

Our cigarette tax variable is the combined state and federal excise tax rate in effect at the end of March of each survey year. The prior literature generally includes only state tax rates since tax changes at the federal level are common to all states and thus absorbed by the time effects. We also include federal taxes because of our focus on nonlinearities: starting place along the distribution matters for the predicted marginal effect, and federal tax rate matters for the starting place. Our use of the tax rate from March, which follows CC and HSR, is done because the YRBS does not provide survey dates and most states administer YRBS in the spring when school is in session. Finally, we convert the nominal tax rate to 2013 dollars using the Consumer Price Index for All Urban Consumers (CPI–U).

We control for individual characteristics and state-level policies that could correlate with changes in both cigarette taxes and youth smoking. The individual-level controls are age in years as well as dummy variables for gender (female), race/ethnicity (non-Hispanic white (base category), non-Hispanic black, Hispanic, and other races), and grade level (9th grade (base category), 10th, 11th, and 12th). The first state-level control is an indicator variable for the comprehensiveness of smoke-free air laws, set equal to one if smoking is banned in government and private worksites, restaurants, and bars, and 0 otherwise. This information comes from the CDC STATE system. The other state-level variables are unemployment rates in March and the natural logarithm of per capita personal income, obtained from the Bureau of Labor Statistics and the Bureau of Economic Analysis.

Table 1 presents summary statistics for the variables discussed above for CC's sample period of 1991-2005 and HSR's other sample periods of 1991-2013 and 2007-2013. From 1991-2005 to 2007-2013, youth smoking prevalence declined from 27% to 16% while cigarette taxes and the prevalence of comprehensive smoke-free air laws increased substantially. The demographic characteristics stayed relatively steady over time, aside from a modest shift in the racial/ethnic makeup of the population from non-Hispanic white to Hispanic and other groups. We also observe a higher unemployment rate in the later sample period, which corresponds with the Great Recession and gradual recovery.

III. Replication

We begin our empirical analysis by showing that we can replicate CC's and HSR's results with our data. Following their approaches, we estimate the average marginal effects of cigarette taxes on youth smoking by running logistic regressions of the form

$$Y_{ist}^{*} = \beta \mathrm{CigTax}_{\mathrm{st}} + \mathbf{X}'\boldsymbol{\gamma} + \mathrm{w}_{\mathrm{s}} + \mathrm{v}_{\mathrm{t}} + \varepsilon_{\mathrm{ist}}. \quad (1)$$

Y_{ist}^{*} is a latent variable reflecting the smoking frequency of youth *i* in state *s* in year *t*. We do not observe Y^{*}, but instead observe the dichotomous variables for current and frequent smoking. The vector **X** contains the aforementioned individual- and state-level controls. State fixed effects, which account for time-invariant state-specific unobserved heterogeneity, and year fixed effects, which capture any macro-level shocks common to all states, are denoted by w_{s} and v_{t}, respectively. By convention, we cluster standard errors at the state level (Bertrand, Duflo, and Mullainathan 2004, Cameron and Miller 2015).

Table 2 reports the resulting average marginal effects of cigarette taxes on youth current and frequent smoking, alongside estimates from CC and HSR. The first three columns use CC's sample period of 1991-2005, the next two use HSR's full sample period of 1991-2013, and the final two use HSR's other sample period of interest: 2007-2013. As in HSR, we present results from the state, national, and combined state and national versions of the YRBS.

The main takeaway from Table 2 is that we are able to replicate the results of CC and HSR fairly closely despite small differences in sample sizes. Using data from the national YRBS between 1991 and 2005, CC find that a dollar increase in the state cigarette excise tax is associated with a 5.9 percentage point (pp) decrease in youth smoking participation and a 4.1 pp decrease in frequent smoking. Using the same dataset, our calculation suggests that a one-dollar increase in the tax rate reduces youth smoking participation by 4.4 pp and frequent smoking by 2.6 pp. The magnitudes of the tax effects are slightly smaller in the dataset we use, but they are quite close to those of HSR (4.6 pp and 2.6 pp respectively).[8] We also confirm HSR's result that the effects shrink roughly in half after adding data from the 2007-2013 waves and become statistically insignificant if the sample is restricted to just the 2007-2013 period. Also similarly to HSR, we find that the results remain qualitatively unchanged if we use the state or combined state and national versions of the YRBS as opposed to just the national version. Since the estimates are the most precise in the combined dataset, we will use that for the remainder of our analyses.

Table 3 presents the results for the combined dataset after adding state-specific linear time trends, alongside the corresponding estimates from HSR. Again, consistent with their results, cigarette tax is no longer statistically significantly associated with youth smoking once state trends are included, even during the period (1991-2005) over which taxes exhibit a strongly deterrent effect without the state trends. This could indicate that the observed relationship between cigarette taxes and youth smoking is attributable to time-varying state unobservables rather than a genuine causal effect. Alternatively, the state trends could be eliminating useful variation. After including them, only 5% of the variation in cigarette tax remains, and the effect

[8] One reason that our estimates, as well as those of HSR, are smaller than those reported by CC is that CC calculated the "marginal" change in smoking rates resulting from a $1 change in cigarette tax using the linear projection function after running the logistic regression. We, and HSR, instead calculate the average marginal effects.

of that small portion of the variation could conceivably be different from the genuine causal effect of the remaining, discarded variation. Researchers have debated the appropriateness of controlling for state trends in the cigarette taxation literature. See, for instance, the dialogue between Gruber and Frakes (2006) and Chou, Grossman, and Saffer (2006). We therefore take an agnostic view about which model is more appropriate and will show that, fortunately, the distinction will not ultimately matter after better accounting for nonlinearities.

IV. Semi-parametric Analyses

In this section, we employ Yatchew's difference estimator to trace out the impacts of cigarette excise tax on youth smoking semi-parametrically, thereby allowing the data to choose the appropriate functional form (Yatchew 2003, 1997). The model becomes

$$Y_{\mathrm{ist}} = \beta f(\mathrm{CigTax}_{\mathrm{st}}) + \mathbf{X}'\boldsymbol{\gamma} + \mathrm{w}_{\mathrm{s}} + \mathrm{v}_{\mathrm{t}} + \varepsilon_{\mathrm{ist}}, \qquad (2)$$

where the key change is the flexible functional form for cigarette tax.[9] By construction, $f(\bullet)$ is a smooth, single-valued function with bounded first-order derivatives. Yatchew's difference estimator is partially linear; therefore, $\mathbf{X}'\boldsymbol{\gamma}$, $f(\mathrm{CigTax}_{\mathrm{s,t}})$, and the error term $\varepsilon_{\mathrm{ist}}$ are additively separable. A detailed explanation of the method is outside the scope of this paper but its logic can be summarized as follows. For ease of exposition, let $f(\mathrm{T_L})$ denote $f(\mathrm{CigTax}_{\mathrm{s,t}})$.

To begin with, the estimator arranges data in the order of $\mathrm{Tax}_1 < \mathrm{Tax}_2 < \cdots < \mathrm{Tax}_{\mathrm{j}}$, where j indicates the total number of observations in the estimation sample. The specification in (2) is then estimated in the form of "first-order" differences: $y_I - y_{I-1} = \beta f(\mathrm{T_L} - \mathrm{T_{L-1}}) + \mathbf{X}'\boldsymbol{\gamma} + \varepsilon_{\mathrm{i,s,t}} - \varepsilon_{\mathrm{i,s,t-1}}$, generalizing to

[9] Another change is that the discrete nature of the outcome variable is no longer formally modeled. To verify that this alone is inconsequential, Appendix Table 1 reports the results using a linear probability model rather than logit. The estimates are very similar to the corresponding marginal effects from Table 1.

$$\sum_{n=1}^{m}(d_n y_{I-n}) = \gamma\left(\sum_{n=1}^{m} d_n x_{I-n}\right) + \sum_{n=1}^{m} d_n f(T_{L-n}) + \sum_{n=1}^{m} d_n \varepsilon_{I-n} \quad (3)$$

where m denotes the order differencing and $d_0, d_1, \dots, d_m$ are the differencing coefficients that satisfy a pre-imposed condition:

$$\sum_{n=1}^{m} d_n = 0 \ and \ \sum_{n=1}^{m} d_n^2 = 1$$

Since T_L (cigarette excise tax) has a compact support, $\sum_{n=1}^{m} d_n f(T_{L-n})$ shrinks and is removed as the sample size increases. The parameter γ is estimated using OLS regression and the function f is derived by regressing $(y_I - \mathbf{X}'\hat{\gamma}_{\text{dif}})$ on T_L non-parametrically, analogous to a stylized locally weighted regression. The differencing order m affects the estimator's asymptotic efficiency and Monte Carlo simulations report noticeable efficiency gains from higher-order differencing (Lokshin 2006).[10] In the following analyses, we set m equal to 7 because higher order differencing (8th-10th) is no longer associated with efficiency gains, only additional computational intensity.

The upper panel of Figure 2 presents the smoothed tax effects ($f(T_L)$) on youth current smoking while the bottom panel shows the effects on youth frequent smoking, both with data from the combined national and state YRBS, spanning 1991–2013. The figures on the left show the results without the state trends, while those on the right include them. It is apparent that the deterrent effect of cigarette tax on smoking is not constant but diminishing over the tax range. This pattern is particularly pronounced when we account for the state-specific time trends, as the predicted rates of both current and frequent smoking are essentially flat at tax rates of higher than $3.

[10] 10th order differencing is the upper bound imposed by Yatchew's difference estimator.

Figure 3 depicts the same results in a different manner by plotting how the marginal effects, rather than the predicted smoking rates, change across the tax distribution. In all four graphs (both outcomes, with and without state trends), the marginal effect of taxes on youth smoking is negative and significant at low levels of taxation, but eventually becomes insignificant. The effects on current and frequent smoking turn insignificant at tax rates of approximately $2 per pack without state trends, compared to less than $1 once state trends are added. In three of the four graphs, the effects actually turn *positive* and significant at the highest tax rates, though we caution against a literal interpretation of that result since it is based on very few state-year combinations.[11]

V. Ruling Out Alternative Explanations

The results from Figures 2 and 3 are consistent with the hypothesis that the disappearance of an effect of cigarette taxes on youth smoking is due to an inherently nonlinear relationship: steadily rising tax rates over several decades have driven price-sensitive consumers from the market, leaving only those who are price-insensitive continuing to smoke. This section conducts a variety of robustness checks in an effort to rule out possible alternative explanations.

Cigarette Prices Instead of Taxes

First, our hypothesis relates to consumer responses to cigarette *prices*, but our analyses thus far focus on *taxes*. A diminishing marginal effect of taxes does not necessarily imply a diminishing marginal effect of prices. For instance, if tax increases did not pass through as fully to prices in recent years, we might observe a diminishing effect of taxes but linear effect of prices. Figure 4 therefore presents results for a semi-parametric analysis identical to that in

[11] We also conducted similar semi-parametric analyses for adults using 1991-2013 data from the Behavioral Risk Factor Surveillance System. In contrast to the results for teens, the results for adults (available upon request) showed little evidence of non-linearities in the relationship between cigarette taxes and smoking.

equation (3) but replacing tax rates with (tax-inclusive) per-pack prices. The shapes of all four graphs are similar to those from Figure 2, with a diminishing marginal effect being evident in all cases. Particular flattening appears to occur at a price of around $7 per pack.

Alternative Functional Forms

Another possible concern is that the observed pattern of nonlinearity might be an artifact of the particular functional form chosen by the Yatchew semi-parametric method. It is therefore useful to check if a similar pattern emerges using a simpler parametric nonlinear specification. Table 4 therefore reports results from a model including both cigarette tax and its square (i.e. quadratic in cigarette tax). Given the difficulty of interpreting nonlinear models with interaction terms (Ai and Norton 2003), we employ a linear probability model (LPM) rather than a logit. We therefore also present results for a LPM without the squared term in order to verify that they are similar to the average marginal effects from the logistic regressions reported previously.[12]

The results from the quadratic specifications, for both outcomes and regardless of whether state trends are included, are consistent with those from the semi-parametric model. In all four cases, the coefficient estimate for cigarette tax is negative and significant while that for its square is positive and significant. This indicates a negative effect at low levels of taxation that gradually diminishes and eventually turns positive. Without state trends, the marginal effect turns positive at a tax rate of $3.50 for current smoker and $2.67 for frequent smoker, respectively. In the semiparametric results shown in Figure 3, the corresponding marginal effects both cross zero at around $3.20. With state trends, the marginal effects from the

[12] Specifically, since the regressions in Table 4 all use the combined sample from 1991-2013, the -0.012 estimate for current smoker from the first column should be compared to the -0.011 estimate from the combined sample/1991-2013/current paper/current smoker cell in Table 2, while the -0.010 estimate for frequent smoker should be compared to the -0.007 estimate from the combined sample/1991-2013/current paper/frequent smoker cell in Table 2. Similarly, the estimates including state trends from the third column of Table 4 – 0.004 and 0.001, respectively – parallel the estimates of 0.002 and 0.000 from the fourth column of Table 3. Appendix Table 1 reports results from linear probability models using other samples and time periods.

quadratic specification in Table 4 become positive at just \$0.85 and \$0.87 for current and frequent smoker, respectively. In the semiparametric models from Figure 3, the marginal effects with state trends cross zero at somewhat higher rates of about \$2.20 and \$2.60. Nonetheless, the fact that the general shapes of the curves are the same is reassuring.

Appendix Table 2 further reports results from cubic, quartic, and quintic specifications, while Appendix Table 3 does the same adding linear state-specific time trends. The higher-order polynomial terms are always insignificant, meaning that there is little additional information to be learned from parametric models beyond quadratic.

Another issue related to functional form is whether the observed diminishing marginal effect of cigarette taxes on youth smoking could simply reflect a constant elasticity. If every 100% increase in the tax rate leads to the same percentage change in smoking, this would still show up as a diminishing marginal effect when the regression is run in levels.[13] Elasticities can be estimated using a log-log functional form, but that is not feasible with the individual-level YRBS data because of the dichotomous nature of the outcomes. We therefore aggregate the data to the state-by-year level and re-estimate regression equation (1) as a LPM with the natural logarithm of the percentage of youth who are current (or frequent) smokers as the dependent variable and the natural logarithm of the tax rate as the independent variable. The coefficient β from this new specification can be interpreted as the (approximate) tax elasticity of cigarette consumption. We weight each observation by the number of individuals in the state-by-year cell to preserve comparability to individual-level estimates (Chetty, Looney, and Kroft 2007).

[13] To illustrate, suppose an increase in the tax rate from \$0.50 to \$1 reduces the smoking rate from 20% to 17%. This would mean a 100% increase in tax reduces smoking by 15%, for an elasticity of 0.15. At the same elasticity, an additional 100% increase in taxes to \$2 would only decrease the smoking rate to 14.45%. Since we achieve a smaller decrease in smoking rates out of a larger increase in tax rates (in levels), it follows that for an equivalent increase in cigarette taxes (\$0.5), we would have seen an even smaller decrease in smoking rates. Therefore, when estimated in levels, this constant elasticity would show up as a diminishing marginal effect, as the increase in taxes at higher values will always be a larger dollar amount than the increase in taxes at lower values, with the resulting percentage point change in the smoking rate being smaller.

The results in Table 5 show that the cigarette tax elasticity did change over time. Specifically, the tax elasticities from 1991-2005 are 17% for current smoking and 31% for frequent smoking. The elasticities shrink roughly in half after incorporating survey waves through 2013, and they turn positive but small and insignificant in 2007-2013 alone. This is essentially the same pattern observed in our main estimates from Table 2.

E-Cigarettes

E-cigarettes, whose popularity among teens rose sharply during the years added to the sample by HSR, are a possible confounding factor. Is it possible that the availability of this new nicotine delivery system accounts for the reduced tax elasticity observed above? Theoretically, this seems unlikely, as the availability of a new substitute should, if anything, increase consumers' price responsiveness in the traditional cigarette market.[14] To further rule out this concern, we next conduct an analysis of the effect of cigarette taxes on youth e-cigarette use.

Since the YRBS did not include e-cigarette questions during our study period, we instead use data from the National Youth Tobacco Survey (NYTS), which included such questions from 2011-2013. During this period, the percentage of youth who report ever using e-cigarettes rose from 3% to 8%, while the percentage reporting current use (past 30 days) rose from 1% to 3%. Therefore, while we are not able to study e-cigarettes until 2011, the very low rate of use as of 2011 suggests that it is unlikely that there was any meaningful effect of cigarette taxes on e-cigarette use prior to then.

[14] There is debate in the literature about whether cigarettes and e-cigarettes are actually substitutes. Conceivably, they could be complements if e-cigarettes serve as a gateway to subsequent traditional smoking. Available evidence from quasi-experimental studies of the impact of e-cigarette regulations on youth smoking seems to suggest that, if anything, the two products are substitutes (Friedman 2015, Pesko, Hughes, and Faisal 2016, Dave, Feng, and Pesko 2017). Moreover, even if they were complements, subsequent transition to traditional cigarettes might occur after the respondents leave high school, in which case they would be outside of our sample age range.

Table 6 reports the results from logistic regressions of the same form as equation (1) but with ever using and currently using e-cigarettes as the outcomes. The coefficient estimate for cigarette tax is small and statistically significant in both cases. These results suggest that our finding of a diminishing marginal effect of cigarette taxes on youth smoking is unlikely to be attributable to the introduction of e-cigarettes toward the end of our sample period.

V. Average Effects in States with Low Baseline Tax Rates

The results thus far provide, in our view, compelling evidence of fundamental nonlinearity in youths' responses to rising cigarette taxes, with effects being relatively strong at low baseline levels of taxation and small or zero at higher levels. This nonlinearity provides an explanation for the disappearance of an average effect of cigarette taxes on youth smoking in the 2007-2013 sample period. However, it also implies that youths in states with low tax rates at the start of this period may still have been responsive to tax increases, as their states were not yet on the "flat of the curve". In other words, price-sensitive consumers had not yet been driven out of the market in these states.

To directly test this hypothesis, we re-estimate equation (1) for the 2007-2013 sample period, stratifying into three groups based on baseline (2007) state tax rates.[15] The first group consists of 13 states with baseline state taxes rates of no more than $0.50 per pack. These states are AL, GA, FL, IA, KY, LA, MS, MO, NC, ND, SC, TN, and VA. Between 2007 and 2013, six of these states (FL, KY, MS, NC, SC, TN) raised cigarette taxes at least once, with Florida implementing the largest increase, from $0.39 to $1.39 per pack. The middle group consists of

[15] Since the number of states in each stratified sample is relatively small, we use bootstrapped standard errors instead of clustering standard errors by state (Courtemanche and Zapata 2014).

25 states with baseline state tax rates between $0.50 and $1.50, while the high tax group contains 13 states with tax rates over $1.50.

Table 7 presents the results, both with and without state-specific linear time trends. Among these 13 states with low 2007 tax rates, taxes are indeed negatively and significantly associated with youth smoking during the 2007-2013 period. A one-dollar increase reduces current and frequent smoking by 0.9 and 1 pp, respectively, in the regressions without state trends and 2.3 and 2.5 pp in the regressions with them. The latter are similar to the magnitudes from the 1991-2005 period during which baseline (1991) tax rates in most states were low and, accordingly, CC, HSR, and the current study found statistically significant average effects across the whole country.[16] In contrast, the effects in the middle and high tax groups are all small and statistically insignificant. Since the vast majority of the population lives in the middle and high tax states as opposed to the low tax states, the null average effect during 2007-2013 pooling all states together is not surprising.

VI. Conclusion

A recent study by HSR finds that the deterrent effect of cigarette excise taxes on youth smoking documented by CC and others has disappeared in recent years, raising questions about their continued effectiveness in achieving public health objectives. In this paper, we provide evidence from semi-parametric and parametric models that this phenomenon is attributable to a fundamentally nonlinear relationship. Tax increases are effective in reducing youth smoking up to a point, but once tax rates are sufficiently high that price sensitive consumers have already left

[16] Appendix Table 4 explores adding higher order polynomials and finds that quadratic, cubic, quartic, and quintic terms are all insignificant. This suggests that the cigarette tax effect is approximately linear for low-baseline-tax states, consistent with the tax increases occurring in the left portion of the curves from Figure 2, before the diminishing marginal effects become particularly evident.

the market, further tax increases are ineffective (other than as a revenue source). During the 1991-2005 period examined by CC, initial tax rates were sufficiently low that subsequent increases did reduce youth smoking. In contrast, during the 2007-2013 period added by HSR, baseline tax rates in most states were sufficiently high that additional increases did not prove to be effective deterrents on average. However, in states that still had low taxes in 2007, tax increases in subsequent years did indeed reduce smoking. In other words, the disappearance of the average effect is simply due to the extensive nature of prior tax increases, as opposed to, for instance, an underlying change in consumer demand. Interestingly, our conclusions are not sensitive to the inclusion of state-specific linear time trends, which contrasts the sensitivity observed by HSR in regressions with a more restrictive functional form.

Our findings have implications for cigarette tax policy moving forward. In principle, our results suggest that further tax increases would be effective in reducing youth smoking in states that still have low tax rates. For how many states might this be the case? The point estimates from our semi-parametric regressions imply that the "flat of the curve" begins at a tax rate of no less than $2.20 or greater (Figure 3, upper right graph). As of this writing, sixteen states still had combined state and federal tax rates of under $2.20.[17] The somewhat sizeable confidence intervals around our semi-parametric estimates mean that this is only a rough estimate, but there are likely at least some states that have not yet reached the flat of the curve. In other words, cigarette taxation can still be an effective tool to curb youth smoking in some cases.

[17] State and federal tax rates from June 2018 come from https://www.tobaccofreekids.org/assets/factsheets/0097.pdf.

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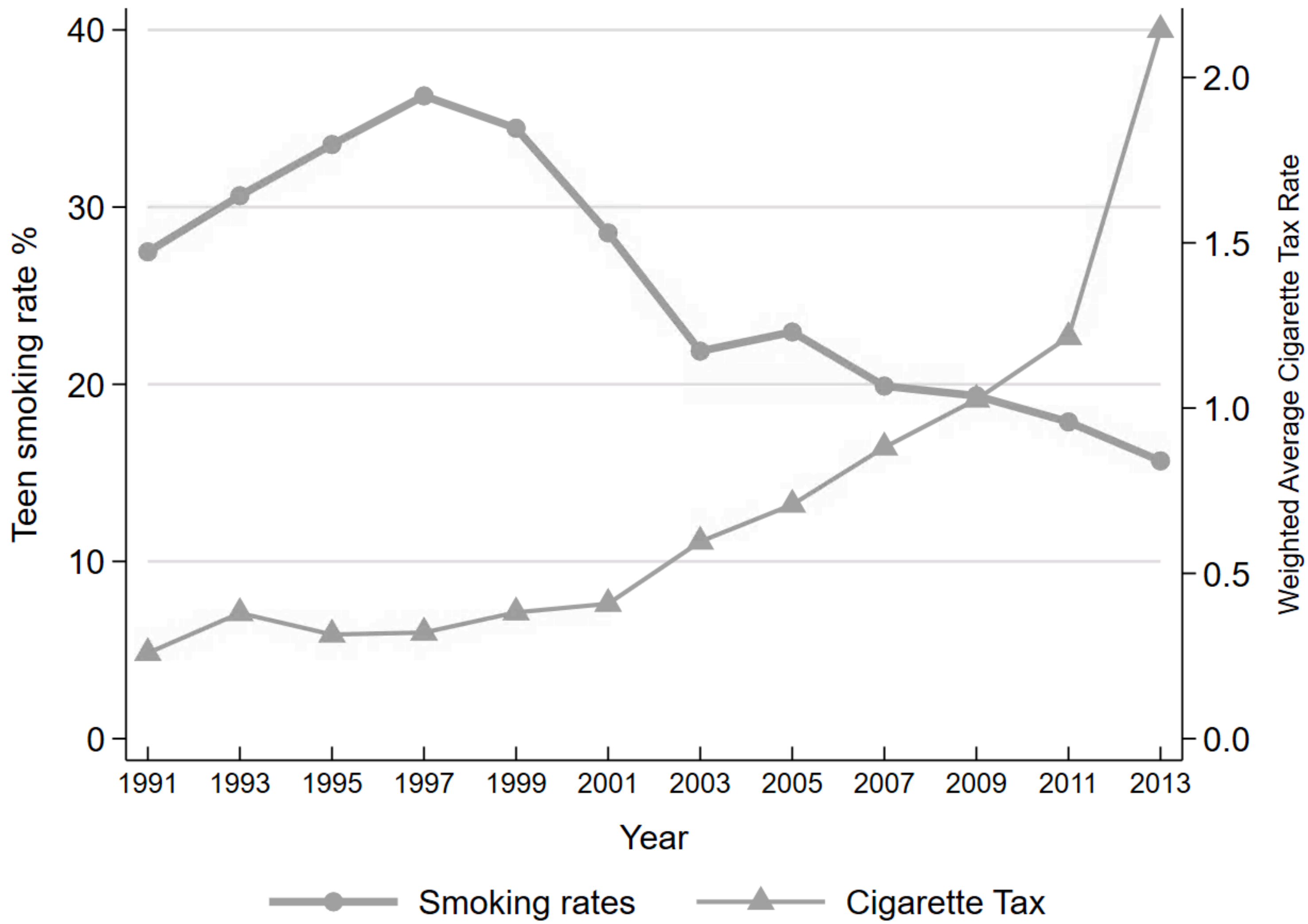
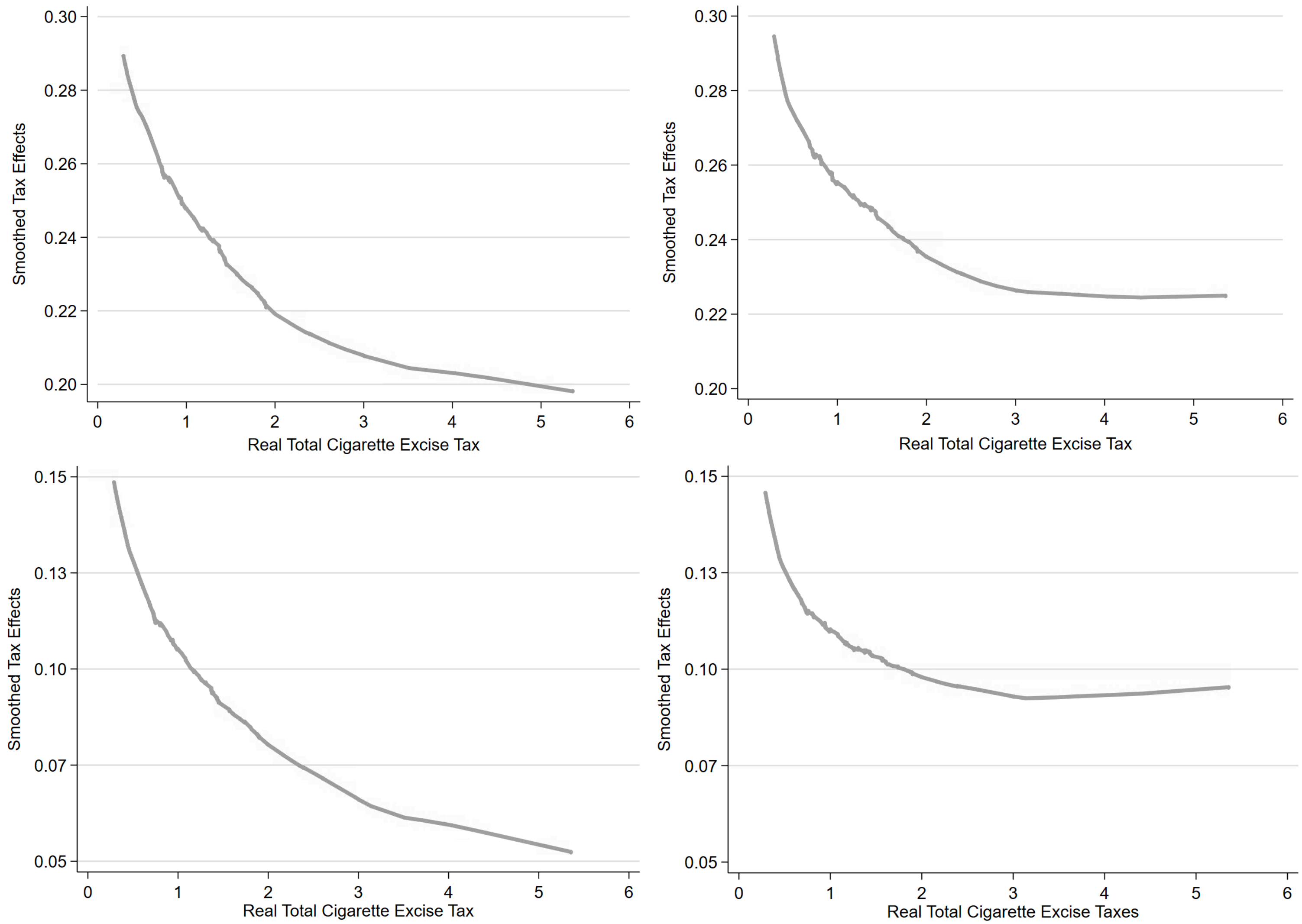
Figure 1 – Teen Smoking Rates and Weighted Average Cigarette Tax Rate
National YRBS: 1993 - 2013



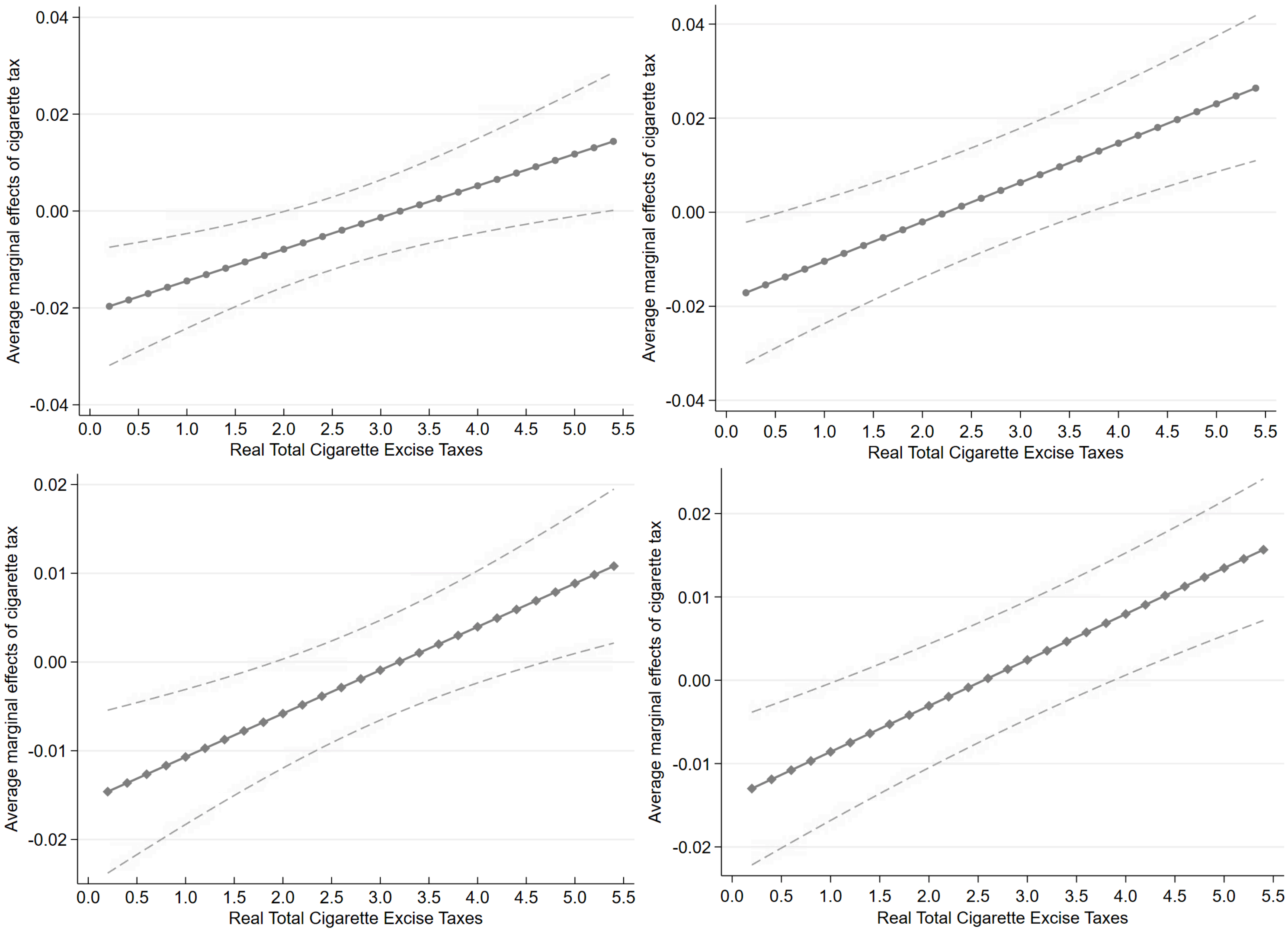
Notes: Teen smoking rates are imputed using the national YRBS and the weighted average cigarette tax rates come from *The Tax Burden on Tobacco* (Orzechowski and Walker 2014).

Figure 2 – Semi-Parametric Estimates of Relationship between Cigarette Taxes and Youth Smoking



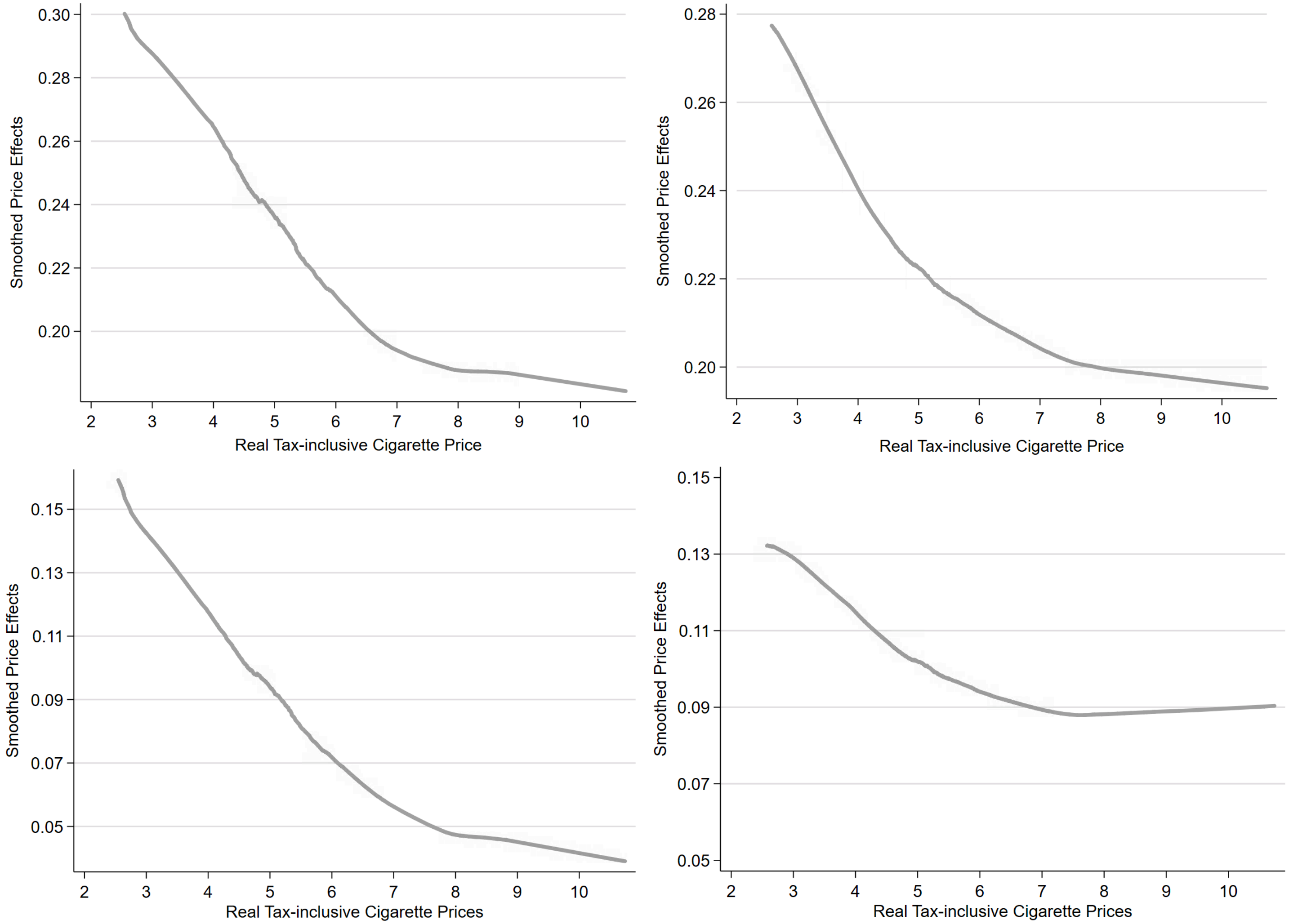
Notes: All figures are generated using Yatchew's difference estimator with 7th-order differencing. All models control for individual- and state- level covariates as well as state and year fixed effects. Taxes are converted to 2013 dollars using CPI-U. Values on the vertical axis denote the smoothed marginal tax effects ($f(T_L)$) on youth smoking. The upper panel focuses on youth current smoking while the bottom panel focuses on frequent smoking. Figures to the right are generate using models further include the state-specific linear time trends. The analysis sample uses data from the combined national and state YRBS, spanning 1991–2013.

Figure 3 – Average Marginal Effects of Cigarette Taxes on Youth Smoking



Notes: The figure plots the average marginal effects of cigarette tax on youth current smoking (upper panel) and frequent smoking (bottom panel) using models under column 2 and 4 in Table 3.
On the right side of the panel, the average marginal effects of cigarette tax are calculated using models that further include state-specific linear time trends.

Figure 4 – Semi-Parametric Estimates of Relationship between Cigarette Prices and Youth Smoking



Notes: All figures are generated using Yatchew's difference estimator with 7th-order differencing. All models control for individual- and state- level covariates as well as state and year fixed effects. Tax-inclusive prices are converted to 2013 dollars using CPI-U. Values on the vertical axis denote the smoothed marginal price effects ($f(T_L)$) on youth smoking. The upper panel focuses on youth current smoking while the bottom panel focuses on frequent smoking. Figures to the right are generate using models further include the state-specific linear time trends. The analysis sample uses data from the combined national and state YRBS, spanning 1991–2013.

Table 1 — Summary Statistics

	1991-2005	2007-2013	1991-2013
Current smoker	0.27 [0.44]	0.16 [0.36]	0.21 [0.41]
Frequent smoker	0.13 [0.33]	0.06 [0.24]	0.09 [0.29]
Female	0.51 [0.50]	0.52 [0.50]	0.52 [0.50]
Age	16.0 [1.21]	16.0 [1.23]	16.0 [1.22]
Non-Hispanic white	0.64 [0.48]	0.56 [0.50]	0.60 [0.49]
Non-Hispanic black	0.16 [0.36]	0.14 [0.35]	0.15 [0.36]
Hispanic	0.11 [0.31]	0.17 [0.37]	0.14 [0.35]
Others	0.09 [0.29]	0.13 [0.34]	0.11 [0.32]
9th grade	0.28 [0.45]	0.28 [0.45]	0.28 [0.45]
10th grade	0.27 [0.44]	0.27 [0.44]	0.27 [0.44]
11th grade	0.24 [0.43]	0.25 [0.43]	0.24 [0.43]
12th grade	0.21 [0.41]	0.21 [0.41]	0.21 [0.41]
Cigarette excise taxes (2013 $)	0.80 [0.48]	2.29 [1.10]	1.54 [1.13]
Comprehensive smoke-free air law	0.03 [0.18]	0.47 [0.50]	0.25 [0.44]
State unemployment rates	5.12 [1.31]	6.98 [2.03]	6.05 [1.95]
Natural logarithm of per capita personal income	10.19 [0.25]	10.64 [0.17]	10.41 [0.31]
Observations	535,135	537,320	1,072,455

Notes: means and standard deviations (in brackets) are reported.
We define youth as a current smoker if any day of smoking is reported. We define youth as a frequent smoker if she smoked cigarettes in 20 or more days over the past month.
Cigarette excise taxes include federal and state tax rates, effective in March of a given survey year. Cigarette tax data come from *The Tax Burden on Tobacco* (Orzechowski and Walker 2014).
We inflation adjust cigarette tax rates to 2013 dollars using CPI-U.
Comprehensive smoke-free air law is an indicator variable set equal to one if smoking is restricted in government and private work places, restaurants, and bars, effective in February of a given survey year. Data come from CDC STATE System.
State unemployment rates, in February of a given survey year, come from the Bureau of Labor Statistics.
Per capita income comes from the Bureau of Economic Analysis.

Table 2 — Average Marginal Effects of Cigarette Taxes on Youth Smoking

	CC	HSR	Current Paper	HSR	Current Paper	HSR	Current Paper
			State YRBS				
Current Smoker	-0.027 (N/A)	-0.026*** (0.009)	-0.025*** (0.007)	-0.010** (0.005)	-0.009** (0.004)	0.007 (0.006)	0.006 (0.005)
Frequent Smoker	-0.024 (N/A)	-0.019* (0.006)	-0.023*** (0.005)	-0.007*** (0.003)	-0.008*** (0.003)	0.002 (0.003)	0.001 (0.003)
N	181	409,385	431,298	883,691	913,239	474,306	481,941
			National YRBS				
Current Smoker	-0.059 (N/A)	-0.046*** (0.022)	-0.044** (0.020)	-0.028*** (0.009)	-0.020* (0.010)	-0.011 (0.020)	-0.012 (0.026)
Frequent Smoker	-0.041 (N/A)	-0.026* (0.014)	-0.026* (0.015)	-0.016*** (0.006)	-0.012* (0.007)	-0.006 (0.015)	-0.009 (0.020)
N	101,633	103,408	103,837	158,605	159,216	55,197	55,318
			Combined State and National YRBS				
Current Smoker	N/A	-0.030*** (0.008)	-0.030*** (0.007)	-0.011** (0.005)	-0.011** (0.004)	0.007 (0.006)	0.006 (0.005)
Frequent Smoker	N/A	-0.019*** (0.006)	-0.020*** (0.005)	-0.007*** (0.002)	-0.007*** (0.002)	0.002 (0.003)	0.007 (0.005)
N		512,793	535,135	1,042,296	1,072,455	529,503	537,320
Time Span	1991–2005	1991–2005	1991–2005	1991–2013	1991–2013	2007–2013	2007–2013

Notes: Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.
CC=Carpenter and Cook (2008), HSR=Hansen, Sabia, and Rees (2017).
Survey weights applied when the analysis sample uses data solely from the national YRBS.

Table 3 — Average Marginal Effects of Cigarette Taxes on Youth Smoking Including Linear State-Specific Time Trends

	HSR	Current Paper	HSR	Current Paper	HSR	Current Paper
Current Smoker	-0.007 (0.008)	-0.004 (0.008)	0.003 (0.009)	0.002 (0.008)	-0.005 (0.006)	-0.006 (0.006)
Frequent Smoker	-0.008 (0.006)	-0.008 (0.006)	0.000 (0.005)	0.000 (0.005)	0.001 (0.003)	0.000 (0.004)
N	512,793	535,135	1,042,296	1,072,455	529,503	537,320
Time Span	1991–2005	1991–2005	1991–2013	1991–2013	2007–2013	2007–2013

Notes: Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.
CC=Carpenter and Cook (2008), HSR=Hansen, Sabia, and Rees (2017).
Survey weights applied when the analysis sample uses data solely from the national YRBS.

Table 4 — Estimated Effects of Cigarette Taxes on Youth Smoking from Quadratic Specification

	Linear	Quadratic	Linear Adding State Trends	Quadratic Adding State Trends
Youth is a Current Smoker				
Cigarette Tax	-0.012* (0.006)	-0.021*** (0.006)	0.004 (0.008)	-0.017** (0.008)
Cigarette Tax Squared		0.003*** (0.001)		0.004*** (0.001)
Youth is a Frequent Smoker				
Cigarette Tax	-0.010** (0.004)	-0.016*** (0.005)	0.001 (0.005)	-0.013*** (0.005)
Cigarette Tax Squared		0.003*** (0.001)		0.003*** (0.001)
Observations	1,072,455	1,072,455	1,072,455	1,072,455

Notes: Results are from linear probability models estimated using the combined state and national YBRS sample from 1991-2013. Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.

Table 5 — Estimated Cigarette Tax Elasticities using Aggregated State-Level Data

	1991-2005	2007-2013	1991-2013
Panel A: ln(% Current Smokers)			
ln(Cigarette Tax)	-0.172**	0.077	-0.088*
	(0.069)	(0.088)	(0.044)
Panel B: ln(% Frequent Smokers)			
ln(Cigarette Tax)	-0.313***	0.079	-0.153**
	(0.098)	(0.131)	(0.064)
N	299	188	487

Notes: Results are from linear probability models using the combined state and national YRBS sample.
Standard errors, clustered at the state level, are shown in parenthesis.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.
Observations are weighted by the state/year cell size.

Table 6 — Estimated Effects of Cigarette Taxes on Youth E-Cigarette Use

Panel A: Youth Ever Used E-Cigarettes	
Cigarette Tax	-0.010
	(0.012)
N	57,178
Panel B: Youth is a Current E-Cigarette User	
Cigarette Tax	0.001
	(0.005)
N	56,916

Notes: Results are from logistic regressions using the National Youth Tobacco Survey: 2011-2013
Standard errors, clustered at the state level, are shown in parenthesis.
Average marginal effects reported. Sampling weights are applied.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.

Table 7 — Average Marginal Effects of Cigarette Taxes on Youth Smoking in 2007-2013
States Grouped by 2007 Tax Rate

	Low 2007 Tax States	Low 2007 Tax States; Add State Trends	Medium 2007 Tax States	Medium 2007 Tax States; Add State Trends	High 2007 Tax States	High 2007 Tax States; Add State Trends
Current Smoker	-0.009**	-0.023**	0.004	-0.005	-0.005	-0.004
	[0.004]	[0.011]	[0.007]	[0.012]	[0.009]	[0.014]
Frequent Smoker	-0.010**	-0.025**	0.001	0.004	-0.005	0.002
	[0.004]	[0.009]	[0.003]	[0.008]	[0.006]	[0.006]
Observations	114,078	114,078	275,070	275,070	148,172	148,172

Notes: Results are estimated using the combined state and national YBRS sample.
Bootstrapped standard errors are shown in square brackets.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.
States included in the low tax group are AL, GA, FL, KY, IA, LA, MS, MO, NC, ND, SC, TN, and VA.
States included in the medium tax group are AR, CA, CO, DC, DE, ID, IL, IN, KS, MD, MN, NE, NV, NH, NM, NY, OH, OK, OR, PA, TN, UT, WV, WI, and WY.
States included in the high tax group are AK, AZ, CT, HI, ME, MA, MI, MT, NJ, RI, SD, VT, and WA.

Appendix Table 1 — Estimated Effects of Cigarette Taxes on Youth Smoking from Linear Probability Models

	1991-2005	1991-2013	2007-2013
		State YRBS	
Current Smoker	-0.027***	-0.011**	0.006
	(0.009)	(0.005)	(0.006)
Frequent Smoker	-0.023***	-0.006	0.004
	(0.007)	(0.004)	(0.004)
N	431,298	913,239	481,941
		National YRBS	
Current Smoker	-0.036**	-0.022**	-0.012
	(0.018)	(0.010)	(0.023)
Frequent Smoker	-0.025*	-0.010*	-0.008
	(0.014)	(0.006)	(0.018)
N	103,837	159,216	55,318
		Combined State and National YRBS	
Current Smoker	-0.022***	-0.012*	0.008*
	(0.007)	(0.006)	(0.004)
Frequent Smoker	-0.017***	-0.010**	0.006**
	(0.005)	(0.004)	(0.003)
N	535,135	1,072,455	537,320

Notes: Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.
CC=Carpenter and Cook (2008), HSR=Hansen, Sabia, and Rees (2017).
Survey weights applied when the analysis sample uses data solely from the national YRBS.

Appendix Table 2 — Estimated Effects of Cigarette Taxes on Youth Smoking using Different Functional Forms

	(1)	(2)	(3)	(4)	(5)
Panel A: Youth is a current smoker					
Cigarette Taxes	-0.012*	-0.021***	-0.007	-0.033	-0.029
	(0.006)	(0.006)	(0.015)	(0.042)	(0.085)
Cigarette Taxes^2		0.003***	-0.003	0.019	0.013
		(0.001)	(0.007)	(0.032)	(0.090)
Cigarette Taxes^3			0.001	-0.006	-0.003
			(0.001)	(0.010)	(0.044)
Cigarette Taxes^4				0.001	0.000
				(0.001)	(0.010)
Cigarette Taxes^5					0.000
					(0.001)
Panel B: Youth is a frequent smoker					
Cigarette Taxes	-0.010**	-0.016***	-0.011	-0.065+	-0.093
	(0.004)	(0.005)	(0.010)	(0.036)	(0.083)
Cigarette Taxes^2		0.003***	-0.000	0.044	0.078
		(0.001)	(0.005)	(0.028)	(0.088)
Cigarette Taxes^3			0.001	-0.014	-0.032
			(0.001)	(0.009)	(0.041)
Cigarette Taxes^4				0.002	0.006
				(0.001)	(0.009)
Cigarette Taxes^5					-0.000
					(0.001)
Observations	1,072,455	1,072,455	1,072,455	1,072,455	1,072,455

Notes: Results are estimated using the combined state and national YBRS sample and linear probability models.
Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.

Appendix Table 3 — Estimated Effects of Cigarette Taxes on Youth Smoking using Different Functional Forms

	(1)	(2)	(3)	(4)	(5)
Panel A: Youth is a current smoker					
Cigarette Taxes	0.004	-0.017**	-0.023	-0.038	-0.209
	(0.008)	(0.008)	(0.019)	(0.063)	(0.144)
Cigarette Taxes^2		0.004***	0.006	0.018	0.213
		(0.001)	(0.010)	(0.047)	(0.147)
Cigarette Taxes^3			-0.000	-0.004	-0.103
			(0.001)	(0.014)	(0.067)
Cigarette Taxes^4				0.000	0.023
				(0.001)	(0.014)
Cigarette Taxes^5					-0.002
					(0.001)
Panel B: Youth is a frequent smoker					
Cigarette Taxes	0.001	-0.013***	-0.027*	-0.039	-0.111
	(0.005)	(0.005)	(0.011)	(0.037)	(0.091)
Cigarette Taxes^2		0.003***	0.009	0.019	0.101
		(0.001)	(0.006)	(0.027)	(0.093)
Cigarette Taxes^3			-0.001	-0.004	-0.045
			(0.001)	(0.008)	(0.043)
Cigarette Taxes^4				0.000	0.010
				(0.001)	(0.009)
Cigarette Taxes^5					-0.001
					(0.001)
Observations	1,072,455	1,072,455	1,072,455	1,072,455	1,072,455

Notes: Results are estimated using the combined state and national YBRS sample and linear probability models.
Standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.

Appendix Table 4 — Youth Smoking and Cigarette Excise Taxes
Combined National and State YRBS: 2007–2013
Linear Probability Model

Youth is a current smoker	(1)	(2)	(3)	(4)	(5)
Cigarette Taxes	-0.015**	-0.012	-0.153	0.425	1.509
	[0.006]	[0.045]	[0.128]	[0.520]	[0.870]
Cigarette Taxes^2		-0.001	0.136	-0.692	-2.901
		[0.015]	[0.122]	[0.751]	[1.722]
Cigarette Taxes^3			-0.038	0.439	2.536
			[0.034]	[0.426]	[1.643]
Cigarette Taxes^4				-0.096	-1.026
				[0.083]	[0.747]
Cigarette Taxes^5					0.156
					[0.129]
Youth is a frequent smoker					
Cigarette Taxes	-0.008*	0.010	-0.102	0.287	-0.645
	[0.004]	[0.022]	[0.078]	[0.297]	[0.633]
Cigarette Taxes^2		-0.006	0.103	-0.454	1.446
		[0.007]	[0.075]	[0.415]	[1.211]
Cigarette Taxes^3			-0.030	0.291	-1.512
			[0.021]	[0.234]	[1.099]
Cigarette Taxes^4				-0.064	0.735
				[0.046]	[0.475]
Cigarette Taxes^5					-0.134
					[0.078]
Observations	114,078	114,078	114,078	114,078	114,078

Notes: Results are estimated using the combined state and national YBRS sample and linear probability models.
Bootstrapped standard errors, clustered at the state level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions control for youth demographic characteristics (gender, race/ethnicity, grade levels, and age), state-level covariates (comprehensive smoke-free air laws, state unemployment rates, and natural logarithm of per capita personal income), and state and year fixed effects.