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CIGARETTE TAXES, SMOKING, AND HEALTH IN THE LONG-RUN

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Cigarette Taxes, Smoking, and Health in the Long-Run
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ABSTRACT

Medical experts have argued forcefully that using cigarettes harms health, prompting the adoption of myriad anti-smoking policies. The association between smoking and mortality may, however, be driven by unobserved factors, making it difficult to discern the underlying long-term causal relationship. In this study, we explore the effects of cigarette taxes experienced as a teenager, which are arguably exogenous, on adult smoking participation and mortality. A one-dollar increase in teenage cigarette taxes is associated with an 8 percent reduction in adult smoking participation and a 6 percent reduction in mortality. Mortality effects are most pronounced for heart disease and lung cancer.

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1. Introduction

In 1964, the Surgeon General's report warned Americans about possible health hazards of smoking cigarettes, including respiratory disease, cancer, and heart disease (Centers for Disease Control and Prevention 2014). Since then, policymakers around the world have aggressively pursued tobacco control efforts, despite the fact that much of the evidence on the long-term harms of smoking comes from correlational studies published in the medical literature that typically account for only a limited number of confounding factors such as age, sex, location, education, and occupation.

This reliance on correlational studies leaves open the possibility that the smoking-mortality association is driven, at least in part, by selection on unobserved factors such as prudence, precaution, or a predisposition to other illness (Fang et al. 2007). Indeed, smoking initiation is associated with indicators of poor health (Adda and Lechene 2013), and recent estimates from structural dynamic models suggest that unobserved health is an important correlate of smoking decisions (Darden 2017; Darden et al. 2018).

In this paper, we combine data from several sources to estimate the long-run effects of cigarette taxes experienced as a teenager on smoking and mortality. We focus on cigarette taxes experienced as a teenager for two reasons. First, teenage smoking is particularly sensitive to cigarette taxes, especially among the cohorts for whom we can observe mortality (Carpenter and Cook 2008; Lillard et al. 2013; Hansen et al. 2017).[1] Second, most smokers take up the habit before reaching the age of 20 (Lillard et al. 2013; Holford et al. 2014), and teenage smoking is strongly correlated with smoking later in life (Chassin et al. 1996; Gruber 2001; Glied 2002;

[1] A large literature provides evidence that, while cigarette taxes in adulthood reduce adult smoking, the magnitude of this effect is small, with most studies producing elasticities in the range of -0.1 to -0.3 (DeCicca and McLeod 2008; Callison and Kaestner 2014; DeCicca et al. 2020).

Gilleskie and Strumpf 2005), suggesting that cigarette taxes experienced as a teenager are a plausibly exogenous source of variation in lifetime smoking.

Our analysis begins by exploring the effect of teenage cigarette taxes on adult smoking. We combine data from the Tobacco Use Supplement to the Current Population Survey (TUS-CPS) with annual state cigarette tax rates from 1957 to the present. We regress adult smoking participation on teenage taxes, controlling for state fixed effects, age-specific cohort effects, state-specific linear time trends, and adult-dated policy variables (including state cigarette taxes). The identifying assumption is that changes in cigarette taxes are unrelated to pre-existing trends in smoking and mortality. The results suggest that adult smoking is sensitive to taxes experienced as a teenager: specifically, a one-dollar increase in teenage taxes reduces adult smoking by 1.8 percentage points on a base of 23 percent. While a large literature has investigated the sensitivity of teenage and adult smoking to the contemporaneous taxes on cigarettes, our study is among the first to explore longer-run effects.

To measure how this reduction in adult smoking translates into health, we combine the historical data on cigarette taxes with the universe of death certificates in the U.S. from 1990 to 2018. These data include detailed information on cause of death, allowing us to identify mortality that is likely related to smoking. Using the same empirical approach as described above, we find that a one-dollar increase in cigarette taxes experienced as a teenager reduces adult mortality by 24 per 100,000 population, a decrease of 6 percent. This reduction is driven by men (whose smoking behavior exhibited greater tax sensitivity), and three-quarters of the estimated effect comes from reductions in illnesses that are known to be caused by smoking cigarettes, including diabetes and specific types of heart disease, cancer, and respiratory disease. In support of our identifying assumption, we show that teenage cigarette taxes are not associated with accidental deaths or homicides, suggesting that their estimated effects on smoking-related illnesses are not driven by underlying trends in risky behavior. Our results suggest that cigarette tax increases over the course of the 20th century produced long-lasting reductions in adult smoking and mortality. More broadly, they provide support for the notion that efforts to reduce teenage smoking—through cigarette taxes, raising the minimum legal purchase age, or other mechanisms—will yield lifelong health benefits.

The remainder of this paper proceeds as follows. In the next section, we situate our results in the context of the literature on smoking, taxes, and mortality. In Section 3 we describe the smoking, mortality, and tax data. Section 4 explains the empirical methods employed, Section 5 reports our results, and Section 6 concludes.

2. Background and Contribution

The consensus view is that cigarette smoking causes lung cancer, heart disease, and a host of other serious ailments. Emerging in the late 1950s and early 1960s, the consensus view was famously summarized by the U.S. Surgeon General's Report of 1964.[2] Based on the results of case-control and prospective studies—as well as results from laboratory and clinical studies such as autopsies and animal experiments—cancer societies, medical associations, and national task forces around the world reached similar conclusions (Bayne-Jones. 1964).

Early evidence on the risks of smoking came from case-control studies showing smoking rates were higher among patients with lung cancer than among controls with other cancers (e.g., Doll and Hill 1950). Subsequent evidence came from prospective studies, which surveyed large samples of (typically) men about their smoking history, and then measured mortality in the

[2]The Surgeon General's Report of 1964 concluded that "cigarette smoking contributes substantially to mortality from certain specific diseases and to the overall death rate" (Bayne-Jones, 1964, p. 31).

following years or decades. Often-cited examples of prospective studies include Doll and Hill (1954, 1964), Hammond and Horn (1958), and Doll et al. (2004), all of which conditioned on age, sex, and occupation, but did not account for selection on unobservables.[3] More recent work (Jha et al. 2013; Pirie et al. 2013; Carter et al. 2015) has taken a similar empirical approach, adjusting for a limited number of factors such as age, sex, alcoholism and adiposity, but not taking into account the influence of difficult-to-measure factors at the individual level, including prudence, precaution, and any predisposition to other illnesses. We might expect these difficult-to-measure factors to be correlated with smoking because of what Fang et al. (2007) termed the "Mickey Mantle Effect": individuals who expect to die at a young age could behave recklessly in other aspects of their lives.[4] The Mickey Mantle Effect may have been especially pronounced for smokers in the second half of the 20th century, who were likely to have been aware of the health risks associated with smoking (Khwaja et al. 2009).

One promising method of controlling for the influence of unobservables is to exploit arguably exogenous changes in policy. In this study, our focus is on exposure to cigarette taxes during adolescence, when most smokers initiate (Lillard et al. 2013; Holford et al. 2014). As noted in the introduction, prior work suggests that teenagers are particularly sensitive to cigarette prices, which may be because they are not yet addicted and are not earning as much as adults.[5]

[3] Indeed, the literature recognized (but did not attempt to solve) the problem of selection on unobservables—in particular, the concern that people with high mortality expectations might be more likely to start smoking or less likely to give it up. Comparing smokers to people who had recently quit, Doll and Hill (1964, p. 1402) wrote, "a man who suspects that he has developed a fatal disease is unlikely to quit smoking; therefore men who have recently given it up may form a relatively healthy group."

[4] Mickey Mantle was an all-star baseball player whose career was derailed by injury and alcoholism. He died of cancer at 63 after experiencing liver failure. Mantle "explained his reckless behavior by noting he never expected to live past his early 40s, as most males on his father's side died young due to Hodgkin's disease" (Fang et al. 2007, p. 53-54).

[5] Hansen et al. (2017) provide evidence that more recent cigarette tax increases have done little to discourage youth from smoking.

The fact that teenage and adult smoking are so highly correlated (Paavola et al. 1996) suggests that understanding the long-run causal effects of exposure to cigarette taxes early in life is key to estimating the welfare impacts of anti-smoking legislation.[6]

There is a paucity of evidence on the relationship between cigarette taxes and long-run smoking behaviors. Most previous studies have focused on documenting contemporaneous effects. Their results suggest that, unlike teenagers, adults are not particularly responsive to changes in cigarette prices and taxes (DeCicca et al. 2020, pp. 41-43). For example, using data from the Tobacco Use Supplement to the Current Population Survey for the period 1995-2007, Callison and Kaestner (2014) found that a 10 percent increase in the cigarette tax is associated with a 0.2 to 0.4 percent decrease in smoking participation among adults ages 35-54. DeCicca et al. (2020) conclude that most studies estimate price elasticities of adult smoking participation between -0.1 and -0.3.

Teenagers appear to be more responsive to changes in cigarette prices and taxes. Using data on U.S. high school students from the Youth Risk Behavior Surveys (YRBS), Hansen et al. (2017) found that a one-dollar increase in the cigarette tax was associated with a contemporaneous reduction in the probability of smoking of .031, or 12 percent relative to the mean. Carpenter and Cook (2008), who also used data on U.S. high school students from the YRBS, found that the contemporaneous relationship between taxes and participation (i.e., $\frac{\partial \Pr(Smoke=1)}{\partial Tax}$) ranged from -.027 to -.059. Using data from the Panel Study of Income Dynamics, Lillard, Molloy, and Sfekas (2013) found that a one-dollar increase in the cigarette

[6] Gruber and Kőszegi (2004) and O'Donoghue and Rabin (2006) noted that welfare calculations for "sin taxes" such as tobacco taxes are not straightforward if individuals have time-inconsistent preferences.

tax was associated with a .031 reduction in the probability that 13- through 17-year-olds smoked regularly.

Only two previous studies have estimated the long-run association between cigarette taxes and smoking (Gruber and Zinman, 2001; Glied 2002). Gruber and Zinman (2001) used data from birth certificates to estimate the association between teenage cigarette taxes and smoking during pregnancy, adjusting for cohort and state fixed effects. These authors found small negative effects on smoking, which is perhaps unsurprising given that women are advised against smoking during pregnancy (so those who do may be particularly price-inelastic).[7] Using data from the 1979 National Longitudinal Survey of Youth, Glied (2002) found that taxes at age 14 were not predictive of smoking at age 39. Glied's empirical design differed from ours in that she did not adjust for state-specific fixed effects and was, as a consequence, unable to account for the effects of potentially persistent state-level unobservables such as anti-smoking sentiment.[8]

Our analysis also builds upon previous work by Moore (1996) and Bowser, Canning and Okunogbe (2016), who studied the contemporaneous (or near-contemporaneous) effects of cigarette taxes on state-level mortality rates. Moore (1996) found that increases in state cigarette taxes led to an almost immediate reduction in adult mortality from heart disease and respiratory cancers, holding constant deaths from other causes. However, because smoking may crowd-out

[7] See also recent efforts to estimate the effects of anti-smoking legislation on various birth outcomes (Evans and Ringel 2001; Lien and Evans 2005; Simon 2012; Bharadwaj et al. 2014). For example, Bharadwaj et al. (2014) found that the introduction of smoking bans in restaurants and bars led to reductions in maternal smoking and improved infant health. Simon (2012) found that in-utero exposure to higher cigarette taxes led to improvements in health during childhood.

[8] See also Auld and Zarrabi (2015). Using data from the Canadian Community Health Survey, Auld and Zarrabi (2015) found that exposure to higher cigarette prices in adolescence was associated with a reduced likelihood of smoking as an adult. These authors did not, however, observe cigarette taxes, which are plausibly more exogenous to local factors than prices (Gruber and Frakes 2006).

(or crowd-in) other causes of death, this association is difficult to interpret. Bowser, Canning and Okunogbe (2016) found a strong, negative association between cigarette taxes and adult mortality, suggesting the importance of controlling for contemporaneous cigarette taxes (i.e., cigarette taxes experienced during adulthood) when attempting to gauge the long-run effects of cigarette taxes experienced as a teenager.

Finally, our analysis complements the seminal work of Darden (2017) and Darden et al. (2018). These authors estimated dynamic, stochastic models of smoking behaviors and health over the life cycle using data from the Framingham Heart Study, which followed the lives of approximately 5,000 individuals starting in 1948 and collected rich information on health behaviors and outcomes. Darden (2017) found compelling evidence of selection: smoking at age 30 is highly correlated with the unobserved component of health. Darden et al. (2018) found that controlling for this unobserved heterogeneity is important: models that do not control for unobserved heterogeneity imply that smoking reduces life expectancy by 10 years, but models that do control for it yield an estimated effect only half as large. Our contribution is to provide direct evidence on the causal path from lifelong smoking to health by estimating the effects of cigarette taxes experienced as a teenager on adult smoking and mortality.

3. Data

3.1. The Tobacco Use Supplement to the Current Population Survey

We measure smoking participation using data from the Tobacco Use Supplement to the Current Population Survey (TUS-CPS), a National Cancer Institute-sponsored cross-sectional survey, administered every 3-4 years since 1992-1993 as a part of the Current Population Survey. It collects nationally representative data from U.S. adults and can be used to monitor smoking trends and assess the effectiveness of tobacco-related policies and programs. Each wave of the TUS-CPS includes information on approximately 240,000 respondents.

Several steps were taken to obtain the analytic sample. Because our interest is in estimating the effects of cigarette taxes experienced as a teenager on adult smoking participation, we restrict our analysis to TUS-CPS respondents ages 20 and older. Respondents residing outside the 50 states and the District of Columbia were excluded from the analysis due to a lack of information on cigarette taxes. In addition, we limit the TUS-CPS to U.S.-born respondents because we cannot accurately measure teenage taxes for foreign-born residents, a majority of whom migrated to the United States as adults (Camarote and Zeigler 2019). Finally, the sample is restricted to observations with non-missing smoking measures and covariates, effectively limiting it to respondents born in 1943 or later because our covariates include state unemployment rates experienced as a teenager (ages 14-17), which are unavailable before 1957. Our sample consists of 1,060,693 observations from the TUS-CPS covering the period 1992-2018. Summary statistics are reported in Panel A of Table 1.

3.2. U.S. death certificates

To measure the long-run effects of cigarette taxes on mortality, we use microdata consisting of the universe of death certificates for the U.S. These data were obtained from the Division of Vital Statistics (DVS) at the National Center for Health Statistics (NCHS) and cover the years 1990-2018. Our focus is on these years because the 1990 Census is used to denominate death rates and because the U.S. standard death certificate was revised in 1989 (Hetzel, 1997).

Death certificates include information on age at death, sex, and state of birth.[9] Following Gruber and Zinman (2001), we use state of birth to proxy for state of residence during adolescence.

Death certificates also give an underlying cause of death, indicated by an International Classification of Disease (ICD) code.[10] We use the ICD code to identify diseases that are known to be caused by smoking cigarettes, following the Centers for Disease Control's method of calculating "smoking-attributable mortality" (CDC 2014, Lariscy 2019). These diseases include specific types of cancer (e.g., lung cancer, esophageal cancer, and stomach cancer), respiratory disease, and heart disease, as well as diabetes.[11] Appendix A lists the ICD codes corresponding to these diseases. These diseases are those for which the CDC determines that there is sufficient evidence, drawn from a literature review of medical studies, to infer a causal link between smoking cigarettes and the specified disease. [12] Our definition of "smoking-related mortality"

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[9] Mortality records for the period 1990-2004 are available publicly and can be downloaded from this link: https:
//www.cdc.gov/nchs/data access/vitalstatsonline.htm. From 2005 onward, state of birth is not available in the public-use data. Researchers can obtain a restricted-use version of the death certificate data that contain state of birth by submitting an application to the National Vital Statistics System at the National Center for Health Statistics, found here: https://www.cdc.gov/nchs/nvss/nvss-restricted-data.htm.

[10] For years 1990-1998, ICD-9 codes are provided. Starting in 1999, ICD-10 codes are provided.

[11] While the death certificate includes an indicator for whether tobacco use contributed to death, it is inconsistently reported. Some states do not require reporting during our sample period and the variable is missing for a large share of observations in states that do. Deaths included in our smoking-related category may therefore be caused by factors unrelated to smoking (e.g., diet may contribute to deaths due to heart disease). Using data from 2005 to 2009, the CDC estimates that 33 percent of deaths due to the causes used to define "smoking-related" are directly attributable to smoking (49 percent of cancer deaths, 82 percent of lung cancer deaths, 62 percent of respiratory diseases, and 20 percent of heart disease and diabetes deaths).

[12] Specifically, to calculate "smoking-attributable mortality," the CDC takes the following steps. First, they identify all deaths in the mortality records due to diseases known to be caused by smoking (as we do). Then, they multiply the mortality counts for each disease category by a risk ratio equal to the share of those deaths thought to be caused by smoking (as opposed to other factors, such as diet). Examples of these risk ratios are given in Footnote 11. Finally, they add up the resulting sums of "smoking-attributable" deaths across disease categories. To differentiate from this method, we call our category of deaths linked to smoking "smoking-related mortality."

therefore excludes deaths caused by diseases that may be linked to smoking but for which there is a limited evidence base.[13] In addition, it excludes deaths that are indirectly caused by smoking. For example, smoking is known to be a leading cause of home fires, which may be fatal (FEMA 2012).[14]

For the purpose of conducting placebo exercises, we also created a category of deaths caused by external forces unlikely to have been smoking-related. Specifically, this category is composed of homicides and accidental deaths (except for those due to fire and flames, which may be caused by cigarettes). Appendix A lists the ICD codes that correspond to these categories, which follow definitions used by the NCHS. Thus, our category of placebo deaths excludes those directly due to the adverse health effects of smoking, although it should be noted that we cannot rule out indirect effects of smoking on some of our placebo causes. For example, the adverse health effects of smoking could increase the likelihood of accidental death due to falling.[15]

The death certificate data are used to produce mortality counts for adults at least 20 years of age (and born in 1943 or later) at the birth-state by birth-year by death-year level. In some specifications, we examine sex-specific effects by disaggregating to sex-specific cells. To

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[13] In fact, the CDC also publishes a separate list of "associated diseases" for which the evidence is "suggestive of" a causal link with smoking.

[14] Finally, smoking cigarettes could lead to other forms of risky behavior that could elevate mortality risk. For example, there is evidence to suggest that cigarettes serve as a complement to alcohol (Decker and Schwartz 2000; Tauchmann et al. 2013). In addition, smoking has been shown to increase the severity of certain underlying conditions, either directly or by interfering with treatment. For example, nicotine can promote tumor growth in cancer patients (CDC 2014). Thus, it is important for us to consider both smoking-attributable mortality and all-cause mortality to gauge the full effect of smoking on long-run mortality.

[15] To take another example, it is possible that the act of smoking encourages other types of risky behavior, leading to more fatal accidents. As mentioned above, evidence that alcohol and cigarettes are complements comes from Decker and Schwartz (2000) and Tauchmann et al. (2013).

convert these death counts into per-capita mortality rates, we calculate the population in year 1990 at the birth-state by cohort level using the 5% sample from the 1990 Census (which includes information on state of birth) and then age forward these estimates to cover the period 1990-2018.[16] Dividing the death counts by this population estimate gives the relevant mortality rate. For example, we divide the number of individuals born in New York in 1950 who died in 2000 by our population estimate (i.e., the estimated number of individuals born in New York in 1950 who were still alive in 2000) to obtain the age-50 mortality rate for this cell. Gross death counts and mortality rates are reported in Panel B of Table 1.

3.3. Cigarette taxes

Prior research often uses variation in cigarette taxes rather than prices to estimate the price elasticity of smoking because policy-driven variation is arguably more exogenous to local conditions than prices (Gruber and Frakes 2006). State and federal cigarette taxes come from historical data collected by Orzechowski and Walker (2019). The cigarette tax in year *t* (i.e., the adult tax, $tax_{s(i)t}$) is measured as the real (i.e., 2005 dollars) combined state and federal cigarette per-pack excise tax for state s and year t. Federal tax changes do not contribute to identification because our models account for year fixed effects.

To measure the teenage tax, we would ideally match each respondent to his or her teenage state of residence and measure $Teen\ Tax_i$ as the average cigarette tax in effect while i was between the ages of 14 and 17. This choice of age range follows Gruber and Zinman (2001), although our results are robust to using alternative age ranges. When analyzing data

[16] Note that the population counts we construct exclude individuals from a given birth state who died or left the U.S. prior to 1990, as they would not appear in the 1990 Census.

from the TUS-CPS, we impute $Teen\ Tax_i$ under the assumption that i's current state of residence (i.e., her state of residence when surveyed as an adult) is where she lived as a teenager. When analyzing data from mortality records, we impute $TeenTax_i$ under the assumption that *i's* birth state is where she lived as a teenager. Specifically, we impute $Teen\ Tax_i$ as follows:

$$Teen\ Tax_i = \frac{1}{4}\sum_{\tau=14}^{\tau=17} tax_{s(i),y(i)+\tau}\,.$$

Here, $y(i)$ is i's year of birth and $s(i)$ is their current state of residence (TUS-CPS) or birth state of residence (death certificates). Our measure of $Teen\ Tax_i$ is the average per-pack cigarette tax in i's state of residence at ages of 14-17. We average over these ages rather than examining the effects of cigarette taxes at particular ages (e.g., at age 14, at age 15, etc.) to improve the precision of our estimates and simplify the analysis.

Changes in the real state cigarette tax rate occurring over the period 1957-2015 identify the effect of $Teen\ Tax_i$ on adult smoking. There were 477 changes in state cigarette taxes stemming from legislation during this period, with rich temporal and geographic variation (Appendix Figure 1). Before 1990, most cigarette tax increases were modest in terms of magnitude, but state cigarette taxes increased dramatically in the 1990s and 2000s. The interquartile range is from \$0.061 to \$0.24 per pack (Appendix Figure 2) However, there is a long right-hand tail to this distribution: there were 70 changes in the per-pack cigarette tax stemming from legislation between \$0.24 and \$0.50; there were 49 changes between \$0.50 and \$1.00; and there were 3 changes between \$1.00 and \$1.42.[17]

[17] Appendix Figure 3 shows the average per-pack cigarette tax in 2005 dollars during the period 1957-2015.

Imputing $Teen\ Tax_i$ based on the current state of residence or birth state, rather than the state of residence as a teenager, plainly creates measurement error. In the smoking analysis, we limit this measurement error by restricting the sample to TUS-CPS respondents born in the United States because most foreign-born residents migrated to the United States after their teenage years (Camarote and Zeigler 2019). This likely reduces, but certainly does not eliminate, measurement error in our estimates of the effects of teen cigarette taxes on adult smoking. However, we expect that measurement error that occurs as a result of imputing the teenage tax is roughly classical, in the sense that we do not think that we are systematically over- or under-stating teenage taxes. The consequence of this classical measurement error is that we may underestimate the effect of teenage taxes on both adult smoking and adult mortality.[18] Information on the cigarette taxes used in our analysis are reported in Table 1.

3.4. Adult and teen-dated state-level variables

To address concerns that cigarette taxes may be correlated with other anti-tobacco policies or economic conditions, we include a set of state-level variables on the right-hand side of our estimating equations. Specifically, we control for the unemployment rate, whether smoking was banned in public areas, and indicators for the minimum legal purchase age. Because our interest is in the effect teenage cigarette taxes on adult outcomes, we control for not only the current (adult-dated) state-level variable but also its value during adolescence. We define the teenage-dated variables analogously to $Teen\ Tax_i$, assuming that the respondent currently lives in his or her teenage state of residence and we set teenage-dated state-level

[18] It seems plausible that birth state is more highly correlated with teenage state of residence than it is with adult state of residence. If so, then our estimates of the effects of teenage taxes on adult smoking participation may be attenuated as comparted to our estimates of their effects on mortality.

variables equal to their average value when i was aged 14 -17. For example, we define $unemp_i^{teen}$, the teenage unemployment rate for respondent i as:

$$unemp_i^{teen} = \frac{1}{4}\sum_{\tau=14}^{\tau=17} unemp_{s(i),y(i)+\tau},$$

where $y(i)$ is i's year of birth and $s(i)$ is their state of residence in year t. [19]

4. Methods

4.1. Specifications

We begin our analysis by reporting ordinary least squares (OLS) estimates of the following regression:

$$AdultSmoking_{it} = \alpha_1 Teen\,Tax_i + \alpha_2 tax_{s(i)t} + \boldsymbol{X}_{it}\boldsymbol{\alpha}_3 + \boldsymbol{W}_{s(i)t}\boldsymbol{\alpha}_4 + \boldsymbol{W}_i^{teen}\boldsymbol{\alpha}_5 \qquad (1)$$

$$+\mu_{s(i)} + \gamma_{s(i)} \cdot t + \epsilon_{it}\,.$$

Our interest is in α_1, the coefficient on $TeenTax_i$, which, under the identification conditions discussed below, gives the relationship between cigarette taxes experienced when respondent *i* was a teenager and the probability that *i* smoked in year *t*. We control for individual-level characteristics (represented by the vector $\boldsymbol{X}_{it}$), contemporaneous state-level observables

[19] MLPAs for the period 1957-2018 (when the respondents in our sample were between the ages of 14 and 17) are from Downey (1981), Unknown Author (1996), Yan (2014), Committee on the Public Health Implications of Raising the Minimum Age for Purchasing Tobacco Products (2015), and Ballotpedia (2020). State unemployment rates for the period 1976-2018 are from the U.S. Bureau of Labor Statistics' Local Area Unemployment Statistics (https://www.bls.gov/lau/). State unemployment rates for the period 1957-1975 come from U.S. Bureau of the Census (1970, 1971, 1972, 1974, 1977) and Manpower Report of the President (1966, 1973). Information on comprehensive smoke-free laws for worksites, restaurants, and bars comes from the Centers for Disease Control and Prevention (2020).

(represented by the vector $\boldsymbol{W}_{s(i)t}$), state fixed effects ($\mu_{s(i)}$), and state-specific linear trends ($\gamma_{s(i)} \cdot t$). In our baseline specification, the individual-level characteristics are simply a set of birth-year by age fixed effects (which subsume the time fixed effects), although the results reported below are robust to controlling further for indicators for gender, race, and education. The state-level observables include the unemployment rate in year t, indicators for the minimum legal cigarette purchase age (MLPA) for tobacco products, and an indicator for whether there was a comprehensive ban on smoking in public areas. We control for both the year-t value of these variables ($\boldsymbol{W}_{\boldsymbol{s(i)t}}$) as well as their average value for the years when i was a teenager ($\boldsymbol{W}_i^{teen}$).

To estimate the effect of $TeenTax_i$ on mortality in year t, we estimate a variant of equation (1), but with data aggregated to the birth state-cohort-year level for computational ease. There is little loss from this aggregation because our key regressor, $TeenTax,$ varies at the birth-state by birth-year level. The mortality rate in year t of the cohort born in year c and state s is given by the following equation:

$$MortalityRate_{cst} = \beta_1 TeenTax_{cs} + \beta_2 tax_{cst} + \boldsymbol{X}_{ct}\boldsymbol{\beta}_3 + \boldsymbol{W}_{st}\boldsymbol{\beta}_4 + \boldsymbol{W}_c^{teen}\boldsymbol{\beta}_5 \qquad (2)$$
$$+\mu_s + \gamma_s \cdot t + \epsilon_{cst},$$

where the mortality rate is calculated as the death count divided by population in each cell (as estimated from the 1990 census). As in equation (1), the individual characteristics $\boldsymbol{X}_{\boldsymbol{it}}$ include a set of birth-year by age fixed effects which subsume time fixed effects. Observations are weighted by population (i.e., the denominator of the mortality rate).

Our interest is in β_1, the effect of a one-dollar increase in the teenage cigarette tax on the mortality rate. Although we control for birth-year by age fixed effects, teenage and adult policy variables, and state-specific time trends, we note three important differences between equations (1) and (2). First, we lack detailed individual-level covariates in the death certificate data and therefore do not explore robustness to including controls such as gender, race, and education. Second, the adult-dated variables correspond to the year of death (as opposed to the year in which the TUS-CPS was administered).[20] Third, the state-level variables in the TUS-CPS analysis are based on adult state of residence because we do not observe state of residence as a teenager. In the death certificate data, we observe state of birth (as well as state of death) and aggregate to the birth-state by birth-year by death-year level.[21] Teenage taxes and the adult-policy variables are imputed under the assumption that the teenage and adult states are the same as the birth state.

4.2. Identification

Equations (1) and (2) will give unbiased estimates of the effect of teen taxes on adult smoking and mortality if teen tax is uncorrelated with unobserved determinants of smoking or mortality. In practice, this means that we have modelled all relevant sources of confounding.

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[20] Because they are measured at time *t*, the adult-dated controls are potentially endogenous. Below, we present results with and without controlling for the adult-dated policy variables.

[21] We do not aggregate to birth-state by death-state by birth-year by death-year level for three reasons. First, some of these cells are very thin (e.g., individuals born in 1943 Rhode Island and dying in Wyoming in 1990), making it difficult to precisely measure the denominator of the death rate in the 5% Census data (i.e., the population alive in each cell in 1990, which in this example would be the number of people born in Rhode Island in 1943 and living in Wyoming in 1990). Second, we do not observe state of residence after 1990 in the Census, so calculating denominators would involve assumptions about cross-state mobility rates. Finally, the death state is arguably endogenous in the sense that adult location is determined after exposure to cigarette taxes as a teenager.

Our specification is designed to address several potentially important sources of confounding. We have a rich set of fixed effects (i.e., birth-year by age and state fixed effects) that control for many potential concerns. For example, we control for general aging effects (important for both smoking and mortality) and cohort effects with birth-year by age fixed effects. These fixed effects also control for common trends in mortality and in anti-tobacco sentiment. State fixed effects control for permanent differences across states, and state-specific linear trends address the concern that changes in the cigarette tax are somehow linked to slow-moving changes in anti-tobacco sentiment that may themselves independently affect smoking or mortality.

A further concern, however, is that $TeenTax$ changes at the same time as other policy variables, possibly reflecting sharp shifts in anti-tobacco sentiment. We address this concern by controlling for other teenage-dated policy variables as well as teenage-dated economic conditions (which may also influence $TeenTax$). Many state policy variables are highly persistent over time, so the association between $TeenTax$ and $AdultSmoking$ may reflect the effect of current, rather than teenage, taxes. We address this concern by controlling for adult-dated policy variables, including adult-dated cigarette taxes.

5. Results

5.1. Teenage cigarette taxes and adult smoking

In the first column of Table 2, we report the OLS estimate of α_1 from equation (1), the effect of teen taxes on adult smoking participation, for the pooled sample composed of both male and female TUS-CPS respondents. Its standard error, which is corrected for clustering at the state level, is reported in parentheses. The estimate of α_1 is negative and statistically significant at conventional levels, providing strong evidence that cigarette taxes experienced as a teenager affect adult smoking. Specifically, a one-dollar increase in the teenage cigarette tax is associated with a 1.8 percentage point reduction in adult smoking participation, which is 7.7 percent of the sample mean (23.3 percent).

In the remaining columns of Table 2, we report estimates of α_1 by the sex of the respondent. Among male TUS-CPS respondents, a one-dollar increase in the teenage cigarette tax is associated with a 2.1 percentage point reduction in adult smoking participation, which is 8.4 percent of the sample mean (25.0 percent). The estimated effect for female respondents is slightly smaller: a one-dollar increase in the tax is associated with a 1.5 percentage point reduction, or almost 7 percent relative to the mean (22.0 percent).[22, 23]

5.2. Teenage cigarette taxes and mortality

Table 3 reports OLS estimates of equation (2) for all-cause mortality. These estimates are weighted by cell size (i.e., by the number of people born population in state *s* and year *t*, and alive in 1990). Standard errors are corrected for clustering at the state level. In the pooled sample, a one-dollar increase in teenage cigarette taxes is associated with 24.09 fewer deaths per 100,000 population, which is 6.4 percent of the mean all-cause mortality rate (375.41). Again, there is evidence of more pronounced effects among men. A one-dollar increase in teenage cigarette taxes is associated with a 36.99 (8.0 percent) reduction in the male mortality rate. By contrast, a one-dollar increase in the teenage tax is associated with a 12.42 (4.0 percent)

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[22] We cannot, however, reject the hypotheses that the estimated effect of teenage cigarette taxes is the same for male and female respondents.

[23] Our estimate is smaller than many estimates of the contemporaneous effects of cigarette taxes on teenage smoking, which is perhaps unsurprising as smoking behavior may change in the years between adolescence and adulthood due to factors unrelated to teenage taxes. For example, Carpenter and Cook (2008) estimated that a one-dollar increase in taxes (in 2005$) decreases contemporaneous teen smoking by 3 to 6 percentage points, or 10 to 20 percent.

reduction in the female mortality rate. We can easily reject the hypothesis that these two estimated coefficients are equal in magnitude.

In Table 4, we focus on the relationship between teenage cigarette taxes and smoking-related deaths as defined by the CDC (2014). The results provide evidence that the reductions in all-cause mortality documented in Table 3 are largely driven by diseases known to be caused by smoking. Of the overall mortality effect, 77 percent comes from smoking-related causes of death. The share of deaths coming from smoking-related causes of death is also 77 percent for the subsets of men and women. In addition, compared to the effect for women on all-cause mortality, the coefficient on smoking-related disease is now statistically significant at the 5 percent level.

The fact that the all-cause mortality effects are larger than the corresponding effects for smoking-related mortality suggests that there may be additional deaths caused by smoking but excluded from our definition of smoking-related mortality. As explained above, the CDC requires that there be sufficient medical research to prove a causal link between smoking and a given disease to include it in "smoking-attributable mortality." The all-cause mortality estimates may reflect deaths caused by smoking but excluded from this definition due to the fact that medical research is lacking. Moreover, smoking may lead to behavioral changes (e.g., drinking) that independently raise an individual's mortality risk or worsen the severity of underlying conditions.

Next, we break down smoking-related mortality into its four components (certain types of respiratory disease, cancer, and heart disease, as well as diabetes).[24] We also break out the

[24] Recall that, with the exception of lung cancer, these categories include the (strict) subset of diseases known to be caused directly by smoking (i.e., "heart disease" does not include all deaths due to heart disease, but rather those due to the causes listed in Appendix A).

results for lung cancer separately (although it is still included in "cancer") due to its close association with smoking. Increases in teenage cigarette taxes are associated with statistically significant reductions in each of these causes (Table 5), although the estimated effect on lung cancer is only significant at the 10 percent level. The largest estimated effect is for heart disease: a one-dollar increase in teenage cigarette taxes is associated with a 9.49 reduction in deaths from respiratory disease, which is almost 40 percent of the estimated effect. It is important to keep in mind that our focus is on mortality among individuals between the ages of 20 and 75, and some smoking-related diseases (e.g., lung cancer) tend to manifest later in life than others.[25] The largest percentage decline is in mortality due to respiratory disease (a 16 percent decline relative to the mean). By comparison, the percentage effects for the other causes are -8 percent for cancer, -12 percent for lung cancer, -12 percent for heart disease, and -13 percent for diabetes.

5.3. Robustness

The results reported thus far appear to be robust to reasonable changes in specification. We present results obtained from alternative specifications in Appendix Tables A1-A4 and summarize them here. We begin by showing that the estimated effect of teenage cigarette taxes on adult smoking participation is robust to including controls for personal characteristics such as gender, race, and educational attainment (Appendix Table A1). These characteristics are included as additional controls and do not replace the birth-year by age fixed effects in the TUS-CPS analysis.

[25] For instance, the average age of lung cancer diagnosis is 70. While chronic obstructive pulmonary disorder (COPD) is generally diagnosed earlier in life than lung cancer, it develops slowly. Eighty-six percent of deaths due to COPD occur after the age of 65. Source: https://www.lung.org/research/trends-in-lung-disease/copd-trends-brief/copd-mortality

In Appendix Table A2, we report mortality effects obtained by dropping the adult-dated variables (which are potentially endogenous because they depend on year of death). Dropping these controls in fact strengthens our results, roughly doubling our estimates, suggesting that including them is the conservative choice. We experiment with alternative definitions of "teenage years," in Appendix Tables A3 and A4. Redefining the cigarette tax and policy variable so that they pertain to ages 11-19 has no appreciable effect on the results for adult smoking or mortality.

5.2. Placebo test

Our identifying assumption is that state-specific cigarette tax increases are unrelated to underlying trends in smoking and mortality. This assumption could fail, in particular, if taxes were driven by attitudes towards risk or risky behaviors. We provide an indirect test of this identifying assumption by examining the relationship between teenage cigarette taxes and accidental deaths from non-fire causes. In addition, we examine the relationship between teenage cigarette taxes and homicides. The logic for considering these outcomes is that they are unlikely to be directly affected by smoking, but they could be affected by attitudes towards risk, risky behaviors, and other potential confounds. A null effect for these placebo outcomes provides some assurance that the changes in smoking-related mortality observed in the data are not driven by underlying, difficult-to-observe trends.

We report the results of this placebo test in Table 6. In the pooled sample we observe small and statistically insignificant effects of teenage cigarette taxes on these outcomes. Likewise, the estimates by sex are small and statistically indistinguishable from zero. This pattern of results is not an artifact of small sample sizes or infrequent deaths. For the ages we study, accidental deaths from non-fire causes account for an eighth of total mortality and are about as common as all cancers (and are more common than deaths due to respiratory disease or lung cancer). Confidence intervals from the placebo causes of death allow us to rule out effects as large as 5 percent of the mean; in proportional terms, we can rule out effects half as large or larger than our estimated effect for all-cause mortality. In Appendix Table A5, we disaggregate the placebo estimates into separate effects on homicides, vehicle deaths, and other accidents (that is, all non-vehicle, non-fire accidents). We find null effects in each category. These null effects are particularly striking in contrast to results of observational studies, which find that smokers have higher rates of mortality not only from internal causes such as heart disease and lung cancer, but also deaths from external causes such as accidents and poisonings (Doll et al., 2004).[26]

6. Conclusion

In this study we establish a two key features of taxes on cigarettes over the long run. First, cigarette taxes experienced as a teen are effective at reducing smoking participation into adulthood. This result implies that these taxes do not simply delay smoking behavior until later in life but are effective at changing long-term habits. We do not observe to what extent this result is due to fewer individuals taking up the habit versus to what extent this is due to decreased duration of smoking (i.e., increased quitting).

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[26] Doll et al. (2004, p. 1521) interpret these external deaths as evidence of selection bias in most cases, writing “The excess mortality from “external” causes—accidents, injury, and poisoning—among smokers is unlikely to be due chiefly to smoking (although two men did die from fire because of smoking in bed) but, rather, is likely to be due to other behavioural factors with which smoking is associated, such as the heavy consumption of alcohol or a willingness to take risks.”

Second, our findings show a connection between cigarette tax exposure as a teenager and mortality risk when older, especially smoking-related mortality. Because these estimates are identified by changes in the cigarette tax experienced as a teenager, they are not driven by the selection into smoking of people with high mortality expectations, low discount rates, or low prudence. Our estimates provide clean evidence of a direct causal chain between smoking and health outcomes that is not available in the extant medical literature. In addition, our results suggest that the long-run impact of cigarette taxation is gendered. Men may be more responsive than women to cigarette tax increases experienced as a teenager; and the effect of cigarette tax increases experienced as a teenager on male mortality is clearly more pronounced than their effect on female mortality. While some of the mortality difference could be physiological, it could also reflect responsiveness of adult smoking to teenage cigarette taxes.

Between 2000 and 2010, there were 41 legislative increases in state cigarette taxes greater than \$0.75, and 18 of these tax increases were greater than \$1.00. Our results suggest that teenagers who were exposed to these recently enacted higher cigarette taxes will be less likely to smoke in adulthood. Thus, from a public health perspective, our findings imply that the largest health benefits from recently enacted cigarette taxes have yet to accrue: many of those who were exposed in their teens have not reached the age at which the most severe tobacco-related illnesses typically manifest.

7. References

Adda, Jérôme, and Valérie Lechene. 2013. "Health Selection and the Effect of Smoking on mortality." *The Scandinavian Journal of Economics*, 115(3): 902-931.

Auld, M. Christopher, and Mahmood Zarrabi. 2015. "Long-term Effects of Tobacco Prices Faced by Adolescents." *Forum for Health Economics & Policy*, 18(1): 1-24.

Bayne-Jones, S., 1964. *Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service* (No. 1103). Washington DC: U.S. Department of Health, Education, and Welfare, Public Health Service.

Bowser, Diana, David Canning, and Adeyemi Okunogbe. 2016. "The Impact of Tobacco Taxes on Mortality in the USA, 1970–2005." *Tobacco Control*, 25(1): 52–59.

Callison, Kevin and Robert Kaestner. 2014. "Do Higher Tobacco Taxes Reduce Adult Smoking? New Evidence of the Effect of Recent Cigarette Tax Increases on Adult Smoking." *Economic Inquiry,* 52(1): 155-172.

Carpenter, Christopher, and Philip J. Cook. 2008. "Cigarette Taxes and Youth Smoking: New Evidence from National, State, and Local Youth Risk Behavior Surveys." *Journal of Health Economics*, 27(2): 287-299.

Carter, Brian D., Christian C. Abnet, Diane Feskanich, Neal D. Freedman, Patricia Hartge, Cora E. Lewis, Judith K. Ockene, Ross L. Prentice, Frank E. Speizer, Michael J. Thun, and Eric J. Jacobs. 2015. "Smoking and Mortality—Beyond Established Causes." *New England Journal of Medicine*, 372(7): 631-640.

Centers for Disease Control and Prevention (CDC). 2014. *The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General*. Atlanta (GA): Centers for Disease Control and Prevention. PMID: 2445578.

Chassin, Laurie, Clark C. Presson, Jennifer S. Rose, and Steven J. Sherman. 1996. "The Natural History of Cigarette Smoking from Adolescence to Adulthood: Demographic Predictors of Continuity and Change." *Health Psychology,* 15(6): 478.

Darden, Michael. 2017. "Smoking, Expectations, and Health: A Dynamic Stochastic Model of Lifetime Smoking Behavior." *Journal of Political Economy*, 124(5): 1465-1522.

Darden, Michael, Donna B. Gilleskie, and Koleman Strumpf. 2018. "Smoking and Mortality: New Evidence from a Long Panel." *International Economic Review,* 59(3): 1571-1619.

DeCicca, Philip, Donald S Kenkel, Michael F Lovenheim. 2020. "The Economics of Tobacco Regulation: A Comprehensive Review." NBER Working Paper No. 26923.

DeCicca, Philip, Donald Kenkel, and Alan Mathios. 2008. "Cigarette Taxes and the Transition from Youth to Adult Smoking: Smoking Initiation, Cessation, and Participation." *Journal of Health Economics*, 27(4): 904-917.

DeCicca, Philip, and Logan McLeod. 2008. "Cigarette Taxes and Older Adult Smoking: Evidence from Recent Large Tax Increases." *Journal of Health Economics*, 27(4): 918-929.

Decker, Sandra L. and Amy Ellen Schwartz. 2000. "Cigarettes and Alcohol: Substitutes or Complements?" NBER Working Paper No. 7535.

Doll, Richard and A. Bradford Hill. 1950. "Smoking and Carcinoma of the Lung." *British Medical Journal,* 2(4682): 739-748.

Doll, Richard and A. Bradford Hill. 1954. "The Mortality of Doctors in Relation to their Smoking Habits." *British Medical Journal,* 1(4877): 1451-1455.

Doll, Richard and A. Bradford Hill. 1964. "Mortality in Relation to Smoking: Ten Years' Observations of British Doctors." *British Medical Journal*, 1(5395): 1399-1410.

Doll, Richard, Richard Peto, Jillian Boreham, and Isabelle Sutherland. 2004. "Mortality in Relation to Smoking: 50 Years' Observations on Male British Doctors." *British Medical Journal*, 328(7455): 1519–1528.

Fang, Hanming, Michael Keane, Ahmed Khwaja, Martin Salm, and Dan Silverman. 2007. "Testing the Mechanisms of Structural Models: The Case of the Mickey Mantle Effect." *American Economic Review*, 97(2): 53-59.

Federal Emergency Management Agency (FEMA), 2012. "Smoking-Related Fires in Residential Buildings." *Topical Fire Report Series,* 13(6).

Gilleskie, Donna B. and Koleman S. Strumpf. 2005. "The Behavioral Dynamics of Youth Smoking." *Journal of Human Resources*, 40(4): 822-866.

Glied, Sherry. 2002. "Youth Tobacco Control: Reconciling Theory and Empirical Evidence." *Journal of Health Economics*, 21(1): 117-135.

Gruber, Jonathan. 2001. "Youth Smoking in the 1990's: Why Did it Rise and What are the Long-Run Implications?" *American Economic Review*, 91(2): 85-90.

Gruber, Jonathan and Michael Frakes. 2006. "Does Falling Smoking Lead to Rising Obesity?" *Journal of Health Economics*, 25: 183–197.

Gruber, Jonathan and Botond Kőszegi. 2004. "Tax Incidence When Individuals are Time-Inconsistent: The Case of Cigarette Excise Taxes." *Journal of Public Economics,* 88(9-10): 1959-1987.

Gruber, Jonathan, and Jonathan Zinman. 2001. "Youth Smoking in the United States: Evidence and Implications." In *Risky Behavior Among Youths: An Economic Analysis*, Chicago: University of Chicago Press, pp. 69-120.

Hammond, E. Cuyler and Daniel Horn. 1958. "Smoking and Death Rates—Report on Forty-Four Months of Follow-up of 187,783 Men." *JAMA*, 166(11): 1294-1308.

Hansen, Benjamin, Joseph J. Sabia, and Daniel I. Rees. 2017. "Have Cigarette Taxes Lost Their Bite? New Estimates of the Relationship between Cigarette Taxes and Youth Smoking." *American Journal of Health Economics,* 3(1): 60-75.

Hetzel, Alice M. 1997. *History and Organization of the Vital Statistics System*. Washington DC: National Center for Health Statistics.

Holford, Theodore R., David T. Levy, Lisa A. McKay, Lauren Clarke, Ben Racine, Rafael Meza, Stephanie Land, Jihyoun Jeon, and Eric J. Feuer. 2014. "Patterns of Birth Cohort–Specific Smoking Histories, 1965–2009." *American Journal of Preventive Medicine*, 46(2): e31-e37.

Jha, Prabhat, Chinthanie Ramasundarahettige, Victoria Landsman, Brian Rostron, Michael Thun, Robert N Anderson, Tim McAfee, and Richard Peto. 2013. "21st-Century Hazards of Smoking and Benefits of Cessation in the United States." *New England Journal of Medicine*, 368(4): 341-350.

Khwaja, A., Silverman, D., Sloan, F. and Wang, Y., 2009. "Are Mature Smokers Misinformed?" *Journal of Health Economics*, 28 (2): 385-397.

Lariscy, Joseph T., 2019. "Smoking-attributable Mortality by Cause of Death in the United States: An Indirect Approach." *SSM Population Health*, 7: 100349.

Lillard, Dean R., Eamon Molloy and Andrew Sfekas. 2013. "Smoking Initiation and the Iron Law of Demand." *Journal of Health Economics*, 32(1): 114-127.

Manning, Willard, Emmett Keeler, Joseph P. Newhouse, Elizabeth Sloss, and Jeffrey Wasserman. 1991. "*The Costs of Poor Health Habits*. Cambridge, MA: Harvard University Press.

Moore, Michael J. 1996. "Death and Tobacco Taxes." *The Rand Journal of Economics*, 27(2): 415–428.

O'Donoghue, Ted, and Matthew Rabin. 2006. "Optimal Sin Taxes" *Journal of Public Economics,* 90(10-11): 1825-1849.

Orzechowski, W. and R.C. Walker. 2018. *The Tax Burden on Tobacco 2017: Historical Compilation*. Arlington, VA.

Paavola, M., Vartiainen, E. and Puska, P., 1996. "Predicting Adult Smoking: The Influence of Smoking during Adolescence and Smoking Among Friends and Family." *Health Education Research*, 11(3): 309-315.

Pirie, Kirstin, Richard Peto, Gillian K. Reeves, Jane Green, Valerie Beral, and Million Women Study Collaborators. 2013. "The 21st Century Hazards of Smoking and Benefits of Stopping: A Prospective Study of One Million Women in the UK." *The Lancet*, 381(9861): 133-141.

Tauchmann, Harald, Silja Lenz, Till Requate, and Christoph M. Schmidt. 2013. "Tobacco and Alcohol: Complements or Substitutes? A Structural Model Approach to Insufficient Price Variation in Individual-level Data." *Empirical Economics*, 45: 539–566.

Table 1. Summary Statistics

A. TUS-CPS, 1992-2018

	All	Men	Women
Observations	1,060,693	469,119	591,574
Currently Smokes	0.23	0.25	0.22
	Mean	**Min**	**Max**
Age at Interview	40.9	20	75
Birth year	1962	1943	1998
Cigarette Tax, Ages 14 to 17 (2005 $/pack)	$0.76	$0.23	$4.63

B. U.S. Death Certificates, 1990-2018

	All	Men	Women
Total Deaths	15,057,114	9,317,431	5,739,683
All-Cause Mortality Rate	375	463	287
Smoking-Related Mortality Rate	170	213	126
	Mean	**Min**	**Max**
Age at death	41.6	20	75
Birth year	1964	1943	1990
Cigarette Tax, Ages 14 to 17 (2005 $/pack)	$0.77	$0.23	$2.83

Notes: The sample in Panel A is limited to respondents 20 years of age and older, born 1943 and later in the 51 states and D.C. with non-missing information on smoking and gender. The sample in Panel B is drawn from the universe of death certificates in the U.S. from 1990 to 2018, limited to birth years 1943-1990 and to people born in the 50 states and Washington D.C. "Currently smokes" is the share of population reporting smoking some days or every day. Mortality rates are per 100,000 person-years. See appendix for the definition of smoking-related mortality.

Table 2. Teenage Cigarette Taxes and Adult Smoking Participation

	(1)	(2)	(3)
Sample	TUS-CPS Pooled	TUS-CPS Male	TUS-CPS Female
Teen Tax	-0.018***	-0.021**	-0.015*
	(0.007)	(0.009)	(0.008)
Mean of dependent variable	0.233	0.250	0.220
N	1,060,693	469,119	591,574

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: The sample is composed of TUS-CPS respondents 20 years of age and older, 1992-2018. OLS estimates of the effect of cigarette taxes experienced as a teenager on adult smoking participation are reported. The dependent variable is equal to 1 if respondent *i* was a current *s*moker in year *t*. Controls include birth-year by age fixed effects, state fixed effects, and state-specific linear time trends. In addition, the following current (i.e., year of survey) and teenage (i.e., at ages 14-17) state-level variables are included: the per-pack cigarette tax in 2005 dollars, the state unemployment rate, minimum legal purchase age of tobacco indicators, and an indicator for whether there was a comprehensive smoking law in effect. Current state of residence is used to impute state of residence as a teenager. Standard errors corrected for clustering at the state level are reported in parentheses.

Table 3. Teenage Cigarette Taxes and All-Cause Mortality

	(1)	(2)	(3)
Sample	Pooled	Men	Women
Teen Tax	-24.09***	-36.99***	-12.42*
	(8.43)	(11.26)	(6.46)
Mean of dependent variable	375.40	463.44	286.92
N	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: The mortality data are composed of U.S. death certificates from 1990 to 2018, limited to ages 20 and older. The data are collapsed to the birth state-birth year-year level and combined with the 1990 Census to calculate mortality rates per 100,000 person-years. OLS estimates of the effect of cigarette taxes experienced as a teenager on mortality rates are reported. The dependent variable is the all-cause mortality rate in year *t* for birth cohort *c* and birth state *s*. Controls include birth-year by age fixed effects, birth state fixed effects, and birth state-specific linear time trends. In addition, the following current (i.e., year of death) and teenage (i.e., at ages 14-17) state-level variables are included: the per-pack cigarette tax in 2005 dollars, the state unemployment rate, minimum legal purchase age of tobacco indicators, and an indicator for whether there was a comprehensive smoking law in effect. Observations are weighted by population per birth-state by birth-year cell. Standard errors corrected for clustering at the state level are reported in parentheses.

Table 4. Teenage Cigarette Taxes and Smoking-Related Mortality

	(1)	(2)	(3)
Sample	Pooled	Men	Women
Teen Tax	-18.48***	-28.42***	-9.55**
	(5.77)	(7.91)	(4.19)
Mean of dependent variable	169.98	212.80	126.95
N	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: The dependent variable is the smoking-related mortality rate in year *t* for birth cohort *c* and birth state *s*. Please see the notes to Table 3 for more details and Appendix A for the definition of smoking-related mortality.

Table 5. Teenage Cigarette Taxes and Smoking-Related Mortality by Cause

	(1)	(2)	(3)	(4)	(5)
	Respiratory Disease	*Cancer*	*Lung Cancer*	*Heart Disease*	*Diabetes*
Sample	Pooled	Pooled	Pooled	Pooled	Pooled
Teen Tax	-2.88***	-4.61**	-3.28*	-9.49***	-1.50**
	(1.01)	(2.07)	(1.76)	(3.36)	(0.69)
Mean of dep. var.	17.96	59.92	26.57	80.12	11.98
N	60,282	60,282	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: The dependent variable is the smoking-related mortality rate by component in year *t* for birth cohort *c* and birth state *s*. Please see the notes to Table 3 for more details and Appendix A for the definition of smoking-related mortality. The sample is pooled across genders in each column.

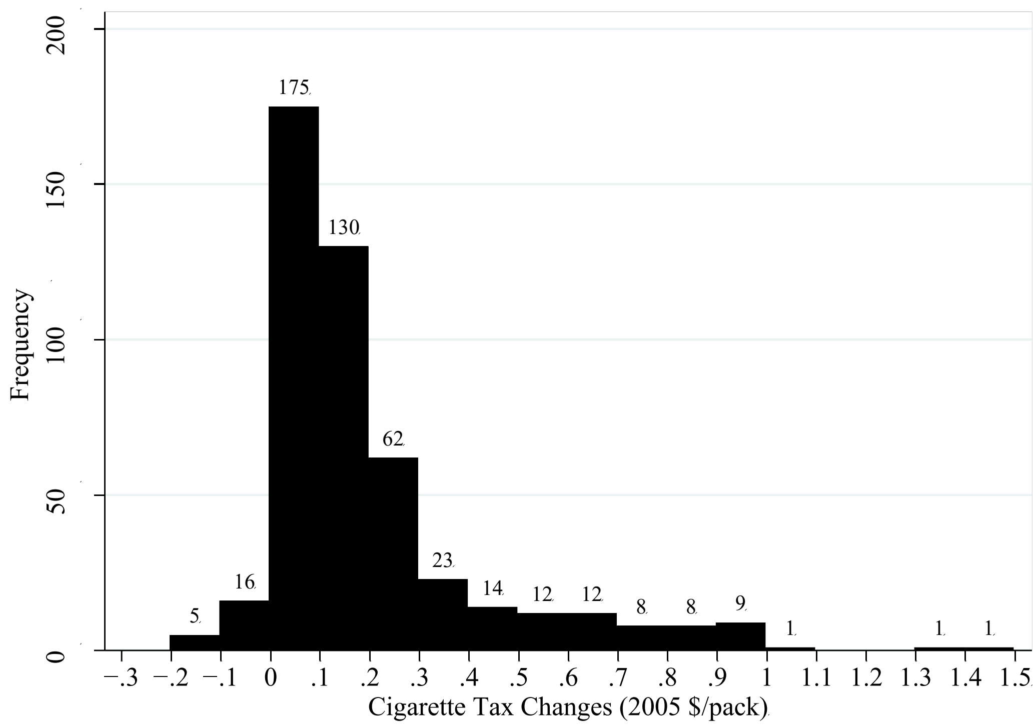
Table 6. Teenage Cigarette Taxes on Homicides and Non-Fire Accidents (Placebo Causes)

	(1)	(2)	(3)
Sample	All	Male	Female
Teen Tax	-0.42	-1.67	0.91
	(1.40)	(2.06)	(0.98)
Mean of dependent variable	46.84	67.81	25.77
N	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

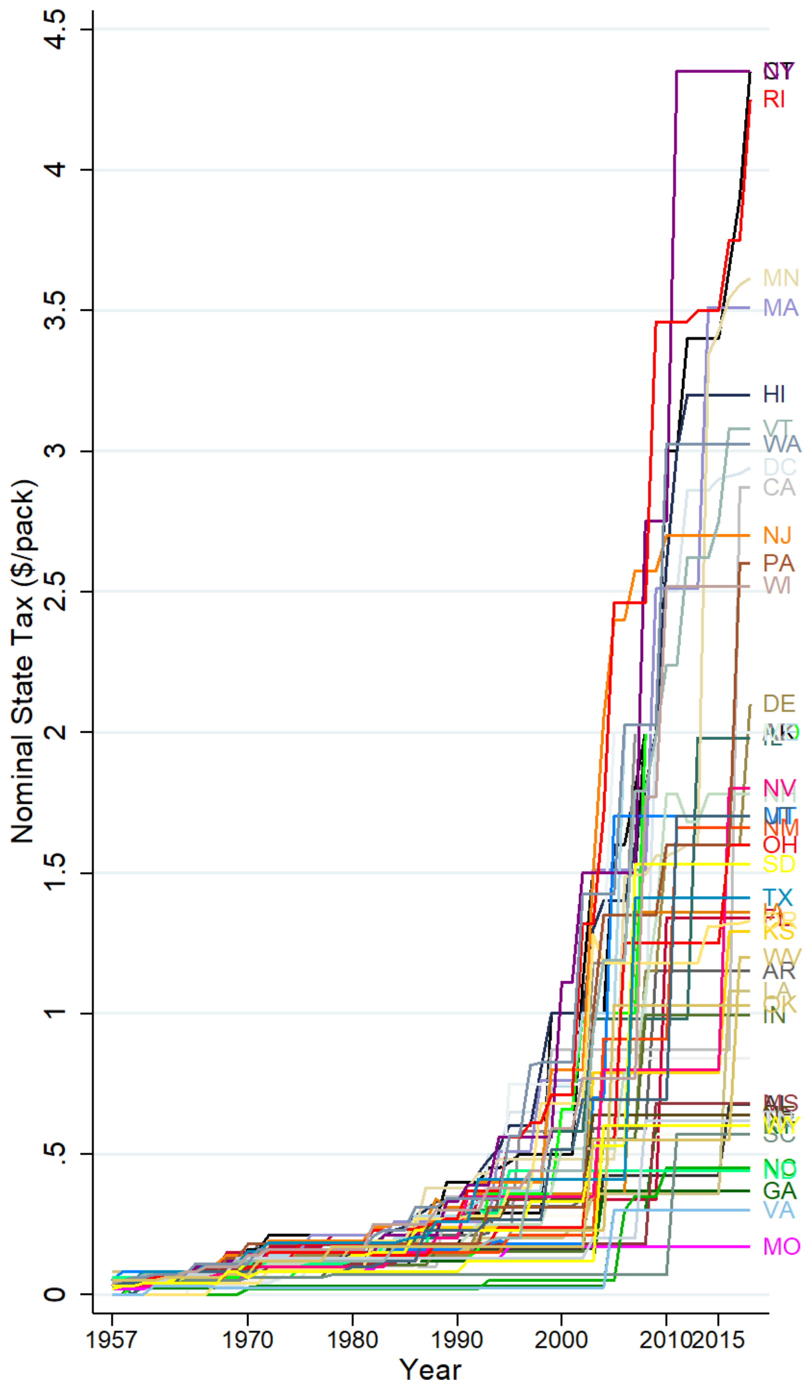
Notes: The dependent variable is mortality from homicides and non-fire accidents per 100,000 in year *t* for birth cohort *c* and birth state *s*. Please see the notes to Table 3 for more details and Appendix A for the definitions of homicides and non-fire accidents.

Appendix Figure 1. Real Cigarette Tax Changes Stemming from Legislation, 1957-2015.

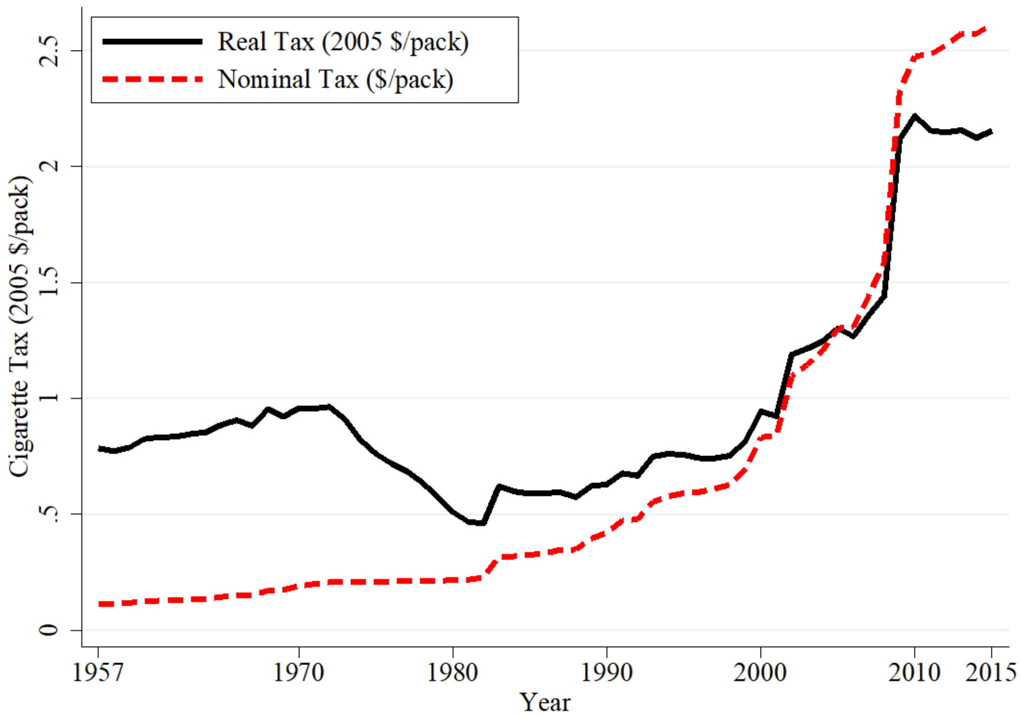


Notes: Cigarette tax data are from Orzechowski and Walker (2019).

Appendix Figure 2. Nominal Cigarette Tax Changes across States, 1957-2015.



Appendix Figure 3. Average Per-pack Cigarette Tax (Population Weighted and in 2005 dollars), 1957-2015



Notes: Cigarette tax data are from Orzechowski and Walker (2019). State populations come from the U.S. Census Bureau State Intercensal Population Tables, available at https://www.census.gov/programs-surveys/popest/data/tables.html.

Table A1. Teenage Cigarette Taxes and Adult Smoking: Controlling for Individual-Level Demographics

	(1)	(2)	(3)
Sample	*Adult Smoking* TUS-CPS All	*Adult Smoking* TUS-CPS Male	*Adult Smoking* TUS-CPS Female
Teen Tax, 11 to 19	-0.013**	-0.018**	-0.009
	(0.006)	(0.009)	(0.008)
Mean of dependent variable	0.233	0.250	0.220
N	1,060,693	469,119	591,574

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: All respondents were at least 20 years of age. Adult Smoking is equal to 1 if *i* was a current smoker (and is equal to 0 otherwise). Controls include birth year fixed effect, gender, race, education level, state specific time trend fixed effects, age-birth cohort fixed effects, state fixed effects, current (year of survey, in state of residence) and teen (ages 14-17, in state of residence): unemployment rates, minimum legal purchase age of tobacco, comprehensive smoking law. Specifications also control for current cigarette tax rates. In the TUS-CPS, we use the current state of residence to impute state of residence as a teenager. Standard errors are clustered at state level and are reported in parentheses.

Table A2. Teenage Cigarette Taxes All-Cause Mortality: No Adult-Dated Controls

	(1)	(2)	(3)
Sample	All	Male	Female
Teen Tax	-44.85***	-66.50***	-25.82***
	(11.53)	(16.50)	(8.05)
Mean of dependent variable	375.40	463.44	286.92
N	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

The dependent variable is the smoking-related mortality rate in year *t* for birth cohort *c* and birth state *s*. Please see the notes to Table 3 for more details. This table differs from Table 3 because it drops the adult-dated controls.

Table A3. Cigarette Taxes at Ages 11-19 and Adult Smoking

	(1)	(2)	(3)
	Adult Smoking	*Adult Smoking*	*Adult Smoking*
Sample	TUS-CPS All	TUS-CPS Male	TUS-CPS Female
Teen Tax, 11 to 19	-0.024***	-0.031**	-0.019*
	(0.009)	(0.012)	(0.010)
Mean of dependent variable	0.235	0.252	0.222
N	996,009	440,338	555,671

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.
Notes: Please see the notes to Table 2 for more details. This table differs from Table 2 because it measures teenage variables (i.e., the cigarette tax and other polices) as the average for ages 11-19 (as opposed to 14-17).

Table A4. Cigarette Taxes at Ages 11-19 and All-Cause Mortality

	(1)	(2)	(3)
Sample	All	Male	Female
Teen Tax	-31.22**	-50.80***	-14.05
	(12.18)	(16.61)	(9.07)
Mean of dependent variable	375.40	463.44	286.92
N	60,282	60,282	60,282

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: Please see the notes to Table 3 for more details. This table differs from Table 2 because it measures teenage variables (i.e., the cigarette tax and other polices) as the average for ages 11-19 (as opposed to 14-17).

Table A5. Teenage Cigarette Taxes and Placebo Causes of Death

	(1)	(2)	(3)
A. Homicide			
	All	Male	Female
Teen Tax	-0.53	-1.23	0.14
	(0.50)	(0.94)	(0.18)
Mean, dep. var.	8.38	13.19	3.54
B. Vehicle Deaths			
	All	Male	Female
Teen Tax	-0.28	-0.46	-0.09
	(0.29)	(0.50)	(0.181)
Mean, dep. var.	15.80	22.92	8.64
D. Accidents, not fire or vehicle deaths			
	All	Male	Female
Teen Tax	0.40	0.02	0.87
	(1.10)	(1.42)	(0.95)
Mean, dep. var.	22.669	31.707	13.586

*Statistically significant at 10% level; ** at 5% level; *** at 1% level.

Notes: Please see the notes to Table 3 for more details. This table differs from Table 3 because because the outcome is the count of deaths due to placebo causes, per 100,000 person-years.

Appendix A: Definitions of Smoking-Related Mortality, Homicide, and Accidental Mortality

The death certificate indicates causes of death using the International Statistical Classification of Diseases and Related Health Problems ("ICD Codes"). For deaths occurring before 1999, codes from the 9th edition are used ("ICD-9"). For deaths occurring after 1999, codes from the 10th edition are used ("ICD-10").

Smoking-Related Mortality

Following the Lariscy (2019) and CDC (2014) we define smoking-related mortality as deaths due to the following diseases, which are known to be directly caused by smoking:

- Cancers:
  - lip, oral cavity and pharynx (ICD9: 140-149, ICD10: C00-C14), esophagus (ICD9: 150, ICD10: C15), stomach (ICD9:151, ICD10: C16), colorectal (ICD9: 153, 154, ICD10: C18-C20), liver (ICD9: 155, ICD10: C22), pancreas (ICD9: 157, ICD10: C25), larynx (ICD9: 161, ICD10: C32), trachea/lung/bronchus (ICD9: 162, ICD10: C33-C34), cervix uteri (ICD9: 180, ICD10: C53), urinary bladder (ICD9: 188, ICD10: C67), kidney and renal pelvis (ICD9: 189, ICD10: C64-C65), and acute myeloid leukemia (ICD9: 205, ICD10: C920.0)
- Diabetes: ICD9: 250, ICD10: E10-E14
- Respiratory diseases:
  - pneumonia, influenza, tuberculosis, bronchitis, emphysema, and chronic airways obstruction disease (ICD9: 010-018, 480-487, 490-492, 496, ICD10: A16-A19, J10-J18, J40-J44)

- Heart disease:
    - ischemic, cerebrovascular, atherosclerosis, aortic aneurysm, other arterial diseases (ICD9: 410-414, 390-398, 415-429, 430-434, 436-438, 440.1, 440.2, 441, 442-448, ICD10: I20-I25, I00-I09, I26-I51, I60-I69, I70-I71, I72-I78)

Homicides and Accidental Mortality

To define homicides and accidental mortality, we follow definitions developed by the NCHS as part of an effort to categorize ICD codes. Specifically, before 1999, the NCHS grouped ICD-9 codes into 256 mortality categories. Starting in 1999, DVS updated the groupings to 358 categories. Homicides and accidental deaths are defined consistently across both grouping schemes, as follows:

- Homicides include:
    - ICD-9: E960 to E969; ICD-10: U01-U02X85-X99, Y01-Y09,Y87.1
- Accidental Deaths include:
    - motor vehicle deaths (ICD-9: E810-E825, ICD-10: V02-V04,V09.0,V09.2,V12-V14,V19.0-V19.2, V19.4-V19.6,V20-V79,V80.3-V80.5,V81.0-V81.1,V82.0-V82.1,V83-V86, V87.0-V87.8,V88.0-V88.8,V89.0,V89.2), accidental poisonings (E850-E869, X40-X49), accidental falls (E880-E888, W00-W19), deaths due to fire and flames (ICD9: E890-E899, ICD-10: X00-X09), and other accidents, including late effects (E900-E929)

Our definition of accidental deaths excludes deaths those caused by fire and flames (ICD9: E890-E899, ICD-10: X00-X09).