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Michael F. Pesko

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University of Kentucky
244 Gatton College of Business and Economics
Lexington, KY 40506-0034
http://isfe.uky.edu/

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Effects of E-Cigarette Minimum Legal Sales Ages on Youth Tobacco Use in the United States

Michael F. Pesko[a], PhD

Affiliations:

[a] Department of Economics, Andrew Young School of Policy Studies,
Georgia State University, Atlanta, GA, United States.

Abstract

In the United States, individual states established a minimum legal sale age (MLSA) for e-cigarettes between 2010 and 2016 when a federal MLSA came into place. These policies provide a natural experiment from which we can better understand the effect that e-cigarettes have on youth combustible tobacco use. This paper uses National Youth Tobacco Survey data to estimate the effect of the gradual roll-out of e-cigarette MLSAs in the United States on youth e-cigarette use, cigarette use, and cigar use (i.e., cigars, cigarillos, or little cigars). Using an estimator designed to correct for dynamic heterogeneity in treatment effects, e-cigarette MLSAs are estimated to reduce lifetime e-cigarette use by approximately 25% and increase daily cigarette use and daily cigar use by approximately 35%. Therefore, these MLSAs operate as intended in reducing e-cigarette use, although at the expense of more dangerous combustible tobacco use. The Food and Drug Administration should consider the impact of e-cigarette availability in reducing youth combustible tobacco use as an important public health benefit of e-cigarettes in their regulatory activity.

Address Correspondence to: Michael F. Pesko, PhD; Department of Economics; Andrew Young School of Policy Studies; Georgia State University, Atlanta, GA, United States (mpesko@gsu.edu).

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Introduction

The FDA is currently assessing whether specific e-cigarette products are sufficiently appropriate for public health to be legally sold in the United States. To date, 23 unflavored e-cigarette products from three companies have been approved, thousands of e-cigarette products remain under review, and more than one million e-cigarettes have been denied (which recently includes Juul e-cigarettes).[1] Approval can be rescinded at any time if insufficient evidence exists that these products are benefiting public health. E-cigarettes that are under review, or that are denied marketing orders but these orders are being judicially appealed, can often be sold through enforcement discretion.

One key question in determining whether e-cigarettes are appropriate for the protection of public health is the impact that e-cigarette use has on combustible tobacco use. If e-cigarettes can be shown to causally reduce combustible tobacco use, which are more dangerous products [1], this suggests a public health benefit of e-cigarettes. Trends in cigarette use and e-cigarette use over time support this notion that e-cigarettes may be reducing youth cigarette use in aggregate. In 2009, public health leaders set a goal of reducing youth cigarette use from 19.5% in 2009 to 16.0% by 2019 [2]. Youth cigarette use reached 6% in 2019, so this objective was exceeded by 386%, potentially due to e-cigarette availability during the decade. This trend has continued its acceleration, and by 2021, high school student cigarette use reached 1.9% [3]. Cigar use has also declined sizably, to 2.1% in 2021 [3]. While these trends are suggestive of a beneficial effect of

[1] See here for press release of the FDA's first e-cigarette marketing orders, allowing their legal sale: https://www.fda.gov/news-events/press-announcements/fda-permits-marketing-e-cigarette-products-marking-first-authorization-its-kind-agency (accessed Sept. 26, 2022). Current premarket tobacco product marketing granted orders is provided here: Premarket Tobacco Product Marketing Granted Orders | FDA (accessed Sept. 26, 2022).

e-cigarettes on teen combustible tobacco use, these trends alone are insufficient for establishing e-cigarettes as the causal factor.

Natural experiments, such as from policy changes, can be used to provide causal evidence towards the question of the effect of e-cigarettes on teen cigarette use [4]. In this paper, the gradual roll-out across states of an e-cigarette minimum legal sale age (MLSA) is used as a form of natural experiment. MLSAs prohibit the sale of e-cigarettes to individuals under specific ages; before MLSAs it was legal to sell e-cigarettes to minors. Five states implemented e-cigarette MLSAs by the end of 2010, 7 by the end of 2011, 12 by the end of 2012, 24 by the end of 2013, 39 by the end of 2014, and 47 by the end of 2015, before federal action applied a national MLSA in 2016 [5, 6]. Online Appendix Table 1 shows the dates of MLSA implementation.

Three other studies explore the effect of e-cigarette MLSAs on e-cigarette use in the United States, but each has substantial methodologic limitations: two studies use a single cross-section of data (due to limited data availability at the time of writing) [7, 8], and the third uses multiple waves of data (through 2014 only) but does not control for state fixed effects to address several likely sources of confounding [9]. Additionally, this third study includes cigarette use as a control variable despite evidence that it is endogenously impacted by e-cigarette MLSAs [5, 7, 8, 10, 11], and it assumes that no youth used e-cigarettes in 2009 despite e-cigarettes being available in the United States since 2006 [12]. One study uses Canadian data through 2017 to estimate the effect of staggered adoption of e-cigarette MLSAs using a two-way fixed effect (TWFE) model. This study finds adoption of e-cigarette MLSAs reduces youth e-cigarette use by 4.3 percentage points (ppt), but does not examine effects on combustible cigarette use [13].

This current study estimates the effect of e-cigarette MLSAs in the United States on both e-cigarette use and combustible tobacco use using multiple waves of National Youth Tobacco Survey (NYTS) data through 2017.[2] By extending the analysis through 2017, this study covers the full time period leading up to a national e-cigarette MLSA in August 2016 [14]. In addition to estimating a TWFE model, the current study is the first e-cigarette MLSA study to use a method to account for the presence of dynamic heterogeneity in treatment effects [15, 16]. Additionally, the study improves on the previous study using NYTS data from 2009 to 2014 [9] by not including endogenous control variables nor making assumptions about e-cigarette use in a given year.

Background

E-cigarettes are a relatively new tobacco product that was first imported into the United States in August 2006 [12]. E-cigarettes began to be sold in stores tracked by the Nielsen retail scanner data in 2010 [17]. National e-cigarette sales revenue is estimated to have increased from $500 million in 2012 to $6.6 billion in 2018 [18].[3] In late 2017, Juul e-cigarettes became the most commonly used e-cigarette and in 2018 and reached 75% of e-cigarette market share [19].[4] According to the NYTS, youth e-cigarette use in the past 30 days (current use) rose from 1.5% in 2011 to 27.5% in 2019, before falling precipitously in 2020 (19.7%) and 2021 (11.3%).

Lillard (2020) provides a theoretical framework for hypothesizing how the emergence of a new tobacco product, e-cigarettes, affects consumer tobacco purchasing decisions. His model

[2] E-cigarette MLSAs may increase the difficulty of purchasing e-cigarettes and awareness of potential risks, both of which could raise the costs vis-à-vis cigarettes. This could generate substitution to cigarette use despite previously existing cigarette MLSAs, as has been shown in several studies [5, 7, 8, 10, 11].
[3] E-cigarette Intelligence estimates an e-cigarette market size of $5.6 billion in 2021.
[4] In June 2022 Juul was estimated to have 33.1% market share (https://vaporvoice.net/2022/06/02/vuse-continues-to-expand-u-s-market-share-over-juul/) (accessed September 25, 2022).

posits that the demand for tobacco products is a derived demand based on the demand for nicotine. The choice of products is determined by the shadow price of nicotine, which is driven by the cost of the product, the efficiency of nicotine delivery, and the health and social effects of different products. Depending on these factors, different categories of nicotine products could theoretically be complements or substitutes.

In terms of prices, e-cigarettes are generally cheaper than cigarettes. One study using Nielsen Retail Scanner data from 2013-19 found a national cigarette pack price (including excise taxes) of $6.71 per pack versus $4.82 per fluid milliliter (ml) (or $3.37 per the equivalent amount in a Juul pod that is roughly equivalent to one pack of cigarettes) [20, 21]. In 2020, the average American resided in a location with $3.08 in cigarette taxes and $0.34 in e-cigarette taxes [22]. Therefore, consumers have a financial incentive to use e-cigarettes instead of cigarettes, in part because of lower average taxes.

In terms of efficacy of nicotine delivery referred to in Lillard (2020), one recent study finds that a Juul-experienced user can receive a nicotine boost from a 40 mg / ml pod (which is commonly used in the United States) similar to a cigarette user [21]. However, fourteen countries prohibit e-cigarettes from being sold with a nicotine concentration exceeding 20 mg / ml [23], so e-cigarettes sold in these countries may have considerably lower nicotine delivery efficacy than cigarettes.

In terms of health, the National Academies of Sciences, Engineering, and Medicine in the United States state that e-cigarettes are not without risk, but compared to combustible tobacco cigarettes they contain fewer toxicants and are likely to be far less harmful than combustible tobacco cigarettes [1]. One survey of 137 experts' perceptions of e-cigarette harms relative to cigarettes, conducted in August 2020, found an average response of 37 percent [24]. Despite e-cigarettes being less harmful products, the public significantly over-estimates the risks of e-cigarettes, and this trend has grown over time. According to the Health Information National Trends Survey, 38.2% of individuals correctly believed e-cigarettes to be less harmful than cigarettes in 2012, and this has declined to only 11.2% in 2020.[5] Consumers' desired users of e-cigarettes are found to be more strongly related to health risk perceptions than perceived nicotine levels [27] or prices [28].

While not specifically discussed in Lillard (2020)'s demand for nicotine model, flavors are also important drivers of consumer demand for e-cigarettes [29, 30]. While federal law prohibits cigarettes from being flavored with anything except menthol since 2009 [31], e-cigarettes are regularly sold flavored. One study using Nielsen retail scanner data from 2013-19 finds that 38.7% of e-cigarette liquid volume is sold unflavored, 21.9% is mentholated, and 39.4% is non-mentholated flavored [20]. The FDA attempted to ban non-mentholated flavored e-cigarette cartridges in 2020; additionally, as of March 2022 six states had implemented some version of an e-cigarette flavor ban [32].

Methods

The NYTS is a nationally-representative survey on middle and high school youth's tobacco use. Since 2000, the NYTS is collected in the spring of each year.[6] The NYTS was the first national survey to collect information on e-cigarette use. Between the years 2011 to 2017, the NYTS was collected annually and 125,820 respondents under the age of 18 years of age

[5] One study finds the outbreak of "e-cigarette, or vaping product use associated lung injury" (EVALI) in mid- to late-2019 caused sharp increases in risk perception of e-cigarettes relative to cigarettes [25], despite this outbreak being caused by contaminated THC vapes rather than nicotine e-cigarettes. Another study finds that public risk perceptions of e-cigarettes are over-estimated, though not necessarily due to EVALI [26].

[6] An NYTS wave was also collected in Fall 1999. I do not use this original wave because it is the only one of the waves to be collected in the fall and because it is very near in time to the spring 2000 wave.

provide information on e-cigarette use.[7] Additionally, NYTS data was also collected in non-sequential years 2000, 2002, 2004, 2006, and 2009, thus providing 125,409 additional respondents under the age of 18 years of age for cigarette and cigar outcomes. When combined with the more recent waves of NYTS data, there are 251,229 respondents in total under the age of 18 for cigarette and cigar outcomes.[8] Individuals over the age of 18 or with missing age are excluded because an e-cigarette MLSA was never lower than this age nationally during the time period studied.[9] The NYTS data is imbalanced, and per year is collected by between 30 to 42 states between 2000 to 2017.

The Centers for Disease Control and Prevention (CDC) originally released the National Youth Tobacco Survey with state and county information through 2015 and state information through 2017; therefore, this study is carried out at the state-level since that is the level at which geocoded data is consistently available.[10] Similar to this study, several other published studies have used geocoded NYTS data to perform state-level policy evaluation research [9, 33, 34].

Our primary analysis uses a new estimator proposed by Callaway and Sant'anna (2021) (henceforth referred to as C&S) to expunge potential biases arising in the standard TWFE estimator with staggered treatment adoption in the presence of dynamic heterogeneity in treatment effects [15, 16]. For example, such bias could be introduced if (1) earlier-adopting (e-cigarette MLSA) states are poor controls for later-adopting states due to dynamic treatment effects across adoption timing, or (2) heterogeneity in adoption timing gives greater (less) weight

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[7] Additionally, following two other studies [5, 11], Massachusetts is excluded from all analyses because an unusually large number of e-cigarette MLSAs were implemented at the local level,

[8] N reflects the population without consideration to missing outcomes, which ranges from 1.7% to 2.8% depending on outcome and time horizon (2011-17 or 2000-17).

[9] Four states (Alabama, Alaska, New Jersey, and Utah) have used a cigarette MLSA of 19 since 2005. By mid-2017, two states (Hawaii and California) had increased the MLSA to 21.

[10] The analysis was approved by the Georgia State University IRB, Protocol # H18423. Archived versions of the NYTS are used that include geographical information. Please see the online appendix for additional information.

to jurisdictions that implement e-cigarette MLSAs around (away from) the mid-point panel. This issue of heterogenous treatment effect dynamics may be particularly problematic in the context of studying e-cigarette MLSAs since all states adopt these policies between 2010 and 2016. Consequently, there are many instances of earlier-treated units serving as a counterfactual for later-treated units, thus elevating this concern.[11] The Stata package -csdid- is used to estimate C&S models.

Our baseline model is as follows:

$$(1)\ Y_{i,s,t} = \beta_0 + \beta_1 MLSA_{s,t} + X_{i,s,t}\beta_X + \sigma_s + \tau_t + \varepsilon_{i,s,t},$$

$MLSA_{s,t}$ is an indicator for whether an e-cigarette MLSA is in place at the start of the survey year. Outcomes are six available measures of tobacco use: e-cigarette use during lifetime, current e-cigarette use (i.e., use in the past 30 days), current cigarette use, daily cigarette use, current cigar use (i.e., cigars, cigarillos, or little cigars), and daily cigar use. NYTS does not collect information on daily e-cigarette use during the time period studied.

$X_{i,s,t}$ are available individual-level demographics of sex (male, female, missing), age (indicators for each age), and race/ethnicity (White non-Hispanic, Black non-Hispanic, other/multiple race non-Hispanic, Hispanic, missing). Year and state fixed effects are controlled for. Standard errors are clustered at the level of state.

I estimate alternative versions of this primary model. I remove individual controls for the C&S estimator to explore sensitivity of this estimator to the inclusion of any controls. I also estimate the effect of state-level time varying controls in TWFE models.[12] Additionally, I modify the baseline TWFE estimate by adding a vector of state-level policy and environment

[11] This can often be tested by a formal Goodman-Bacon decomposition [16], but this diagnostic aid cannot be used for imbalanced data.
[12] I do not use state economic and policy controls with the C&S estimator because the -csdid- documentation reports that only the base-period values are used for the estimation if variables are time-varying.

characteristics: cigarette taxes, e-cigarette taxes, cigar taxes, smoking and vaping restrictions, Tobacco-21 laws (state + local population-weighted), beer taxes, medical and recreational marijuana laws, minimum wage, poverty rate, and unemployment rate (all as of the start of the survey year and averaged over the first two quarters over which NYTS data is collected). These time-varying control variables could otherwise be correlated with both e-cigarette MLSA adoption and tobacco product outcomes, and are directly controlled for to remove these potential sources of confounding. Please see data appendix for further details on the time-varying variables.

Results

Table 1 shows descriptive statistics for sample respondents over the 2011 to 2017 time period that is used for e-cigarette analyses, and the 2000 to 2017 period that is used for cigarette and cigar analyses. Between 2011 to 2017, 14.2% of youth report ever using e-cigarettes and 5.5% report currently using e-cigarettes. Over the same time period, 6.6% report current cigarette use, 1.3% report daily cigarette use, 6.0% report current cigar use, and 0.6% report daily cigar use. When including the earlier waves of data (2000 to 2009), combustible tobacco use rates are higher and tobacco control policies are weaker.

Figure 1 compares the effect of e-cigarette MLSAs on all six outcomes using C&S and TWFE estimators. Table 2 presents these same results in tabular form. Using C&S, e-cigarette MLSAs are associated with decreases in ever e-cigarette use (2.2 ppt, 23.7% of pre-treatment sample mean, $p<0.05$) and imprecisely estimated reductions in current e-cigarette use. E-cigarette MLSAs are also associated with increases in cigarette use, which is precisely estimated for daily cigarette use (0.5 ppt, 32.9%, $p<0.05$). Since cigarette use rates are declining over this time period, these "increases" in cigarette use are likely accounted for by reduced smoking cessation. E-cigarette MLSAs are also associated with increases in current cigar and daily cigar use, which is estimated precisely for daily cigar use (0.3 ppt, 38.5%, $p<0.05$).[13]

As shown in Figure 1 and Table 2, the previously reported C&S results from 2011 to 2017 do not vary if dropping individual-level demographics. For combustible measures, the magnitudes of the coefficients do not vary if adding the earlier waves back to 2000, through precision is lower. Lower precision may be due in part to adding several years of data in which e-cigarettes were not widely available. The TWFE point estimate though (continuing to use earlier data if available) is larger than the C&S estimate for current cigarette use, and now suggests a statistically-significant increase in cigarette use of 0.8 ppt (6.9%; p<0.10)., which is very close to e-cigarette MLSA point estimates ranging from 0.8 to 1.0 ppt in other research on general youth populations [5, 7, 10]. For cigar use, the TWFE estimate is smaller than the C&S estimate and is now statistically-insignificantly negative. Combustible tobacco use TWFE results are unaffected by adding state controls.

Figure 2 presents event study coefficients in waves before and after an MLSA is implemented in that particular state. Event study models are estimated with C&S to expunge bias due to heterogenous dynamic effects.[14] For e-cigarette use outcomes, there is a shorter pre-period

[13] There is also evidence from the e-cigarette tax literature [35] [56] that current use margins respond relatively imprecisely to policy changes, but ever and daily use margins respond more precisely. One explanation could be recall bias. The NYTS defines current use as any use over the past 30 days. Non-daily users make up the majority of users, and these individuals may have greater difficulty in answering this question accurately. In contrast, it should be relatively easier for people to report daily use or ever use of e-cigarettes (defined as having tried an e-cigarette even once or twice). A second explanation is that non-daily users may not purchase their products directly and be more likely to "bum" products off of others. This behavior may respond differently e-cigarette policies than the behaviors of daily users purchasing their own products. Either explanation could contribute to the estimated pattern of results.

[14] For combustible tobacco use outcomes, the data is collected irregularly in earlier years (2000, 2002, 2004, 2006, and 2009). Our event studies imply that each "wave" is of equal temporal distance, which could introduce noise into pre-period coefficients for combustible tobacco use outcomes. This issue does not affect post-period coefficients, however, as the NYTS is collected each year that MLSAs come into place.

due to e-cigarette data only becoming available in 2011. There is some evidence of noise in the data, demonstrated by many of the outcomes having at least one statistically significant pre-period ($p<0.10$). There are three sources of imbalance that could be contributing to this noise: 1) "traditional" event study imbalance in that some states do not contribute to each event period's time bin depending on when they adopted their MLSA (this particularly affects states adopting early or late and is partially resolved in the figure by suppressing the endpoints), 2) imbalance from many states not being surveyed in any given year, and 3) imbalance from the NYTS not being collected annually prior to 2011. Reassuringly, statistically significant pre-period coefficients appear to represent random fluctuations (consistent with data imbalance) rather than a monotonically increasing or decreasing pre-period trend that suggests omitted variable bias. Overall, these event study figures provide suggestive evidence that the parallel trends assumption is satisfied. In the post-period, coefficients generally align in the direction of the previously reported C&S estimates, and for some outcomes statistically significant post-period coefficients are found.

Figure 3 shows heterogeneity in C&S estimates (using data from 2011 to 2017) by sex and age. Individuals <16 years of age are more responsive to e-cigarette MLSAs than older teens, which is consistent with younger teens being less likely to have ever tried e-cigarettes. Therefore, the pool of people that can be affected by e-cigarette MLSAs in terms of ever e-cigarette use is larger for younger teens than for older teens. For cigarette and cigar outcomes (current and daily), the effects of e-cigarette MLSAs appear significantly larger for males and older teens, which is consistent with these groups being more likely to use e-cigarettes.

Figures 4 through 6 provide a set of robustness checks. Figure 4 shows that results from Figure 1 are largely unchanged when survey weights provided by the NYTS are applied, with one possible exception being larger C&S estimates for current cigarette use that are closer to TWFE estimates. Figure 5 drops five states with county-level MLSAs [5] to reduce concern of bias from uncontrolled local MLSAs. These results are generally consistent with Figure 1 main results, though there is some attenuation in the C&S effect on daily cigarette use. Figure 6 meanwhile shows that the results in Figure 1 are relatively unchanged when dropping five state-year pairs that had an MLSA occur within a given NYTS survey year (January to May) and four state-year pairs with statewide/districtwide Tobacco-21 laws in place, thus reducing concerns about confounding from these sources.[15]

Discussion

This study contributes the strongest evidence to date on the effect of e-cigarette MLSAs in the United States on e-cigarette use by leveraging multiple waves of national survey data and using both C&S and TWFE estimators. This study shows that e-cigarette MLSAs work as intended in the United States by reducing youth e-cigarette initiation; however, at the expense of higher daily combustible tobacco use. Overall, results from this study suggest that e-cigarettes have public health benefit in reducing high-frequency combustible tobacco use among youth, which is an important input for the FDA to consider as they decide whether to allow e-cigarettes to be legally sold or not.

The FDA may also wish to carefully review other natural experiment-style studies that similarly explore the effect of policies designed to reduce e-cigarette availability or appeal on combustible tobacco product use outcomes. For example, there are 15 fixed effect studies using variation in e-cigarette tax rates, MLSAs, or advertising, with 13 studies finding that e-cigarettes

[15] Even though all individuals in our sample are <18 years of age, two papers show spillover effects on younger ages of Tobacco-21 laws [36, 37].

and cigarettes are substitutes [5, 7, 10, 11, 20, 35, 38-42, 55, 56], one study finding they are largely unrelated goods (though some evidence of substitution is present) [24], and one study finding they are complements [8]. The current paper provides another data point in favor of substitution. The evidence from natural experiments therefore leans heavily towards e-cigarette reducing cigarette use at the population level.

In the United States, the MLSA for all tobacco (including e-cigarettes) is now 21 years of age. Results from this study suggest that raising MLSAs for combustible tobacco, but leaving them lower for e-cigarettes, could have public health benefit over raising both ages to 21 [44]. Additionally, 56 countries ban e-cigarette sales to minors and 28 countries ban e-cigarette sales altogether, so a sizable number of countries do neither [43]. To the extent that the United States situation is generalizable to these countries, the current study would therefore provide evidence on likely effects of implementing e-cigarette MLSAs in places without them: lower youth e-cigarette initiation but at the expense of higher regular combustible tobacco use rates.

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Table 1: Descriptive Statistics for Estimation Sample, NYTS

Sample Time Period:	2011-2017		2000-2017	
Outcomes				
Ever E-Cig Use	0.142	[0.349]	NA	
Current E-Cig Use	0.055	[0.227]	NA	
Current Cig Use	0.066	[0.249]	0.103	[0.304]
Daily Cig Use	0.013	[0.113]	0.023	[0.151]
Current Cigar Use	0.060	[0.237]	0.073	[0.261]
Daily Cigar Use	0.006	[0.079]	0.007	[0.080]
Demographics				
Male	0.497	[0.500]	0.495	[0.500]
Female	0.499	[0.500]	0.502	[0.500]
Missing Sex	0.004	[0.062]	0.004	[0.060]
Age	14.209	[1.851]	14.210	[1.829]
NH White	0.420	[0.494]	0.440	[0.496]
NH Black	0.151	[0.358]	0.163	[0.369]
Other/Multiple	0.120	[0.325]	0.108	[0.310]
Hispanic	0.269	[0.444]	0.259	[0.438]
Missing Race/Ethnicity	0.040	[0.196]	0.031	[0.174]
State Time-Varying Controls				
Cig Tax (Fed./State/Local, in 2011 $)	2.519	[1.117]	1.966	[1.096]
E-cigarette tax rate, 35% mark-up (county wt) (2011 CPI-adjusted)	0.032	[0.223]	0.017	[0.161]
Index of Indoor Smoking Restrictions	0.792	[0.214]	0.629	[0.311]
Index of Indoor Vaping Restrictions	0.114	[0.240]	0.059	[0.182]
Tobacco 21 Percent Population	0.031	[0.142]	0.016	[0.103]
Cigar Tax ($ each)	0.007	[0.032]	0.005	[0.026]
Cigar Tax Percent	27.310	[25.713]	24.636	[23.986]
Cigar tax cap?	0.262	[0.440]	0.210	[0.407]
Beer Tax (in 2011 $)	0.292	[0.262]	0.298	[0.263]
Minimum Wage (in 2011 $)	7.481	[0.697]	7.201	[0.804]
Marijuana Recreational Law	0.040	[0.196]	0.021	[0.142]
Medical Marijuana Law	0.339	[0.473]	0.278	[0.448]
Poverty Rate	14.094	[2.902]	13.436	[2.956]
Unemployment Rate	6.725	[1.975]	6.254	[2.050]

N	125,820	251,229

Note: N reflects the population without consideration to missing outcomes, which ranges from 1.7% to 2.8% depending on outcome and time horizon (2011-17 or 2000-17).

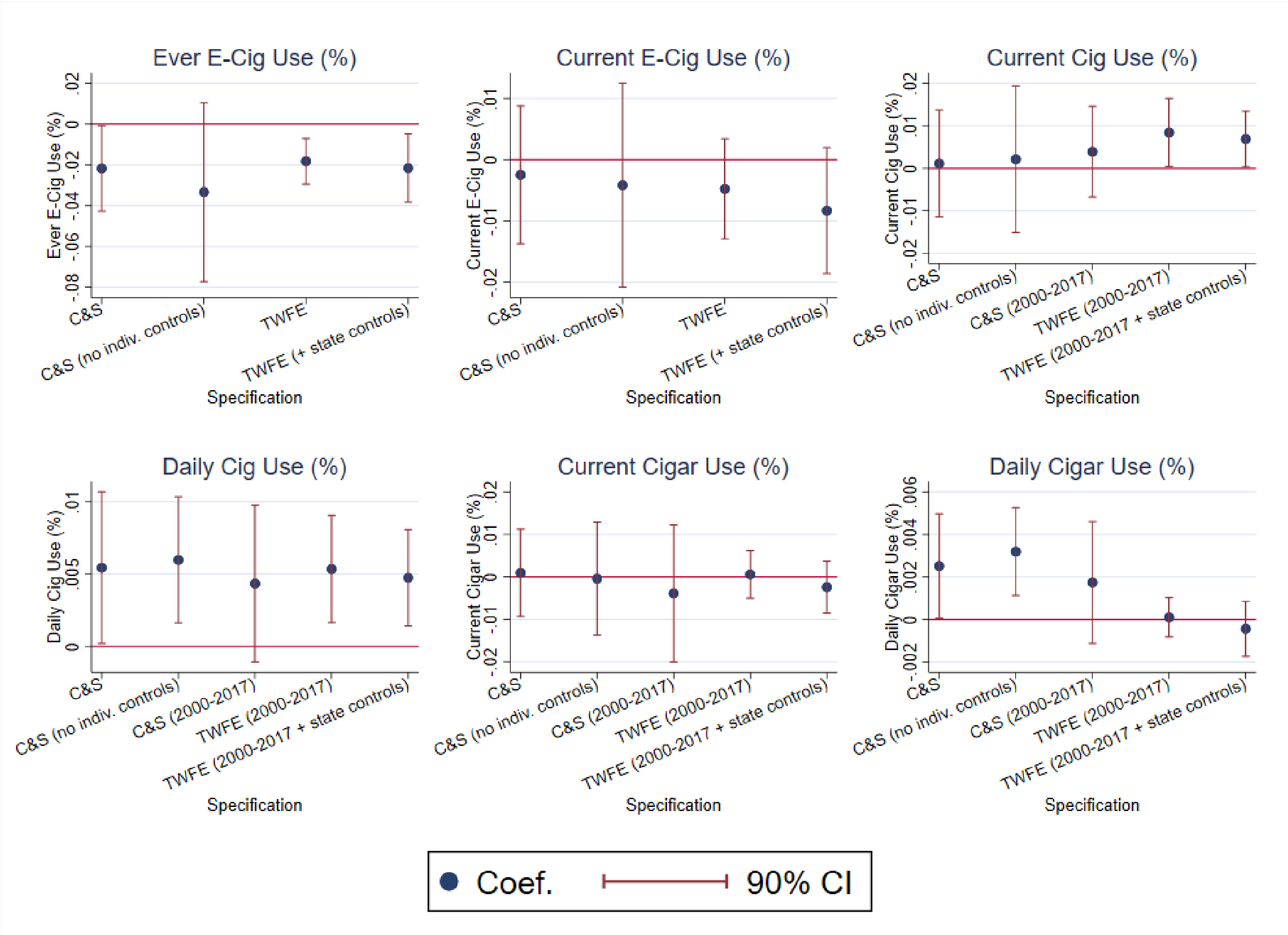
Table 2: Main Results

Model / Outcome	C&S, 2011-2017	C&S, 2011-2017	C&S, 2000-2017	TWFE[1]	TWFE[1]
Ever E-Cig Use	-0.0218*	-0.0334	NA	-0.0182**	-0.0216*
	(0.0107)	(0.0224)		(0.0067)	(0.0099)
	[86,067]	[86,067]		[122,311]	[122,311]
	< 0.0921>	<0.0921>		<0.0921>	<0.0921>
Current E-Cig Use	-0.0025	-0.0042	NA	-0.0047	-0.0083
	(0.0057)	(0.0085)		(0.0049)	(0.0061)
	[85,965]	[85,965]		[122,266]	[122,266]
	<0.0366>	<0.0366>		<0.0366>	<0.0366>
Current Cig Use	0.0011	0.0021	0.0039	0.0084+	0.0069+
	(0.0064)	(0.0088)	(0.0054)	(0.0048)	(0.0039)
	[86,998]	[86,998]	[221,956]	[238,112]	[238,112]
	<0.0805>	<0.0805>	<0.1216>	<0.1216>	<0.1216>
Daily Cig Use	0.0054*	0.0060**	0.0043	0.0054*	0.0047*
	(0.0027)	(0.0022)	(0.0028)	(0.0022)	(0.0020)
	[86,998]	[86,998]	[221,956]	[238,112]	[238,112]
	<0.0164>	<0.0164>	<0.0283>	<0.0283>	<0.0283>
Current Cigar Use	0.0010	-0.0004	-0.0039	0.0006	-0.0024
	(0.0052)	(0.0068)	(0.0082)	(0.0033)	(0.0036)
	[86,925]	[86,925]	[223,897]	[239,965]	[239,965]
	<0.0692>	<0.0692>	<0.0813>	<0.0813>	<0.0813>
Daily Cigar Use	0.0025*	0.0032**	0.0017	0.0001	-0.0004
	(0.0012)	(0.0011)	(0.0015)	(0.0005)	(0.0008)
	[86,925]	[86,925]	[223,897]	[239,965]	[239,965]
	<0.0065>	<0.0065>	<0.0067>	<0.0067>	<0.0067>

Year Fixed Effects	Y	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y	Y
Individual Controls	Y	N	Y	Y	Y
State Controls	N	N	N	N	Y

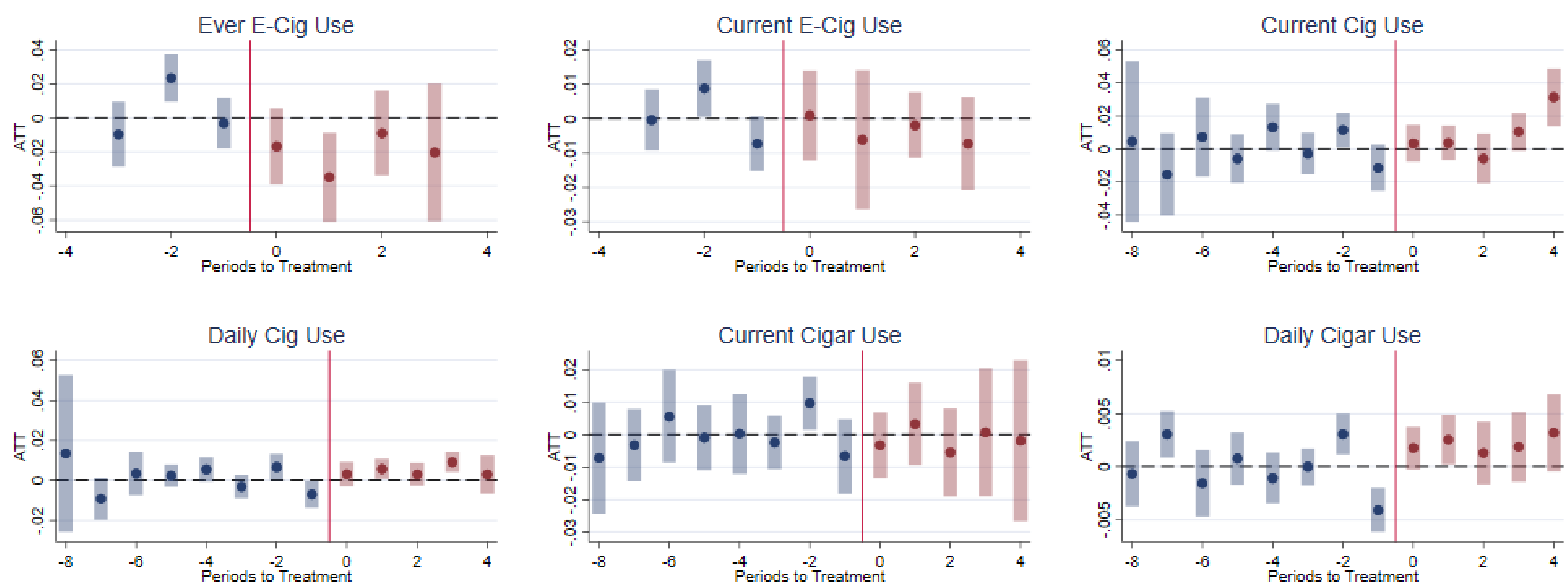
Notes: These results are also presented visually in Figure 1. [1] TWFE models use 2011-2017 data for e-cigarette outcomes and 2000-2017 data for cigarette and cigar outcomes. () refers to standard errors, clustered at the level of state. [] refers to estimation sample size. <> refers to pre-treatment dependent variable mean. + p<0.10; * p<0.05; ** p<0.01; *** p<0.001.

Figure 1: Main Results



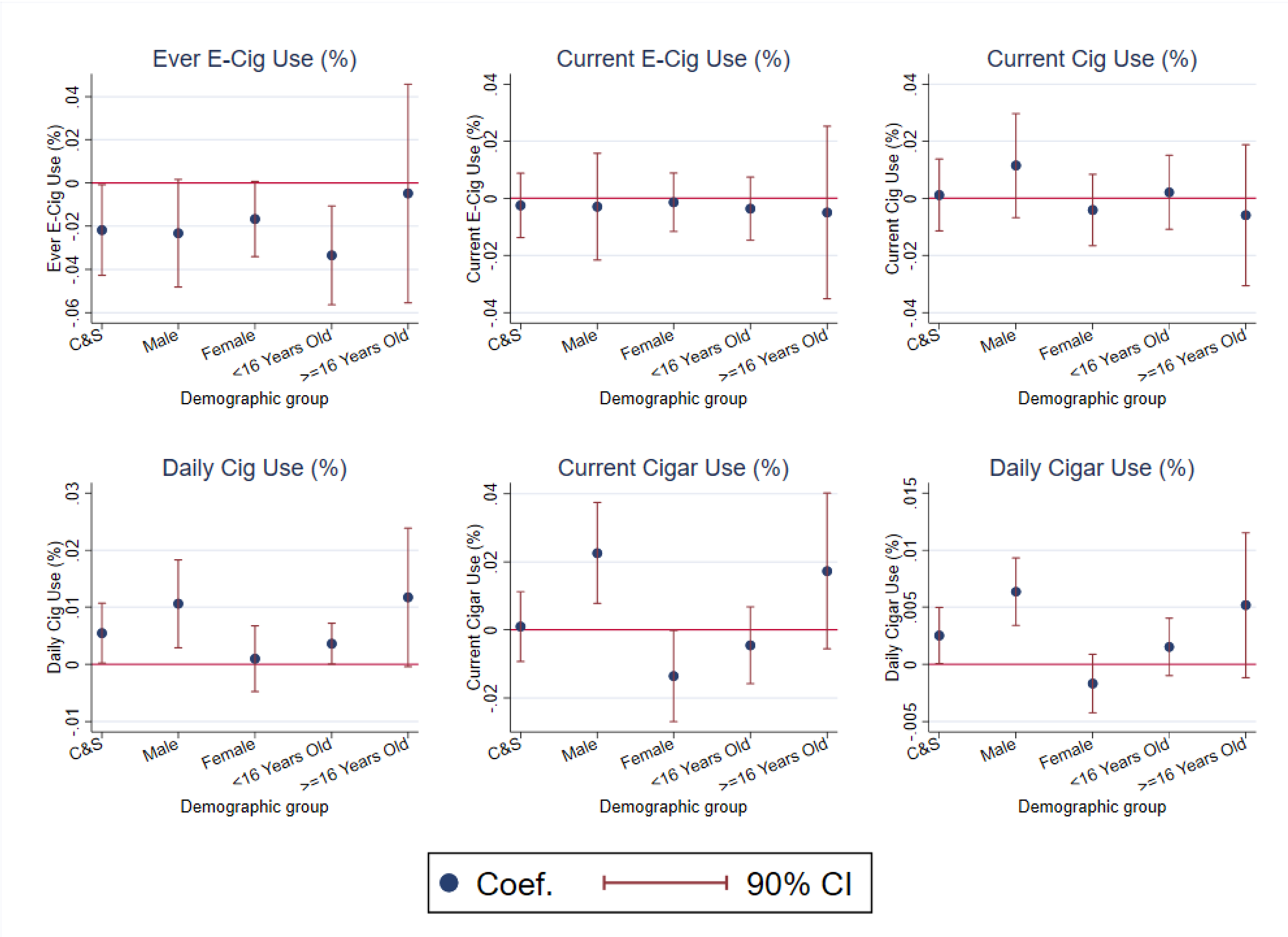
Notes: These results are also presented in Table 1. All coefficient estimates are derived from separate regressions. All regressions control for state and survey year fixed effects. Unless otherwise stated, all regressions control for individual characteristics (shown in Table 1). The final specification adds state-level time-varying controls (also shown in Table 1).

Figure 2: Callaway & Sant'anna Event Study Estimates



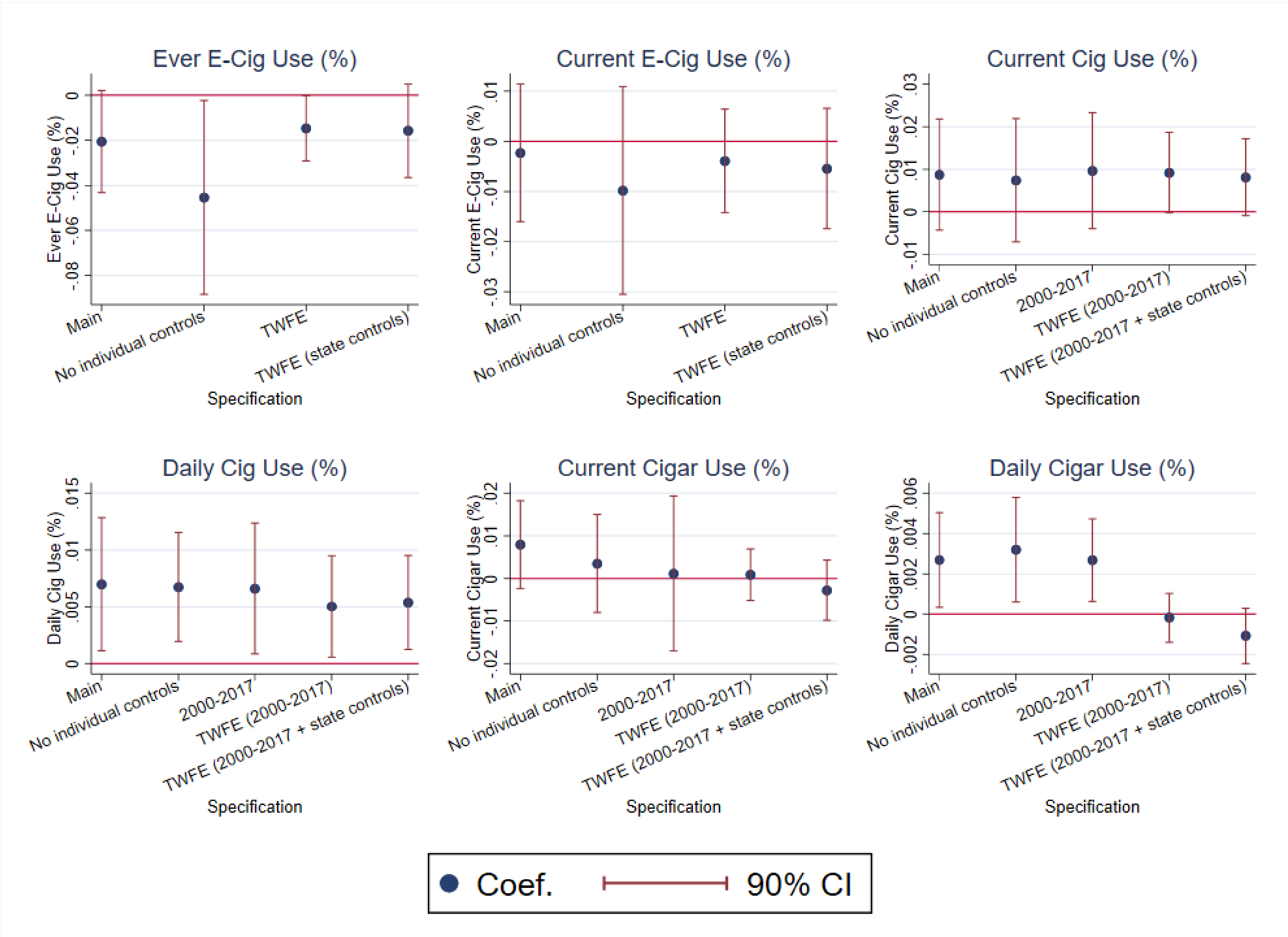
Notes: All figures are derived from separate regressions using the main C&S specification in Figure 1 (including individual controls). Endpoints are included in the estimation but suppressed from these figures due to imbalance in which units contribute to these time-bins.

Figure 3: Callaway & Sant'anna Estimates by Sex and Age



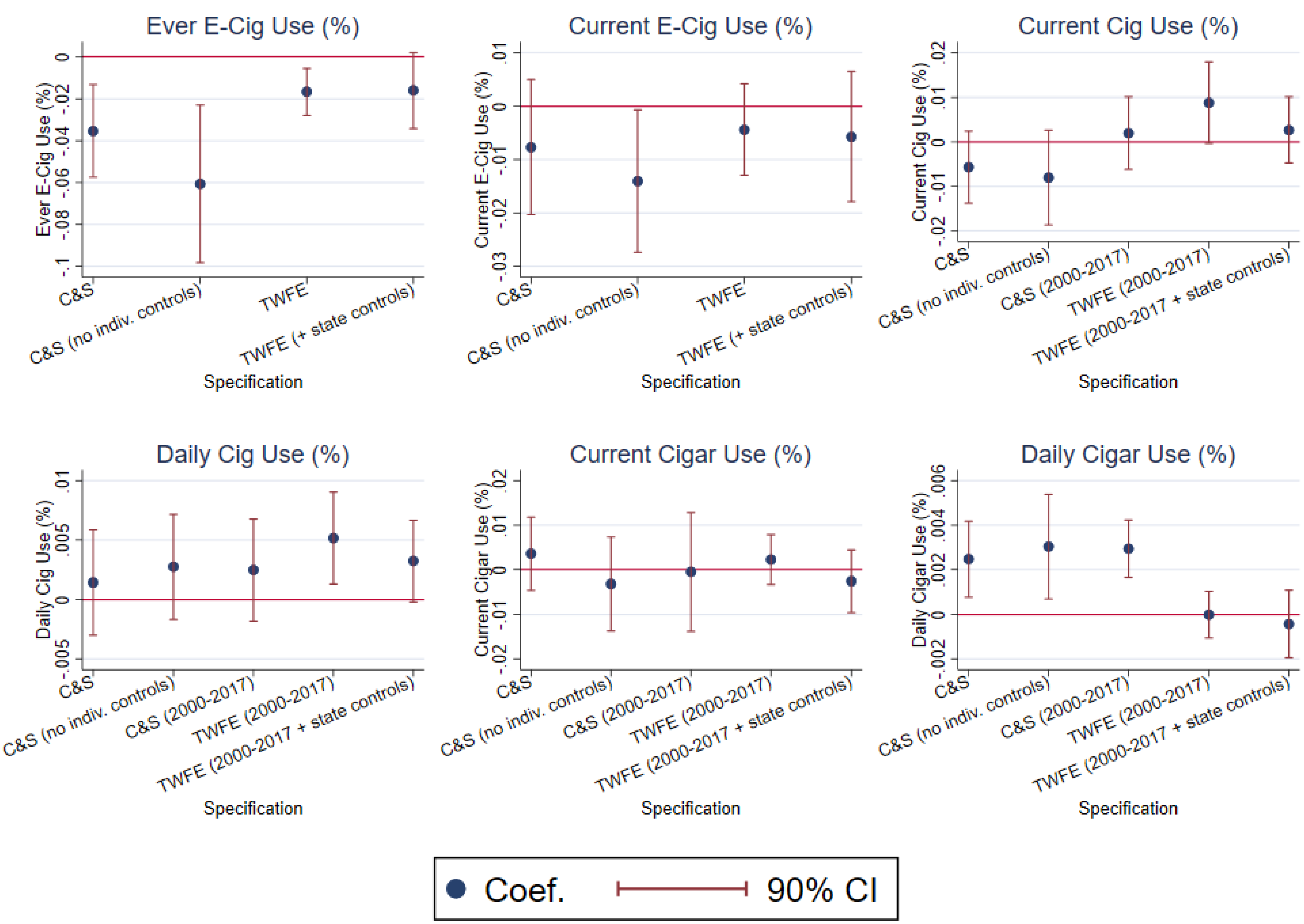
Notes: All coefficient estimates are derived from separate regressions. All regressions control for state and survey year fixed effects and demographics.

Figure 4: Callaway & Sant'anna and Two-Way Fixed Effect Estimates, Weighted



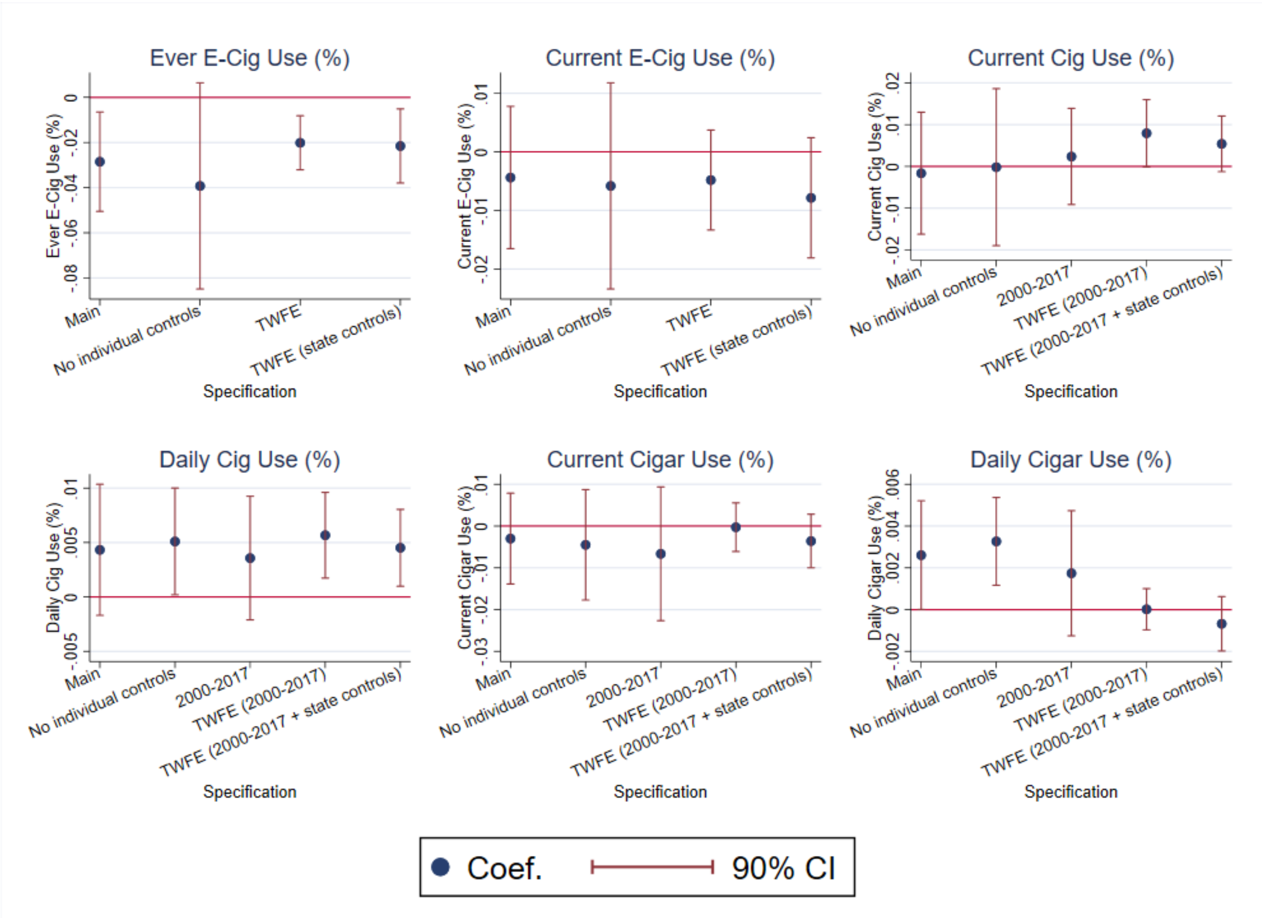
Notes: All coefficient estimates are derived from separate regressions and use survey weights provided by NYTS. All regressions control for state and survey year fixed effects and demographics.

Figure 5: Callaway & Sant'anna and Two-Way Fixed Effect Estimates, Dropping States with Local MLSA



Notes: The five states with local MLSAs are New Mexico, New York, Oregon, Pennsylvania, and Washington. See Online Appendix Table 1. All regressions control for state and survey year fixed effects and demographics.

Figure 6: Callaway & Sant'anna and Two-Way Fixed Effect Estimates, Dropping State-Year Pairs with Partial MLSA Adoption and Tobacco 21 Laws



Notes: Each survey period is between January through May of a given year. Therefore, the four NYTS data state-year pairs with Tobacco 21 laws are CA-2017, DC-2017, HI-2016, and HI-2017. The five state-year pairs with MLSAs implemented between the survey period of a given year are CO-2011, KY-2014, NE-2014, WI-2012, and WY-2013. All regressions control for state and survey year fixed effects and demographics.

Online Appendix: Use of National Youth Tobacco Survey Data

The NYTS data is publicly available and at the time of downloading there were no stipulations concerning its use. The NYTS provided the state of the school in the Excel-based version of the data (through a column named "State Code") and in the primary sampling unit field.

Some researchers have been told by CDC officials that state information was not in the NYTS data and this information could not be released. In 2016, I spoke with one of the main CDC officials responsible for the data collection and informed him about the possibility that geographical information was being released in error. The CDC official did not acknowledge any mistakes were made or ask me not to use the geocodes in my own work. After this conversation, the CDC continued to release state in 2016 and 2017 waves of the NYTS. In 2018, CDC scientists and outside academics published an e-cigarette MLSA paper using state information from the NYTS [9]. One student also used state information for an honors thesis [45]. Similar to me, the student did not have special permission to use this data, and simply downloaded it (like I did) from the public NYTS website.

Around mid-2017, the CDC removed and replaced old extracts of NYTS data [46]. The CDC then added to their website an advisory that among other things asks that any researchers using their data protect the confidentiality of participants, not attempt to learn the identifies of individuals or schools, not link to other personally-identifiable information, and, "understand that sub-national analyses are not appropriate for this national sample and will not be conducted." This advisory was placed well after I began work on the current project; therefore, I do not feel bound by them.[16] However, while I am not entirely clear on what is meant by "sub-national analyses" I believe that my current analysis conforms to these rules since I do not identify individuals and I estimate a national average effect of e-cigarette MLSA laws (rather than state-specific effects). Nationally-representative data sources are regularly used to study state-specific policies; for example, many studies have used Monitoring the Future data to study state policies. My continued use of NYTS data is consistent with other examples of research published despite geocodes being retroactively removed by the government [47-49]. I also follow the NYTS consent/assent language which states that schools will not be identified.[17]

I regret that the CDC has informed some researchers that geographical information was not available when it was. I can only speculate that it may have been easier to place potentially useful data on their website as "free use" and then pull it back if problems arose later, rather than go through a cumbersome bureaucratic process to get permission in advance.

To promote data sharing and reproducibility, I will share my historical versions of the NYTS data with geocodes for anybody that would like to use these.

[16] Allowing governments to retroactively change rules on how data can be used would introduce potential for government abuse, as it would make it easier for governments to shut down research it found unflattering. Additionally, unequal access to data reduces academic debate and can create imbalance in the literature; for this reason, any data that the CDC publishes with, as they have using NYTS data to study e-cigarette policies [9], should be accessible without prior approval to outside academics.

[17] I received these NYTS consent/assent forms through a Freedom of Information Act request.

Data Appendix:

The following policy and economic covariates are used, as of the first quarter of each survey year.

- Tobacco laws:
    1. Cigarette taxes are the federal cigarette excise tax ($1.01 over the study period) + state cigarette excise tax (from the CDC State System) [6] + local cigarette excise tax (from the American Non-Smokers Rights Foundation) [50], population-weighting local taxes to the state level.
    2. Standardized e-cigarette taxes per fluid mL, as described in [22].
    3. State-level cigar taxes from the CDC State System [6]. States either use an ad valorem tax or an excise tax, and both variables are controlled separately. Additionally, some states cap the maximum dollar amount of the cigar tax, which is controlled for as well.
    4. Percent of residents living in areas with a state or local tobacco 21 law, derived from state laws and local law information [51]. Local tobacco 21 laws are weighted to the state level using the percent of the state's population covered under each local law. This weighted average allows us to control for states' local Tobacco-21 policy environment.
    5. Indoor air laws: I follow prior work in generating a smoke-free air law index ased on American Non-Smokers Rights Foundation data on states and localities banning smoking in restaurants, bars, and private workplaces [50]. Specifically, I use the percent of the population covered under these laws in each state, weighing laws applied to bars, restaurants, and private workplaces equally, and treating partial bans (e.g., separate smoking areas) with half the weight of a full ban. I use the same method to create a parallel vape-free air law index.
- Laws affecting availability of tobacco substitutes/complements:
    1. The state's beer tax [52],
    2. Indicators for medical and recreational marijuana laws [53], and
- Economic climate [54]:
    1. The unemployment rate,
    2. The percent of residents living below the poverty line,
    3. The highest of either the state or federal minimum wage.

Online Appendix Table 1: E-cigarette MLSA Effective Dates

State	Date of E-cigarette MLSA
Alabama	8/1/2013
Alaska	8/22/2012
Arizona	9/13/2013
Arkansas	8/16/2013
California	9/27/2010
Colorado	3/25/2011
Connecticut	10/1/2014
Delaware	6/12/2014
District of Columbia	10/1/2015
Florida	7/1/2014
Georgia	7/1/2014
Hawaii	6/27/2013
Idaho	7/1/2012
Illinois	1/1/2014
Indiana	7/1/2013
Iowa	7/1/2014
Kansas	7/1/2012
Kentucky	4/10/2014
Louisiana	5/28/2014
Maine[+]	7/4/2015
Maryland	10/1/2012
Massachusetts	9/25/2015
Michigan	8/8/2016
Minnesota	8/1/2010
Mississippi	7/1/2013
Missouri	10/10/2014
Montana	1/1/2016
Nebraska	4/9/2014
Nevada	10/1/2015
New Hampshire	7/31/2010
New Jersey	3/12/2010
New Mexico	6/19/2015
New York	1/1/2013
North Dakota	8/1/2015
North Carolina	8/1/2013
Ohio	8/2/2014
Oklahoma	11/1/2014
Oregon	1/1/2016
Pennsylvania	8/8/2016
Rhode Island	1/1/2015
South Carolina	6/7/2013
South Dakota	7/1/2014
Tennessee	7/1/2011
Texas	10/1/2015
Utah	5/11/2010
Vermont	7/1/2013
Virginia	7/1/2014
Washington	7/28/2013
West Virginia	6/6/2014
Wisconsin	4/20/2012
Wyoming	3/13/2013

County	Date of E-cigarette MLSA
Santa Fe County, NM	2/13/2014
New York, Kings, Bronx, Richmond, and Queens Counties, NY	11/19/2013
Suffolk County, NY	11/1/2009
Cattaraugus County, NY	2/14/2012
Multnomah County, OR	4/4/2015
Philadelphia County, PA	3/27/2014
King County, WA	12/16/2010
Spokane County, WA	3/31/2011
Pierce County, WA	6/2/2011
Clark County, WA	6/23/2011

Notes: Reprinted from Pesko and Currie, 2019.