E-cigarettes and Cigarettes: Complements or Substitutes?

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ABSTRACT

This paper explores the relationship between e-cigarettes and cigarettes by considering how state-level variation in cigarette taxes across time influences youth e-cigarette usage. The extensive and intensive margin measures of smoking are drawn from the National Youth Tobacco Survey (NYTS), which provides a nationally representative sample of middle school and high school students across the U.S from 2011-2017. The analyses use a state and year fixed effects model and controls for other e-cigarette regulations and demographic characteristics are included. The results suggest a complement relationship between e-cigarettes and cigarettes. With a one dollar increase in cigarette taxes per pack, for every two people that decrease their likelihood of ever trying a cigarette, about one individual decreases their likelihood of ever trying an e-cigarette.

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I. INTRODUCTION

In recent years, the rapid rise in the popularity and use of electronic cigarettes[2], or e-cigarettes, has resulted in an epidemic among youth[3]. E-cigarettes were first invented in 2003 by Hon Lik, a Chinese pharmacist (HHS 2016) and were first introduced into the United States' market in 2007 (Noel, Rees, and Connolly 2011). In comparison to conventional combustible cigarettes, hereafter referred to as cigarettes, e-cigarettes are noncombustible and less harmful as the aerosol produced by e-cigarettes contains fewer toxic chemicals (CDC 2019b). Nonetheless, e-cigarettes are not completely harmless as they still contain chemicals and the majority of e-cigarettes sold in the U.S. contain nicotine (HHS 2016)[4].

Although e-cigarettes have grown in popularity among all age groups, it is the most pervasive among youth in middle school and high school. Compared to adults, youth are more likely to engage in e-cigarette usage (CDC 2019b)[5]. By 2014, e-cigarettes became the most commonly used tobacco product, surpassing cigarettes, within the youth age group (Arrazola et al. 2015). In 2018, the National Youth Tobacco Survey (NYTS) found that e-cigarettes were used by 20.8% of high school students and 4.9% of middle school students, which is equivalent to 3.05 million and 570,000 students, respectively (Gentzke et al. 2019)[6]. Despite a trend of declining current youth tobacco usage in previous years, the expansion of e-cigarettes has negated this progress and has been the

[2] E-cigarettes come in three main forms: large devices such as tanks and mods, rechargeable or refillable e-cigarettes, and disposable e-cigarettes (CDC 2019b). E-cigarettes function by using a battery to power an atomizer that heats a cartridge of liquid to produce an aerosol that is then inhaled by the user (NIDA 2018).

[3] The epidemic status of e-cigarette usage among youth was labeled by the U.S. Surgeon General in 2018 (U.S. Department of Health and Human Services 2018).

[4] According to the Office of the Surgeon General's 2016 report on e-cigarettes, nicotine can lead to addiction and impede adolescent brain development (HHS 2016). E-cigarettes also introduce other chemicals, such as carbonyl compounds and volatile organic compounds, that can harm the user's health (HHS 2016).

[5] The increasing youth usage alongside the harmful health effects of nicotine on adolescent development prompt concern for the spread of e-cigarettes.

[6] These percentages increased from 2017 to 2018 by 77.8% (from 11.7% to 20.8%) for high school students and by 48.5% (from 3.3% to 4.9%) for middle school students (Gentzke et al. 2019).

primary force increasing current tobacco product use among middle school and high school students (Gentzke et al. 2019).

This trend prompts the question of how e-cigarettes impact cigarette usage. To effectively and appropriately regulate e-cigarettes, it is essential to determine if e-cigarettes are an on-ramp into other tobacco product usage or an off-ramp from cigarettes. Research indicates that youth e-cigarette usage is associated with other tobacco usage, suggesting that e-cigarettes may be a gateway (Auf et al. 2019, HHS 2016)[7]. This paper specifically focuses on youth and aims to explore the relationship between e-cigarettes and cigarettes by exploiting the state-level variation in cigarette taxes across time to determine how increasing the cost of cigarettes impacts e-cigarette usage among middle school and high school students. At this time, it appears that no other papers have taken this approach to identify the relationship between cigarettes and e-cigarettes in youth. The most comparable paper is Cotti et al. (2018) which also uses state-level variation in cigarette taxes but uses household panel data to estimate how tobacco control policies impact adult e-cigarette purchases. Whereas Cotti et al. (2018) only focused on adults, this paper will focus on the relationship between the two products among youth, a subpopulation of interest, by using survey data from the NYTS.

The majority of other research in this area directly estimates the cross-price elasticity of demand using price and sales data[8] or examines the relationship between the products using state-level variation in e-cigarette minimum legal sales age (MLSA) laws[9], both of which do not explicitly consider how cigarette regulation may impact e-cigarette usage[10]. Among the studies using price and sales data, three studies found a substitute relationship (Stoklosa et al. 2016; Pesko and Warman

[7] Higher likelihood of lifetime and current use of tobacco products including cigarettes, cigars, and smokeless tobacco (Auf et al. 2019).
[8] Nielsen Retail Scanner data is the most commonly used source of price and sales data. Papers using this data are limited to analysis of e-cigarette/cigarette sales in Nielsen participating stores, which do not include online or local vape shop sales. Nielsen data is also aggregated at the market level, preventing analysis of youth, a subpopulation of interest.
[9] Minimum legal sales age (MLSA) laws will also be referred to as youth access laws or youth purchasing restrictions throughout the remainder of the paper.
[10] Please refer to Appendix A for further details regarding the research covered in the literature review.

2017; Zheng et al. 2017), one found a complement relationship (Cotti et al. 2018), and three found no consistent relationships (Huang et al. 2014; Pesko et al. 2018; Zheng et al. 2016). The studies that focus on adolescents by exploiting variation in youth e-cigarette access laws have similarly mixed results. Three papers reinforce the substitute relationship (Friedman 2015; Pesko et al. 2016; Dave et al. 2019), one supports a complement relationship (Abouk and Adams 2017), and one paper finds an inconsistent relationship (Dutra et al. 2018).

This paper contributes to the existing e-cigarette research in several ways. First, by extracting individual-level youth e-cigarette usage data from the NYTS, this paper provides insight specifically on youth, an important subpopulation of interest. The studies using Nielsen price and sales data were not able to analyze the e-cigarette and cigarette relationship among youth due to the aggregated nature of the Nielsen data[11]. Although Pesko et al. (2018) was unique among those papers to focus on youth by regressing measures of youth e-cigarette usage[12] on cigarette prices, the e-cigarette data was limited to only two years (2014-2015). By incorporating e-cigarette usage data from the NYTS, this paper is able to analyze seven years (2011-2017) of e-cigarette usage on both the extensive and intensive margins[13]. Additionally, whereas the papers exploiting state-level variation in e-cigarette MLSA laws concentrate on the impact of e-cigarette regulation on cigarette usage, this paper adds to the literature by exploring the alternative – the impact of cigarette regulation on e-cigarette usage.

Insight into how youth e-cigarette usage reacts to policies on cigarettes has a broader influence on how public health policy should approach developing e-cigarette regulation and the continuing cigarette regulation. If e-cigarettes and cigarettes are substitutes, increasing e-cigarette regulation may have the unintended consequence of increasing cigarette usage. Likewise, further

[11] Stoklosa et al. 2016; Pesko and Warman 2017; Zheng et al. 2017; Cotti et al. 2018; Huang et al. 2014; Pesko et al. 2018; Zheng et al. 2016.
[12] Pesko et al. (2018) extracts youth e-cigarette usage data from the Monitoring the Future (MTF) survey.
[13] The aforementioned weaknesses (see footnote 8) of the studies that utilize Nielsen sales data are avoided by using the National Youth Tobacco Survey (NYTS) to measure e-cigarette usage instead of e-cigarette sales.

cigarette regulation could influence individuals to use e-cigarettes instead. The desirability of this outcome depends on the relative harm of e-cigarettes compared to cigarettes and if e-cigarettes are an effective smoking cessation method. However, if the two products are complements, additional regulation on either e-cigarettes or cigarettes could help curb the use of both products and decrease overall tobacco usage among youth.

The remainder of the paper is organized as follows. Section II will detail the data used in the analyses. Section III will describe the empirical model and methodology. Section IV will examine the empirical results and Section V will conclude with a discussion of the results, its implications and limitations, and future areas of research.

II. DATA

National Youth Tobacco Survey (NYTS)[14]

Repeated cross-sectional data on youth e-cigarette and cigarette usage from 2011-2017 is derived from the National Youth Tobacco Survey (NYTS), a survey conducted jointly by the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA) annually since 2011[15]. The survey provides representative data of U.S. public and private school students in grades 6th through 12th by using a stratified, three-stage cluster sample design. The sample is stratified at the country level, school level, and class/student level. Students self-administered the survey voluntarily and anonymously participated. All surveys were conducted between February and June of each year. The NYTS was chosen for its focus on youth and as it was the earliest survey to start including questions on e-cigarettes in 2011, providing for more years of data. Summary statistics on the overall survey regarding the number of states selected, school participation rates, and student participation rates are provided in Table 1. Following that, Table 2 provides additional individual-level summary statistics by year for the samples used in the subsequent analyses.

Table 1: NYTS Overall Survey Summary Statistics

Year	2011	2012	2013	2014	2015	2016	2017
Number of States Selected	34	39	39	36	36	36	32
School Participation Rate	83.2%	80.3%	74.8%	80.2%	72.6%	81.5%	76.8%
Student Participation Rate	88.0%	91.7%	90.7%	91.4%	87.4%	87.9%	88.7%
Overall Participation Rate	73.0%	73.6%	67.8%	73.3%	63.4%	71.6%	68.1%

Note: Overall participation is defined as the product of the school-level participation rate and student-level participation rate as provided by the NYTS(CDC 2019a)

[14] Source: (CDC 2019a)

[15] The NYTS was conducted prior to 2011, however, only beginning in 2011 the survey was administered on an annual basis (CDC 2019a).

Table 2: Individual-level Characteristics of Youth Surveyed in the NYTS (2011-2017)

Year	2011	2012	2013	2014	2015	2016	2017
n	16,188	20,391	15,110	18,237	15,294	17,162	14,927
Individual-level variables	% (SE)	% (SE)	% (SE)	% (SE)	% (SE)	% (SE)	% (SE)
Ever tried							
E-cigarette	2.92809 (.132512)	5.93889 (.16552)	6.90933 (.20633)	18.9517 (0.29235)	26.18513 (.35724)	21.2786 (.31388)	20.30305 (.33159)
Cigarette	30.17154 (.36453)	24.30675 (.30104)	24.05803 (.35031)	20.91276 (.3023)	20.01579 (.32457)	17.18126 (.28902)	15.74968 (.29931)
P30D use							
E-cigarette	.87102 (.07303)	1.84885 (.09434)	2.57445 (.12884)	8.94892 (.21282)	10.64576 (.25088)	6.91411 (.1952)	7.01315 (.21022)
Cigarette	9.9068 (0.2387)	8.53225 (.19619)	7.52882 (.21538)	5.87358 (.17478)	5.61191 (.18679)	4.23769 (0.15444)	4.84176 (.17652)
Sex							
Female	50.84086 (.39603)	50.41955 (.35025)	50.78146 (.40686)	49.19958 (.37209)	49.47292 (.40584)	49.7945 (.38313)	50.41954 (.4113)
Male	49.15914 (.39603)	49.58045 (.35025)	49.21854 (.40686)	50.80042 (.37209)	50.52708 (.40584)	50.2055 (.38313)	49.58046 (.4113)
Race							
Hispanic, Latino, Latina, or of Spanish origin	32.72899 (.37231)	23.36135 (.29931)	25.41363 (.3542)	31.58414 (.34423)	30.476 (.37222)	30.87635 (.35266)	28.28432 (.36864)
Black or African American	24.43786 (.33775)	17.8314 (.26806)	25.87028 (.35627)	22.19663 (.30774)	20.24977 (.32496)	21.938 (.3159)	24.10397 (.35009)
White	52.42772 (.39253)	62.82674 (.33844)	58.53739 (.4008)	59.1435 (.36402)	61.3574 (.39375)	56.95723 (.37797)	59.14785 (.40235)

Note: The table above does not include summary statistics for the following racial demographic groups: American Indian or Alaska, Asian, Native Hawaiian or other Pacific Islander. However, these are included as controls in the analyses that follow. Source: (CDC 2019a)

State Tobacco Activities Tracking and Evaluation (STATE) System

Information regarding e-cigarette taxes, cigarette taxes, and e-cigarette youth access restrictions was obtained from the State Tobacco Activities Tracking and Evaluation (STATE) System (CDC STATE System 2019c). The STATE system contains both legislative and case law information that provides historical, state-level data on tobacco legislation focused on prevention and control. Table 3 provides summary statistics regarding taxes and MLSA laws.

Table 3: Summary Statistics on Cigarette and E-cigarette Regulations

Year	2011	2012	2013	2014	2015	2016	2017
Average Cigarette Tax	1.42768	1.45188	1.48428	1.51518	1.54968	1.61098	1.67413
(Standard Deviation)	(.93995)	(.95612)	(.98259)	(1.00754)	(1.01216)	(1.02088)	(1.05049)
Average E-Cigarette Tax	0	0	0	0	.00125	.00275	.006
(Standard Deviation)	(0)	(0)	(0)	(0)	(.00783)	(.01222)	(.02459)
Num. of States with E-cigarette MLSA Law	7	12	24	39	45	46	47

Note: These are the averages across all states excluding DC. All numbers were pulled from the STATE System data sets (CDC STATE System 2019, CDC STATE System 2019a, CDC STATE System 2019b)

III. EMPIRICAL MODEL & METHODOLOGY

To explore the effects of cigarette taxation on e-cigarette usage, state-level cigarette tax data on the total excise tax per pack of cigarettes across 2011-2017 from the STATE system is merged with the NYTS cross-sectional survey data on past 30 days usage and ever tried measures of smoking. This paper estimates a linear probability model with state and year fixed effects to control for time-invariant and entity-invariant effects such as attitudes toward smoking and demographic characteristics that do not vary over a short period of time. Additional controls are added for e-cigarette taxes and youth e-cigarette access laws, which are both time and state variant, as well as for demographic and racial characteristics. The same model specifications are also estimated on measures of cigarette usage to provide a point of comparison for the relative size and economic significance of the coefficients in the e-cigarette usage regressions. The sample restricts observations to students aged 12-17 and in grades 6th-12th for consistency with other comparable research. The two primary, fully specified regression equations which include state and year fixed effects, control for e-cigarette regulations, and control for demographic characteristics are provided below:

$$evertried\_ecig_{ist} = \beta_0 + \beta_1 cig\_tax_{st} + \beta_1 ecig\_tax_{st} + \beta_2 ecig\_access_{st} + \theta X_{ist} + \lambda_s + \gamma_t + \varepsilon_{ist} \quad (1)$$

$$p30days\_1plus\_ecig_{ist} = \beta_0 + \beta_1 cig\_tax_{st} + \beta_1 ecig\_tax_{st} + \beta_2 ecig\_access_{st} + \theta X_{ist} + \lambda_s + \gamma_y + \varepsilon_{ist} \quad (2)$$

$evertried\_ecig_{st}$ is whether or not a student has ever tried an e-cigarette in their lives for a given state s and year t and $p30days\_1plus\_ecig_{st}$ is whether or not a student has used an e-cigarette at least one day in the past 30 days in a given state s and year t. Analogous measures of $evertried\_cig_{st}$ and $p30days\_1plus\_cig_{st}$ are used for the regressions on cigarette usage. cig_tax_{st} is the dollar tax per pack of cigarettes in a given state s and year t and $ecig\_tax_{st}$ is a binary indicator variable for if an e-cigarette tax per e-cigarette is present in a given state s and year

t. $ecig\_access_{st}$ is a binary indicator for if a state in a given year has a minimum legal selling age for e-cigarettes. λ_s represents state fixed effects and γ_t represents year fixed effects, and X_{ist} represents the individual-level demographic controls – age, grade, sex, and race[16].

Survey Measures of E-cigarette and Cigarette Usage

E-cigarette Usage

The dependent variables of interest are the two main measures of e-cigarette usage. The paper uses the number of students that have ever tried e-cigarettes to measure the extensive margin and uses the information on how many days e-cigarettes were used in the past 30 days to measure smoking intensity, the intensive margin. These two measures are utilized as the NYTS began collecting data on both these areas since 2011.

Although questions on e-cigarettes appeared the earliest in the NYTS, the scope of the questions asked was limited. From 2011 to 2013 there was no separate section for e-cigarettes. Instead, the NYTS included e-cigarettes as one option to the following two questions[17]:

1. "Which of the following tobacco products have you ever tried, even just one time? (You can CHOOSE ONE ANSWER or MORE THAN ONE ANSWER)"
2. "During the past 30 days, which of the following tobacco products did you use at least one day? (You can CHOOSE ONE ANSWER or MORE THAN ONE ANSWER)"

[16] Controls are dummy variables for ages 12-17, grades 6th-12th, and male or female. Race includes the following categories: 1) Hispanic, Latino, Latina, or of Spanish origin; 2) American Indian or Alaska; 3) Asian; 4) Black or African American; 5) Native Hawaiian or other Pacific Islander. Each racial category is coded as a binary variable where "1" is if the individual is of that race.

[17] Questions are pulled from the 2011 NYTS. For 2012 and 2013, the question structure and approach remain the same, however, the wording is slightly changed.

Then in 2014, the NYTS incorporated a specific, independent section for questions on e-cigarettes. Listed below are the two questions analogous to those from 2011 to 2013[18]:

1. "Have you ever used an electronic cigarette or e-cigarette, even once or twice?"
2. "During the past 30 days, on how many days did you use electronic cigarettes or e-cigarettes?"

The question related to the extensive margin remains consistent across all years and takes the form of a binary indicator variable where "0" is if the student has never tried e-cigarettes before and "1" is if the student has ever used an e-cigarette. Due to the limitation of the intensive margin question from 2011-2013, the data from the following years are adapted to be compatible with the earlier information. Thus, for past 30 days usage, the question is recoded into a dummy variable where "0" indicates no days of e-cigarette usage within the past 30 days and "1" indicates e-cigarettes usage for at least one day within the past 30 days.

Applying these two primary measures for e-cigarettes introduces both advantages and disadvantages to this paper's analyses. As an advantage, these two measures provide insight into both the extensive and intensive margins. The extensive margin contributes to the understanding of how cigarette taxes impact the likelihood of a student ever initiating e-cigarettes in their youth. This is an area of concern as most tobacco use starts during youth and young adulthood (Gentzke et al. 2019), and therefore, public health policy seeks to decrease the likelihood of smoking initiation during this time period. Among the students that have used e-cigarettes, the intensive margin offers insight into how frequently the students smoke them. However, this insight is limited as the intensive margin is a measure of "0 days" or "≥1 day" of usage and therefore equates any days of

[18] Questions are pulled from the 2015 NYTS. For all other years 2014 onwards, the question structure and approach were similar, but with altered wording.

usage as the same. For example, the measure does not differentiate if an individual marked that they used e-cigarettes one day in the past 30 days versus all 30 days in the past 30 days. As mentioned by Pesko et al. (2018), a better intensive margin measure would have been the amount of e-cigarette liquid consumed as it directly determines nicotine intake[19].

Cigarette Usage

The measures on cigarette usage are analogous to those employed for e-cigarettes[20]. In 2011-2017, the past 30 days usage question for cigarettes follow a similar format to the post-2014 e-cigarette question and is therefore reformatted in an identical manner as an indicator of any use within the past 30 days ("0" for no days, "1" for ≥1 day).

E-cigarette and Cigarette Regulations

Cigarette Taxes

State-level cigarette excise taxes from 2011-2017 are obtained from the STATE System[21]. The tax amounts used are the total state excise tax collected, federal plus state, per pack of cigarettes expressed in dollar amounts. To merge with the NYTS data, the provided quarterly cigarette taxes are averaged over each respective year for each state.

The coefficient on this variable is our primary estimate of interest as it will reveal the relationship between cigarette taxes and e-cigarette usage. If the coefficient is positive when regressed on e-cigarette usage, this suggests that cigarettes and e-cigarettes are substitutes. However, if the coefficient is negative, this indicates that cigarettes and e-cigarettes are complements.

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[19] Measuring the amount of e-cigarette liquid consumed would be more comparable to the intensive margin measure of how many cigarettes an individual has used in the past 30 days.
[20] Note, although questions on cigarette usage were more comprehensive than the two measures used in the analyses, these two were extracted for comparability with the e-cigarette usage measures.
[21] Refer to Appendix B for details on which states had changes in their cigarette excise taxes over 2011-2017.

E-cigarette Taxes

Although not many states enacted taxes on e-cigarettes during 2011-2017[22], it is crucial to control for taxes as a potential confounding variable that impacts e-cigarette usage. There is currently no federal level e-cigarette excise tax, and the state-level e-cigarette excise taxes are also pulled from the STATE System. Due to the limited number of states with e-cigarette excise taxes and the wide range of tax sizes, e-cigarette taxes are incorporated as a binary variable where "1" represents that an excise tax, per e-cigarette, is present in a given state and year and "0" if otherwise.

Any taxes on e-cigarettes that appear as a percent value of the wholesale purchase price are excluded from this analysis. This is due to the fact that the three states, excluding D.C., employing this type of taxation have varying definitions of what is taxable for e-cigarettes[23], making it unclear how to incorporate this into the model. In two states, e-cigarettes fall under the regulation of the state tobacco tax laws, whereas in one state there is a separate tax specifically for e-cigarettes which taxes regardless of if there is nicotine.

E-cigarette Youth Access Laws

E-cigarette purchasing restrictions also vary across time and state from 2011-2017. Although federal law mandated in 2016 that the minimum legal selling age for e-cigarettes is 18, several states have since increased the minimum age of sale to 19 or 21 ("E-Cigarettes: Facts, Stats and Regulations" 2018). This paper accounts for the MLSA laws as a binary variable where "1" signifies that an MLSA law was present in a given state at any point in the year.

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[22] Progressively over time, starting in 2010, various states have passed excise taxes on e-cigarettes and as of 2018, five states have imposed e-cigarette excise taxes per e-cigarette (CDC STATE System 2019a). Refer to Appendix C for further information e-cigarette taxes during 2011-2017.

[23] The three states that tax e-cigarettes based on wholesale purchase price are California, Minnesota, and Pennsylvania. For more details on state-specific taxation approaches refer to CDTFA (n.d.), Minnesota Department of Revenue (2018), and Pennsylvania Department of Revenue (n.d.)

IV. RESULTS

Table 4: Fully Specified Regressions and Ratio Calculations for Ever Tried and Past 30 days Usage Measures of E-cigarettes and Cigarettes

	(1) Ever tried e-cig	(2) Ever tried cig	(3) P30D e-cig use	(4) P30D cig use
Cig Tax (Per Pack)	-0.0151	-0.0316**	-0.00318	-0.0148***
	(0.0100)	(0.0122)	(0.00559)	(0.00519)
E-Cig Tax (Per E-Cig)	-0.0391**	-0.0674***	-0.0241*	-0.0339***
	(0.0153)	(0.0209)	(0.0131)	(0.0113)
E-Cig Access	-0.00826	-0.0154	-0.00527	-0.00563
	(0.00731)	(0.0129)	(0.00561)	(0.00452)
Age	0.0465***	0.0696***	0.0288***	0.00881
	(0.00900)	(0.00795)	(0.00579)	(0.00615)
Age Squared	-0.00173**	-0.000411	-0.00109**	0.00156***
	(0.000734)	(0.000596)	(0.000465)	(0.000478)
Sex	0.0258***	0.0192***	0.0179***	0.0118***
	(0.00229)	(0.00401)	(0.00163)	(0.00193)
Grade	0.0156***	-0.00244	0.000895	-0.00546***
	(0.00186)	(0.00259)	(0.000970)	(0.00167)
Constant	-0.298***	-0.0947**	-0.133***	0.00992
	(0.0302)	(0.0378)	(0.0214)	(0.0238)
Observations	114686	114619	114618	114431
Race Controls	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes
Ratio	0.476275**		.2156134	
	(.1931304)		(.3594003)	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Ratio: Separately, for both the ever tried and past 30 days usage measures the ratio is calculated by dividing the coefficient on cigarette tax for e-cigarettes by the coefficient on cigarette tax for cigarettes

Table 4 presents the regression table for equations (1) and (2) as well as the corresponding equations for cigarette usage. Columns (1) and (2) have the ever tried measures for e-cigarettes and cigarettes, respectively, and Columns (3) and (4) have the past 30 days usage measures. These regressions are fully specified as they include both state and year fixed effects and all demographic controls.

At the bottom of the table is a ratio of the primary coefficients of interest, the coefficient on cigarette taxes, between e-cigarette usage and cigarette usage. The first ratio on the left is calculated by dividing the regression coefficient on cigarette tax for the e-cigarette measure of ever tried by the corresponding coefficient on cigarette tax for the cigarette measure of ever tried[24]. The second ratio computes the same calculation for the regressions using past 30 days usage as the dependent variable.

The positive ratio between e-cigarettes and cigarettes for the binary indicator of having ever tried an e-cigarette/cigarette suggests a complement relationship between e-cigarettes and cigarettes. Corresponding to a one dollar increase in cigarette taxes per pack, for every one individual that decreases their likelihood of ever trying a cigarette, 0.48 of an individual decreases their likelihood of ever trying an e-cigarette. Therefore, with a one dollar increase in cigarette taxes, for every two individuals that decrease their likelihood of ever trying a cigarette, about one individual decreases their likelihood of ever trying an e-cigarette.

The ratio for past 30 days usage is not statistically significant and this may in part be due to a lack of statistical power and the limitations from converting the past 30 days usage measure into a dichotomous variable.

Table 5.1 and 5.2 provide the same ratio calculated for different model specifications of both the ever tried and past 30 days usage measures. All models include state and year fixed effects. In both Table 5.1 and 5.2, ratio (1) is only computed with e-cigarette regulations (tax and MLSA) as controls and then ratio (2) adds demographic characteristics, excluding race. Ratio (3) is calculated for the fully specified models; this is equivalent to the ratios presented in Table 4. The ratio between the coefficients for the ever tried measure increases slightly in size as more controls are added –

[24] As an example, for the ever tried measures, the ratio is equal to the coefficient on Cig Tax in regression (1) divided by the coefficient on Cig Tax in regression (2) in Table 4.

from 0.45 to 0.48. The ratio is statistically significant at the 1% level without controls for race and statistically significant at the 5% level with race controls. Across all model specifications, the ratios for the past 30 days usage coefficients are not statistically significant but do increase slightly as more controls are added. Again, the past 30 days usage measure may lack statistical power as it is limited to only an assessment of ever use within the past 30 days and not a measure of how many days within the past 30 days.

Table 5.1: Ratios for Ever Tried Usage Measures Calculated Under Various Model Specifications

	(1)	(2)	(3)
Cig Tax (Per Pack)	✓	✓	✓
E-Cig Tax (Per E-Cig)	✓	✓	✓
E-Cig Access	✓	✓	✓
Age		✓	✓
Age Squared		✓	✓
Sex		✓	✓
Grade		✓	✓
Fixed Effects	Yes	Yes	Yes
Race Controls	No	No	Yes
Ratio	.4492924*	.4664766***	.476275**
	(.2292738)	(.1763767)	(.1931304)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5.2: Ratios for Past 30 Days Usage Measures Calculated Under Various Model Specifications

	(1)	(2)	(3)
Cig Tax (Per Pack)	✓	✓	✓
E-Cig Tax (Per E-Cig)	✓	✓	✓
E-Cig Access	✓	✓	✓
Age		✓	✓
Age Squared		✓	✓
Sex		✓	✓
Grade		✓	✓
Fixed Effects	Yes	Yes	Yes
Race Controls	No	No	Yes
Ratio	.1705643	.2240609	.2156134
	(.4150599)	(.3420489)	(.3594003)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Ever Tried E-cigarette Dependent Variable Regressions

	(1)	(2)	(3)	(4)
Cig Tax (Per Pack)	-0.0123	-0.0161	-0.0164	-0.0151
	(0.0111)	(0.00990)	(0.00992)	(0.0100)
E-Cig Tax (Per E-Cig)	-0.0619***	-0.0490***	-0.0489***	-0.0391**
	(0.0158)	(0.0154)	(0.0154)	(0.0153)
E-Cig Access	-0.00657	-0.00772	-0.00779	-0.00826
	(0.00799)	(0.00769)	(0.00770)	(0.00731)
Age		0.0242***	0.0469***	0.0465***
		(0.00212)	(0.00899)	(0.00900)
Sex		0.0252***	0.0252***	0.0258***
		(0.00231)	(0.00231)	(0.00229)
Grade		0.0149***	0.0153***	0.0156***
		(0.00191)	(0.00190)	(0.00186)
Age Squared			-0.00178**	-0.00173**
			(0.000735)	(0.000734)
Constant	-0.0155	-0.193***	-0.264***	-0.298***
	(0.0223)	(0.0229)	(0.0298)	(0.0302)
Observations	116527	115270	115270	114686
Race Controls	No	No	No	Yes
Fixed Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Ever Tried Cigarette Dependent Variable Regressions

	(1)	(2)	(3)	(4)
Cig Tax (Per Pack)	-0.0274*	-0.0352***	-0.0785***	-0.0316**
	(0.0157)	(0.0127)	(0.0147)	(0.0122)
E-Cig Tax (Per E-Cig)	-0.0876***	-0.0675***	-0.0721**	-0.0674***
	(0.0212)	(0.0235)	(0.0309)	(0.0209)
E-Cig Access	-0.0137	-0.0173	-0.0776***	-0.0154
	(0.0164)	(0.0128)	(0.00738)	(0.0129)
Age		0.0662***	0.0757***	0.0696***
		(0.00298)	(0.00805)	(0.00795)
Sex		0.0190***	0.0189***	0.0192***
		(0.00395)	(0.00390)	(0.00401)
Grade		-0.00500*	-0.00582**	-0.00244
		(0.00263)	(0.00286)	(0.00259)
Age Squared			-0.000673	-0.000411
			(0.000621)	(0.000596)
Constant	0.308***	-0.0357	0.0216	-0.0947**
	(0.0321)	(0.0289)	(0.0361)	(0.0378)
Observations	116194	115169	115169	114619
Race Controls	No	No	No	Yes
Fixed Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 provides the results of four different model specifications with ever tried e-cigarettes as the dependent variable. Table 7 provides the same model specifications but instead with the cigarette ever tried measure for comparison.

First, examining the results in Table 6, the coefficient on cigarette tax is statistically insignificant for e-cigarettes. However, the coefficient is consistently negative across all model specifications and therefore provides support for the complement relationship revealed through the calculated ratios. Using the fully specified regression, it is interesting to note that an increase in taxes per e-cigarette by one dollar decreases the likelihood of an individual to ever try an e-cigarette by 3.91 percentage points. This indicates that tax increases on e-cigarettes could be an effective way to decrease e-cigarette initiation among youth.

In Table 7, there is further support for the complement relationship through the negative coefficient on e-cigarette tax. This suggests that by increasing the e-cigarette tax per e-cigarette by one dollar, the likelihood to ever try a cigarette decreases by 6.74 percentage points. Additionally, the coefficient on cigarette tax is statistically significant across all the model specifications and varies in magnitude across the different specifications. Using the fully specified model, an increase in cigarette taxes per pack by one dollar decreases the likelihood of ever trying a cigarette by 3.16 percentage points.

Table 8: Past 30 Days E-cigarette Dependent Variable Regressions

	(1)	(2)	(3)	(4)
Cig Tax (Per Pack)	-0.00210	-0.00318	-0.00338	-0.00318
	(0.00548)	(0.00540)	(0.00543)	(0.00559)
E-Cig Tax (Per E-Cig)	-0.0335***	-0.0297**	-0.0296**	-0.0241*
	(0.0119)	(0.0124)	(0.0124)	(0.0131)
E-Cig Access	-0.00432	-0.00462	-0.00467	-0.00527
	(0.00581)	(0.00589)	(0.00588)	(0.00561)
Age		0.0144***	0.0288***	0.0288***
		(0.000981)	(0.00580)	(0.00579)
Sex		0.0175***	0.0175***	0.0179***
		(0.00164)	(0.00163)	(0.00163)
Grade		0.000809	0.00105	0.000895
		(0.00101)	(0.000987)	(0.000970)
Age Squared			-0.00112**	-0.00109**
			(0.000463)	(0.000465)
Constant	0.0152	-0.0740***	-0.119***	-0.133***
	(0.0121)	(0.0142)	(0.0205)	(0.0214)
Observations	116445	115202	115202	114618
Race Controls	No	No	No	Yes
Fixed Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Past 30 Days Cigarette Dependent Variable Regressions

	(1)	(2)	(3)	(4)
Cig Tax (Per Pack)	-0.0123*	-0.0154***	-0.0151***	-0.0148***
	(0.00636)	(0.00526)	(0.00529)	(0.00519)
E-Cig Tax (Per E-Cig)	-0.0479***	-0.0411***	-0.0412***	-0.0339***
	(0.0117)	(0.0114)	(0.0114)	(0.0113)
E-Cig Access	-0.00324	-0.00459	-0.00453	-0.00563
	(0.00579)	(0.00467)	(0.00468)	(0.00452)
Age		0.0284***	0.00923	0.00881
		(0.00220)	(0.00624)	(0.00615)
Sex		0.0116***	0.0116***	0.0118***
		(0.00190)	(0.00190)	(0.00193)
Grade		-0.00501***	-0.00534***	-0.00546***
		(0.00184)	(0.00180)	(0.00167)
Age Squared			0.00150***	0.00156***
			(0.000479)	(0.000478)
Constant	0.106***	-0.0365**	0.0235	0.00992
	(0.0146)	(0.0161)	(0.0234)	(0.0238)
Observations	116033	114988	114988	114431
Race Controls	No	No	No	Yes
Fixed Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 presents the results for four different model specifications with past 30 days e-cigarette usage as the dependent variable. Table 9 provides the same model specifications, but instead with the past 30 days cigarette usage measure for comparison.

In Table 8, the coefficient on cigarette tax is statistically insignificant for e-cigarettes. However, similar to the ever tried measure of e-cigarettes, the coefficient is consistently negative across all model specifications and provides evidence for a complement relationship. The coefficient on e-cigarette tax is statistically significant across all model specifications. For the fully specified regression, an increase in taxes per e-cigarette by one dollar decreases the likelihood of an individual to smoke at least one day within the past 30 days by 2.41 percentage points. The effect of an increase in e-cigarette taxes seems to be slightly more effective at decreasing the likelihood of using e-cigarettes at the extensive margin versus the intensive margin.

Cigarette taxes appear to be less effective on the intensive margin for cigarette use as well. In the fully specified model in Table 9, a one dollar increase in cigarette taxes per pack is associated with a decrease in the likelihood to smoke a cigarette at least one day in the past 30 days by 1.48 percentage points. This is less than the decrease in the likelihood of 3.16 percentage points at the extensive margin (Table 7). Again, there is further support for the complement relationship through the negative coefficient on e-cigarette tax. For past 30 days cigarette usage (Table 9), the coefficient on e-cigarette tax suggests that a one dollar increase in e-cigarette taxes per e-cigarette will decrease the likelihood of using a cigarette at least one day in the past 30 days by 3.39 percentage points. Although the coefficient decreases in size as demographic controls are added, the coefficient remains negative and statistically significant when all controls are considered.

V. DISCUSSION AND CONCLUSION

Implication of Results

The results support a complement relationship between e-cigarettes and cigarettes, consistent with the complement relationship found by Abouk and Adams (2017) and Cotti et al. (2018), who also incorporated state-level variation in cigarette taxes. With e-cigarettes and cigarettes holding a complement relationship, this indicates that by increasing the cost of obtaining cigarettes, there could be potential benefits of decreasing the likelihood that an individual ever tries not only cigarettes but also e-cigarettes. Whereas, with a substitute relationship, the primary concern is that by increasing the cost of obtaining cigarettes, individuals will become more likely to ever try and consume e-cigarettes.

Nonetheless, these results should be interpreted with caution. The complement effect seen through the ratio may potentially be driven by the fact that the dual use of e-cigarettes and cigarettes are common among youth (HHS 2016). In addition, further research needs to examine if initiating e-cigarette or cigarettes first has an impact on the likelihood of dual-use and the motivation behind dual-use.

Limitations of Analyses and Results

There are a few limitations of this approach and methodology that should be considered. First, although the NYTS provided the most years of data regarding e-cigarette usage, it comes at a tradeoff. The wording and terminology of the question with respect to e-cigarettes changed across the sample period, which may have impacted the reported e-cigarette usage. Additionally, as previously mentioned, the structure of the 2011-2013 e-cigarette questions restricts the available past 30 days usage data as it required it to be a binary indicator variable of "0" for no days and "1" for ≥1

day of usage in the past 30 days. Furthermore, the NYTS is a self-reported questionnaire, which introduces concerns regarding recall and memory issues.

Another limitation is inherent to the time period analyzed. Although e-cigarettes have grown in popularity among youth in the U.S., state-level and federal-level regulations are still developing. Federal-level regulations, such as the minimum legal selling age for e-cigarettes, were introduced relatively recently within the past couple of years. The majority of states do not have excise taxes on e-cigarettes, which restricts the ability to use and interpret the state-level e-cigarette tax variation to explore its impacts on cigarette consumption. In conjunction with this, many states are also changing the definition of what are considered tobacco products. As states begin to define and tax e-cigarettes in a similar manner to cigarettes, this could introduce additional complexities. However, as these changes progress and more states incorporate e-cigarette regulation, it would be beneficial to include the taxes that materialize as a percentage of the wholesale cost in future analyses.

Conclusion

This paper used state-level variation in cigarette taxes to explore the relationship between e-cigarettes and cigarettes. Due to increasing concerns surrounding youth e-cigarette usage, the measures of smoking were drawn from the NYTS, which provides a nationally representative sample of middle school and high school students across the U.S. With questions on e-cigarettes beginning as early as 2011, the time period analyzed is from 2011-2017. The sample was restricted to students in 6^{th}-12^{th} grade and aged 12-17 to follow other similar studies. The analyses considered a state and year fixed effects model and controlled for other e-cigarette regulations and demographic characteristics. The cross-sectional survey data from the NYTS was merged with state-level cigarette tax data on the total excise tax per pack of cigarettes from the STATE system.

The results support a complement relationship between e-cigarettes and cigarettes. The primary result of interest suggests that with a one dollar increase in cigarette taxes per pack, for every two individuals that decrease their likelihood to ever try a cigarette, one individual decreases their likelihood to ever try an e-cigarette. As e-cigarette regulation on the federal and state level continue to establish itself, these findings suggest that imposing regulations to increase the cost of obtaining e-cigarettes would be beneficial as it would be associated with a decline in the usage of both e-cigarettes and cigarettes. Additionally, any further increases in cigarette excise taxes could also help stem the growing e-cigarette epidemic among youth. However, future research should also examine potential differences in the e-cigarette and cigarette relationship among other subpopulations, such as adults, as regulation on such products has impacts beyond just youth.

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APPENDIX A – Literature Review Summary Table

Study Name	Citation	Country / Dataset	Methodology	Relationship between E-Cigs and Cigs?
How does electronic cigarette access affect adolescent smoking	(Friedman 2015)	National Survey on Drug Use and Health (NSDUH)	E-cigarette MLSA laws and Cigarette usage	Substitute
Prices and E-Cigarette Demand: Evidence From the European Union	(Stoklosa, Drope, and Chaloupka 2016)	Neisen Retail Scanner data - 6 EU Markets (Estonia, Ireland, Latvia, Lithuania, Sweden, and the United Kingdom) 2011-2014	Cigarette prices and E-cigarette sales	Substitute
The impact of price and tobacco control policies on the demand for electronic nicotine delivery systems.	(Huang, Tauras, and Chaloupka 2014)	Nielsen Retail Scanner Data (2009-2012) and American Community Survey (ACS)	Cigarette prices and E-cigarette sales	No consistent relationship
E-cigarette price sensitivity among middle- and high-school students: evidence from monitoring the future	(M. Pesko et al. 2018)	Nielsen Retail Scanner Data and Monitoring the Future Survey (2014-2015)	Cigarette prices and E-cigarette usage	No consistent relationship
The Effect of Prices on Youth Cigarette and E-Cigarette Use: Economic Substitutes or Complements?	(M. Pesko and Warman 2017)	Nielsen Retail Scanner Data (2011-2015) and NYTS	Cigarette prices and E-cigarette usage	Substitute
The influence of electronic cigarette age purchasing restrictions on adolescent tobacco and marijuana use	(M. F. Pesko, Hughes, and Faisal 2016)	Youth Risk Behavior Surveillance System (2007–2013)	E-Cigarette purchasing restrictions and Cigarette usage	Substitute
The effects of e-cigarette minimum legal sale age laws on youth substance use	(Dave, Feng, and Pesko 2019)	Youth Risk Behavior Surveillance System (2005-2015)	E-cigarette MLSA laws and Cigarette usage	Substitute
Bans on electronic cigarette sales to minors and smoking among high school students	(Abouk and Adams 2017)	Monitoring the Future Survey (2007-2014)	E-cigarette purchasing restrictions and Cigarette usage	Complement
Impact of E-Cigarette Minimum Legal Sale Age Laws on Current Cigarette Smoking	(Dutra et al. 2018)	NYTS (2009, 2011-2014)	E-cigarette MLSA laws and Cigarette usage	No consistent relationship
The relationship between cigarettes and electronic cigarettes: Evidence from household panel data	(Cotti, Nesson, and Tefft 2018)	Nielsen Consumer Panel and Individual Scanner Data (2011-2015)	Cigarette excise taxes and E-cigarette purchases	Complement
U.S. Demand for Tobacco Products in a System Framework	(Zheng et al. 2017)	Nielsen Scanner Data (ScanTrack)	E-cigarette prices and Cigarette Sales	Substitute
Advertising, habit formation, and U.S. tobacco products demand.	(Zheng et al. 2016)	Nielsen Scanner Data (ScanTrack)	E-cigarette/Cigarette Prices and Budget Share	No consistent relationship

APPENDIX B – State Cigarette Excise Tax Changes (2012-2017)

Year	# of States w/ Cig Tax Change	States	Average Change ($)
2012	1	IL	$1.00
2013	3	MA, MN, NH	$0.90
2014	2	OR, VT	$0.13
2015	8	AL, CT, KS, LA, MN, NV, OH, VT	$0.41
2016	6	CT, LA, MN, OR, PA, WV	$0.37
2017	4	CA, CT, DE, MN	$0.75

Source: (CDC STATE System 2019)

APPENDIX C – State E-cigarette Excise Taxes Per E-cigarette (2011-2018)

Year	Num. of States with E-cigarette Tax	States	Average E-cigarette Tax (Standard Deviation)
2011	0	-	-
2012	0	-	-
2013	0	-	-
2014	0	-	-
2015	2	LA, NC	.05 (0)
2016	3	LA, NC, WV	.055 (.0105409)
2017	4	KS, LA, NC, WV	.075 (.05)
2018	5	DE, KS, LA, NC, WV	.055 (.0102598)

Note: These averages are only across states with an e-cigarette tax per e-cigarette. Source: (CDC STATE System 2019a)