E-Cigarettes, Cigarettes, and Obesity: An Interaction of Epidemics

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Abstract:

The US Food and Drug Administration has declared both youth e-cigarette usage and obesity to be epidemics. With my research I attempt to identify the causal effect of state policies regulating e-cigarettes on predicted weight and traditional cigarette usage. In this paper I examine if restrictive state policies are in fact deterring youths use of nicotine and the effect this has on their weight status. I exploit variation in state policy by setting up a difference-in-differences model. I use 17 years of repeated cross-sectional data from the Behavioural Risk Factor Surveillance Survey (BRFSS) and create my own database of state policies regulating e-cigarettes. I find no impact for women. For men facing additional years of restricted access to e-cigarettes causes their predicted weight status to be lower. I provide evidence that this lower predicted weight can be explained, in part, though their substitution towards traditional cigarettes. These results suggest that restrictive e-cigarette policies alone are not enough to deter youth from using nicotine products, and that harmful substitution may result from such policies.

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Introduction

The US Food and Drug Administration (FDA) has declared both youth e-cigarette usage and obesity to be epidemics. In this paper I consider the interaction of these two epidemics, and I attempt to identify the causal effect of state policies regulating e-cigarettes on youth weight and traditional cigarette use outcomes.

E-cigarettes were introduced to the North American market in 2006, and as such research looking at their effects are scarce and limited in time span. In recent years e-cigarettes containing nicotine have greatly increased in popularity among youth. In 2018 the Food and Drug Administration declared e-cigarette usage, or 'vaping', among youth to be an epidemic as over one in five high school students reported being e-cigarette users that year (Cullet *et al*, 2018). Although e-cigarettes are less toxic than traditional cigarettes, nicotine still has adverse effects on developing brains. Nicotine use in youth can lead to the development of cognitive deficits, reduced impulse control, and mood disorders (US Department of Health and Human Services, 2016).

Obesity in the US has been a growing concern for many years among both youth and adults. The average obesity rate in the US for adults is just under two fifths and for youth is just under one fifth (Hales *et al.*, 2017). The increased health risks related to obesity include diabetes, cardiovascular diseases, and cancer (Tremmel *et al.*, 2017).

Nicotine, contained in e-cigarettes, acts as an appetite suppressant and has a negative impact on weight status (Audrain-McGovern & Benowitz, 2011). If youth vaping affects weight, then policies targeting youth vaping may either exacerbate or mitigate the obesity epidemic. If one substance is restricted by policy, it can cause substitution towards another. Therefor, I examine the potential substitution effect towards traditional cigarettes if access to e-cigarettes is restricted.

Each US state can choose their own restrictive e-cigarette policy. To analyze the effect of the different state policies on weight outcomes I use data from the Behavioural Risk Factor Surveillance Survey (BRFSS) for the years 2001-2017 along with a policy data set I compiled at the state level. Using these data I employ a microeconometric difference-in-differences approach to identify the effect of e-cigarette regulation on weight outcomes and cigarette usage.

I contribute to the literatures of youth smoking and obesity by being the first to do a national level analysis of the effects of e-cigarette policies on obesity and cigarette use outcomes. I analyze the substitution towards traditional cigarette usage among youth and young adults in the US when they face restricted access to e-cigarettes.

I find no consistent and significant effect of facing restrictions to the legal purchase of e-cigarettes on weight status for women. I find that for the male cohort facing more restrictions on e-cigarette access leads to lower predicted weight outcomes. I find for males, on average, there is a statistically significant and increasing effect on predicted weight loss the more years an individual faces restricted access to the legal purchase of e-cigarettes. This lower predicted weight can be explained in part by the substitution towards traditional cigarettes.

Trends in Obesity, E-Cigarette Use, Cigarette Use, and Policy

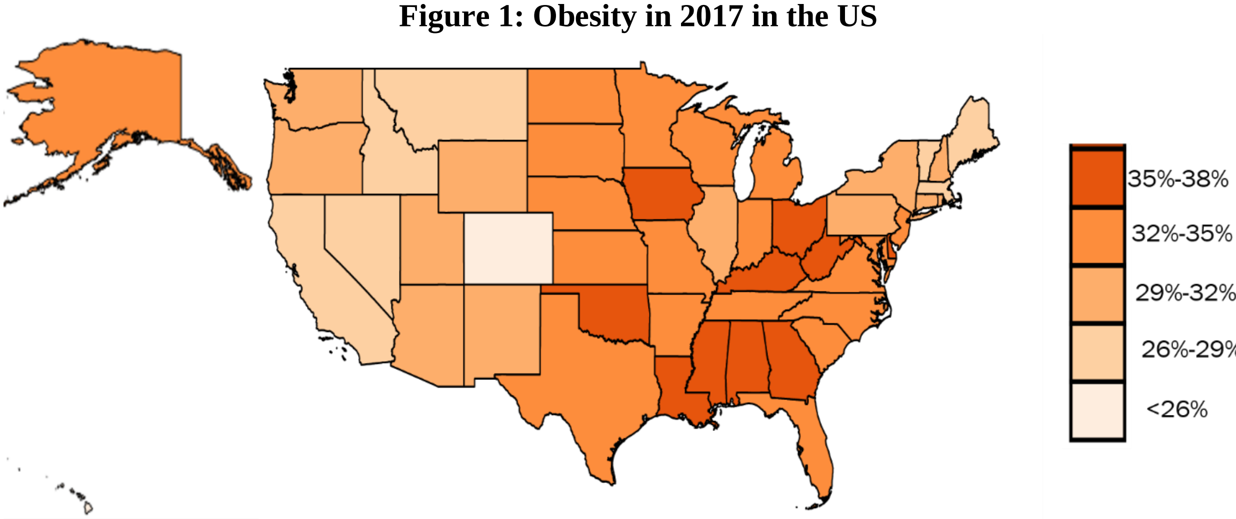
E-cigarettes are a relatively new nicotine delivery device. They deliver a vapour to the user by heating a solution made of glycerin, nicotine, and flavoring agents. In 2006 e-cigarettes were first introduced into the North American Market (CASSA, 2018) and by 2014 they were the most popular nicotine delivery device among youth (Cullet *et al*, 2018). In 2017 over 2 million American youth were current e-cigarette users (Cullet *et al*, 2018).

Body Mass Index (BMI) is used as a general measure for weight status as it is calculated by dividing a person's weight in kilograms by their height in meters squared. The ranges of interest for BMI are: underweight (BMI<18.5), normal weight (18.5<BMI<25), overweight (25<BMI<30), and obese (BMI>30).

The global obesity epidemic is estimated to cost nearly 3% of GDP each year (Tremmel *et al*, 2017). The costs of obesity include both direct and indirect costs. The direct costs of obesity include items such as increased health care expenses due to an increased risk for diabetes, cardiovascular diseases, and cancer (Tremmel *et al.*, 2017). The indirect costs include the productivity loss resulting from obesity. The Centers for Disease Control (CDC) estimate the annual direct cost of obesity in the US to be $147 billion, and the indirect costs to be nearly $10 billion (CDC, 2017). The portion of direct costs associated with severe obesity in the US is $69 billion (Wang, Pamplin, Long, 2015).

I show in the following map how the severity of obesity in the US varies by state in my 2017 sample. In the US the average adult obesity rate is over one third. For comparison, in Canada just over one quarter of adults are obese.

Figure 1: Obesity in 2017 in the US

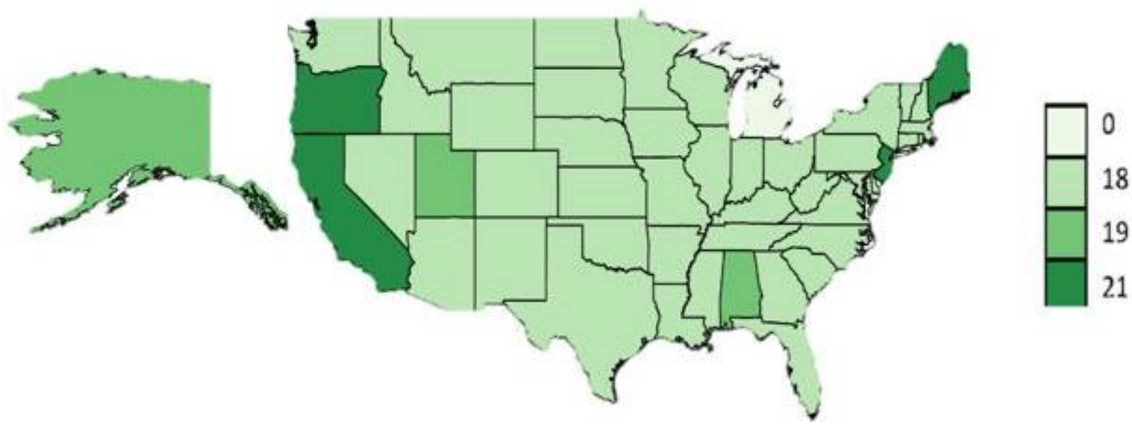


Cigarettes in the US continue to be a substantial market, with annual sales of over $80 billion (CDC, 2018). The CDC estimate annual direct costs of cigarette use in the US to be $170 billion and the indirect costs to be $156 billion (CDC, 2018). Counteracting the costs of cigarette use is the tax revenue gained. In the US, on average, nearly half of the cost of a package of cigarettes is either state or federal tax (CDC, 2018). If one considers only direct healthcare costs associated with smoking compared to the additional tax revenues, some estimates show that individuals who smoke save the government money by dying sooner (Tiihonen, Ronkainen, and Kangasharju, 2012). However, if one takes into account the average loss of quality adjusted life years experienced by smokers, these cost savings are reversed (Tiihonen, Ronkainen, and Kangasharju, 2012). If e-cigarettes have an effect on the traditional cigarette market, this will have implications for both the healthcare system as well as state and federal tax revenues.

Policies regulating e-cigarettes are implemented at the state level in the US. There is a great deal of variation between states that I exploit for the purposes of identifying the causal effects of vaping regulation on BMI outcomes. Variation is present in both the type of policy that was implemented and when it was put into place. The first state policy was implemented in 2010 and the most recent was implemented in 2018.

The US federal government recommends that all states make 18 the minimum age of legal purchase for e-cigarettes, and all states except for Michigan have complied. Each state varies in its choice of whether to tax e-cigarettes and whether to require a license to sell them. I show in the following map the age restrictions currently present in each state.

Figure 2: E-Cigarette Age Restrictions by state as of 2019



Literature Review

The existing literature supporting my work is concentrated in four major areas. The first examines the relationship between e-cigarettes, cigarettes, and BMI outcomes. The second examines the relationship between cigarettes and e-cigarettes, and whether they are substitutes. The third is primarily medical literature and examines the effects of nicotine on adolescents. The fourth examines the effect of different policies on the use of nicotine products.

The primary paper investigating the relationship between e-cigarettes and youth weight outcomes is by Delk, *et al.* They perform a cross-sectional analysis using the Texas Adolescent Tobacco and Marketing Surveillance System data which surveys seventh, ninth, and eleventh graders on specific e-cigarette use habits and motivations (Delk *et al*, 2018). Using logit regressions to estimate the correlation between weight status and nicotine use they find that obese boys are more likely to use e-cigarettes than their healthy-weight counterparts, and that there is not a significant relationship between weight status and e-cigarette usage for girls (Delk *et al.*, 2018). Delk *et al.* show that there is a positive correlation between dissatisfaction with weight status and e-cigarette usage for both genders, and that this is a better predictor of e-cigarette use than is actual weight status (Delk *et al*, 2018). My research builds on their work by using national level data and by using state-level policy experiments to identify the causal relationship between e-cigarette restrictions, BMI, and traditional cigarette usage.

Because e-cigarettes are relatively new to the market, research on the effect of smoking on BMI has focused primarily on traditional cigarettes. Verhaegen and Van Gaal (2018) give an overview of the published effects of e-cigarette use on weight and cardiometabolic outcomes which are those related to diabetes, heart disease, and stroke. They note that the cardiometabolic effects of e-cigarettes have not yet been thoroughly studied in humans. However, the results of animal studies show that e-cigarettes have effects on weight and body fat distribution similar to those of cigarettes (Verhaegen and Van Gaal, 2018). They show that the cardiovascular risk factors are less pronounced for e-cigarette smokers relative to cigarette smokers, and that the cardiometabolic side effects would likely occur even in the absence of nicotine for cigarette smokers (Verhaegen and Van Gaal, 2018). Although the e-cigarette liquids contain several potentially toxic chemicals, the levels are between one fifth and one fortieth of those in traditional cigarettes (Verhaegen and Van Gaal, 2018). Nicotine does not cause many of the negative health effects associated with cigarette smoking. However, nicotine does cause appetite suppression and weight loss (Verhaegen and Van Gaal, 2018).

There is extensive literature supporting the relationship between cigarette use and lower body weights. Audrain-McGovern and Benowitz (2011) find that young adults who are looking to lose weight are 40% more likely to start smoking cigarettes than their peers. Age related weight gain occurs more slowly for smokers relative to non-smokers (Audrain-McGovern and Benowitz, 2011). The weight loss associated with cigarettes can be explained both by the effect of the nicotine and the psychological and behavioural effects of using cigarettes. The psychological and behavioural effects of smoking include use as a snacking alternative and the exacerbated effects of nicotine on appetite suppression when nicotine is used for the purpose of weight loss (Audrain-McGovern and Benowitz, 2011). In addition to supressing appetite, nicotine also reduces the body's efficiency at absorbing nutrients. Even if the same diet were consumed before and after starting to use nicotine, smoking would cause the average observed weight to decrease (Wellman, *et al*., 1986). On average, cigarette smokers are more likely to have BMI's in the healthy range than are their non-smoking peers.

If there were no negative effects of nicotine use on adolescents the policy questions regarding their increased usage would be less pressing. However, the medical literature overwhelmingly supports the finding that nicotine is an addictive substance and has especially detrimental effects on youth development. The Surgeon General's report states that the effects of nicotine on youth include addiction, reduced impulse control, attention deficits, cognitive deficits, and the development of mood disorders (US Department of Health and Human Services 2016). Bonnie *et al.* (2015) summarize the animal experiments done with adolescent rodents and nicotine consumption, and their findings mirror the statements of the Surgeon General. Bonnie *et al* (2015) and Ambrose *et al* (2014) both find that youth overwhelmingly believe their own risk from smoking is lower than their peers' and that their susceptibility to peer pressure is much higher than their adult counterparts.

Other compounds found in e-cigarette liquids may harm users. Many of the flavoured liquids include diacetyl, which is the chemical that allows margarine to taste like butter and in this solid state is harmless. However, when diacetyl is vaporized it can cause damage to the cells lining the airways and causes injuries similar to obliterative bronchiolitis which has colloquially been referred to as 'popcorn lung' disease (CDC, 2017). This is a permanent lung disease which causes scarring of the lung's air sacs and narrowing of the airways (American Lung Association, 2018).

In North America the popularity of traditional cigarette use among youth has rapidly declined in recent years. The 2017 National Youth Tobacco Survey shows that in the period from 2011 to 2017 cigarette use among high school students decreased by 73% falling to 7.6% by 2017 (Wang *et al.*, 2018). Cigarette use among young adult and adult males was in decline until 2015, when it plateaued at around 15% (CDC, 2018). It is important for policy makers to know the extent to which this decrease in high school cigarette use is due to the increase in e-cigarette use, and if the plateau in smoking rates among men is due in part to substitution away from e-cigarettes and towards traditional cigarettes as youth transition in to adulthood.

A longitudinal study of grade 12 students in California finds that e-cigarettes and cigarettes are not perfect substitutes (Barrington-Trimis *et al*, 2016). Using Children's Health Study (CHS) data over two decades they show that although the proportion of cigarette users has fallen among high school students, the proportion of e-cigarette users has grown to more than offset the decrease in cigarette users (Barrington-Trimis *et al* 2016). These findings support the notion that e-cigarettes are creating nicotine users out of those who normally would not have started using traditional cigarettes.

Increased e-cigarette use has led to research into the question of why the appeal is so strong and why so many youth are using the product. The CHS data suggest that people's social circles affect their future use habits (Barrington-Trimmis *et al*., 2016). Those with friends who use e-cigarettes are more likely to use nicotine products themselves (Barrington-Trimmis *et al*, 2016). Presently as individuals' age and their social settings change they are more likely to transition from e-cigarettes to traditional cigarettes, as their older colleagues are more likely to be traditional smokers (Barrington-Trimmis *et al*, 2016). These separate findings are important as combining them implies that e-cigarettes appeal to people who otherwise would not have started using traditional cigarettes, and that over time these people are more likely to transition to traditional cigarettes.

Traditional cigarettes, and especially youth smoking, have long been a focus of policy discussions. Manivong *et al*. (2017) analyze the effect of changing provincial policies on youth cigarette use. They use a difference-in-differences approach to analyze the effect of variation in taxes across Canada over time on youth smoking. They control for provincial and demographic differences with provincial and year fixed effects, though they do not have a control for e-cigarette use. While they find little effect of restrictive policy on consumption trends, this may be due to the fact they examine cigarette consumption at a time when it was already in decline and at a very low level. I use their methods as a starting point for my own analysis.

Data

I use data from the Behavioural Risk Factor Surveillance Survey (BRFSS) for my analysis. This survey is conducted annually by the US Center for Disease Control. It is a telephone survey which collects responses from all 50 states using a population based random digit dialing technique for both landlines and cellphones (CDC, 2014). Those conducting the interviews are trained to help with response consistency. In 2017 there were over 400,000 individuals surveyed, providing millions of observations over my sample period. I use the annual survey results from 2001 to 2017. This survey produces data that includes responses from different income, race, education, and gender demographic backgrounds. The sample is representative of the US adult population.

The BRFSS demographic variables that are of interest for my study are income, education, sex, and race. The income responses are grouped into eight income categories: $0-$10k, $10k-$15k, $15k-$20k, $20k-$25k, $25k-$35k, $35k-$50k, $50k-$75k, and $75k+. Education attainment is grouped into six categories: kindergarten or lower, elementary, some high school (HS), high school completed, some college, and college completed. Sex in this survey is reported as either male or female. The race categorical variable I use is preferred race. With this variable if a person is mixed race they are asked "Which one of these groups would you say best represents your race?" (CDC 2015, p18). Race is broken into six categories: White, Black, First Nations, Asian, Pacific Islander, or other.

Table 1: Summary Statistics

INCOME	%	EDUCATION:	%	RACE	%	SEX	%
$0-$10K	5.70	<Kindergarten	0.16	White	83.97	Male	60.05
$10k-$15k	6.05	Elementary	3.13	Black	8.71	Female	39.95
$15k-$20k	7.99	Some HS	6.10	First Nations	1.98	No Response	0.01
$20k-$25k	9.77	All HS	29.61	Asian	1.15		
$25k-$35k	12.31	Some College	29.94	Pacific Islander	1.44		
$35k-$50k	15.55	All College	34.07	Other	2.74		
$50k-$75k	16.21						
$75+	26.42						

As the BRFSS dataset does not begin to record individual responses on e-cigarette use until 2016, I am limited to using exposure to a policy restricting e-cigarette usage rather than an individual's actual e-cigarette behaviour as a right-hand side variable. Another limitation of the data for my purposes is that the BRFSS only begins surveying individuals once they have reached the age of 18, so I do not have any responses from younger people. Therefore, I can only observe their BMIs as young adults. I use their state and reported age to determine how many years their access to e-cigarette purchase was legally restricted when they were youth.

I use the calculated BMI, tobacco use, alternative tobacco use, desire to quit tobacco use, household dynamics, and the demographic variables discussed above. With these data I can measure how different policy implementations and lengths of exposure affect BMI outcomes.

I assemble my own policy dataset for state specific e-cigarette restrictive policies. I construct a variable that measures the number of years a person was subject to a policy that restricted their access to legally purchase e-cigarettes. I use these data to measure the effect of exposure to restrictive e-cigarette policy on BMI and cigarette use outcomes.

Methodology

I estimate a difference-in-differences model using the BRFSS health data along with my policy dataset to identify the causal effect of an additional year facing restricted access to e-cigarettes on predicted BMI outcomes.

$$\boldsymbol{BMI_{ijt} = \beta X_{ijt} + \emptyset_j + \delta_t + \sum_{k=0}^{8} \pi_k D_{ijt}^{k} + \mu_{ijt}} \quad \textbf{(1)}$$

I model the BMI of the i^{th} person in the j^{th} state in year t as a function of policy and control covariates. In equation (1) X contains the demographic controls including race, age, income, and education. $\boldsymbol{\emptyset_j}$ denotes the state fixed effects. $\boldsymbol{\delta_t}$ denotes the year effects. D_{ijt}^{k} is the difference-in-differences variable of interest. $D_{ijt}^{k} = 1$ if the individual experienced k years of exposure to a policy that limited their access to legal purchase of e-cigarettes based on age. For example, if an individual was 15 when their state imposed a policy setting the legal age of purchase to 18, and their age at the time of survey was 18 or above, they would have experienced three years of limited legal access to purchase e-cigarettes. Therefore, for this individual, $D_{ijt}^{3} = 1$. If an individual was 18 and their state imposed a policy setting the legal age of purchase to 21, and their age at the time of the survey was 21 or above, that individual would also have been exposed to three years of restricted access.

In order to face *k*>0 years of restricted access to e-cigarettes an individual must have been under the legal age of purchase when their state implemented policy; this, paired with the BRFSS minimum age of response of 18 limits my sample size. In the repeated cross-sectional data set there are just over 33 000 respondents who faced some degree of limited legal access to e-cigarettes. Although this number is significantly smaller than my original sample size of over 6 million, it still provides substantial variation in treatment.

Table 2: Years Facing E-Cigarette Purchase Restrictions

Years Legal Access Was Restricted	Frequency	%
1	11,876	35.00
2	9,139	26.94
3	6,136	18.09
4	3,423	10.09
5	1,774	5.23
6	916	2.70
7	499	1.47
8	164	0.48

The first state e-cigarette policies were passed in 2010 in Minnesota, Utah, and New Hampshire. Minnesota and New Hampshire both set the minimum legal age of e-cigarette purchase at 18, and Utah set the minimum age of purchase at 19. Because the BRFSS starts surveying at age 18 and I have data up to 2017, the maximum number of years restricted to access is 8. Someone who lived in Utah when surveyed in 2017 at the age of 18 would have been 10 years old when Utah's state policy was implemented. This person would have faced restricted access to legal purchase of e-cigarettes for 8 years. In each subsequent year from 2010 onwards at least one state introduced e-cigarette legislation, with the most states putting policies into effect in 2013. California, in 2016, was the first state to set the minimum legal age of e-cigarette purchase at 21.

All other states, except for Michigan and Maine, implemented state policies that limited legal access to e-cigarettes based on age during my sampling period. Maine's e-cigarette legislation went into effect in 2018 after my sample period. Michigan still has no policies that regulate access to, or sale of, e-cigarettes.

I estimate a variant of Equation 1 that allows me to measure the marginal effect of an additional year of exposure to e-cigarette purchase restrictions. I replace the sum of dummy variables with a single variable, $\boldsymbol{\rho_j}$, that is equal to the number of years an individual faced restricted access to e-cigarettes.

$$\boldsymbol{BMI_{ijt} = \beta_1 X_{ijt} + \emptyset_j + \delta_t + \beta_2 \rho_j + \mu_{ijt}} \quad \textbf{(2)}$$

One possible unintended consequence of restricting access to e-cigarettes is that it might cause substitution toward traditional cigarettes. If BMI results are being negatively affected by increased restricted access to e-cigarettes, this may be explained by the substitution towards traditional cigarettes. In order to test for this, I specify a different model with traditional cigarette use as the outcome variable of interest. I use the same right-hand-side variables as in Equation 1, and add an additional right-hand-side variable, $\boldsymbol{\gamma_j}$, denoting previous e-cigarette use. The resulting model is given by Equation 3.

$$\boldsymbol{Cigarette_{ijt} = \beta_1 X_{ijt} + \emptyset_j + \delta_t + \beta_2 \gamma_j + \sum_{k=0}^{8} \pi_k D_{ijt}^{k} + \mu_{ijt}} \quad \textbf{(3)}$$

I estimate the effect that each year of e-cigarette legal purchase restrictions has on future cigarette consumption with this model. The BRFSS measure of smoking I use is a binary variable =1 if an individual reports having smoked at least 100 cigarettes in their life. The BRFSS measure of e-cigarettes use is a binary variable =1 if the individual has ever vaped.

Results

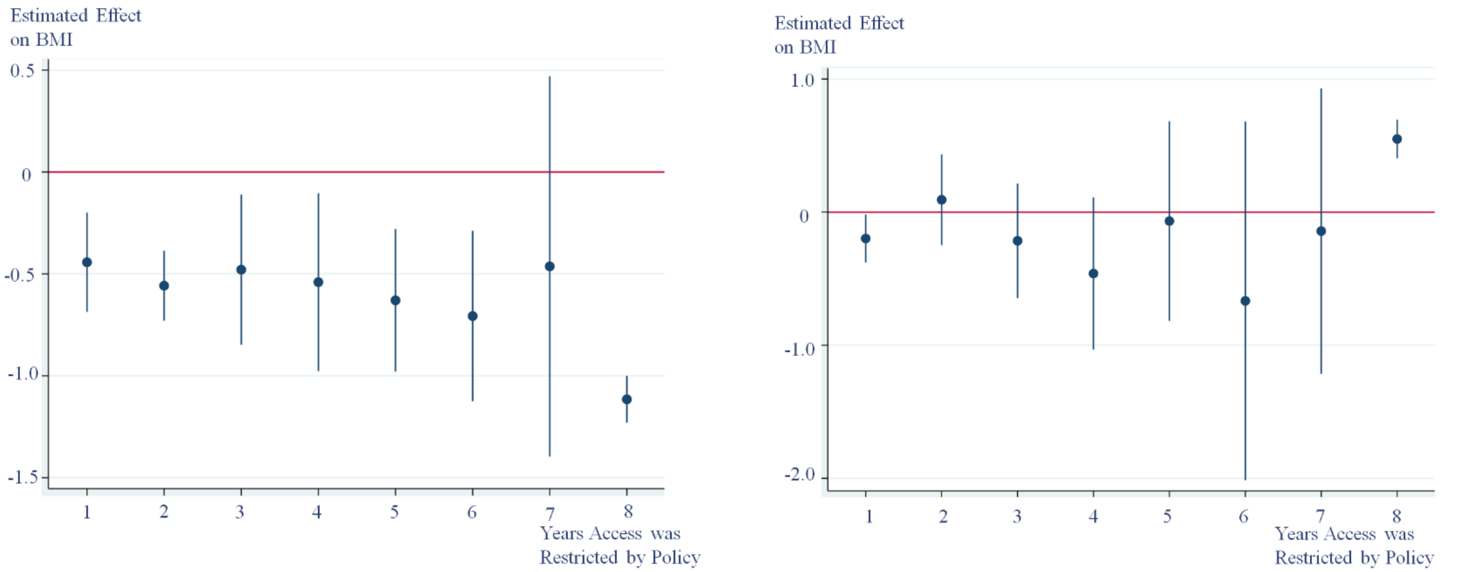
In Table 3 I present results on the estimated effects of e-cigarette policy restrictions from Equation (1). As done in Delk *et al* (2018) I analyze my models separately by gender. The estimated effect of restricted access to e-cigarettes differed substantially by gender. For women the estimated effect of years facing e-cigarette restrictions on BMI appears to be very near 0, as 6 of 8 estimates are not statistically significant. However, for men there appears to be an increasing negative effect on BMI the more years of restricted access to e-cigarettes that they face. When a self reported male individual faced restricted access to e-cigarettes for 8 years the expected effect on his BMI is -1.1 points. For a male that is 5’9” (average height) a 1.1 point drop in BMI is equivalent to a 7 ¾ pound weight loss. I graphically show the estimates of Equation (1) in Figure 3 with male estimates on the left and female estimates on the right, with a 95% confidence interval.

Table 3: Estimated Effect of E-Cig Restriction on BMI

	Men	Women
1 Year E-Cig Access Restricted	-0.443*** (0.122)	-0.198* (0.090)
2 Years E-Cig Access Restricted	-0.558*** (0.085)	0.0928 (0.169)
3 Years E-Cig Access Restricted	-0.479* (0.184)	-0.215 (0.215)
4 Years E-Cig Access Restricted	-0.540* (0.217)	-0.461 (0.285)
5 Years E-Cig Access Restricted	-0.630*** (0.175)	-0.0670 (0.372)
6 Years E-Cig Access Restricted	-0.707** (0.209)	-0.667 (0.674)
7 Years E-Cig Access Restricted	-0.463 (0.463)	-0.143 (0.530)
8 Years E-Cig Access Restricted	-1.115*** (0.057)	0.549*** (0.072)
Income: $10k-$15k	0.323*** (0.030)	-0.0297 (0.037)
Income: $15k-$20k	0.216*** (0.037)	-0.356*** (0.042)
Income: $20k-$25k	0.302*** (0.037)	-0.644*** (0.043)
Income: $25k-$35k	0.243*** (0.043)	-0.865*** (0.045)
Income: $35k-$50k	0.366*** (0.045)	-1.136*** (0.047)
Income: $50k-$75k	0.431*** (0.044)	-1.544*** (0.059)
Income: $75+	0.245*** (0.050)	-2.648*** (0.071)
Elementary	0.0877 (0.137)	0.184 (0.148)
Some HS	-0.0542 (-0.132)	-0.175 (0.148)
All HS	0.0353 (0.131)	-0.608*** (0.167)
Some College	0.0309 (0.134)	-0.608*** (0.173)
All College	-0.859*** (0.135)	-1.616*** (0.070)
Black	0.450*** (0.060)	2.582*** (0.091)
First Nations	-0.966*** (0.169)	-0.994*** (0.194)
Asian	-1.101* (0.485)	-0.960 (0.585)
Pacific Islander	0.977*** (0.164)	1.346*** (0.150)
Other	0.209*** (0.055)	0.434*** (0.058)
Number of Observations	2,323,098	3,152,035

Equation 1 Regression Output: Standard Errors in parentheses * p<0.05, ** p<0.01, *** p<0.001

Figure 3: Equation (1) Graph – Estimated Effect of Years of E-Cigarette Legal Purchase Restrictions on BMI



Estimated coefficients for men on the left and women on the right

I estimate the joint significance F-statistic for the coefficient estimates for the set of Years E-Cig Access Restricted variables for Equation (1). The reported F-Statistic for men is 13.3 and the reported F-Statistic is 47.7 for women. The set of coefficients are jointly significant at all conventional significance levels, though for women it is not clear which direction the effect is working and the majority of individual coefficient estimates are not significant.

I estimate Equation (2) in which years facing restricted access is included as a single right-hand-side variable, rather than a summation of dummy variables. I present the estimates in Table 4 below. The estimated effect of facing an additional year of e-cigarette restrictions on predicted BMI is a statistically significant 0.159 BMI point decrease for males and a statistically insignificant 0.055 BMI point decrease for females.

Table 4: Estimated Effect of E-Cig Restriction on BMI

	Men	**Women**
Years E-Cig Access Restricted	-0.159*** (0.028)	-0.0554 (0.045)
Income: $10k-$15k	0.323*** (0.030)	-0.0297 (0.037)
Income: $15k-$20k	0.216*** (0.037)	-0.356*** (0.042)
Income: $20k-$25k	0.302*** (0.037)	-0.644*** (0.043)
Income: $25k-$35k	0.243*** (0.043)	-0.865*** (0.045)
Income: $35k-$50k	0.366*** (0.045)	-1.136*** (0.047)
Income: $50k-$75k	0.431*** (0.044)	-1.544*** (0.059)
Income: $75+	0.245*** (0.050)	-2.648*** (0.071)
Elementary	0.0877 (0.137)	0.184 (0.148)
Some HS	-0.0542 (0.132)	-0.175 (0.148)
All HS	0.0353 (0.131)	-0.608*** (0.167)
Some College	0.0309 (0.134)	-0.608*** (0.172)
All College	-0.859*** (0.135)	-1.616*** (0.183)
Black	0.450*** (0.060)	2.582*** (0.091)
First Nations	-0.966*** (0.169)	-0.994*** (0.194)
Asian	-1.101* (0.485)	-0.960 (0.585)
Pacific Islander	0.977*** (0.164)	1.346*** (0.150)
Other	0.209*** (0.055)	0.434*** (0.058)
Number of Observations	2,323,098	3,152,035

Equation 2 Regression Output: Standard Errors in parentheses * p<0.05, ** p<0.01, *** p<0.001

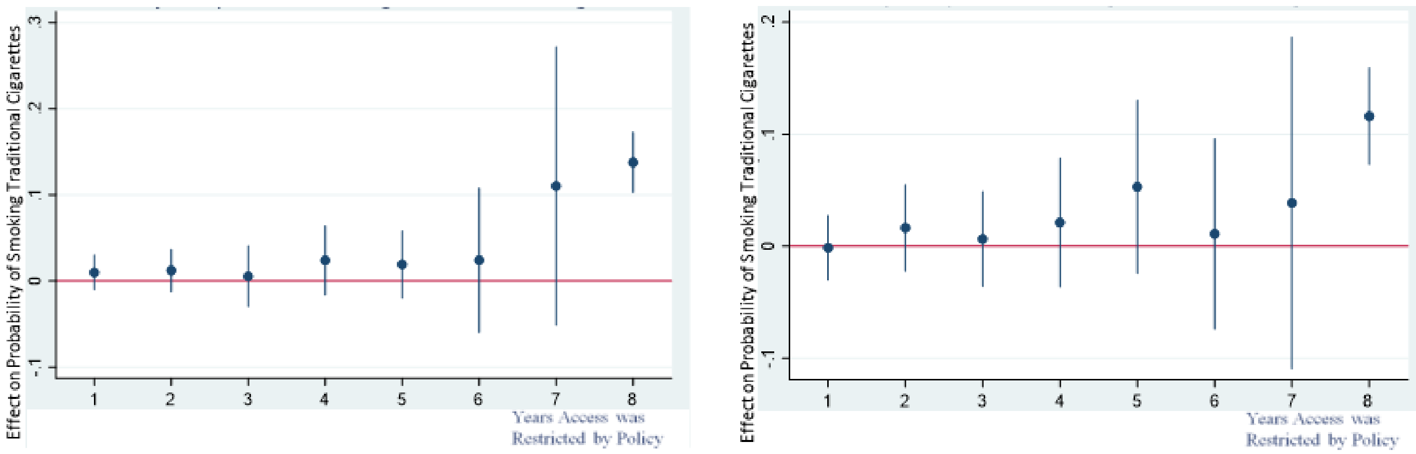
These results support the hypothesis that: for men, facing an additional year of restricted access to the legal purchase of e-cigarettes has a significant negative impact on their predicted BMI, and for women there is no clear and consistently significant effect.

The finding that restricting access to e-cigarettes causes weight loss for men may seem counter-intuitive, but can be partially explained when considering the interaction between e-cigarettes and traditional cigarettes. Cigarette users, on average, consume more nicotine than e-cigarette users (Schroeder, & Hoffman, 2014). So, if an individual faced with restricted access to e-cigarettes were to substitute towards traditional cigarettes their predicted BMI would be lower, and this could explain the observed negative relationship between e-cigarette restrictions and predicted BMI.

To measure how e-cigarette restrictions affect cigarette smoking I estimate Equation (3) and report the coefficient estimates in Table 5. According to my estimates, a male individual who faced restricted access to the legal purchase of e-cigarettes for 8 years is nearly 14% more likely to report having smoked 100 cigarettes relative to those who faced no years of restricted access to e-cigarettes. For women the estimated effect of facing 8 years of restricted access to legal purchase of e-cigarettes is a nearly 12% increase in the probability of having smoked 100 cigarettes relative to those who faced no years of restricted access to e-cigarettes.

I graphically show the results from Equation (3) in Figure 4. I plot coefficient estimates with a 95% confidence interval for men on the left and for women on the right.

Figure 4 – Equation (2) graph - Estimated Effect of Years of E-Cigarette Legal Purchase Restrictions on probability of having smoked 100 cigarettes



Estimated coefficients for men on the left and women on the right

I estimate the joint significance test on the Years E-Cig Access Restricted set of coefficients for Equation (3). The reported F-Value for men is 47.42 and for women 35.04. The coefficient estimates of years of restricted e-cigarette access as a group are statistically significant for predicted traditional cigarette use.

Table 5: Estimated effect of E-Cig Restriction on Tobacco Use

	Men	Women
1 Year E-Cig Access Restricted	0.00994 (0.010)	-0.00133 (0.015)
2 Years E-Cig Access Restricted	0.0123 (0.012)	0.0164 (0.019)
3 Years E-Cig Access Restricted	0.00542 (0.017)	0.00648 (0.021)
4 Years E-Cig Access Restricted	0.0240 (0.02)	0.0212 (0.029)
5 Years E-Cig Access Restricted	0.0193 (0.020)	0.0530 (0.039)
6 Years E-Cig Access Restricted	0.0242 (0.042)	0.0110 (0.042)
7 Years E-Cig Access Restricted	0.110 (0.080)	0.0388 (0.073)
8 Years E-Cig Access Restricted	0.138*** (0.018)	0.116*** (0.021)
Ever Vaped	0.424*** (0.004)	0.509*** (0.006)
Income: $10k-$15k	-0.0000451 (0.005)	-0.00703 (0.004)
Income: $15k-$20k	-0.0174*** (0.004)	-0.0245*** (0.005)
Income: $20k-$25k	-0.0302*** (0.004)	-0.0367*** (0.005)
Income: $25k-$35k	-0.0355*** (0.004)	-0.0473*** (0.005)
Income: $35k-$50k	-0.0490*** (0.005)	-0.0552*** (0.006)
Income: $50k-$75k	-0.0561*** (0.005)	-0.0670*** (0.006)
Income: $75+	-0.0923*** (0.005)	-0.0930*** (0.006)
Elementary	0.121*** (0.027)	0.0846*** (0.021)
Some HS	0.204*** (0.026)	0.237*** (0.021)
All HS	0.110*** (0.025)	0.181*** (0.021)
Some College	0.0684* (0.027)	0.181*** (0.022)
All College	-0.0635* (0.027)	0.0852*** (0.021)
Black	-0.0741*** (0.007)	-0.0931*** (0.010)
First Nations	0.0322 (0.017)	0.0482 (0.029)
Asian	-0.0601*** (0.007)	-0.158*** (0.007)
Pacific Islander	-0.0374* (0.014)	-0.00780 (0.017)
Other	-0.0530*** (0.007)	-0.0904*** (0.016)
Number of Observations	332,506	406,217

Equation 3 Regression Output: Standard Errors in parentheses * p<0.05, ** p<0.01, *** p<0.001

The above results are estimated average effects. I look at the effects of e-cigarette restrictions on BMI, so it is important to consider the effects on different BMI percentiles. My conclusions are sensitive to the percentile of population BMI that is being affected. If the effect on BMI is different depending on where in the BMI distribution an individual is, this could have a significant effect on policy recommendations.

I present the BMI's that correspond to 5 quantile groups in Table 6:

Table 6: BMI percentiles for Male and Female

Percentile	Male BMI	Female BMI
10th	22	20
25th	24	22
50th	27	25
75th	30	30
90th	34	35

I estimate Equation (1) again but at 5 different points in the BMI distribution. I graphically show the estimated effect of each year of e-cigarette restriction on predicted BMI outcomes at the 25th, 50th, 75th, and 90th quantile for both men and women in Figures 5 and 6 below. I do not show the 10th percentile in the graph because I do not want the graph to be too cluttered and the results are in line with the relation observed between the other percentile estimates.

Figure 5: Estimated Effect on BMI of Facing *k* Years of Restrictions to E-Cigarettes at Different Percentiles (Males)

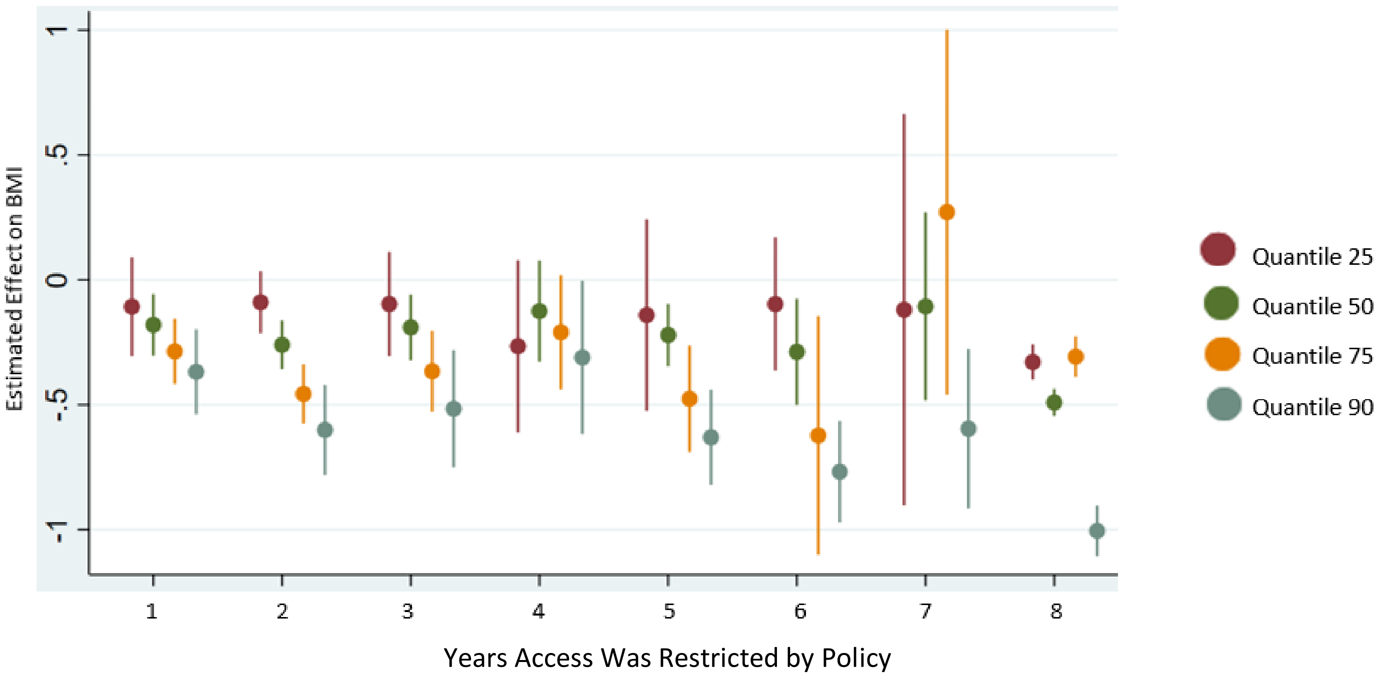
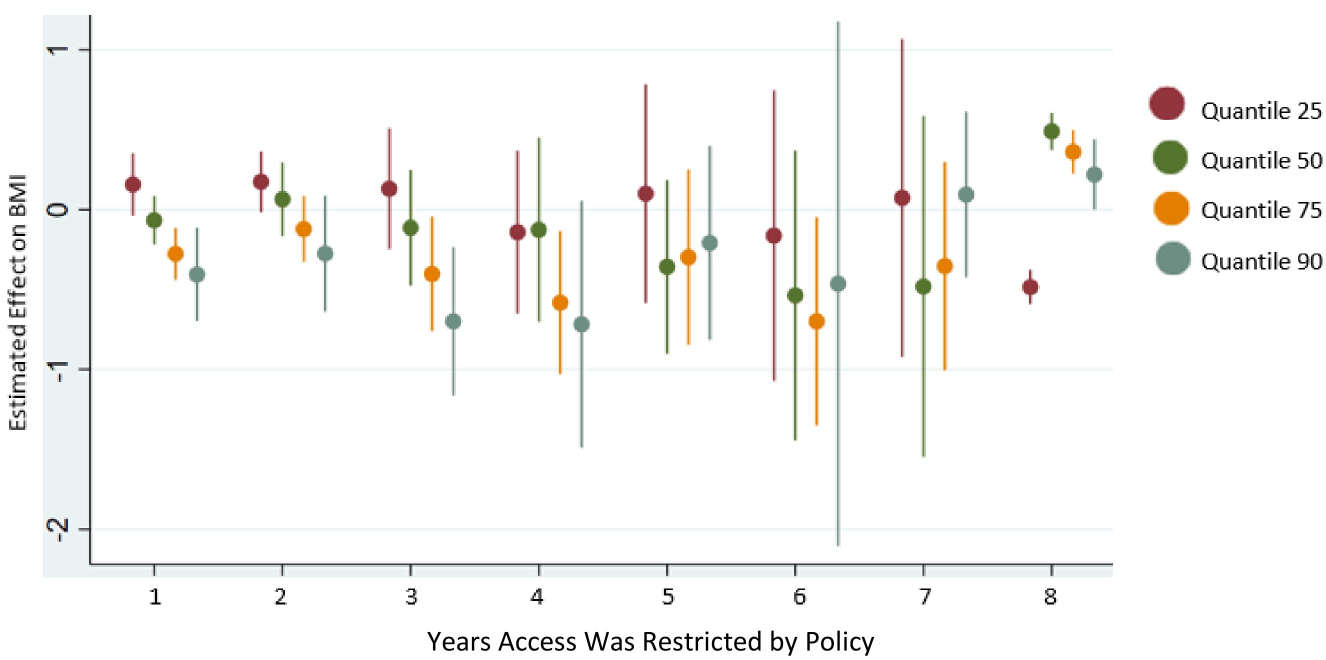


Figure 6: Estimated Effect on BMI of Facing *k* Years of Restrictions to E-Cigarettes at Different Percentiles (females)



I estimate equation (1) by gender for the 10th, 25th, 50th, 75th, and 90th BMI percentiles and report the coefficient estimates in Table 7 below.

Table 7: Estimated Effect of Years Facing E-Cig Restriction on BMI by Percentiles

Men		**Percentile 10**	**Percentile 25**	**Percentile 50**	**Percentile 75**	**Percentile 90**
	1 Year E-Cig Restriction	-.1744706	-.1069737	-.1797414	-.286123	-.3680789
	2 Year E-Cig Restriction	-.1952891	-.0894284	-.2597925	-.4563289	-.6002686
	3 Year E-Cig Restriction	-.3461405	-.0962803	-.1900419	-.365683	-.515565
	4 Year E-Cig Restriction	-.4857716	-.2654976	-.1248429	-.2096319	-.3105359
	5 Year E-Cig Restriction	-.0034736	-.1406857	-.2206284	-.4758058	-.6299512
	6 Year E-Cig Restriction	.0477278	-.0966408	-.2881143	-.6224415	-.76793
	7 Year E-Cig Restriction	-.5955699	-.1192562	-.1061232	.271454	-.5953477
	8 Year E-Cig Restriction	-.1842708	-.3288891	-.4905844	-.3072896	-1.004545
Women						
	1 Year E-Cig Restriction	.1410311	.156492	-.0673408	-.2774081	-.4061086
	2 Year E-Cig Restriction	.1860563	.1731596	.064457	-.1218438	-.2756243
	3 Year E-Cig Restriction	.0567665	.129985	-.113915	-.4025865	-.6994883
	4 Year E-Cig Restriction	.3699812	-.1413416	-.1262119	-.5822174	-.7178858
	5 Year E-Cig Restriction	.2652156	.0993697	-.3581598	-.2978346	-.2086882
	6 Year E-Cig Restriction	.1496497	-.1629775	-.5371137	-.6993675	-.4641328
	7 Year E-Cig Restriction	.3523153	.0726969	-.4811605	-.3537895	.0934402
	8 Year E-Cig Restriction	.7124372	-.4844765	.48945	.360313	.2193816

These results show that on average there appears to be an increasing negative effect on weight the higher in the BMI distribution a person falls.

Sensitivity Analysis

I perform several robustness checks. Utah is the only state where people could be restricted to legal e-cigarette access for 8 years, so I remove Utah from my analysis to ensure it is not driving my results. I present coefficient estimates from Equation (1), predicting BMI with the set of dummy variables for the number of years facing restricted e-cigarette access, with and without Utah in Table 8 below.

Table 8: Estimated effect of e-cig restriction on BMI with and without Utah

	Men	**Men – No Utah**	**Women**	**Women – No Utah**
1 Year E-Cig Access Restricted	-0.443*** (0.122)	-0.359** (0.108)	-0.198* (0.090)	-0.175 (0.099)
2 Years E-Cig Access Restricted	-0.558*** (0.085)	-0.508*** (0.084)	0.0928 (0.169)	0.158 (0.182)
3 Years E-Cig Access Restricted	-0.479* (0.184)	-0.371* (0.185)	-0.215 (0.215)	-0.0560 (0.193)
4 Years E-Cig Access Restricted	-0.540* (0.217)	-0.331 (0.166)	-0.461 (0.285)	-0.237 (0.325)
5 Years E-Cig Access Restricted	-0.630*** (0.175)	-0.531* (0.221)	-0.0670 (0.372)	0.423* (0.163)
6 Years E-Cig Access Restricted	-0.707** (0.209)	-0.540* (0.225)	-0.667 (0.674)	0.127 (0.343)
7 Years E-Cig Access Restricted	-0.463 (0.463)	0.245 (0.395)	-0.143 (0.530)	-0.942** (0.329)
8 Years E-Cig Access Restricted	-1.115*** (0.057)	/	0.549*** (0.07)	/

Equation 1 Regression Output: Standard Errors in parentheses * p<0.05, ** p<0.01, *** p<0.001

These results show that whether I include Utah or not, the overall trend remains the same for both genders. For men there continues to be an increasing and negative effect of increased years of e-cigarette restrictions on predicted BMI outcomes. For women, although with removing Utah one coefficient gains statistical significance, there is still no clear or significant effect.

I perform another robustness check to support my model's estimates as true causal effects, and to ensure that something in the model is not falsely driving my results. I estimate Equation (1) again but predict something independent from the years facing restricted access to e-cigarettes instead of BMI. As the BRFSS is a random digit dialing phone survey the month of the interview is, arguably, entirely independent form the years of restricted access to e-cigarettes the respondent faced. I estimate this model and anticipate seeing no relationship between the number of years facing restricted access to e-cigarettes and the month of the interview if the model is specified appropriately. For the entire set of estimated coefficients, for both genders, the number of years facing restricted access to e-cigarettes is not statistically significant. This supports my claim that my model is finding a true causal effect.

I check the robustness of my results by slightly changing the specification of Equation (1), which estimates BMI. I want to ensure that my estimates are not being driven by whether a policy was in place, rather than how many years an individual faced restricted access. I add to Equation (1) a dummy variable that is equal to one if there is an e-cigarette policy in place in the respondent's state during the year of the interview. In Equation (1.1) below η_j is the dummy variable for whether there was a state e-cigarette policy in effect when the respondent was interviewed.

$$\boldsymbol{BMI_{ijt} = \beta_1 X_{ijt} + \emptyset_j + \delta_t + \beta_2 \eta_j + \sum_{k=0}^{8} \pi_k D_{ijt}^{k} + \mu_{ijt}} \quad \textbf{(1.1)}$$

I estimate Equation (1.1) and compare the results to Equation (1) in Table 9 below.

Table 9: Estimated effect of years facing e-cigarette restrictions on BMI

	Men	**Men – With Policy Dummy**	**Women**	**Women – With Policy Dummy**
1 Year E-Cig Access Restricted	-0.443*** (0.122)	-0.448*** (0.121)	-0.198* (0.090)	-0.202* (0.089)
2 Years E-Cig Access Restricted	-0.558*** (0.085)	-0.561*** (0.085)	0.0928 (0.169)	0.0902 (0.170)
3 Years E-Cig Access Restricted	-0.479* (0.184)	-0.481* (0.184)	-0.215 (0.215)	-0.217 (0.215)
4 Years E-Cig Access Restricted	-0.540* (0.217)	-0.538* (0.217)	-0.461 (0.285)	-0.460 (0.286)
5 Years E-Cig Access Restricted	-0.630*** (0.175)	-0.624*** (0.174)	-0.0670 (0.372)	-0.0625 (0.368)
6 Years E-Cig Access Restricted	-0.707** (0.209)	-0.698** (0.207)	-0.667 (0.674)	-0.660 (0.667)
7 Years E-Cig Access Restricted	-0.463 (0.463)	-0.453 (0.462)	-0.143 (0.530)	-0.135 (0.540)
8 Years E-Cig Access Restricted	-1.115*** (0.057)	-1.105*** (0.058)	0.549*** (0.072)	0.558*** (0.075)
Policy In Place	/	0.0434 (0.036)	/	0.0340 (0.047)

Equation 1 and 1.1 Output: Standard Errors in parentheses * p<0.05, ** p<0.01, *** p<0.001

These results show that even when controlling for whether any policy restricting access to e-cigarettes is in place, and not just the number of years an individual faced restricted access, the results are similar to my original findings. The magnitude of the results do not change in any practically significant way, no levels of statistical significance change, and the added variable is both statistically and practically insignificant. Had I found that the added variable had a statistically significant coefficient or greatly changed my other estimated coefficients I would be concerned with my models specification.

Conclusions and Policy Discussion

As the number of youth using e-cigarettes continues to rise, policy makers will be under pressure to quickly address the growing ‘epidemic’. However, it is important for policy makers to understand that by increasing restrictions on one product they may be causing people to substitute toward something more harmful. My results suggest that restrictive e-cigarette policies may be causing substitution towards more harmful traditional cigarettes. Comparatively cigarettes are more harmful than e-cigarettes, and so this substitution is arguably an undesirable outcome.

My results suggest that simply implementing restrictive state policies on e-cigarettes is not a sufficient action to restrict people’s usage of nicotine. My results serve as another reminder to policy makers that the substitution effect may be present with well meaning policies. Policies do not happen in isolation and restricting a slightly harmful substance may cause substitution towards a more harmful alternative. My analysis suggests that policy makers should either pair policies restricting e-cigarette use with policies to prevent substitution to traditional cigarette usage while being mindful of other potential substitutions, or re-evaluate the decision to restrict access.

I am the first to do a national level analysis of the effects of restrictive e-cigarette policies on both BMI outcomes and the subsequent substitution towards traditional cigarettes. My research contributes to the literatures of youth smoking and obesity.

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