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STATE-LEVEL BEER EXCISE TAX AND FIREARM HOMICIDE IN ADOLESCENTS AND YOUNG ADULTS

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Abstract

Introduction: We sought to determine the association between changes in state-level beer excise tax and firearm homicide rates among 15-34 year-olds.

Methods: We conducted a time-series analysis with synthetic controls for the years 2003-2015. Exposed states changed the beer excise tax during the study period. Synthetic controls were weighted mimics that combined portions of unexposed states using state-year specific demographic and firearm covariates. We calculated average annual incidence rate differences (IRD) between each exposed state and its synthetic control. Alcohol taxes were available through the National Institute of Alcohol Abuse and Alcoholism and firearm homicide rates were obtained from the Centers for Disease Control and Prevention. We excluded states that changed the beer excise tax but for which fewer than two years of pre-exposure data were available. (Data collected: 2017, analyzed: 2018).

Results: Five states met inclusion criteria and all raised the beer excise tax: Illinois (2009), New York (2009), North Carolina (2009), Connecticut (2011), and Rhode Island (2013). The percent increase in beer excise tax ranged from 10% to 27%. Differences in pre-exposure firearm homicide rates between exposed states and synthetic controls were minimal. The increase in beer excise tax was associated with a lower average annual firearm homicide rate in all states except

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Illinois (RI: IRD = −2.48, CT: IRD=−2.57, NY: IRD =−1.45, NC: IRD=−0.45 and IL: IRD=1.54 per 100,000 population).

Conclusions: Among 15-34 year olds, price sensitive consumption of beer may represent one feasible tool for policy makers seeking to reduce rates of firearm homicide.

INTRODUCTION

Among US residents ages 15-34 years, over 100,000 deaths between 2003 and 2015 were attributed to firearm homicide.[1] For this age-group, homicide is the 3rd leading cause of death and over 80% of homicide is firearm-related.[1]

Alcohol use is one risk factor for firearm related injury and death.[2] One-third of firearm homicide victims consumed alcohol acutely prior to death and there is an association between availability of off-premises alcohol outlets and firearm assault.[3] Heavy drinkers are nearly three times as likely to be the victim of firearm assault compared with nondrinkers and adolescents with a history of alcohol use have four times the odds of firearm homicide victimization as those without.[4,5] Adolescent alcohol users more frequently possess firearms compared to non-alcohol users and firearm ownership on college campuses has been associated with risky and aggressive alcohol-related behaviors.[3,6] Separating the effects of acute alcohol consumption from other ecological and individual confounding factors related to firearm injuries remains an epidemiologic challenge. Also, alcohol consumption is common and available data are lacking to suggest a direct causal relationship between alcohol use and firearm homicide.

Alcohol consumption is sensitive to price, especially for youth.[7] For beer, evidence suggests that a 1% increase in price results in 0.46% decrease in consumption. [7] Changes to alcohol tax may also impact the distribution of alcohol consumption such that higher prices are associated with fewer days of high-intensity drinking and additional alcohol-free days.[8,9] Though young adults cannot legally purchase alcohol, there is evidence that laws targeting the consumption of beer among adults have helped to lower underage drinking. [10-13]

Alcohol pricing varies by state and alcohol type (i.e. wine, beer, spirits). Most states incorporate a license system that involves volume and price-based taxation for each type of alcohol. Other states, termed “control states” set the price centrally without a typical tax structure. A single state can have a license system for one type of alcohol and a control system for another. As of 2018, Utah is the only control state for beer pricing. For liquor and wine, 17 and 12 states, respectively, are control states.[14] For the purposes of ecological analysis and identifying appropriate comparison states, beer taxes are an ideal exposure because most states make beer tax data available.

Although the association between alcohol use and firearm homicide has been established and beer consumption, especially for youth, is sensitive to price changes, the end-to-end relationship between beer excise tax and firearm homicide rate has not been investigated. Our aim was to determine if states that changed the beer excise tax experienced a change in firearm homicide rates among 15-34 year-olds.

METHODS

Data Source

Annualized mortality data was obtained through the Centers for Disease Control and Prevention (CDC) Vital Statistics. Data was collected in 2017 and analyzed in 2018. We identified firearm homicide deaths using the ICD10 codes X93, X94, and X95 for the years 2003 to 2015. For ages 15 to 34 years, we aggregated the count of firearm homicide deaths for each state-year combination. Annual firearm homicide rates by state for this age group were calculated using age-group specific population estimates obtained from the Web-based Injury Statistics Query and Reporting System (WISQARS) at the CDC.[1]

Data were obtained from the Alcohol Policy Information System of the National Institute on Alcohol Abuse and Alcoholism .[14] This system provides alcohol tax information for each state and year by alcohol type. States were identified that changed the beer excise tax during the study period but were excluded if fewer than two years of pre-exposure firearm homicide and tax data were available. For states that changed the beer excise tax mid-year, the first complete calendar year with the new tax was considered the first exposure year.

Covariates.

There is no standard set of covariates for state-level multivariable modeling of firearm homicide. We included a set of covariates previously utilized in the study of firearm homicide and firearm-related outcomes (such as number of background checks) to construct our models.[15,16] We selected covariates to account for differences in basic demographics, firearm ownership, economic well-being and disparity, education, and crime. For each state –year, we obtained the percentage of the population aged 18-24 years, percentage male, percentage Hispanic, percentage Black, and percentage of suicides with a firearm (proxy for firearm ownership[17]) from CDC WISQARS.[1] State-year specific violent crime rate was obtained from the Federal Bureau of Investigation Uniform Crime Reporting database.[18] State-year data on percentage urban, Gini coefficient, percentage of high school graduates, percentage living in poverty, and median household income were obtained from the United States Census, American Community Survey.[19] Rates of pre-treatment firearm homicide among 15-34 year olds were included in the set of predictive variables per standard synthetic control coding.[20]

Analytic Method.

The synthetic control group method was used to estimate the firearm homicide rate among 15-34 year-olds in states that changed the beer excise tax, had those states, counter to fact, not changed the beer excise tax. The counterfactual homicide rates were subtracted from the observed homicide rates in these states to estimate the Incidence Rate Difference (IRD) due to beer excise tax increases.[20,21] Using a set of pre-specified covariates that are strongly associated with the outcome along with the pre-treatment levels of the outcome (annual rate of firearm homicide among 15-34 year olds), the synthetic control model generates a weighted mimic of the exposed state from a pool of potential controls to maximize the post-treatment similarity in the outcome had the exposed unit not been treated. The estimated effect of the intervention can be seen in the IRD between the exposed state and its synthetic control in the post-intervention period. Estimated IRDs and state-year-age group specific populations were used to calculate the difference in raw deaths in the post-intervention period.

The root mean squared prediction error (RMSPE) and Pearson's pairwise correlation *r* values were used to evaluate the goodness of fit for pre-intervention outcome trends. Descriptions of these methods are included in an Appendix.

To test the sensitivity of any difference seen in the exposed state, the synthetic control model was repeated substituting each unexposed state (no change in beer excise tax) for the exposed one (change in beer excise tax) to replicate a placebo intervention. Each placebo IRD was plotted by year alongside the exposed state. The range of average annual post-treatment IRDs (highest and lowest) among placebo states was captured as well as the proportion of placebos with an effect at least as strong as the exposed state in the same direction (fewer or greater firearm homicides).[22] All states that did not experience a change in the beer excise tax were candidates for the synthetic control. Due to being "control states" (no available tax data) for any or all of the study period, Utah and Washington are without complete beer tax data. Also, Maryland underwent an increase in alcohol specific sales tax in 2011 (6% to 9%). To account for these issues, sensitivity analyses were performed removing Maryland, Utah, and Washington if included in the synthetic control to remove any potential bias introduced by these tax increases or lack of tax data.

For Illinois, additional synthetic control sensitivity analyses were performed to account for a Chicago-specific tax on beer and liquor initiated in 2007.[23] In the main analysis, using the years 2003-2015 this tax created a new partial exposure in the pre-exposure period for Illinois and may bias the formation of the synthetic control mimic. To test for this potential bias, the analysis was repeated using only the years 2007-2015.

All analyses were performed in Stata/SE Version 14.2 (StataCorp LLC, College Station, TX) using both the "synth" and "synth_runner" installation packages.

RESULTS

Between the years of 2003 and 2015, our approach identified five states that changed the beer excise tax for which at least two years of pre-exposure data were available: Illinois, New York, and North Carolina (first complete exposed year 2010), Connecticut (first complete exposed year 2012), and Rhode Island (first complete exposed year 2014). In chronological order the exact dates where the tax changed were May 1st 2009 for New York, September 1st 2009 for Illinois and North Carolina, May 4th 2011 for Connecticut, and July 1st 2013 for Rhode Island. Pre-exposure beer excise tax for Illinois was $0.19/gallon, for New York was $0.11/gallon, for North Carolina was $0.53/gallon, for Connecticut was $0.20/gallon, and for Rhode Island was $0.10/gallon. No states lowered the beer excise tax.

The average annual firearm homicide rate for 15-34 year-olds during the pre-intervention period was 7.93 per 100,000 population in exposed states and 8.19 per 100,000 population in unexposed states. Across all states, the median number of annual firearm homicides in 15-34 year-olds were 7,659 (interquartile range 7,178.5 to 8,232). The minimum annual number of homicides in this age-group was in 2014 at 6,862 and the maximum was in 2006 at 8,627.

The contribution weights for each control state in each synthetic control comparison are shown in Table 1. These weights were generated using the algorithm specified by Abadie et al based on the annual pre-exposure firearm homicide rates and the complete list of previously mentioned covariates.[20] Pre-exposure RMSPE values for synthetic control states were not higher than for control pool states (Table S1). Pearson *r* values for firearm homicide rates in exposed states and their synthetic controls in the pre-intervention period for Illinois, New York, North Carolina, Connecticut and Rhode Island were 0.84, 0.99, 1.00, 0.90, and 0.90, respectively.

The percentage increase in beer excise tax among exposed states ranged from 10% to 27% and the average annual change in firearm homicide rates for 15-34 year-olds ranged from 2.57 fewer deaths per 100,000 population in Connecticut to 1.54 additional deaths per 100,000 population in Illinois (Table 2). The single-year homicide estimates ranged from 4.73 fewer deaths per 100,000 population in 2015 Connecticut and 1.98 additional deaths per 100,000 population in 2012 Illinois. All states except Illinois observed fewer average annual deaths after the increase in beer excise tax (Figure 1). Three of five states that increased beer excise taxes had single year reductions in firearm homicide rates greater than or equal to 4 per 100,000 population (Table 2).

Figure S1 shows the IRD by year (firearm homicide rate of exposed state minus the firearm homicide rate of the synthetic control). On average, deaths averted per post-exposure year were highest in New York (81 deaths/post-exposure year) followed by Connecticut with 24 fewer deaths/post-exposure year. Illinois had an average additional 55 deaths/post-exposure year. After exchanging unexposed states for exposed states in synthetic control models and calculating IRD by year to visualize a “placebo” intervention (no tax change) Rhode Island, Connecticut, and New York, had among the lowest IRDs at the end of the study period (Figure S2). Rhode Island and Connecticut had IRDs lower than the lowest among any of the placebo tests and only two states (4%, Arizona and California) had effects as strong as New York (Table 3). North Carolina and Illinois had post-treatment average annual IRDs within the range of placebo tests. A sensitivity analysis for North Carolina that removes Maryland, Utah, and Washington from the synthetic control group demonstrated an average annual incidence rate difference of −0.43 per 100,000 (main analysis −0.45 per 100,000).

Using only 2007-2015, the average annual IRD in firearm homicide among 15-34 year-olds was 0.54 additional deaths per 100,000 people. There was no difference in the pre-treatment RMSPE values between Illinois and the synthetic control ($p = 0.5464$) for these years. Figure S3 shows the synthetic control and Illinois for this time period.

DISCUSSION

In this analysis, raising the beer excise tax was associated with fewer firearm homicides among 15-34 year-olds in all states except Illinois. Compared to the last pre-intervention year, the average annual incidence rate differences represent a 66% decrease in Rhode

Island, a 31% decrease in Connecticut, a 22% decrease in New York, a 4% decrease in North Carolina, and a 12% increase in Illinois.

Alcohol taxes are a known lever in public health policy, most notably with regards to reducing excessive drinking, road traffic fatalities and alcohol-related diseases such as cirrhosis.[24,25] For example, higher alcohol taxes and alcohol tax increases are associated with a lower burden of traffic injury and death.[24] Similarly, higher taxes have been shown to be associated with lower rates of homicide, assault, rape, robbery, and child abuse.[24,26,27] On college campuses, there is an inverse association between the incidence of violent behavior and the state-specific price of alcohol.[28] Our findings are consistent with the notion that higher alcohol prices may prevent violence.

The effect of state specific alcohol tax increases in Illinois and Maryland have been analyzed.[29-32] Interrupted time series analyses of an alcohol tax increase in Maryland in 2011 found an association between raising the tax and the population rate of alcohol-positive drivers. [29,30] Notably, the percentage decrease in alcohol-positive drivers for age 15-34 drivers was twice that of the overall rate. However, a similar study found nondifferential effects by age-group for sexually transmitted infections.[30] The absence of an age effect may relate to other confounding factors around sexual behavior, stratified differences in prevalence and incidence for different ages, gender, and sexual orientation groups, in addition to detection rates which may be different across age groups in Maryland.

Two studies evaluated the 2009 increase in beer excise tax in Illinois for associations with fatal motor vehicle crashes and sexually transmitted infections (gonorrhea and chlamydia).[31,32] Both studies utilized an interrupted times series approach and found fewer fatal motor vehicle crash fatalities and reductions in both gonorrhea and chlamydia. Reductions for all outcomes were pronounced in the younger ages. These results are in contrast to our findings where the tax increase was associated with additional firearm homicide deaths in 15-34 year-olds. There may be several explanations for these differences. First, the synthetic control approach may not be an ideal candidate to study the impact of state-wide tax changes in Illinois on firearm homicide due to the tax increase in Chicago in 2007, because the selection of controls does not account for this intervention effect and does not represent a good counterfactual for Illinois' time-trend. The results of our sensitivity analysis that show a smaller value of additional firearm homicides in Illinois associated with the beer tax increase in 2009 demonstrates the importance of isolating the and pre-exposure and exposure periods. Also, any differences between Chicago/Cook County's contribution to statewide rates of fatal motor vehicle crashes, sexually transmitted infections, and firearm homicides may explain some of the differences in findings for these public health outcomes at the state level. For instance, most of Illinois' fatal motor vehicle crashes occur in rural areas not exposed to the alcohol taxes of 2007 (Chicago) and 2011 (Cook County) (Figure S4), and, if most firearm homicides occur in urban areas of Chicago and Cook County that were exposed to these additional taxes, a statewide tax applied to both may show discrepant findings.

Understanding how the synthetic control method uses covariate and outcome weighting to draw from other states may aid in interpreting the findings of synthetic control comparisons.

For instance, the synthetic New York was composed by North Dakota, South Carolina, Washington D.C., New Mexico, Nebraska, Arkansas, and Alaska (largest contributions from North Dakota and South Carolina). This list of states may not seem intuitively similar to New York. The synthetic control algorithm models observed outcomes in relation to the covariates, selecting weights for states and covariates that minimize the differences between the exposed state and the synthetic control as they pertain to predicting the outcome. So while Alaska and New York are not directly comparable, the synthetic control group algorithm works to pull in and weight Alaska and six other states (as reflected through the choice of covariates and state weights) to predict an outcome similar to that of New York over the pre-intervention period.[21]

There are some key limitations in this analysis. While investigators have used the synthetic control method to study several public health policies related to injury and taxation,[16,20,33] use of this method is still experimental. Development of confidence intervals for analyses that include both model uncertainty and random error is an area of active research.[34] Third, although we studied only beer excise tax, other policies likely affecting violence and alcohol also changed over this period. Specifically, changes to the wine excise tax overlapped completely in the exposed states with the change in beer excise tax. However, evaluating a wine excise tax is more challenging because fewer are available for comparison due to greater numbers of “control” wine states. Limited data suggests beer is associated with certain alcohol-related harms such as underage drinking, binge drinking and driving after binge drinking, although none of these are violence specific.[35] If wine taxes also affect violence, this effect would be attributed to the beer tax in our model. Liquor taxes changed in CT, RI, and IL, and may also have contributed to the findings. Although unchanging during the study period, New York City has an additional $0.12/gallon excise tax on beer and liquor and may impact the results. [36]Also, prior analyses demonstrated changes in alcohol affordability over time.[37] Our results could be affected if an economic recession obscured the impact of a tax increase on beer affordability and on firearm homicide. While changes in state firearms safety laws did not vary substantially with changes in state beer excise tax, following the Sandy Hook shooting in Connecticut the state legislature passed laws instituting comprehensive background checks and banning large capacity magazines in April of 2013.[38] Current data suggests the background checks may be associated with fewer firearm homicides and may impact our results in Connecticut. [39]Finally, our state-level quasi-experimental design cannot test the hypothesis that decreased consumption mediates the impact of taxes on homicide. For instance, an increase in beer tax may not have impacted consumption but rather funded a job creation program that influenced the firearm homicide rate.

CONCULSIONS

In this analysis, the synthetic control group method demonstrated fewer firearm homicides among 15-34 year-olds in four states that raised the beer excise tax. In Rhode Island, there was an average annual 2.62 fewer firearm homicides per 100,000 population, and 81 deaths averted per post-exposure year in New York. In addition to preventing traffic collisions and alcohol-related disease, raising the beer excise tax may also promote public health by reducing firearm homicide in adolescents and young adults.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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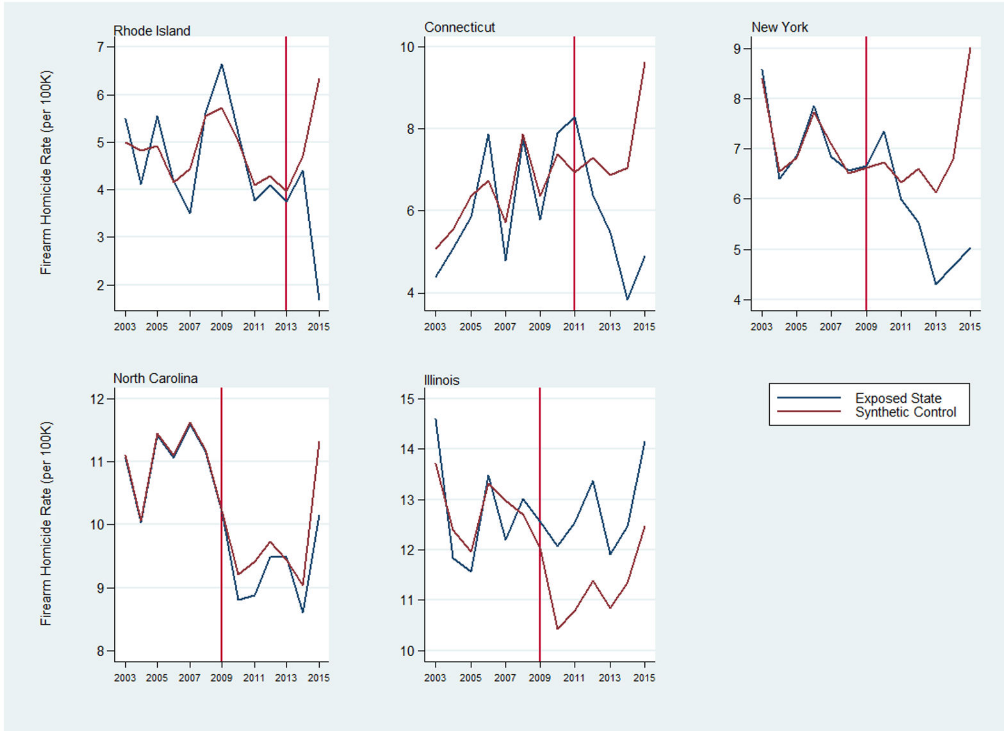

Figure 1. Firearm Homicide Rate in Exposed States and Synthetic Control by Year

*Vertical line represents the end of the pre-exposure period. For example if the excise tax increased in 2010, the line appears at 2009, the last year of pre-exposure data.

Table 1.

Synthetic Control Weights

Pool of Control States	Treated States				
	Illinois (2010)	New York (2010)	North Carolina (2010)	Connecticut (2012)	Rhode Island (2014)
Alabama	0	0	0.061	0	0
Alaska	0	0.106	0.008	0	0
Arizona	0	0	0.005	0	0
Arkansas	0	0.054	0.018	0	0.01
California	0	0	0.008	0	0
Colorado	0	0	0.008	0	0
Delaware	0	0	0.016	0	0.107
District of Columbia	0.028	0.008	0.026	0	0.009
Florida	0	0	0.022	0	0
Georgia	0	0	0.038	0	0
Hawaii	0	0	0.011	0	0
Idaho	0	0	0.007	0	0
Indiana	0	0	0.037	0	0
Iowa	0	0	0.01	0.374	0
Kansas	0	0	0.011	0	0
Kentucky	0	0	0.008	0	0
Louisiana	0.1	0	0.022	0	0
Maine	0	0	0.009	0	0
Maryland	0	0	0.006	0	0
Massachusetts	0	0	0.007	0	0
Michigan	0	0	0.009	0	0
Minnesota	0	0	0.008	0	0
Mississippi	0	0	0.01	0	0
Missouri	0	0	0.055	0.287	0.094
Montana	0	0	0.012	0	0.135
Nebraska	0	0.094	0.025	0.165	0
Nevada	0	0	0.008	0	0
New Hampshire	0	0	0.007	0	0
New Jersey	0	0	0.007	0	0
New Mexico	0.578	0.199	0.075	0	0
North Dakota	0	0.304	0.017	0	0.169
Ohio	0	0	0.008	0.174	0
Oklahoma	0	0	0.024	0	0
Oregon	0	0	0.008	0	0
Pennsylvania	0	0	0.007	0	0
South Carolina	0.295	0.235	0.047	0	0
South Dakota	0	0	0.024	0	0.358
Tennessee	0	0	0.227	0	0

Pool of Control States	Treated States				
	Illinois (2010)	**New York (2010)**	**North Carolina (2010)**	**Connecticut (2012)**	**Rhode Island (2014)**
Texas	0	0	0.011	0	0
Utah	0	0	0.01	0	0
Vermont	0	0	0.01	0	0
Virginia	0	0	0.011	0	0.118
Washington	0	0	0.009	0	0
West Virginia	0	0	0.013	0	0
Wisconsin	0	0	0.011	0	0
Wyoming	0	0	0.009	0	0

Table 2.

Incidence Rate Difference (IRD) per 100,000 by State and Post-Intervention Year

State (year of tax increase)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Average Annual Change	Percent Increase in Beer Excise Tax (%)
Rhode Island (2014)	−0.31	−4.64	*NA*	*NA*	*NA*	*NA*	−2.48	10
Connecticut (2012)	−0.93	−1.40	−3.22	−4.73	*NA*	*NA*	−2.57	20
New York (2010)	0.63	−0.34	−1.06	−1.82	−2.13	−4.00	−1.45	17
North Carolina (2010)	−0.41	−0.52	−0.24	0.05	−0.44	−1.16	−0.45	27
Illinois (2010)	1.65	1.76	1.98	1.06	1.12	1.68	1.54	21

Table 3.

Highest and Lowest Average Annual Post-Treatment IRD During Exposure Among 46 Placebo State Models

Exposed State (Year of Exposure)	Proportion with effect at least as strong as exposed state	Lowest (IRD)	State for Lowest IRD	Highest (IRD)	State for Highest IRD
Rhode Island (2014)	0	−2.31	MA	3.08	DC
Connecticut (2012)	0	−1.91	AZ	5.67	LA
New York (2010)	0.04	−1.46	CA	5.55	LA
North Carolina (2010)	0.26	−1.46	CA	5.55	LA
Illinois (2010)	0.20	−1.46	CA	5.55	LA

IRD = Incidence Rate Difference