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The impact of 1998 Massachusetts gun laws on suicide: A synthetic control approach☆

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HIGHLIGHTS

- We study the impact of 1998 gun law changes in Massachusetts on suicide rates.
- Overall suicide rates initially decline but later return to 1998 trend levels.
- Gun suicide rates appear to fall and remain below 1998 trend levels.

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ABSTRACT

In 1998 Massachusetts enacted nearly two dozen gun laws. Using the synthetic control method, we find evidence that these laws led to reduced overall suicide rates for several years, and a sustained reduction in suicides carried out with a firearm.

1. Introduction

According to the Centers for Disease Control and Prevention (CDC), suicide rates increased by 25.4 percent from 1999 to 2016.[1] In 2016 there were nearly 45 thousand suicides making it the tenth overall cause of death in that year. About half of those suicides were carried out with a gun. Research from the medical and public health fields notes that access to firearms is a serious risk factor with regard to suicide.[2] This paper considers the case of the state of Massachusetts which dramatically changed its gun laws in 1998. Using the synthetic control method (SCM) for case studies (Abadie and Gardeazabal, 2003; Abadie et al., 2010, 2015), the results show that the implementation of state guns laws in 1998 was followed by a significant reduction in overall suicide rates in the first several years. Rates later began to climb back to pre-implementation trend levels. The gun suicide rate also showed a significant decrease following the implementation of the laws, and its rate remained largely below pre-implementation trend levels.

2. Gun policy and suicide

Suicide tends to be an impulsive act set in motion by a recent crisis, (Simon et al., 2001; Deisenhammer et al., 2009). Furthermore, guns are the most lethal means of suicide attempts with a death rate of about 91 percent, whereas the most common method ('poisoning by drugs') results in death only about two percent of the time (Miller et al., 2004). Certain gun laws that delay the acquisition of guns, or keep them out of the hands of those at greater risk of suicide, may reduce suicide deaths as individuals have time to change their mind or carry out an attempt with a less lethal method.

There is evidence that reduced access to guns can reduce suicide rates. Chapman et al. (2006) describes how gun law reforms

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1 "Suicide rates rising across the U.S". Centers for Disease Control and Prevention, accessed at: https://www.cdc.gov/media/releases/2018/p0607-suicide-prevention.html, on August 3, 2018.

2 See: "Means Matter", Harvard T.H. Chan School of Public Health, accessed at: https://www.hsph.harvard.edu/means-matter/, on August 3, 2018.

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Table 1
Pre-treatment predictor balance.

Variable	Source	All suicides		Gun suicides	
		Treated	Synthetic	Treated	Synthetic
Suicide rate (1997)	CDC	7.742	7.746	2.223	2.376
Suicide rate (1984)	CDC	8.787	8.801	2.500	2.698
Suicide rate (1982)	CDC	9.011	8.873	2.467	2.778
Real income per capita (2015 dollars)	Bureau of economic analysis	40 040.95	40 191.39	40 040.95	41 791.61
Poverty rate (percent of pop.)	U.S. census bureau	9.729	10.172	9.729	11.071
Divorced–separated (proportion of pop.)	Current population survey (March Sup.)	0.067	0.068	0.067	0.068
Unemployment rate	Bureau of labor statistics	5.553	6.006	5.553	6.336
College degree (percent of pop.)	Mark W. Frank website[a]	18.766	15.949	18.766	16.276
Alcohol (gals. per person per year)	Nat. Inst. Alcohol Abuse and Alcoholism	2.703	2.663	2.703	2.486

[a]Accessed at http://www.shsu.edu/eco_mwf/inequality.html on August 14, 2018.

implemented by the Australian government in 1996 led to reduced suicides involving firearms. Lubin et al. (2010) discusses how Israeli soldier suicides decreased by 40 percent when the military enacted a policy in 2006 that prevented soldiers from bringing their firearms off base during weekend leaves.

3. Gun law changes in Massachusetts

In 1998 Massachusetts made unprecedented changes to their gun legislation when the state enacted 23 laws.[3] The laws placed restrictions on both buyers and gun dealers. Of the laws put in place, several stand out as being more likely to delay access or keep guns out of the hands of individuals who are at high risk for suicide. These include:

- minimum age restrictions for guns and ammunition purchases (21 and older)
- banning the sale of inexpensive 'junk guns'
- criminal liability for not storing guns properly
- requiring guns be locked up at home at all times
- requiring dealers to search state mental health records before selling guns to individuals
- requiring first time buyers to undergo safety training prior to issuing a permit to purchase guns
- prohibiting firearm possession for those involuntarily committed to an outpatient mental health facility
- a ban on gun possession by some people with a history of a violent misdemeanor offense
- a requirement that all lost and stolen guns be immediately reported to law enforcement officials
- new authority given to law enforcement officials to revoke concealed carry permits of individuals who become ineligible to possess a firearm
- a requirement that every gun sold must include a safety lock
- a law banning firearm possession by anyone convicted of a misdemeanor crime of domestic violence and requiring these offenders to relinquish any firearms in their possession.

Each of these laws either reduces ease of access to guns or requires greater scrutiny of those attempting to purchase them.

4. Methodology and data

In order to study the impact of the gun laws discussed earlier on suicide rates in Massachusetts the SCM approach is employed. The SCM is a data-driven approach that produces a 'synthetic Massachusetts' composed of an optimally weighted combination of other, non-treated states. The non-treated states are chosen such that the predictor variables of the synthetic Massachusetts closely match the predictor variables of the actual Massachusetts prior to the treatment period. Once created, the synthetic Massachusetts best represents what the suicide rates would be in Massachusetts had the 1998 gun laws *not* been enacted. Differences between the synthetic and actual Massachusetts suicide rates after 1998 can be attributed to the gun laws that were enacted. Two synthetic Massachusetts' are created, one for all suicides and another for gun suicides.

To carry out the SCM estimation, state-level data on suicide rates (overall any by gun) were obtained from the CDC.[4] These data are age-adjusted and report the number of deaths by suicide per 100,000 people. Table 1 shows the predictor variable balance produced by the SCM estimation for each case.[5,6]

As can be seen, the 'Treated' (actual Massachusetts) and 'Synthetic' (synthetic Massachusetts) predictor values match closely in both cases.

Fig. 1 provides a graph of suicide rates for both Massachusetts and synthetic Massachusetts. The vertical line for 1998 indicates the year the laws were enacted.[7] The synthetic Massachusetts matches well with the actual Massachusetts prior to 1998. Starting in 1998, there is a distinct drop in the actual suicide rate as compared to the synthetics values. The gap persists until 2004, after which actual rates increase and converge on the synthetic rates.

In order to determine if the gap between the synthetic and actual Massachusetts represents a statistically significant difference in a given year following 1998, standardized p-values are produced using the placebo method described in Abadie et al. (2010, 2015). The solid line in Fig. 2 plots these p-values for 1998 to 2007. The initial p-value for 1998 is quite large (0.75). This is likely due to the fact that the laws went into effect in late October of 1998, thus reducing the potential impact for that year. The following three years (1999–2001) the p-values fall dramatically to 0.07, 0.0 and 0.04, respectively, suggesting the overall suicide rate was significantly below what it would have been had the gun laws not been enacted. The p-value increases for 2002 (to 0.32) before falling to 0.07 and 0.0 for the years 2003 and 2004. Thereafter the gap closes between the synthetic and actual Massachusetts, suggesting

[3] See: "An Act Relative to Gun Control in the Commonwealth", Massachusetts Session Law, Chapter 180, accessed at: https://malegislature.gov/Laws/SessionLaws/Acts/1998 on August 7, 2018. A complete list of all Massachusetts gun law changes in 1998 is available from the corresponding author.

[4] The data are available at: https://www.cdc.gov/injury/wisqars/index.html.

[5] These predictors were chosen based on previous research studying the determinants of suicide. See Chen et al. (2012) for a survey of the literature on the socio-economic factors contributing to suicide.

[6] In terms of the donor pool of states, we include all other 49 states. Massachusetts is the only state to implement state gun laws in 1998. Several other states (Connecticut, Hawaii, Maryland and Washington), made notable changes to their state gun laws several years just prior to 1998. Estimating the synthetic Massachusetts excluding these states from the donor pool produced nearly identical results, with the exception of a small loss of efficiency (likely due to the reduction of the number of placebo tests from 49 to 45).

[7] The root mean squared prediction error was 0.270. The synthetic Massachusetts was composed of the following states (and weights): Minnesota (0.134), New Hampshire (0.069), New Jersey (0.612), New York (0.096) and Rhode Island (0.09).

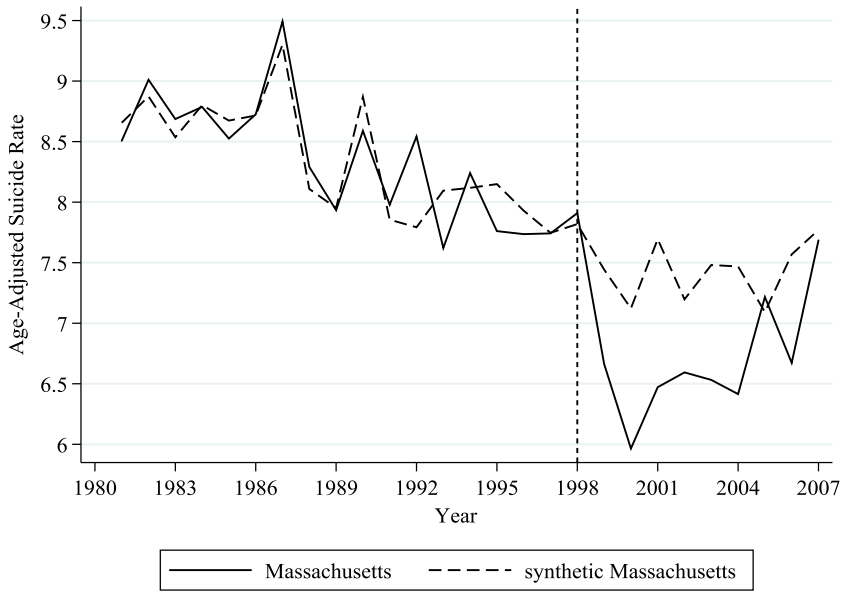

Fig. 1. Actual and synthetic Massachusetts suicide rates, 1981 to 2007.

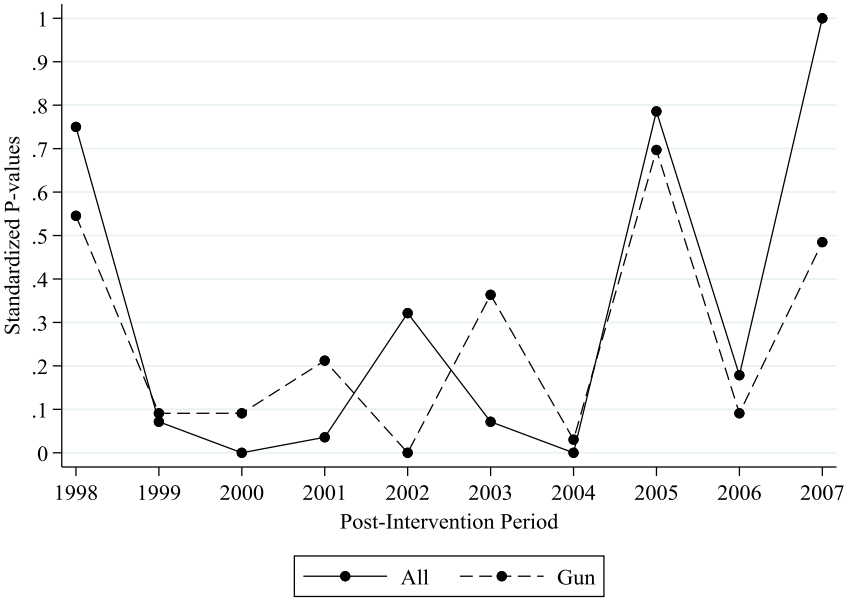

Fig. 2. Standardized P-values for all and gun suicides.

the impact of the gun laws enacted in 1998 dissipated by 2005. Based on the difference between the actual and synthetic suicide rates in Massachusetts over the years 1999 to 2007, the 1998 gun laws resulted in approximately 436 fewer suicide deaths.

Fig. 3 shows the path of gun-related suicides in synthetic and actual Massachusetts. In this case, the pre-intervention fit is not as tight compared to that for all suicides, but a sizeable drop is shown for 1999, the first full year after enactment.[8] The actual gun-related suicide rate is below the synthetic Massachusetts rates for all years following 1998. Regarding statistical significance, the dashed line in Fig. 2 shows the relevant p-values. Once again, a large *p*-value is shown for 1998, then a notable decrease to 0.09 for 1999 and 2000. The years 2002, 2004 and 2006 also indicate significant reductions in gun-related suicides with p-values equal to 0.0, 0.03 and 0.09, respectively. Taken as a whole, these results suggest that the gun laws enacted in 1998 led to a significant reduction in the gun suicide rate in the years that followed.

5. Conclusion

According to the CDC, in 2016 suicide was the second leading cause of death for those aged 10 to 34. It was the tenth leading cause of death across all age groups. About 23 thousand of the total 45 thousand suicides in that year were carried out with a firearm.[9] Members of the medical field have argued that gun laws that either delay the access to firearms, or better scrutinize those attempting

[8] The root mean squared prediction error in this case was 0.206. The synthetic Massachusetts for gun-related suicides was composed of the following states (and weights): New York (0.707) and New Jersey (0.293).

[9] CDC, "Ten Leading Causes of Death and Injury", at: https://www.cdc.gov/injury/wisqars/leadingcauses.html, accessed August 13, 2018.

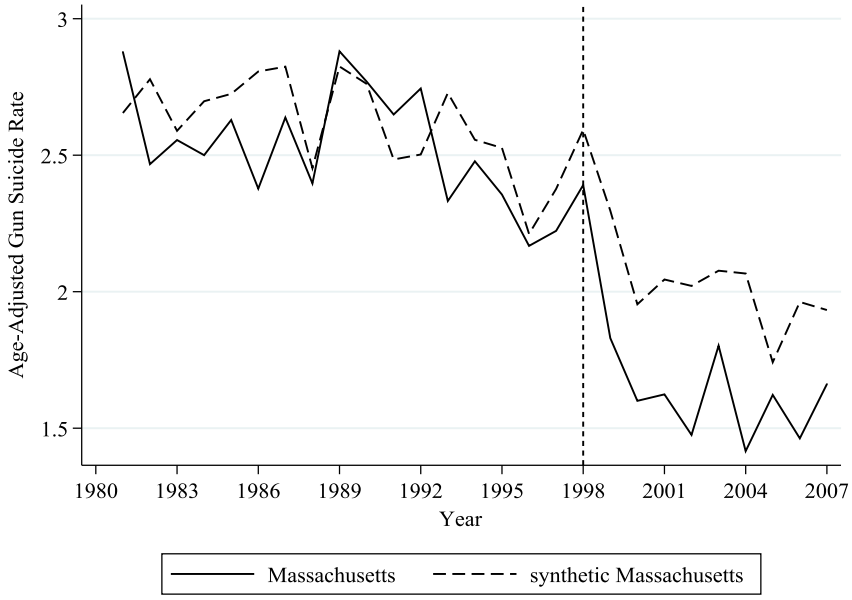

Fig. 3. Actual and synthetic Massachusetts gun-related suicide rates, 1981 to 2007.

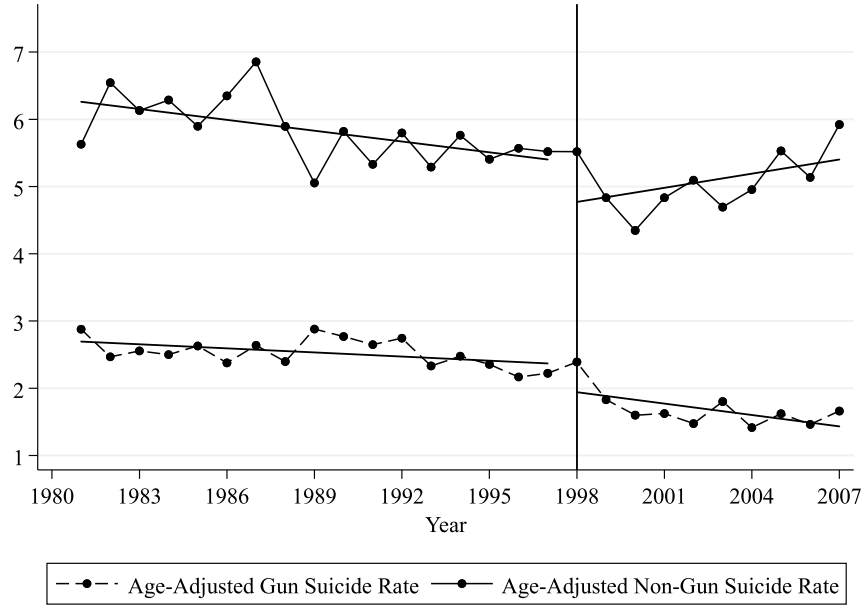

Fig. 4. Gun and non-gun suicide rates, 1981 to 2007.

to acquire a gun will reduce suicides. Studying the case of Massachusetts over the decade following the 1998 enactment of nearly two dozen gun laws, the results of the SCM estimation produced evidence that, for at least several of the years following enactment, suicide rates (overall and by gun) were significantly reduced. An interesting element displayed in Fig. 1 is that the gap between actual and synthetic overall suicide rates widens for several years, then begins to close. Fig. 3, however, shows the gap between the synthetic and actual Massachusetts gun suicide rates remaining largely intact. This would suggest that, in order for the gap for all suicides to be closing, the *non*-gun suicide rate would be rising after 1998. Indeed, there does seem to be evidence of this occurring. Fig. 4 plots age-adjusted gun and non-gun suicide rates for the period 1981 to 2007. Also plotted are trend lines for both rates and for the periods before and after 1998. The graph shows that prior to 1998, the two suicide rates have slightly negative trends which are nearly parallel. Starting in 1998 and going forward, the two series appear to undergo a structural break. Further, the negative trend line for gun related suicides steepens while the trend line for non-gun related suicides, following an initial dip after 1998, now has a positive trend.[10] Taken together, these changing trends seem to indicate a substitution occurring between gun and non-gun suicide

[10] The initial drop in the non-firearm suicide rate after 1998 may be due to an initial cohort effect. Previous research (see: Barber and Miller, 2014), notes that when lethal means for suicide are restricted, this may cause those contemplating suicide to delay their attempt. With the advent of the dramatic changes in Massachusetts state gun laws, this may have led to individuals considering suicide (whether by firearm or non-firearm methods) in this initial cohort to pause, thus allowing some to get past their crisis and ultimately change their mind. For later cohorts, this change in the 'landscape' of state gun laws will have been established and, as such, they would not face an unexpected delay. In this scenario, the short-term impact of the new gun laws may be to reduce all suicides (firearm and non-firearm), with substitution of non-firearm methods later occurring.

methods post-1998. This phenomenon remains as a topic for future research.

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