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Effects of changes in permit-to-purchase handgun laws in Connecticut and Missouri on suicide rates

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ABSTRACT

Objective. In 2013, more than 40,000 individuals died from suicide in the United States. Restricting access to lethal means has the potential to prevent suicide, as suicidal thoughts are often transient. Permit-to-purchase (PTP) laws for handguns could potentially reduce suicides by making it more difficult for persons at risk of suicide to purchase a handgun.

Methods. We used a quasi-experimental research design with annual, state-level suicide data to evaluate changes to PTP laws in Connecticut and Missouri. Data were analyzed for 1981–2012. We used synthetic control modeling as the primary method to estimate policy effects. This methodology provided better prediction of pre-PTP-law-change trends in the two states with PTP law changes than econometric models and is thus likely to provide more accurate estimates of policy effects.

Results. The synthetic control model estimated a 15.4% reduction in firearm suicide rates associated with Connecticut's PTP law. Missouri's PTP law repeal was associated with a 16.1% increase in firearm suicide rates. Evidence that PTP laws were associated with non-firearm suicide rates was mixed in Connecticut and negative in Missouri.

Conclusion. The findings are consistent with prior research linking firearm availability to increased risk of suicide and lower suicide risks associated with PTP handgun laws.

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Introduction

In the United States, suicide is the second leading cause of death for persons age 15–34 years, and the tenth leading cause of death overall (CDC, 2015a). In 2013 alone, more than 40,000 individuals lost their lives to suicide, compared to approximately 16,000 homicides (CDC, 2015b). More than half of all suicides were committed with a firearm (CDC, 2015a).

Household-level and state-level studies have found that access to firearms is positively associated with suicide risk after controlling for other risk factors (Anglemyer et al., 2014). Case fatality rates for suicide attempts by firearm exceed 90% (Miller et al., 2004). Though many commonly think that a person contemplating suicide will use an equally lethal alternative method if the original means of suicide is restricted, suicidal ideation is often transient (Miller et al., 2006; Deisenhammer et al., 2009). And for many individuals attempting suicide, the time between suicidal ideation and attempt can be as little as 10 min (Deisenhammer et al., 2009). If a person's access to particularly lethal means can be restricted during periods of distress or impulsivity, a suicide may be prevented. For these reasons, suicide prevention research has explored what impact lethal means restriction can have on suicide attempts and completion (Hawton, 2007; Barber & Miller, 2014).

Laws requiring permits to purchase firearms represent one method of means restriction for firearms, especially for some high-risk individuals, which require handgun purchasers to obtain a permit-to-purchase (PTP) that is contingent upon the applicant passing a background check. These PTP laws typically require an in-person application at a law enforcement agency and, in some cases, applicants must successfully complete safety training and experience significant waits for review. Permits are required for virtually all transfers of handguns including those conducted by private unlicensed sellers. A background check requirement for private sales should prevent a sale to someone with a prohibiting condition that reflects heightened risk for suicide, including conviction for violent crimes, being under a restraining order for domestic violence, multiple offenses involving drugs or alcohol abuse, and being involuntarily committed to a mental hospital or found by a court to be a threat to themselves or others due to mental illness. Also, the additional time required to obtain a gun in states with a PTP law could restrict access to firearms among those not already owning firearms during times of suicidal ideation or planning. Federal law does not require a permit or background check for handgun purchasers are only required under federal law if the seller is a licensed gun dealer.

Missouri had a PTP law for handguns in place beginning in 1921. Anyone wanting to legally purchase a handgun from a licensed dealer or

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private seller was required to apply in-person at a local sheriff's office. A PTP for a handgun was issued to approved individuals and good for 30 days. Missouri's PTP law was repealed effective August 28, 2007, reducing a barrier to handgun access for prohibited persons. Prior research evidence indicates that the PTP law repeal was associated with an increase in the diversion of guns to criminals Webster et al., 2013 and homicides committed by firearms in Missouri (Webster et al., 2014).

Prior to 1995, Connecticut's laws regarding background checks for handgun sales could be characterized as vague. In 1965, the state enacted a law requiring all handgun sellers and buyers to use a written application that was to be mailed to the local authorities prior to a sale. If that municipal authority were to "have knowledge" that the buyer had a felony conviction, then the authority would notify that seller that no sale could take place. A one week waiting period — extended to two weeks in 1975 — was also instituted. A new state law went into effect in October 1994, establishing an optional eligibility certificate for handgun buyers that could be issued by local authorities upon the purchaser passing a background check. Holders of an eligibility certificate for handgun purchases were not required to comply with the waiting period. Local authorities were instructed to make a "reasonable effort" to determine if any applicant was ineligible to own a handgun. It was not until October 1, 1995 that Connecticut established a mandatory PTP system applicable to all handgun buyers and made it illegal to sell a handgun to anyone who did not have an eligibility certificate. Such certificates required the applicant to pass a background check and successfully complete an 8-hour handgun safety course. A recent study demonstrated that enactment of Connecticut's PTP law was associated with decreases in firearm homicides and had no impact on homicides committed by other means (Rudolph et al., 2015).

The current study was designed to estimate the effects that these two changes in PTP handgun laws had on suicide rates. Prior research has shown a negative association between the presence of PTP laws and suicide rates;Andrés & Hempstead, 2011; Fleegler et al., 2013 however, most of the variation examined in these studies was cross-sectional and did not focus on whether the policies changed the risk of suicides over time in states when they adopted or repealed a PTP law. A recently published study by Anestis et al. (Anestis et al., 2015) also explored this topic, however, this study had important limitations including that it principally estimated cross-sectional associations. Our study seeks to provide a thorough and rigorous evaluation of the impact of changing PTP handgun laws on suicide in Connecticut and Missouri.

Methods

Design

A quasi-experimental research design was used with annual, state-level suicide rates and counts to contrast differences pre- versus post-PTP law change in Connecticut and Missouri compared with states that did not experience a PTP law change. State-level data for suicides were available for the years 1981–2012. Suicides were stratified by mechanism (firearm vs. non-firearm) to test the specificity of the policy effects and examine if possible method substitution occurred following the PTP law change.

Data

Suicide data were accessed from the Centers for Disease Control and Prevention's Web-based Injury Statistics Query and Reporting System (WISQARS) CDC, 2015c for years 1981–2007. For data after 2007, WISQARS suppresses the data if counts for individual state-years are less than 10 — which was particularly prevalent when examining the data within age strata. Data were obtained for years 2008–2012 through a request to the National Association for Public Health Statistics and Information Systems (NAPHSIS. National Association for Public Health Statistics and Information Systems, 2014).

The analyses controlled for a number of factors previously associated with suicide rates at the state level including: unemployment; poverty; demographics (percentage of the population that was male, black, Hispanic, married, completed high school, a military veteran, or who lived in a Metropolitan Statistical Area (MSA)), per capita consumption of ethanol spirits, firearm availability, and rate of religious adherence. The analyses also included control variables for states with strong mental health parity laws because access to mental health services could protect against suicides.

Annual unemployment rates (per 100 population age 16 or older) were accessed from the Bureau of Labor Statistics (BLS, 2012). Poverty rates (per 100 population) were from the Current Population Survey (Census, 2012a). Percent MSA was obtained from the Crime in the United States reports (FBI, 2012). The proportions of state population that were black or Hispanic were from the Census Bureau and interpolated between census years (Census, 2012b). Marital status, percent completing high school, proportion male, and proportion of the state that are military veterans were accessed from Census data and the American Community Survey (Census, 2015). Per capita ethanol spirit consumption was obtained from National Institute on Alcohol Abuse and Alcoholism (NIAAA, 2014). Rates of religious adherence were obtained from the Religion and Congregation Membership Survey interpolated between census years (ARDA, 2014). A commonly used firearm availability proxy (ratio of firearm suicides to all suicides) was created using data from WISQARS (used only to improve matching in the synthetic control models) (CDC, 2015c).

A significant challenge to deriving valid estimates of the impact of new state policies on public health and safety outcomes is the considerable heterogeneity among states and the inability to directly measure important factors that influence trends that vary across states. An innovative approach for dealing with this challenge is creating so-called "synthetic controls" to estimate the counterfactual for states that adopt new policies. This method uses data from a pool of potential comparison states that do not have the type of law being evaluated to create a synthetic control. This synthetic control is derived from a combination of observations from the comparison pool that are weighted according to their ability to accurately predict the pre-law trends in the outcome variable of the state where the law of interest is being changed. This approach can produce a more accurate counterfactual for the state where the law change occurs and therefore a more accurate estimate of a policy impact than analytic approaches that estimate policy effects based on a much broader set of data that include non-intervention comparisons that may be substantially different from the intervention state.

The synthetic control methodology avoids the heterogeneity assumption, that an intervention has constant effects across all observations, which underlies estimates derived from regression analyses. This methodology allows us to separately estimate the effects of a law's change on suicide for Connecticut and Missouri over different time periods.

To construct appropriate synthetic controls, we restricted the donor pool of comparison states for Connecticut's synthetic control to the 39 other states without a PTP handgun law in 1995. For Missouri, which repealed its PTP law in 2007, we included the other 9 states (excluding the District of Columbia and Connecticut) that had a PTP law in 2007. We used covariate and suicide data from 1981–2006 for Connecticut, which adopted its law in late 1995, avoiding extrapolation beyond ten years after the passage of Connecticut's PTP law as recommended by Abadie, Diamond, and Hainmueller (Abadie et al., 2010). For Missouri, which repealed its law in 2007, we used data from 1981–2012. Dependent variable rates were smoothed by analyzing three-year moving averages for Y_{t-1}, Y_t, and Y_{t+1} to ease interpretation of otherwise volatile data (Rudolph et al., 2015; Abadie et al., 2010; Abadie & Gardeazabal, 2003; Abadie et al., 2015). Separate analyses were performed for firearm suicides and non-firearm suicides to assess whether any estimates of policy effects were specific to firearm suicides and if the policy change was associated with method substitution. The synthetic controls' ability to predict pre-law-change trends in suicide rates in the states that changed their PTP laws was assessed by calculating the root mean square prediction error (RMSPE) and contrasting it with the RMSPE for a simple average of the entire pool of control states that were used to predict suicide rates in Connecticut and Missouri.

Because this method does not produce traditional p-values or tests of statistical significance, we performed so-called placebo tests with each of the states in the donor pool of control states for Connecticut and Missouri. Using firearm suicide rates, we ran the analyses with each state from the donor pool as if it were the "treated" state that experienced the PTP law change at the time that Connecticut or Missouri did. We then calculated the cumulative percent change in firearm suicides during the post-law change periods for Connecticut (1996–2005) and Missouri (2008–2012). We calculated the percent difference in cumulative post-law-change firearm and non-firearm suicide rates between the observed and the counterfactual estimated by each of the synthetic controls. This allowed us to examine the estimated percentage change associated with the changes in the PTP laws in Connecticut and Missouri in comparison to the percentage change estimates from the placebo tests in the states from each of

the respective donor pools of control states and thus assess how unique the changes observed in the intervention states were.

To compare the results of the synthetic control methods to a more traditional approach to policy evaluation, we also conducted standard econometric time series analyses. We used pooled time series with annual cross-sectional data from all 50 states to evaluate the associations between the passage (Connecticut — 1995) and repeal (Missouri — 2007) of the PTP laws and total, firearm, and non-firearm suicides. We created an indicator variable for each state (Connecticut and Missouri) to represent the state's change in PTP law status. For Connecticut, the indicator was coded as 0 prior to the passage of the law, a fraction for the proportion of the days in the year the law was in effect, and 1 for each subsequent year. The opposite was true for Missouri; the indicator was coded as 1 prior to the repeal, a fraction for the proportion of the days in the year the law was in effect, and 0 for each subsequent year without the law. To estimate the effects of a change in PTP law status and firearm suicides, we used negative binomial regression models using state and year fixed effects. Fixed effects were used to account for time-invariant factors and omitted variables that may be associated with suicides. Standard errors were adjusted to account for clustering by state. Negative binomial regression was used due to over-dispersion in the outcome variables. The same covariates as with the synthetic control models were used (excluding the gun availability proxy).

All analyses were conducted using Stata IC v. 13.0 (StataCorp., 2013). This study was deemed to be "not human subjects research" by the Johns Hopkins Bloomberg School of Public Health.

Results

Synthetic control model

Table 1 compares the mean value of predictors in the treated unit and the synthetic control for the period prior to the PTP law change. The means are averaged over the entire pre-law-change period except for the lagged firearm and non-firearm suicide rates.

Table 1
Predictor balance averaged over pre-law-change period for Connecticut, Missouri, and their synthetic controls.

	Connecticut	Synthetic control firearm suicides	Synthetic control non-firearm suicide
Percent white	89.8	94.2	90.0
Percent ages 18–34	27.4	28.8	28.0
Gun availability proxy*	0.44	0.38	0.61
Percentage with veteran status	16.9	17.1	17.1
Percentage male	47.4	47.4	48.0
Unemployment rate	5.14	5.94	6.60
State-years of any mental health parity law	0.00	0.00	0.00
	Firearm/ non-firearm		
Suicide rate, 1981	3.68/4.93	3.81	4.93
Suicide rate, 1987	4.21/5.41	4.21	5.42
Suicide rate, 1994	4.41/5.13	4.41	5.13
	Missouri	Synthetic control firearm suicides	Synthetic control non-firearm suicide
Percent white	87.8	79.8	86.9
Percent ages 18–34	25.4	26.8	25.5
Gun availability proxy*	0.62	0.66	0.50
Percentage with veteran status	16.2	14.6	14.4
Percentage male	47.3	47.9	47.7
Unemployment rate	5.70	4.94	5.49
State-years of any mental health parity law	0.27	0.06	0.13
	Firearm/ non-firearm		
Suicide rate, 1981	7.48/4.41	8.70	4.56
Suicide rate, 1993	8.43/4.38	8.33	4.47
Suicide rate, 2006	7.55/5.77	6.78	5.43

The intervention states and their respective synthetic controls are very similar on baseline suicide rates and predictors. There are some divergences between, for instance, the value of Connecticut's gun availability proxy and its synthetic control for firearm suicides and between Missouri's racial demographic composition and its synthetic control for firearm suicides. Several other predictors were used in sensitivity analyses including a measure of the urban population, per capita consumption of ethanol derived from spirits, a measure of poverty, and marital status. These additional predictors neither improved the pre-intervention fit nor substantially altered the results.

States with the largest weights for Connecticut's synthetic controls were Rhode Island (0.741) and North Dakota (0.259) for firearm suicides and Utah (0.332) and Pennsylvania (0.210). The largest weights for Missouri's synthetic controls were North Carolina (0.790) and Nebraska (0.210) for firearm suicides and Iowa (0.447) and New Jersey (0.285). Appendix Table 1 lists all states with non-zero weights for the synthetic controls for each intervention state for firearm and non-firearm suicide rates. The prediction error (RMSPE) for the pre-law-change period produced by an average of all the states in the respective donor pools for each PTP law change studied were 19 times higher than the "synthetic Connecticut's" firearm suicide rates, 3.8 times higher than the "synthetic Connecticut's" non-firearm suicide rate, 6.9 times higher than "synthetic Missouri's" firearm suicide rates, and 3.2 times higher than "synthetic Missouri's" non-firearm suicide rates (Table 2). Prediction error for the baseline periods were 2 to 3 times higher in the synthetic control models for the 20–29 age group versus the synthetic control models for the overall state populations, yet was considerably lower than the prediction error when using the average of the donor pool states.

Figs. 1 and 2 show a panel of synthetic control analyses for Connecticut and Missouri, respectively for: (a) firearm suicide, (b) non-firearm suicide; (c) firearm suicide for persons age 20–29, and (d) non-firearm suicide rates for persons age 20–29. For firearm suicides, no systematic differences between Connecticut and its synthetic control are evident during the pre-law period. During the post-intervention period, Connecticut's firearm suicide rate consistently stays below that of its synthetic control. Connecticut's non-firearm suicide rate is relatively stable throughout the entire study period (Fig. 1(b)). After actual non-firearm suicide rates closely tracked the synthetic control during the pre-law period, the rate for Connecticut's synthetic control rose gradually above the actual rate for the state during the post law period. The pattern observed for Connecticut relative to its synthetic control for all firearm suicides is evident for firearm suicides among 20–29 year olds, though the departure of Connecticut's post-law trend from its synthetic control's path appears more pronounced (Fig. 1(c)). Among 20–29 year-olds, Connecticut's non-firearm suicide rate closely tracts its synthetic control until it dips well below its synthetic control during the middle years of the post-law period (1998–2002) (Fig. 1(d)).

Missouri's firearm suicide rates were slightly higher than its synthetic control's during the 1990s, but the difference began to grow the year prior to the PTP law repeal (2006) and the divergence grew over the 5-year period following the repeal of the PTP law when Missouri's rate is noticeably higher than the control (Fig. 2(a)). Missouri's non-firearm suicide rate tracks closely with that of its synthetic control throughout most of the study period with the actual rate slightly higher than its

Table 2
Root Mean Square Prediction Error (RMSPE) for the pre-law-change period for the synthetic controls for Connecticut and Missouri compared with the RMSPE for the average of all donor states who could have changed their PTP law at the time Connecticut's and Missouri's PTP laws changed.

	Connecticut		Missouri	
	Synthetic control	All donor states	Synthetic control	All donor states
Firearm suicides	0.27	5.03	0.52	3.58
Non-firearm suicides	0.13	0.50	0.14	0.47

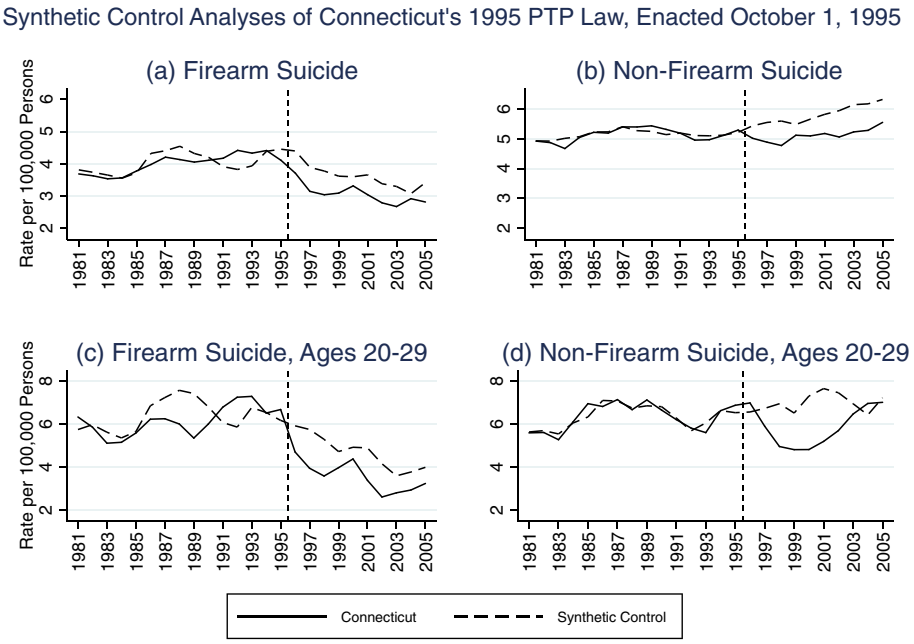

Fig. 1. Synthetic control analyses of Connecticut's PTP law, enacted October 1, 1995.

control 2006–2010 (Fig. 2(b)). Among persons age 20–29, Missouri's firearm suicide rate is above its synthetic control for much of the initial pre-intervention period; however, the actual and predicted rates are similar during the 8 years leading up to the law's repeal. During the post-repeal period, Missouri's firearm suicide rate among individuals age 20–29 increases and stays above that of the control (Fig. 2(c)). A similar pattern is evident for non-firearm suicide rates for age 20–29 except that the increase in Missouri relative to its control begins in 2005, prior to the repeal of the state's PTP law (Fig. 2(d)).

Connecticut's firearm suicide rates were 15.4% lower than that of its synthetic control during the 10-year post-law period. Fig. 3(a) shows that only 2 of the 39 control states experienced reductions in firearm suicides that were larger in percentage terms based on the placebo tests. The largest percentage reduction in firearm suicide rates based on the placebo tests occurred in Rhode Island; however, its prediction error for the pre-law period revealed the worst model fit among the pool of control states. Connecticut's non-firearm suicide rates, however, were 11.9% lower during the post-law period than predicted by the synthetic control. Six states had percentage reductions in non-firearm suicide rates relative to their synthetic controls during 1996–2005 that were larger than Connecticut's (Fig. 3(c)).

The synthetic control model estimate for the effect of Missouri's repeal of its PTP law was 16.1% higher than the counterfactual during the 5-year post-law period. The increase in firearm suicides in Missouri following the repeal of its PTP law was unusual among states that had a PTP handgun law in 2006 (Fig. 3(b)). Among the donor pool of 9 control

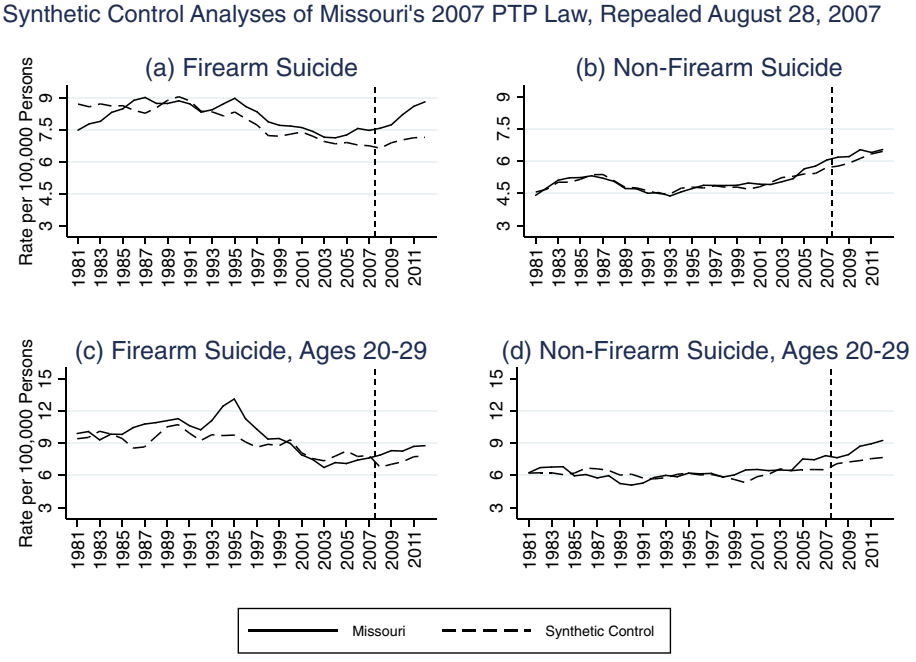

Fig. 2. Synthetic control analyses of Missouri's PTP law, repealed August 28, 2007.

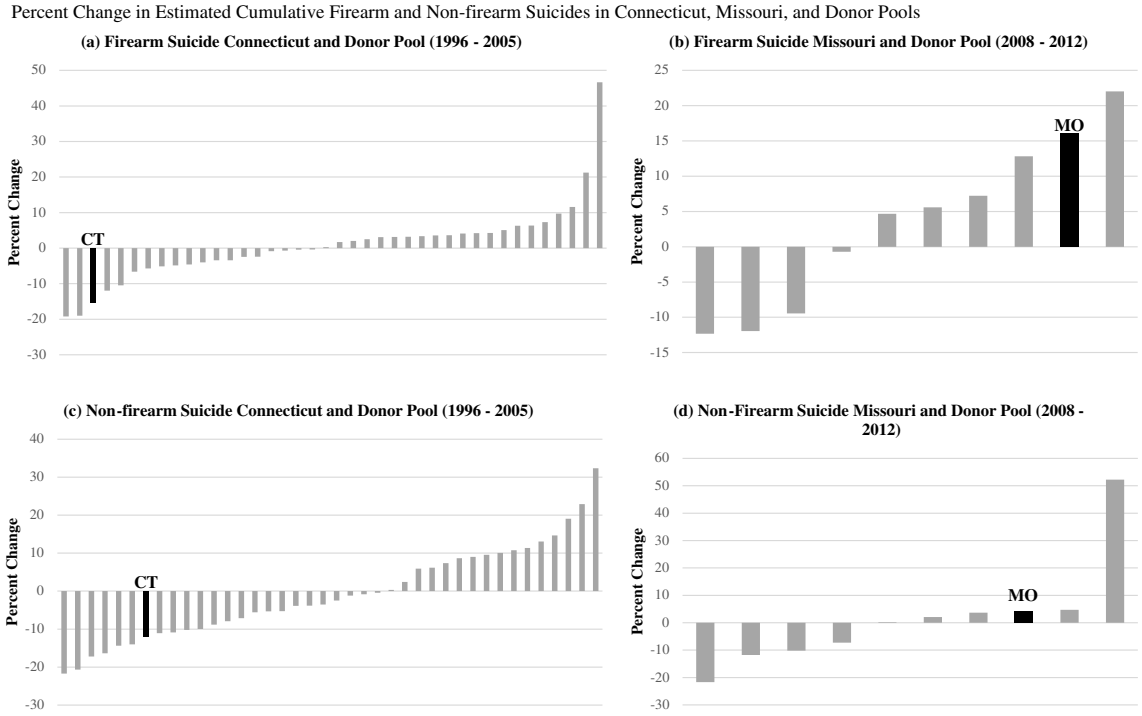

Fig. 3. Percent change in estimated firearm and non-firearm suicides in Connecticut, Missouri, and donor pools.

states for Missouri, only Hawaii's placebo test for policy effects at the same time as Missouri's law change produced a larger percentage increase in firearm suicide rates. However, Hawaii's synthetic control model produced the worst pre-law-change model fit among the pool of donor states and its baseline rate of firearm suicide was less than a third as high as that of Missouri's. In absolute terms, the increase in Hawaii's annual firearm suicide rates (0.61) during 2008–2012 was half that observed in Missouri (1.29). Missouri's non-firearm suicides were 4.2% higher than the control during the period after the PTP law repeal (Fig. 3(d)).

For the 20–29 year age group, Missouri's observed suicide rates after the PTP law repeal were 14.5% higher than that of the synthetic control for suicides committed with firearms and 15.0% higher for non-firearm suicides.

Alternative regression model estimates

The alternative method of estimating policy effects — negative binomial regression models with panel data from 50 states — produced estimates indicating that Connecticut's PTP law was associated with a 12% reduction in firearm suicide rates ($p = 0.004$), a 14% increase in rates of non-firearm suicide ($p = 0.002$), and no association with overall suicide rates. Among 20–29 year-olds, Connecticut's law was associated with a 28% reduction in firearm suicide rates ($p = 0.001$) and a 16% increase in non-firearm suicide rates ($p = 0.046$). The repeal of Missouri's PTP law was not associated with changes in any of the suicide measures (Appendix Table 2). Comparisons of the RMSPE for Connecticut and Missouri generated from these regression analyses reveal poor model fit compared with the synthetic control models.

Discussion

Prior research produced evidence suggesting that handgun purchaser licensing laws were associated with lower suicide rates, but focused principally on cross-sectional associations (Andrés & Hempstead, 2011; Fleegler et al., 2013; Anestis et al., 2015). This study investigates if recent changes in permit-to-purchase (PTP) handgun laws led to changes in suicide rates in ways consistent with the hypothesis that these laws reduce suicides by decreasing the availability of a highly lethal means of suicide.

We applied a relatively new approach that has been used to study the effects of state laws on public health outcomes that identifies comparison states that, in combination, constitute so-called synthetic controls that best predict the outcome measures in the states where the policies of interest are changing. Using this method, we find some support for this hypothesis that PTP laws reduce suicides. Connecticut experienced a drop in its firearm suicide rate coincident with the adoption of a PTP handgun law that was greater than nearly all of the 39 other states that did not have such a law at that time and Missouri experienced an increase in its firearm suicide rate following the repeal of its PTP handgun law that was larger than all states that retained their PTP laws. The estimated effects of the PTP law on firearm suicide rates were more pronounced among individuals ages 20–29, the age at which young adult first become legally eligible to purchase handguns. What one infers about the strong negative association between Connecticut's PTP law and firearm suicide rates, depends on how one interprets the data on the law's association with non-firearm suicides. The synthetic control method indicated a reduction in non-firearm suicides associated with Connecticut's PTP law that was proportionately similar to that derived for firearm suicides. However, the estimate for non-firearm suicides was based principally on increases that occurred in the state's synthetic control during the post-law period when Connecticut's actual rate was stable. Further, the estimated effect was not so unusual relative to the placebo tests in the 39 other states without PTP laws in 1995. The regression analyses with 50 states' data estimated a large and statistically significant negative association between Connecticut's PTP law and firearm suicides rates, but a statistically significant positive association between the law and non-firearm suicide rates. Thus, the evidence that Connecticut's PTP law was associated with any change in non-firearm suicides is unclear at best.

Missouri's firearm suicide rates rose 16% over and above the counterfactual estimated by the synthetic control for the first 5 full years after the repeal of Missouri's PTP handgun law. The percentage increase was greater than 8 of the 9 other states that had a PTP law when

Missouri's was repealed and four times that estimated for Missouri's non-firearm suicide rates. We would expect the effects of the repeal of Missouri's PTP law would be more concentrated among those in their twenties; however, that was not evident.

Findings from the alternative method for estimating policy effects, negative binomial regressions using data from all 50 states, differ from those generated by the synthetic control method with the exception of also showing Connecticut's PTP law negatively associated with firearm suicide rates in the overall population and among the 20–29 age group. Inferences about the association between PTP laws and suicides for the other outcomes, therefore, depends on which method of estimating the counterfactual for suicide trends in the two states that changed their PTP laws is more accurate. The negative binomial models used data from all 50 states to generate treatment effects averaged across 50 states. We believe that the synthetic control approach is more defensible because it selects and weights comparison states based solely on how well the data from those states predict baseline suicide trends in the states that changed their PTP laws. As is evident by the data in Table 2, using data for the entire pool of donor states for Connecticut and Missouri regardless of how well those state's data predict suicide rates in the states that changed their PTP law can provide for a poor counterfactual for states with the law changes in comparison to that of synthetic controls. Furthermore, prediction error for Connecticut and Missouri's suicide rates from the negative binomial regression models was much greater than was produced by the synthetic control models.

There are several strengths to the study in addition to the use of synthetic controls to estimate temporal relationships between PTP laws and suicide rates. The analyses controlled for a number of state demographic characteristics that could be associated with the risk of suicide including the proportion of the state population who were military veterans in any given year. Since veterans are at increased risk of suicide compared to the general population, we controlled for this to ensure our results were attributed to the policy change and not some unmeasured factor. Finally, we tested the specificity of our results by examining the effects of the law changes on non-firearm suicides. Since means substitution is an important consideration when studying suicide, we were able to evaluate whether a substitution effect occurred due to means restriction after the passage of Connecticut's PTP law.

As with most evaluations of public policy, we cannot rule out the possibility that our estimates of the associations between PTP laws and suicide rates are confounded by unmeasured determinants of suicide correlated with changes in the laws. Furthermore, data are not available to ascertain whether the reductions in firearm suicides were experienced by groups legally prohibited from purchasing handguns or who might otherwise be deterred from purchasing handguns as a result of a law requiring handgun purchaser permits contingent upon applicants passing background checks and safety training requirements.

The use of synthetic control methods provides the best available estimates and suggests that the presence of a PTP law could prevent a significant number of suicides. Based on the nature of the synthetic control, however, these results do not provide a confidence interval leading to uncertainty around the point estimate. These laws appear to be protective in ways that you might hypothesize based on what is known about the role of firearms and risk of suicide, but it is unclear exactly what magnitude effect on lives saved these laws have. Despite these limitations, the current study finds evidence to suggest that PTP laws for handguns reduce suicide rates. Future research should explore other factors that may predict state-level suicide rates so that models to test the effects of policies that could serve as a form of means restriction produce more precise estimates of policy effects.

The findings of the study are relevant to physicians as it provides further evidence that reducing access to a firearm can prevent suicide. Physicians who treat patients at elevated risk for suicide can counsel patients and family members about the link between access to a firearm and suicide risk and the potential benefit of reducing firearm access. The study also highlights the value of a population based approach to suicide prevention. Many who are at elevated risk for suicide do not seek care or have limited access to care and those who are seen may not follow the advice of physicians on matters related to firearms. A PTP law that would restrict access to handguns for individuals with a history of severe mental illness, criminal behavior, domestic violence or substance abuse, or by simply delaying access to a firearm during a time of crisis through an application review period could prevent suicide.

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No financial disclosures were reported by the authors of this paper.

Conflict of interest statement

This study was funded by The Joyce Foundation. The funder had no role in the study design, collection, analysis, or interpretation of the data, writing of the report, or the decision to submit the report for publication.

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Appendix A

Appendix Table 1
States with non-zero weights for synthetic controls for Connecticut's and Missouri's firearm and non-firearm suicide rates.

	Firearm suicides	Non-firearm suicides
	Connecticut	
Rhode Island	0.791	0.071
North Dakota	0.078	–
South Dakota		0.140
Pennsylvania	–	0.210
Utah	–	0.332
Arkansas	–	0.124
New Mexico	–	0.117
Mississippi		0.033
	Missouri	
Nebraska	0.210	–
North Carolina	0.790	0.145
Iowa		0.447
Massachusetts		0.002
Michigan		0.121
New Jersey		0.285

Appendix Table 2
Estimates of the association between permit-to-purchase handgun laws changes in Connecticut and Missouri from negative binomial regression analyses* with data from 50 states for the years 1981–2012.

State	Total population	Age 20–29 years
All methods suicides IRR (95% CI, p-value)		
Connecticut	1.01 (0.95 to 1.08, p = 0.765)	0.92 (0.81 to 1.04, p = 0.175)
Missouri	1.03 (0.97 to 1.08, p = 0.326)	0.96 (0.86 to 1.07, p = 0.430)
Firearm suicides IRR (95% CI, p-value)		
Connecticut	0.88 (0.81 to 0.96, p = 0.004)**	0.70 (0.57 to 0.84, p < 0.001)**
Missouri	1.02 (0.96 to 1.09, p = 0.450)	0.97 (0.84 to 1.11, p = 0.619)
Non-firearm suicides IRR (95% CI, p-value)		
Connecticut	1.14 (1.05 to 1.24, p = 0.002)**	1.12 (0.96 to 1.31, p = 0.140)
Missouri	1.03 (0.95 to 1.11, p = 0.456)	0.93 (0.81 to 1.07, p = 0.317)

**Indicates $p < 0.05$.
*These analyses controlled for the presence of a strong parity law; percent MSA; per capita consumption of ethanol; percent poverty; unemployment; marital status, percent completed high school; percent male; percent veteran; and rate of religious adherence.

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