J Urban Health (2023) 100:425–430
https://doi.org/10.1007/s11524-023-00739-6

BRIEF REPORT

Examining a Hypothesized Causal Chain for the Effects of the 2007 Repeal of the Permit-to-Purchase Licensing Law in Missouri: Homicide Guns Recovered in State and within a Year of Purchase

Michelle Li · Dylan Small · Ting Ye · Yuzhou Lin · Daniel Webster

Accepted: 27 April 2023 / Published online: 30 May 2023

Abstract Firearm-related deaths are a leading cause of death in the USA. Webster et al. (2014) found an association between Missouri's repeal of a permit-to-purchase handgun licensing law and an increase in firearm-related homicides. The evidence for causality of this association would be strengthened by finding that the increase occurred through the hypothesized mechanism of increasing the ease with which those with violent intent could obtain guns. This study examines two measures: (1) proportion of guns recovered and purchased in-state and (2) time between firearm purchase and recovery by police following criminal use. The repeal was associated from 2008 to 2019 with a 0.05 increase in the proportion own-state gun trace ($p < 0.0001$, 95% confidence interval: 0.08,0.13) and a 0.10 increase in the proportion of guns recovered prior to 1 year after purchase ($p = 0.01$, 95% confidence interval: 1.20, 1.90). Our study provides supportive evidence for the repeal increasing firearm-related homicides.

M. Li (✉) · D. Small
Department of Statistics, University of Pennsylvania, Philadelphia, PA, USA
e-mail: mishell@wharton.upenn.edu

D. Small
e-mail: dsmall@wharton.upenn.edu

T. Ye
Department of Biostatistics, University of Washington, Seattle, WA, USA
e-mail: tingye1@uw.edu

Y. Lin
Department of Statistics, Harvard University, Cambridge, MA, USA
e-mail: yuzhoulin@g.harvard.edu

D. Webster
Department of Health Policy and Management, Johns Hopkins University, Baltimore, MD, USA
e-mail: dwebster@jhu.edu

Background

The USA faces a disproportionately large number of firearm related homicides every year, ranking second only behind Mexico in 2019 [1]. Among the 37,038 gun-deaths in America that year, 37% were homicides, up from less than 25% in 2018 [2]. More recent data from 2020 exhibits another staggering increase in both gun deaths and firearm homicide rate: CDC information revealed that 45,222 died from firearm-related causes, and of those deaths, 43% were homicides [2, 3]. Currently, this is the highest level of gun violence ever recorded in the USA.

This new level of gun violence has significantly affected American youth. In 2020, firearms became the leading cause of death among US children aged 1 to 19, surpassing motor vehicle crashes [4]. Gun violence victims are additionally five times more likely to be male than female. Young Black males specifically from ages 15 to 34, are even more dramatically

impacted, accounting for 38% of homicide victims while only accounting for 2% of the population [2].

Gun homicide risk is also distributed disproportionately across the USA. While the adjusted firearm death rate for rural and urban counties are relatively similar with around a 3% increase in deaths for urban versus rural counties, the urban firearm homicide rate was 1.90 times the rural firearm homicide rate [2].

Because gun availability is commonly considered a significant risk factor for homicide, policymakers have long debated the costs and benefits of stricter gun policy. Policy discussion over limiting gun accessibility has recently increased in response to the growing rate of mass shootings and gun homicides. One policy of interest is handgun purchaser licensing, which has had differing levels of support in the USA [5]. In this paper, we consider the effects of the repeal of Missouri's Permit-to-Purchase (PTP) gun licensing law in 2007.

The motivation for this study is to expand on research conducted on Missouri's PTP gun licensing law by Webster et al. in 2014 [6]. Webster et al. estimated the impact of the policy by using data through 2010 and a difference-in-difference approach. Results determined that the repeal of Missouri's PTP law was associated with a 23% increase (95% confidence interval: (17%, 30%) increase) in gun homicide rates. Causal inference from an observational study approach such as difference-in-difference is strengthened if there is evidence supporting the proposed causal chain between the intervention, mediators, and outcomes under study [7, 8]. PTP and other background check laws are hypothesized to affect gun homicide rates by reducing gun diversions to criminals and other prohibited groups [6]. Thus, Missouri's repeal of its PTP law is hypothesized to increase gun diversions to criminals and other prohibited groups. If an increase is observed, we would expect more guns involved in crimes in Missouri to have been purchased in Missouri (since the repeal of the PTP law makes it easier for diverted guns to be bought in Missouri) and more guns involved in crimes that were purchased within a year (such purchases are suggestive of a straw purchase in which one person buys a firearm at another's request). Webster et al. [6] examined the evidence for these two hypotheses informally but not through rigorous statistical analysis. The goal of this brief report is to examine these hypotheses through rigorous statistical analysis using a difference-in-difference approach and to provide updated evidence about the effect of the repeal of Missouri's PTP law on gun homicides through 2019 (Webster et al. (2014) only considered data through 2010).

Design

We hypothesized that the policy change expedited the gun obtention process for those with violent intent. The design of the study is a quasi-experimental difference-in-difference design using states that are most like Missouri in terms of baseline covariates as a control group.

Data and Measures

There are three primary outcome measures: time to recovery for in-state firearm purchases, the proportion of own-state gun traces, and age-adjusted gun homicide rate. We predicted that both the proportion of own-state gun traces and proportion of guns recovered in less than a year would increase, given the comparative ease of access to firearms. The datasets for both proportion measures were sourced from the Bureau for Alcohol, Tobacco, and Firearms (ATF) [9], and the homicide dataset was obtained from the CDC [2]. Because there was only firearms trace data on the site from 2006 to 2019 at the time of data collection for our two measures, we defined the pre-treatment period as 2006. Given that there was a significant landmark shooting in Ferguson, Missouri, in 2014, we defined two post-treatment periods: 2008–2013 and 2008–2019. We eliminated the data from 2007 because the policy was enacted in August of 2007 [6].

To account for other changes to the environment that may have affected the outcome measures, we obtained datasets on unemployment, poverty, incarceration, burglary, officers per capita, and four other gun control policies: Stand Your Ground (SYG) laws, right-to-carry (RTC) laws, Saturday Night Special (SNS) bans, and young adult firearm prohibition (YA)s. These factors were taken from Webster et al. (2014) [6].

To determine the best control states for our study, we calculated the Mahalanobis distance [10] between Missouri and the other 49 states and the District of Columbia. The covariate variables we used included those previously listed: SYG, RTC, YA, Unemployment, Poverty, Incarceration, Burglary, and Officers variables in the year 2006, the earliest year we had

data for two of our variables. We used as controls the eight states (CO, GA, IL, IN, KY, OH, SC, TX) with the lowest Mahalanobis distance values from Missouri in 2006.

Analytic Methods

We then fitted linear regression models for three outcomes: proportion of guns recovered from crime scenes within 1 year after purchase, the proportion of own state gun traces, and gun homicides. The models adjust for state- and year-fixed effects, and an indicator variable for Missouri in the post-treatment years.

Standard errors for the difference-in-differences estimators were adjusted to account for clustering by state and for heteroskedasticity [11, 12], using the clubSandwich R package (version 0.5.3) with small sample corrections (option "CR2").

In the original WISQARS dataset, there was data labeled as missing or unreliable [2]. Therefore, in our Mahalanobis calculations, we omitted these points. In our regression analysis, we averaged the data from the previous and subsequent years for any missing datapoints.

Results

Controlling for baseline differences across states and year effects, the repeal of Missouri's PTP law was found to have a statistically significant effect and estimated to be associated with an increase in annual firearm homicide rate of 1.55 per 100,000 ($p=0.01$, 95% confidence interval from 1.20 to 1.90) during 2008–2019 (Fig 1). The results were less significant from 2008 to 2013. The repeal of the PTP law was not found to not have a statistically significant effect at a 0.05 level of significance, though it was significant at the 0.1 level of significance with an estimated increase of 0.70 firearm homicides per 100,000 people ($p=0.07$; 95% confidence interval −0.04 to 1.45).

For the proportion time-to-recovery variable, after controlling for baseline differences across states and year effects, the repeal of Missouri's PTP law was associated with a 0.10 increase in the proportion of guns recovered less than a year after purchase using data from 2008 to 2019 ($p<0.0001$, 95% confidence interval from 0.08 to 0.13). From 2008 to 2013, we found that the law repeal is also associated with a 0.10 increase in the proportion of guns recovered less than a year after purchase ($p<0.0001$, 95% confidence interval from 0.08 to 0.13).

For the proportion own-state recovery variable, after controlling for baseline differences across states and year effects, the repeal of Missouri's PTP law was estimated to increase the proportion of guns recovered that were from Missouri by 0.05 from 2008 to 2019 but the result was not statistically significant ($p=0.35$, 95% confidence interval from −0.06 to 0.16). From 2008 to 2013, we found that the law repeal was significantly associated with an increase in proportion of guns recovered from Missouri with an estimated increase of 0.11 ($p=0.04$, 95% confidence interval from 0.01 to 0.21).

Discussion

Our study aimed to determine whether the repeal of the PTP law in Missouri could be associated with two variables hypothesized to be on the causal chain to an effect of the law on gun homicide rates: proportion own-state gun trace and proportion time-to-recovery. This study provides mostly supportive evidence on the hypothesized causal chain between the repeal of the Missouri PTP law and an increase rate of gun homicides although not all evidence is supportive.

Our estimates indicate that the law repeal had a significant impact on reducing the time between a gun's purchase and recovery from a crime. The 95% confidence interval for the law's association with an increase in the proportion of crime guns recovered in less than a year is 0.08 to 0.13. Contextualized, 10% of Missouri gun recoveries would be between 616 and 1000 guns a year. This reinforces previous findings that show increases in crime gun purchases from Missouri gun dealers following the repeal [13].

The proportion own-state gun trace variable test showed significance during the period from 2008 to 2013 following the repeal compared to before the repeal. However, our estimates were inconclusive for the period for the repeal period from 2008 to 2019 compared to before the repeal. This difference in the 2008–2013 results compared to in 2008–2019 may be attributed to how the proportion own-state gun trace variable showed consistent growth until meeting an unexplained and persistent drop in Missouri 2014 that was not apparent in control state trends. We hypothesize that after the landmark shooting in Ferguson, a major police department may have stopped sending

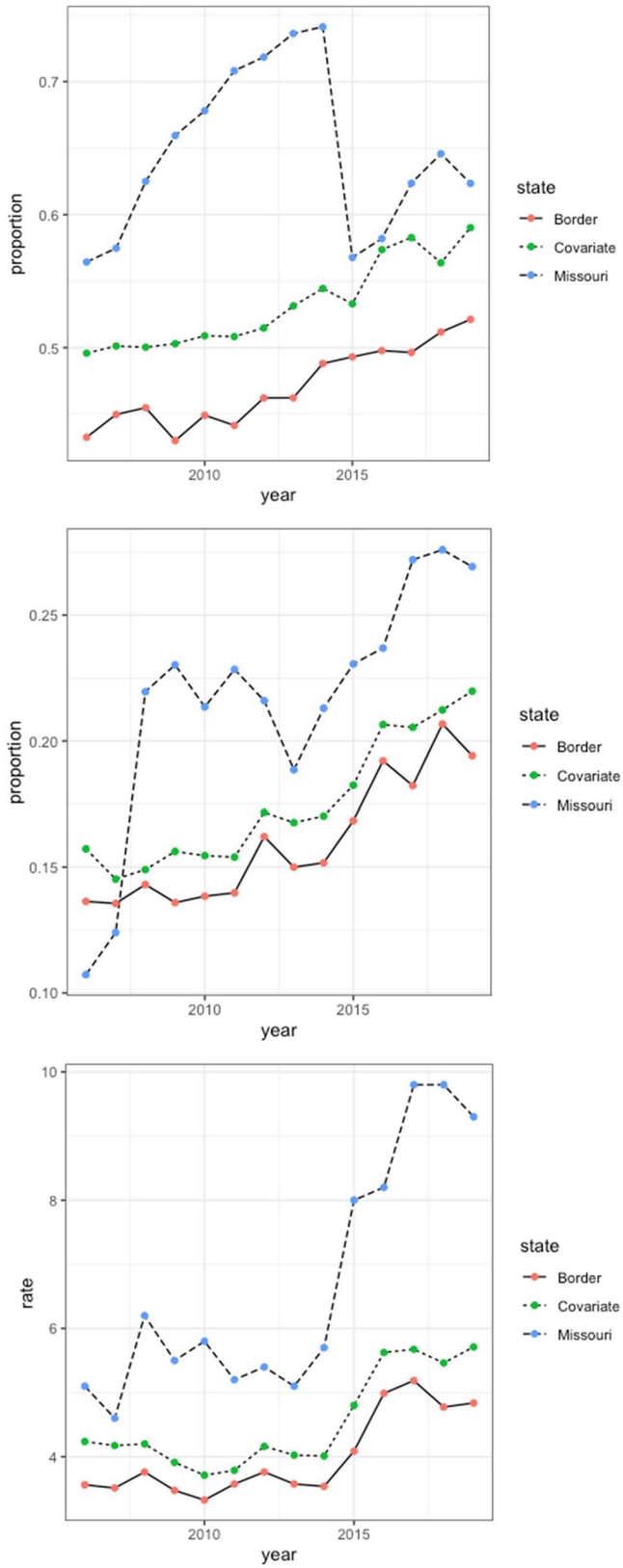

Fig. 1 Difference-in-difference estimation. (From top to bottom) The proportion of own-state gun traces from 2006 to 2019 for Missouri versus control states. The proportion of gun recoveries from crimes in under 1 year versus after 1 year from 2006 to 2019 for Missouri versus control states. The age-adjusted homicide rates for Missouri versus control states from 2006 to 2019

trace requests to ATF. Additional research into the reasons behind this drop is necessary.

In contrast to the Webster et al. study, we used 8 covariate-selected states rather than 43 as our control. We aimed to find states that with economic and political conditions that were most like Missouri. We found evidence of a significant increase in homicides in the repeal period from 2008 to 2019 compared to before the repeal when using covariate-selected states. We did not find a significant increase in the repeal period from 2008 to 2013 compared to before the repeal.

There are a couple of factors that could have affected our results in comparison to Webster et al. (2014)'s results. The gun repeal could have contributed to gun trafficking to neighboring states, as stated in prior studies [6, 14]. When we conducted a difference in difference test comparing Missouri to its border states, homicide increases were much less significant ($p = 0.08$; 95% confidence interval from −0.18 to 4.26) though the results did. Hence, using some border states as covariates may understate the homicide effect in Missouri because of the potential overflow effect.

A limitation of our study is that we lacked reliable data prior to 2006, which limited our pre-intervention period to 1 year. Another limitation is that Missouri's repeal of its PTP law in 2007 was confounded by the adoption of a modest expansion of its self-defense law in 2007 enabling more places where Stand Your Ground (SYG) applied and then more significant expansions in 2010 and 2016. However, we controlled for SYG laws in other states in the analysis. Additionally, Webster et al. (2014) had found from an analysis of justifiable homicide data from the FBI's Uniform Crime Reports that there were approximately three additional justifiable homicides per year in Missouri in 2008–2010 following the adoption of the state's SYG law above pre-SYG-law levels—less than 1% of the total number of gun homicides from 2008 to 2010 [6]. Also, this study focuses on the mechanisms in which the Missouri PTP law repeal may have led to increased homicides that are unrelated to the SYG law.

Overall, we found mostly supportive evidence for the repeal of Missouri's PTP law increasing gun homicides by the hypothesized mechanism of expediting the gun obtention process for those with violent intent.

Nevertheless, more longitudinal studies on other forms of gun policy are necessary to help inform government policy decisions. While this study provides evidence that the PTP law increased homicides, reinstating the law may not cause an immediate effect [6], as it may take time before guns are again cycled out of the system.

Acknowledgements This work was supported by the Penn Undergraduate Research Mentoring program and the Wharton Dean's Research Fund.

Data Availability The data used in this study are available in the Missouri_PTP_Repeal dataset, which can be accessed at the Harvard Dataverse repository (https://doi.org/10.7910/DVN/V4K3HA). The dataset is provided by Michelle Li and is cited as Li, Michelle, 2023, 'Missouri_PTP_Repeal', Harvard Dataverse, V1, UNF:6:FMeoDdXTwsL9GaHaKqaYOw== [fileUNF].

References

1. United Nations Office on Drugs and Crime. Victims of intentional homicides. https://dataunodc.un.org/dp-intentional-homicide-victims. Accessed 3 July 2022.
2. Centers for Disease Control and Prevention. *Leading causes of death, Web-based Injury Statistics Query and Reporting System (WISQARS)*. Atlanta, GA. https://www.cdc.gov/injury/wisqars/LeadingCauses.html. Accessed 3 July 2022.
3. Gramlich J. What the data says about gun deaths in the U.S. Pew Research Center. https://www.pewresearch.org/fact-tank/2022/02/03/what-the-data-says-about-gun-deaths-in-the-u-s/. Published May 16, 2022. Accessed 3 July 2022.
4. Sacks CA, Ingelfinger JR, Taichman DB, et al. Current causes of death in children and adolescents in the United States. *N Engl J Med*. 2022. https://doi.org/10.1056/NEJMc2201761.
5. Crifasi CK, Stone EM, McGinty B, Vernick JS, Barry CL, Webster DW. Differences in public support for handgun purchaser licensing. *Inj Prev*. 2020;26:93–5.
6. Webster D, Crifasi CK, Vernick JS. Effects of the repeal of Missouri's handgun purchaser licensing law on homicides [published correction appears in J Urban Health. 2014 Jun;91(3):598–601]. *J Urban Health*. 2014;91(2):293–302. https://doi.org/10.1007/s11524-014-9865-8.
7. Rosenbaum PR. Reasons for effects. *Chance*. 2005;18(1):5–10.
8. Cochran WG. Observation studies. *Statistical papers in honor of George W. Snedecor*, 77–90. Reprinted *Obs Stud*. 2015;1(1):126–36.
9. United States Bureau of Alcohol, Tobacco, Firearms and Explosives. Firearms trace data. 2006–2019. https://www.atf.gov/resource-center/firearms-trace-data-2019. Accessed 28 Aug 2021.
10. Mahalanobis PC. On the generalized distance in statistics. *Sankhyā: The Indian Journal of Statistics, Series A*. 2008;80:S1–7.
11. Rubin DB. Using multivariate matched sampling and regression adjustment to control bias in observational studies. *J Amer Stat Assoc*.1979;74(366a):318–28. https://doi.org/10.2307/2286330.
12. Pustejovsky JE, Tipton E. Small-sample methods for cluster-robust variance estimation and hypothesis testing in

fixed effects models. *J Bus Econ Stat.* 2018;36(4):672–83. https://doi.org/10.1080/07350015.2016.1247004.

13. Webster DW, Vernick JS, McGinty EE, Alcorn T. Preventing the diversion of guns to criminals through effective firearm sales laws. In: Webster DW, Vernick JS, editors. *Reducing gun violence in America: informing policy with evidence and analysis*. Baltimore, MD: Johns Hopkins University Press; 2013. p. 109–22.
14. Braga AA, Wintemute GJ, Pierce GL, Cook PJ, Ridgeway G. Interpreting the empirical evidence on illegal gun market dynamics. *J Urban Health*. 2012;89:779–93. https://doi.org/10.1007/s11524-012-9681-y.