Testing the validity of the link between gun availability and fatal shootings by police

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Abstract: Recent studies have linked proxies for state-level gun availability to fatal shootings by police. We exploit state panel data on police shootings and a number of different measures of firearm availability to assess the robustness of this correlation. We show that conclusions about the relationship between firearm availability and police shootings are premature if based on cross-sectional data and just one proxy for firearm ownership. The relationship does not hold up once one identifies causal, rather than state-level correlations, through panel data estimation. Moreover, the results are sensitive to how one measures firearm availability.

1. Introduction

The number of times police have fatally shot civilians in the United States is alarmingly high. Proper tracking of such shootings is a recent phenomenon, with the most comprehensive database available beginning in 2015. In that year, the *Washington Post*'s "Fatal Force Database" began assembling information from every police shooting, including location, date, demographic information of the person killed, as well as information on whether they were armed. According to their database, there have been about 1000 incidents annually of officers using fatal force.[1] There have been other attempts to count the number of fatal shootings, including the Guardian's "The Counted" project that ran from 2015 to 2016. Other sources have crowdsourced numbers and suggest the number of police shootings might be higher (Finch et al. 2019).

Regardless of the number of shootings, scholars and activists alike have cast police shootings as a public health issues (e.g., Gilbert and Ray 2016, Cooper and Fullilove 2016, Geller, Fagan, Tyler, and Link 2014, Cooper, Moore, Gruskin, and Krieger 2004, and Alang, McAlpine, McCreedy, and Hardeman 2017). Although fatal police shootings have not been found to have systematic racial disparities when controlling for situational benchmarks (Fryer 2016, Tregle, Nix, and Alpert 2019, and Johnson, Tress, Burkel, Taylor, Cesario 2019), the negative public health effects of police shootings are concentrated among racial minorities and therefore still add potentially another source to differentially health and mortality outcomes by race in this country (Bor, Venkataramani, Williams, and Tsai 2018).

[1] See https://www.washingtonpost.com/graphics/2019/national/police-shootings-2019/?noredirect=on&utm_term=.ca0c5a072d40; full database acessible at https://github.com/washingtonpost/data-police-shootings/blob/master/fatal-police-shootings-data.csv

Because of the importance of the issue from a public health policy standpoint researchers have produced a number of studies attempting to assess the role of various factors that potentially determine the prevalence of shootings. These include issues related to police organizational and structural rules (Willits and Nowacki 2014, Smith 2003, Smith 2004, Legewie and Fagan 2016), violent crime rates (Kania and Mackey 1977, Lersch, Bazley, Mieczkowski, and Childs 2008), structural racism (Mesic et. al. 2018, Ross 2015), urbanization (Jacobs and O'Brien 1998), the percent of the city that is non-white or African-American(Jacobs et. al. 1998, Lersch et. al 2008), racial segregation (Jacobs 1998, Holmes, Painter, and Smith 2018), and inequality (Jacobs and Britt 1979, Sorensen, Marguart, and Brock 1993).

One factor that has received attention recently is the potential relationship between firearm prevalence in a population and police shootings. It is correct that the U.S. has the most firearms per capita of any developed country (Karp 2018). It is also reasonable to consider that firearm prevalence and police shootings are related. A higher rate of firearm ownership may increase fatal police shooting rates by exacerbating violent activity, increasing the likelihood that a person will have an altercation with a police officer in the first place. Previous research has extensively analyzed the relationship between firearms and crime rates (e.g., Miller, Azael, and Hemenway 2002, Kleck and Patterson 1993, Duggan 2001).

A higher rate of firearm ownership in a community may also increase the likelihood that a person who has an altercation with a police officer will be shot by the police officer. This secondary causal relationship may occur in two primary ways. During an altercation, an officer may be more likely to shoot a civilian if he sees that the civilian is armed. As one criminologist noted: "gun density would be expected to be positively related to police homicide because greater gun density should increase the frequency of defense of life situation in which police homicides occur" (Hemenway, Azrael, Conner, and Miller 2019 citing Sherman and Langworthy 1979). Jennings, Hollis, and Fernandez (2019) suspect being armed with a firearm is associated with a fatal police shooting rather than a non-fatal police shooting. Out of the 3943 people shot and killed by police from 2015 to 2019, 2221, or about 56%, are confirmed to have been armed with a firearm at the time of the encounter (see footnote 1). Alternatively, a higher rate of gun ownership in the community may increase the probability the officer will believe the civilian is armed, even if he cannot tell that the civilian is armed, and prematurely shoot the civilian, perhaps in response to sudden movement by the civilian. Indeed, a police officer has good reason to be more afraid of being killed in jurisdictions with higher firearm ownership rates: Swedley, Simmons, Dominici, and Hemenway (2015) find that higher rates of gun-ownership is associated with more homicides of law enforcement officers, even when controlling for other factors related to homicides. Many incidents of fatal police shootings occur because the police officer thinks the civilian is reaching into his pocket to reach for a handgun and shoots him in ostensibly preventive self-defense.[2] We are only aware of three studies that relate firearm ownership to fatal police shootings. First, a city-wide study in 1979, found that firearm availability was correlated with fatal police shootings, varying 0.25–0.54 (Sherman and Langworthy, 1979).

Second, Kivisto et al. (2017) link anti-gun legislation to police shootings using the *Guardian* data from 2015 and 2016. Using data from only 2015, they find that states with higher scores from the Brady state legislative scorecards have fewer shootings. The scorecards award

[2] See: https://www.chicagotribune.com/investigations/ct-chicago-police-shootings-no-gun-20160914-story.html; https://www.vox.com/identities/2018/3/22/17151960/stephon-clark-sacramento-police-shooting-video; https://www.apnews.com/a67157455b8f4cb5a9e0077aa98a03f0 for a few examples.

points on a number of factors, including background check regulations, safe storage, and prevention of gun trafficking. Specifically, after accounting for some sociodemographic characteristics, they find states with the top quartile of Brady scores experienced rates of fatal police shootings more than 50% lower than states with the bottom quarter of Brady scores. Once again, a significant limitation is the absence of state fixed effects to determine the extent missing cofounders play in explaining the outcome variable.

Finally, the comprehensive database generated by the *Washington Post* was recently used to assess the role of firearm availability on the prevalence of police shootings. Hemenway et al. (2019) used cross-sectional state data to assess the relationship between firearm ownership and fatal shootings. They use a common proxy variable for firearm ownership, which is the fraction of all suicides that involve a firearm. Controlling for the violent crime rate, urbanization, poverty rate, and percent of population that is non-white, all at the state level, they find significant correlations between firearm prevalance and the rate of fatal police shootings, which they measure in two ways: the rate of fatal police shootings per one million residents and the rate of fatal police shootings per one-hundred thousand arrests. However, a significant limitation to their results is the absence of state fixed effects, without which it is very difficult to determine the extent missing cofounders play in explaining the outcome variable, and, therefore, the association in question.

In this paper, we expand on the analysis of Hemenway et al. (2019) and Kivisto et al. (2017). We utilize additional measures of gun availability, additional controls at the state level, and exploit the panel data of police shootings across states that now exist. From that standpoint, we can move beyond the ecological associations of the cross-sectional state analyses to tests aimed to more directly confirm the role firearm ownership and gun legislation have had on police shootings. Starting from the point of confirming the basic findings of the previous studies, we proceed to show that the correlations become weaker once we consider alternative measures of firearm ownership. Moreover, we show that there is no effect once one includes state fixed effects and identifies effects off of changes in gun ownership. The latter brings into question the underlying causal interpretation that changing gun availability will have any effect on the number of police shootings. Additional data, with more variation in both state-level gun ownership rates and fatal police shooting rates, are needed to establish a more robust association.

2. Data and Methodology

2.1 Outcome measure: fatal shootings

We utilize the Washington Post's database of fatal police shootings from 2015-2018. The Washington Post database is the most comprehensive record of fatal police shootings available to the public. According to the Post: "The FBI and the Centers for Disease Control and Prevention log fatal shootings by police, but officials acknowledge that their data is incomplete. In 2015, The Post documented more than two times more fatal shootings by police than had been recorded by the FBI."[3] The Post's information is confirmed from multiple independent sources and includes over a dozen details about each shooting, including the race of the deceased and whether they were armed at the time of the shooting (ibid). As with Hemenway et al. (2019), we

[3] https://github.com/washingtonpost/data-police-shootings; accessed 8/12/19.

aggregate the total number of shootings for each state and employ four different outcome measures of fatal police shootings.

As a primary measure, we also follow Hemenway et al. (2019) by using the number of shootings per one million residents (FPS/P). Data on the number of fatal police shootings per state is acquired from the Washington Post's database. Data on the resident population per state is from The Census Bureau.[4] The second measure is the number of fatal police shootings in which the decedent was armed per one million residents (FPSA/P). The third measure is the number of fatal police shootings in which the decedent was unarmed per one million residents (FPSU/P). Finally, the fourth outcome measure is the number of fatal police shootings per one hundred thousand arrests (FPS/A). The number of arrests comes from the FBI "Arrests by State" report for the years 2015, 2016, and 2017. Data for 2018 are unavailable and replaced with the average state-level arrests of the three previous years. Observations with incomplete data from police stations reporting on the number of arrests are dropped; IL and NY are dropped for all four years.

2.2. Measures of firearm ownership

We utilize a number of different measures of firearm ownership at the state level, each of which varies by year. First, the measure chosen by Hemenway et al. (2019) is the number of total suicides with a firearm divided by total suicides (FS/S) reported in a state-year multiplied

[4] Census Bureau. NST-EST2018-01: Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2018" https://www.census.gov/newsroom/press-kits/2018/pop-estimates-national-state.html. accessed 2/25/19.

by 100. They suggest that this method matches up well with survey data on firearm ownership (Azrael et. al. 2004). FS/S data is obtained from the CDC's Web-based Injury Statistics Query and Reporting System (WISQARS) database.[5] 2018 is the average of the past three years.

We also use a second hybrid measure developed by Siegel, Ross, and King (2014) that combines the proportion of suicides due to firearms and hunting licenses per capita. The explicit formula for this measure is (0.62 * FS/S)+(0.88 * per capita hunting licenses). Comparing correlations with surveys of gun ownership in the late 1990s and early 2000s, Siegel et. al find preliminary evidence that such a proxy more accurately measures gun ownership at the state-level than FS/S (0.95 and 0.97 compared to 0.80). We do not change this function except for multiplying the final fraction by 100. Data on the number of hunting licenses is from the U.S. Fish & Wildlife Service.[6] The number of hunting licenses were divided by a state's population ages 15+[7] to derive hunting licenses per capita for each state. The third proxy is the number of firearms registered under the National Firearms Act (NFA) per 1000 residents in a state-year.[8] While these numbers do not fully capture the rate of gun availability, they should capture relative differences between states fairly accurately, as well as changes in state firearm availability over time.

[5] Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQUARS): Fatal Injury Reports. http://www.cdc.gov/injury/wisqars/fatal_injury_reports.html, accessed 8/12/19.

[6] US Fish & Wildlife Service, Wildlife & Sport Fish Restoration Program. Historical hunting license data. https://wsfrprograms.fws.gov/Subpages/LicenseInfo/Hunting.htm. accessed 8/12/19.

[7] Census Bureau

[8] The Bureau of Alcohol, Tobacco, Firearms and Explosives.2015, 2016, 2017, and 2018 annual "Firearms in the United States Annual Statistical Update" reports. https://www.atf.gov/resource-center/data-statistics, accessed 8/12/19.

2.3 Covariates

The violent crime rate per 100,000 residents will function as a control variable. Data is from the FBI.[9] 2018 data is the average of the three previous years.

Table 1:
Descriptive statistics

	Description	**Mean**
Measures of police shootings: 1. FPS/P	Annual state fatal police shootings per 1 million people	3.52
2. FPSA/P	Annual state fatal police shootings of armed decedents per 1 million people	3.24
3. FPSU/P	Annual state fatal police shootings of unarmed decedents per 1 million people	0.28
4. FPS/A	Annual state fatal police shootings per 100,000 arrests	11.78
Measures of Gun ownership: 1. FS/S	Annual state proportion of suicides involving a firearm, %	51.08
2. Hybrid	Annual state proportion equivalent to (0.62 * FS/S) + (0.88 * per capita hunting licenses), %	39.95
3. NFA/1000	Annual state number of firearms registered under the National Firearms Act per 1000 people	21.14
Covariate Violent crime	Annual state number of violent crimes per 100,000 people	387.82

[9] FBI. "Crime in the United States by Region, Geographic Division, and State, 2014–2015" and "Crime in the United States by Region, Geographic Division, and State, 2016–2017" reports.

There were 3931 fatal police shootings in the 50 states from 2015 through 2018 (983 per year). 3677, or 93.54%, of decedents were armed. Average fatal police shootings per 1 million people by state over the four years ranged from a high of 9.97 in New Mexico to a low of 0.87 in New York (mean 3.50; SD 1.94).

As shown in Table xxx in the appendix, the ten states with the highest rates of gun ownership collectively have a much higher rate of fatal police shootings per one million resident-years, 3.78, than the five states with the lowest rates of gun ownership, 1.12.

2.4 Methodology

For each outcome variable, the three firearm-ownership proxies are used.

Two regression methods are used: negative binomial (NB) and OLS. Both negative binomial and OLS regression methods will be used. The OLS regression method is used in addition to the negative binomial method in order to interpret coefficients in context as well as to test the robustness of negative binomial regression results, notably for regressions with state-fixed effects (Model 5), which the negative binomial method cannot perform. Five models are used. NB regressions use Models 1-4 while OLS regressions use Models 1-5. Model 1 includes only the outcome variable and firearm-ownership proxy. Model 2 adds state standard error clusters and fixed effects for years to Model 1. Model 3 adds the violent crime rate to Model 2. Model 4 adds a population weight to Model 3. Model 5 replaces the state clusters in Model 4 with state fixed effects. These five models are used with various combinations of outcome variables, firearm proxies, and regression methods.

All coefficient and interval numbers are rounded down to two decimal points.

3. Results

3.1 Fatal police shootings per 1 million people (FPS/P) as outcome variable

TABLE2 Effect of FSS on FPS/P; collapsed NB; observations are 2015-2019 (most similar to Hemenway et. al.)

Model	FSS Coefficient
Just FSS	infinite iterations
Add vcrime	1.021346 (1.006252 1.036666)
Add college & vcrime	1.018844 (1.002009 1.035962)
Add population weight, college, vcrime	1.02003 (1.020024 1.020037)
Add vcrime, poverty & urbanization	1.025628 (1.00323 1.048526)

TABLE3 Negative binomial -- Effects of firearm ownership (FS/S) on fatal police shootings per 1 million people (FPS/P)

	(1)	(2)	(3)	(4)
FS/S	1.025647 (1.017975 1.033377)	1.025624 (1.013051 1.038354)	1.020841 (1.008138 1.033704)	1.018322 (1.001808 1.035108)
Violent crime	…	…	1.001502 (1.000716 1.002289)	1.001528 (1.000507 1.002551)
Clustered standard errors:	No	Yes	Yes	Yes
Population weighted	No	No	No	Yes
Fixed effects:				
year	No	Yes	Yes	Yes

state	No	No	No	No
R-squared	0.0529	N/A	N/A	N/A

Note: Coefficient and 95% IRR are in parentheses.

(For Table 2 and 3) With negative binomial regressions, the effect of firearm ownership (FS/S) on the rate of fatal police shootings (FPS/P) across all fifty states is robust even when controlling for violent crime rates and year fixed effects, weighting by population and clustering state standard errors. However, the coefficient is practically insignificant. Compared with states with average firearm prevalence, rates of overall police shootings of civilians is only about 2% higher in states where firearm prevalence was one standard deviation higher, even when the observations are collapsed by state.

TABLE 4. OLS--Effects of firearm ownership (FS/S) on fatal police shootings per 1 million people (FPS/P)

	(1)	(2)	(3)	(4)	(5)
FS/S	.0754035 (.0523025 .0985046)	.0753842 (.041998 .1087705)	.0589342 (.0242907 .0935777)	.0504167 (.0146635 .0861699)	.0451264 (-.0548358 .1450886)
Violent crime	…	…	.0061 (.0020,.010)	.0051 (.0014,.0089)	.002528 (-.0063, .011)
<u>Clustered standard errors:</u>	No	Yes	Yes	Yes	No
<u>Population weighted</u>	No	No	No	Yes	Yes
<u>Fixed effects</u>:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.1730	0.1778	0.3223	0.2796	0.8234

Note: Coefficient and 95% CI are in parentheses.

(For Table 4)Using OLS regressions, firearm ownership (FS/S) is positively associated with a higher rate of fatal police shootings. This result is robust even accounting for violent crime. An increase in FS/S by one percent, on average, is associated with an increase of about 0.05 fatal police shootings per million residents in a state year. In California, for example, that translates into an increase of roughly 2 fatal police shootings per year. But incorporating state fixed effects eliminates the significant result (95% CI -.055, .15). It is unclear how much of the correlation between gun ownership and FS is to do other factors in the state – that are not included in this model – but are still related to both. State-level variables whose association with fatal police shootings is known — such as urbanization, percent of the population that is non-white, and the poverty rate — as well as state-level variables whose association with fatal police shootings is either unknown or unquantifiable — such as the effect of poor policing and race-relations, or synergic combination thereof — are all captured with state-fixed effects. This is evidenced by the increase in R-squared after state effects are captured from .2796 to .8234. The difference in R-squared strongly suggests the existence of confounding factors. These state-level factors may be theoretically difficult to identify and quantity (hence the function of state fixed effects), but without more years of data to provide for variation in state-level data, is it difficult to isolate the impact of firearms ownership upon FPS.

3.2 Fatal police shootings of armed decedents per 1 million people (FPSA/P) as dependent variable

TABLE 5. Effect of FSS on FPSA/P; collapsed NB; observations are 2015-2019 (most similar to Hemenway et. al.)

	FSS Coefficient

Just FSS	1.027408 (1.012014 1.043037)
Add vcrime	1.02266 (1.006892 1.038674)
Add college	1.020205 (1.002615 1.038104)
Add population weight	1.020227 (1.02022 1.020233)

TABLE 6. Negative binomial -- Effects of firearm ownership (FS/S) on fatal police shootings of armed decedents per 1 million people (FPSA/P)

	(1)	(2)	(3)	(4)
FS/S	1.027064 (1.019138 1.035051)	1.02707 (1.01531 1.038967)	1.022341 (1.010492 1.034328)	1.0188 (1.002418 1.03545)
Violent crime	...	...	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
<u>Clustered standard errors:</u>	No	Yes	Yes	Yes
<u>Population weighted</u>	No	No	No	Yes
<u>Fixed effects</u>:				
year	No	Yes	Yes	Yes
state	No	No	No	No
R-squared	0.0576	N/A	N/A	N/A

Note: Coefficient and 95% IRR are in parentheses.

TABLE 7. OLS--Effects of firearm ownership (FS/S) on fatal police shootings of armed decedents per 1 million people (FPSA/P)

	(1)	(2)	(3)	(4)	(5)
FS/S	.073 (.052, .095)	.073 (.044, .103)	.0583 (.029, .088)	.048 (.016, .081)	.052 (-.045, .015)
Violent crime	...	...	.0056 (.0017,.0095)	.0046 (.0012 .0080)	.00056 (-.0080, .0092)

Clustered standard errors:	No	Yes	Yes	Yes	No
Population weighted	No	No	No	Yes	Yes
Fixed effects:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.1817	0.1899	0.3245	0.2783	0.8073

Note: Coefficient and 95% CI are in parentheses.

(For Tables 5-7) We find similar results for FPSA/P as the outcome variable compared to FPS/P. When using NB regressions, FPSA/P rates are about 2% higher in states where firearm prevalence was one standard deviation higher than states with average firearm prevalence. When using OLS regressions, an increase in FS/S by one percent, on average, is associated with an increase of almost 0.05 fatal police shootings per million residents in a state year. However, robustness breaks down upon the introduction of state fixed effects (95% CI -.045, .015). Is it difficult to isolate the impact of firearms ownership upon FPSA/P for reasons stated above.

3.3 Fatal police shootings of unarmed decedents per 1 million people (FPSU/P) as outcome variable

TABLE 8. Effect of FSS on FPSA/P; collapsed NB; observations are 2015-2019 (most similar to Hemenway et. al.)

	FSS Coefficient
Just FSS	1.011074 (.9616664 1.063019)

Add vcrime	1.005233 (.9541465 1.059055)
Add college	1.00229 (.9455449 1.06244)
Add population weight	infinite iterations

TABLE 9. Negative binomial -- Effects of firearm ownership (FS/S) on fatal police shootings of unarmed decedents per 1 million people (FPSU/P)

	(1)	(2)	(3)	(4)
FS/S	1.009058 (.9846651 1.034055)	1.0088 (.9809349 1.037456)	1.002709 (.9728615 1.033472)	1.011372 (.9901042 1.033097)
Violent crime	...	...	1.00(1.00,1.00)	1.00 (1.00, 1.00)
Clustered standard errors:	No	Yes	Yes	Yes
Population weighted	No	No	No	Yes
Fixed effects:				
year	No	Yes	Yes	Yes
state	No	No	No	No
R-squared	0.0025	N/A	N/A	N/A

Note: Coefficient and 95% IRR are in parentheses.

TABLE 10. OLS--Effects of firearm ownership (FS/S) on fatal police shootings of unarmed decedents per 1 million people (FPSU/P)

	(1)	(2)	(3)	(4)	(5)
FS/S	.20 (-.22, .63)	.20 (-.43, .83)	.063 (-.60, .72)	.21 (-.14, .57)	-.72 (-3.20, 1.76)
Violent crime	...	...	.00051 (-.00019, .0012)	.00054 (.00012, .00097)	.0020 (-.00022, .0042)
Clustered standard errors:	No	Yes	Yes	Yes	No

Population weighted	No	No	No	Yes	Yes
Fixed effects:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.0046	0.0466	0.0831	0.1301	0.2496

Note: Coefficient and 95% CI are in parentheses.

(For Tables 8-10) The association between firearm ownership (FS/S) and rates of fatal police shootings of unarmed decedents per 1 million people (FPSU/P) is not significant, regardless of the model used (NB 95% CI .9901042, 1.033097; OLS 95% CI -3.20, 1.76). Is it difficult to isolate the impact of firearms ownership upon FPSA/P for reasons stated above.

3.4 Fatal police shootings per 100,000 arrests (FPS/A) as outcome variable

TABLE 11. Effect of FSS on FPS/A; collapsed NB; observations are 2015-2019 (most similar to Hemenway et. al.)

	FSS Coefficient
Just FSS	1.020384 (1.008984 1.031913)
Add vcrime	1.017382 (1.00628 1.028607)
Add college	1.01595 (1.003395 1.028662)
Add population weight	1.008785 (1.00878 1.00879)

TABLE 12. Negative binomial -- Effects of firearm ownership (FS/S) on fatal police shootings per 100,000 arrests (FPS/A)

	(1)	(2)	(3)	(4)
FS/S	1.019646 (1.012647 1.026694)	1.019633 (1.005826 1.033629)	1.016784 (1.002863 1.030898)	1.010487 (.9970131 1.024143)
Violent crime	...	...	1.00(1.00,1.00)	1.00(1.00,1.00)

Clustered standard errors:	No	Yes	Yes	Yes
Population weighted	No	No	No	Yes
Fixed effects:				
year	No	Yes	Yes	Yes
state	No	No	No	No
R-squared	0.0222	N/A	N/A	N/A

Note: Coefficient and 95% IRR are in parentheses.

TABLE 13. OLS--Effects of firearm ownership (FS/S) on fatal police shootings per 100,000 arrests (FPS/A)

	(1)	(2)	(3)	(4)	(5)
FS/S	.21 (.12, .29)	.21 (.08, .33)	.17 (.03, .30)	.10 (-.03, .23)	.16 (-.26 .58)
Violent crime	...	...	.01 (-.002, .03)	.01 (-.004, .02)	.02 (-.02, .05)
Clustered standard errors:	No	Yes	Yes	Yes	No
Population weighted	No	No	No	Yes	Yes
Fixed effects:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.1132	0.1178	0.1840	0.1061	0.7176

Note: Coefficient and 95% CI are in parentheses.

(For Tables 11-13) The association between fatal police shootings per 100,000 arrests and firearm prevalence is again generally robust, until state fixed effects are used. Is it difficult to isolate the impact of firearms ownership upon FPS/A.

4. Conclusion

Using state panel data on police shootings and a number of different measures of firearm availability, we show that conclusions about the relationship between firearm availability and police shootings are premature if based on cross-sectional data and just one proxy for firearm ownership. The relationship does not hold up once one identifies causal, rather than state-level correlations, through panel data estimation. Moreover, the results are sensitive to how one measures firearm availability.

Limitations. The Washington Post database does not include non-fatal shootings, non-shooting deaths, and fatal shootings by off-duty officers. Therefore, it is conceivable that their database is not a true reflection of the true rate of intended fatal police shootings as it relates to how it could be influenced by gun availability. Our results only speak to the robustness of current available evidence on a causal relationship between firearm availability and police shootings at the *state* level. It provides no insight on the robustness of such evidence on such a relationship at the *local* level. We hypothesize that such a relationship is more likely to be robust at the local level because many of the factors related to fatal police shootings and police violence more broadly (e.g. police organizational and structural rules, violent crime rates, racial segregation) vary at the local level. Further research on this level is needed.

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NTS: as test, can replace the percentage of the state population that is under the age of 35, Number of police departments per capita, number of police per capita. All were found to be positively related to arrest related deaths (ARDs).

APPENDIX

- sensitivity analyses

Table 2 Fatal police shootings in the 5 states with the lowest and the 10 states with the highest firearm availability (FS/S): United States, 2015–2017

Characteristics	Low-gun states	High-gun states
Average state FS/S, %	23.85	64.35
Total population 2015–2018, person-years	161,337,764	150,067,032
Total fatal police shootings 2015–2017	181	568
Fatal police shooting rate per 1,000,000 resident-years	1.12	3.78
Decedents armed with a firearm, %	92.82	93.13

Low-gun states: HI, MA, NJ, NY, CT

High-gun states: ID, WY, GA, KY, SC, LA, MT, WV, MS, AL

Sensitivity Analyses: OLS--Effects of firearm ownership (FS/S) on...

Robustness Check	(4)	(5)
fatal police shootings per 1 million people (FPS/P)		.045 (-.055, .15)

replace FSS with hybrid proxy	.056 (.012, .10)	.098 (-.05, .25)
replace FSS with NFA/1000	.040 (.0014, .078)	.015 (-.070, .10)
add college percent		
exclude 2018		.045 (-.044, .14)
exclude state outliers		
Add poverty and non-white pct		
Add poverty pct		.046 (-.054, .15)
Add urbanization		
fatal police shootings per 100,000 arrests (FPS/A)		.16 (-.26, .58)
replace FSS with hybrid proxy		.35 (-.27, .98)
replace FSS with NFA/1000		.0054 (-.35, .36)
Exclude 2018		.16 (-.25, .57)
All arrest data (include IL and NY)		.06 (-.36, .47)
Exclude vcrime		.14 (-.27, .56)
Exclude state outliers		
Add poverty pct		.16 (-.26, .58)
Add urbanization		
Add poverty pct & urbanization		
Add poverty pct, urbanization, and non-white pct		

Poverty rate is defined as the percentage of the state population living in poverty. Data come from the US Census Bureau. 2018 is the average of the previous three years.

Urbanization is defined as the percentage of the state population living in urbanized areas of 50,000 or more people or urban clusters of at least 2500 and less than 50,000 people. Data come from the US Census Bureau. Data were not available for 2015–2017. Data from the 2010 Census were used (mean=73.6; SD=14.6).

Effect of FSS on FPS/P when controlling for state regions - OLS

	FSS coefficient (multiplied by 100)
Just northeast	.046 (.02, .07)
Just northeast, pop weight	.03 (.02, .05)
Just northeast, state clusters	.05 (.02, .07)
Just northeast, pop weight & state clusters	.03 (.01, .05) P>t = 0.005
Just west, pop weight & state clusters	.10 (.04, .16) P>t = 0.005
Just midwest, pop weight & state clusters	.07 (.03, .12) P>t= 0.006
Just south, pop weight & state clusters	.09 (.05, .12)
Excluding northeast	.05 (.02, .09)
Excluding northeast, pop weight	.03 (.00, .05)
Excluding northeast, state clusters	.05 (.01, .10)
Excluding northeast, pop weight & state clusters	.03 (-.02, .08) P>t = 0.291

Effect of FSS on FPS/P when controlling for state regions - NB, 2015-2017, collapsed

	FSS coefficient (multiplied by 100) IRR
All regions	1.026776 (1.011823 1.041951)
All regions, population weight	1.019389 (1.019383 1.019395)
All regions, college pct	1.023056 (1.00637 1.040019)
All regions, pop weight & college pct	1.020023 (1.020017 1.02003)
Just northeast	1.026168 (.9871748 1.066702)
Just northeast, pop weight	1.020866 (1.020846 1.020885)
Just northeast, pop weight & college pct	1.020529 (1.020509 1.020548)
Excluding northeast (west south, and midwest) (endless iterations when done with pop weight)	1.017681 (.9994481 1.036246)
excluding south, pop weight	1.026852 (1.026844 1.0268)
excluding midwest, pop weight	1.017999 (1.017993 1.018005)
excluding west, pop weight	1.033328 (1.03332 1.033336)
Just west, pop weight	1.015968 (1.015957 1.01598)
Just midwest, pop weight	1.032462 (1.032437 1.032487)
Just south, pop weight	1.029429 (1.029411 1.029448)
West and south, pop weight	.9994631 (.9994558 .9994704)
West and northeast, pop weight	1.034522 (1.034513 1.034531)
West and midwest, pop weight	1.009845 (1.009834 1.009856)

South and northeast, pop weight	1.033652 (1.033644 1.033661)
South and midwest, pop weight	1.03159 (1.031578 1.031603)
Midwest and northeast, pop weight	1.031531 (1.031519 1.031544)

Effect of FSS on FPS/P when controlling for state regions - OLS, 2015-2017, collapsed

	FSS coefficient (multiplied by 100) IRR
All regions	.076644 (.0383844 .1149037)
All regions, population weight	.0538756 (.0222446 .0855066)
All regions, college pct	.065584 (.0221586 .1090094)
All regions, pop weight & college pct	.0547193 (.0198952 .0895434)
Just northeast	.0421201 (.0135275 .0707127)
Just northeast, pop weight	.029097 (.0033808 .0548131)
Excluding northeast (west south, and midwest), pop weight	.0201193 (-.0260278 .0662664)

Effect of FSS on FPS/P when controlling for state regions - NB, 2015-2018, collapsed

	FSS coefficient (multiplied by 100) IRR
All regions	*infinite iterations
All regions, population weight	1.021475 (1.021469 1.02148)
All regions, pop weight, vcrime	1.018278 (1.018272 1.018284)
All regions, pop weight, pct college & vcrime	1.02003 (1.020024 1.020037)

Just northeast	
Just northeast, pop weight	
Just northeast, pop weight & vcrimes	1.018904 (1.018883 1.018926)
Just northeast, pop weight, vcrimes, college pct	1.018878 (1.018857 1.018899)
Excluding northeast (west south, and midwest)	*infinite iterations
excluding south, pop weight	1.030892 (1.030884 1.0309)
excluding midwest, pop weight	1.019999 (1.019993 1.020005)
excluding west, pop weight	1.034642 (1.034634 1.03465)
Just west, pop weight, vcrimes	1.021437 (1.021425 1.021449)
Just midwest, pop weight, vcrimes	1.033987 (1.033961 1.034012)
Just south, pop weight, vcrimes	1.027686 (1.027667 1.027704)
West and south, pop weight, vcrimes	1.001289 (1.001281 1.001296)
West and northeast, pop weight, vcrimes	1.035276 (1.035267 1.035285)
West and midwest, pop weight, vcrimes	1.01461 (1.014599 1.01462)
South and northeast, pop weight, vcrimes	1.033069 (1.03306 1.033078)
South and midwest, pop weight, vcrimes	1.030032 (1.030019 1.030044)
Midwest and northeast, pop weight, vcrimes	1.03397 (1.033957 1.033983)

Effect of FSS on FPS/P when controlling for state regions - OLS, 2015-2018, collapsed

	FSS coefficient (multiplied by 100) IRR
All regions	.0768376 (.0367734 .1169019)
All regions, population weight	.0591408 (.027167 .0911145)
All regions, vcrime, pop weight	.0502819 (.0198002 .0807636)
All regions,vcrime, pop weight & college pct	.05279 (.0196402 .0859398)
Just northeast	.0457849 (.0224259 .069144)
Just northeast, pop weight, vcrime, college pct	.0262843 (.004363 .0482055)
Excluding northeast (west south, and midwest), pop weight, vcrime, college pct	.0209851 (-.0344068 .076377)

OLS--Effects of firearm ownership (hybrid) on fatal police shootings per 1 million people (FPS/P)

	(1)	(2)	(3)	(4)	(5)
Hybrid	.0740 (.05090, .0971)	.0739 (.0424, .1055)	.0645 (.0332, .0959)	.0558 (.0117,.0 999)	.0980 (-.0531, .2491)
Violent crime	...	...	.0066 (.0027, .010)	.0056 (.0018, .0093)	.0025 (-.0063, .011)
Clustered standard errors:	No	Yes	Yes	Yes	No
Population weighted	No	No	No	Yes	Yes

Fixed effects:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.1678	0.1678	0.3481	0.2706	0.8244

Note: Coefficient and 95% CI are in parentheses.

OLS--Effects of firearm ownership (NFA/1000) on fatal police shootings per 1 million people (FPS/P)

	(1)	(2)	(3)	(4)	(5)
NFA/1000	.019 (.0087, .028)	.018 (.0019, .035)	.016 (.0069, .025)	.040 (.0014, .078)	.015 (-.070, .10)
Violent crime	...	...	.0048 (-.12 3.06)	.0055 (.0025, .0086)	.00341 (-.0050, .012)
Clustered standard errors:	No	Yes	Yes	Yes	No
Population weighted	No	No	No	Yes	Yes
Fixed effects:					
year	No	Yes	Yes	Yes	Yes
state	No	No	No	No	Yes
R-squared	0.0643	0.0656	0.2111	0.2193	0.8198

Note: Coefficient and 95% CI are in parentheses.