HHS Public Access

Author manuscript

Epidemiology. Author manuscript; available in PMC 2022 January 01.

Published in final edited form as:

Epidemiology. 2021 January ; 32(1): 36–45. doi:10.1097/EDE.0000000000001262.

Firearm Homicide Incidence, Within-State Firearm Laws, and Interstate Firearm Laws in US Counties

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Abstract

Background: Firearm homicides occur less frequently in US states with more firearm control laws. However, firearms are easily transported across state lines, and laws in one location may affect firearm violence in another. This study examined associations between within-state firearm laws and firearm homicide while accounting for interference from laws in other nearby states.

Methods: The units of analysis were 3,107 counties in the 48 contiguous US states, arrayed in 15 yearly panels for 2000–2014 (n = 46,605). The dependent measure was firearm homicides accessed from CDC Compressed Mortality Data. The main independent measures were counts of firearm laws and the proportion of laws within categories (e.g., background checks, child access prevention laws). We calculated these measures for interstate laws using a geographic gravity function between county centroids. Bayesian conditional autoregressive Poisson models related within-state firearm laws and interstate firearm laws to firearm homicides.

Results: There were 172,726 firearm homicides in the included counties over the 15 years. States had between 3 and 100 firearm laws. Within-state firearm laws (IRR [Incidence rate ratio] = 0.995, 95%CI: 0.992, 0.997) and interstate firearm laws (IRR = 0.993, 95%CI: 0.990, 0.996) were independently associated with fewer firearm homicides, and associations for within-state laws were strongest where interstate laws were weakest.

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Conflicts of Interest: None declared

Data and Code:
Statistical code used for these analyses are available in the Supplemental Digital Content (SDC) for this paper. CDC Compressed Mortality Data are available from the Centers for Disease Control and Prevention by restricted access agreement.

Conclusions: Additional firearm laws are associated with fewer firearm homicides both within the states where the laws are enacted and elsewhere in the US. Interference from interstate firearm laws may bias associations for studies of within-state laws and firearm homicide.

Keywords

firearm; homicide; mortality; law; causal inference; interference

Introduction

Firearm homicide in the United States is a modern public health crisis. Around 14,000 US civilians died to due interpersonal firearm violence each year since 2016,[1] and over 75,000 people present to emergency departments with firearm-related injuries annually.[2] Firearm homicide is the leading cause of death for black men aged 15–34.[3]

Empirical studies provide some evidence that firearm laws can reduce firearm violence, including homicide.[4,5] For example, analyses that use composite measures of overall firearm law strength find fewer firearm homicides where laws are generally more restrictive.[12,13] Other studies assess associations for specific types of laws. Evidence is strongest for laws requiring individuals to undergo background checks before purchasing a firearm,[6,7] and there is moderate evidence that other regulations such as dealer registration laws[8,9] and licensing laws[10,11] also reduce firearm homicides.

Most studies of firearm laws and firearm violence are conducted as spatial ecological analyses,[4,5] meaning that violent firearm events are aggregated as counts within spatial units and firearm laws are treated as global environmental conditions that affect the extent of each unit.[12] Spatial ecological study designs are appropriate and useful for estimating population-level associations within geographic areas, provided no inferences are made regarding risks for individuals.[13] However, determining whether identified spatial ecological associations are causal is often problematic. Experimental study designs are often infeasible because researchers cannot assign geographic regions to an exposure status, and observational studies are subject to unmeasured confounding that can impede exchangeability. Moreover, ecological study designs assume that included spatial units are independent and that exposures in one unit do not affect outcomes in other units. The absence of such interference (or “spillover”) is an essential part of the stable unit treatment value assumption (SUTVA) which was first articulated by Rubin[14,15] and is now considered essential for causal inference.[16,17] Geographic mobility, defined as the movement of people and goods though space over time, can produce conditions that violate this assumption and lead to misestimation of an exposure’s full impacts.

There is reason to expect that mobility will arise in the presence of spatially varying market restrictions. Federal law prohibits sales of handguns to interstate residents who do not have a Federal Firearms License to deal firearms.[18] Long gun (e.g. rifle, shot gun) sales are subject to fewer federal restrictions but must still comply with laws in both the dealer and the purchaser’s home state[19], and long guns contribute a very small proportion of firearm homicides compared to handguns.[20] Thus, most firearms that are transferred interstate and subsequently used in homicides were likely to be transferred illegally. Assuming illegal goods are a perfect substitute for legal goods,[21] black markets will emerge to meet demand when supply is artificially restricted, particularly when the good is small, easily concealed, and easily transported.[22,23] These informal sources will originate from locations that have larger populations, have fewer restrictions, and that are proximate to the destination (minimizing transportation costs).[24] Given that firearms are lightweight goods that are easily transported, and that there is considerable variation in firearm laws between US states,[25] firearms will flow illegally from origin states with fewer restrictions to destination states with more restrictions. To the extent that firearm availability is related to the incidence of firearm violence,[26] this flow will be detectable as increased firearm violence in destination states. Whether illegal firearms are indeed a substitute for legal firearms is not clear, however some available data supports these overall economic geographic predictions regarding firearm flow. In 2017, the Bureau of Alcohol, Tobacco, Firearms, and Explosives recovered 239,175 firearms that were used or suspected of being used in a crime,[27] including 69,718 (29.1%) that were originally purchased in another state. Studies identify that firearm sales[28], firearm homicide[29,30], and firearm crime[31] are related to composite measures of firearm law strength in nearby locations.

Four main approaches are available to account for mobility within spatial ecologic study designs. First, researchers can measure mobility between all spatial units using archival or primary data. For example, American Community Survey data includes a matrix of 5-year averages for commuter flows between origin and destination counties. However, full mobility data (comprising commuter flow and trips for other purposes) is rare and is often infeasible to collect. Researchers must therefore approximate mobility in some other way. A second approach is to use container-based methods that relate outcomes within smaller spatial units (level 1 units) relative to exposures within larger spatial units (level 2 units). For example, Venkataramani et al.[32] related opioid overdose deaths in US counties to manufacturing plant closures within larger commuter zones. Third, adjacency-based approaches account for exposures in immediate neighboring units, such as Freisthler et al's[33] study in Long Beach, California, that detected increases in crime in census block groups adjacent to block groups where medical marijuana dispensaries were present. Finally, proximity-based approaches weight exposure for all spatial units within a defined extent, including beyond the bounds of level 2 or adjacent units, using some measure of spatial interaction. Stewart[34] first identified that the "social physics" of human mobility approximate a geographic gravity function—based on Newton's law of universal gravitation—while others have demonstrated that radiation functions predict commuter patterns in some urban settings.[35]

The aim of this longitudinal study was to assess associations between within-state firearm laws and firearm homicides, while accounting for possible threats to causal inference due to interference from interstate firearm laws. Because mobility may vary within and between US states, we used counties as our units of analysis. Because firearms may travel beyond state lines and beyond adjacent counties, and full measures of firearm flow are not available for US counties, we used a geographic gravity function to approximate mobility.

Methods

Study Design, Population, and Setting

This study used an ecologic spatial panel design. The units of analysis were 3,107 counties in the 48 contiguous US states, arrayed in 15 yearly panels for 2000–2014 (n = 46,605). County boundaries were for 2000. In 2001, the independent city of Clifton Forge, VA, was incorporated into Allegheny County, VA, and Broomfield County, CO, was created from parts of four neighboring counties. We assigned the population of Clifton Forge to Allegheny County for 2000, and distributed the population of Broomfield County evenly between the four neighboring counties for 2001–2014. Washington, DC, was excluded because firearm law data was not available for this municipality. We excluded Alaska and Hawaii because we estimated the impacts of interstate firearm laws (see below), and our methods were not applicable for these non-contiguous states.

Data and Measures

The dependent measure was a count of firearm homicides, calculated using the Compressed Mortality Data from the Centers for Disease Control and Prevention. These data record mortality incidence according to International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) classification. We identified firearm homicides using ICD-10 codes U014 and X93-X95. There was a total of 172,726 firearm homicides in the 3,107 included counties from 2000–2014.

The main independent measure was the year-specific count and composition of firearm laws for US states. The Boston University State Firearm Laws Database provided information on the firearm laws that were active in each US state per year.[36] Boston University researchers identified 133 unique types of firearm laws,[25] which we grouped into nine categories (Table 1). An important methodologic concern for firearm research is that laws are often highly correlated within states, and it can be difficult to isolate the effect for any individual law.[4] To address this problem, we calculated the total count of laws per state per year and the proportion of this total within each of the nine categories. The total count of firearm laws per state–year is very highly correlated with composite measures of firearm law strength used in previous studies, such as the Traveler's Guide permissiveness scores for 2000 to 2014 ($r = -0.88$) and The Law Center to Prevent Gun Violence State Scorecard for 2007 to 2011 ($r = 0.93$).[37,38] The Traveler's Guide is a score developed by legal professionals for firearm owners who wish to understand firearm laws other US states, whereas the State Scorecard ranks all states in order to identify opportunities to strengthen laws. Compared to these composite measures, our chosen approach has the additional benefit that we are able to identify the types of laws that contribute most substantially to the associations for overall firearm laws.

Interstate Firearm Laws

A geographic gravity model provides a straightforward approximation of routine human mobility:[40]

$$I_{ij} = e_i \times a_j \times d_{ij}^{\beta_{ij}}$$

Flow I from origin i to destination j can be approximated as a function of the "emissiveness" (e) of the origin, the "attractiveness" (a) of the destination, and a decay term β that describes the willingness of populations to travel over distance d from origin i to destination j.[41] Per convention,[40] we used the size of the population in the origin and destination counties as measures of emissiveness and attractiveness. Because transporting firearms by mail or commercial airlines is prohibited and subject to detection by authorities,[42] d approximated land transport distances using a matrix of great circle distances between the centroids of the 3,107 counties. Distance decay is unlikely to be uniform across all US counties, and it is possible to calculate origin- and destination-specific decay terms;[43] however, these terms can be noisy when calculated using small area data. Given that our sample included many rural counties with very small populations, we chose to use a constant inverse distance square decay term ($\beta = -2$) rather than an unstable variable decay term.

For each US county, we calculated the year-specific, gravity-weighted average of firearm laws for all interstate counties. We scaled the resulting interstate firearm law measures similarly to the within-state firearm law, such that a one-unit increase corresponds to an increase of one law. The approach assumes counties will be affected most substantially by the firearm laws in more populous and more proximate interstate counties. In addition to calculating the gravity-weighted total count of interstate firearm laws for each county per year, we also calculated the gravity-weighted count of interstate firearm laws within the nine categories. Like the measures of within-state firearm laws, counts of interstate firearm laws were also highly collinear across categories, so we again separated the total count and the proportion within categories.

Covariates

We controlled for social environmental characteristics that were likely to be causally related to firearm homicide incidence and associated with within-state firearm laws, and could therefore confound associations between within-state firearm laws and firearm homicides. US Census Bureau's County Characteristics Intercensal Population Estimates[44] provided time varying population characteristics within categories of age (≤24 years, 25–44, 45–64, ≥65) and race/ethnicity (non-Hispanic black, non-Hispanic white, Hispanic, native American). We also accessed the median household income in 2014 USD from the US Census Bureau's Small Area Income and Poverty Estimates,[45] and the proportion of the population aged > 16 years who were unemployed from the Bureau of Labor Statistics Local Area Unemployment Statistics.[46] Time invariant covariates were land area (which represents population density because the model also controlled for population size) and 2010 classifications of Rural–urban Continuum Codes (RUCC) from the US Department of Agriculture[47] divided into metropolitan (RUCC: 1 to 3), urban (RUCC: 4 to 6), and rural (RUCC: 7 to 9). We calculated total estimated population in-flow using the geographic gravity function. To limit the possibility that social and criminal justice policies confound associations between within-state firearm laws and firearm homicide, we added controls for a state policy liberalism index[48] and state and local government policing expenditure,[49] accessed through the Michigan State University's Institute for Public Policy and Social Research.[50]

Statistical Analysis

We used a Poisson model for observed counts of firearm homicides Y in county i at time t:

$$Y_{i,t} | u_{i,t} \sim Poisson(E_{it}\exp(u_{it}))$$

where $E_{i,t}$ is the time varying population size for county i. This term serves as the expected number of homicides, similar to an offset term in a negative binomial model. The mean and variance of the Poisson distribution is $E_{i,t}$ multiplied by $\exp(u_{i,t})$, which is the incidence rate for firearm homicide in county i at time t.

We modeled the log of the incidence rate linearly:

$$u_{i,t} = (\alpha + \Omega_s) + \lambda \bullet t + \beta \bullet X'_{i,t} + \theta_i + \varphi_i + \omega_t$$

The term α is an overall intercept and Ω_s is a random intercept capturing time-invariant variation between s, the 48 states. The term $\lambda \cdot t$ is linear time trend for all counties across the 15 years and ω_t captures additional temporal variation around this average. Parameter β is a vector of fixed effect estimates that we interpret as the associations of interest for a matrix of dependent variables $X'_{i,t}$, including within-state firearm laws, interstate firearm laws, and the potential confounders. The term φ is a conditional autoregressive random effect that controls for the loss of unit independence and addresses the small area problem by "borrowing strength" from adjacent counties,[51,52] and θ is a spatially unstructured error term which accounts for over-dispersion of the count data. Bayes theorem provides a statistically efficient approach for estimating conditional autoregressive models.[51] Using WinBUGS v.1.4.3,[53] we began with non-informed normally distribution priors (mean = 0, precision = 0.00001) and allowed two Markov Chain Monte Carlo simulations to stabilize over 50,000 iterations, before sampling a further 50,000 iterations. We specified three variants of these models. Model 1 included only the total count of within-state and interstate firearm laws, Model 2 added an interaction term between within-state and interstate laws, and Model 3 included the composition of within-state and interstate laws.

Sensitivity Analyses

We conducted sensitivity analyses to test whether results differed based on model or variable specification. First, we removed the social policy variables to assess possible bias due to moderate correlation between these variables and the within-state firearm laws (eFigure 1). Second, we lagged the values of the firearm laws by 1 year. That is, we compared firearm laws in 1999 to firearm homicides in 2000, firearm laws in 2000 to firearm homicides in 2001, and so on. This procedure ensures that the exposure precedes the outcome, and accounts for the possibility that the effect of laws on homicides does not manifest until the following year. Finally, we assessed model performance by combining observations of the independent variables for 1999 with the parameter estimates derived from 2000–2014 data

(Model 3) to calculate predicted counts of firearm homicides for 1999, and calculate the global Moran's I to estimate the geographic structure of the prediction errors.

Results

Within-State and Interstate Firearm Laws

On average states had 24.0 of the 133 statewide firearm laws (SD = 22.6). The greatest overall number of laws was for California in 2014 and Massachusetts in 2000–2014 (100 laws) and the least overall number of laws was for Vermont in 2000–2014 (three laws)). The number of laws did not change for three states from 2000–2014 (Massachusetts: 100 laws; Oregon: 24 laws; Vermont: three laws). The most common laws were concealed carry laws; of the seven possible laws in this category, states had an average of 4.0 (SD = 1.5) laws active per year. Temporal variation in the total counts of within-state firearm laws for each state is shown in Figure 1, and the geographic variation for laws for a single year (2000) are shown in Figure 2 (upper panel). Interstate firearm laws in 2000 are shown in Figure 2 (lower panel). The county exposed to the fewest interstate firearm laws was Monroe County, Illinois, in 2007, which had a gravity-weighted total of 9.5 interstate laws because it is adjacent to St Louis County, Missouri, and Missouri had just six of the 133 firearm laws in 2007. The county exposed to the most interstate firearm laws was Bristol County, Rhode Island in 2014, which had a gravity-weighted total of 90.7 interstate laws. Bristol County is adjacent to Massachusetts, which had 100 firearm laws in that year.

Relative Associations

Parameter estimates for Model 1 identify that each additional firearm law was associated with 0.6% fewer firearm homicides in within-state counties (IRR = 0.994, 95%CI: 0.993, 0.996) and 0.7% fewer firearm homicides in interstate counties (IRR = 0.993, 95%CI: 0.990, 0.996)(Table 2). Note that the variation was smaller for interstate firearm laws (SD = 10.2) compared to within-state firearm laws (SD = 18.0), so the point estimates for interstate firearm laws will be larger given the same association per standard deviation increase in the exposure. In Model 2, associations for within-state and interstate laws were in the same direction, while the association for the interaction term was positive. Figure 3a shows the predicted association for within-state firearm laws from Model 1, and Figure 3b shows the predicted association for within-state firearm laws from Model 2, stratified by the minimum and maximum observed values for the interstate firearm laws. Interstate firearm laws were most strongly associated with fewer firearm homicides where within-state laws were weakest, but were not associated with firearm homicides where within state laws were strongest.

Model 3 adds that the composition of both within-state and interstate firearm laws is also important. After conditioning upon firearm law composition, firearm laws were associated with 0.5% fewer firearm homicides in within-state counties (IRR = 0.995, 95%CI: 0.992, 0.997). Recall that we reserved concealed carry laws as a reference category, so the point estimate for firearm laws is interpretable as the association for an increase of one concealed carry law. Compared with concealed carry laws, background checks were associated with the greatest benefit (IRR = 0.994, 95%CI: 0.991, 0.997), and child access prevention (IRR =

1.012; 95%CI: 1.005, 1.020) was associated with least benefit. Possession regulations were associated with the greatest benefit for counties in nearby states (IRR = 0.977; 95%CI: 0.968, 0.985).

The predicted counts of firearm homicides for 1999 (based on Model 3) were highly correlated with the observed counts of firearm homicides for 1999 (Spearman's ρ = 0.72). Compared with the observed total of 10,637 firearm homicides that occurred in all counties in 1999, the model predicted a total of 8,247 firearm homicides (95% credible interval [CrI]: 5,388, 12,601). However, the predicted rate per 100,000 population was only moderately correlated with the observed rate (Spearman's ρ = 0.46; eFigure 2), suggesting that variation in the population size accounted for a substantial portion of the correlation for the count values. The predicted rate per 100,000 population was generally poorer in the southern US states, though there was no geographic structure to the overestimated or underestimated values (Global Moran's I = 0.01; eFigure 3).

Results of the sensitivity analyses were substantively similar to the main models (Supplementary Tables S1 and S2).

Discussion

Firearm laws are a divisive issue in the United States. On one hand, the 2nd Amendment to the constitution protects the right of the people to keep and bear arms. On the other hand, over 10,000 people die per year in firearm homicides,[1] and research indicates that some firearm laws—such as universal background checks—are associated with relatively fewer homicides.[5] It is therefore essential that epidemiologic studies report unbiased measures of associations between firearm laws and firearm homicide, and that threats to causal inference are minimized. This study considered the possible effects of interference from interstate firearm laws that could theoretically arise due to mobility between units in spatial ecologic studies. Using data for US counties for 2000–2014, we found that stronger within-state firearm laws were associated with fewer firearm homicides, particularly where interstate firearm laws were weakest.

Our results are consistent with previous studies that identify relative associations between specific firearm laws and firearm homicides within US states. Several studies identify that universal background checks are most strongly associated with fewer firearm homicides,[4] notwithstanding problems related to implementation and fidelity.[54] Likewise, it is becoming clear that that child access prevention laws are associated with fewer firearm injuries among children, but are not necessarily related to firearm homicides in the population.[5] States with stronger overall laws also tend to have fewer homicides.[37] This study adds that both the count and composition of a states' laws affect within-state homicide incidence and that associations are strongest for background checks. However, our results also emphasize that the benefits of within-state firearm laws are not independent of firearm laws in nearby states. Future studies of within-state firearm laws and firearm homicides should address this important threat to causal inference.

We also found that firearm laws are directly associated with firearm homicides across state lines.[30,55] Our results partially support the proposed economic geographic mechanism—that illegal firearms will flow from origin states with weak laws—but the finding for the interaction term was contrary to expectation. Strong interstate firearm laws were most strongly associated with fewer firearm homicides where within-state laws were weaker, suggesting that states with weak laws are most substantially affected by other states' weak laws. Rather than illegal firearm sales serving as a substitute for legal firearm sales, it is possible that the markets for illegal and legal firearms are separate, albeit closely linked.[21] Consumers of legal firearms may be a different population from consumers of illegal firearms. Illegal firearms sales may be easier to conceal where laws are weaker, lowering the risks for traffickers and thereby reducing the costs of illegal sales.

This study explicitly addressed interference as a potential violation of the stable unit treatment value assumption. However, there is much work to be done before these findings and results from other spatial ecologic studies can be interpreted causally. Two areas of particular importance are establishing exchangeability and confirming the direction of these associations. Exchangeability (meaning the absence of unmeasured confounding) is a complement to non-interference and is another key plank of the stable unit treatment value assumption.[17] Our space–time units are unlikely to be exchangeable. Counties differ on many more characteristics that affect firearm homicide incidence than the available variables we included in our statistical analyses. For example, firearm ownership and norms related to firearm ownership likely differ over space and time and may affect firearm laws and firearm homicides, but valid firearm ownership data were not available for all county–years.[56] Similarly, establishing the direction of the association is an intractable problem for observational research of firearm laws and firearm homicide. Laws may be enacted in response to firearm homicides (e.g. following the Sandy Hook school shooting in Connecticut[57]), which would bias associations in favor of stronger laws if additional homicides were isolated and statistically random, or would bias associations in favor of weaker laws if the additional homicides were part a systematic increasing trend. Other observational study designs are more likely to produce exchangeable units and are better able to assess directionality than the current spatial panel design, such as studies that compare units that are matched based on relevant characteristics or within-unit studies that assess change over time.[58] These designs may also have greater external validity than our analysis, as indicated by the poor predictive value of our statistical models.

This study provides evidence that the count and composition of within-state firearm laws are negatively associated with firearm homicides. The findings accord with prior studies that suggest stronger firearm laws are associated with fewer firearm homicides and add that firearm laws in nearby states interfere with these associations. Researchers conducting spatial ecologic analyses of within-state associations should consider that their results may be affected by spillover due to human mobility.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

We are grateful to Charles Branas (Columbia University) and Bill Ponicki (Prevention Research Center) for assistance editing the manuscript.

Funding:

This study was supported in part by the National Institute on Alcohol Abuse and Alcoholism of the National Institutes of Health under Award Number K01AA026327. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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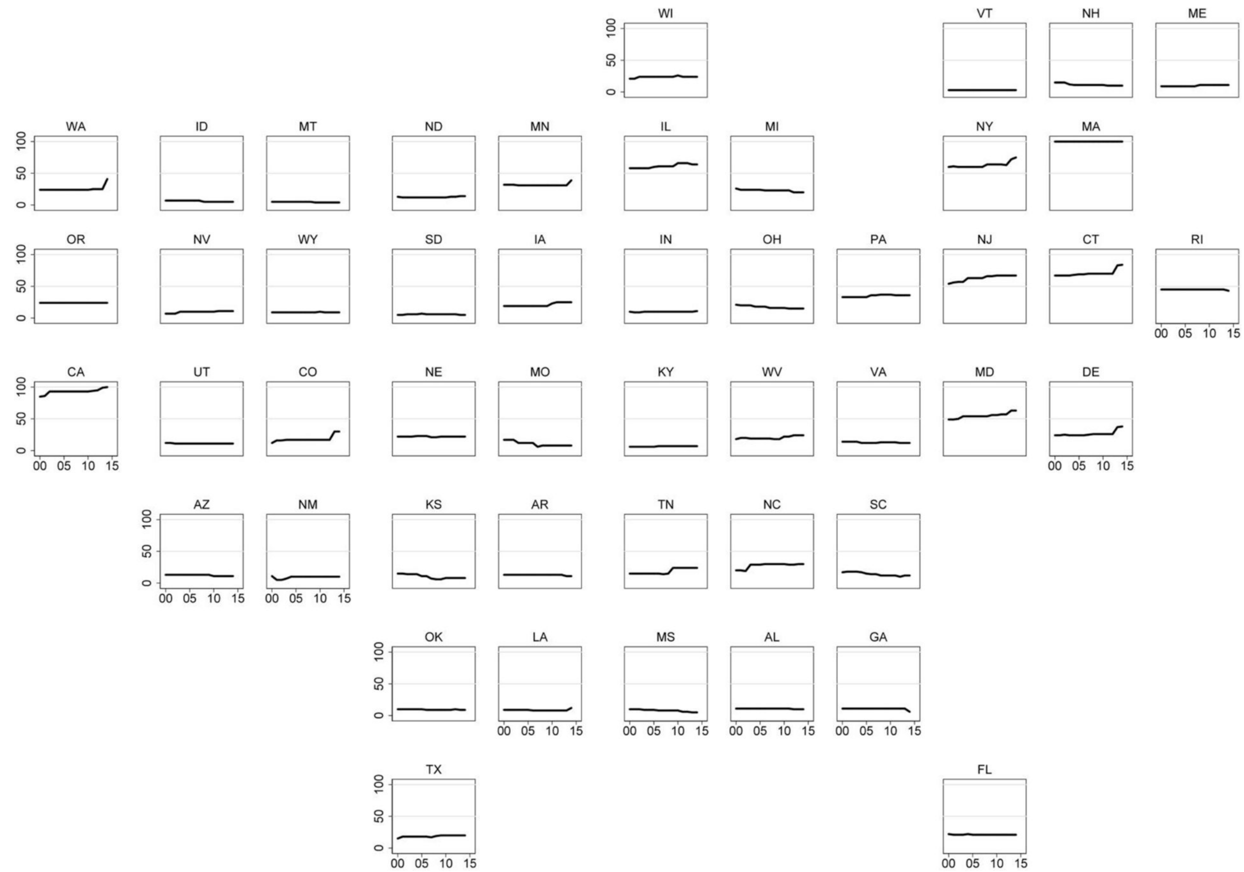

Figure 1.

Total counts of within-state firearm laws; 2000–2014. Y-axis represents law counts; x-axis represents years.

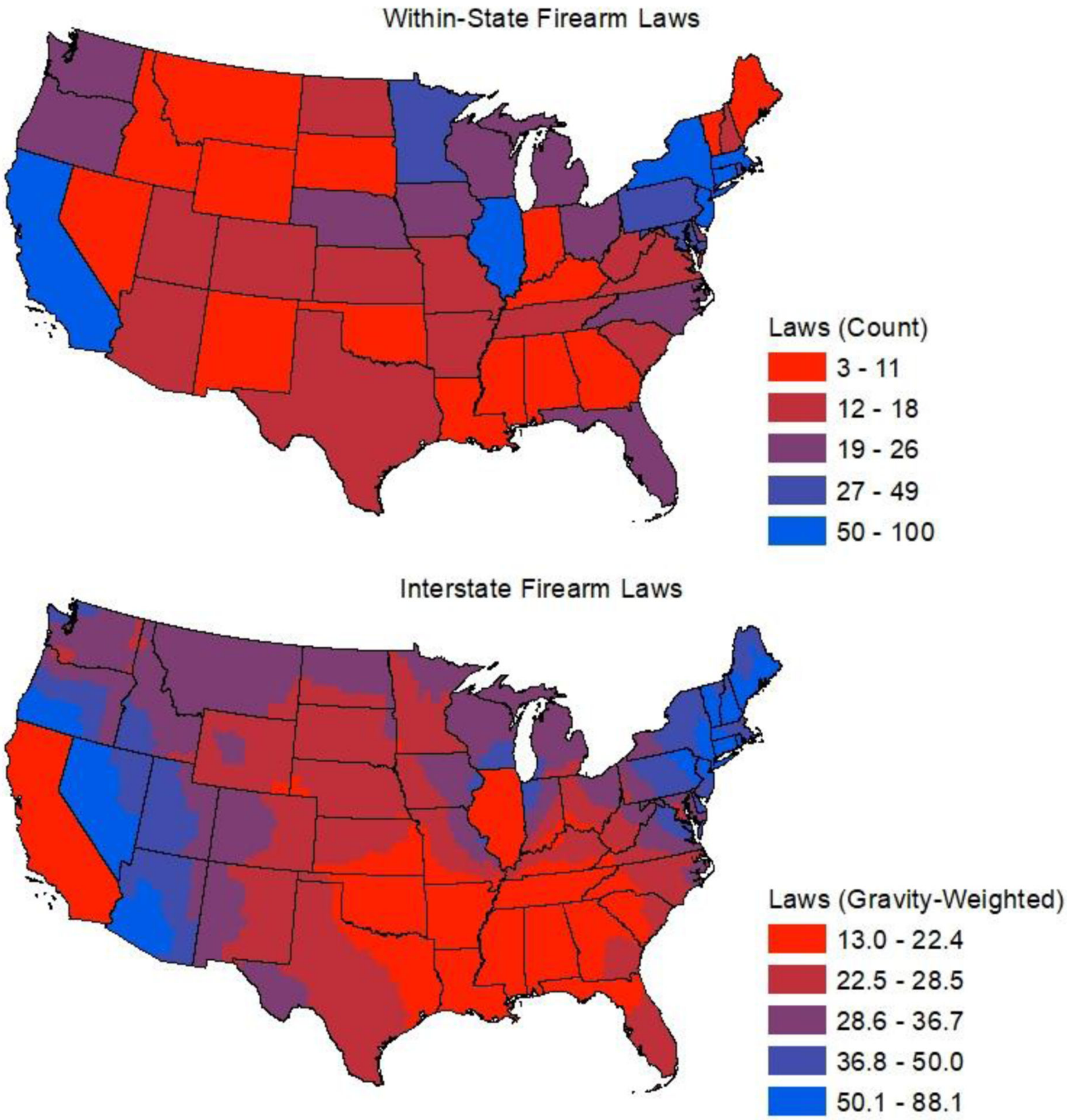

Figure 2.

Total counts of within-state and interstate firearm laws for 2000. This procedure was repeated for each year. Illinois and California have many laws and are marked in blue in the within-state map, but they are surrounded by states with few laws, so they are red in the interstate map.

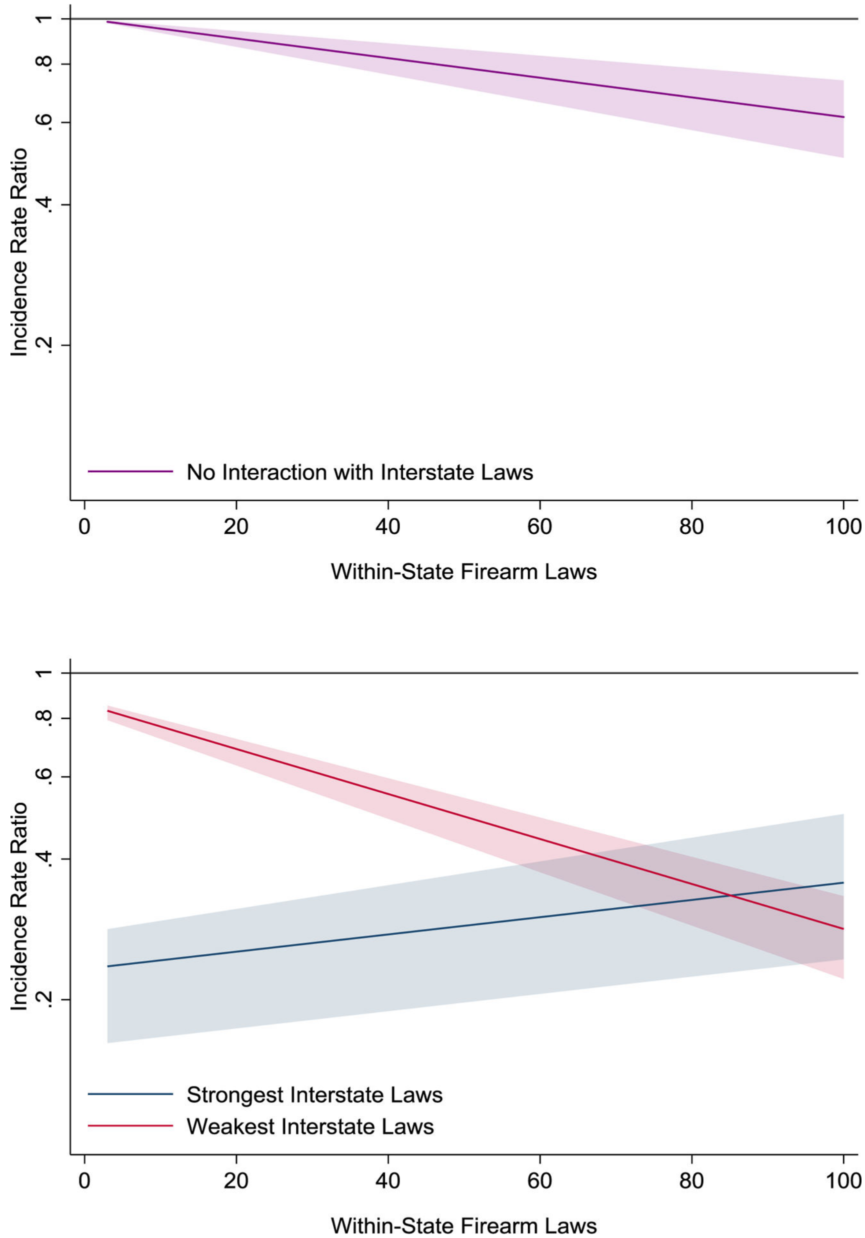

Figure 3.

Linear combinations of maximum and minimum observed values and parameter estimates for associations between within-state firearm laws and incidence of firearm homicide. Figure 3a shows predicted association for Model 1. Figure 3b shows the predicted association for Model 2 stratified by the maximum and minimum observed values of the interstate firearm laws.

Table 1.

Firearm law categories and distribution of laws within 48 states over 15 years. Data and variable descriptions extracted with permission from McClenathan, Pahn, and Siegel.[16]

Law Category	Description	Laws in this Category	Mean (SD) for State-Years
Dealer laws	Establish rules for anyone in the business of selling, lending, or trading firearms.	17	2.6 (3.8)
Buyer laws	Laws that firearm purchasers must obey in order to obtain a firearm.	17	2.0 (2.9)
Prohibitions for high-risk firearm possession	Prevent individuals with a history of crime, substance use, or mental health issues from possessing firearms.	10	2.7 (2.3)
Background checks	Establish requirements and procedures for firearm dealers to perform background checks on prospective firearm purchasers.	11	1.9 (3.2)
Possession laws	Establish age limitations for firearm possession, conditions under which possession is allowed, and places where firearm carrying is permitted.	12	2.7 (2.1)
Concealed carry permitting	Outline the process that individuals must undergo to obtain a concealed carry permit in their state.	7	4.0 (1.5)
Child access prevention	Establish rules for fire-arm safety locks and hold firearm owners criminally liable for negligent firearm storage.	11	1.6 (2.5)
Domestic Violence	Establish conditions under which individuals convicted of domestic violence-related offenses are prohibited from possessing firearms.	21	3.1 (4.4)
Other	Includes regulations on ammunition, assault weapons and large-capacity ammunition magazines, firearm trafficking, and the absence of stand your ground laws, laws granting states preemption, and laws providing immunity from prosecution	27	3.5 (4.7)
Total laws	Sum of the total count of laws from all categories	133	24.0 (22.6)

SD indicates standard deviation.

Table 2.

Bayesian conditional autoregressive Poisson models for counts of firearm homicides; US counties (n = 3,107) from 2000–2014 (t = 15).

	Model 1			Model 2			Model 3		
Variable	**IRR**	**(95%**	**CrI)**	**IRR**	**(95%**	**CrI)**	**IRR**	**(95%**	**CrI)**
Within-State Firearm Laws									
Laws (count)	0.994	0.993	0.996	0.987	0.984	0.990	0.995	0.992	0.997
Dealer laws (%)							1.000	0.997	1.003
Buyer laws (%)							0.999	0.996	1.002
High risk (%)							0.997	0.994	0.999
Background checks (%)							0.994	0.991	0.997
Possession laws (%)							0.997	0.995	0.999
Concealed carry [reference]									
Child access prevention (%)							1.012	1.005	1.020
Domestic Violence (%)							0.999	0.997	1.001
Other laws (%)							1.001	0.999	1.003
Interstate Firearm Laws									
Laws (gravity weighted)	0.993	0.990	0.996	0.984	0.979	0.988	0.991	0.986	0.996
Dealer laws (%)							1.011	1.001	1.023
Buyer laws (%)							0.984	0.974	0.992
High risk (%)							0.984	0.977	0.991
Background checks (%)							0.991	0.981	1.000
Possession laws (%)							0.977	0.968	0.985
Concealed carry [reference]									
Child access prevention (%)							0.978	0.962	0.992
Domestic Violence (%)							0.998	0.992	1.005
Other laws (%)							0.991	0.983	1.000
Interaction Term									
Within-state laws*interstate laws (*100)				1.019	1.013	1.028			
County Demographics									
Age < 25 [reference]									

	Model 1			Model 2			Model 3		
Variable	**IRR**	**(95%**	**CrI)**	**IRR**	**(95%**	**CrI)**	**IRR**	**(95%**	**CrI)**
Age 25–44 (%)	1.010	1.004	1.018	1.011	1.005	1.016	1.006	0.998	1.016
Age 45–64 (%)	1.027	1.021	1.036	1.026	1.019	1.034	1.024	1.015	1.032
Age > 64 (%)	0.994	0.986	1.001	0.995	0.988	1.002	0.992	0.985	1.001
Black (%)	1.032	1.030	1.034	1.032	1.030	1.034	1.032	1.029	1.034
Hispanic (%)	1.013	1.010	1.016	1.013	1.011	1.016	1.014	1.010	1.017
White [reference]									
Native (%)	1.015	1.011	1.020	1.015	1.011	1.019	1.014	1.010	1.019
Median household income (2014 US$10,000)	0.906	0.889	0.923	0.902	0.886	0.919	0.901	0.883	0.919
Unemployment (%)	0.988	0.983	0.993	0.988	0.982	0.993	0.989	0.983	0.994
Human Geography									
Population in-flow (standardized)	1.009	0.986	1.033	1.002	0.978	1.027	1.015	0.992	1.040
Policy liberalism	1.007	0.971	1.041	0.998	0.964	1.034	1.006	0.966	1.046
Policing expenditure	0.985	0.982	0.988	0.986	0.983	0.989	0.982	0.978	0.985
RUCC Metropolitan [reference]									
RUCC Urban	0.906	0.866	0.947	0.904	0.865	0.945	0.901	0.861	0.942
RUCC Rural	0.986	0.916	1.063	0.984	0.913	1.059	0.984	0.913	1.060
Land area (1,000 square kms)	1.006	0.972	1.040	1.004	0.970	1.040	1.012	0.977	1.049
Constants and Error Terms									
Constant	1.481	0.996	1.856	1.945	1.513	3.028	5.089	2.017	8.117
Trend	0.990	0.985	0.996	0.991	0.985	0.998	0.991	0.983	1.000
Variance explained by conditional autoregressive random effect (proportion)	0.801	0.709	0.883	0.821	0.732	0.894	0.808	0.709	0.891
Variance explained by state random effect (proportion)	0.007	0.001	0.046	0.007	0.001	0.041	0.080	0.029	0.172

RUCC indicates rural-urban continuum codes. IRR indicates incidence rate ratio. CrI indicates credible interval.