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RESEARCH ARTICLE

Neighbors Do Matter: Between-State Firearm Laws and State Firearm-Related Deaths in the U.S., 2000–2017

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Introduction: Firearm injury is a major U.S. public health concern. This study aims to evaluate whether the relationship between state firearm laws and state firearm deaths are affected by comparatively lenient firearm laws in neighboring states.

Methods: This observational study used 2000–2017 data on firearm deaths and firearm laws of the 48 contiguous states of the U.S. (Alaska, Hawaii, and the District of Columbia excluded). The associations among state firearm deaths, state firearm laws, and presence of neighboring states with more lenient laws were analyzed using negative binomial regression models with state- and year-fixed effects. Analyses were conducted in 2019–2020.

Results: There were 578,022 firearm deaths of all intents during the study period or 11.1 firearm deaths (IQR=8.5−14.0) per 100,000 population. The presence of more state firearm laws was associated with decreased firearm deaths (incident rate ratio=0.991, 95% CI=0.987, 0.996). However, weaker firearm laws in neighboring states correlated with more firearm deaths within a state (incident rate ratio=1.016, 95% CI=1.004, 1.028). Failing to account for weaker laws in neighboring states led to the underestimation of the impact of 1 additional law on state's own firearm deaths (incident rate ratio=0.994, 95% CI=0.989, 0.998 vs 0.991, 95% CI=0.987, 0.996) by approximately 20%.

Conclusions: Weaker firearm laws in neighboring states may undermine the effectiveness of a state's own firearm laws in curbing firearm deaths. Coordinated legislative action across neighboring states may be more effective than an individual state taking legislative action.

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INTRODUCTION

Firearm injury and mortality are major public health concerns for the U.S. By 2017, the number of firearm-related deaths increased to 39,773 per year, representing an annual increase of 11,110 since 2000.[1] Stronger regulations over the selling, buying, and ownership of firearms have been associated with lower rates of firearm-related deaths.[2−8] However, skeptics of the effectiveness of stronger firearm regulations often cite examples of states that have high firearm deaths despite having strong firearm regulations. A recent example was a social media dispute between Texas U.S. Senator Ted Cruz and Chicago Mayor Lori Lightfoot. The former contended that Chicago's high gun homicide numbers, despite Illinois's strict gun laws, were evidence that "gun control doesn't work," and the latter retorted that "60%[9] of illegal firearms recovered in Chicago come from outside Illinois,"[10] essentially implying that the more lax laws of neighboring Indiana were undermining the effectiveness of Illinois's laws. It is feasible that a

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discrepancy between firearm-related policies between neighboring states can lead to guns crossing borders and contribute to higher firearm deaths in states with stricter regulations.[11,12] Hence, this is an important public health and public policy question, for which the scientific literature remains relatively small.

Recent studies show evidence that between-state law differences are linked to firearm deaths and injuries. Matthay et al.[13] reported that gun shows in neighboring Nevada, not in California, were associated with short-term increases in firearm injuries in California. Kaufman et al.[14] showed that counties with less restrictive interstate policy had a higher rate of firearm-related homicide than counties with more restrictive interstate policy, suggesting that less restrictive interstate policy has a detrimental spillover effect on adjacent counties of neighboring states. Olson et al.[15] found that, for the 10 most restrictive firearm legislation states, the correlation between the number of state laws and state firearm homicide rate was stronger after accounting for the strength of gun laws in nearby states.

This observational study adds to the literature by evaluating all the 48 contiguous states over multiple years for the impact of the between-state difference of background checks, dealer regulations, buyer regulations, and gun-trafficking laws, which have been associated with firearm-related mortality in previous studies.[3,16−19] Specifically, this study hypothesizes that the risk of firearm deaths of a state will be higher if the neighboring states have more lenient firearm laws and that failing to account for such neighboring states' regulation can lead to underestimating the impact of states' laws on curbing firearm deaths.

METHODS

Study Sample

All the states of the U.S. were included except Alaska and Hawaii because they are noncontiguous with other U.S. states. The District of Columbia was excluded because it has no applicable state laws in the State Firearm Law Database. The final analysis included 48 states. The study period was from 2000 to 2017.

Measures

The total numbers of firearm-related deaths by state from 2000 to 2017 were extracted from the Web-based Injury Statistics Query and Reporting System (WISQARS) of the Centers for Disease Control and Prevention[20] as main outcome variables, including deaths from all intent (total count and count by sex), homicide excluding legal intervention, and suicide. WISQARS is a public-access, free online database that provides fatal and nonfatal injury, violent death, and cost of injury data from a variety of trusted sources. The WISQARS system suppressed the number of deaths if the counts were <10, which led to missing values. Among the outcome variables, firearm-related all-intent female deaths and homicide excluding legal intervention had missing values—8.7% and 9.0%, respectively.

Information on state firearm law was obtained from the State Firearm Law Database[21] developed by Siegel et al.[22] This database tracks the presence of 134 provisions in 14 categories across all the 50 states for the period 1991 to the present. Examples of the categories are buyer regulations, dealer regulations, background checks, prohibiters for gun purchase and possession, domestic violence−related gun laws, stand your ground laws, concealed carry−permitting laws, assault weapons regulations, gun-trafficking laws, and restrictions on places where guns may be carried. Each of the 134 provisions was coded as being either present (1) or absent (0) for each state during each year. Laws were coded on the basis of their year of implementation. The total number of state firearm-related laws in each year was included to represent the overall strictness of firearm control in each state. The scale ranged from 0 to 134.

The following categories of laws were identified as having the potential to impact the interstate movement of firearms and firearm-related mortality[3,14−19]: (1) background checks, (2) dealer regulations, (3) buyer regulations, and (4) gun-trafficking laws (Appendix Table 1, available online). With these laws, this study aimed to examine whether a state that is more lenient in firearm regulation in those fields (i.e., has fewer of such provisions) would affect the firearm-related deaths of the contiguous states that have more laws but not vice versa. First, the total numbers of laws of all these categories were calculated for each state in each year. Then, a method was developed to evaluate the difference in the strictness of firearm regulation by calculating the mean difference between the numbers of these laws of each state and adjacent states that had equal or fewer laws. For example, in 2017, North Carolina had a total of 7 provisions in those 4 categories. Its neighboring states—Virginia, Tennessee, Georgia, and South Carolina—had 2, 5, 0, and 0 provisions in those categories, respectively. The respective differences in the number of laws in North Carolina compared with those of the neighboring states were 5, 2, 7, and 7 (totaling 21). Therefore, for North Carolina, the between-state law difference for 2017 was 5.25 (21 divided by 4). The mean differences between the number of laws in each state and all adjacent states and the adjacent states that had more laws were used for sensitivity analyses.

State-level, potentially time-varying variables that may conceivably impact the number of violent deaths were controlled on the basis of previous literature.[2,3,14] Population size, proportion aged ≥65 years, race, unemployment rate, poverty rate, and proportion aged ≥25 years without a high school diploma were obtained from the U.S. Census Bureau for 2000−2017.[23] Property crime rates were obtained from the Federal Bureau of Investigation's summary reporting system through Crime Data Explore[24] as a proxy for the propensity for crimes in the state. The per capita number of licensed gun dealers, obtained from U.S. Bureau of Alcohol, Tobacco, Firearms and Explosives,[25] and the percentage of the hunting license holder of the state's population, obtained from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation,[26] were included as proxy controls for household gun ownership.[3,27,28] As a further proxy measure for state sentiment toward firearm control, the vote share differences between the Republican and Democratic presidential candidates in each presidential election year within the study period[29] were included and extrapolated for years between presidential elections.

Statistical Analysis

Continuous variables were presented as medians and IQRs. Rank sums test for trend was used to test the trend of each variable during the study period.

The 2-way fixed-effects models (with state- and year-fixed effects) using negative binomial regression were employed to evaluate the association between the policy discrepancy and the outcomes. Continuous variables were tested for linearity and monotonicity by comparing models using the original variables with their quintiles. The overall difference of the provisions of all the 4 categories of provisions was used to estimate the overall effect of the policy discrepancy on mortality. The aforementioned covariates were controlled as well as the state- and year-fixed effects. SEs were clustered within each state. Model fit was assessed using the Akaike information criterion. Models were compared using the likelihood ratio test.

Incident rate ratios (IRRs) with 95% CIs and p-values are reported. A 2-sided $p<0.05$ was considered statistically significant; $p<0.10$ but $p>0.05$ was considered marginally significant. Stata, version 15.1, was used for all analyses, which were conducted over 2019–2020.

RESULTS

Descriptive analyses for each variable are listed in Table 1. There were 578,022 firearm deaths of all intents or 11.1 firearm deaths (IQR=8.5–14.0) per 100,000 population during the study period. There was a statistically significant increase in firearm-related deaths from 2000 to 2017 for all categories except for firearm-related homicide. For all firearm-related policies, the median number of implemented laws was 15 (range=2–106). There was no evidence of a statistically significant trend in the overall change in the numbers of the state firearm laws for 2000–2017. For policies of interest, the mean between-state difference is shown in Figure 1. This illustrates the relative change of these laws between a state and its neighboring states during the study period. There is an indication of widened gaps in firearm laws between some states.

Adjusted IRRs and 95% CIs estimated from multivariable negative binomial models are shown in Table 2. In all models, despite the small effect sizes, a higher count of state's firearm laws was associated with fewer total firearm deaths (IRR=0.991, $p<0.001$), female firearm deaths (IRR=0.990, $p<0.001$), male firearm deaths (IRR=0.992, $p<0.001$), firearm homicide (IRR=0.990, $p=0.024$), and firearm suicide (IRR=0.994, $p<0.001$).

Table 1. State Characteristics Included in This Analysis From 2000 to 2017

Characteristic	Pooled	2000	2017	*p*-value for trend[a]
Total number of deaths (in thousands)[b]				
Total firearm-related death	578.0 (414.2, 741.8)	28.3 (20.1, 36.6)	39.4 (28.8, 50.1)	**0.004**
Firearm-related homicide	213.8 (143.4, 284.2)	10.6 (7.0, 14.2)	14.4 (10.0, 18.8)	0.69
Firearm-related suicide	341.3 (252.9, 429.7)	16.4 (12.1, 20.8)	23.7 (17.6, 29.8)	**<0.001**
Firearm-related death, male	497.2 (35.6, 63.8)	24.3 (17.2, 31.4)	33.8 (24.7, 42.9)	**0.005**
Firearm-related death, female	80.4 (58.3, 102.4)	4.0 (2.9, 5.1)	5.7 (4.1, 7.2)	**0.041**
Deaths, annual rate per 100,000 population[b]				
Total firearm-related death	11.1 (8.5, 14.0)	10.4 (7.9, 13.2)	12.8 (11.1, 16.9)	**<0.001**
Firearm-related homicide	3.6 (1.9, 5.0)	3.4 (1.9, 5.1)	4.6 (2.2, 6.2)	0.44
Firearm-related suicide	7.3 (5.6, 9.1)	6.9 (5.3, 8.6)	9.2 (6.5, 10.6)	**<0.001**
Firearm-related death, male	19.8 (15.4, 24.3)	18.5 (14.6, 23.2)	22.6 (19.3, 28.3)	**<0.001**
Firearm-related death, female	3.3 (2.1, 4.5)	3.2 (2.3, 4.4)	3.9 (2.7, 5.1)	**<0.001**
Mean between-state law difference[c]	2.0 (0.0, 5.7)	2.0 (0.0, 4.7)	2.0 (0.0, 5.7)	0.52
Total number of state firearm laws	15.0 (10.0, 26.0)	15.0 (10.5, 24.0)	17.0 (9.0, 36.0)	0.84
Population aged ≥65 years, %	13.3 (12.3, 14.4)	12.8 (11.6, 13.6)	15.3 (14.5, 16.1)	**<0.001**
White, %	0.9 (0.8, 0.9)	0.9 (0.8, 0.9)	0.8 (0.8, 0.9)	**<0.001**
Poverty rate, %	0.1 (0.1, 0.2)	0.1 (0.1, 0.1)	0.1 (0.1, 0.2)	**<0.001**
Unemployment rate, %	6.3 (5.1, 7.7)	3.9 (3.1, 4.4)	6.3 (5.0, 7.2)	**<0.001**
Population aged ≥25 years without high school diploma, %	13.0 (10.5, 16.0)	14.1 (11.9, 17.6)	10.7 (9.0, 13.6)	**<0.001**
Property crime (per 100 population)	2.9 (2.4, 3.6)	3.6 (2.9, 4.1)	2.4 (1.8, 2.8)	**<0.001**
Hunting license holder, %	6.5 (3.2, 10.7)	7.0 (3.7, 10.9)	6.7 (3.1, 10.8)	0.13
Licensed gun dealer (per 100,000 residents)	22.1 (14.8, 33.8)	28.9 (20.8, 41.7)	21.1 (15.2, 32.6)	**<0.001**

Note: Boldface indicates statistical significance ($p<0.05$). List pooled statistic for all years, 2000, and 2017 statistics. The test was performed for the whole study period.
[a]Rank sums test for trend.
[b]All variables listed in this table are shown as median (IQR) except for the total number of deaths shown as totals (95% CI).
[c]Laws for calculating the between-state law difference include (1) background checks, (2) dealer regulations, (3) buyer regulations, and (4) gun trafficking laws.

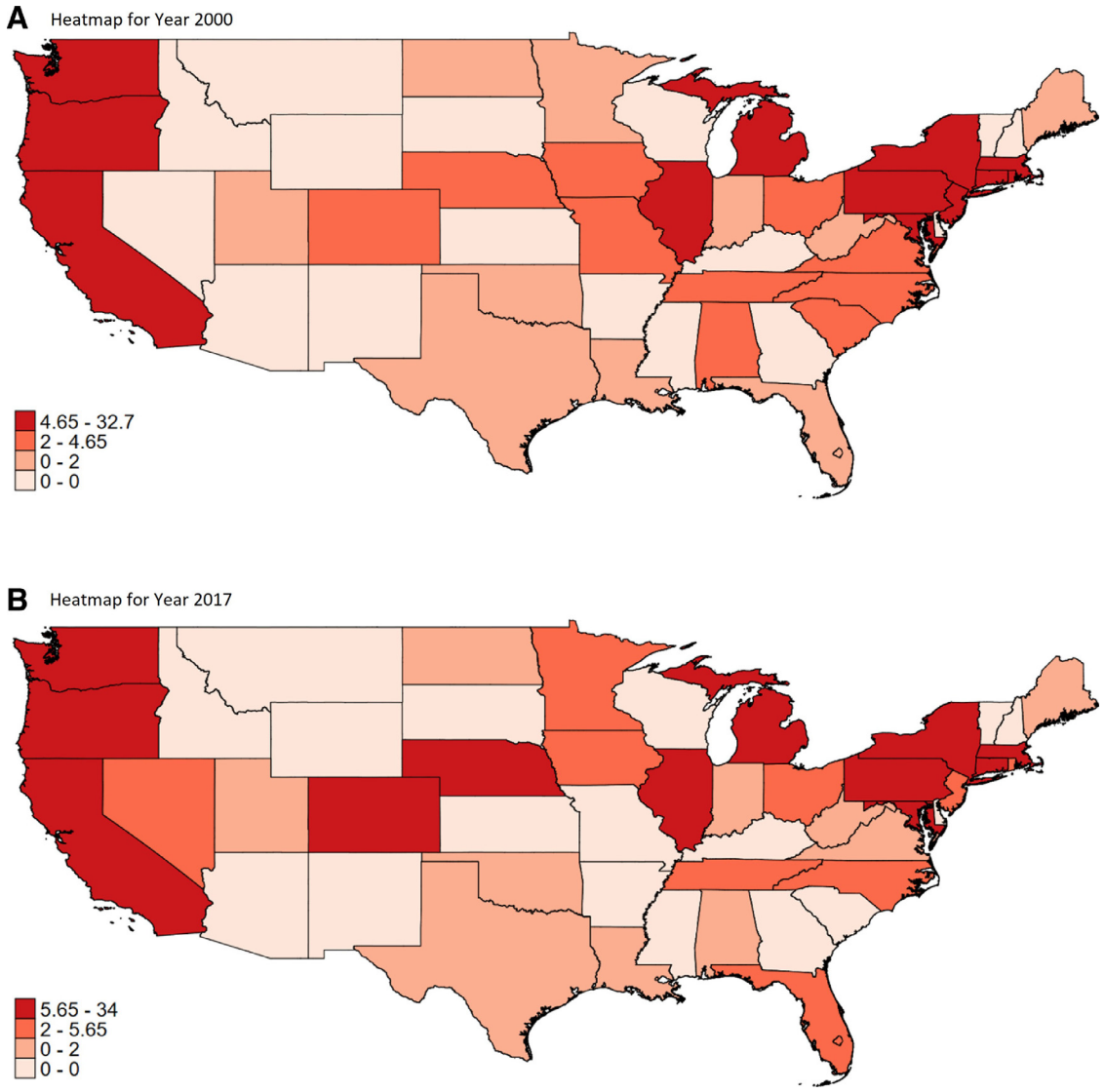

Figure 1. Heatmap of mean between-state law difference of the 48 contiguous states of the U.S. for 2000 and 2017.
Note: Legends showed the quartiles. Deeper red indicates greater difference in the numbers of firearm law[a] between a state and its neighboring states that are more lenient in gun control. (A: Year 2000; B: Year 2017)
[a]Laws including (1) background checks, (2) dealer regulations, (3) buyer regulations, and (4) gun trafficking laws.

Furthermore, having adjacent states with fewer laws appeared to increase firearm deaths of the state. On average, for each increase of 1 in the between-state policy differences (indicating more lax policies in neighboring states), the incidence rate (IR) increased by 1.6% (p=0.007) for total firearm-related deaths, 1.7% for female firearm deaths (p=0.013), 1.6% for male firearm deaths (p=0.008), 2.5% for firearm homicide (p=0.045), and 0.6% for firearm suicide (p=0.028). Results of firearm homicide and female firearm deaths were robust to alternate ways of addressing the missing values (Appendix Table 2, available online). Results for other covariates (Appendix Table 3, available online) indicated that not having a high school diploma, property crimes, percentage of the White population being in the third and fourth quartile of poverty (compared with the first), and Republican-leaning voting in presidential elections were associated with more firearm deaths. Higher state unemployment was associated with fewer firearm deaths. The percentage of hunting license holders and licensed gun dealers were not significantly associated with firearm deaths.

Sensitivity analyses were performed by controlling for the state-specific time trends (Table 2) and including law difference measures for neighboring states with stricter regulations (Table 2). When adding time trends,

Table 2. IRRs and 95% CIs of Mean Between-State Firearm-Related Law Difference from the Multivariable Negative Binomial Regression for Firearm-Related Deaths[a]

Variable	State's firearm-related laws, IRR (95% CI)	Mean between-state law difference for adjacent states that had equal or fewer laws, IRR (95% CI)	Mean between-state law difference for adjacent states that had more laws, IRR (95% CI)`	Mean between-state law difference for all adjacent states,[b] IRR (95% CI)
A: Adjusted for covariates and state and year fixed effects				
Total firearm-related death	0.991 (0.987, 0.996) **$p<0.001$**	1.016 (1.004, 1.028) **$p<0.007$**	—	—
Firearm-related death, female	0.990 (0.985, 0.995) **$p<0.001$**	1.017 (1.003, 1.030) **$p=0.013$**	—	—
Firearm-related death, male	0.992 (0.988, 0.996) **$p<0.001$**	1.016 (1.004, 1.028) **$p=0.008$**	—	—
Firearm-related homicide	0.990 (0.981, 0.999) **$p=0.024$**	1.025 (1.001, 1.050) **$p=0.045$**	—	—
Firearm-related suicide	0.994 (0.992, 0.996) **$p<0.001$**	1.006 (1.001, 1.012) **$p=0.028$**	—	—
B: Adjusted for covariates, state and year fixed effects, and state specific time trends				
Total firearm-related death	0.995 (0.991, 0.999) **$p=0.007$**	1.009 (1.001, 1.016) **$p=0.018$**	—	—
Firearm-related death, female	0.996 (0.990, 1.002) $p=0.211$	1.006 (0.992, 1.020) $p=0.384$	—	—
Firearm-related death, male	0.995 (0.991, 0.998) **$p=0.005$**	1.008 (1.001, 1.015) **$p=0.022$**	—	—
Firearm-related homicide	0.994 (0.986, 1.002) $p=0.126$	1.012 (0.998, 1.026) $p=0.097$	—	—
Firearm-related suicide	0.996 (0.994, 0.999) **$p=0.006$**	1.006 (1.000, 1.012) $p=0.063$	—	—
C: Models using alternate forms of between-state law difference, adjusted for covariates and state and year fixed effects				
Total firearm-related death	0.993 (0.988, 0.998) **$p=0.004$**	—	1.004 (0.996, 1.011) $p=0.352$	—
	0.992 (0.987, 0.996) **$p<0.001$**	1.016 (1.004, 1.028) **$p=0.009$**	1.001 (0.994, 1.008) $p=0.760$	—
	0.992 (0.987, 0.997) **$p=0.001$**	—	—	1.006 (1.000, 1.013) **$p=0.046$**
Firearm-related death, female	0.992 (0.987, 0.998) **$p=0.006$**	—	1.000 (0.988, 1.013) $p=0.951$	—
	0.990 (0.985, 0.995) **$p<0.001$**	1.017 (1.004, 1.031) **$p=0.010$**	0.997 (0.987, 1.007) $p=0.606$	—
	0.992 (0.985, 0.997) **$p=0.003$**	—	—	1.004 (0.995, 1.014) $p=0.365$

(*continued on next page*)

Table 2. IRRs and 95% CIs of Mean Between-State Firearm-Related Law Difference from the Multivariable Negative Binomial Regression for Firearm-Related Deaths[a] (*continued*)

Variable	State's firearm-related laws, IRR (95% CI)	Mean between-state law difference for adjacent states that had equal or fewer laws, IRR (95% CI)	Mean between-state law difference for adjacent states that had more laws, IRR (95% CI)`	Mean between-state law difference for all adjacent states,[b] IRR (95% CI)
Firearm-related death, male	0.993 (0.989, 0.998) **p=0.004**	—	1.004 (0.997, 1.012) p=0.223	—
	0.992 (0.987, 0.996) **p<0.001**	1.016 (1.003, 1.028) **p=0.013**	1.002 (0.995, 1.009) p=0.574	—
	0.992 (0.987, 0.997) **p=0.001**	—	—	1.007 (1.001, 1.013) **p=0.033**
Firearm-related homicide	0.992 (0.984, 1.000) p=0.065	—	1.005 (0.992, 1.019) p=0.454	—
	0.990 (0.982, 0.998) **p=0.018**	1.024 (1.000, 1.050) p=0.052	1.001 (0.989, 1.014) p=0.827	—
	0.991 (0.982, 0.999) **p=0.037**	—	—	1.008 (0.996, 1.020) p=0.179
Firearm-related suicide	0.995 (0.992, 0.997) **p<0.001**	—	1.002 (0.996, 1.007) p=0.579	—
	0.994 (0.991, 0.996) **p<0.001**	1.006 (1.001, 1.012) **p=0.030**	1.001 (0.995, 1.006) p=0.841	—
	0.994 (0.991, 0.997) **p<0.001**	—	—	1.003 (0.997, 1.009) p=0.289

Note: Boldface indicates statistical significance ($p<0.05$).

[a]The following state-level time-varying variables—population size, proportion aged ≥65 years, race, unemployment rate, poverty rate, the proportion aged ≥25 years without a high school diploma, the rates of crime against property, the percentage of the hunting license holder of the state's population, licensed gun dealer per 100,000 residents, and the vote share difference between the Republican and Democratic candidates in the presidential election (linear interpolated)—were adjusted in the year- and state-fixed effect multivariable negative binomial regression models.

[b]Higher values of this variable indicate that the neighboring states are overall more permissive than that state.

IRR, incident rate ratio.

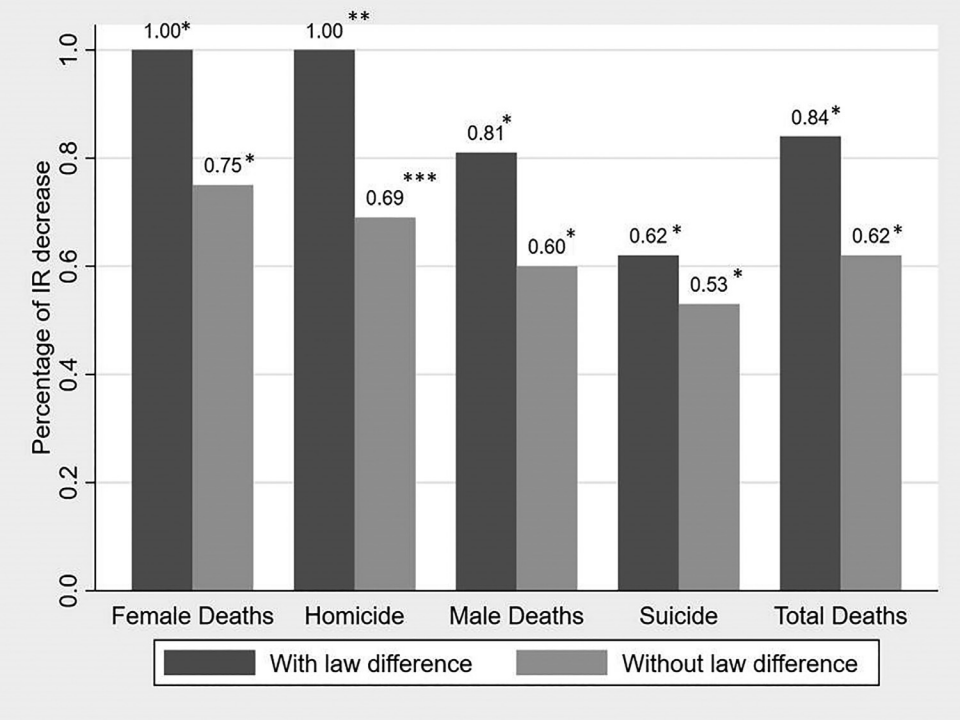

Figure 2. The impact of between-state law difference on the effects of state's gun policies on firearm-related deaths.
Note: The percentages of IR decrease were adjusted for all covariates listed in Table 2 (*p<0.01; **p<0.05; ***p<0.10). The AIC increased after removing the between-state law difference from the models, indicating a decrease in the model fit, and the likelihood ratio test (Appendix Table 4, available online) indicated that the change in model fit was significant in all cases. Details are in Appendix Tables 4 and 5 (available online).
AIC, Akaike information criterion; IR, incidence rate.

interstate law difference became marginally significant for firearm suicide (p=0.063) and homicide (0.097) and nonsignificant for female firearm deaths (p=0.384). For states' firearm laws, the difference levels lost significance for firearm homicide (p=0.211) and female firearm deaths (p=0.126). The law difference measure for neighboring states with stricter regulations was not statistically significant, supporting the study hypothesis, and the inclusion did not change the key results, although the interstate and state law differences became marginally significant in models for firearm homicide. Including an interaction term of states' law and interstate law differences or the sociopolitical characteristics of neighboring states continued to support the main findings (Appendix Text 1, available online).

Finally, the models with and without between-state law differences were compared (Appendix Tables 4 and 5, available online). The Akaike information criterion increased after removing the between-state law difference from the model, indicating a decrease in model fit, and the likelihood ratio tests indicated that the changes in model fit were significant. Thereafter, how the association between a state's policies and firearm mortality appeared to change across models with and without between-state law differences was examined (Figure 2). An increase in state firearm laws by 1 reduced the IR by 0.9% (p<0.001) for total firearm deaths. However, this same increase appeared to reduce the IR of firearm deaths by only 0.6% (p=0.007) when omitting the between-state law difference, essentially a >20% decline in estimated mean effectiveness. Similar results were found for the other outcomes. The differences in the estimated IRs were statistically significant for all models except for firearm-related suicide. Moreover, state laws only showed a marginally significant impact on reducing firearm-related homicide (IRR=0.993, p=0.081) when the between-state law difference was omitted.

DISCUSSION

A substantial literature finds that more restrictive state firearm regulations are associated with fewer firearm deaths in those states,[2,3,8,30,31] although the associations can differ for homicides and suicides.[2,3,32] However, firearm control policies vary greatly across states,[33] and guns can cross state borders with relative ease—a relatively new but growing body of literature is starting to explore whether there is a neighbor effect, whereby weaker regulations in neighboring states dilute the impact of strict in-state regulations. This study analyzed

in-state gun policy, neighboring states with weaker gun policies, and firearm-related mortality data for 2000−2017, including all provisions of background checks, dealer regulations, buyer regulations, and gun-trafficking laws in the State Firearm Law Database. The number of laws of these categories was used to measure how relatively permissive the surrounding states were. Although stronger state gun policies were associated with decreased firearm deaths, the presence of permissive neighboring states undermined this protective effect. Specifically, higher policy differences across states were associated with increased rates of total firearm deaths, suicides, and homicides, although results were statistically stronger for suicide than for homicide. Predictive analyses indicated that for a state with the median number of firearm laws, a 1-unit increase in the mean policy differences would increase a state's firearm deaths by 13 per year (Appendix Table 6, available online). Furthermore, failing to account for the presence of weaker laws in neighboring states led to a statistically significant underestimation of the effectiveness of additional in-state regulations by >20%.

There is support in the literature for the hypothesis that guns may move from states with weaker to states with stronger firearm regulations. Brauer et al.[34] showed that states with relatively permissive laws host more firearms-manufacturing establishments than states with relatively restrictive laws. Strengthened regulation on formal gun marketing and increased price can lead potential consumers to purchase firearms in proximal, relatively unregulated markets,[35,36] which are a frequent source of guns used in crimes.[37] Webster et al.[11] found that for states with licensing and permit regulation, the majority of the recovered crime-related guns were of out-of-state origin. Furthermore, empirical models show that states with weak gun laws were likely to be exporters to states with strict gun laws, but the trafficking flows were more significant between 2 nearby states than between 2 distant states.[38,39] These findings support the approach of this study of using between-state law differences but focusing primarily on guns moving across borders of neighboring states.

Results for other covariates appeared concordant with existing literature, such as a higher state unemployment rate being associated with fewer violent deaths[40] and positive associations between other crimes and firearm deaths.[41] There are media reports of Republican-leaning states having higher gun deaths,[42] although this is relatively unexplored by researchers. However, Appalachian and southeastern states—traditionally Republican leaning—have higher unintentional firearm deaths,[43] and states with Republican-controlled legislatures often loosen firearm restrictions after mass shootings.[44]

The impact of between-state policy discrepancy on firearm violence is a growing area of research. Kaufman et al.[14] found that strong state policies were associated with lower county suicide rates regardless of interstate policies, whereas strong interstate policies were associated with lower county homicide rates where home-state policies were permissive. This suggests that a state with the permissive policy may have detrimental impacts on neighboring states that are also permissive, although a strong home-state policy is protective. Olson et al.[15] used states' Brady score (which ranks and categorizes states using a weighted summary of approximately 30 firearm policies[8,15]) to measure the strictness of gun laws, developed a Border Adjustment score for the 10 most restrictive states, and showed that after adjusting for the Border score, the correlation between the state's Brady score and firearm-related homicide significantly improved. These results broadly support the findings of this study with all states. Specifically, when the between-state law difference was removed from the model, the effect size of states' laws appeared to decrease along with a corresponding decrease in statistical significance. Ignoring the presence of neighboring states with weaker firearm policies can make it appear like the state's firearm regulations have weaker effects than they actually do. This implies that strengthening firearm regulations in a state can reduce firearm deaths within that state and also reduce the adverse spillover impact on firearm deaths on neighboring states.

Limitations

This study has several limitations. First, although the assumptions in calculating the between-state law discrepancy were supported by literature, the impacts from distant states were omitted. Because of the state-fixed effects that subsume the effect of being a border state, the impact of sharing a border with Canada and Mexico cannot be inspected separately. Second, the number of laws per se may not perfectly measure strictness, and states may vary in how diligently firearm regulations are enforced. The use of the state-fixed effects, state-specific trends, number of hunting licenses, and voting patterns can help control for such unobserved between-state variations; however, none of these are perfect controls. Previous literature[18,31] shows that the number of firearm provisions is associated with firearm mortality and the interstate firearm movement. Although not yet validated, this approach is a novel way to address the growing acknowledgment of the importance of accounting for the between-state effects of firearm laws on firearm deaths. Further studies focusing on the impact of firearm regulations in the interstate context are needed to strengthen this research area. Third, the WISQARS

system suppressed the number of deaths for counts fewer than 10. Although the results were robust to alternate approaches to this problem, there still may be some measurement error. Fourth, results could be sensitive to alternate approaches of measuring or grouping firearm policies or calculating between-state differences—something that further studies should explore. Finally, this study is ecologic; although the empirical approach helps minimize omitted variable bias, caution is nonetheless recommended when making causal inferences between state firearm policies and firearm-related mortality.

CONCLUSIONS

This study adds to the growing literature emphasizing the role played by neighboring states' firearm regulations in addition to own-state firearm regulations in firearm deaths. Failing to account for neighboring states with weaker laws, in some instances, canmake a state's own regulations appear less effective in reducing firearm deaths. Further research that uses alternate approaches to measure strictness of laws or focuses on specific categories of laws in their own and neighboring states and explores law differentials with more distant states are called for.

This study suggests that without cooperative legislative actions in neighboring states, efforts in 1 state to strengthen firearm legislation and prevent firearm deaths may be undermined. It also suggests that federal gun regulations may be particularly useful because they affect all states, and legislation such as the Bipartisan Background Checks Act of 2019 passed by the House in February 2019 permits cautious optimism on that front.

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SUPPLEMENTAL MATERIAL

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