Exploring the impact of ‘stand-your-ground’ legislation on per capita victims of gun violence in the US

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Abstract

On the topic of gun violence in the US, there is relatively little data-driven research on how policy decisions regarding firearm ownership and their use for self-defense impact incidents of gun violence. The present work explores publicly available data on gun violence in the US between 2014 and 2017, by comparing individual states and their respective gun policies – specifically, whether the state has introduced a so-called 'stand your ground'-law. This is done using Bayesian methods in R and stan. Some prior work exists which indicates that these laws are associated with an increase in firearms homicides. Results provide some support for this notion, but more data is required to make robust conclusions.

Introduction

In the US, using deadly force for self-defence is legal in certain states and contexts. The 'castle doctrine', which is established in many states, allows a user to protect themselves using deadly force against an intruder in their home, with no duty to retreat from the encounter if possible. So-called 'stand-your-ground' laws (henceforth abbreviated SYG-laws) extend this privilege to areas outside the home, often including anywhere one can legally be present (National Conference of State Legislatures, 2023). The phrase 'stand your ground', and variations thereof, is only used in some of these laws. Colloquially, however, they will still be referred to as 'stand your ground'-laws by media outlets – for example, Wyoming doesn't include the phrase in its 2018 bill (National Conference of State Legislatures, 2023), but the law has been called a 'stand your ground'-bill nonetheless (Beck, 2018). Some states do not have an explicitly codified SYG-law, but "permit the use of deadly force in self-defense through judicial decisions or jury instructions" (National Conference of State Legislatures, 2023, ll. 15–16).

The intent is to protect citizens and deter crime, but there is "a paucity of reliable information about the effects of such policies." (Smart et al., 2023, p. iii). SYG-laws may indeed have the opposite effect. In a comprehensive report on gun policy and its ties to gun violence, Smart et al. (2023) conclude that SYG-laws may increase firearms homicides, and even homicides in general. The former conclusion was considered to have 'supportive evidence', meaning that "at least three studies not compromised by serious methodological weaknesses found suggestive or significant effects in the same direction using at least two independent data sets" (Smart et al., 2023, p. vii).

The present paper attempts to reproduce this link between SYG-laws and more deaths and injuries from gun violence.

Methods

Overview and research question

In this paper, Bayesian regression models are used to analyse differences in gun violence in US states with and without SYG-laws. Data from all 50 states are included in the analysis, but not from other US territories (such as the District of Columbia). The data covers a period of four years (January 2014 to December 2017). The *number of killed and/or wounded per month, per state and per capita* is used as datapoints, leaving 48 datapoints per state. Per capita in this case refers to per 1 million people.

This study is exploratory, rather than explicitly hypothesis driven. The overall research question is:
Do stand-your-ground-laws cause an increase in people killed or wounded by firearms?

Software

The code produced for this paper can be found in the following GitHub repository: https://github.com/AsgerLChristiansen/Data-Science-Exam-2023/tree/main

It was coded in R (R Core Team, 2022) using RStudio version 4.2.0 (*RStudio*, 2022). Furthermore, modelling was done using the probabilistic programming language stan, version 2.32 (Stan Development Team, 2023) R packages used include pacman (Rinkler & Kurkiewicz, 2018), stringr (Wickham, 2022), cmdstanr (Gabry et al., 2022), posterior (Bürkner et al., 2022), ggplot2 (Wickham, 2016) and tidyverse (Wickham et al., 2019).

Data acquisition

The data was published on kaggle.com by Ko (2018), using data from the Gun Violence Archive website (*Gun Violence Archive*, n.d.). Gun Violence Archive is, according to its own mission statement, "a not for profit corporation formed in 2013 to provide free online public access to accurate information about gun-related violence in the United States" (*About | Gun Violence Archive*, n.d., l. 4). Entries listed on the website include number of victims, injured and killed, and several descriptive labels of the incident (suicide, accidental, home invasion, etc.). There are over 260.000 data points, each with its own set of labels. Table 5 in Appendix A shows all the different labels found in the data, and how many of them there were. Technically, data from 2013 and 2018 are available, but entries are sparse, and as a result this study only analyses data from 2014 to 2017 to avoid using incomplete data. In order to adjust per capita estimates, population data for all 50 states throughout the period was acquired from the US Census Bureau's website (US Census Bureau, 2021).

Categorization of states by gun laws

As mentioned, exactly how states allow their citizens to use deadly force in self defence with no duty to retreat varies. As such, categorization of states into those with and without such an allowance will necessarily be an oversimplification. For the purposes of this paper, any state in which a citizen has *no duty to retreat* from an attacker outside of their home, either through explicit legal text or jury instructions, will be considered a 'stand your ground'-state (henceforth SYG-state). Any state in which this is not the case will be considered a 'duty to retreat' state (henceforth DTR-state). In the particular case of Wisconsin, there is neither a SYG-law, nor an affirmative duty to retreat (Cherella, 2021). For the purposes of this analysis, it was classified as a SYG-state.

No examples of a state *repealing* a SYG-law was found. As a result, states without SYG-laws in 2023 are assumed to have never had them in the first place. Compounding the issue of accurate categorization, information was often difficult to come by. In certain cases, access to news articles or government websites was restricted outside the US. As such, this paper relies on what information could be found from news sources, blog posts from law firms and the like, rather than an exhaustive legal analysis of each state's laws. Another issue is the question of *when* a law was implemented, relative to the period in which data is available (2014 through 2017). It was not always possible to verify precisely when a law was implemented. In some cases, it was possible to verify that a law had been in place at least before the period covered by the data. Jury instructions were particularly difficult to find implementation dates on, and as a result, states with such jury instructions are assumed to have had them throughout the entire period covered by the data. Ideally, the data would cover a transition period for many of the states, with data points both before and after the law was implemented. To the best of the author's

ability to determine, however, this is only the case for two states: Iowa and Missouri. These two states were analysed separately from the rest (see Analysis and Modelling).

This left a remaining 48 states which either did or did not have a SYG-law in place throughout the entire period. For these 48 states, then, any evidence found will necessarily be correlational. Table 1 shows how each state was categorized (Group 1 is SYG, group 2 is DTR. Iowa and Missouri have no group), and from what source the information came.

Finally, it was generally observed that almost all states have a castle doctrine in place, even if they do not have an explicit SYG-law.

Table 1: Overview of states with and without SYG-laws.

State	Method	Group	Implemented in	Source
Alabama	Passed into law	1	2006	(Beyerle, 2012)
Alaska	Passed into law	1	2013	(Caroll, 2014)
Arizona	Passed into law	1	2010	(Howard Fischer Capitol Media Services, 2012)
Arkansas	Passed into law	2	2021	(Moritz, 2021)
California	Jury instructions	1	2006	(Advisory Committee on Criminal Jury Instructions & Guerrero, 2022)
Florida	Passed into law	1	2012	(NPR, 2012)
Georgia	Passed into law	1	2006	(Wallace, 2012)
Colorado	Appears to be case law.	1	Unclear	(Becker, 2023)
Connecticut	Has no law.	2	NA	(Randall & DeBoer, 2012)
Delaware	Has no law.	2	NA	(Fries, n.d.)
Hawaii	Has no law.	2	No law passed as of 2022.	(Davis, 2021; Dower & March 10, 2022)
Idaho	Passed into law	1	2018	(Russell, 2018)
Illinois	Case law	1	Since at least the 20th century.	(Pearson & Chicago Tribune reporter, 2013)
Indiana	Passed into law	1	2006	(Keffer Hirschauer LLP, 2022)
Iowa	Passed into law	NA	July 1st, 2017	(Haley, n.d.; Opsahl, n.d.)
Kansas	Passed into law	1	At least since 2012.	(Hanna & Hollingsworth, 2022)
Kentucky	Passed into law	1	2006	(Parham, 2023)
Louisiana	Passed into law	1	2006	(Justia Law, n.d.-b)
Maine	No law.	2	NA	(Maine Legislature, n.d.)
Maryland	No law.	2	NA	(Maronick Law LLC, 2023)
Massachusetts	No law.	2	NA	(Fernandez Firm, 2020)
Michigan	Passed into law	1	2006	(Martin, 2012)
Minnesota	No law.	2	NA	(FindLaw, 2018)
Mississippi	Passed into law	1	2010	(Justia Law, n.d.-a)
Missouri	Passed into law	NA	May 13th, 2016	(Hancock, 2016)
Montana	Passed into law	1	2009	(Fischer-Zernin, 2013)
North Dakota	Passed into law	2	2021	(Turley, 2021; Valley News Live, 2021)

Nebraska	No law.	2	NA	(Petersen, 2023)
New Jersey	No law	2	NA	(*Your Castle Doctrine Rights in New Jersey | Testa Heck Testa & White, P.A.*, 2021)
Nevada	Passed into law	1	2011	(*2011 Statutes of Nevada, Pages 257-382*, n.d., p. 265)
New Hampshire	Passed into law	1	2011	(Citizens Count Editor, n.d.)
New Mexico	Jury instructions	1	Unclear	(Mkhitarian, 2020)
New York	No law	2	NA	(Drenon, 2023)
North Carolina	Passed into law	1	2011	(Jetton & Meredith, 2023)
Ohio	Passed into law	2	2021	(Juris Magazine, 2021)
Oklahoma	Passed into law	1	In place in 2013	(Phillips, 2013)
Oregon	Oregon supreme court decision	1	2007	(Kaufman, 2013)
Pennsylvania	Passed into law	1	2011	(Awad, 2013)
Rhode Island	No law	2	NA	(The Law Office of Thomas C. Thomasian, 2020)
South Carolina	Passed into law	1	2006	(South Carolina Legislature, n.d., secs 16-11–440)
South Dakota	Passed into law	2	2021	(KOTA staff, 2021)
Tennessee	Passed into law	1	2007	(Burke, 2012)
Texas	Passed into law	1	2007	(Wentworth et al., 2007)
Utah	Passed into law	1	1994	(Gehrke, 2012)
Vermont	Jury instruction	1	Unclear	(National Conference of State Legislatures, 2023)
Virginia	Passed into law	1	At least since 2012.	(RVAnews staff, 2012)
Washington	Case law	1	2003	(Kornfeld, 2013)
West Virginia	Passed into law	1	Since at least 2012.	(Crum, 2012)
Wisconsin	Neither a SYG law OR affirmative duty to retreat	1	NA	(Cherella, 2021)
Wyoming	Passed into law	2	2018	(Beck, 2018; National Conference of State Legislatures, 2023)

Preprocessing

Data Selection

The dataset contains over 260.000 incidents of gun violence, far from all of which are relevant for the present paper. Deciding which data points to include wasn't a trivial challenge. Incidents include accidental firearms discharges, children playing with guns, school shootings, etc. As mentioned, each data point has several descriptive labels, with no upper limit to how many labels an incident can have. For example, 'officer-involved shooting' and 'accidental discharge' are not necessarily mutually exclusive. Thus, there is ripe opportunity for including or excluding the wrong incidents. Solving this problem perfectly would require manually flagging each incident as appropriate or not for the analysis. Alternatively, one can investigate how many data points will be removed if a certain label is excluded, and balance excluding an irrelevant label with the probability that it will remove far too many incidents

that should be included. The latter option was done here. After some data exploration, two datasets were created as subsets of the larger dataset.

Dataset 1: Firearms homicides in general, excluding police shootings and suicide

The first, broader dataset is filtered to include all firearms-related homicides, to investigate the claim that SYG-laws increase overall firearms homicides (Smart et al., 2023). All incidents in this dataset must include the label 'Shot - Dead (murder, accidental, suicide)'. Furthermore, the labels 'Officer Involved Shooting - subject/suspect/perpetrator killed' and 'Suicide^' [sic] were excluded. The reason to exclude suicides should be obvious. Excluding officer-involved shootings of perpetrators is that police violence is a complex topic that may vary greatly by state, and its impact on gun violence is beyond the scope of this paper. After filtering out these two labels still results in a dataset (henceforth referred to as the 'homicide data') with over 93.000 incidents. An overview of this dataset can be found in Table 6, Appendix A. Other labels (such as 'Suicide – Attempt') were considered for removal, but ultimately weren't due to how comparably few data points were labelled as such.

Dataset 2: Killed and wounded in defensive use of firearms, excluding Home Invasions

The second dataset was created with the intention of a investigating a particular kind of homicide. Correlating overall homicides with SYG-laws is one thing, but ultimately the laws are about self-defence, and it seems reasonable to assume that self-defence-related shootings especially would increase as the result of implementing a SYG-law, as citizens become less inclined to retreat and more inclined to fire. As such, this study also looked at data labelled 'Defensive Use' (or a variant thereof). Additionally, since SYG laws are an expansion of the castle doctrine, the effect of interest should logically occur outside the home. As such, all labels referring to 'Home Invasion' of some kind were filtered out. This left a much smaller, but more specific dataset with 5058 entries (henceforth labelled 'defensive use data'). To make up for the significant loss in data, all analyses on defensive use data in this paper count both killed *and* injured (henceforth referred to as 'victims'), rather than simply homicides.

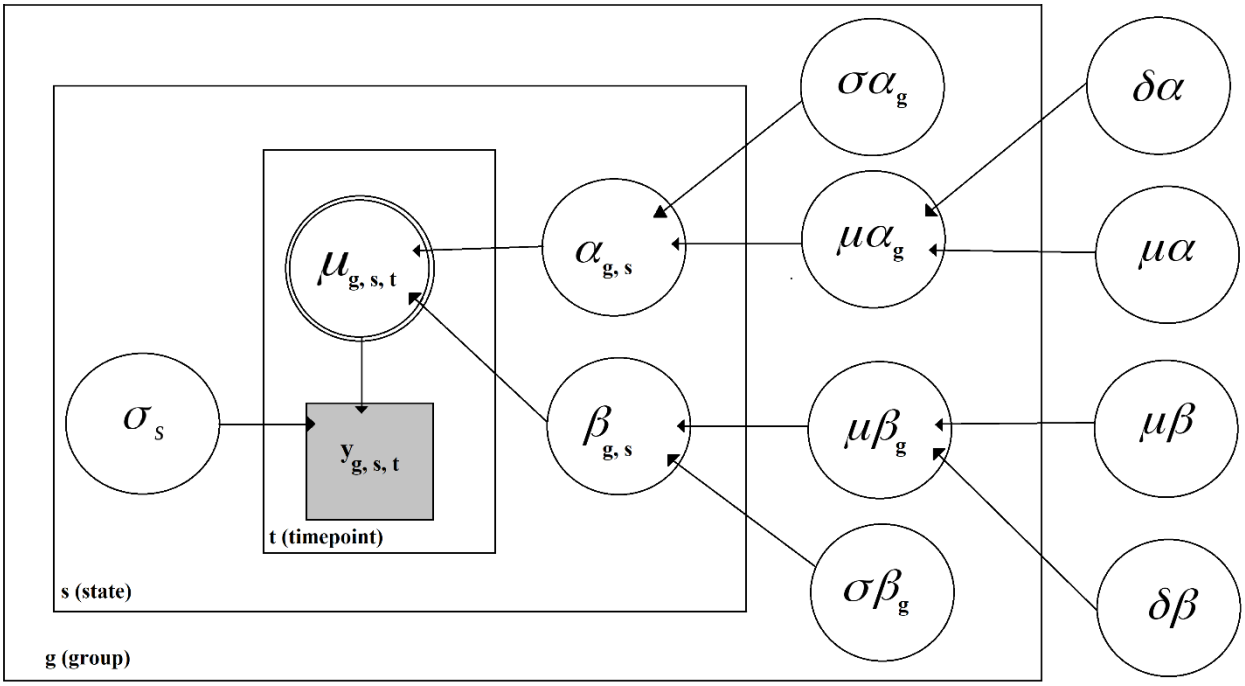
Analysis and Modelling

Two models were constructed, henceforth referred to as Model 1 and Model 2. A DAG and mathematical formulation of Model 1 is shown in figure 1.

Model 1 is a Bayesian hierarchical regression model. At the level of each individual state, the model fits a regression line to that state's monthly homicides or victims, adjusted per capita. The parameter $\alpha_{g,\,s}$ is that state's intercept (how many homicides/victims per capita in January 2014 in this state?), and $\beta_{g,\,s}$ is the slope. $\beta_{g,\,s}$ is a coefficient for the predictor *t,* which represents the number of months passed since January 2014, in order to model whether there is a linear trend over time in that state.
At higher levels, states are explicitly assumed to be grouped together into two groups, as per Table 1. Group 1 represents SYG-states, and group 2 represents DTR-states. Each state's regression parameters are assumed to be derived from the average of their group, and drawn from a normal distribution, parameterized by a mean and variance per group, per parameter. For example, if Alaska is state 2 and belongs to group 1, then its regression parameters $\alpha_{1,\,2}$ and $\beta_{1,\,2}$ are derived, respectively, from the normal distribution $N(\mu\alpha_1, \sigma\alpha_1)$ and $N(\mu\beta_1, \sigma\beta_1)$. The group means are in turn assumed to deviate in opposite directions from an overall country-level mean. For example, the average intercept parameter for the entire country is $\mu\alpha$, and the group mean intercepts deviate from this value by $\pm\delta\alpha/2$. The sign on $\delta\alpha$, then, indicates the directionality of the effect.

Based on the findings of Smart et al. (2023), weakly informed priors were chosen. Specifically, the model assumes that on average, states in group 1 both have larger intercepts *and* a higher trend across the 48-month period. Model 1 was then applied to both homicide and defensive use data. Figure 1A and 1B show the respective prior sets chosen.

Figure 1: Directed Acyclical Graph of Hierarchical Regression Model



A: Priors for Homicide Data Analysis

$$\mu\alpha \sim Gaussian(2, 0.5)$$
$$\mu\beta \sim Gaussian(1, 1)$$
$$\delta\alpha \sim Gaussian(0.5, 2)$$
$$\delta\beta \sim Gaussian(1, 2)$$
$$\sigma\alpha_g \sim Gamma(1, 1)$$
$$\sigma\beta_g \sim Gamma(1, 1)$$
$$\mu\alpha_1 = \mu\alpha + \frac{\delta\alpha}{2}$$
$$\mu\alpha_2 = \mu\alpha - \frac{\delta\alpha}{2}$$
$$\mu\beta_1 = \mu\beta + \frac{\delta\beta}{2}$$
$$\mu\beta_2 = \mu\beta - \frac{\delta\beta}{2}$$
$$\alpha_{g,s} \sim Gaussian(\mu\alpha_g, \sigma\alpha_g)$$
$$\beta_{g,s} \sim Gaussian(\mu\beta_g, \sigma\beta_g)$$
$$\mu_{g,s,t} = \alpha_{g,s} + \beta_{g,s}t$$
$$\sigma_s \sim Gamma(1, 1)$$
$$y_{g,s,t} \sim Normal(\mu_{g,s,t}, \sigma_s)$$

B: Priors for Defensive Use Data Analysis

$$\mu\alpha \sim Gaussian(0.5, 0.2)$$
$$\mu\beta \sim Gaussian(1, 0.5)$$
$$\delta\alpha \sim Gaussian(0.5, 1)$$
$$\delta\beta \sim Gaussian(1, 1)$$
$$\sigma\alpha_g \sim Gamma(1, 1)$$
$$\sigma\beta_g \sim Gamma(1, 1)$$
$$\mu\alpha_1 = \mu\alpha + \frac{\delta\alpha}{2}$$
$$\mu\alpha_2 = \mu\alpha - \frac{\delta\alpha}{2}$$
$$\mu\beta_1 = \mu\beta + \frac{\delta\beta}{2}$$
$$\mu\beta_2 = \mu\beta - \frac{\delta\beta}{2}$$
$$\alpha_{g,s} \sim Gaussian(\mu\alpha_g, \sigma\alpha_g)$$
$$\beta_{g,s} \sim Gaussian(\mu\beta_g, \sigma\beta_g)$$
$$\mu_{g,s,t} = \alpha_{g,s} + \beta_{g,s}t$$
$$\sigma_s \sim Gamma(1, 1)$$
$$y_{g,s,t} \sim Normal(\mu_{g,s,t}, \sigma_s)$$

Model 2 is designed to analyse the data from Iowa and Missouri and is significantly simpler. It uses two predictors: *t*, once again representing months since January 2014, and *l*, a dummy variable representing whether a SYG law was in effect during that month. The parameter α, β, and γ denote intercept, and regression coefficients of the two predictors respectively. The exact mathematical formulation and priors chosen is as follows:

$$\alpha \sim Gaussian(0.2, 0.1)$$
$$\beta \sim Gaussian(0.1, 0.1)$$
$$\gamma \sim Gaussian(0.1, 0.1)$$
$$\mu_t = \alpha + \beta * t + \gamma * l$$
$$\sigma \sim Gamma(1, 1)$$
$$y_t \sim Normal(\mu_t, \sigma)$$

Model 2 was applied separately to both homicide and defensive use data, for both Iowa *and* Missouri, for a total of four separate analyses. In summation, six analyses were undertaken:

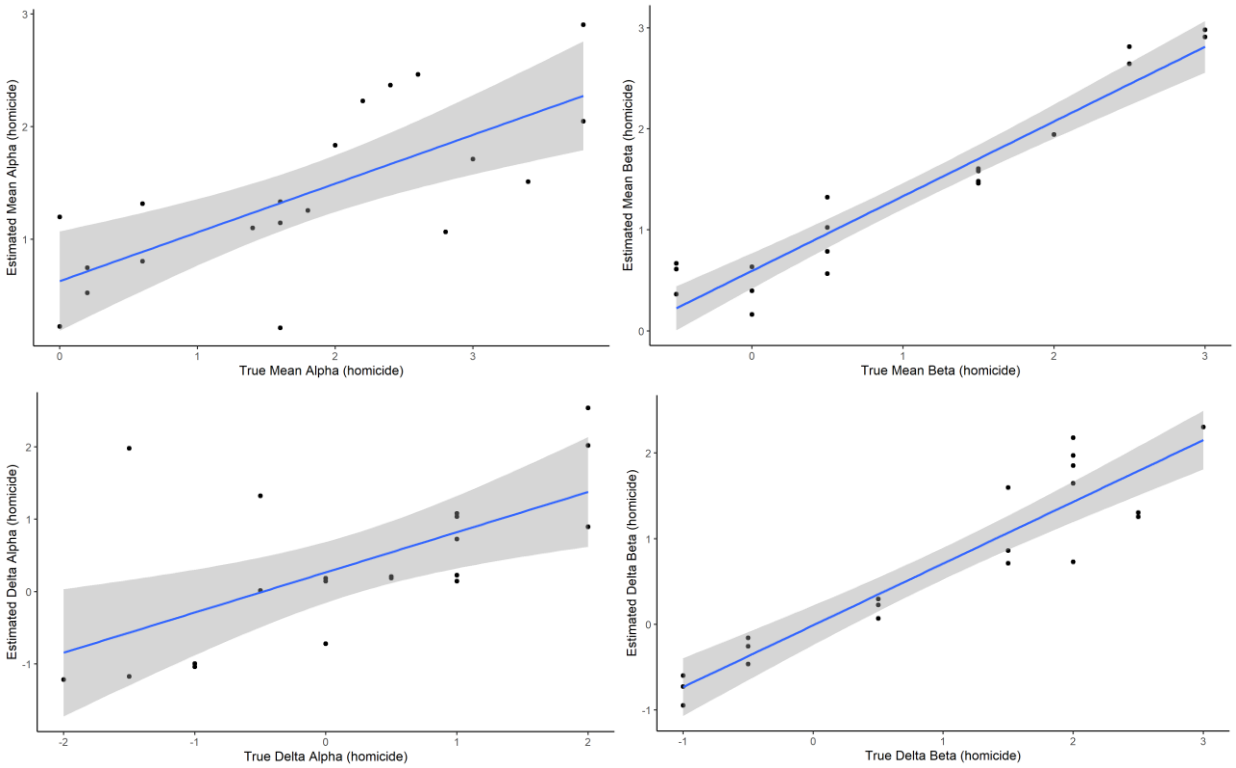
- **Analysis 1:** Model 1 applied to 48 states' homicide data.
- **Analysis 2:** Model 1 applied to 48 states' defensive use data.
- **Analysis 3:** Model 2 applied to Iowa's homicide data.
- **Analysis 4:** Model 2 applied to Iowa's defensive use data.
- **Analysis 5:** Model 2 applied to Missouri's homicide data.
- **Analysis 6:** Model 2 applied to Missouri's defensive use data.

Parameter recovery

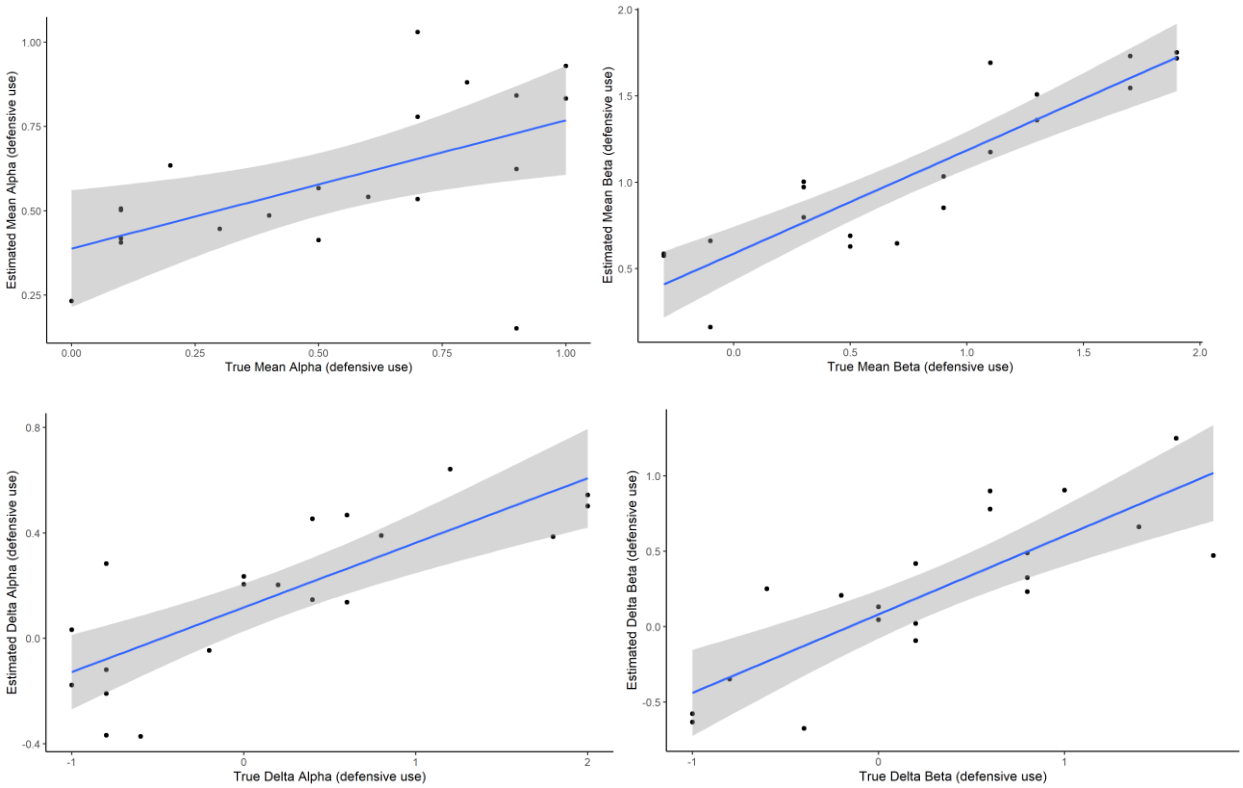
For Analyses 1 and 2, parameter recovery was undertaken for all four population level parameters and group variance estimates. In general, though parameter recovery wasn't perfect, estimates of parameters were proportional to true parameters, and on a similar scale. Figure 2A and 2B show the population level parameters for each analysis respectively. Group level sigma-parameter recovery figures can be found in Appendix B. Parameter recovery was not undertaken for analyses 3-6. All parameter recovery fittings, and subsequent analyses, were run with 1 chain, 1 thread per chain and 1000 warmup iterations and 2000 samples. There were no convergence issues.

Figure 2: *μα, μβ, δα* and *δβ* parameter recovery

A: Homicide parameter recovery



B: Defensive use parameter recovery



Results

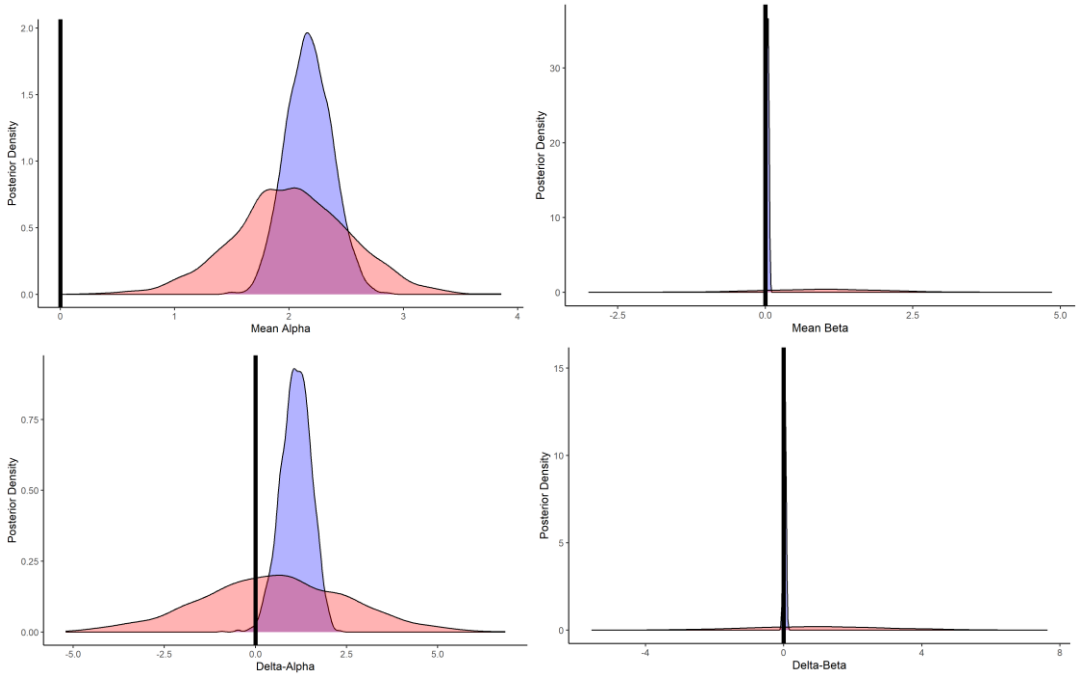
Analyses 1 and 2: Hierarchical regression modelling of homicide and defensive use data

Table 2 displays parameter estimates for the first two analyses. Figure 3 shows prior-posterior differences.

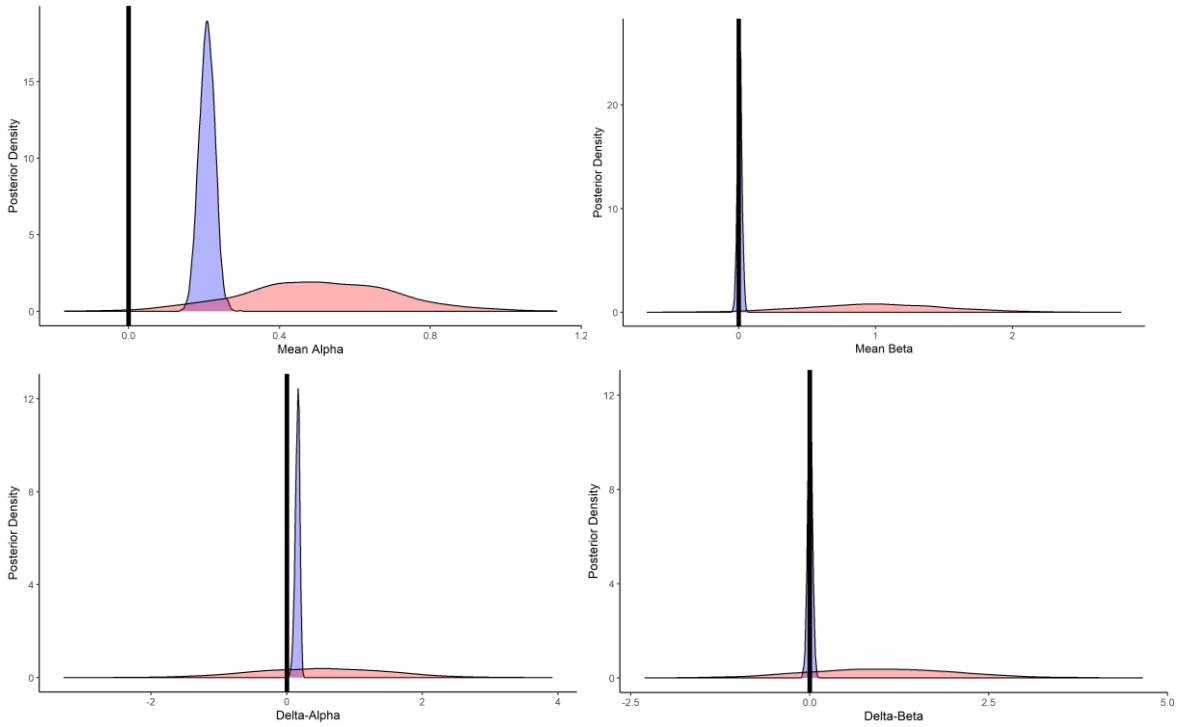
Table 2: Parameter estimates, credibility intervals and R-hat values for analyses 1 and 2

Homicide analysis results									
Variable	mean	Median	Sd	mad	q5	q95	rhat	ess bulk	ess tail
lp__	-1069	-1068	9.57	9.59	-1085.2	-1054.3	1	670.66	1045.
mu_alpha	2.17	2.17	0.20	0.21	1.85	2.51	1	3788.76	1257.3
mu_beta	0.04	0.04	0.02	0.02	0.02	0.07	1	3630.64	1709.8
delta_alpha	1.11	1.12	0.41	0.41	0.41	1.75	1	2950.9	1361.2
delta_beta	0.03	0.03	0.04	0.035	-0.03	0.08	1	3287.18	1731.2
Defensive use analysis results									
Variable	Mean	Median	Sd	mad	q5	q95	rhat	ess bulk	ess tail
lp__	1409	1409.3	10.03	9.87	1391.7	1424.3	1	516.53	883.67
mu_alpha	0.21	0.21	0.02	0.02	0.17	0.24	1	796.81	1135.85
mu_beta	0.00	0.00	0.02	0.01	-0.02	0.03	1	2324.78	1482.23
delta_alpha	0.16	0.16	0.03	0.03	0.1	0.21	1	1153.09	1315.8
delta_beta	0.00	0.00	0.03	0.03	-0.05	0.05	1	2597.45	1319.68

Figure 3: Prior (red) and posterior (blue) plots of analyses 1 and 2.
A: Analysis of overall homicide rate across 48 states



B: Analysis of total killed and wounded in defensive use of firearms in 48 states



For homicide, the population average intercept μα, as well as δα were positive. This implies that on average, roughly 2.2 firearms homicides per million citizens occurred in the US in January 2014, with a small positive difference of .15 firearms homicides per million citizens for SYG states in January 2014,

compared to DTR states. Neither of the 95% credibility intervals intersect with 0. On the contrary, the country level average slope, μβ was estimated on average to be zero, with no meaningful difference between states with and without SYG-laws. This implies that, according to this data, homicides country-wide haven't changed much, with roughly 2.2 homicides per month being the average for the entire period, and slightly more homicides per month in SYG states. Similarly for defensive use, there is a small but noticeable difference between states with and without SYG laws in the average intercept parameter, but none for the slope parameter, with 0.21 victims per month and a comparatively large δα of .16. This implies that, while the numbers are small, SYG states had did have noticeably more victims of gun violence associated with defensive use than DTR states.

Iowa and Missouri

Table 3 shows parameter estimates for Iowa and Missouri's homicide and defensive use data. Figure 5 show prior-posterior plots of population level parameters.

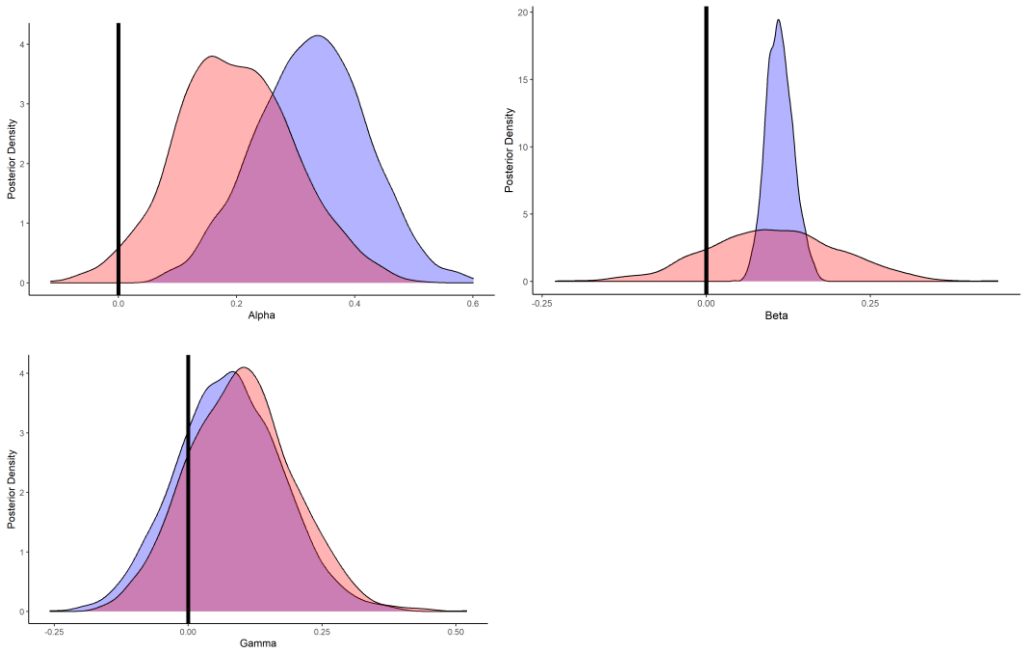
Table 3: Parameter estimates, credibility intervals and R-hat values for analyses 3, 4, 5 and 6

Iowa homicide analysis results									
Variable	mean	Median	Sd	Mad	q5	q95	Rhat	ess bulk	ess tail
lp__	-21.3	-21.06	1.47	1.26	-24.2	-19.65	1	646.79	844.4
Alpha	0.33	0.33	0.09	0.09	0.17	0.48	1	707.16	518.26
Beta	0.11	0.11	0.02	0.02	0.08	0.15	1	990.67	759.62
Gamma	0.08	0.08	0.1	0.1	-0.08	0.24	1	1329.9	1386.3
Sigma	0.87	0.86	0.09	0.09	0.73	1.03	1	929.37	813.86
Iowa defensive use analysis results									
Variable	Mean	Median	Sd	Mad	q5	q95	Rhat	ess bulk	ess tail
lp__	42.93	43.3	1.49	1.23	39.97	44.63	1	700.45	844.43
Alpha	0.14	0.14	0.05	0.06	0.05	0.23	1	819.52	522.78
Beta	0.00	0.00	0.00	0.00	-0.02	0.00	1	809.6	885.57
Gamma	0.05	0.05	0.07	0.07	-0.06	0.16	1	1034.4	993.55
Sigma	0.22	0.22	0.02	0.02	0.19	0.26	1	1130	1089.87
Missouri homicide analysis results									
Variable	Mean	Median	Sd	Mad	q5	q95	Rhat	ess bulk	ess tail
lp__	-91.57	-91.25	1.49	1.35	-94.49	-89.78	1	628.3	1048.7
Alpha	0.37	0.37	0.1	0.1	0.19	0.54	1	1110.27	638.13
Beta	0.6	0.6	0.04	0.04	0.53	0.66	1	1520.81	1269.37
Gamma	0.2	0.19	0.1	0.1	0.04	0.36	1	1403.6	1210.9
Sigma	1.94	1.95	0.05	0.05	1.84	2	1	830.16	531.58
Missouri defensive use analysis results									
Variable	mean	Median	Sd	Mad	q5	q95	Rhat	ess bulk	ess tail
lp__	24.4	24.8	1.55	1.27	21.25	26.12	1	533.88	751.66

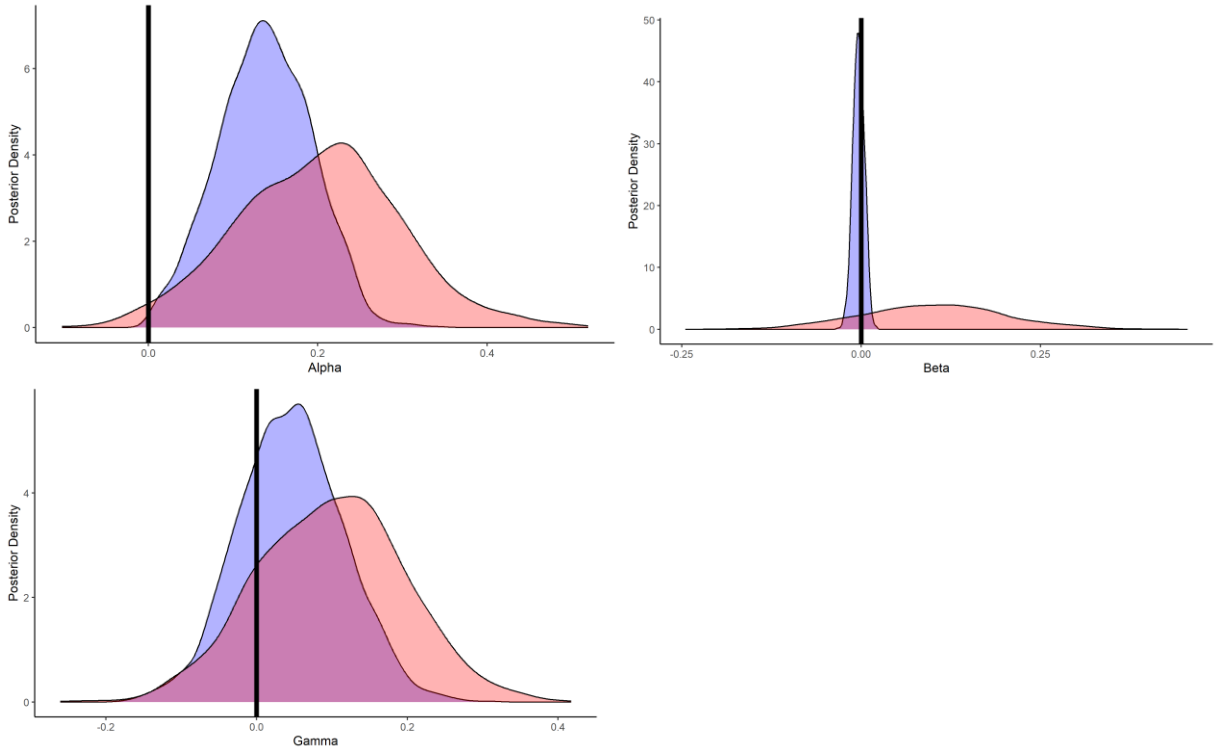
Alpha	0.21	0.2	0.07	0.07	0.09	0.33	1	744.95	479.
Beta	0.03	0.03	0.01	0.01	0.02	0.05	1	877.92	958.3
Gamma	0.14	0.14	0.07	0.07	0.02	0.25	1	1368.1	1098.1
Sigma	0.34	0.34	0.03	0.03	0.29	0.4	1	948.24	1046.4

Figure 4: Prior (red) and posterior (blue) plots of analyses 3 and 4

A: Homicide analysis (Iowa)



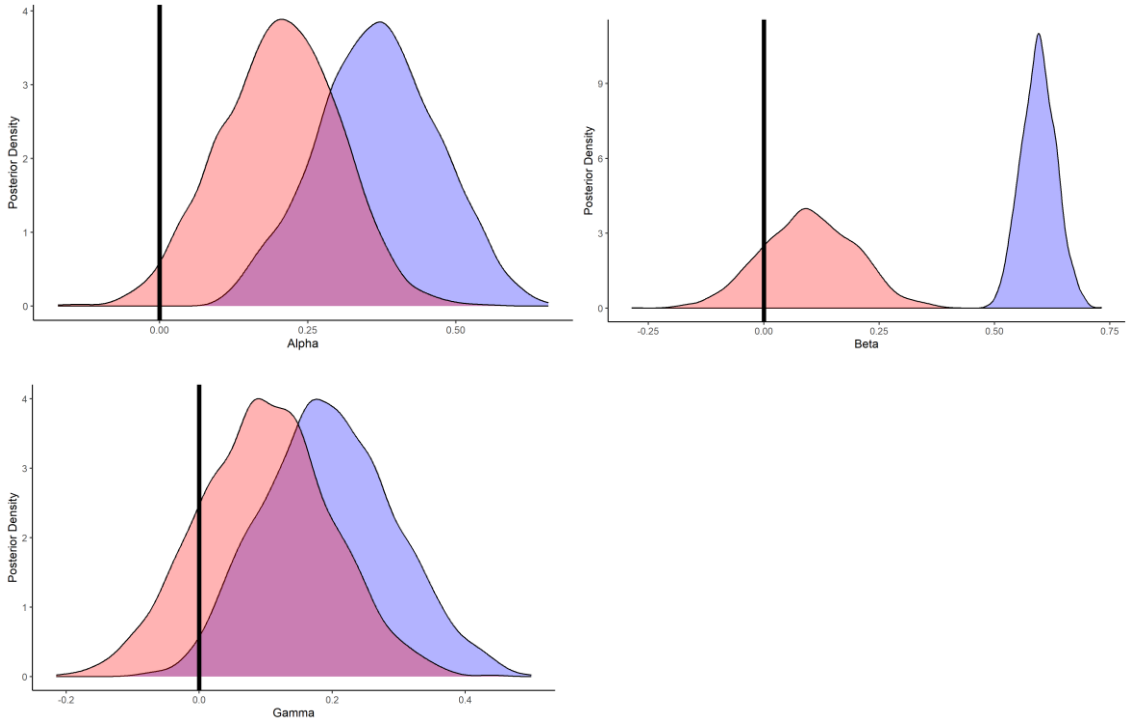
B: Defensive use analysis (Iowa)



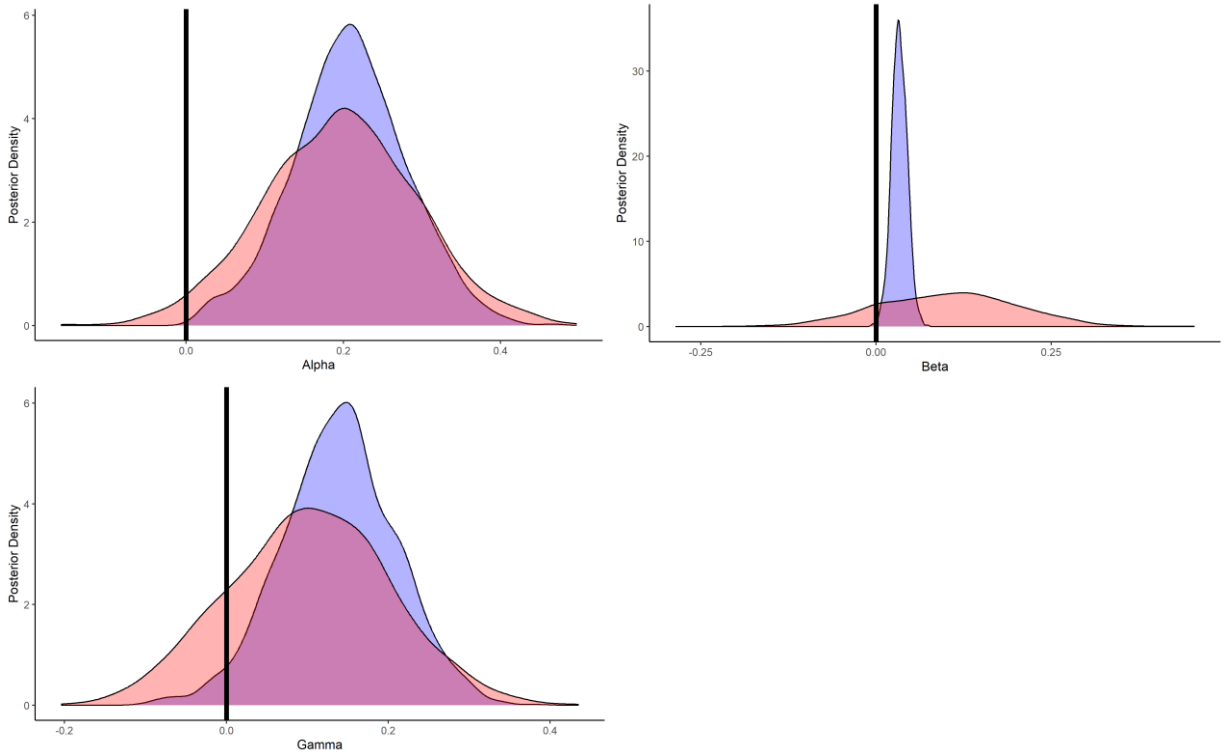
For Iowa's homicide data, α and β are estimated as positive, but the model seems to have learned very little from the data about γ. Given that there is only five months of data (which turns into 5 data points) after the implementation of the law, this is perhaps unsurprising. The pattern is similar for defensive use – the 95% credibility interval for gamma is wide and intersects with 0. As a result, while gun violence

seems to be increasing slightly over time, there seems to be very little direct effect of the law in the Iowa data.

Figure 5: Prior (red) and posterior (blue) plots of analyses 5 and 6
A: Homicide analysis (Missouri)



B: Defensive use analysis (Missouri)



Missouri results are slightly more interesting. Overall, for both homicide and defensive use, there is a positive trend across the whole period. It seems Missouri homicide rates rise sharply in this period.

There is *some* indication of an effect of γ in both the homicide and defensive use data. While not much narrower than the prior in both cases, the posterior does shift to the right. In short, while there is tentative indication that the law change is playing a role and causing a small positive increase in homicides, it is far from certain. More likely than not, there is once again insufficient data for the model to learn much, and thus insufficient data for firm conclusions.

Discussion

The main limitation of this study is the time period in which the data was collected. Only two states changed their laws in the period that the data was collected in, which means that for most states, the present study at best shows correlation. For those states that did change their laws during this period, there is very little data available. An additional problem is that the dataset isn't perfectly labelled – the homicide dataset (as can be seen in Table 6) somehow contains a few incidents labelled both 'No Death' and 'Shot – Dead'. So not only is data quantity an issue, but data *quality* is also an issue. All in all, this paper only offers very moderate evidence of a relation between SYG-laws and gun violence.

With all that said, what evidence there is points in the expected direction. If there is a link between stand-your-ground laws and firearms homicides, both in general and in defensive use actions only, that relationship appears to be positive. In other words, the findings of the present paper are far from robust, but they do line up with the conclusions of Smart et al. (2023). Namely, that more liberal self-defence laws correlate with more people getting killed or injured, both in self-defence situations and in general.

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Appendix A: Additional Information on Dataset Labels

Table 5 shows each unique label and how many times that label appears in the entire dataset. Table 6 shows the same, but for the homicide dataset. Finally, table 7 shows the same, but for the defensive use dataset.

Table 5: Count of each individual label for total dataset

unique_characteristics	count
Shot - Wounded/Injured	93926
Shot - Dead (murder, accidental, suicide)	53409
Non-Shooting Incident	44837
Shots Fired - No Injuries	35750
Possession (gun(s) found during commission of other crimes)	30863
Armed robbery with injury/death and/or evidence of DGU found	19723
Brandishing/flourishing/open carry/lost/found	19017
ATF/LE Confiscation/Raid/Arrest	17991

Officer Involved Incident	17988
Possession of gun by felon or prohibited person	17165
Drug involvement	17099
Drive-by (car to street, car to car)	13655
Institution/Group/Business	11046
Domestic Violence	10841
Home Invasion	10641
Accidental Shooting	8213
Stolen/Illegally owned gun{s} recovered during arrest/warrant	7560
Defensive Use	7391
Accidental/Negligent Discharge	6422
Gun(s) stolen from owner	6313
Gang involvement	5677
Accidental Shooting – Injury	5366
Suicide^	5344
Home Invasion - No death or injury	5152
TSA Action	5036
Car-jacking	4944
Officer Involved Shooting - subject/suspect/perpetrator killed	4655
Bar/club incident - in or around establishment	4590
Officer Involved Incident - Weapon involved but no shots fired	3984
Pistol-whipping	3751
Officer Involved Shooting - subject/suspect/perpetrator shot	3697
Under the influence of alcohol or drugs (only applies to the subject/suspect/perpetrator)	3494
Non-Aggression Incident	3050
Home Invasion - Resident injured	2952
Officer Involved Shooting - Shots fired, no injury	2827
School Incident	2805
Defensive Use - Victim stops crime	2732
Kidnapping/abductions/hostage	2677
Defensive Use - Crime occurs, victim shoots subject/suspect/perpetrator	2649
Murder/Suicide	2480
Shootout (where VENN diagram of shooters and victims overlap)	2331
Officer Involved Shooting - subject/suspect/perpetrator surrender at standoff	2288
Criminal act with stolen gun	2146
Road rage	2140
Child Involved Incident	2123
Assault weapon (AR-15, AK-47, and ALL variants defined by law enforcement)	2052
Shots fired, no action (reported, no evidence found)	2042
Gun at school, no death/injury - elementary/secondary school	2031
Self-Inflicted (not suicide or suicide attempt - NO PERP)	1887
Accidental Shooting – Death	1729
BB/Pellet/Replica gun	1715

Mass Shooting (4+ victims injured or killed excluding the subject/suspect/perpetrator, one location)	1637
LOCKDOWN/ALERT ONLY: No GV Incident Occurred Onsite	1478
Defensive Use - Stand Your Ground/Castle Doctrine established	1392
Implied Weapon	1272
Playing with gun	1140
Officer Involved Shooting - Officer shot	1091
Home Invasion - subject/suspect/perpetrator injured	1066
Defensive Use - WITHOUT a gun	1008
Officer Involved Shooting - subject/suspect/perpetrator suicide at standoff	976
Home Invasion - Resident killed	964
Home Invasion - subject/suspect/perpetrator killed	851
Defensive Use - Shots fired, no injury/death	819
Unlawful purchase/sale	779
House party	767
Animal shot/killed	723
ShotSpotter	702
Child injured (not child shooter)	685
Sex crime involving firearm	654
Concealed Carry License – Victim	624
Child picked up & fired gun	607
Suicide – Attempt	602
Gun shop robbery or burglary	597
Accidental Shooting at a Business	586
Police Targeted	575
Concealed Carry License – Perpetrator	564
Defensive Use - Good Samaritan/Third Party	538
Hunting accident	504
Cleaning gun	501
Attempted Murder/Suicide (one variable unsuccessful)	469
Gun range/gun shop/gun show shooting	434
Defensive use - No shots fired	406
Thought gun was unloaded	403
Spree Shooting (multiple victims, multiple locations)	398
Officer Involved Shooting - subject/suspect/perpetrator unarmed	327
NA	326
Child killed (not child shooter)	281
Gun at school, no death/injury - university/college	276
Officer Involved Shooting - Officer killed	248
Guns stolen from law enforcement	233
School Shooting - elementary/secondary school	232
Officer Involved Shooting - Accidental discharge - no injury required	230
Child injured self	214

Workplace shooting (disgruntled employee)	175
Child killed self	167
Child with gun - no shots fired	165
School Shooting - university/college	161
Child injured by child	159
Officer Involved Shooting - subject/suspect/perpetrator suicide by cop	148
Officer Involved Shooting - Bystander shot	140
Gun buy back action	131
Hate crime	102
Mass Murder (4+ deceased victims excluding the subject/suspect/perpetrator , one location)	98
Child killed by child	88
Ghost gun	81
Mistaken ID (thought it was an intruder/threat, was friend/family)	80
Officer Involved Shooting - Bystander killed	31
Terrorism Involvement	30
Political Violence	13
NAV	2

Table 6: Count of each individual label for homicide dataset

unique_characteristics	**count**
Shot - Dead (murder, accidental, suicide)	44132
Shot - Wounded/Injured	7228
Domestic Violence	2736
Armed robbery with injury/death and/or evidence of DGU found	2552
Drive-by (car to street, car to car)	2053
Defensive Use	1970
Drug involvement	1823
Possession of gun by felon or prohibited person	1820
Possession (gun(s) found during commission of other crimes)	1758
Accidental Shooting	1738
Home Invasion	1656
Accidental Shooting – Death	1643
Gang involvement	1428
Accidental/Negligent Discharge	1279
Defensive Use - Crime occurs, victim shoots subject/suspect/perpetrator	1244
Bar/club incident - in or around establishment	1223
Institution/Group/Business	1050
Home Invasion - Resident killed	899
Mass Shooting (4+ victims injured or killed excluding the subject/suspect/perpetrator, one location)	757
Home Invasion - subject/suspect/perpetrator killed	727

Defensive Use - Stand Your Ground/Castle Doctrine established	652
Brandishing/flourishing/open carry/lost/found	628
Defensive Use - Victim stops crime	600
Child Involved Incident	554
Officer Involved Incident	547
Shootout (where VENN diagram of shooters and victims overlap)	528
Non-Aggression Incident	480
Playing with gun	479
Under the influence of alcohol or drugs (only applies to the subject/suspect/perpetrator)	368
Self-Inflicted (not suicide or suicide attempt - NO PERP)	327
Home Invasion - Resident injured	308
ATF/LE Confiscation/Raid/Arrest	298
Stolen/Illegally owned gun{s} recovered during arrest/warrant	281
House party	256
Car-jacking	233
Kidnapping/abductions/hostage	216
Road rage	205
Child picked up & fired gun	189
Child killed (not child shooter)	186
Assault weapon (AR-15, AK-47, and ALL variants defined by law enforcement)	178
Officer Involved Shooting - subject/suspect/perpetrator shot	177
Criminal act with stolen gun	174
Pistol-whipping	169
LOCKDOWN/ALERT ONLY: No GV Incident Occurred Onsite	166
Suicide - Attempt	158
Officer Involved Shooting - Officer killed	154
Child killed self	154
Concealed Carry License - Victim	149
Attempted Murder/Suicide (one variable unsuccessful)	146
Thought gun was unloaded	144
Hunting accident	144
Defensive Use - Good Samaritan/Third Party	127
Gun(s) stolen from owner	126
Spree Shooting (multiple victims, multiple locations)	123
Murder/Suicide	115
Home Invasion - subject/suspect/perpetrator injured	112
Officer Involved Shooting - subject/suspect/perpetrator surrender at standoff	99
Defensive Use - WITHOUT a gun	94
ShotSpotter	92
Child killed by child	87
Shots Fired - No Injuries	85
Child injured (not child shooter)	66

Mass Murder (4+ deceased victims excluding the subject/suspect/perpetrator , one location)	62
Concealed Carry License - Perpetrator	58
Officer Involved Shooting - Officer shot	57
Accidental Shooting - Injury	56
Gun range/gun shop/gun show shooting	55
Animal shot/killed	54
Accidental Shooting at a Business	54
Workplace shooting (disgruntled employee)	51
School Incident	48
BB/Pellet/Replica gun	43
Cleaning gun	43
Officer Involved Incident - Weapon involved but no shots fired	39
Hate crime	36
Officer Involved Shooting - Shots fired, no injury	35
Sex crime involving firearm	29
Mistaken ID (thought it was an intruder/threat, was friend/family)	27
School Shooting - university/college	26
Police Targeted	24
Officer Involved Shooting - subject/suspect/perpetrator suicide at standoff	23
Officer Involved Shooting - Bystander killed	22
Unlawful purchase/sale	21
School Shooting - elementary/secondary school	18
Defensive Use - Shots fired, no injury/death	17
Officer Involved Shooting - subject/suspect/perpetrator killed	12
Home Invasion - No death or injury	11
Shots fired, no action (reported, no evidence found)	10
Officer Involved Shooting - Bystander shot	8
Implied Weapon	8
Officer Involved Shooting - Accidental discharge - no injury required	7
Officer Involved Shooting - subject/suspect/perpetrator unarmed	6
Guns stolen from law enforcement	6
Defensive use - No shots fired	6
Officer Involved Shooting - subject/suspect/perpetrator suicide by cop	5
Non-Shooting Incident	4
Child injured by child	4
Gun shop robbery or burglary	3
Political Violence	2
Terrorism Involvement	1
Gun buy back action	1

Table 7: Count of each individual label for defensive use dataset

unique_characteristics	count
Defensive Use	5058
Shot - Wounded/Injured	2109
Defensive Use - Victim stops crime	1729
Defensive Use - Crime occurs, victim shoots subject/suspect/perpetrator	1631
Shot - Dead (murder, accidental, suicide)	1565
Armed robbery with injury/death and/or evidence of DGU found	1417
Brandishing/flourishing/open carry/lost/found	971
Shots Fired - No Injuries	885
Defensive Use - WITHOUT a gun	761
Institution/Group/Business	733
Defensive Use - Stand Your Ground/Castle Doctrine established	714
Non-Shooting Incident	679
Officer Involved Incident	635
Defensive Use - Shots fired, no injury/death	591
Domestic Violence	493
Defensive Use - Good Samaritan/Third Party	480
Concealed Carry License – Victim	395
Shootout (where VENN diagram of shooters and victims overlap)	345
Possession (gun(s) found during commission of other crimes)	340
Officer Involved Shooting - subject/suspect/perpetrator killed	303
Defensive use - No shots fired	259
Possession of gun by felon or prohibited person	254
Drug involvement	206
Officer Involved Shooting - subject/suspect/perpetrator shot	186
Bar/club incident - in or around establishment	183
Car-jacking	176
Under the influence of alcohol or drugs (only applies to the subject/suspect/perpetrator)	146

ATF/LE Confiscation/Raid/Arrest	133
Pistol-whipping	127
Drive-by (car to street, car to car)	117
Accidental Shooting	103
Stolen/Illegally owned gun{s} recovered during arrest/warrant	90
Road rage	80
Accidental/Negligent Discharge	77
BB/Pellet/Replica gun	75
Accidental Shooting – Injury	63
Kidnapping/abductions/hostage	61
Implied Weapon	56
Animal shot/killed	49
Gun(s) stolen from owner	48
Criminal act with stolen gun	46
Officer Involved Shooting - Officer shot	43
Gang involvement	39
Officer Involved Incident - Weapon involved but no shots fired	37
Assault weapon (AR-15, AK-47, and ALL variants defined by law enforcement)	33
Mass Shooting (4+ victims injured or killed excluding the subject/suspect/perpetrator, one location)	29
Concealed Carry License – Perpetrator	28
LOCKDOWN/ALERT ONLY: No GV Incident Occurred Onsite	27
Shots fired, no action (reported, no evidence found)	24
Suicide^	24
Officer Involved Shooting - Shots fired, no injury	20
Accidental Shooting at a Business	19
Self-Inflicted (not suicide or suicide attempt - NO PERP)	19
House party	19

School Incident	18
Spree Shooting (multiple victims, multiple locations)	16
Child Involved Incident	15
Workplace shooting (disgruntled employee)	14
Officer Involved Shooting - subject/suspect/perpetrator surrender at standoff	14
School Shooting - elementary/secondary school	11
Officer Involved Shooting - subject/suspect/perpetrator suicide at standoff	11
Sex crime involving firearm	11
Accidental Shooting – Death	11
Gun shop robbery or burglary	9
Murder/Suicide	7
Officer Involved Shooting - Officer killed	7
Officer Involved Shooting - subject/suspect/perpetrator unarmed	7
Officer Involved Shooting - Bystander shot	7
Gun range/gun shop/gun show shooting	7
Child injured (not child shooter)	7
Suicide – Attempt	6
Attempted Murder/Suicide (one variable unsuccessful)	6
Non-Aggression Incident	6
Police Targeted	4
ShotSpotter	4
Mass Murder (4+ deceased victims excluding the subject/suspect/perpetrator , one location)	3
Mistaken ID (thought it was an intruder/threat, was friend/family)	3
Unlawful purchase/sale	3
Child killed (not child shooter)	3
Guns stolen from law enforcement	2
School Shooting - university/college	2

Hate crime	2
Gun at school, no death/injury - elementary/secondary school	2
Officer Involved Shooting - Accidental discharge - no injury required	1
Child picked up & fired gun	1
Child injured by child	1
Gun at school, no death/injury - university/college	1

Appendix B: Additional parameter recovery plots

Present here are parameter recovery plots for group standard deviations $\sigma\alpha_g$ and $\sigma\beta_g$, for groups 1 and 2, and for both the homicide (figure 7) and defensive use (figure 8) respectively.

Figure 6: Homicide SD parameters

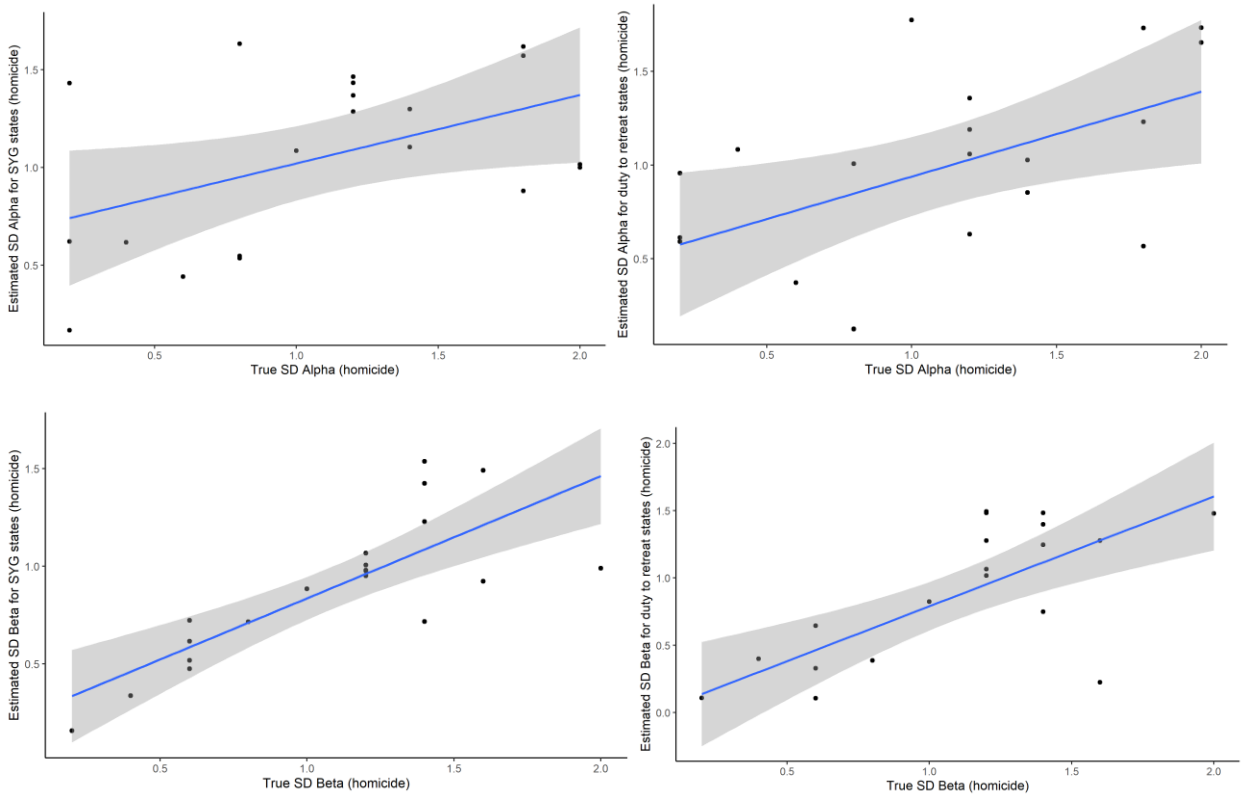
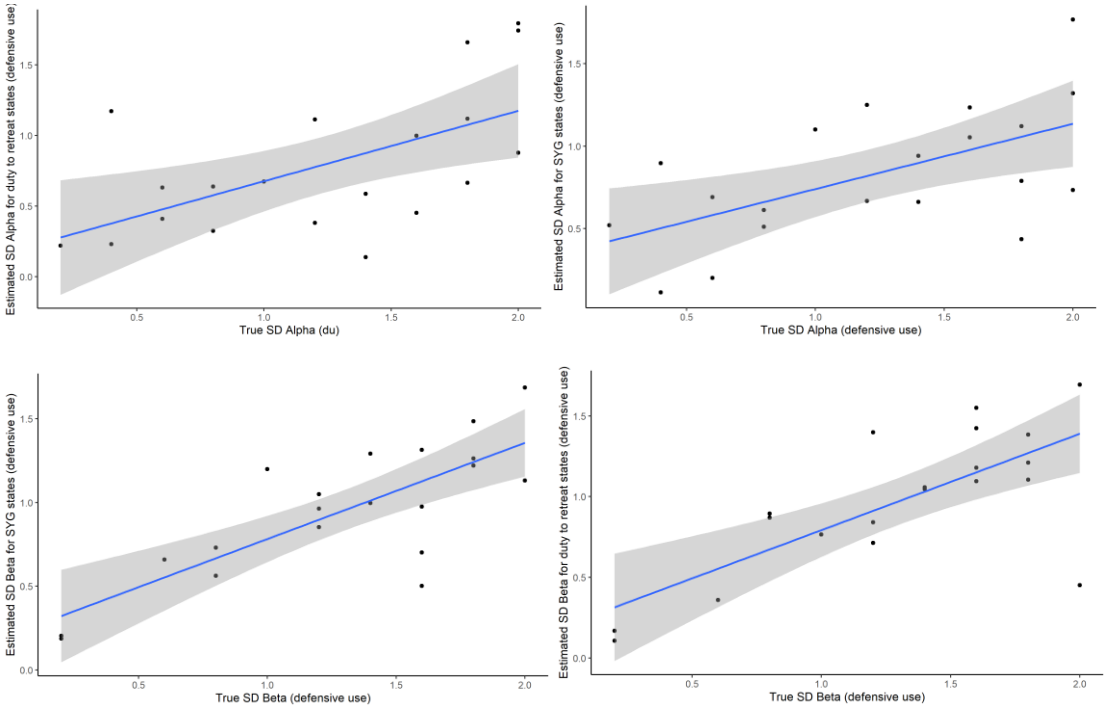


Figure 7: Defensive Use SD parameters


Estimated SD Alpha for duty to retreat states (defensive use)
True SD Alpha (du)
Estimated SD Alpha for SYG states (defensive use)
True SD Alpha (defensive use)
Estimated SD Beta for SYG states (defensive use)
True SD Beta (defensive use)
Estimated SD Beta for duty to retreat states (defensive use)
True SD Beta (defensive use)