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Abstract

The objective of this research was to investigate the relationship between the US and firearms. When investigating rates of different measures related to firearm production, ownership and usage it is clear there has been an increase in production and usage with a drop in ownership. The sequence in which the rates change suggest an increase in demand due to a spike in production and marketing.

Introduction

Firearms relationship with human society throughout history has had huge impacts on the development of our world. Investigating our current relationship with firearms could reveal how it will continue to shape our society. Specifically, in the United States there is a unique tie to firearms as the citizens rights to bear arms is included in the founding document of our nation. Because of this clause, there is a significant difference in the number of civilian owned firearms in the US than the rest of the modern world. Not only is ownership significantly higher in the US, but firearm death rates by homicide, suicide and accident remain significantly higher than other comparable nations.

There are numerous claims as to why these rates differ so much. Many feel that more guns make a country safer, and that having access to the necessary tools to defend oneself will keep them safe. Others claim that much of the violence perpetrated by guns are by those with mental-illness, and that the focus must be shifted towards getting these individuals help. Another often referenced point is stolen firearms. The thinking is that restricting access to firearms would be pointless as most guns used to commit violent crimes are obtained illegally anyway. However, there is little data or evidence to support any of these claims [6].

Not only are gun laws different between the US and the world, but looking at the differences between states can highlight more specific differences in policy which may provide measurable impacts. Studies have shown that in states with more permissive gun laws, there are higher rates of gun homicide, suicide and mass shootings [3]. Increased gun ownership by state is also associated with an increase in these rates.

Not only are civilian usage rates more deadly, but the police in the US kill civilians at rates which are from 80 to 125 times more deadly than other wealthy nations [12]. Nearly all of these deaths occur in situations where a firearm was present or the police officer suspected the civilian had a firearm.

Death rates, mass shootings, and any firearm related violence has a huge impact on the local community. Maintaining low ownership rates is associated with higher social involvement and a more prosperous community [13].

Methods

In the present study we used data from two sources to investigate the relationship between guns and the happiness of a nation, and if there may be any change over time in the rates of gun ownership, usage and manufacturing in the US. Data from the World Happiness Report and 2007 UNODOC Small Arms Survey were compiled to analyze variables related to happiness of a nation and their correlation to international estimated ownership rates [4,14]. The World Happiness Report, released in 2017 ranks 155 countries on variables related to happiness. These variables are based on participant responses to questions concerning main life evaluation from a Gallup World Poll and relate responses with how influential the factor is to happiness levels. The six factors reported are economic production, social support, life expectancy, freedom, absence of corruption and generosity.

The Small Arms Survey estimates percent of homicide by firearm, total number of firearm homicides, firearm homicide rate per 100,000 people, average firearms per 100,000 people, and estimated number of total civilian firearms. These data are estimates from a UN report comprised from numerous sources including government reports, civilian surveys and expert analysis.

To analyze rates of mass shootings and firearm related violence data was compiled from online resources. Because there is little federal funding allocated to research regarding gun usage, the found statistics were put together by individuals from various sources including local law enforcement, media, government and commercial sources. This data was collected “ in an effort to provide near-real time data about the results of gun violence” [11]. Gun Violence Archive is a non-profit founded in 2013 with the mission to provide independent, verified gun violence data to researchers and advocacy workers [11]. They do not publish any findings on analysis of the data, and simply fill the hole left by the lack of national data tracking. As they have only been tracking data for 5 years, it is not possible to do a large-scale, long-term analysis of this data, but short-term trends can be investigated from 2014 through 2018. The data reported includes the date, state, city, address, number killed, number injured, if the gun was stolen, the

gun type, number of guns involved, in addition to information about the participant for any violence event involving a firearm.

The mass shooting dataset accessed contains data from 1966 through 2017 on 400 mass shootings that killed almost 2,000 and injured 2,500. While there is no strict definition for what constitutes a mass shooting, this dataset considers any event with four or more injured or dead a mass shooting. This is the most common definition used in the literature [30]. Columns of data include, location, target of attack, summary of event, number of fatalities, number of injuries, number of police killed, employment status, mental health status, race and gender. The data were compiled from university studies, news and media outlets and cross-referenced by law enforcement reports.

To investigate differences between states, data from the Center for Disease Control and Prevention (CDC) on total deaths by firearm and firearm death rate were analyzed [19]. They have these values reported by state from 2005 and 2014-2017. Again, as the federal government does not allocate many resources to this study, this is the only statistic reported and there is little information about where the data is sourced to estimate the statistic. The website indicates the CDC makes their estimates are based on surveys, research and law enforcement data.

Registration rates by state are reported in the US Department of Justice Bureau of Alcohol, Tobacco, Firearms and Explosives 2017 annual statistical update [27]. The reported registration totals are categorized by destructive device, machine gun, silencer, short barreled rifle and short barreled shotgun. We can look at the correlations this between this data and the data compiled by the CDC to find how state registration rates impact firearm death rate.

In addition to the state breakdown, the ATF statistical update provides information on the firearm supply industry and estimated household and individual ownership rates [23]. Domestic manufacturing totals along with export and import data are reported from 1986-2015 [27]. The data from previous years had been publicly available previously, so this report simply updates the history with the data from the most recent years. The 2018 report was released too, but has no additional information than the 2017 report. The 2017 report was cited overwhelmingly throughout the literature that we felt compelled to continue with this data source.

To carry out the analysis we used python package Pymc3. Pymc3 is a python library for probabilistic programming, which makes it easy to implement a bayesian inference model [7]. I create random variables for both the rates λ_1, λ_2 and switch point τ. Next, we can input the count data over time and the model will sample for appropriate values of the three parameters. This model returns the posterior distributions of these parameters, which can be used to plot the expected rate over time, and where the rate changed.

Results

First, I looked at the significant correlations found in the international happiness and estimated global civilian ownership data. I merged these data on the country name and found few significant correlations. Within the happiness data happiness score was highly correlated with life expectancy (r = 0.78) and GDP (r = 0.81) in addition to rank by rate of gun ownership (r = -0.54) and average firearms per 100 people (r = 0.46). This translates to more guns in a country correlating to a higher happiness level, GDP and life expectancy. As we can see from the following plots, there is a slight negative correlation between happiness rank and average number of firearms per 100 people and between life expectancy and rank by rate of ownership.

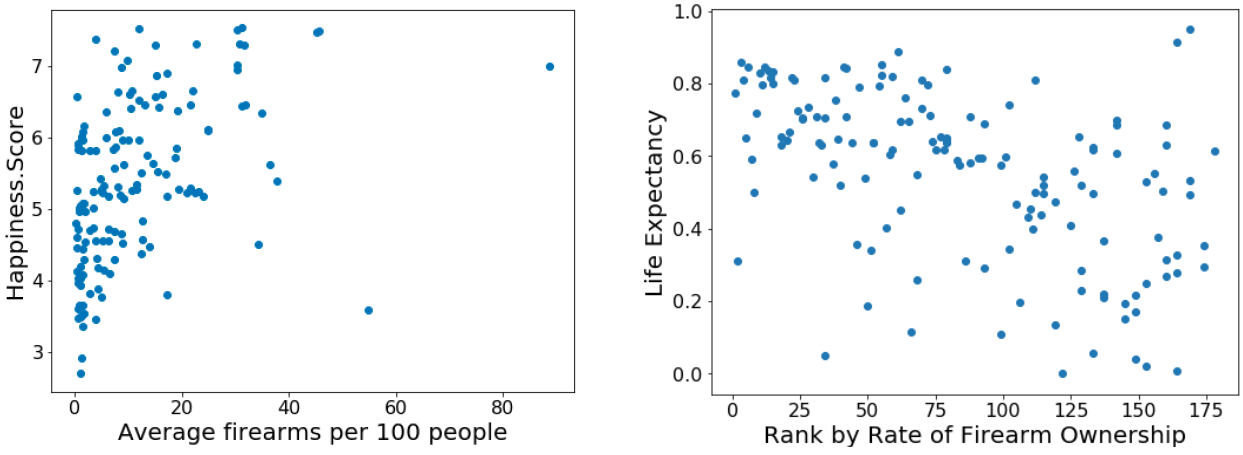

Fig 1: Scatterplots of most insightful findings in global happiness data

These plots and correlations lead me to believe there must be confounding variables that impact this variable interaction. Seeing nations with high gun ownership report higher happiness rankings and life expectancy is an unexpected result. One potential confounder could be wealth, as nations with more access to disposable income to spend on unnecessary goods likely have higher gun ownership in addition to advanced health care.

Next, applying a bayesian inference model to count data over time shows there are many firearm statistics with a meaningful difference in rates. Analyzing when these rate changes happened might give some insight into an event or action that could have influenced the ownership rates and/or use of firearms in America. I applied the model to 6 different types of data all having to do with the domestic relationship to firearms, including manufacturing totals, imported firearms, personal ownership, house ownership, mass shootings and firearm violence events from 2014-2018.

The first rates I looked into were the rate of mass shootings and firearm violence events. When analyzed through the bayesian inference model, we get lambdas that converge, and indicate a clear month where there is a significant change in rate of mass shootings. Because this dataset spans 30 years, we can see a longer scale trend that indicates a clear switch in rates the month of January 2015. On the other hand, the firearm violence data only has observations beginning in 2014, making it more difficult to see long-term trends, but this analysis can be constructed and updated with new data when relevant. I present Figure 2a/c to display the observed data compared to the expected value as predicted by the bayesian inference model. In addition, Figure 2b/d show the posterior distribution of the parameters with their associated trace plots.

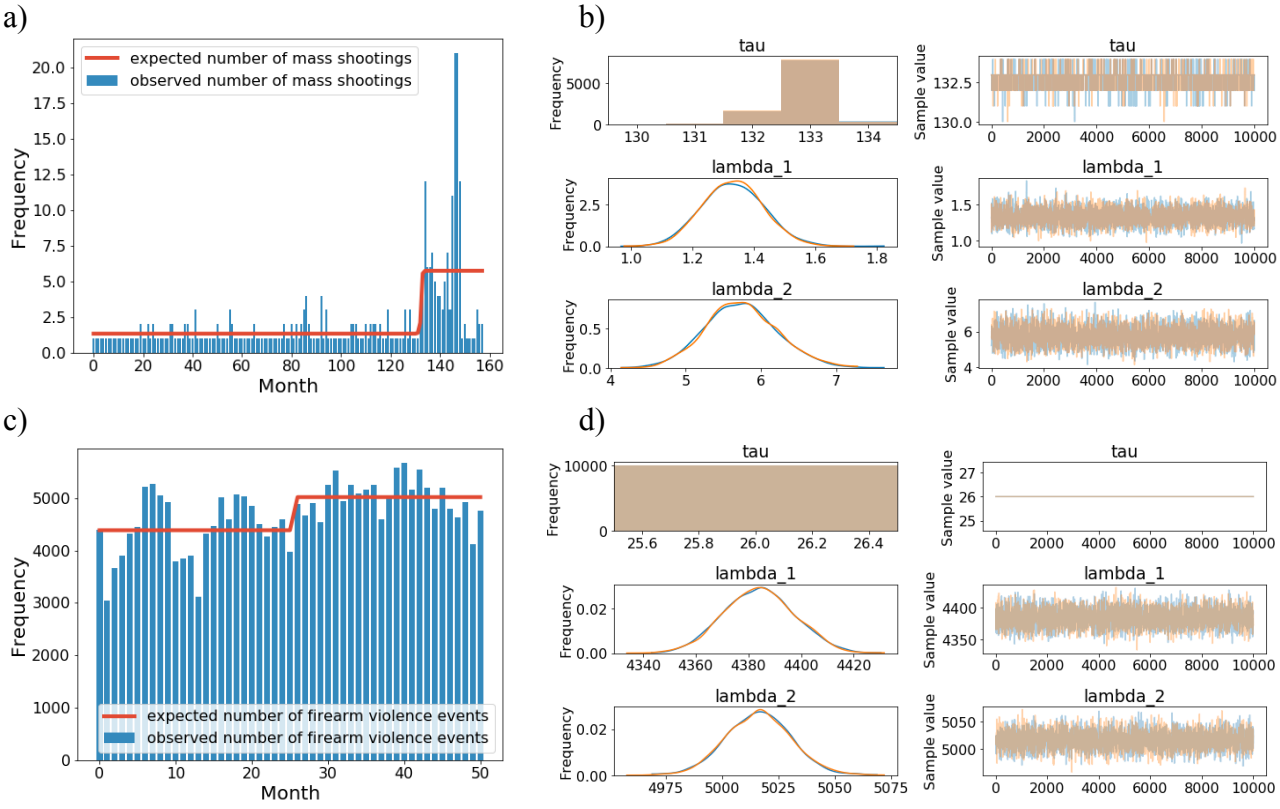

Fig 2: Plotted observed and expected counts of mass shootings per month since 1966 (a) and firearm violence events from 2014-2018 (c). Posterior distributions of λ_1, λ_2 and τ for mass shootings (b) and firearm violence events (d).

As we can see, the switch point τ for the mass shooting dataset is most likely index 133 in the vector, with slight chances of being at index 132 or 134. This index corresponds to the month of January 2015, and is not a surprising expected time of rate change given the histogram of the

mass shootings. We can see there was a somewhat constant rate of mass shootings up to the switch point, as there are not many months with a total number of mass shootings higher than the expected rate, λ_1 and not much variation in the height of the histogram. For the values of λ_1 and λ_2 we see their posterior distributions converging on 1.3 and 5.8 respectively. While there are still some months past τ that have low counts of shootings, the overall rate gets pulled up significantly higher than λ_1 due to a few months with high numbers of observed mass shootings.

Because the firearm violence dataset is not over a significant timespan, this analysis is not very insightful, but we can still see an increased rate over 4 years, with a switch point at March 2016. This rate change is not very drastic, but we can see a positive trend in the data.

Looking at the correlations within the both of these datasets was not fruitful, as there were no meaningful correlations between variables. In the mass shooting dataset the only correlations larger than $r = 0.25$ were between the total number of victims and the number of injuries and the number of fatalities. This correlation makes sense, but does not add to our understanding of our society's relationship with firearms. The largest magnitude correlation reported in the firearm violence dataset was $r = 0.43$, between the state house district and the state senate district. Again, this correlation makes sense as most of these districts are overlapping, but does not add to our understanding of the impact of firearms.

Next, I looked into the production side of the firearm market in America. Manufacturing and import trends can give insight into the market for firearms and the time where a switch in rates occurred could highlight if the relationship with firearms in America is a supply-driven issue, or more about demand. If the rates of manufacturing and imports increase before an increase in ownership, we can say that the increased supply and marketing from manufacturers influenced Americans to buy more guns. If the shift in ownership happens prior to the change in manufacturing, it is more likely that there was an increase in demand, that the retailers were forced to account for in their supply chain. The following figures show an increase in firearms manufactured in 2011 and imported in 2006.

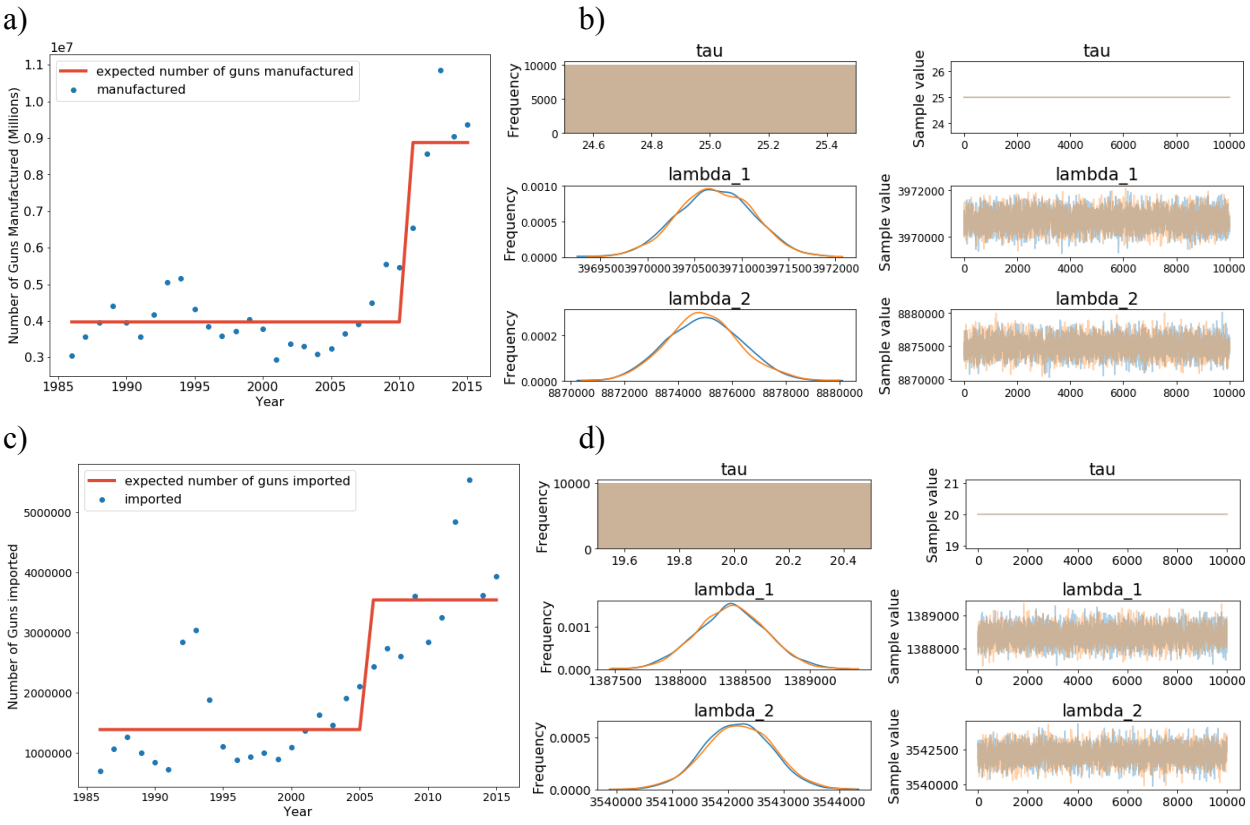

Fig 3: Plotted observed and expected counts of domestically manufactured firearms (a) and imported firearms (c) from 1986-2015. Posterior distributions of λ_1, λ_2 and τ for manufacturing (b) and imports (d).

As we can see, there has been a major shift in firearm manufacturing and import trends over the past decade. While these jumps do not happen at exactly the same point in time, they come after an increased rate in mass shootings. Both of these rate increases precede the increase in rate of mass shootings that I previously reported happened at January of 2015. While I do not wish to imply causality, we can see that the manufacturing increase may have been a response to the increased demand as Americans began importing more guns. In addition, the increase in rate of manufacturing was expected to happen prior to a shift in number of mass shootings, which it did.

From the correlations of the variables we note both are correlated with the year (manufactured r = 0.64, imported r = 0.76) in addition to being highly correlated to one another (r = 0.85). This makes sense, as we would suspect that if more firearms were being imported, this would lead to a rise in domestic manufacturing to account for an increased supply. The increase

in manufacturing might also relate to potential wars in need of firearms, but it is unclear what proportion of manufactured firearms end up in the hands of civilians.

Finally, I looked into firearm ownership percentages over time. This data came from survey responses, which can be biased by the phrasing of the question or a response bias. The survey reported two different metrics for ownership, personal ownership percent and household ownership percent. Both of these statistics give insights into both how many individuals own firearms, in addition to what percent of people have access to a firearm that is not owned by them, but stored in their home.

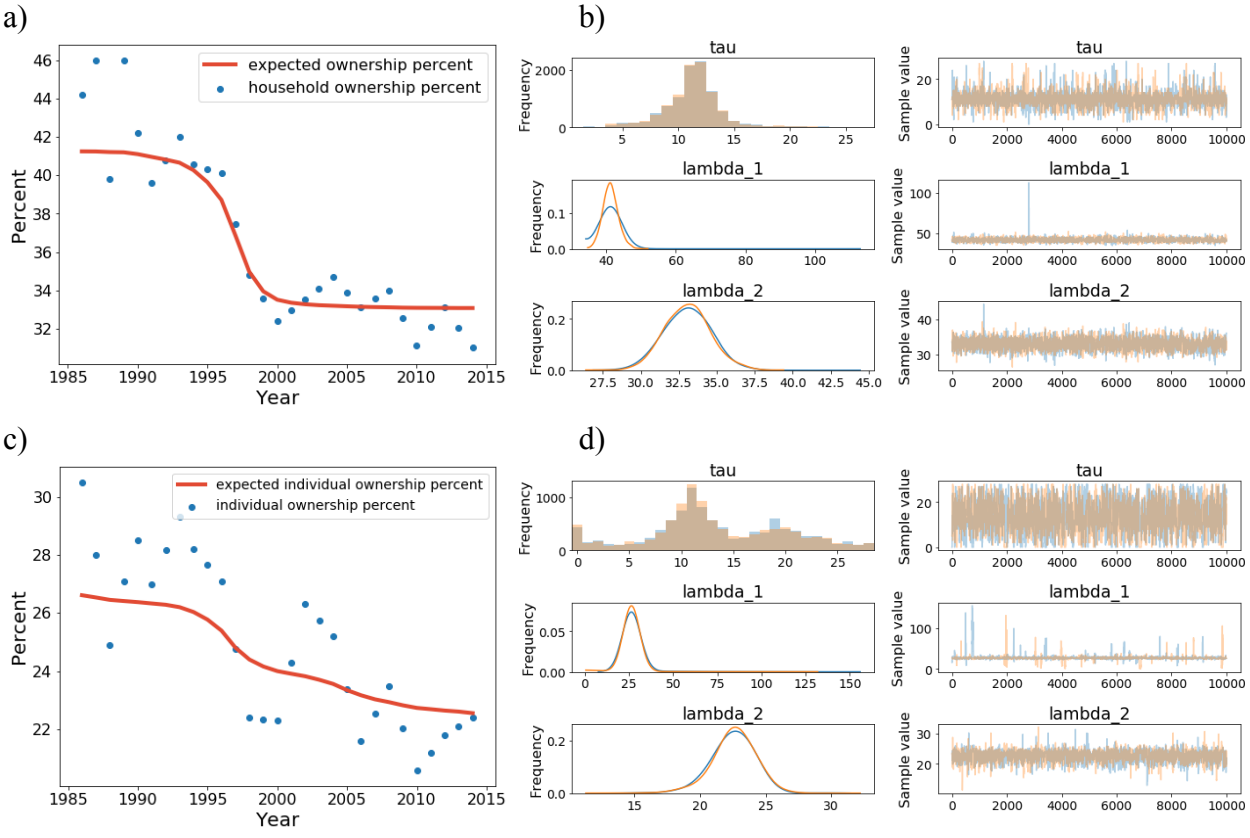

Fig 4: Plotted observed and expected percentages of household ownership (a) and individual ownership (c) from 1986-2014. Posterior distributions of λ_1, λ_2 and τ for household (b) and individual (d) ownership.

While these ownership percentages do not reveal a clear switch point in the data, the negative trend over time is apparent. We can see a switch likely between 1996-1999 for estimated personal ownership percent given the distribution of τ. Even though the switch point in this variable is less certain than those previously analyzed, it still has rates differing more than

the personal ownership percentage. We can see the distributions for τ and λ_1 do not converge on one value, leaving much uncertainty about when the rates changed in the model.

While both variables show the same trend over time, household ownership is a larger magnitude percent, as we would expect. The difference in these percentages are about 12, so we can estimate this is the percent of people who live in a home with a firearm that is not registered to their name. Over time, household ownership percentage is on average 1.5 times personal ownership percentage. This implies that 33% of individuals with immediate access to a gun in their home do not own said firearm. The correlations within these variables reveal both being highly negatively correlated with the year (personal r = -0.83, household r = -0.90), in addition to being highly correlated with one another (r = 0.87).

Given the observed rate changes in the different statistics nationally, I proceeded to investigate the differences between states.

a) b)

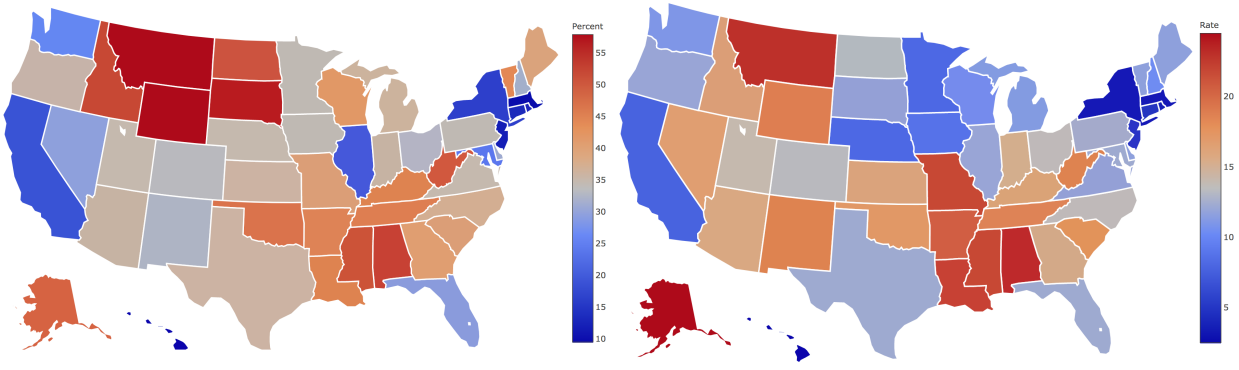

Fig 5: 2016 Estimated household firearm ownership percentage by state (a) and 2017 Firearm death rate by state (b)

States of concern would be those with a low estimated ownership percentage, but high firearm death rate, like Nevada and Illinois. States like, Wyoming, North and South Dakota show the opposite trend of high ownership with lower death rates. As we can see, states with higher ownership percentage tend to have a higher death rate. We can confirm this by looking at the correlation of the two variables. The reported Pearson correlation coefficient is 0.788, so we can say these variables are highly correlated. Additionally, there is much more variance in the household ownership percentages, so many states fall closer to the mean giving a grayer map highlighting the states with large differences in ownership.

I also looked into the number of deaths and injuries per firearm violence incident.

a) b)

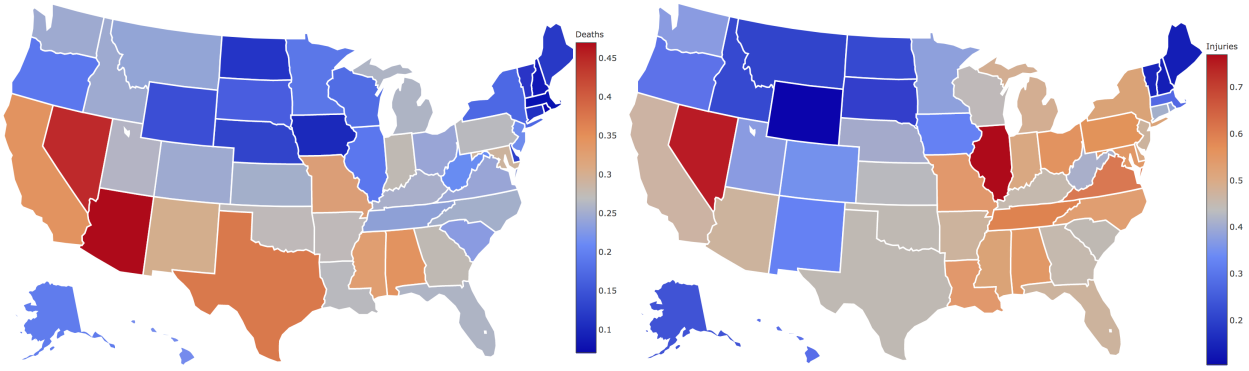

Fig 6: Mean number of deaths (a) and injuries (b) by state per firearm incident from 2014-2018

Again, we can see that these statistics are highly correlated to each other (r = 0.868). In addition, they are highly correlated with the number of guns involved (death = 0.927, injury = 0.919) and the estimated number of registered firearms per state (death = 0.840, injury = 0.621).

Discussion

My analysis shows that there have been significant changes in rates related to America's gun usage, production and ownership. These measures are relevant indicators of the relationship between a country and firearms.

Given the sequence in which the rates change, first the imports (2006), followed by manufacturing (2011) and finally mass shootings (2015) and overall shootings (2016), it is clear that the production of firearms is closely tied to the usage. With handgun sales rising, manufacturers had to shift their production to pistols and semi-automatic rifles to continue making profit. They did so in tandem with a strong ad campaign that helped sales surge in the late 2000's [22].

In terms of homicide deaths by firearm no other nation with a GDP above $25,000 comes close to the US. When adjusting for population, the US's expected daily homicide rate by firearm remains over five times higher than the next highest country [21]. On top of homicide by firearm, rates of suicide by firearm are nearly eight times higher in the US, while overall suicide rates are average [10]. The lethality of these attempts are tied to the method of attempt, with cutting and poisoning attempts successful only 6.3% of the time while firearm attempts are 96.5% successful [17, 25]. Evidence also suggests that increased access to firearms does not increase the overall crime rate of a nation, but the lethality of crime in these countries remain is significantly higher [15].

While these comparisons are well-documented it is difficult to isolate specific risk factors that could be altered to create beneficial social change [16]. To change cultural emotions is difficult, but necessary as state firearm death rate is highly correlated with strictness of gun control legislation [24].

Even though the US is currently isolated in this issue, other nations have dealt with their own hazardous relationship to guns in different ways []. Australia saw an average of one mass shooting per year from 1979-1996, until the government instituted new gun reform laws [5]. These policies removed semi-automatic and pump-action shotguns and rifles from civilians with a large-scale buy back program [5, 28]. In the two decades since, Australia has not had a single mass shooting and has seen declines in nearly every category of firearm related death, other than unintentional firearm deaths [5]. This policy worked for Australia because the government could afford to buy back these firearms at full cost, but there are so many of these firearms in America that the government could not afford to buy back all of the civilian owned arms at full market value.

Domestically, firearm deaths make up over 16.4% of all cause of injury related deaths [29]. This is slightly higher than motor vehicle accidents (15.9%) and second only to drug poisoning (28.9%) [29].

Even with the data suggesting the harm that firearms bring to communities, there is still a large proportion of Americans that view firearm violence as a national issue as opposed to a local one [20]. This can make proposing solutions feel like a daunting task and nearly impossible to implement real changes given such a large scale. This belief is false, and it has been shown that exposure to a victim or perpetrator of gun violence in ones own social network significantly increases the risk of that individuals victimization or perpetration. More specifically, high concentration of gun violence in ones social network is highly correlated with the probability of being a gunshot victim [26].

Many people feel that mass shootings are isolated incidents, sparked by individuals with mental health issues or illegal access to a firearm [8]. Again, evidence suggests this sentiment is misled and there is no correlation between mental health issues and mass shootings [2]. In other nations with restricted access to firearms attackers must turn to knives and other less-deadly weapons, leading to lower death counts in these attacks [8].

Fortunately, there is a consensus among Americans that the current laws are at least necessary. Over 45% of Americans feel the need for stricter gun laws, while only 8% want less strict laws, and 40% satisfied with the current state of gun legislation [1].

One of the most difficult things about analyzing firearm data are the lack of reliable, accurate data in addition to the complexity of the issue. In places like South Africa, there has been aa notable decrease in gun deaths since 2003, with no associated cause. When analyzed, much of the decrease could be accounted for in misclassification of cause-of-death data [18]. This cause of death data lacks precision, as it is difficult to identify a direct causal relationship and can be easily misclassified [9].

Most of the available data consists of survey responses and expert estimates with wide ranges. This leads to inaccurate data and analysis that may be carried out well, but has little relevance as it does not represent the story appropriately [30].

To continue these research efforts, a focus must be put on collecting accurate data. Most of the meaningful analyses on gun statistics have been implemented, but given the lack of specific, reliable data only general conclusions can be made. If we hope to get real insight into the relationships between a country and firearms precise data must be tracked over an extended period of time to be able to proceed with a comprehensive analysis.

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