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Research Project on the Factors Impacting Gun Fatalities in the US and the Most Effective Gun Laws Using Correlation And Regression Analysis

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Abstract
This paper is a study of various factors impacting gun violence in the US over the last decade. The factors chosen for this analysis are Social - Mental Illness; Economic - Unemployment, Consumer Price Index and Personal Income; Demographic – Gun Ownership and Legal- Gun Laws. Data for this analysis is sourced from various government bodies and forums. The compiled data has been analyzed using correlation and regression analysis to study the strength of correlation of each of these factors to gun violence fatalities. Based on the correlation analysis, a further analysis has also been done to examine the most impactful gun laws that have been implemented by some States, which can be effective in controlling gun violence in other States as well.

Keywords: correlation analysis, Pearson Correlation Coefficient, multivariate correlation analysis, regression analysis

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I would like to express my heartfelt gratitude to my mentor, **Anne Paoletti Bayna** (Mathematics Research & Writing Program Course Author, and Instructor, Haddon Heights, New Jersey, United States), who, despite being in a different time zone, was kind enough to guide and encourage me throughout the project, right from research topic selection to reviewing the analysis and conclusions over the past six months. She has been a great source of inspiration and without her help, this project would have been a faraway dream.

I would also like to thank my family for their unwavering support. Their belief in me has kept me motivated and enabled me to push myself to the fullest.

Why did I choose this research topic?
Gun violence in the US is something I've always been curious about – I've never really understood the reasons behind it. It is common to think that a developed country like the United States of America, with a high literacy rate, a good economy and overall high happiness index, would be devoid of issues like gun violence. However, recently, there have been so many mass shooting incidents in the US where innocent people, including school children have been victims of gun violence, that I just had to explore more about this topic, and this curiosity took the shape of a research project.

Background

The US has seen a rising trend in gun violence over the past decade. Recently, a lot of studies have been done to gain further insight into this issue. However, certain targeted measures need to be implemented to really have an impact. Based on a study, the US accounted for 4% of world population but 44% of global suicides by firearms in 2019. As of 2020, there are more guns (393 million) than people (326 million) in the US, according to the Switzerland-based Small Arms Survey. Based on CDC provisional data released in July 2023, 48,830 people died of gun related injuries in the US in 2022, of which 19,592 were homicides and 26,993 were suicides.

Methodology

This research paper aims at studying the correlation between gun violence and various factors impacting gun violence and determining the major factor(s) affecting it, while also identifying the most impactful gun laws that could be implemented to contain this issue.

Data for this research has been collected from various sources – Centers for Disease Control and Prevention (CDC), Substance Abuse and Mental Health Services Administration (SAMHSA), Bureau of Economic Analysis (BEA), RAND Corporation, U.S. Census Bureau, and more.

The analysis uses the Pearson Correlation Coefficient (r) to assess association of factors to gun violence fatalities. In statistics, the Pearson Correlation Coefficient measures the linear correlation between two variables. It has a value ranging from -1 to 1. Any value greater than or equal to 0.5 or less than or equal to -0.5 represents a strong positive and strong negative correlation, respectively. A value of r=-1 shows a perfect negative correlation while a value of r=I represents a perfect positive correlation. If the correlation coefficient has a value of 0, it is indicative of no correlation between the variables. In the case where the dataset contains only one variable, a univariate analysis is conducted, whereas, when the dataset consists of more than two variables, a multivariate analysis is carried out.

The analysis also makes use of regression analysis. Regression analysis estimates statistically the relations between a dependent variable (variable on the Y-axis) and one or more independent variables (variables on the X-axis).

While a correlation analysis measures the strength and direction of the relationship between two variables, a regression analysis measures the effect of those variables on each other.

Both correlation and regression analysis have been executed using the Data Analysis toolpak in MS excel using data collected from various sources.

How has gun death rate changed with population growth?

U.S. population data is plotted against gun deaths per 100,000 people per year from 1999 to 2020 as shown in Fig1 below. It is observed that, with steady increase in population, gun violence per capita is nearly unchanging until 2011. However, an upward trend in gun violence death rate is observed from 2012. Most of this study is focused on the period 2009-2020.

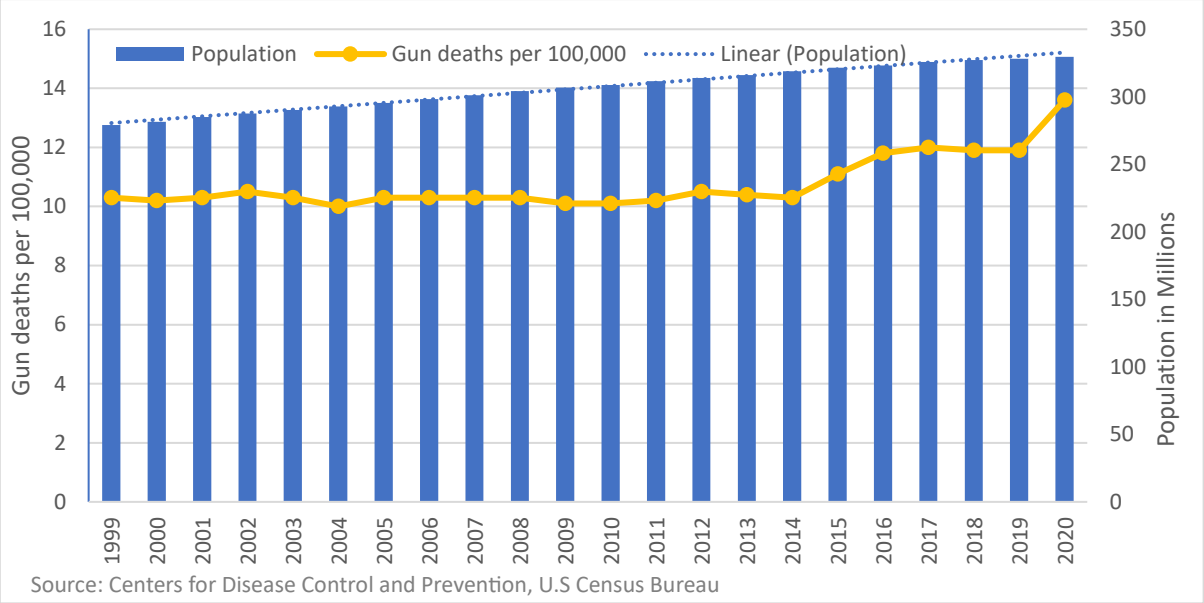

Figure 1: Population growth and gun deaths per capita trends

Is mental illness a factor?

To study the correlation between gun violence death rate and Any Mental Illness (AMI), a scatterplot has been plotted for all states with gun violence death rate as the dependent variable and AMI % (estimated prevalence rate of any mental illness among adults aged 18 or older) as the independent variable as shown in Fig2 below.

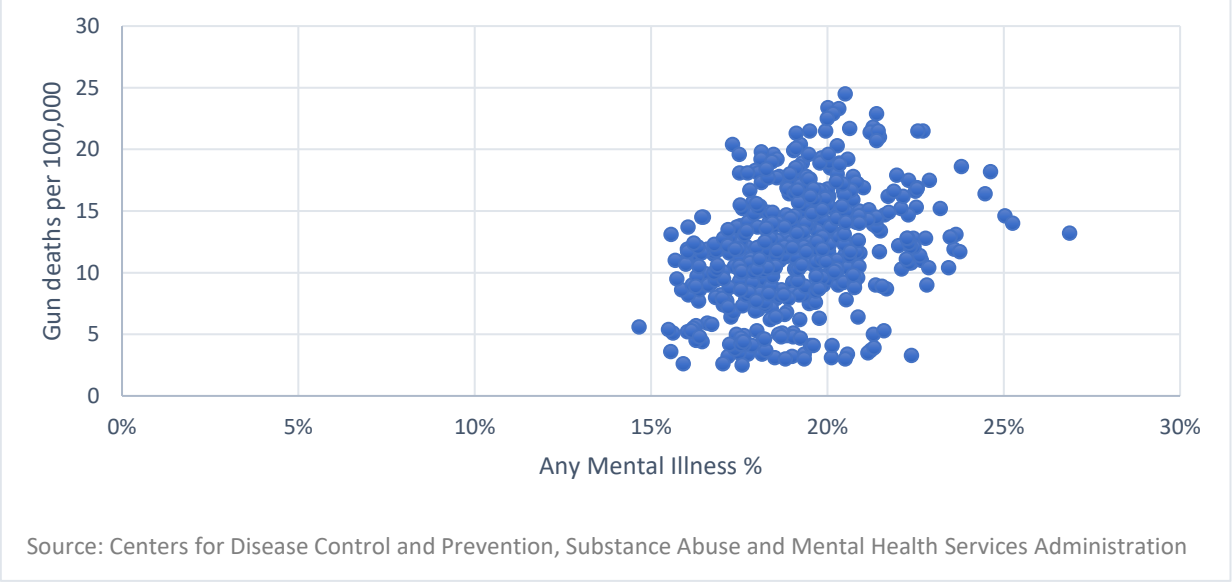

Figure2: Scatterplot showing AMI % and gun death per capita

A regression analysis has been run to study the strength of the correlation as shown in Table1 below. The correlation coefficient (r) is observed to be 0.337, which indicates a weak correlation. The value of R square is 0.11, which implies only 11% of dependent variables are explained by the independent variable.

Table1: Regression Statistics of Gun Violence death rate and AMI %

Regression Statistics	
Multiple R	0.3368
R Square	0.1135
Standard Error	4.2338
Observations	510

To further analyze if mental illness has a correlation with gun violence deaths, correlation between Serious Mental Illness (SMI) and gun violence death rate has been studied. A scatterplot has been plotted with SMI % (estimated prevalence rate of any serious mental illness among adults aged 18 or older) as the independent variable and gun violence death rate as the dependent variable, as shown below in Fig3.

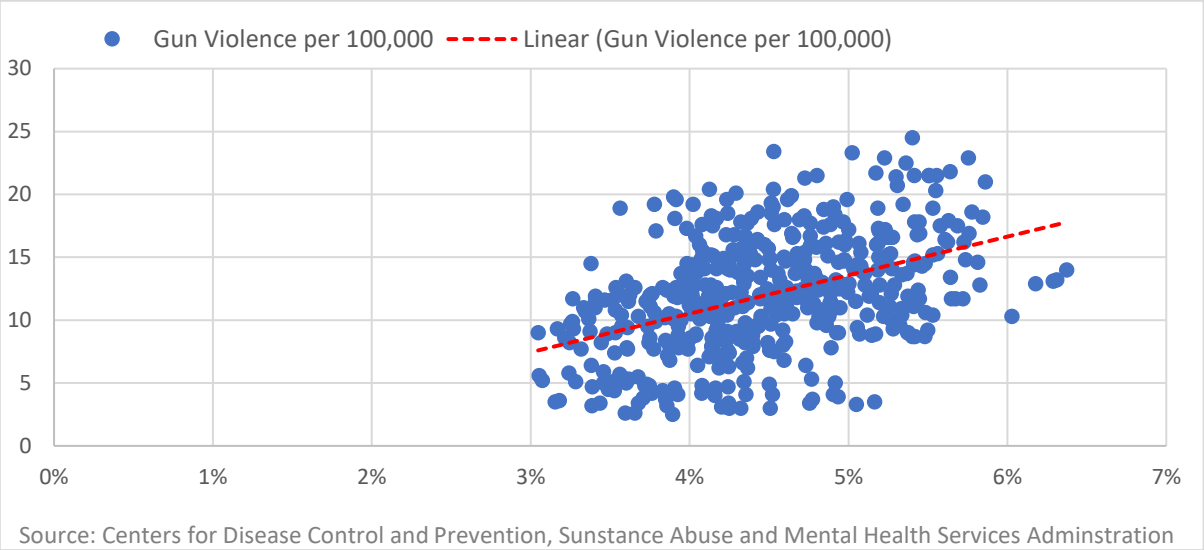

Figure 3: Scatterplot showing SMI % and gun death rate per capita

As observed from the graph, there is a linear positive correlation between the variables. A regression analysis has been run to determine the strength of the correlation, as shown in Table2. The value of r is found to be 0.446, which is indicative of a moderate correlation. The value of R square is 0.20, which implies only 20% of dependent variables are explained by the independent variable.

Table2: Regression statistics of gun violence death rate and Serious Mental Illness %

Regression Statistics	
Multiple R	0.4457
R Square	0.1987
Standard Error	4.0617
Observations	500

While serious mental illness is observed to have relatively stronger correlation than any mental illness, further state-wise analysis needs to be done to get more insight into correlation to gun fatalities.

Do more firearms lead to more fatalities?

To identify the possibility of a correlation between gun ownership and gun death rate, a scatterplot has been plotted between gun death rate as the dependent variable and an estimated proportion of adult noninstitutionalized residents in each U.S. state per year from 2008–2016, who live in a household with a firearm, as the independent variable. A linear relationship is observed between the variables as shown in Fig4 below.

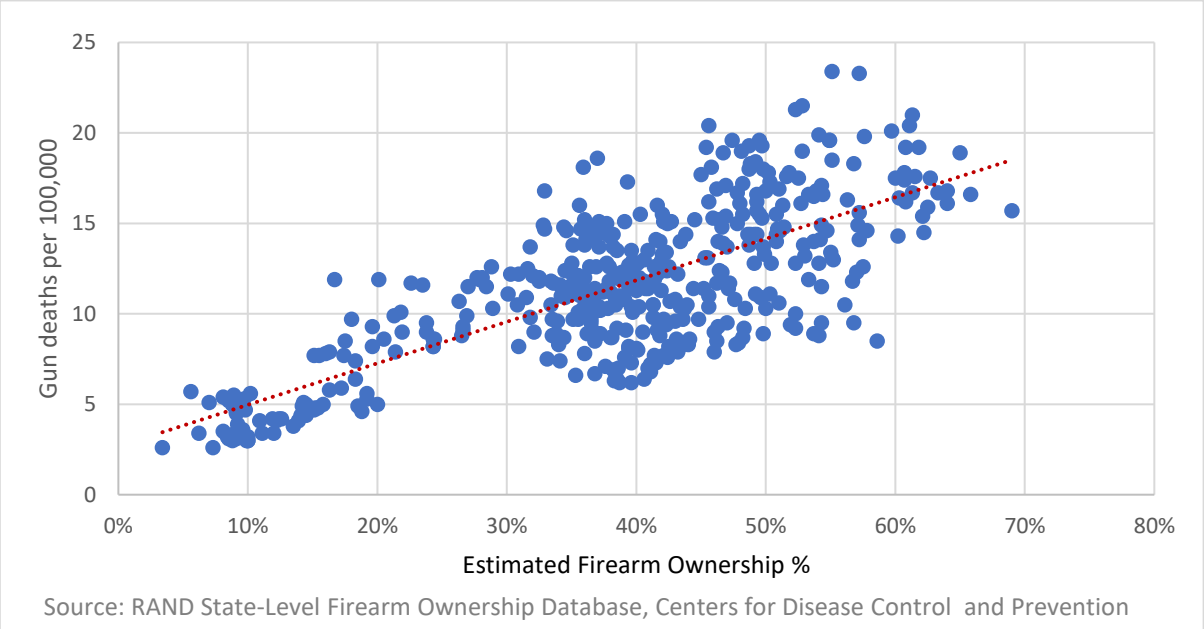

Figure 4: Scatterplot of estimated state firearm ownership and gun deaths per capita

To verify the strength of the relationship, a correlation analysis has been run, and a high value of correlation coefficient r (= 0.75) is obtained, indicating a strong positive correlation between gun deaths and gun ownership as shown in Table3 below. The value of R square is 0.56, which implies 56% of dependent variables are explained by the independent variable.

Table3: Regression statistics of gun violence death rate and firearm ownership %

Regression Statistics	
Multiple R	0.7495
R Square	0.5617
Standard Error	2.8094
Observations	450

Does the economy impact gun violence?

To assess the relationship between economic factors and gun violence, three economic factors have been studied - Personal Income per capita, Consumer Price Index and Unemployment rate. Scatterplots have been plotted individually for each of these factors against gun death rate as shown in Fig5, Fig6 and Fig7 below. As observed for all three factors, scatterplot is either round or flat and a line does not fit the points.

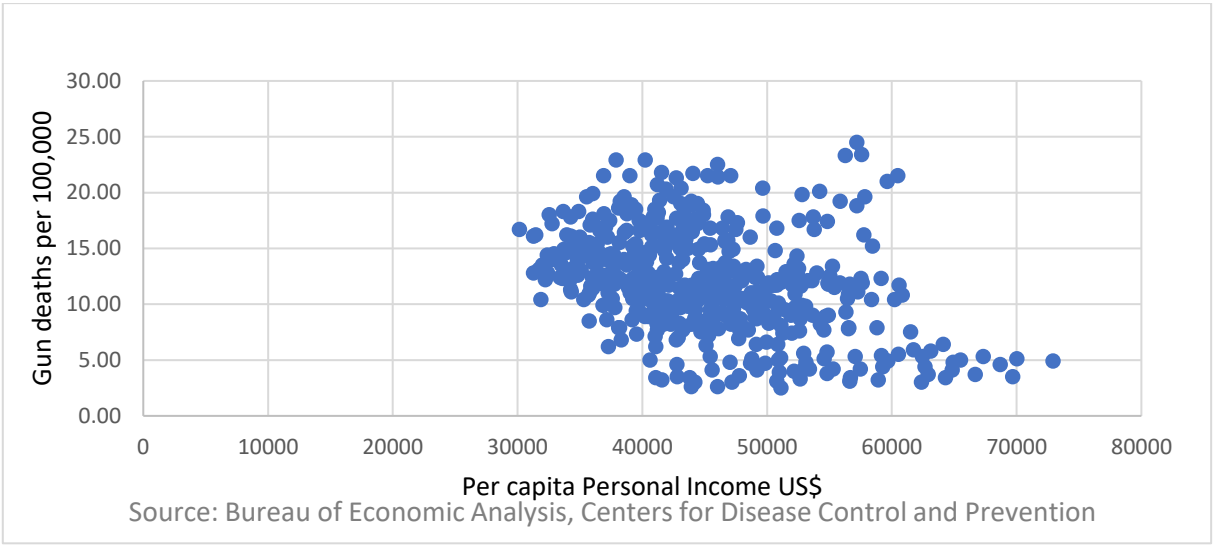

Figure 5: Scatterplot of Per capita personal income and gun deaths per capita

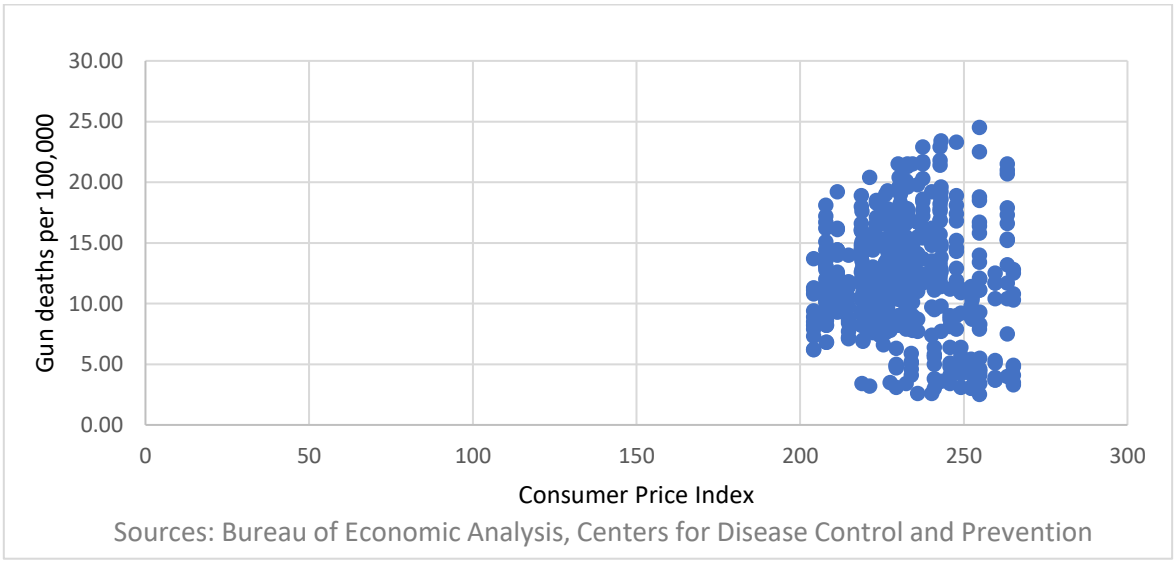

Figure 6: Scatterplot of Consumer Price Index and gun deaths per capita

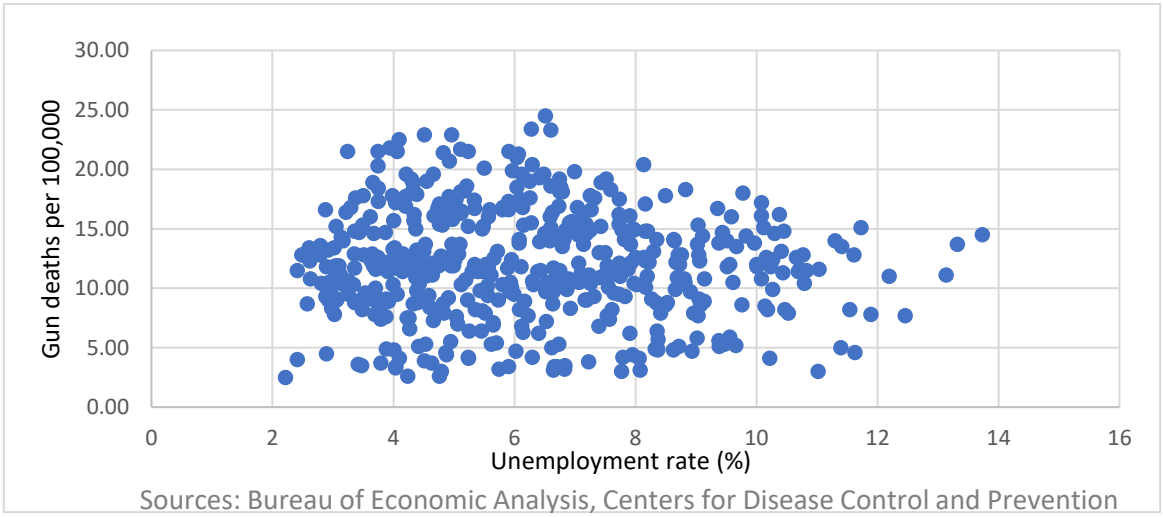

Figure 7: Scatterplot of Unemployment rate and gun deaths per capita

Multivariate regression analysis has been carried out between gun death rate as the dependent variable and the 3 economic factors per state per year during 2009-2018 as the independent variables. From the regression analysis, r was observed to be 0.434, as shown in Table4 below. The low value of r is indicative of a weak correlation between the dependent and independent variables. R square value or 0.19, which implies only 19% of dependent variables are explained by the independent variable.

Table4: Regression statistics of economic factors and gun death rate

Regression Statistics	
Multiple R	0.4339
R Square	0.1883
Adjusted R Square	0.1845
Standard Error	4.3072
Observations	648

Are gun laws a major factor?

The State Firearm Database maintains a catalog of the presence or absence of firearm safety laws per state. Since there is a lot of variation in the laws provisioned between different states, this analysis has been done at state level instead of looking at national level. To get more insight, the analysis has been done for two groups (Top10 and Bottom10) of ten states each. States with highest rates of growth in gun deaths during 2010-2020 are grouped into 'Top10', as shown in Table5 below. States with lowest gun death rate growth within the same period are grouped into 'Bottom10' as shown in Table6 below.

Table5: Top10 group-States with highest gun rate growth

State	Gun death rate (2010)	Gun death rate (2020)	% Growth
Mississippi	16.1	28.6	78%
Illinois	8.2	14.1	72%
Missouri	14	23.9	71%
Wyoming	15.6	25.9	66%
Iowa	6.8	11.2	65%
Kentucky	12.4	20.1	62%
Kansas	10.5	16.9	61%
Indiana	10.8	17.3	60%
South Carolina	14	22	57%
Arkansas	14.4	22.6	57%

Table6: Bottom10 group- States with lowest gun rate growth

State	Gun death rate (2010)	Gun death rate (2020)	% Growth
Massachusetts	4.1	3.7	-10%
New Jersey	5.2	5	-4%

Connecticut	5.9	6	2%
New York	5.1	5.3	4%
Hawaii	3.2	3.4	6%
New Hampshire	8.2	8.9	9%
California	7.7	8.5	10%
Rhode Island	4.6	5.1	11%
Utah	12.2	13.6	11%
Vermont	10.3	11.6	13%

A scatter plot was plotted for number of gun provisions made by gun death rates for states in Bottom 10 group, as shown in Fig8 below. Negative linear relationship is observed between the two variables.

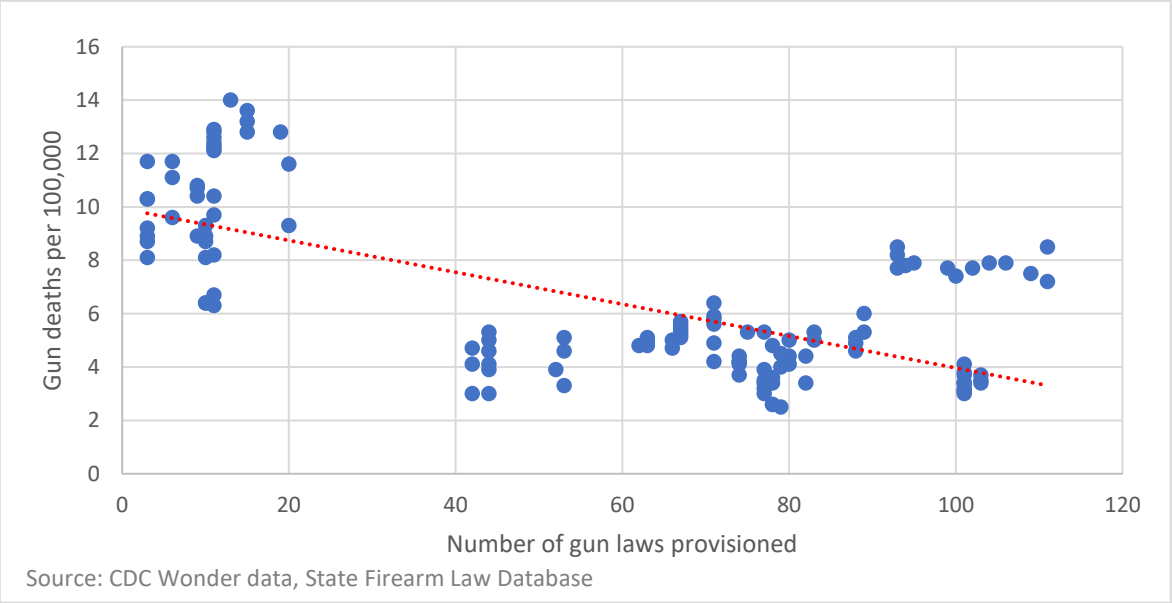

Figure 8: Scatterplot showing relationship between number of gun laws provisioned by states in 'Bottom 10' group and gun deaths per capita

A correlation analysis has been performed on the data set of the ten states with the lowest growth in gun death rates in Table6, to identify the most impactful laws, by selecting laws which show a strong negative correlation. Based on the value of r, most correlative gun laws for these states are, as shown in Table7 below.

Table7: Gun law provisions which show a strong negative correlation based on value of correlation coefficient (r)

Provision No.	Firearm provisions (variable)	Gun death rate (correlation coefficient)	Brief Description of Provision
P1	Permith	-0.609	A license or permit is required to purchase handguns

P2	age21handgunpossess	-0.601	No possession of handguns until age 21
P3	mayissue	-0.583	Discretion in deciding whether to grant a concealed carry permit, or the law bans all concealed weapons.
P4	permitlaw	-0.582	Individuals must obtain a permit to purchase a firearm through a permit approval process that includes law enforcement personnel. This may not apply to the purchase of long guns.
P5	capuses	-0.576	Criminal liability for negligent storage of guns if child uses or carries the gun
P6	cap14	-0.576	Criminal liability for negligent storage applies to access by children less than 14 years old
P7	preemptionnarrow	-0.570	Any state law that pre-empts local regulation of firearms is narrow in its scope (i.e., in one area of regulation)
P8	preemptionbroad	-0.562	State law does not completely pre-empt local regulation of firearms
P9	preemption	-0.549	State law does not pre-empt local regulation of firearms in any way
P10	immunity	-0.541	No law provides blanket immunity to gun manufacturers or prohibits state or local lawsuits against gun manufacturers
P11	universalpermith	-0.541	Background checks conducted through permit requirement for all handgun sales (or universal background checks)
P12	nosyg	-0.527	No stand your ground law
P13	Permit	-0.525	A license or permit is required to purchase all firearms
P14	cap16	-0.524	Criminal liability for negligent storage applies to access by children less than 16 years old
P15	mcdvsurrenderdating	-0.524	The surrender provisions apply if the defendant is a dating partner of the victim
P16	statechecksh	-0.514	State conducts separate background checks, beyond the federal NICS check, for handguns

The above 16 most impactful gun provisions (P1-P16) have then been checked for implementation by the 10 states with the highest growth in gun death rates (Top10 group), as shown in Table8 below:

Table8: Provisioning of the most impactful gun laws by 10 states with highest gun violence rates

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Mississippi	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Wyoming	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗
Missouri	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Arkansas	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗
South Carolina	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Kentucky	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Indiana	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Kansas	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Illinois	✓	✗	✗	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✗	✓	✓
Iowa	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✗	✗	✗	✓
	✗	indicates gun law not provisioned in state														
	✓	indicates gun law provisioned in state														

It is observed that most Top 10 states (other than Illinois and Iowa) have not implemented most of above impactful laws. Further studies are needed to determine the reason for the break in pattern with Illinois and Iowa.

Inferences

Correlation analysis done with the factors considered provides a quantitative association and not causation. Independent variables and their associations to gun violence are summarized as in table below.

Table9: Statistical summary

Independent variable	**Correlation Coefficient (r)**	**Dependent variable linear equation (y = mx + b) for significant r**
Any Mental Illness	0.337 (Weak)	r insignificant
Serious Mental Illness	0.4457 (Moderate positive)	r moderately significant, low R Square value
Economic Parameters	0.434 (Moderate positive)	r moderately significant, low R Square value
Gun Ownership	0.749 (Strong positive)	$y = 22.943x + 2.6742$
Gun Laws	-0.663 (Strong negative)	$y = -0.0597x + 9.9382$

Also, the degree of impact based on correlation coefficient r, is illustrated as in Fig9 below.

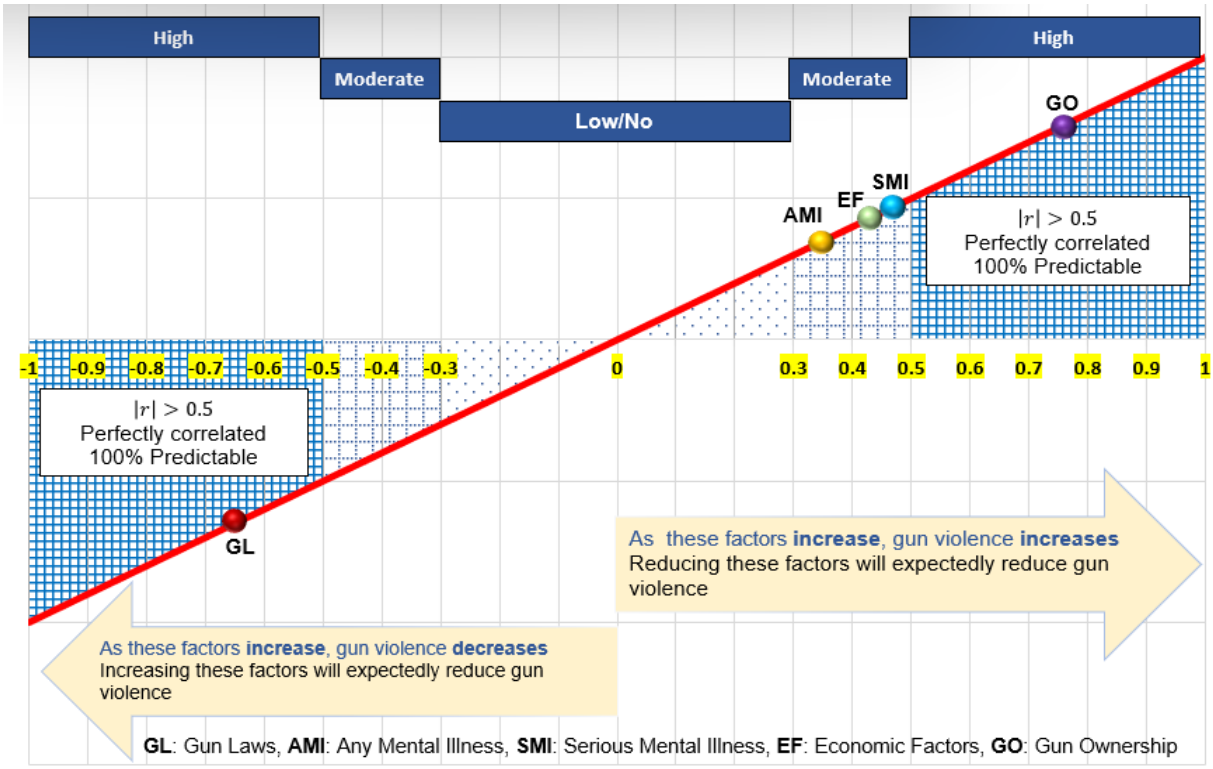

Figure 9: Illustration of degree of impact based on strength of correlation

Following inferences are drawn based on the analysis:

- Mental illness is a broad category and needs further study for better analysis. Although "Any Mental Illness" shows weak correlation, "Serious Mental Illness" shows moderate correlation and needs further insight to establish its association to gun violence.
- Gun Ownership is observed to be a major factor influencing gun violence.
- Implementation of gun provisions is observed to be a major factor influencing gun violence. Among gun provisions, specific provisions are observed to have more effect in controlling gun violence as observed from the data analysis of states where gun violence death rate has not grown significantly over the past decade.
- Among the factors considered for statistical analysis, gun ownership and gun provisions implemented are observed to have a stronger association to gun fatalities. Gun ownership restrictions and effective gun laws should be considered for implementation across all states to curb gun violence.

Scope of future studies

- The demographic profile of the population (racial distribution) can be considered for correlation to gun violence fatalities.
- While this paper has considered the impact of various factors on gun violence fatalities, it is also important to study non-fatal incidents for a comprehensive analysis. Non-fatal incidents have not been included in this analysis due to the unavailability of reliable data at the time the paper was written.
- The weightage of strong correlating factors can be arrived at based on mathematical techniques using standardized regression coefficients instead of correlation coefficients directly.

- To draw conclusions about the entire population and not just samples, a statistical significance test can be conducted using a hypothesis test.
- To gain a more in-depth understanding of the correlation between mental illnesses and gun violence deaths, different mental illnesses can be narrowed down upon and analyzed individually for their correlation with gun violence deaths.

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