Applied Econometrics & Time Series Analysis
Project Report: Do more guns reduce crime?

Group 1 - Members
Azadeh Rastegari
Devarya Raman
Kathryn Walsh
Linson Miranda
Mandeep Kaur

Abstract
The issue of local violence and crime in America has seen a tremendous spike in the last 50 years. In response, multiple US states began adopting the controversial right-to-carry laws a.k.a. (shall-issue laws) that legalizes the issuance of handgun permits to specific individuals. While many studies have been conducted by both pro & anti-gun groups on the efficacy of this law & the impact it has had on rising criminal & violence rates, the evidence presented in each of these studies has been accused of bias and therefore, triggered public debate.
This paper is a comparative study that aims to analyze the impact of these laws on violence, robbery & murder using historical data for the 50 US states & Washington D.C. between 1977 to 1999.

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A. Introduction to the Dataset
Guns is a balanced panel of data on 50 US states, plus the District of Columbia (for a total of 51 “states”), by year for 1977 – 1999. Each observation is a given state in a given year. There are a total of 51 states × 23 years = 1173 observations

Variable Definitions

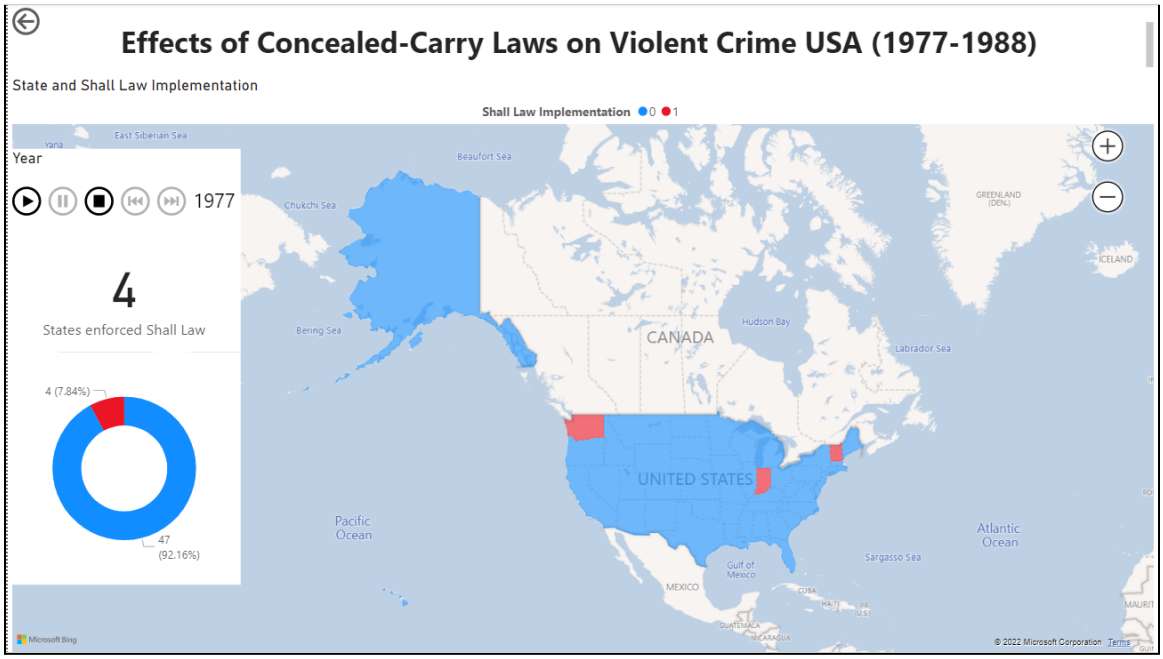
Variable	Definition
vio	violent crime rate (incidents per 100,000 members of the population)
rob	robbery rate (incidents per 100,000)
mur	murder rate (incidents per 100,000)
shall	= 1 if the state has a shall-carry law in effect in that year = 0 otherwise
incarc_rate	incarceration rate in the state in the previous year (sentenced prisoners per 100,000 residents; value for the previous year)
density	population per square mile of land area, divided by 1000
avginc	real per capita personal income in the state, in thousands of dollars
pop	state population, in millions of people
pm1029	percent of state population that is male, ages 10 to 29
pw1064	percent of state population that is white, ages 10 to 64
pb1064	percent of state population that is black, ages 10 to 64
stateid	ID number of states (Alabama = 1, Alaska = 2, etc.)
year	Year (1977-1999)

B. Exploratory Data Analysis (EDA)

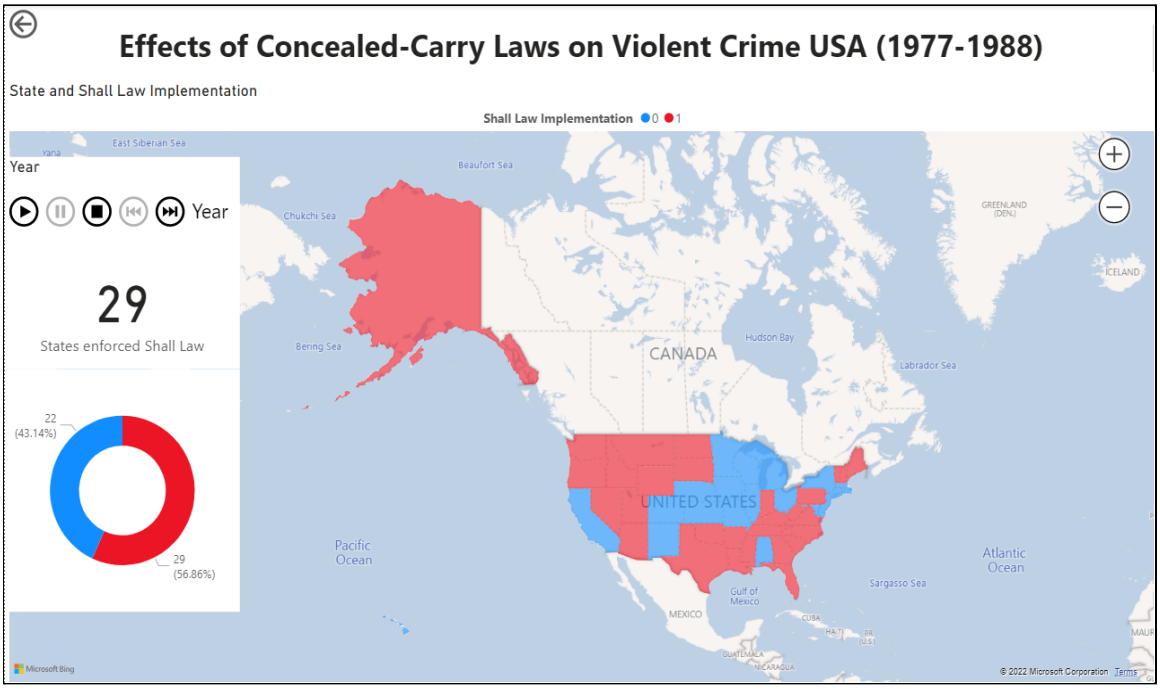
In EDA, we will first try to analyze the given dataset based on its features and try to answer a few simple questions:

1. ***How many states have enforced the shall law since its inception in 1977?***

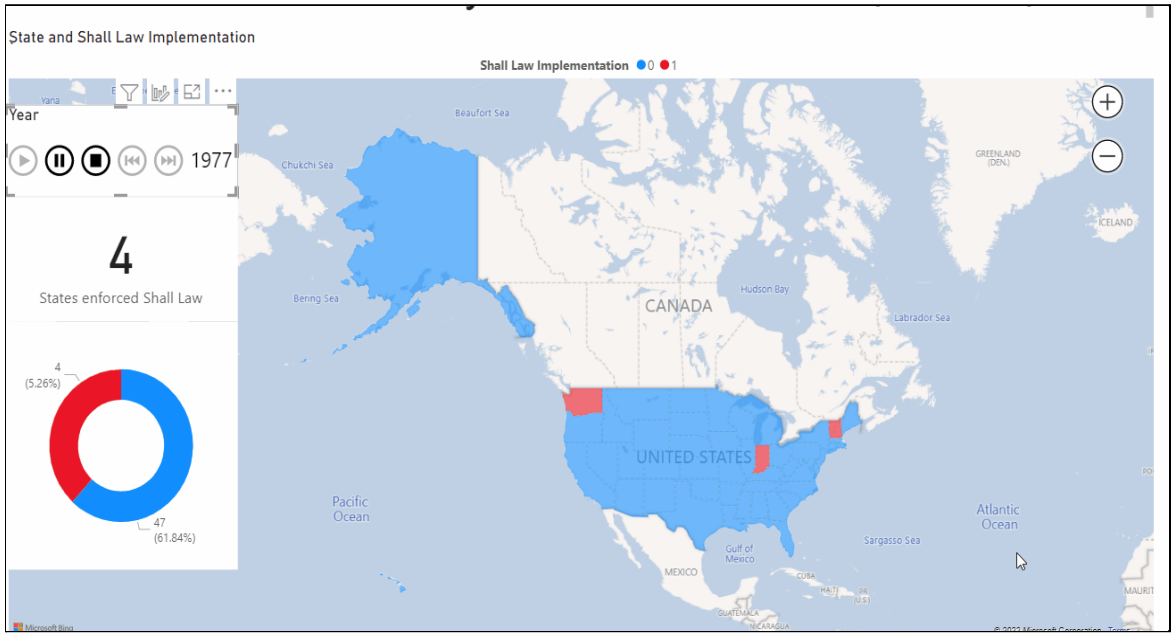
a. In 1977, only 4 states (Washington, Indiana, New Hampshire & Vermont) enforced the Shall law. This accounted for a mere 7.4% out of the total number of states.



b. However, by the end of 1999, 29 states i.e. 56.86% had enforced the shall law. We assume this radical shift in stance could be the result of the certain crime statistics presented by pro-shall law states to sway public opinion.



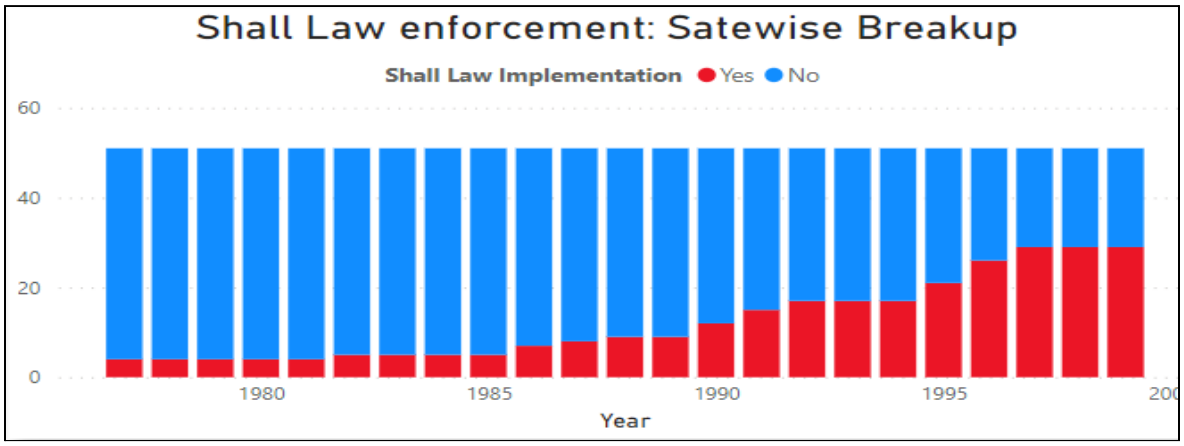
The below clip visualizes the manner in which states switched between the anti and pro-shall law between 1977 to 1999.

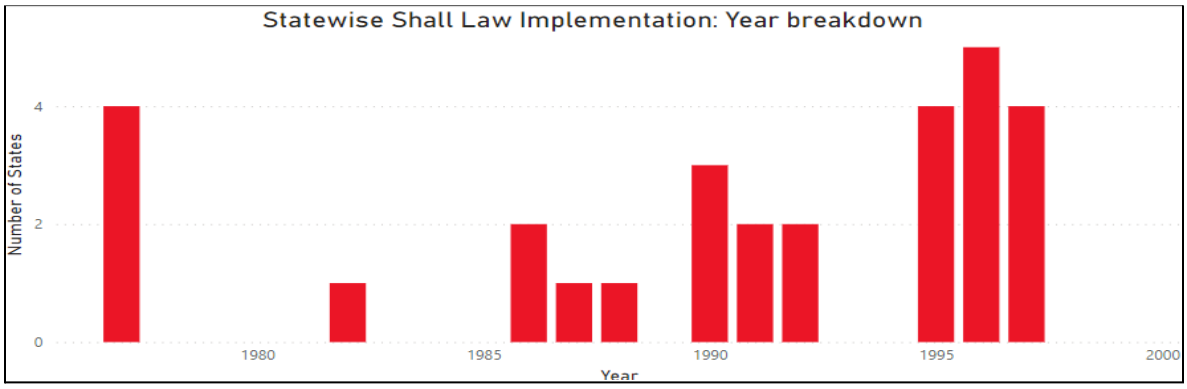


2. ***In which years did the states enforce the shall law during these 20 years?***
   In the below graphs, we plot the number of states that implemented a shall law between 1977 to 1999.

a. Here, we see in 1990, only 4 few states enforced the law in 1977 and did not see much interest up to 1990.

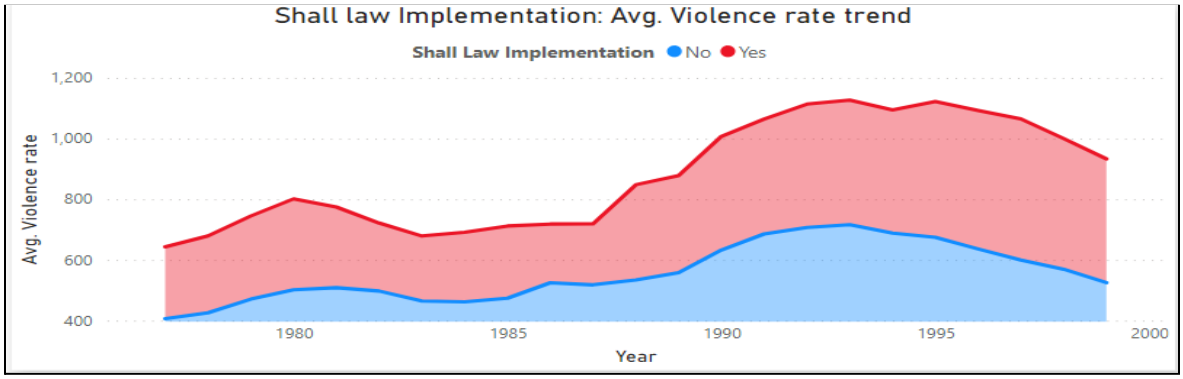
b. However, a large number of states switched sides post 1990 and within 6 years, about 25 states(>50%) had enforced shall law. This could be the effect of gun-related crime that peaked in the late 1980's and early 1990's, causing states to change their decisions.

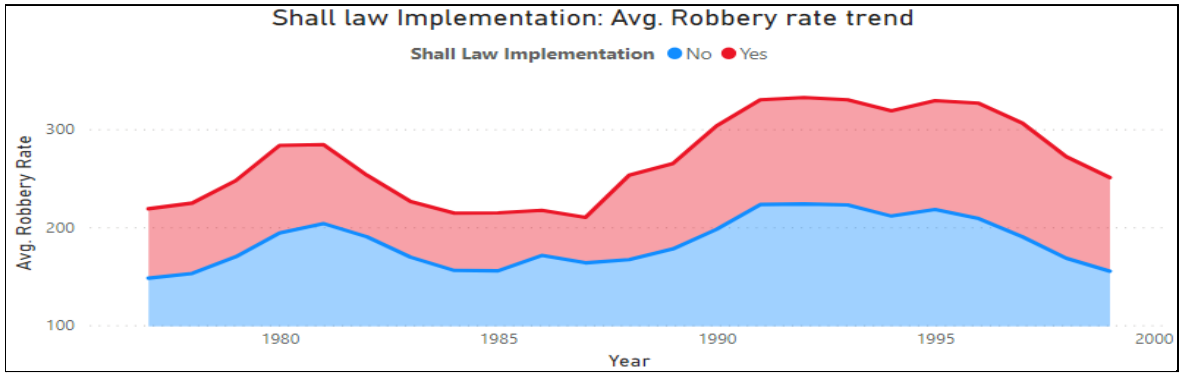


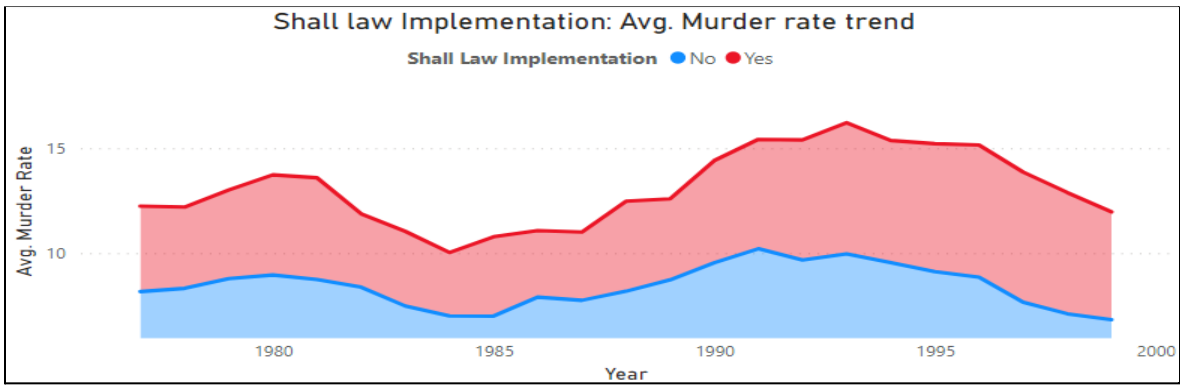


c. From the above graph, we also notice that the number of states that flipped was sporadic in the first 10 years but saw an increase since 1990. Also, there was a sharp increase post 1995 that continued in 1996 before dropping.

3. ***How does average violence, murder and robbery rates vary between the 2 groups?***





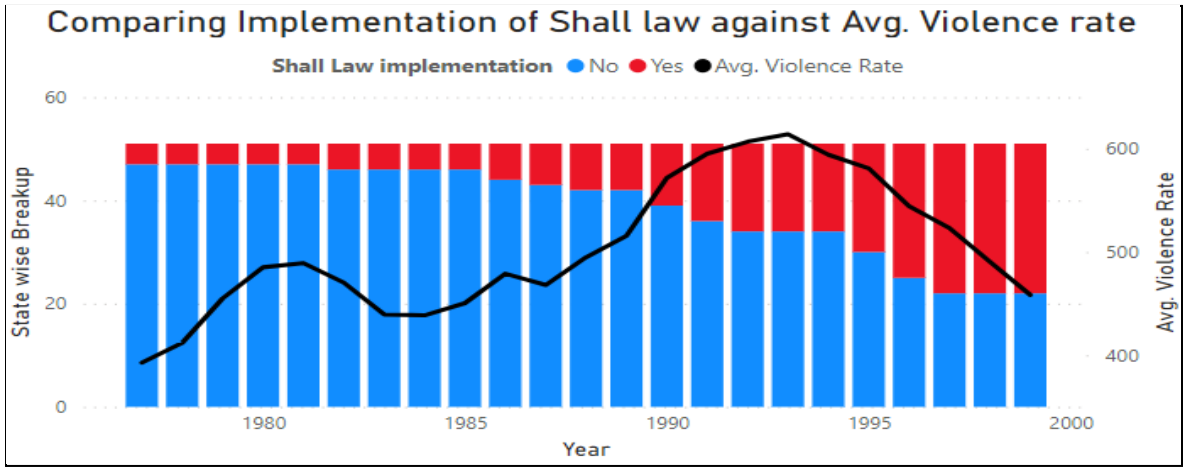


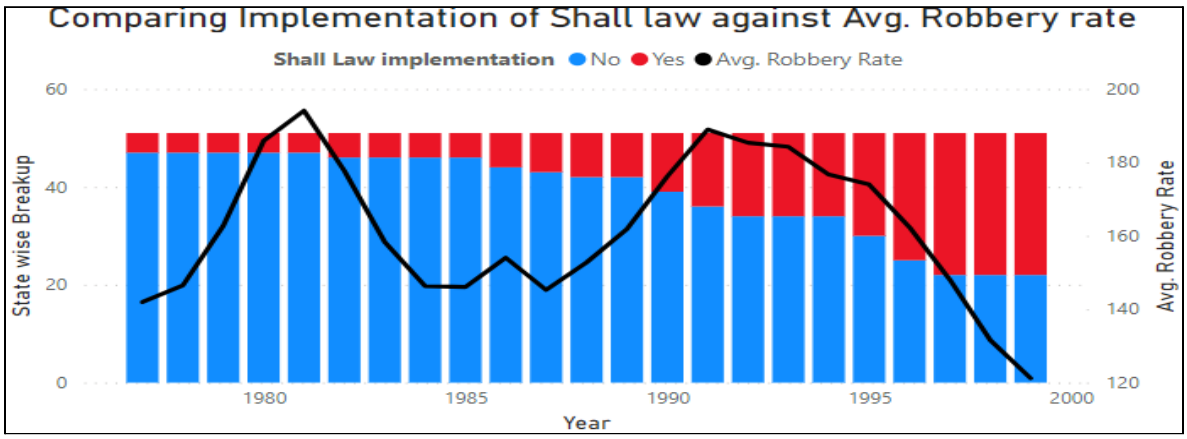
Based on the graphs plotted above, we see that:

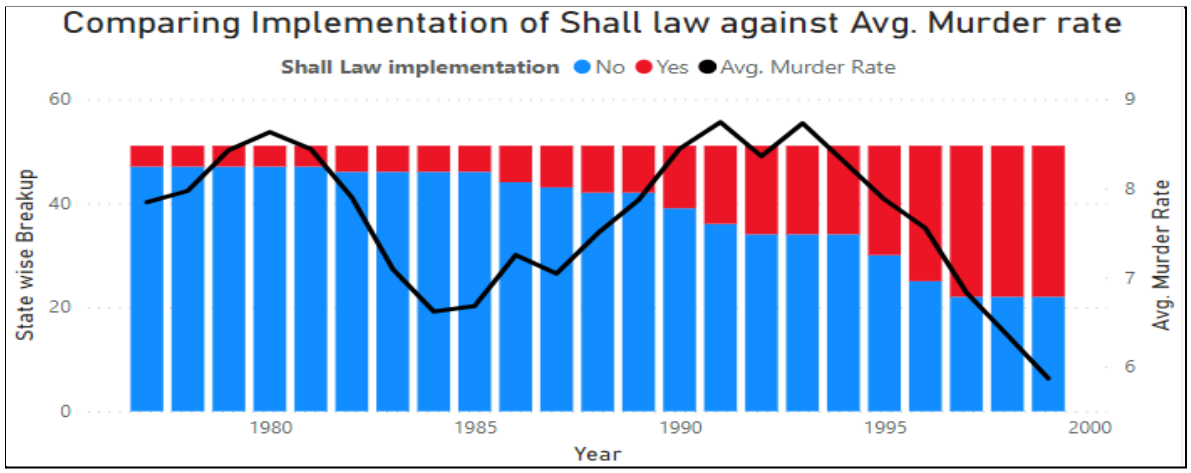
a. States that have implemented shall carry laws have higher violence, robbery & murder rates over time than states that did not enforce these laws. This might be suggestive of the general nature & behavior of the population in these states.
b. We see a drop in these trend lines around 1985 but see a steep rise peaking in 1990. This corresponds with the increase in the number of states that enforced the shall carry law. However, we cannot confirm whether this is an effect of causation or simply correlation.

4. ***Did the introduction of the law result in a reduction in violence, robbery & murder rates or not?***

   To understand the effect of shall law adoption with the average violence rate, average robbery rate and average murder rate, we plot the following graphs



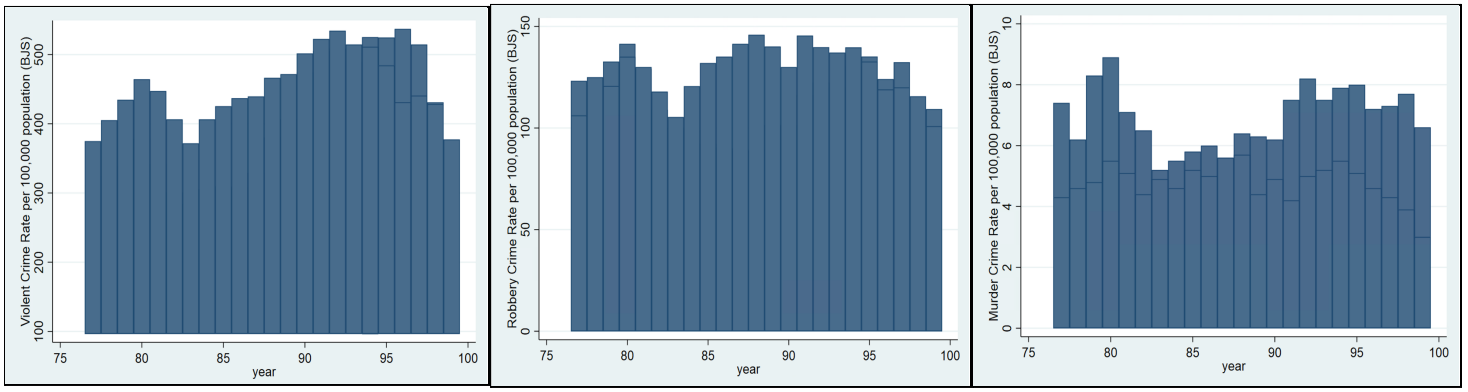




a. As more and more states continue to adopt the shall law, we observe a general decreasing trend for violence, robbery & murder rates.

5. ***Analyzing differences in violence, robbery & murder rates between states that never had a shall-law, states that had a shall-law from 1977, and states that previously had no shall-law but enacted one between 1977 and 1999.***

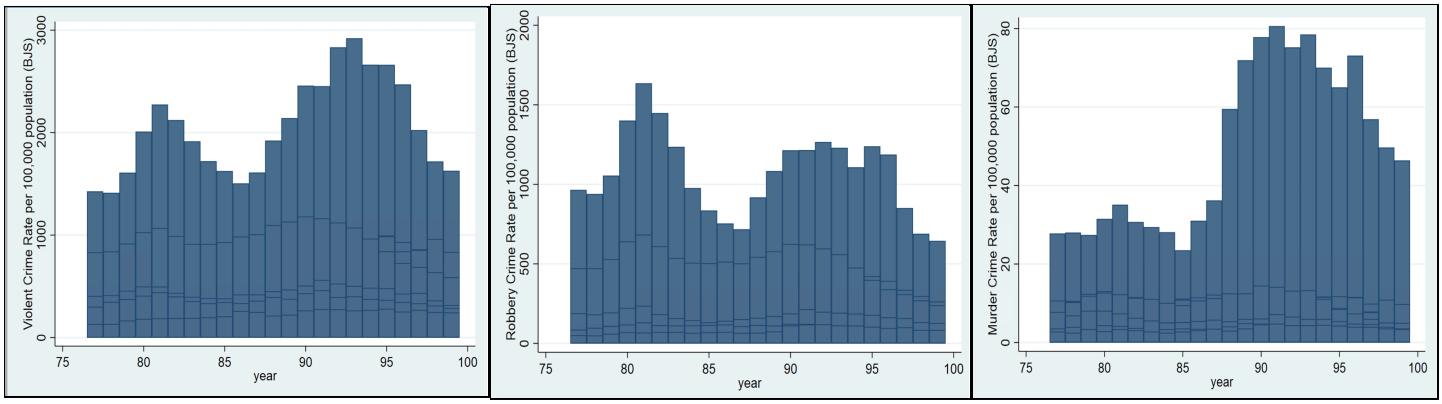
I. *States that are pro-shall law*



Histogram of violence, robbery & murder rates(per 100,000 people) for Pro-Shall states

From the three bar graphs, we observe a general spike in crime between 1977 and 1980 and another sharp increase in crime around 1985. For the states that had a shall law throughout the time-series period, the maximum violent crime rate was around 520 crimes per 100,000 people.

II. *States that are anti-shall law*

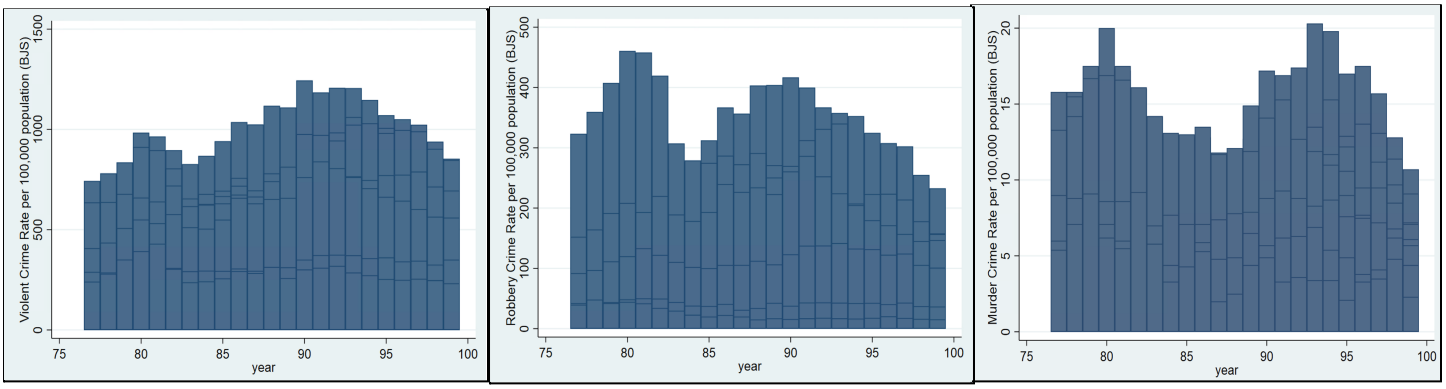


Histogram of violence, robbery & murder rates(per 100,000 people) for Anti-Shall states

a. From the three bar graphs from anti-shall law states, we observe a general spike in crime between 1977 and 1980 and another sharp increase in crime around 1985.
b. However, compared to the states that had a shall law, the violent crime rate in these states are generally much higher. The rate of violent crime rate increase during the late 1970s and from 1985 to the early 1990s is also much higher when compared to always shall law states.

c. For the states that did not have a shall law throughout the time-series period, the maximum violent crime rate was around 2900 crimes per 100,000 people.

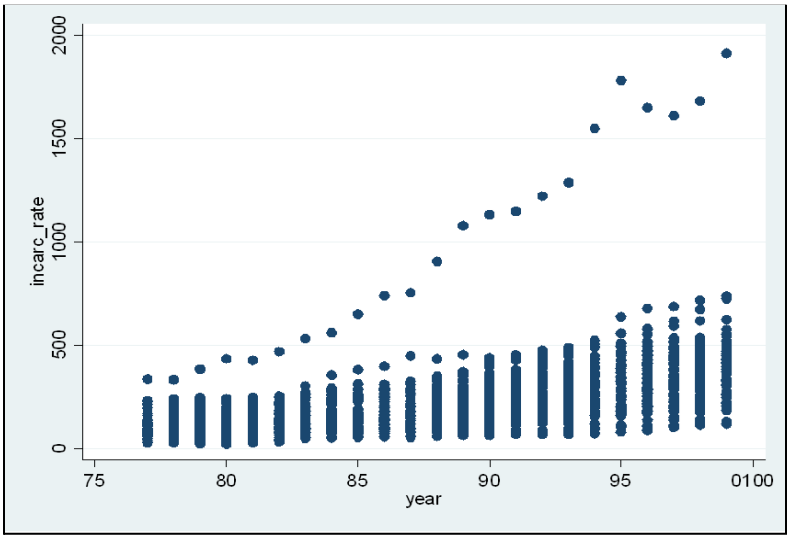
III. States that have switched their positions



Histogram of violence, robbery & murder rates(per 100,000 people) for states that flipped

a. From the states that have switched their positions, we can observe that the general spike in crime between 1977 and 1980 and from 1985 is much smaller than states which do not have the shall law.
b. However, the violent crime rate is still higher than states that always had a shall law during this period. For the states that enacted a shall law during the time-series period, the maximum violent crime rate was around 1300 crimes per 100,000 people.

6. Effect of Incarceration rate over time



a. Incarceration rate has seen an overall rise over time, regardless of whether the crime rate was rising or falling.
b. We see a spike in the incarceration rates in the year 1990 and again in 1995. This is consistent with our previous observations.

C. Variable Transformation and Model Selection

The choice to use Fixed Effects was based on the type of dataset. Since the dataset was not from a random sample, a Random Effects model would not have been appropriate for panel data on states. A Hausman test was performed and endogeneity was not present in the model with the transformed variables.
Transformations were made on the variables that exhibited skewness over 2.5 as well as avginc. ***Vio, mur, rob, incarc_rate, density and avginc were all transformed with the natural log.***

Variable	Skewness
vio	2.538371
mur	5.785826
rob	3.882311
incarc_rate	3.881709
pb1064	2.351575
pw1064	-2.223298
pm1029	0.2675794
pop	2.430632
avginc	0.7342556
density	6.694125

Table confirming skewness for variables

D. Regression Models

Based on the previously conducted EDA, we will run multiple regression models based on the following nature of our data:

1. **Dependent Variables**: ln_vio, ln_mur, ln_rob
2. **Policy Variables**: Shall law, ln_incarc_rate
3. **Control Variables**: pb1064, pw1064, pm1029, pop, ln_avginc, ln_density

I. **Pooled OLS output with different dependent variables** (*Note: *highlighted values indicate significance at the 5% level)*

Pooled OLS						
	Dependent Variable					
	ln_vio		ln_mur		ln_rob	
	Coefficient	P-value	Coeffiicent	P-value	Coefficient	P-value
ln_incarc_rate	.7787033	.000	.8639285	0.000	.7638845	0.000
pb1064	.0089273	0.883	.1055691	0.107	.0627676	0.521
pw1064	.0049681	0.869	.0377115	0.222	.0217928	0.652
pm1029	.0292098	0.603	-.0155371	0.744	-.0319248	0.773
pop	.023915	0.000	.0255733	0.001	.0475258	0.000
ln_avginc	.6336883	0.036	-.4984617	0.243	1.177088	0.005
ln_density	.0574516	0.106	.0192626	0582	.1573608	0.005
shall	-.1836674	0.071	-.0819958	0.315	-.2545526	0.062
78	-.004568	0.827	-.0026412	0.937	-.0640509	0.060
79	.0384778	0.221	-.0273056	0.468	-.035552	0.468
80	.0876887	0.035	-.0652756	0.135	.0646969	0.326
81	.045459	0.387	-.0970248	0.046	.0325036	0.703
82	-.0705334	0.299	-.3013698	0.000	-.1326137	0.252
83	-.2179184	0.016	-.4503089	0.000	-.3656172	0.018
84	-.2733812	0.010	-.5654233	0.000	-.5394626	0.004
85	-.2899391	0.020	-.5522331	0.000	-.6040128	0.006
86	-.2853206	0.037	-.5249333	0.000	-.6280725	0.011
87	-.3536119	0.022	-.5941619	0.000	-.7554993	0.008
88	-.3582957	0.034	-.6263066	0.000	-.8162256	0.009
89	-.3743226	0.046	-.6698902	0.000	.8606335	0.013
90	-.3489951	0.103	-.7713059	0.000	-.9206223	0.032
91	-.3382807	0.138	-.8108946	0.000	-.8584747	0.056
92	-.3658919	0.129	-.8851193	0.000	-.9429728	0.047
93	-.3892596	0.120	-.851315	0.000	-.9909246	0.046
94	-.4538487	0.083	-.9987249	0.000	-1.054593	0.042
95	-.5173907	0.061	-1.043008	0.000	-1.11695	0.039
96	-.6180558	0.035	-1.152315	0.000	-1.227472	0.029
97	-.6852062	0.024	-1.279063	0.000	-1.353451	0.019
98	-.8122259	0.010	-1.356222	0.000	-1.543431	0.009
99	-.9224078	0.005	-1.453339	0.000	-1.690264	0.006

Conclusions: Shall is insignificant in all 3 models. However, vio may be less sensitive to cover the effect of guns – it includes robbery, murder, and other types of incidents (that may or may not have guns involved).

II. Entity Only Fixed Effects output with different dependent variables

Entity Only Fixed Effects

	Dependent Variable					
	ln_vio		ln_mur		ln_rob	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
ln_incarc_rate	-.0805993	0.004	-.1487028	0.000	-.2159391	0.000
pb1064	.0904255	0.000	-.0293896	0.161	.1033073	0.000
pw1064	.0414985	0.000	.0111261	0.126	.0343295	0.000
pm1029	-.0635651	0.000	.0050915	0.662	-.0186265	0.097
pop	.0238807	0.010	-.008172	0.523	.018348	0.137
ln_avginc	.1079137	0.208	.5210514	0.000	.1578425	0.166
ln_density	-.2513291	0.004	-.3889377	0.001	.0740293	0.516
shall	-.0393126	0.039	-.0617759	0.019	-.0147575	0.559

Conclusions: Shall is significant in the ln_vio and ln_mur models but not in the ln_rob model. All variables except ln_avginc are significant in the ln_vio model.

Interpretation of Significant Variables

- **Shall**: there is a significant decrease in the log of violence and the log of murder when there is a shall law. When the state has a shall law:
  - the violent crime rate decreased by 3.9%.
  - the murder rate decreased by 6.2%
- **Ln_incarc_rate**: there is a significant decrease in the log of violence, the log of murder and the log of robbery when the incarceration rate increases. For each additional 1% in the incarceration rate:
  - the violent crime rate decreased by .08%.
  - the murder rate decreased by .15%.
  - the robbery rate decreased by .22%.
- **pm1029**: there is a significant increase in the log of murder when the percent of the state population that is male increases. For each additional 1% in the percent of males in the state population:
  - the violent crime rate decreased by 6.4%.
- **Ln_avginc**: there is a significant increase in the log of murder when the average income increases. For each additional 1% increase in average income:
  - the murder rate increased by .52%.
- **Ln_density**: there is a significant increase in the log of violence and the log of murder. when the population density increases. For each additional 1% increase in population density:
  - the violent crime rate decreased by .25%.
  - the murder rate decreased by .39%.
- **Pb1064**: there is a significant increase in the log of violence and the log of robbery when the percentage of the state population that is black, between the ages of 10 and 64 increases. For each additional percent of the population that is black:

- the violent crime rate increased by 9%.
- the robbery rate increased by 10.3%.

- **Pw1064**:there is a significant increase in the log of violent crime and the log of robbery when the percentage of the state population that is white, between the ages of 10 and 64 increases. For each additional percent of the population that is white:
  - the murder rate decreased by 4.1%.
  - the robbery rate decreased by 3.4%.

III. Entity and Time Fixed Effects output with different dependent variables

Entity and Time Fixed Effects

	Dependent Variable					
	ln_vio		ln_mur		ln_rob	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
ln_incarc_rate	-.1004285	0.000	-.0842807	0.044	-.2101612	0.000
pb1064	-.0064952	0.736	-.0970694	0.001	-.0137291	0.600
pw1064	.0006527	0.929	-.023375	0.033	-.0189824	0.059
pm1029	.0719969	0.000	.0757267	0.001	.0989393	0.000
pop	.0070702	0.394	-.0223477	0.069	-.0005821	0.959
ln_avginc	.2077611	0.031	.9480867	0.000	.6438548	0.000
ln_density	-.2472361	0.001	-.3187096	0.005	.0570104	0.583
shall	-.024987	0.145	-.028296	0.266	.0134867	0.563
78	.0584121	0.038	.0003987	0.992	.020595	0.590
79	.1764923	0.000	.0768775	0.072	.1424602	0.000
80	.2433379	0.000	.1345601	0.002	.2691699	0.000
81	.2488727	0.000	.1534418	0.001	.3033493	0.000
82	.2414126	0.000	.089622	0.065	.2712593	0.000
83	.2144464	0.000	.0402565	0.451	.1880954	0.000
84	.2451291	0.000	-.0715775	0.232	.1311309	0.017
85	.2972698	0.000	-.0228373	0.729	.1621992	0.007
86	.3787046	0.000	.0520038	0.474	.2391121	0.000
87	.3823207	0.000	.0392426	0.621	.2098464	0.004
88	.4479604	0.000	.0574585	0.507	.2466676	0.002
89	.5072814	0.000	.0657371	0.482	.3043146	0.000
90	.6372379	0.000	.1955801	0.080	.4377799	0.000
91	.7014149	0.000	.2540949	0.030	.5704461	0.000
92	.7384475	0.000	.2266942	0.067	.5690689	0.000
93	.7683348	0.000	.3231513	0.012	.5926833	0.000
94	.7598568	0.000	.2213674	0.099	.6095177	0.000
95	.7620421	0.000	.2465635	0.078	.6206364	0.000
96	.7133716	0.000	.1896704	0.192	.5690349	0.000
97	.6973466	0.000	.0959775	0.523	.5031635	0.000
98	.6445748	0.000	.0434861	0.781	.404572	0.005
99	.5905128	0.000	-.0124235	0.939	.3302345	0.026

Conclusions: Shall is insignificant in all 3 models. The variables ln_incarc_rate, pm1029, and ln_avginc are significant in all 3 models. In addition to these variables, ln_density is also

significant in the ln_vio model; pb1064, pw1064, ln_density are also significant in the ln_mur model.

Interpretation of Significant Variables

- **Ln_incarc_rate**: there is a significant decrease in the log of violence, the log of murder, and the log of robbery when the incarceration rate increases. For each additional 1% in the incarceration rate:
    - the violent crime rate decreased by .10%.
    - the murder rate decreased by .08%.
    - the robbery rate decreased by .21%.
- **pm1029**: there is a significant increase in the log of violence, the log of murder and the log of robbery when the percent of the state population that is male increases. For each additional 1% of males in the state population:
    - the violent crime rate increased by 7.2%.
    - the murder rate increased by 7.6%.
    - the robbery rate increased by 9.9%.
- **Ln_avginc**: there is a significant increase in the log of violence, the log of murder and the log of robbery when the average income increases. For each additional 1% increase in average income:
    - the violent crime rate increased by .21%.
    - the murder rate increased by .95%.
    - the robbery rate increased by .64%.
- **Ln_density**: there is a significant increase in the log of violence and the log of murder. when the population density increases. For each additional 1% increase in population density:
    - the violent crime rate decreased by .25%.
    - the murder rate decreased by .32%.
- **Pb1064**: there is a significant decrease in the log of murder when the percentage of the state population that is black, between the ages of 10 and 64 increases. For each additional percent of the population that is black:
    - the murder rate decreased by 10%.
- **Pw1064**: there is a significant decrease in the log of murder and the log of robbery when the percentage of the state population that is white, between the ages of 10 and 64 increases. For each additional percent of the population that is white:
    - the murder rate decreased by 2%.
- The coefficients on the significant years are all positive, indicating increases in the percent of violent crime, murder and robbery rates as indicated in the table above.

E. Making a choice: Entity Only or Entity and Time Fixed Effects?

Next, we will see if we should use entity and time fixed effects for this model or if entity only fixed effects is the better model. Is time significant? We will use an F-test to answer this question.

STATA Code and F-test Results:

ln_vio

```
. testparm i.year

      F( 22,  1092) =   20.01

            Prob > F =   0.0000
```

ln_mur

```
. testparm i.year

       F( 22,  1092) =    8.75

             Prob > F =    0.0000
```

ln_rob

```
. testparm i.year

       F( 22,  1092) =   14.53

             Prob > F =    0.0000
```

Time is significant - we need to use Entity and Time Fixed Effects regardless of which dependent variable we choose.

F. Hausman test for Endogeneity

We conduct the Hausman test to test for endogeneity and to determine whether we should use the random effects or fixed effects model.

STATA Code:

ln_vio

```
   chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B)

            =   9.61

Prob > chi2 = 0.9999
```

```
ln_mur

chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B)

         = -188.82

Warning: chi2 < 0 ==> model fitted on these data

         fails to meet the asymptotic assumptions

         of the Hausman test; see suest for a

         generalized test.

ln_rob

chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B)

         = -58.58

Warning: chi2 < 0 ==> model fitted on these data

         fails to meet the asymptotic assumptions

         of the Hausman test; see suest for a

         generalized test.
```

Do not reject the null. There is no endogeneity so using the random effects model is an option. However, our sample is not random, so we will use the fixed effects model.

G. Summary and Conclusions

Based on our regressions, Shall laws do not reduce crime. Shall is insignificant regardless of which dependent variable we choose in our Entity and Time Fixed Effects model.

Summary of our descriptive analysis and regression models and how we obtained the following conclusions:

1. We began with exploratory analysis.
    - Based on the trend graphs, we observe violence, murder & robbery rates seem to reduce over time. While this might hint that the implementation of the shall law could have played a crucial role in controlling the rates of violent crimes, robberies & murder in US states, this could also be a case of correlation & not causation. Thus, we cannot draw to a firm conclusion that the shall laws are effective in curbing violence, robbery & murder in the US.

- Based on the histograms of shall trends, there is more difference between with shall and without shall in the earlier years of the panel. In the last half of the years, there is no significant difference between them.

2. We also check the skewness of variables, some variables show more skewness than the others like: vio, mur, rob, incarc-rate, avginc and density. We log transformed these variables.

3. We consider 3 dependent variables, ln_vio, ln_mur, and ln_rob, and then conduct Pooled OLS, Entity FE, Entity and Time FE, and RE models separately for each of these dependent variables to decide which one would be the best model.

4. In the Pooled OLS model, shall is insignificant for all of these 3 variables.

5. In the Entity Only Fixed Effect model, shall is significant when we use ln_vio or ln_mur as our dependent variables but not when we use ln_rob as the dependent variable.

6. In the Entity and Time Fixed Effect model, shall is insignificant in all 3 models regardless of which dependent variable we use.

7. To determine if we should use the Entity Only FE model or the Entity and Time FE model, we consider the effect of time in our analysis by running an F-test. We concluded that time is significant, so we will use the Entity and Time FE model.

8. Based on the result of the Hausman test to decide whether to choose the FE model or RE model, we concluded that we don't have endogeneity, but we still use the Entity and Time FE model because our data is not randomly selected.

9. Based on our results of the F-test, time is significant so we chose the Entity and Time FE model. Shall is insignificant in all models, regardless of which dependent variable we use, so we can conclude that shall law doesn't reduce crime.