Do More Guns Reduce Crime?

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APPLIED ECONOMETRICS AND TIME SERIES ANALYSIS
GROUP PROJECT
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OBJECTIVE

The aim of this report is to analyze the historical data provided on crime in the U.S and find out if shall-issue laws help reduce crime or not.

OVERVIEW

What is "shall-issue" law?

A shall-issue law is one that provides handgun permits to citizens that allows them to carry handguns if they met the necessary criteria. The criteria for the applicant are:

- Must be an adult
- Have no significant criminal record
- No history of mental illness
- Successfully complete a course in firearms safety training (if required by law).

If the applicant meets the above criteria, the license is issued and there is no requirement to demonstrate "good cause".

Idea behind the law:

The idea perceived is that when law-abiding citizens are equipped with a weapon like gun, the crime rate would decrease because the victims are no longer defenseless. It is aimed to make the citizens safer.

ANALYSING DATA

What do we have?

The dataset provided **(Guns)** has is a balanced panel of data containing 1173 observations. These observations are data collected across 51 states of the USA (represented by the variable *stateid)* from the years 1977-1999 (represented by the variable *year)*. Each observation is a given state in a given year. The dataset captures the following information on the states:

- **Crime –** Represented by the variables *vio*, *rob* and *mur*
- **Population-** Represented by the variables *density*, *pop*, *pm1029*, *pw1064* and *pb1064*
- **Per Capita Income-** Represented by the variable *avginc*
- **Shall-Issue Law:** Represented by the variable *shall*

Since the *stateid* corresponds to the US states in alphabetical order, we have mapped the *stateid* variable to their respective *State Name* as follows:

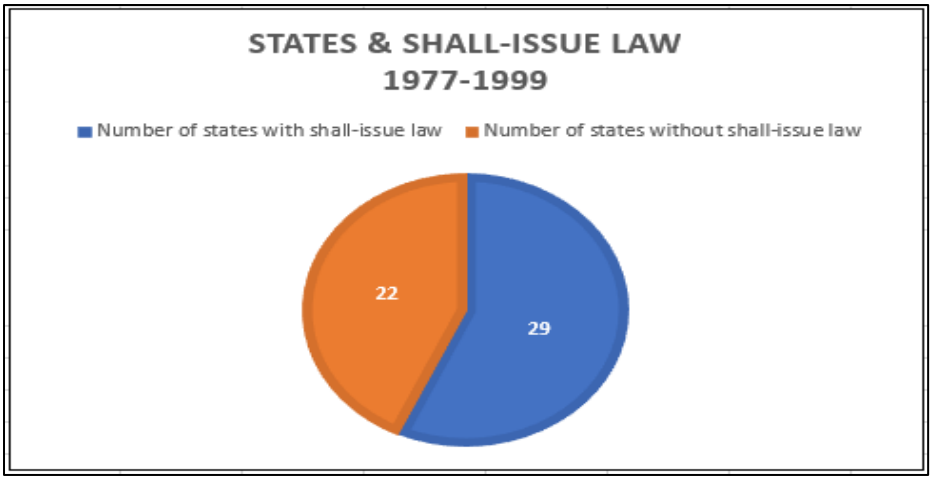
State ID	***State Name***	***Abbreviation***	***State ID***	***State Name***	***Abbreviation***
1	Alabama	AK	30	Nebraska	NC
2	Alaska	AL	31	Nevada	ND
3	American Samoa	AS	32	New Hampshire	NE
4	Arizona	AR	33	New Jersey	NH
5	Arkansas	AZ	34	New Mexico	NJ
6	California	CA	35	New York	NM

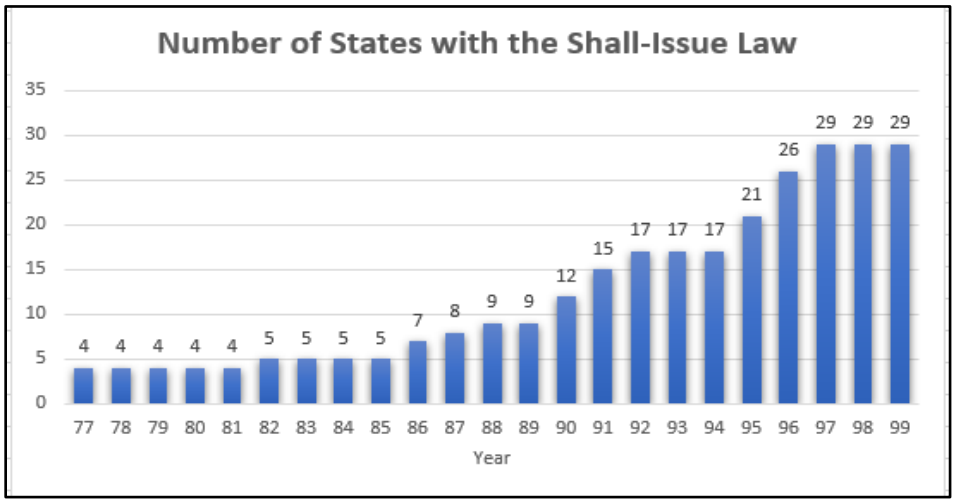
7	Colorado	CO	36	North Carolina	NV
8	Connecticut	CT	37	North Dakota	NY
9	Delaware	DE	38	Northern Mariana Islands	MP
10	District of Columbia	DC	39	Ohio	OH
11	Florida	FL	40	Oklahoma	OK
12	Georgia	GA	41	Oregon	OR
13	Guam	GU	42	Pacific Trust Territory	
14	Hawaii	HI	43	Panama Canal Zone	
15	Idaho	IA	44	Pennsylvania	PA
16	Illinois	ID	45	Puerto Rico	PR
17	Indiana	IL	46	Rhode Island	RI
18	Iowa	IN	47	South Carolina	SC
19	Kansas	KS	48	South Dakota	SD
20	Kentucky	KY	49	Tennessee	TN
21	Louisiana	LA	50	Texas	TX
22	Maine	MA	51	U.S. Virgin Islands	US VI
23	Maryland	MD	52	Utah	UT
24	Massachusetts	ME	53	Vermont	VT
25	Michigan	MI	54	Virginia	VA
26	Minnesota	MN	55	Washington	WA
27	Mississippi	MO	56	West Virginia	WI
28	Missouri	MS	57	Wisconsin	WV
29	Montana	MT	58	Wyoming	WY

What do we observe from the data?

SHALL-ISSUE LAW:

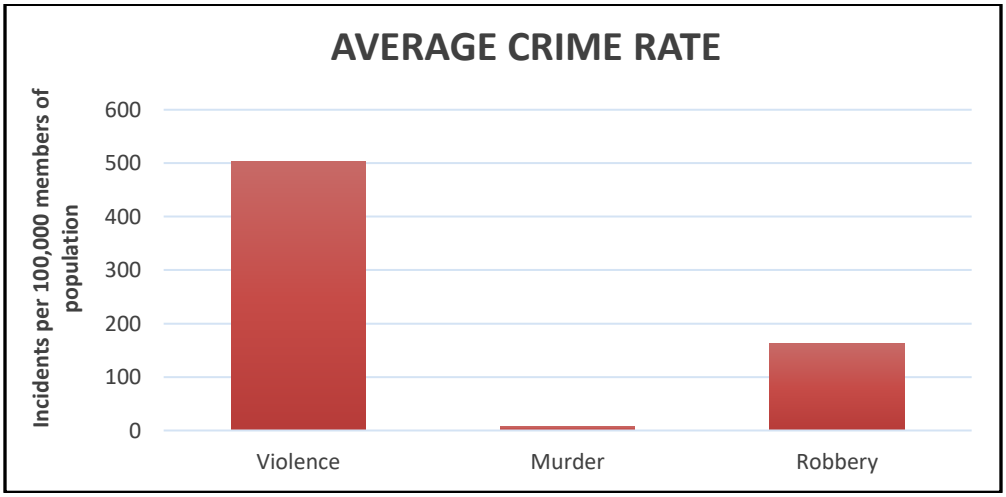
- Among the 51 states, 29 states had implemented the *shall-law*, out of which 25 states had them implemented between the observation years 1977-1999.
- The remaining 4 states had this law implemented before and throughout the observation years.
- The number of states with the *shall-law* increases gradually from 4 in 1977 to 29 in 1999.



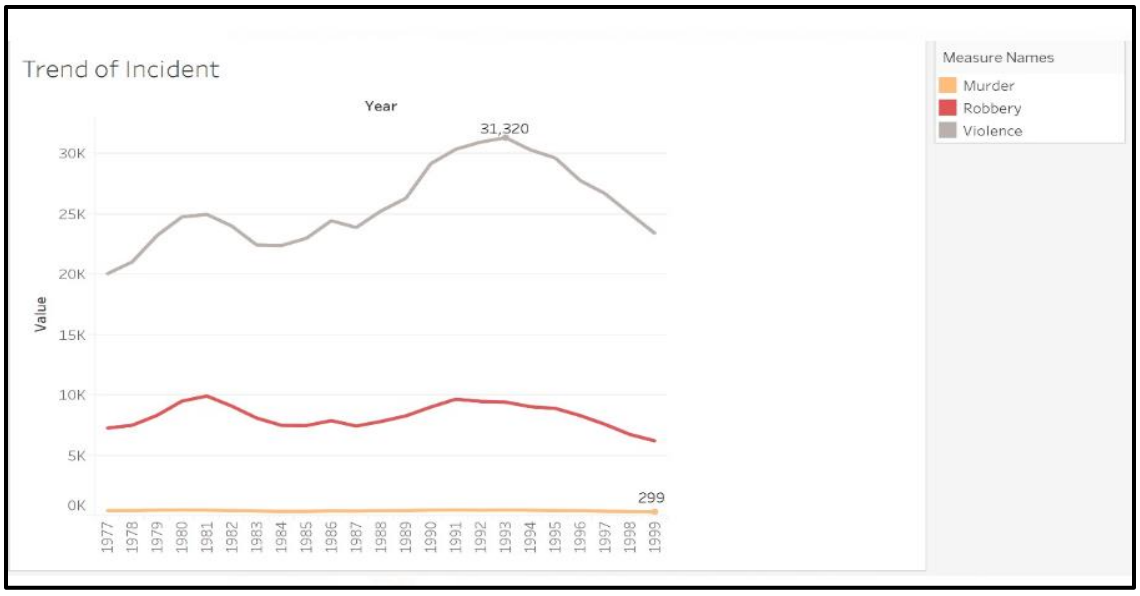


CRIME RATE

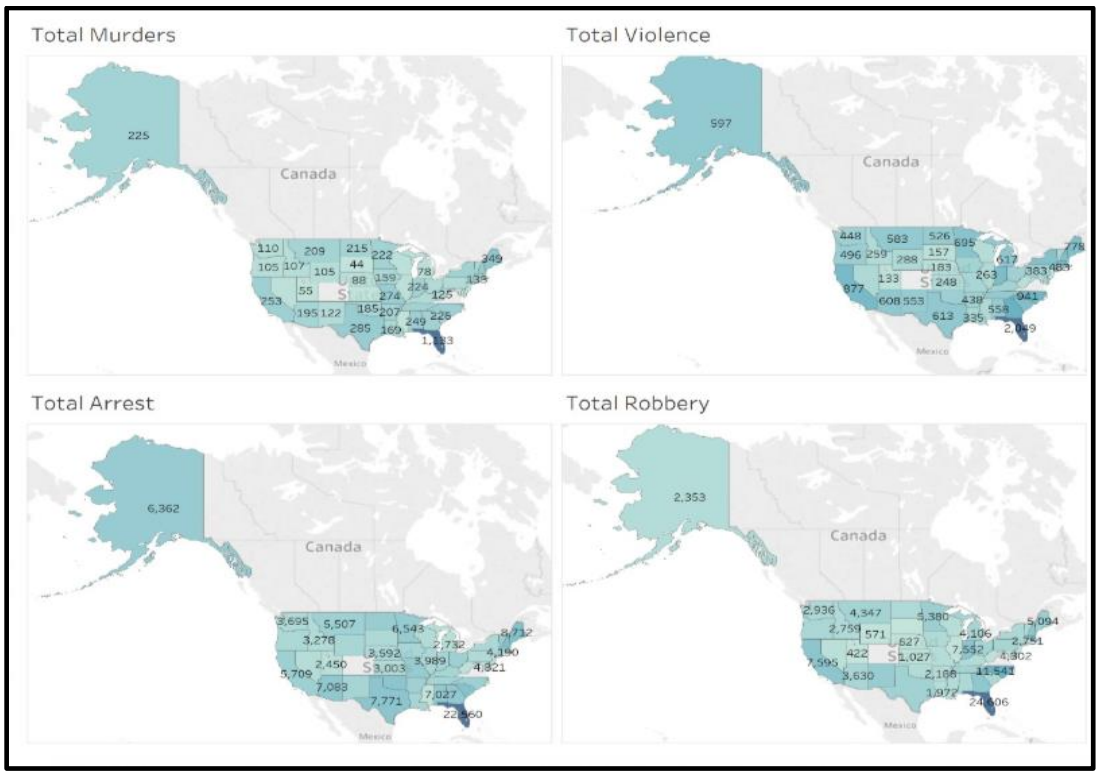
- Considering the crime rate factors, we observe that consistently violence had the highest rate followed by robbery and murder.



- The crime rate is peak during 1991-1993 and gradually begins to decrease after the mid-90's.

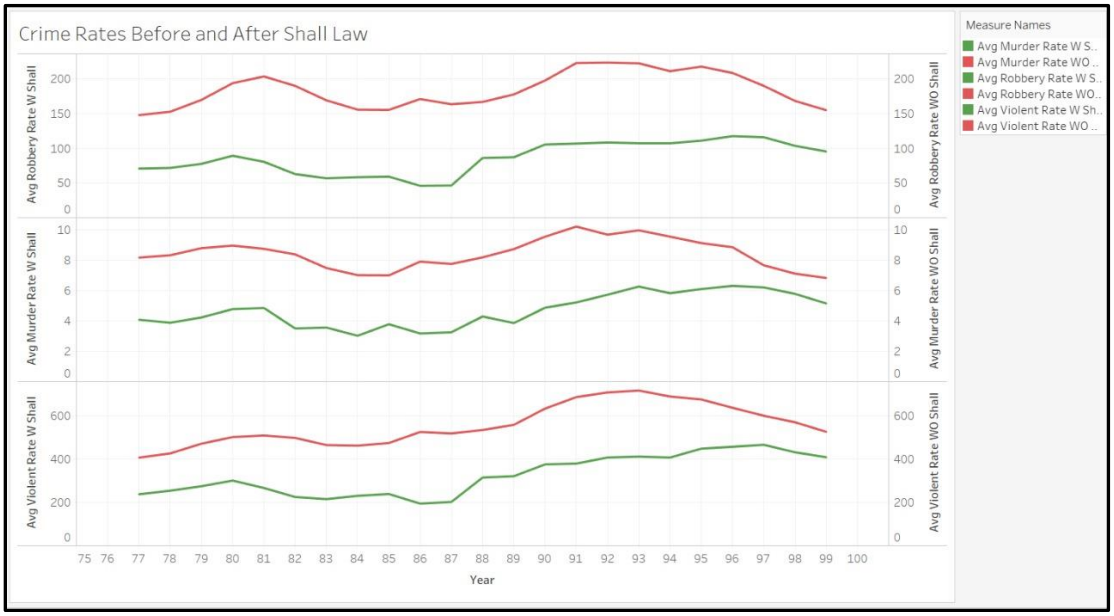


- State with *stateid* **11 (Florida)** has the highest violence rate, robbery rate and murder rate. Furthermore, it has the highest population density and incarceration rate.
- State with *stateid* **38 (Northern Mariana Islands)** has the lowest violence rate, robbery rate and murder rate.



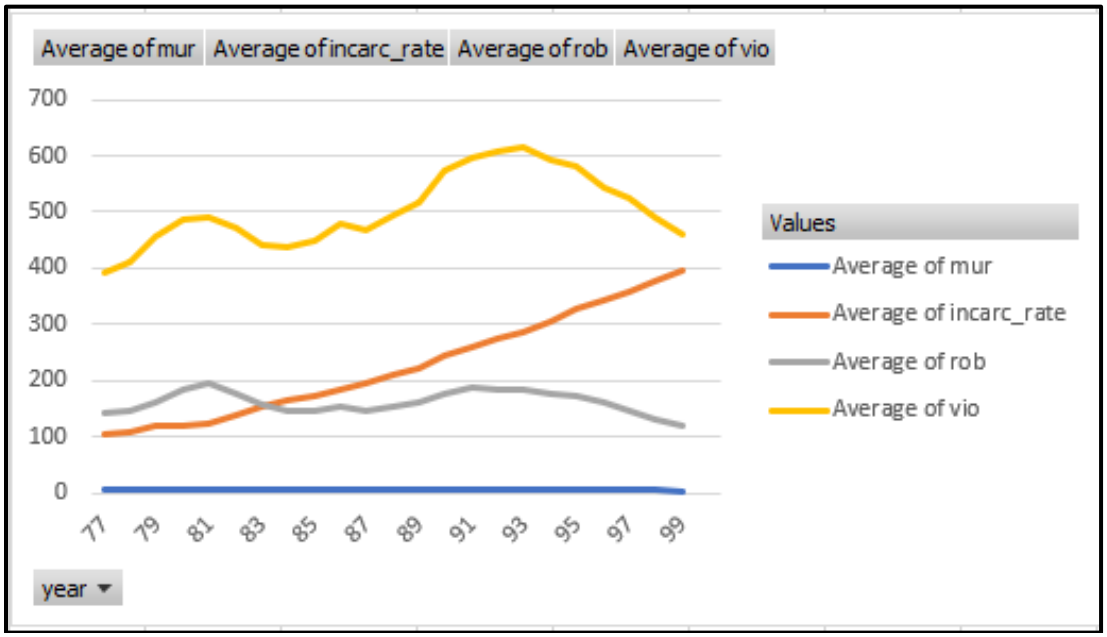
SHALL-LAW Vs CRIME RATE

- We find that the average crime rate has always been higher in states where shall-law has not been implemented.



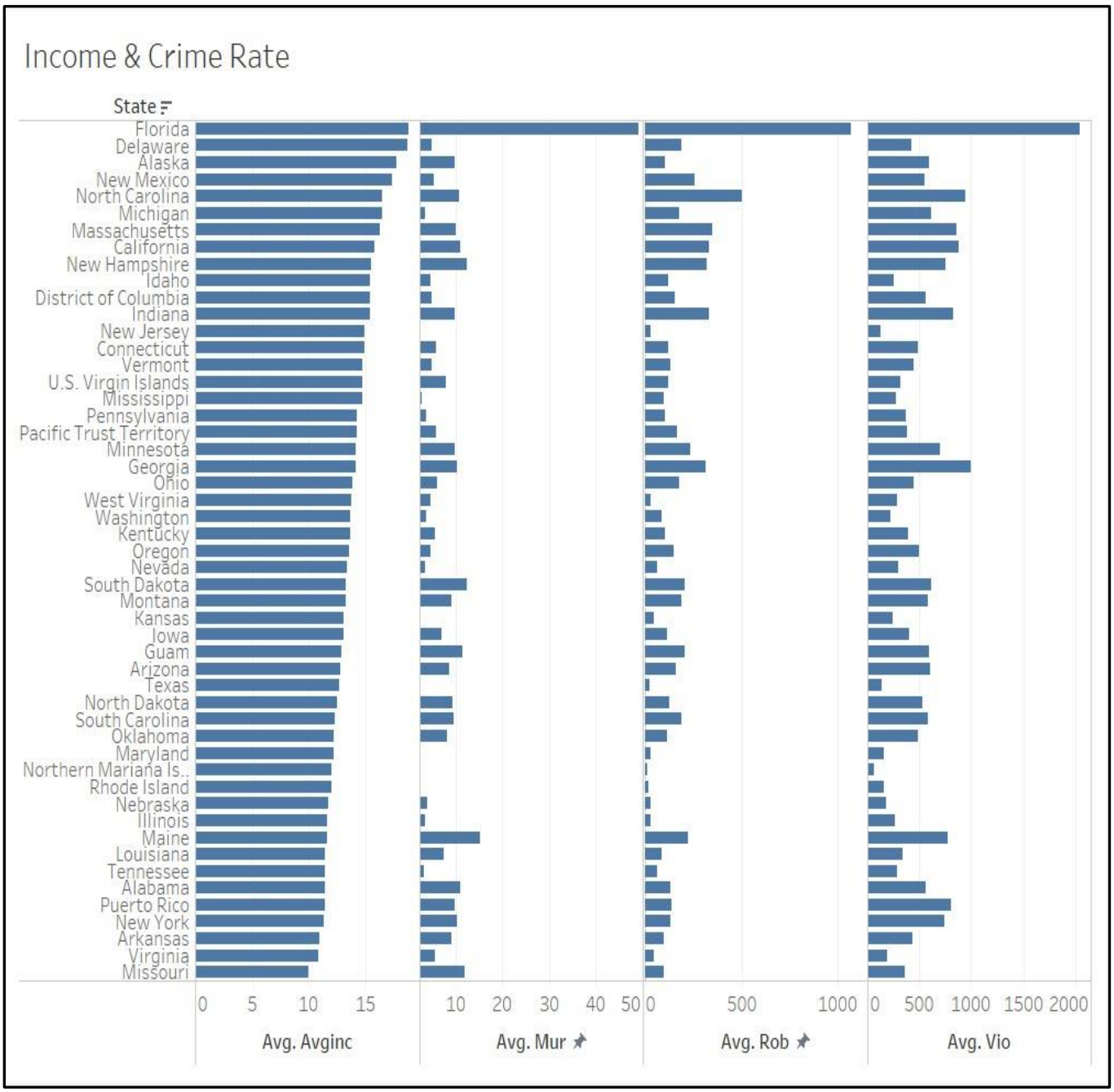
INCARCERATION RATE

- Incarceration rate on an average has increased over the years across the USA.
- It is maximum in 1999 where crime rates were declining.



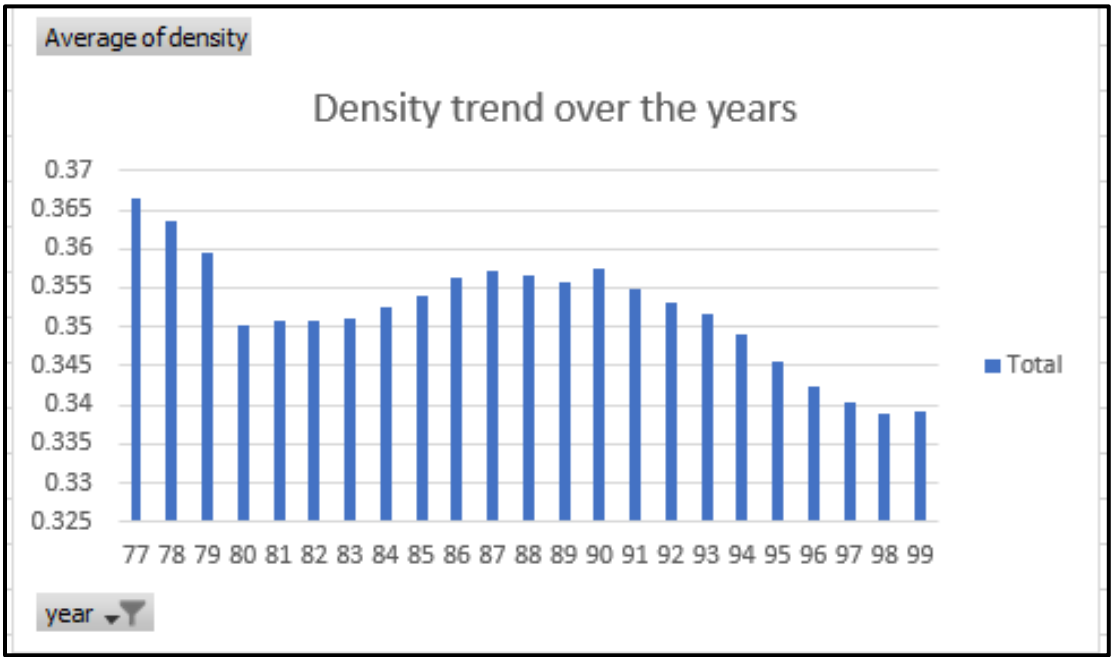
AVERAGE INCOME Vs CRIME RATE

- State with *stateid* 11 (Florida) has the highest real per capita personal income.
- It is observed that the state with highest average income is also the sate with maximum crime rate.
- Other than Florida, we find neither positive nor negative correlation between the average income of a state and its crime rate.

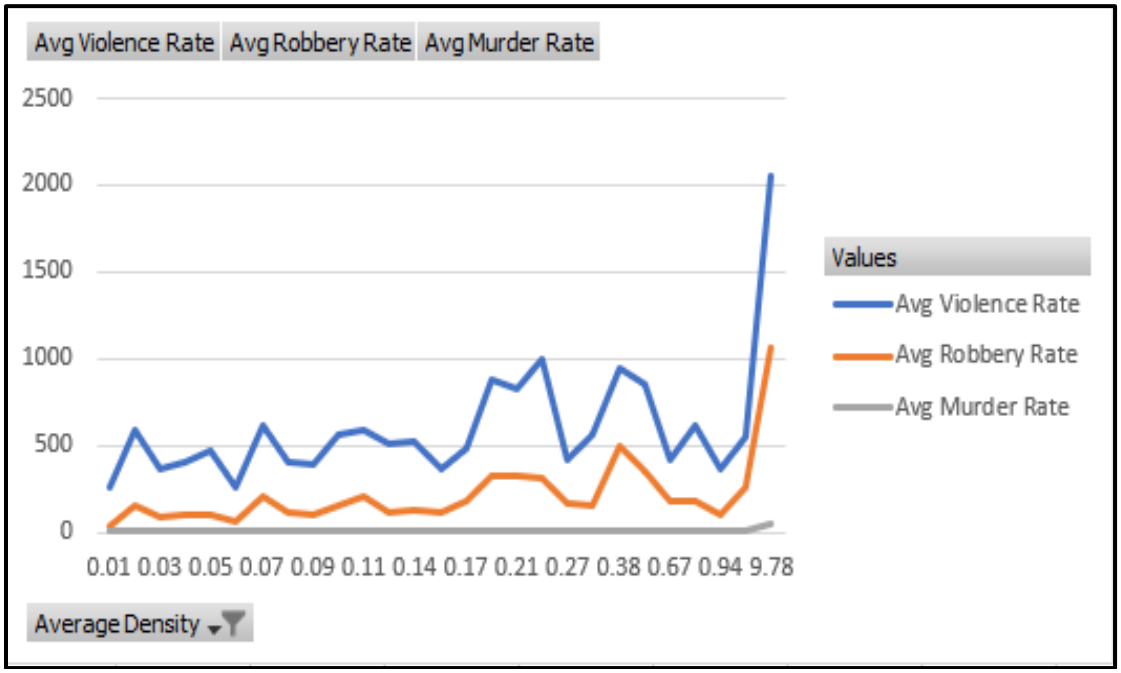


POPULATION & DENSITY

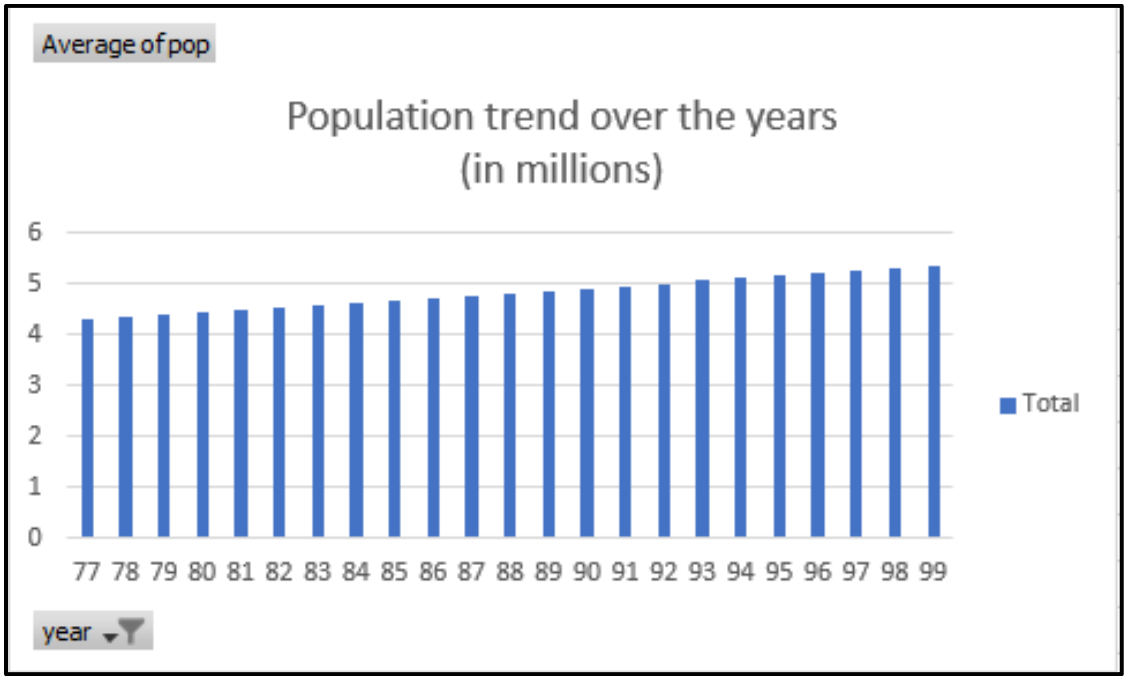
- We find that the population density has decreased towards the end of the observation years.
- This means that the population had become more scattered and wide spread over the years.



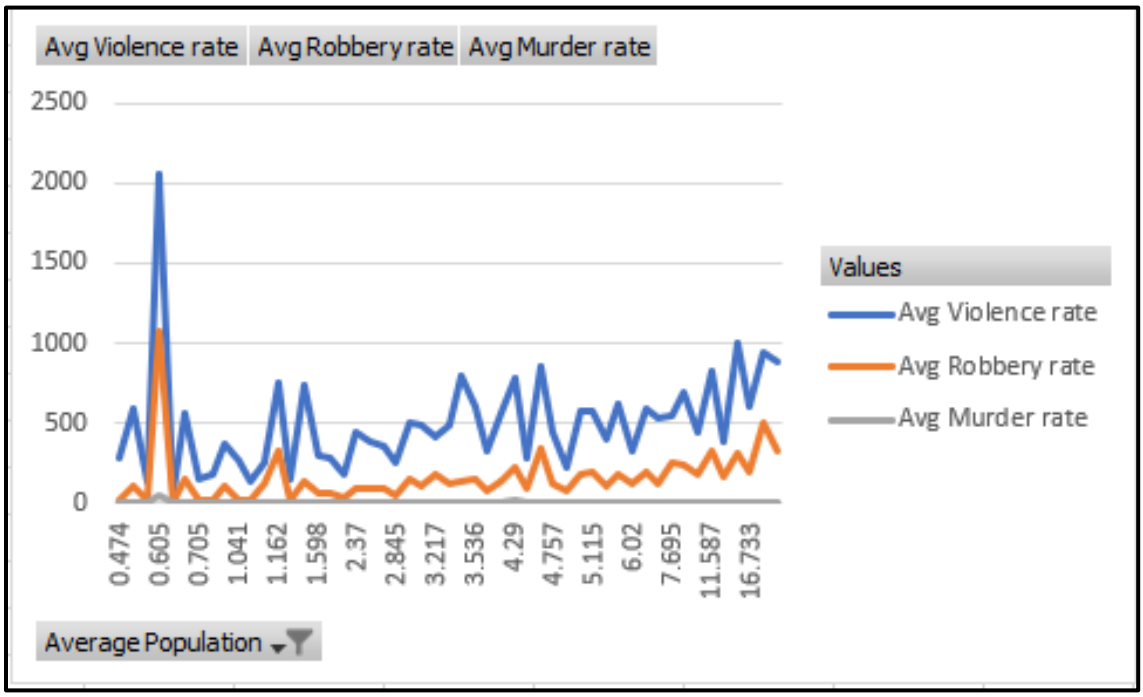
- Population density and crime rate seem to be almost positively correlated.
- Crime rate is maximum where population density is the highest.



- Population in the USA had gradually increased over the years.



- We find that the crime rate is not maximum when the population is highest.



UNDERSTANDING DATA

Based on analysis and intuition, our understanding and hypotheses of the data is as follows:

Shall-Issue Law & Crime Rate:

- Over the years, the number of states that implemented the *Shall-Issue* law has increased (from 4 to 29) which means there is a possibility that more states trust this law to be effective in bringing down the crime rate.
- Hence, we expect the *shall-law* variable to play a significant role in bringing down the crime rate like violence and murder.
- However, we feel that this might not be applicable to robbery since in general robbery, property crimes, theft and stealth are more associated with weapons like guns and is expected to increase when more people have access to them.

Incarceration & Crime Rate:

- Incarceration rate has always been increasing over the years. However, the crime rate is not perfectly negatively correlated with incarceration rate.
- Hence, it is hard to believe that incarceration rate has effectively brought down crime rate.
- In fact, we feel that incarceration rate increased because crime rate increased which could lead to a direct correlation.

Population & Crime Rate:

- We intuit that population density is a key factor in explaining crime rate as it is common to expect more crime happening in more densely populated areas.
- The percentage of whites in any state is always higher than that of black and we don't find any meaningful relationship between race and crime rate or gender and crime rate.
- Thus, we expect *pm1029, pw1064* and *pb1064* variables to be less significant in explaining crime rate.

REGRESSION ANALYSIS

We proceed our analysis with regression. We try to find out the factors influencing violence rate, robbery rate and murder rate by constructing various regression models. Our aim is to find out whether the regression results match with our hypotheses and estimation of the data. This would help get better insights of the effects of shall-law in the USA.

The various models we choose to run are:

- **Pooled OLS model**
- **Fixed Effects model**
- **Fixed Effects model with Time Effects**
- **Random Effects model**

By putting these models to tests, we try to choose the best model by interpreting and analyzing the test results. Some of the tests include:

- **F-Test**
- **Hausman Test**

Violence Rate:

We begin by running a Pooled OLS regression to understand how different variables affect the violence rate. We used the log-linear model because we found out that violence rate is positively skewed. Below is the regression output.

Pooled OLS regression:

```
Pooling Model

Call:
plm(formula = lnvio ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "pooling")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-1.723001 -0.266205  0.047669  0.304780  1.059977

Coefficients:
              Estimate  Std. Error  t-value  Pr(>|t|)
(Intercept)  2.98173825  0.54339379   5.4873 5.006e-08 ***
shall       -0.36838695  0.03256743 -11.3115 < 2.2e-16 ***
incarc_rate  0.00161263  0.00010716  15.0495 < 2.2e-16 ***
density      0.02668847  0.01316805   2.0268 0.0429146 *
avginc       0.00120512  0.00778022   0.1549 0.8769305
pop          0.04270983  0.00255883  16.6912 < 2.2e-16 ***
pm1029       0.00887088  0.01077367   0.8234 0.4104577
pw1064       0.03120051  0.00837759   3.7243 0.0002053 ***
pb1064       0.08085260  0.01665138   4.8556 1.364e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    488.63
Residual Sum of Squares: 212.92
R-Squared:      0.56426
Adj. R-Squared: 0.56126
F-statistic: 188.411 on 8 and 1164 DF, p-value: < 2.22e-16
```

As per the above results, the presence of shall issue law reduces the violence rate by 36.83% and the model shows that this value is highly significant . All the others variables impact the violence rate positively. All variables except pm1029 and avginc are significant. But the provided data is panel data and this model doesn't take into consideration the below factors:

- Heteroskedasticity (increase in variance of error)
- The correlation between errors of the same entity (serial correlation).
- The correlation between error term and the dependent variable- shall (endogeneity).

The first two factors violate assumptions of Gauss Markov theorem and hence this produces inefficient estimates even though they are unbiased and consistent. Due to inefficiency, the obtained standard errors are incorrect. In presence of the third factor, the coefficients become biased and inconsistent which renders the model invalid. Hence in the upcoming models, we will try to solve all the above factors.

Pooled OLS with Robust Standard Errors:

In this model, we try to overcome the standard error problem by using White robust standard errors which help us to make valid statistical inferences though the estimates are not BEST.

```
> coeftest(pooled, vcov=vcovHC(pooled,type="HC1"))

t test of coefficients:

               Estimate  Std. Error t value  Pr(>|t|)
(Intercept)  2.98173825  2.14608239  1.3894 0.1649809
shall       -0.36838695  0.11286253 -3.2640 0.0011303 **
incarc_rate  0.00161263  0.00059429  2.7135 0.0067551 **
density      0.02668847  0.04109968  0.6494 0.5162340
avginc       0.00120512  0.02385371  0.0505 0.9597156
pop          0.04270983  0.01161835  3.6761 0.0002477 ***
pm1029       0.00887088  0.03377483  0.2626 0.7928686
pw1064       0.03120051  0.03376852  0.9240 0.3557025
pb1064       0.08085260  0.07071429  1.1434 0.2531201
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

We can see that the robust standard errors for all the variables have increased compared to the previous model. This proves that there is heterogeneity in the model.

Fixed Effect Model:

In this model, we include the effect of both observed and unobserved heterogeneity(endogeneity). Also it takes into account the serial correlation between the errors of same entity. Time invariant variables will not affect the fixed effect model.

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnvio ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064, data = datapanel, model = "within")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-0.612487 -0.111442  0.010288  0.111701  0.538090

Coefficients:
               Estimate  Std. Error t-value  Pr(>|t|)
shall       -2.6960e-02  1.9210e-02 -1.4034  0.160769
incarc_rate  2.5160e-04  8.6354e-05  2.9136  0.003644 **
density     -4.1563e-02  8.5627e-02 -0.4854  0.627487
avginc       1.2336e-02  5.3730e-03  2.2959  0.021867 *
pop          7.0200e-03  8.9385e-03  0.7854  0.432408
pw1064       3.4232e-02  5.1380e-03  6.6626 4.218e-11 ***
pb1064       1.1327e-01  1.8195e-02  6.2256 6.781e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    36.789
Residual Sum of Squares: 30.369
R-Squared:      0.17452
Adj. R-Squared: 0.13232
F-statistic: 33.6748 on 7 and 1115 DF, p-value: < 2.22e-16
```

We can see that the estimate of shall variable has decreased from 36% to 2% and has become insignificant at 10% significance level. This shows that shall effect law does not have much impact on the violence rate.

Fixed Effect model With Time Effect:

There still can exists omitted variables which can possibly vary over time but are constant across states. The time fixed effects model addresses the bias from such omitted variables.

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnvio ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064 + year, data = data, model = "within",
    index = c("stateid"))

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.4731862 -0.0774088  0.0031778  0.0852814  0.7049161

Coefficients:
              Estimate  Std. Error t-value  Pr(>|t|)
shall       -1.7832e-02  1.7184e-02 -1.0377 0.2996350
incarc_rate  1.3076e-04  9.0386e-05  1.4467 0.1482566
density     -6.7228e-02  7.6836e-02 -0.8750 0.3817902
avginc       8.3188e-03  6.3010e-03  1.3202 0.1870302
pop          4.5518e-03  7.6868e-03  0.5922 0.5538646
pw1064       3.5053e-02  5.6768e-03  6.1748 9.326e-10 ***
pb1064       9.1459e-02  1.8591e-02  4.9196 1.001e-06 ***
year78       4.1215e-02  2.8162e-02  1.4635 0.1436189
year79       1.3443e-01  2.8163e-02  4.7734 2.057e-06 ***
year80       1.7881e-01  2.8192e-02  6.3427 3.299e-10 ***
year81       1.6509e-01  2.8251e-02  5.8438 6.728e-09 ***
year82       1.2567e-01  2.8369e-02  4.4299 1.037e-05 ***
year83       7.0379e-02  2.8559e-02  2.4644 0.0138787 *
year84       8.0495e-02  2.9114e-02  2.7648 0.0057907 **
year85       1.1045e-01  2.9688e-02  3.7203 0.0002091 ***
year86       1.6791e-01  3.0539e-02  5.4983 4.771e-08 ***
year87       1.4600e-01  3.1363e-02  4.6550 3.636e-06 ***
year88       1.8492e-01  3.2441e-02  5.7001 1.539e-08 ***
year89       2.1954e-01  3.3580e-02  6.5380 9.548e-11 ***
year90       2.5320e-01  3.5372e-02  7.1583 1.496e-12 ***
year91       2.8812e-01  3.5582e-02  8.0973 1.489e-15 ***
year92       3.0129e-01  3.7121e-02  8.1166 1.282e-15 ***
year93       3.0900e-01  3.7827e-02  8.1689 8.533e-16 ***
year94       2.7813e-01  3.9279e-02  7.0809 2.558e-12 ***
year95       2.5547e-01  4.1136e-02  6.2102 7.504e-10 ***
year96       1.8570e-01  4.3116e-02  4.3069 1.804e-05 ***
year97       1.5234e-01  4.5383e-02  3.3568 0.0008156 ***
year98       8.2707e-02  4.8542e-02  1.7038 0.0886998 .
year99       9.6539e-03  5.1039e-02  0.1891 0.8500127
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    36.789
Residual Sum of Squares: 21.844
R-Squared:      0.40624
Adj. R-Squared: 0.36333
F-statistic: 25.787 on 29 and 1093 DF, p-value: < 2.22e-16
```

After doing a joint hypothesis test (F-test), we found that the time variables are jointly significant. The shall variable estimate further got reduced to 1.78% and remains insignificant.

Random Effect:

We want to consider the effect of both within and between entities. The random effect model will capture this effect.

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = lnvio ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "random")

Balanced Panel: n = 51, T = 23, N = 1173

Effects:
                  var std.dev share
idiosyncratic 0.02583 0.16072 0.184
individual    0.11418 0.33791 0.816
theta: 0.9013

Residuals:
    Min.  1st Qu.   Median  3rd Qu.     Max.
-0.54197 -0.10665  0.01310  0.11380  0.52468

Coefficients:
              Estimate  Std. Error z-value  Pr(>|z|)
(Intercept)  3.5255e+00  3.8740e-01  9.1003 < 2.2e-16 ***
shall       -6.9609e-02  1.9084e-02 -3.6476 0.0002647 ***
incarc_rate  1.8883e-04  6.8735e-05  2.7472 0.0060099 **
density      6.6159e-02  3.7363e-02  1.7707 0.0766099 .
avginc      -1.0511e-02  5.8749e-03 -1.7892 0.0735883 .
pop          2.2576e-02  6.3498e-03  3.5553 0.0003776 ***
pm1029      -3.7529e-02  6.0462e-03 -6.2071 5.397e-10 ***
pw1064       4.0072e-02  5.0987e-03  7.8591 3.868e-15 ***
pb1064       1.0670e-01  1.3298e-02  8.0242 1.022e-15 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    41.19
Residual Sum of Squares: 31.938
R-Squared:      0.22461
Adj. R-Squared: 0.21929
Chisq: 337.189 on 8 DF, p-value: < 2.22e-16
```

Although the shall estimate has become significant now, the random effects model is always prone to endogeneity issues. So we run the Hausman test to conclude whether there is endogeneity or not.

Hausman Test between Fixed Effect and Random:

```
> ## Hausman Test between Fixed and Random Effect
> phtest(fete,re)

        Hausman Test

data:  lnvio ~ shall + incarc_rate + density + avginc + pop + pw1064 +  ...
chisq = 77.755, df = 7, p-value = 3.95e-14
alternative hypothesis: one model is inconsistent
```

From the above test, we can clearly see that endogeneity is there in the model. Hence we reject the null hypothesis and conclude the Random Effect model is invalid. So we choose **Fixed effects with time effects model** as our preferred model.

Robbery Rate

Pooled OLS:

```
Pooling Model

Call:
plm(formula = lnrob ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "pooling")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-2.350140 -0.359929  0.082074  0.445931  1.531312

Coefficients:
              Estimate Std. Error  t-value  Pr(>|t|)
(Intercept)  0.9041383  0.7733572   1.1691 0.2425994
shall       -0.5288202  0.0463499 -11.4093 < 2.2e-16 ***
incarc_rate  0.0010057  0.0001525   6.5949 6.444e-11 ***
density      0.0905048  0.0187408   4.8293 1.553e-06 ***
avginc       0.0407325  0.0110728   3.6786 0.0002452 ***
pop          0.0778177  0.0036417  21.3684 < 2.2e-16 ***
pm1029       0.0272565  0.0153331   1.7776 0.0757264 .
pw1064       0.0275209  0.0119230   2.3082 0.0211614 *
pb1064       0.1021882  0.0236982   4.3121 1.754e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    1068
Residual Sum of Squares: 431.27
R-Squared:      0.59621
Adj. R-Squared: 0.59343
F-statistic: 214.832 on 8 and 1164 DF, p-value: < 2.22e-16
```

As per the above results, the presence of shall issue law reduces the robbery rate by 52.88% and the model shows that this value is highly significant . All the others variables impact the robbery rate positively. All variables except pm1029 are significant.

Pooled OLS with Robust Standard Error :

```
> coeftest(pooled1, vcov=vcovHC(pooled1,type="HC1"))

t test of coefficients:

               Estimate  Std. Error t value  Pr(>|t|)
(Intercept)  0.90413830  3.03262931  0.2981 0.7656520
shall       -0.52882023  0.15935939 -3.3184 0.0009333 ***
incarc_rate  0.00100573  0.00063404  1.5862 0.1129556
density      0.09050478  0.04554604  1.9871 0.0471448 *
avginc       0.04073249  0.02789125  1.4604 0.1444489
pop          0.07781765  0.02230700  3.4885 0.0005039 ***
pm1029       0.02725647  0.04133195  0.6595 0.5097355
pw1064       0.02752086  0.04458436  0.6173 0.5371733
pb1064       0.10218815  0.08856445  1.1538 0.2488075
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can see that the robust standard errors for all the variables have increased compared to the previous model. This proves that there is heterogeneity in the model

Fixed Effect:

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnrob ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064, data = datapanel, model = "within")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.6799138 -0.1369235  0.0070358  0.1395328  0.8161254

Coefficients:
               Estimate  Std. Error t-value  Pr(>|t|)
shall       -0.01208543  0.02505093 -0.4824  0.629592
incarc_rate -0.00014810  0.00011261 -1.3151  0.188742
density     -0.21516798  0.11166345 -1.9269  0.054242 .
avginc      -0.02231030  0.00700670 -3.1841  0.001492 **
pop          0.01733510  0.01165643  1.4872  0.137253
pw1064       0.02865511  0.00670029  4.2767 2.059e-05 ***
pb1064       0.10954181  0.02372721  4.6167 4.351e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    53.526
Residual Sum of Squares: 51.645
R-Squared:      0.035147
Adj. R-Squared: -0.014177
F-statistic: 5.80236 on 7 and 1115 DF, p-value: 1.268e-06
```

We can see that the estimate of shall variable has decreased from 52% to 1.2% and has become insignificant at 10% significance level. This shows that shall effect law does not have much impact on the robbery rate.

Fixed Effect with Time Effect:

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnrob ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064 + year, data = data, model = "within",
    index = c("stateid"))

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.7207796 -0.1115487 -0.0020808  0.1159125  0.7248161

Coefficients:
             Estimate Std. Error t-value  Pr(>|t|)
shall        0.0413261  0.0237650  1.7389  0.082326 .
incarc_rate  0.0001095  0.0001250  0.8760  0.381208
density     -0.0100400  0.1062615 -0.0945  0.924742
avginc       0.0248568  0.0087141  2.8525  0.004420 **
pop          0.0132926  0.0106307  1.2504  0.211421
pw1064       0.0239779  0.0078509  3.0542  0.002311 **
pb1064       0.1029454  0.0257107  4.0040 6.649e-05 ***
year78       0.0081542  0.0389475  0.2094  0.834203
year79       0.0954847  0.0389484  2.4516  0.014379 *
year80       0.1888218  0.0389885  4.8430 1.463e-06 ***
year81       0.1992974  0.0390708  5.1009 3.982e-07 ***
year82       0.1176149  0.0392342  2.9978  0.002781 **
year83      -0.0051035  0.0394958 -0.1292  0.897211
year84      -0.0816507  0.0402634 -2.0279  0.042811 *
year85      -0.0780541  0.0410580 -1.9011  0.057555 .
year86      -0.0332336  0.0422342 -0.7869  0.431517
year87      -0.0972407  0.0433747 -2.2419  0.025170 *
year88      -0.0951604  0.0448649 -2.1210  0.034143 *
year89      -0.0689263  0.0464398 -1.4842  0.138042
year90      -0.0625113  0.0489180 -1.2779  0.201563
year91       0.0277136  0.0492090  0.5632  0.573426
year92      -0.0020627  0.0513371 -0.0402  0.967957
year93      -0.0063985  0.0523131 -0.1223  0.902674
year94      -0.0153264  0.0543215 -0.2821  0.777887
year95      -0.0369836  0.0568902 -0.6501  0.515772
year96      -0.1159942  0.0596281 -1.9453  0.051996 .
year97      -0.2022183  0.0627635 -3.2219  0.001311 **
year98      -0.3180185  0.0671323 -4.7372 2.452e-06 ***
year99      -0.4142965  0.0705859 -5.8694 5.794e-09 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    53.526
Residual Sum of Squares: 41.779
R-Squared:      0.21947
Adj. R-Squared: 0.16306
F-statistic: 10.5977 on 29 and 1093 DF, p-value: < 2.22e-16
```

After doing a joint hypothesis test(F-test), we find that the time variables are jointly significant. The shall estimate further got increased to 4.1% and becomes significant at 10% significance level.

Random Effect :

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = lnrob ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "random")

Balanced Panel: n = 51, T = 23, N = 1173

Effects:
                 var std.dev share
idiosyncratic 0.04629 0.21515 0.165
individual    0.23492 0.48469 0.835
theta: 0.9078

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.8054451 -0.1414150  0.0081219  0.1575517  0.6598344

Coefficients:
              Estimate  Std. Error z-value  Pr(>|z|)
(Intercept)  1.8759e+00  5.2089e-01  3.6013 0.0003166 ***
shall       -4.1119e-02  2.5590e-02 -1.6069 0.1080872
incarc_rate  1.7350e-04  9.3124e-05  1.8631 0.0624431 .
density      9.9752e-02  5.2767e-02  1.8904 0.0587024 .
avginc      -1.5298e-02  7.8914e-03 -1.9385 0.0525616 .
pop          4.0586e-02  8.7624e-03  4.6319 3.624e-06 ***
pm1029       2.5300e-02  8.1299e-03  3.1119 0.0018587 **
pw1064       2.8264e-02  6.8389e-03  4.1328 3.584e-05 ***
pb1064       1.0745e-01  1.8176e-02  5.9116 3.387e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    62.143
Residual Sum of Squares: 57.246
R-Squared:      0.078813
Adj. R-Squared: 0.072482
Chisq: 99.5877 on 8 DF, p-value: < 2.22e-16
```

Hausman Test between Random Effect and Fixed Effect :

```
> ## Hausman Test between Fixed and Random Effect
> phtest(fete1,re1)

        Hausman Test

data:  lnrob ~ shall + incarc_rate + density + avginc + pop + pw1064 +  ...
chisq = 720.95, df = 7, p-value < 2.2e-16
alternative hypothesis: one model is inconsistent
```

From the above test, we can clearly see that endogeneity is present in the model. Hence we reject the null hypothesis and conclude Random Effect model is invalid. So we choose **Fixed effects with time effects model** as our preferred model.

Murder Rate

Pooled OLS

```
Pooling Model

Call:
plm(formula = lnmur ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "pooling")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-2.546829 -0.242742  0.050402  0.310012  1.134890

Coefficients:
              Estimate  Std. Error t-value  Pr(>|t|)
(Intercept) -2.48559346  0.56299889 -4.4149 1.104e-05 ***
shall       -0.31317351  0.03374243 -9.2813 < 2.2e-16 ***
incarc_rate  0.00209696  0.00011102 18.8879 < 2.2e-16 ***
density      0.03966691  0.01364314  2.9075  0.003713 **
avginc      -0.07725777  0.00806093 -9.5842 < 2.2e-16 ***
pop          0.04161749  0.00265115 15.6979 < 2.2e-16 ***
pm1029       0.06553076  0.01116238  5.8707 5.655e-09 ***
pw1064       0.04707956  0.00867984  5.4240 7.083e-08 ***
pb1064       0.13076406  0.01725214  7.5796 7.053e-14 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    579.9
Residual Sum of Squares: 228.56
R-Squared:      0.60587
Adj. R-Squared: 0.60316
F-statistic: 223.663 on 8 and 1164 DF, p-value: < 2.22e-16
```

As per the above results, the presence of shall issue law reduces the murder rate by 31.31% and the model shows that this value is highly significant. All the other variables impact the murder rate positively and are significant.

Pooled OLS with Robust Standard Error

```
> coeftest(pooled2, vcov=vcovHC(pooled2,type="HC1"))

t test of coefficients:

              Estimate Std. Error t value  Pr(>|t|)
(Intercept) -2.485593   1.973297 -1.2596 0.2080610
shall       -0.313174   0.098108 -3.1921 0.0014500 **
incarc_rate  0.002097   0.000456  4.5986 4.718e-06 ***
density      0.039667   0.039517  1.0038 0.3156848
avginc      -0.077258   0.026789 -2.8839 0.0039997 **
pop          0.041617   0.011814  3.5229 0.0004435 ***
pm1029       0.065531   0.035823  1.8293 0.0676121 .
pw1064       0.047080   0.028322  1.6623 0.0967198 .
pb1064       0.130764   0.060614  2.1573 0.0311859 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can see that the robust standard errors for all the variables have increased compared to the previous model. This proves that there is heterogeneity in the model.

Fixed Effect model :

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnmur ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064, data = datapanel, model = "within")

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-1.7327018 -0.1185917  0.0016014  0.1212542  0.8648697

Coefficients:
             Estimate Std. Error t-value  Pr(>|t|)
shall       -0.0757817  0.0257593 -2.9419  0.003329 **
incarc_rate -0.0006118  0.0001158 -5.2834 1.524e-07 ***
density     -0.7727469  0.1148212 -6.7300 2.708e-11 ***
avginc       0.0074995  0.0072048  1.0409  0.298147
pop         -0.0221894  0.0119861 -1.8513  0.064395 .
pw1064       0.0155050  0.0068898  2.2504  0.024615 *
pb1064       0.0236816  0.0243982  0.9706  0.331943
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    63.314
Residual Sum of Squares: 54.607
R-Squared:      0.13752
Adj. R-Squared: 0.093431
F-statistic: 25.398 on 7 and 1115 DF, p-value: < 2.22e-16
```

We can see that the estimate of shall variable has decreased from 31% to 7.57% but has become highly insignificant. As per this model, shall law has a huge impact on murder rate.

Fixed Effect Model with Time Effect:

```
Oneway (individual) effect Within Model

Call:
plm(formula = lnmur ~ shall + incarc_rate + density + avginc +
    pop + pw1064 + pb1064 + year, data = data, model = "within",
    index = c("stateid"))

Balanced Panel: n = 51, T = 23, N = 1173

Residuals:
       Min.     1st Qu.      Median     3rd Qu.        Max.
-1.74456843 -0.10505740 -0.00010382  0.10991866  0.86088617

Coefficients:
              Estimate  Std. Error t-value  Pr(>|t|)
shall       -0.00536335  0.02474781 -0.2167 0.8284667
incarc_rate -0.00006472  0.00013017 -0.4972 0.6191517
density     -0.52130696  0.11065594 -4.7111 2.781e-06 ***
avginc       0.06359466  0.00907446  7.0081 4.219e-12 ***
pop         -0.02329496  0.01107032 -2.1043 0.0355826 *
pw1064       0.02385984  0.00817554  2.9184 0.0035899 **
pb1064       0.08074763  0.02677400  3.0159 0.0026214 **
year78      -0.01705507  0.04055819 -0.4205 0.6741967
year79       0.03139515  0.04055906  0.7741 0.4390627
year80       0.05407372  0.04060088  1.3318 0.1831916
year81       0.05293257  0.04068659  1.3010 0.1935384
year82      -0.04266342  0.04085672 -1.0442 0.2966143
year83      -0.11473166  0.04112909 -2.7896 0.0053698 **
year84      -0.24207468  0.04192843 -5.7735 1.011e-08 ***
year85      -0.21309178  0.04275590 -4.9839 7.240e-07 ***
year86      -0.15965399  0.04398079 -3.6301 0.0002964 ***
year87      -0.19735128  0.04516851 -4.3692 1.366e-05 ***
year88      -0.20791292  0.04672029 -4.4502 9.459e-06 ***
year89      -0.22468601  0.04836026 -4.6461 3.794e-06 ***
year90      -0.21351878  0.05094094 -4.1915 2.995e-05 ***
year91      -0.18517544  0.05124398 -3.6136 0.0003157 ***
year92      -0.23974284  0.05346017 -4.4845 8.079e-06 ***
year93      -0.16711390  0.05447652 -3.0676 0.0022107 **
year94      -0.29289307  0.05656791 -5.1777 2.672e-07 ***
year95      -0.29558652  0.05924289 -4.9894 7.042e-07 ***
year96      -0.37962693  0.06209395 -6.1138 1.352e-09 ***
year97      -0.49754453  0.06535905 -7.6125 5.794e-14 ***
year98      -0.57378896  0.06990859 -8.2077 6.296e-16 ***
year99      -0.65480724  0.07350493 -8.9083 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    63.314
Residual Sum of Squares: 45.306
R-Squared:      0.28443
Adj. R-Squared: 0.23271
F-statistic: 14.9812 on 29 and 1093 DF, p-value: < 2.22e-16
```

After doing a joint hypothesis test(F-test), we find that the time variables is jointly significant. The shall estimate further got reduced to 0.5% and becomes insignificant at 10% significance level. Hence shall issue law does not have any effect after the inclusion of Time variable in the fixed effect model.

Random Effect:

```
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = lnmur ~ shall + incarc_rate + density + avginc +
    pop + pm1029 + pw1064 + pb1064, data = datapanel, model = "random")

Balanced Panel: n = 51, T = 23, N = 1173

Effects:
                 var std.dev share
idiosyncratic 0.04815 0.21943 0.337
individual    0.09459 0.30755 0.663
theta: 0.8529

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-1.826732 -0.124006  0.012699  0.155455  0.745616

Coefficients:
               Estimate  Std. Error z-value  Pr(>|z|)
(Intercept) -3.3014e-01  5.3650e-01 -0.6154  0.538323
shall       -1.1537e-01  2.6884e-02 -4.2914 1.776e-05 ***
incarc_rate  4.4375e-04  9.2481e-05  4.7983 1.600e-06 ***
density      1.6343e-02  3.8166e-02  0.4282  0.668500
avginc       9.3982e-03  8.1589e-03  1.1519  0.249364
pop          2.9126e-03  7.2821e-03  0.4000  0.689183
pm1029       7.3472e-02  8.4037e-03  8.7428 < 2.2e-16 ***
pw1064       6.9318e-03  7.1688e-03  0.9669  0.333575
pb1064       5.1266e-02  1.6824e-02  3.0471  0.002311 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    74.499
Residual Sum of Squares: 65.01
R-Squared:      0.12738
Adj. R-Squared: 0.12138
Chisq: 169.916 on 8 DF, p-value: < 2.22e-16
```

Hausman Test:

```
> ## Hausman Test between Fixed and Random Effect
> phtest(fete2,re2)

        Hausman Test

data:  lnmur ~ shall + incarc_rate + density + avginc + pop + pw1064 +  ...
chisq = 50.344, df = 7, p-value = 1.236e-08
alternative hypothesis: one model is inconsistent
```

From the above test, we can clearly see that endogeneity is there in the model. Hence we reject the null hypothesis and conclude that the Random Effect model is invalid. So we choose **Fixed effects with time effects model** as our preferred model

CONCLUSION

- We see that from the regression models, the shall issue law does not have any significant impact on violence and murder rates. This contradicts our assumptions that the shall issue law affects both the violence and murder rates.
- However in case of robbery, the shall issue law seems to have a positive impact. The robbery rates increase in the presence of shall issue law. This is in agreement with our assumption that the presence of shall issue law increases the robbery rate.
- Thus we can conclude that **"MORE GUNS DO NOT REDUCE CRIME!"**