# The effect of shall laws on crime rate

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# Introduction

The impact of guns on crime in America has triggered a lot of public debate. Many strongly believe that state laws enabling citizens to carry concealed handguns has reduced crime. According to this view, gun control laws take away guns from law-abiding citizens, while would-be criminals ignore them leaving potential victims defenseless. Following this view, The National Rifle Association (NRA) and many politicians across the country campaign for greater freedom to carry guns.

As a result, many states in the United States have passed right-to-carry laws (also known as a shall-issue law). A Shall-issue law is one that requires that governments issue concealed carry handgun permits to any applicant who meets the necessary criteria. These criteria are: the applicant must be an adult, have no significant criminal record, have no history of mental illness, and successfully complete a course in firearms safety training (only in certain states). If these criteria are met, the granting authority has no discretion in the awarding of the licenses, and there is no requirement of the applicant to demonstrate "good cause".

We are examining and analyzing historical data on crime in the U.S to answer the question “Do shall-issues law reduce crime or not?” Previous studies suggest that evidence for the effect of shall-issue laws on total homicides, firearm homicides, robberies, assaults, and rapes is inconclusive.Some studies find that right-to-carry laws reduce violent crime,[Lott and Mustard (1997)] others find that the effects are negligible[e.g., Duggan, 2001; Ayres and Donohue, 2003a, 2003b], and still others find that such laws increase violent crime.[Rosengart et al. (2005) ] We would like to find out whether our data would lead to the same conclusion or show that the shall-issue law has an effect on reducing the crime rate.

# Documentation for Guns Data

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<br>= 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 |
| *State-id* | ID number of states (Alabama = 1, Alaska = 2, etc.) |
| *year* | Year (1977-1999) |

# Theory

## Speculations on variable’s relations:

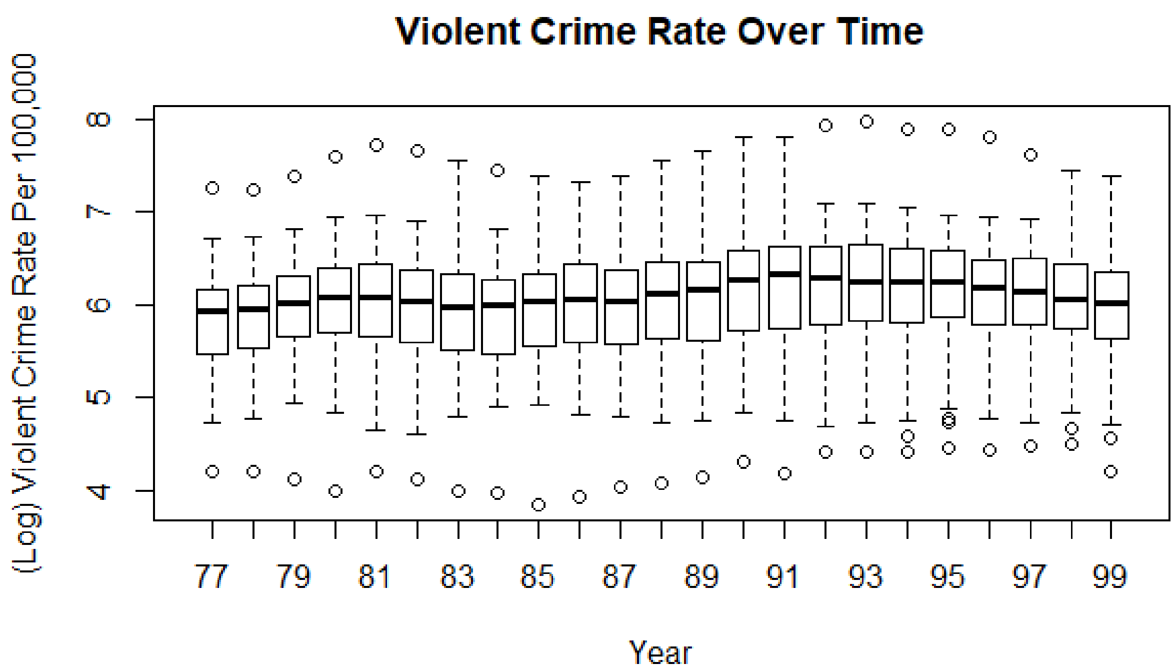
1. **Violent crime rate**: This variable includes robbery and murder rate and we expect it to be strongly correlated with them. Also, we expect that in states that violent crime rate is high we have higher density and higher incarceration rates.
2. **Robbery rate**: We expect robbery rate to be correlated with incarceration rate, density, and possibly pm1029. Shall-carry laws should have a positive effect on it (shall = 1 will lead to lower robbery rates).
3. **Murder rate**: We expect that the murder rate to be highly correlated with the violent crime rate and murder rate.
4. **Shall**: If we believe shall carry laws to be effective we expect it to have a negative impact on violent crime, robbery, and murder rate (these will decrease when shall = 1). We believe when states allow citizens to own guns, the crime rate should reduce. The logic is that people will think twice before committing a crime since the person whom they want to attack may have a gun and can shoot them back.
5. **Incarceration_rate**: when the incarceration rate increases, the crime rate will reduce. When criminals are put in jail, they cannot go out on the street to commit a crime.
6. **Density**: We expect that states with higher density will have higher crime rates and higher incarceration rates because of the proximity of people to each other which increases interaction (including criminal activity) among themselves.
7. **Average income**: we expect that the higher average income has a negative effect on crime, robbery and murder rates. When people do not have enough money for their daily spending, crime seems to increase. In contrast, people who earn higher incomes tend to be happy and enjoy their life, so there is no reason for them to destroy their life by committing a crime.
8. **Pop**: Crimes are committed more often in more populated areas, so we expect a higher population to have a positive effect on crime rates. It seems likely that the crime rate increases when the population increases because life will become more competitive and stressful. However, when we have more people in the vicinity, it could lower the chance to be attacked in public. Therefore, we could see there being a positive or negative effect of population on crime rates.
9. **Pm1029**: We expect that robbery rates to be highly correlated with this variable. The crime rate will decrease when the median age of citizens increases. In other words, people in their teenage years, the twenties and thirties are more likely to commit a crime. As such, the crime rate is likely to increase when there is a higher percentage of young people, especially young men who are typically more violent than women.

10. **pw1064 and pb1064**: We expect these variables to have a positive relationship with the crime rate, however, we can’t guess the possible difference in magnitude of that effect because it might differ from state to state. Many studies found that in most violent crimes, the victim and the offender were of the same race and that there was a higher rate of black offenders compared to that of white offenders. Therefore, it suggests that the crime rate tends to increase when the percentage of black people increases, but it will decrease when the percentage of white people increases.

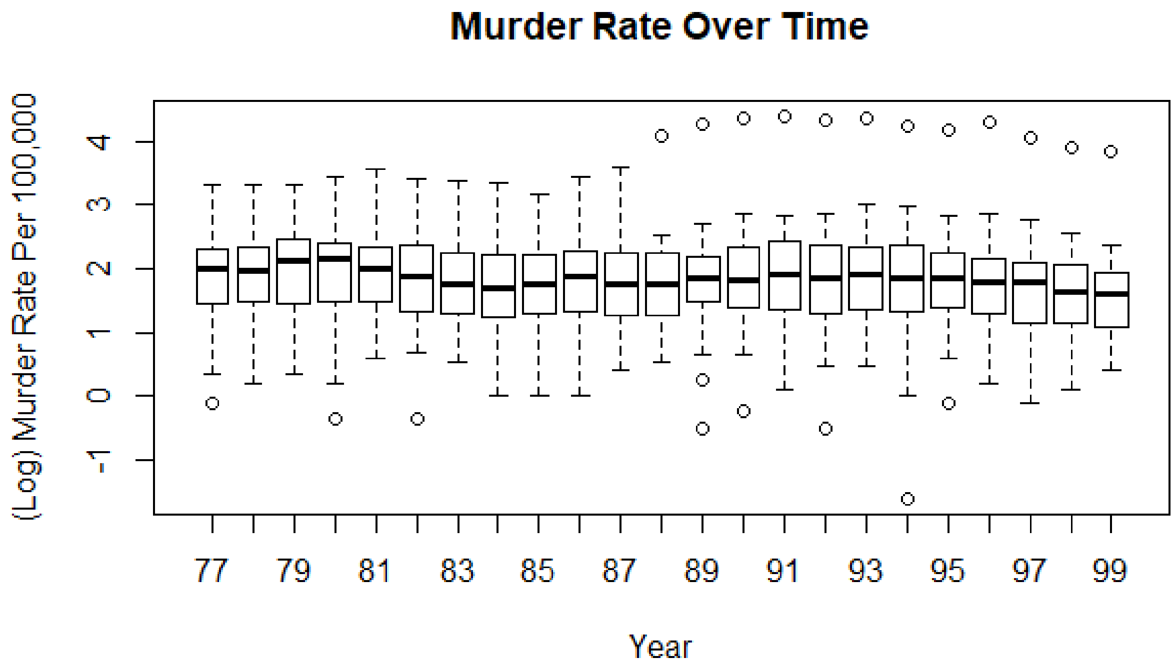
# Data exploration:

## Trends Over Time

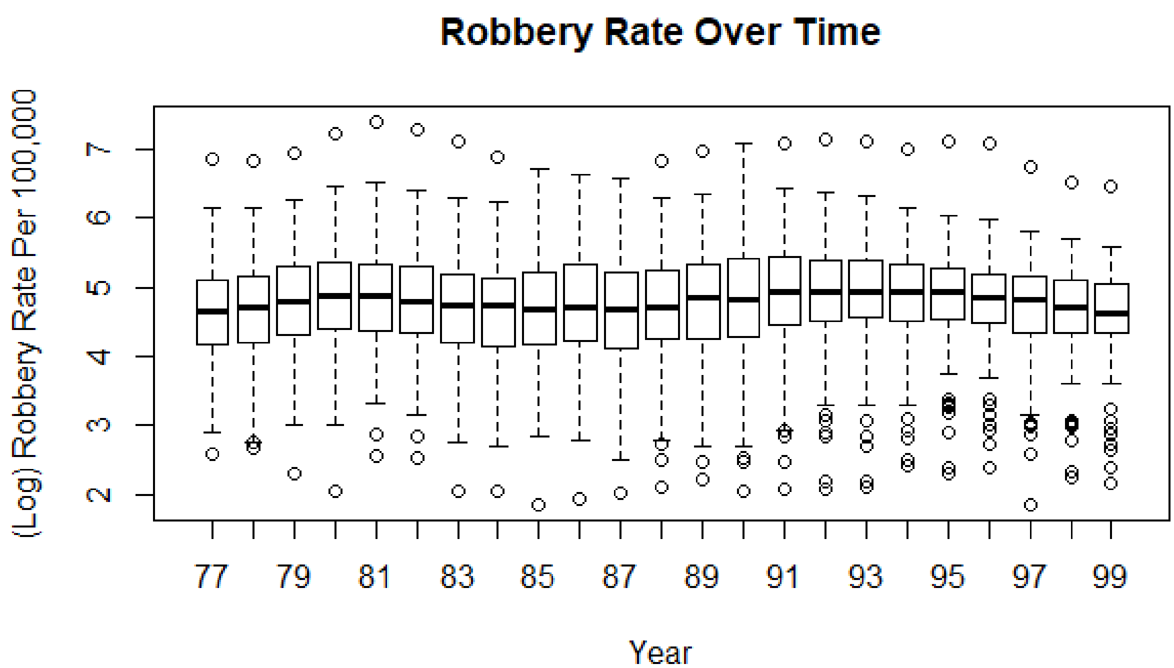
Below are boxplots showing the outliers of each crime rate for each period of time:




We can see that there are outliers both above and below the quartile of log(violent crime rate). There also seems to be a slight increase in violent crime rate over time.

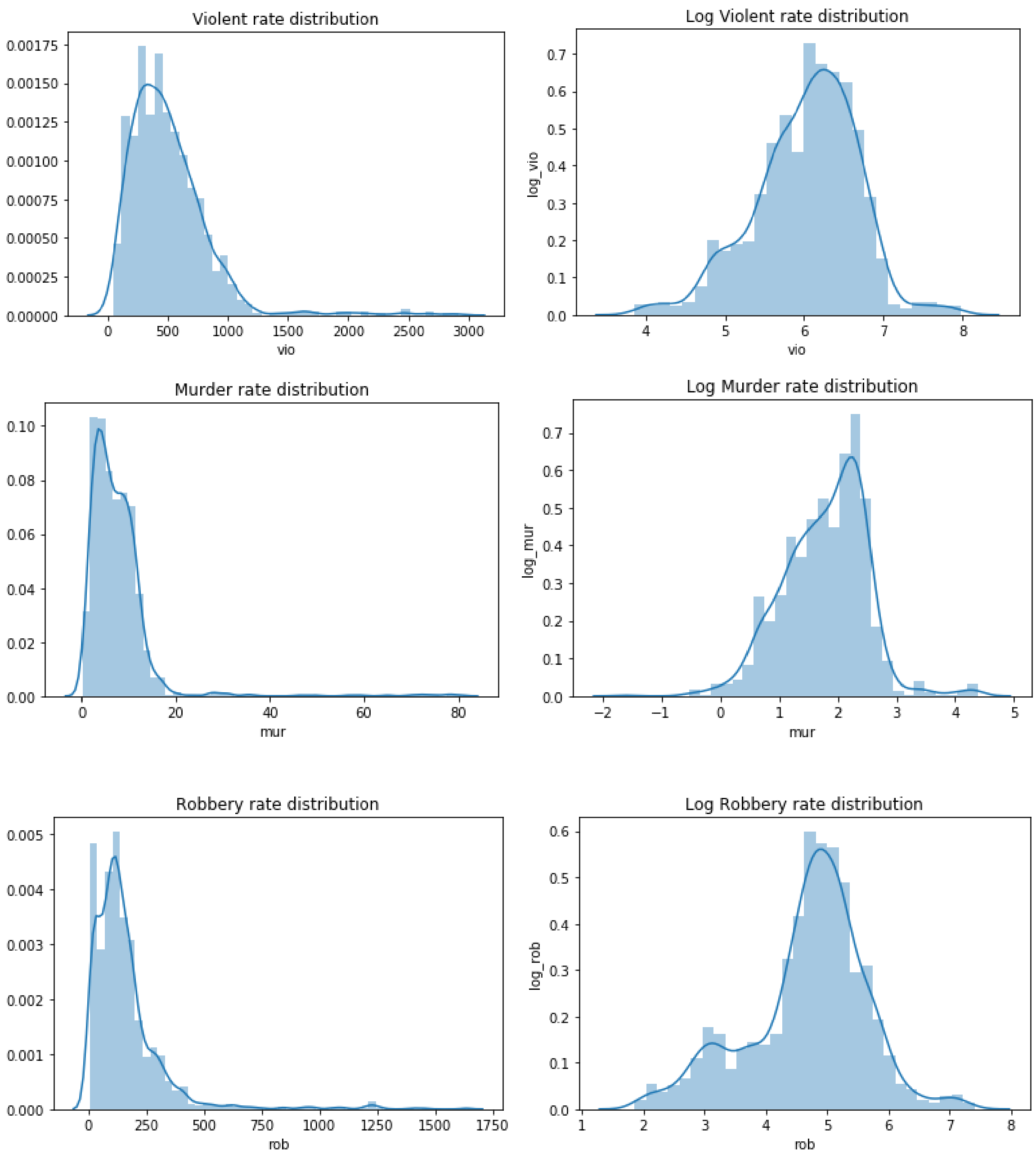



Once again there are a few outliers above and below the quartiles of log(murder rate). Murder rate also seems to have slightly decreased over time.



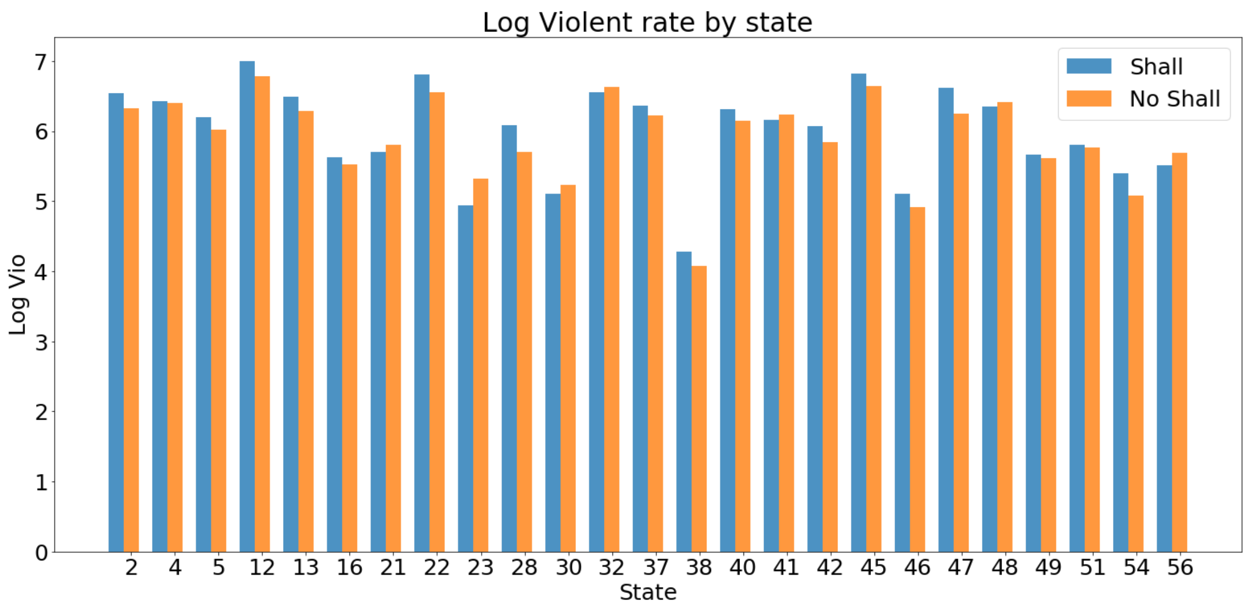

There are many outliers in robbery rate, especially after 1987. This is important to note, as this could heavily skew any results or insights we receive from robbery rate models. There also seems to be a slight decrease in robbery rate over time.

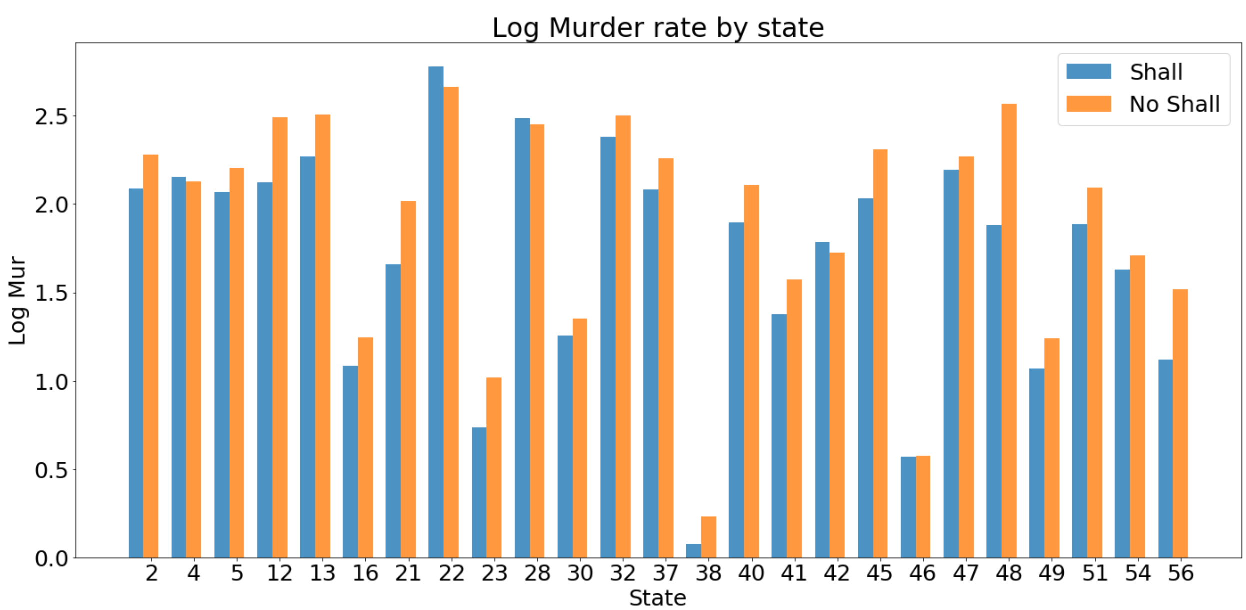
# Distribution of violent, murder, and robbery rate

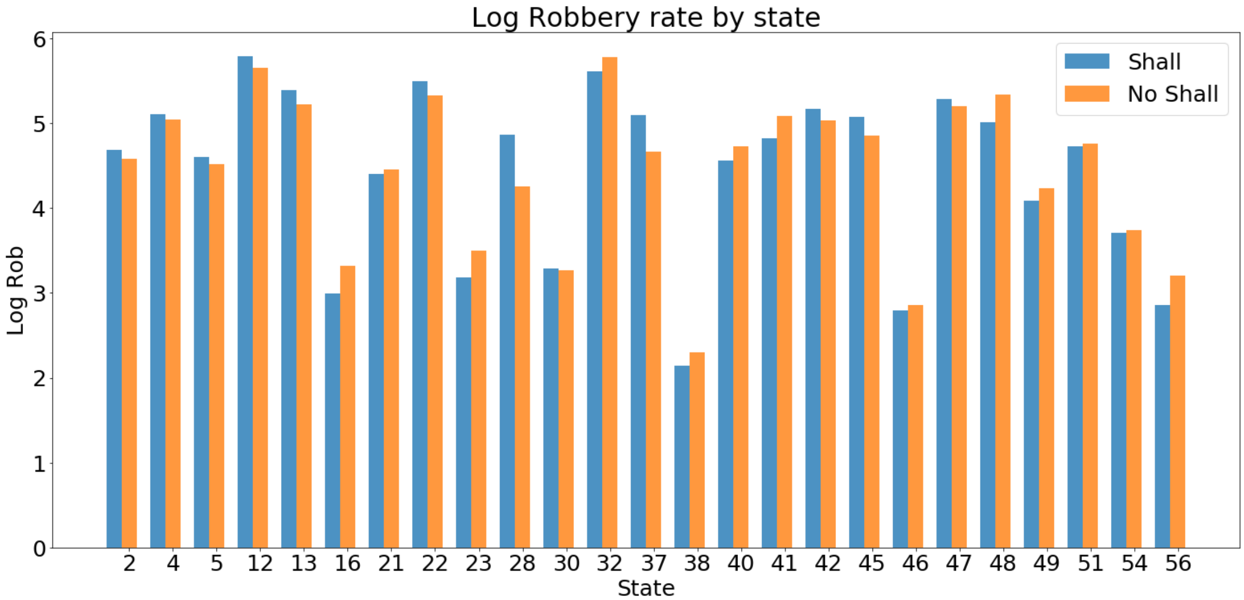



It is clearly seen that the distribution of violent rate, murder rate, and robbery rate are highly skewed to the right on the graphs above. Therefore, we transform them using natural logs to have a more normal distribution. By doing so, we can reduce the influence of outliers on the model, and thus have a more accurate model. The graphs of the transformed rates can be found on the right side of the graphs above.

# Violent, Murder, Robbery Rate by State (only includes states which have both Shall = 0 and 1)





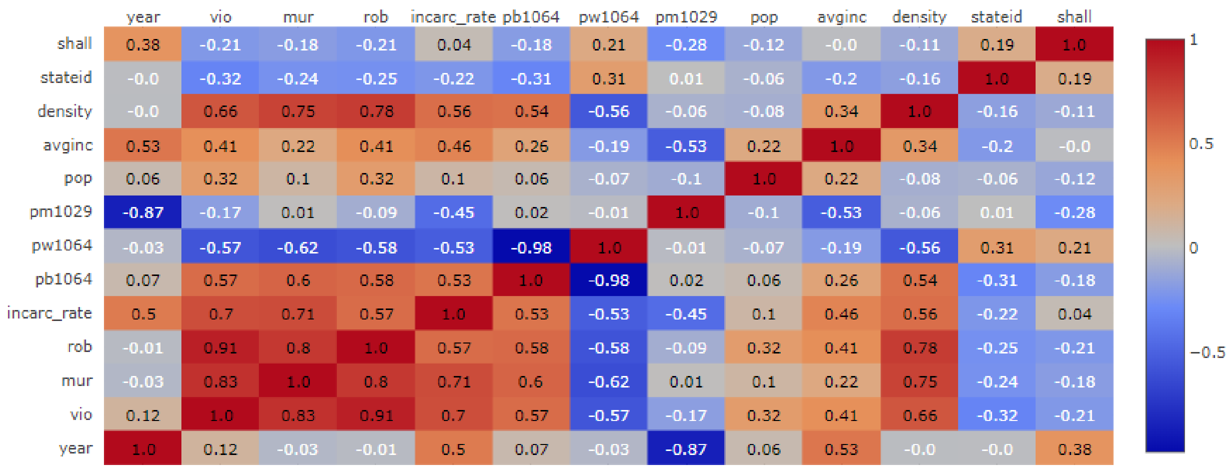

The graphs above compare the average log violent rate, log murder rate, and log robbery state by each state and by whether shall law was passed or not. Because it compares also within-state rates by whether shall law was passed or not, only 25 out of 51 states are included in these graphs. We can see that in the graph of log violent rate, the rate when shall law was passed is higher than when shall law was not passed in the majority of the states. On the other hand, the log murder rate is much higher when shall law was not passed compared to when it is passed in the majority of the states. Last but not least, there is no clear trend in the effect of shall law on log robbery rate, as the rate is higher than when it is not passed in some states and lower in other states. There is a trend however that is more observable in states that either had Shall before 1977 or never had Shall until 1999. Observing these trends would suggest the use of both fixed effects and time fixed-effect models would be appropriate.

## Scatter Matrix

**Shall = 1 (orange)**
**Shall = 0 (blue)**


This scatter matrix shows the distribution of all variables in the dataset and a scatter plot for each combination of 2 variables from the dataset. As we discussed above, the “vio”, “mur”, and “rob” here are actually the log-transformed variables. The graphs are also colored code as blue for observations with shall = 0 and orange for shall = 1.

# Correlation matrix




### Significant correlations:

| Top Absolute Correlations | | |
|---|---|---:|
| pb1064 | pw1064 | 0.981978 |
| vio | rob | 0.907077 |
| year | pm1029 | 0.865828 |
| vio | mur | 0.826509 |
| mur | rob | 0.797606 |
| rob | density | 0.781834 |
| mur | density | 0.748592 |
| mur | incarc_rate | 0.709608 |
| vio | incarc_rate | 0.70266 |
| vio | density | 0.664726 |
| mur | pw1064 | 0.615368 |
| mur | pb1064 | 0.601833 |
| rob | pw1064 | 0.584192 |

| | | |
|---|---|---|
| rob | pb1064 | 0.581202 |
| vio | pw1064 | 0.573018 |
| vio | pb1064 | 0.569788 |
| rob | incarc_rate | 0.56685 |
| incarc_rate | density | 0.559313 |
| pw1064 | density | 0.555113 |
| pb1064 | density | 0.543244 |

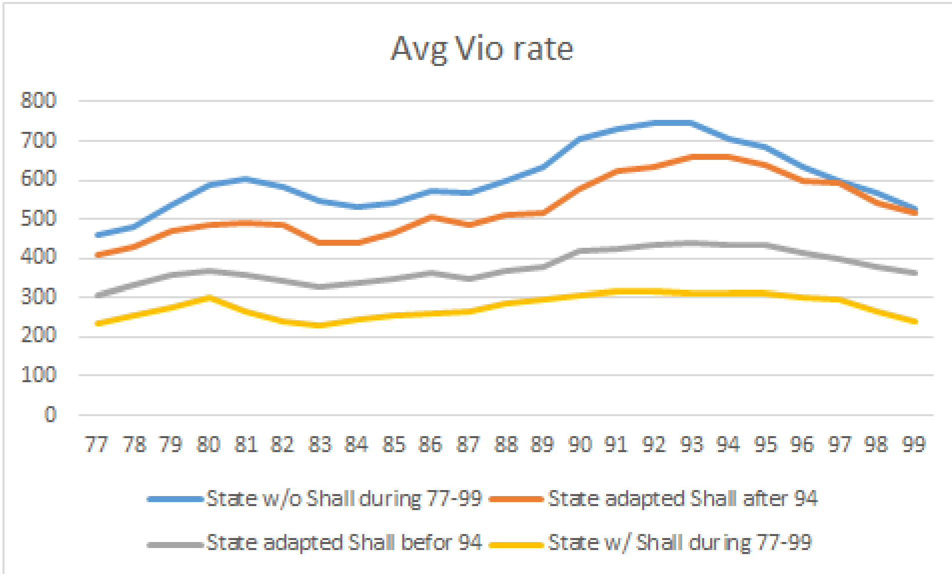
As shown pb1064 and pw1064 are strongly correlated (0.98, close to perfect correlation) and it makes sense because an increase in percentage of white will lead to a decrease in percentage of black, and vice versa. From this point, the report is going to use only pw1064 due to multicollinearity and redundancy if we add both pw1064 and pb1064 to our model.

Year and pm1029 are highly correlated but there shouldn't be any logical relation between them, and it is likely the two are correlated by chance.

The only other variables with a correlation over 80% are vio, mur, and rob which is completely expected with the knowledge that vio is the sum of rob and mur and a few other crimes rates that were not mentioned in the database. For this matter, the report will use all three variables as the dependent variables, with the main focus on the variable vio.

There is also a high correlation between murder rate / violent crime rate and robbery rate and variables density and incarceration rate.

The correlation between murder rate/violent crime rate and robbery rate and pw1064 and pb1064 is almost equal with pw1064 in the lead with very little difference.




The plots of the data above are supporting that Shall states have lower crime rates, so it is expected to see the negative sign for Shall variable. The rest of the report will discuss if Shall variable is significant and the effect of Shall variable with other factors held constant on reducing the crime rate. The plot excluded state 11 (blue group) because it looked like an outlier.

# Modeling

## Methodology

We began by running five different types of models for violent crime rate, murder rate, and robbery rate (in natural log form): Entity Fixed Effects, Time Fixed Effects, Time and Entity Fixed Effects, Random Effects, and Pooled OLS. Intuitively, Pooled OLS and Random Effects models would not be appropriate. Our data is taken from one sample over time, not multiple. Similarly, the data was collected from all 51 states/Washington D.C. which would mean the data is not randomly sampled, so random effects would also not be appropriate. We will also be using F-test to see which Fixed Effects model is the most appropriate and Hausman test to confirm our intuition that the Random Effects model is not appropriate in this case. In each mode, we excluded the percentage of black persons from the models because of multicollinearity and redundancy.

From our analysis, we draw the same conclusion about the effect of shall on each crime rate. Therefore, we will include the detailed analysis of the violent crime rate in this report and include the results from Stata for the murder rate and robbery rate in the appendix.

# Pooled OLS

```
. reg lvio i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster st
> ateid)

Linear regression                               Number of obs     =      1,173
                                                F(7, 50)          =      65.69
                                                Prob > F          =     0.0000
                                                R-squared         =     0.5554
                                                Root MSE          =     .43182

                               (Std. Err. adjusted for 51 clusters in stateid)
```

| lvio | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.3319326 | .1031395 | -3.22 | 0.002 | -.5390944 | -.1247709 |
| incarc_rate | .0016557 | .000625 | 2.65 | 0.011 | .0004003 | .0029111 |
| density | .0112286 | .041934 | 0.27 | 0.790 | -.0729984 | .0954556 |
| avginc | .02243 | .0211547 | 1.06 | 0.294 | -.0200604 | .0649205 |
| pop | .0405908 | .0111395 | 3.64 | 0.001 | .0182165 | .0629652 |
| pm1029 | .0293499 | .0283894 | 1.03 | 0.306 | -.0276719 | .0863716 |
| pw1064 | -.0086201 | .0102158 | -0.84 | 0.403 | -.0291391 | .011899 |
| _cons | 5.296106 | 1.040506 | 5.09 | 0.000 | 3.206187 | 7.386024 |

**Interpretation**

- Shall - Enacting shall laws will decrease the violent crime rate by 33.19326%. This is significant at 1% level of significance.
- Incarc_rate - 1% increase in incarc_rate will increase the violent crime rate by 0.16557%. Although this estimate is significant at 5% level of significance, the sign is not the same as we expected.
- Density - 1000 unit increase in density will increase the violent crime rate by 1.12286%. This coefficient is not significant even at 10% level of significance.
- Avginc - 1,000 dollars increase in avginc will increase the violent crime rate by 2.243%. This coefficient is not significant even at 10% level of significance and the sign is not the same as we expected.
- Pop - 1,000,000 people increased in population will increase the violent crime rate by 4.05908%. This is significant at 1% level of significance.
- Pm1029 - 1% increase in percent of state population that is male, ages 10 to 29 will increase violent crime rate by 2.93499%. This coefficient is not significant even at 10% level of significance.
- Pw1064 - 1% increase in percent of state population that is white, age 10 to 64 will decrease the violent crime rate by 0.86201%. This coefficient is not significant even at 10% level of significance.

The pooled OLS model is not an appropriate model because it does not control for endogeneity. Additionally, although the coefficient of shall is significant, its negative impact is quite high and unrealistic. Therefore, we suspect that endogeneity problem exists and it inflates the negative impact of shall on the violent crime rate.

For example, we suspect there is an omitted variable named “using-gun culture”. This variable is expected to have a positive correlation with shall because states with strong using-gun culture tend to enact the law which allows people to carry guns. Moreover, these two variables are expected to have a negative impact on the violent crime rate because people will think twice before committing a crime since the person whom they want to attack may have a gun and can shoot them back. Therefore, this omitted variable will make the coefficient of shall become downwardly biased.

Because the pooled OLS did not give desired result, we proceed to run an entity fixed effects model.

## Entity fixed effects model

```
. xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster
>  stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.1936                                         min =         23
     between = 0.0211                                         avg =       23.0
     overall = 0.0089                                         max =         23

                                                F(7,50)           =      42.06
corr(u_i, Xb)  = -0.4433                        Prob > F          =     0.0000

                              (Std. Err. adjusted for 51 clusters in stateid)
```

| lvio | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| shall | -.0243845 | .0427534 | -0.57 | 0.571 | -.1102572 | .0614882 |
| incarc_rate | .0000167 | .0002482 | 0.07 | 0.947 | -.0004818 | .0005151 |
| density | .0847004 | .1169536 | 0.72 | 0.472 | -.1502078 | .3196085 |
| avginc | -.000474 | .0126619 | -0.04 | 0.970 | -.0259061 | .0249582 |
| pop | .0171825 | .0113758 | 1.51 | 0.137 | -.0056666 | .0400315 |
| pm1029 | -.0526988 | .0215897 | -2.44 | 0.018 | -.096063 | -.0093346 |
| pw1064 | .0264819 | .0127587 | 2.08 | 0.043 | .0008553 | .0521085 |
| _cons | 5.103919 | .7297495 | 6.99 | 0.000 | 3.638174 | 6.569664 |
| sigma_u | .7014404 | | | | | |
| sigma_e | .16311876 | | | | | |
| rho | .94869576 | (fraction of variance due to u_i) | | | | |

**Interpretation**

- Shall - Enacting shall laws will decrease the violent crime rate by 2.43845%. This is not significant even at a 10% level.
- Incarc_rate - When incarc_rate increases by 1, the violent crime rate increases by 0.00167%. This is not significant at even a 10% level.
- Density - When density increases by 1000 units, the violent crime rate increases by 8.47004%. This is not significant, even at a 10% level.
- Avginc - When avginc increases by 1000 dollars, the violent crime rate decreases by 0.0474%. This is not significant at a 10% significance level.
- Pop - When pop increases by 1000000, the violent crime rate increases by 1.71825%. This is not significant even at a 10% level.
- Pm1029 - When the percent of young males increases by 1, the violent crime rate decreases by 5.26988%. This is significant at a 5% level.

- Pw1064 - When the percent of whites increases by 1, the violent crime rate increases by 2.64819%. This is significant at a 5% level.

The negative impact of shall in this model is much lower than that of the pooled OLS model, 2.4% compared to 33.19%. This further strengthens our suspicion of the presence of endogeneity. Because of the ignorance of this problem, the estimate in the pooled OLS is highly biased, and this bias has been controlled by the entity fixed effects model.

## Time fixed effects model

```
. reg lvio i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
```

| Source | SS | df | MS |
|---|---|---|---|
| Model | 284.114747 | 29 | 9.79706025 |
| Residual | 204.516811 | 1,143 | .178929844 |
| Total | 488.631558 | 1,172 | .416921125 |

| | | |
|---|---|---|
| Number of obs | = | 1,173 |
| F(29, 1143) | = | 54.75 |
| Prob > F | = | 0.0000 |
| R-squared | = | 0.5814 |
| Adj R-squared | = | 0.5708 |
| Root MSE | = | .423 |

| lvio | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.2658717 | .0338612 | -7.85 | 0.000 | -.3323088 | -.1994346 |
| incarc_rate | .0018912 | .0001155 | 16.37 | 0.000 | .0016645 | .0021178 |
| density | -.0181562 | .0140198 | -1.30 | 0.196 | -.0456636 | .0093511 |
| avginc | .036601 | .0067631 | 5.41 | 0.000 | .0233315 | .0498706 |
| pop | .0387541 | .0025271 | 15.34 | 0.000 | .0337959 | .0437124 |
| pm1029 | .0004109 | .0156871 | 0.03 | 0.979 | -.0303679 | .0311897 |
| pw1064 | -.0090939 | .0017161 | -5.30 | 0.000 | -.0124609 | -.0057269 |
| year | | | | | | |
| 78 | .0197058 | .0838627 | 0.23 | 0.814 | -.1448362 | .1842479 |
| 79 | .0977111 | .0839685 | 1.16 | 0.245 | -.0670386 | .2624607 |
| 80 | .1452645 | .0841097 | 1.73 | 0.084 | -.0197622 | .3102912 |
| 81 | .1244171 | .0843612 | 1.47 | 0.141 | -.041103 | .2899373 |
| 82 | .0612233 | .0849927 | 0.72 | 0.471 | -.1055359 | .2279825 |
| 83 | -.0406518 | .0859837 | -0.47 | 0.636 | -.2093554 | .1280518 |
| 84 | -.0735526 | .087399 | -0.84 | 0.400 | -.245033 | .0979278 |
| 85 | -.0788076 | .0890804 | -0.88 | 0.377 | -.2535872 | .0959719 |
| 86 | -.0514485 | .091239 | -0.56 | 0.573 | -.2304632 | .1275661 |
| 87 | -.1050394 | .0935577 | -1.12 | 0.262 | -.2886035 | .0785247 |
| 88 | -.0988709 | .0961198 | -1.03 | 0.304 | -.2874619 | .0897201 |
| 89 | -.10478 | .0986294 | -1.06 | 0.288 | -.298295 | .088735 |
| 90 | -.0178119 | .100869 | -0.18 | 0.860 | -.215721 | .1800972 |
| 91 | .007957 | .1033192 | 0.08 | 0.939 | -.1947597 | .2106736 |
| 92 | -.006263 | .1057859 | -0.06 | 0.953 | -.2138193 | .2012934 |
| 93 | -.0239928 | .1076386 | -0.22 | 0.824 | -.2351842 | .1871985 |
| 94 | -.0939241 | .1098314 | -0.86 | 0.393 | -.3094179 | .1215697 |
| 95 | -.1409046 | .1122136 | -1.26 | 0.209 | -.3610724 | .0792633 |
| 96 | -.2166912 | .1144237 | -1.89 | 0.059 | -.4411952 | .0078128 |
| 97 | -.2669911 | .1163289 | -2.30 | 0.022 | -.4952332 | -.0387491 |
| 98 | -.3830017 | .1181782 | -3.24 | 0.001 | -.6148723 | -.1511312 |
| 99 | -.4910099 | .1197198 | -4.10 | 0.000 | -.7259051 | -.2561147 |
| _cons | 5.622147 | .3534906 | 15.90 | 0.000 | 4.928584 | 6.31571 |

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,  1143) =    3.23
            Prob > F =    0.0000
```

### Interpretation

- Shall - Enacting shall laws will decrease the violent crime rate by 26.58717%. This is significant at 1% level.
- Incarc_rate - When incarc_rate increases by 1, violent crime increases by 0.18912%. This is significant at 1% level.
- Density - When density increases by 1000 units, the violent crime rate decreases by 1.81562%. This is not significant even at 10% level.
- Avginc - When avginc increases by 1000 dollars, violent crime increases by 3.6601%. This is significant at 1% level.
- Pop - When pop increases by 1000000 people, violent crime increases by 3.87541%. This is significant at 1% level.
- Pm1029 - When the percent of young males increases by 1, the violent crime rate increases by 0.04109%. This is not significant even at 10% level.
- Pw1064 - When the percent of whites increases by 1, the violent crime decreases by 0.90939%. This is significant at 1% level.

  Since there are many year dummy variables, we will only include the ones that were statistically significant:

- D97 – There was a 26.69911% decrease in violent crime in 1997 when compared to 1977. This is statistically significant at 5% level.
- D98 – There was a 38.30017% decrease in violent crime in 1998 when compared to 1977. This is statistically significant even at 1% level.
- D99 – There was a 49.10099% decrease in violent crime in 1999 when compared to 1977. This is statistically significant even at 1% level.

We also performed an F-test to check if there is a trend over time in this dataset. According to the result of p-value = 0.0000, we conclude that at least one of the coefficients of the time indicator variables is different from zero, meaning there is a trend over time in this model.

However, since the coefficient of shall is significantly larger than the one in the entity fixed effects model, we believe the estimate here is also biased and does not account for variations within entities (like different cultures about guns by state). Therefore, we believe a time and entity fixed effects model will be the most appropriate.

## Entity and time fixed effects model

```
. xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(
> cluster stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.4171                                         min =         23
     between = 0.1874                                         avg =       23.0
     overall = 0.0341                                         max =         23

                                                F(29,50)          =      56.65
corr(u_i, Xb)  = -0.4205                        Prob > F          =     0.0000

                                (Std. Err. adjusted for 51 clusters in stateid)
```

| lvio | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| shall | -.027778 | .0406985 | -0.68 | 0.498 | -.1095234 | .0539674 |
| incarc_rate | .0000554 | .0002134 | 0.26 | 0.796 | -.0003731 | .000484 |
| density | -.0688809 | .1248715 | -0.55 | 0.584 | -.3196926 | .1819308 |
| avginc | -.0000542 | .0161126 | -0.00 | 0.997 | -.0324174 | .0323089 |
| pop | -.005865 | .0149676 | -0.39 | 0.697 | -.0359283 | .0241983 |
| pm1029 | .0850608 | .0410262 | 2.07 | 0.043 | .0026574 | .1674643 |
| pw1064 | .0013344 | .0157847 | 0.08 | 0.933 | -.03037 | .0330389 |
| year | | | | | | |
| 78 | .0620148 | .0137248 | 4.52 | 0.000 | .0344477 | .0895819 |
| 79 | .1701687 | .0199884 | 8.51 | 0.000 | .1300208 | .2103167 |
| 80 | .2260275 | .0259314 | 8.72 | 0.000 | .1739427 | .2781122 |
| 81 | .2288942 | .0297194 | 7.70 | 0.000 | .169201 | .2885874 |
| 82 | .2091683 | .0346815 | 6.03 | 0.000 | .1395085 | .278828 |
| 83 | .1760194 | .0449874 | 3.91 | 0.000 | .0856597 | .2663792 |
| 84 | .21391 | .0597426 | 3.58 | 0.001 | .0939134 | .3339066 |
| 85 | .2685073 | .0724408 | 3.71 | 0.001 | .1230057 | .4140089 |
| 86 | .3511997 | .0878029 | 4.00 | 0.000 | .1748424 | .527557 |
| 87 | .3549432 | .1013891 | 3.50 | 0.001 | .1512972 | .5585891 |
| 88 | .4213344 | .1127411 | 3.74 | 0.000 | .1948873 | .6477815 |
| 89 | .4804591 | .1246676 | 3.85 | 0.000 | .2300569 | .7308612 |
| 90 | .599714 | .1457238 | 4.12 | 0.000 | .3070192 | .8924088 |
| 91 | .6560187 | .1516843 | 4.32 | 0.000 | .3513517 | .9606856 |
| 92 | .6912976 | .1616617 | 4.28 | 0.000 | .3665905 | 1.016005 |
| 93 | .7165591 | .1675905 | 4.28 | 0.000 | .3799437 | 1.053175 |
| 94 | .7057119 | .1743984 | 4.05 | 0.000 | .3554223 | 1.056001 |
| 95 | .7014781 | .1810414 | 3.87 | 0.000 | .3378458 | 1.06511 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 96 | .6484529 | .1885485 | 3.44 | 0.001 | .2697421 | 1.027164 |
| 97 | .630363 | .1946614 | 3.24 | 0.002 | .2393741 | 1.021352 |
| 98 | .5770057 | .204232 | 2.83 | 0.007 | .1667937 | .9872178 |
| 99 | .5202477 | .2107391 | 2.47 | 0.017 | .0969658 | .9435296 |
| _cons | 4.205056 | .8682941 | 4.84 | 0.000 | 2.461036 | 5.949076 |
| sigma_u | .68988853 | | | | | |
| sigma_e | .14006831 | | | | | |
| rho | .9604106 | (fraction of variance due to u_i) | | | | |

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,    50) =   21.46
            Prob > F =    0.0000
```

**Interpretation**

- Shall - Enacting shall laws will decrease the violent crime rate by 2.7778%. This is not significant even at a 10% level.
- Incarc_rate - When incarc_rate increases by 1, violent crime increases by 0.00554%. This is not significant even at a 10% level.
- Density - When density increases by 1000, violent crime decreases by 6.88809%. This is not significant at even a 10% level.

- Avginc - When avginc increases by 1000 dollars, violent crime decreases by 0.00542%. This is not significant even at a 10% level.
- Pop - When pop increases by 1000000 people, violent crime decreases by 0.5865%. This is not significant even at a 10% level.
- Pm1029 - When the percent of young males increases by 1, violent crime increases by 8.50608%. This is significant at a 5% level.
- Pw1064 - When the percent of whites increases by 1, the violent crime increases by 0.13344%. This is not significant at a 10% level.
- Year variables - All of the year variables are significant at the 1% level of significance, except for 1999 which is still significant at a 5% level.

We also performed an F-test to check if there is a trend over time in this dataset. According to the result of p-value = 0.0000, we conclude that there is a trend over time in this model, which aligns with what we found in the previous part.

The entity and time fixed effects model is believed to be the best model according to our investigation, since it controls for both variables that vary over time but constant across states and that are constant over time but vary by states.

## Random effects model

```
. xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, re

Random-effects GLS regression                   Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.1748                                         min =         23
     between = 0.2468                                         avg =       23.0
     overall = 0.2408                                         max =         23

                                                Wald chi2(7)      =     259.25
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000
```

| lvio | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| shall | -.0264826 | .01883 | -1.41 | 0.160 | -.0633887 | .0104236 |
| incarc_rate | .0002083 | .0000704 | 2.96 | 0.003 | .0000703 | .0003464 |
| density | .181367 | .034834 | 5.21 | 0.000 | .1130936 | .2496404 |
| avginc | -.0005904 | .0059071 | -0.10 | 0.920 | -.0121681 | .0109873 |
| pop | .0257448 | .0064512 | 3.99 | 0.000 | .0131007 | .0383889 |
| pm1029 | -.0366962 | .0062142 | -5.91 | 0.000 | -.0488758 | -.0245165 |
| pw1064 | .0110645 | .0037326 | 2.96 | 0.003 | .0037487 | .0183803 |
| _cons | 5.700438 | .2855744 | 19.96 | 0.000 | 5.140723 | 6.260154 |
| sigma_u | .33409053 | | | | | |
| sigma_e | .16311876 | | | | | |
| rho | .80750312 | (fraction of variance due to u_i) | | | | |

Although we believe a random effects model will not be appropriate in this case (because the data set is not from a random sampling process), we still run a random effects model and perform a Hausman test to further support our argument.

## Hausman test

```
. hausman vio_fixed vio_random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   vio_fixed    vio_random     Difference          S.E.
-------------+----------------------------------------------------------------
       shall |   -.0243845    -.0264826        .0020981                .
 incarc_rate |    .0000167     .0002083       -.0001917         .0000619
     density |    .0847004      .181367       -.0966666         .0652883
      avginc |    -.000474    -.0005904        .0001165                .
         pop |    .0171825     .0257448       -.0085623         .0059848
      pm1029 |   -.0526988    -.0366962       -.0160026         .0018567
      pw1064 |    .0264819     .0110645        .0154173         .0025331
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       73.57
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

According to the Hausman test, the null hypothesis will be that there is no correlation between the explanatory variables and the error terms. With the p-value = 0.0000, we will reject the null hypothesis and conclude that there is a correlation between the explanatory variables and the error terms. Therefore, the estimates derived from the random-effects model will be biased and inconsistent, and thus, fixed effects model will be the better model in this case. This is on the same line with our argument in the previous part.

# Conclusion and Limitations:

From our analysis in the previous section, the entity-time fixed effects model is the best model for this dataset. According to this model, we can conclude that there is no statistically significant effect of shall laws on the violent crime rate. The p-value of shall in this model is 0.498, so this coefficient is not significant even at 10% level of significance.

However, there are some limitations to our model since we are using fixed effects:

1. While our estimators are immune from omitted variable bias for variables that are constant over time within entities and constant across entities, our estimates could still be biased if there is unobserved heterogeneity changing over time. While the bias is likely quite small because we used time and entity fixed effects, there is still the possibility that some bias is present.

2. Because of possible unobserved heterogeneity changing over time, there is also a chance that serial correlation of the errors is present. This would cause the standard errors to be incorrect and lead to problems utilizing hypothesis tests and confidence intervals. We used cluster robust standard errors to prevent serial correlation of the errors from occurring.

3. Since we used a fixed effects model, our estimators will be inefficient. This is because our model only considers the variations over time within individuals that contributes to the coefficient. This means that our estimator would not be a BLUE estimator because it would not be the best estimator.

### References

David B. Mustard & John Lott, "Crime, Deterrence, and Right-to-Carry Concealed Handguns" (Coase-Sandor Institute for Law &Economics Working Paper No. 41, 1996).

Mark Duggan, “More Guns, More Crime” (Journal of Political Economy vol. 109 no. 5, 2001).

Ayres, Ian and John J. Donohue III. "Shooting Down the More Guns, Less Crime Hypothesis." 55 Stanford Law Review 1193 (2003).

Rosengart M, Cummings P, Nathens A, Heagerty P, Maier R, Rivara F. An evaluation of state firearm regulations and homicide and suicide death rates. *Inj Prev*. 2005;11(2):77–83. doi:10.1136/ip.2004.007062

# Appendix

## Robbery rate

### Pooled OLS

```
. reg lrob i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster st
> ateid)

Linear regression                               Number of obs     =      1,173
                                                F(7, 50)          =      33.24
                                                Prob > F          =     0.0000
                                                R-squared         =     0.5898
                                                Root MSE          =     .61327

                               (Std. Err. adjusted for 51 clusters in stateid)
```

| lrob | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.4827463 | .1445347 | -3.34 | 0.002 | -.7730528 | -.1924397 |
| incarc_rate | .0010602 | .0006726 | 1.58 | 0.121 | -.0002907 | .0024111 |
| density | .0709653 | .0467574 | 1.52 | 0.135 | -.0229497 | .1648803 |
| avginc | .0675583 | .0263543 | 2.56 | 0.013 | .0146241 | .1204924 |
| pop | .0751395 | .021459 | 3.50 | 0.001 | .0320378 | .1182412 |
| pm1029 | .0531395 | .0383434 | 1.39 | 0.172 | -.0238755 | .1301545 |
| pw1064 | -.0228076 | .01143 | -2.00 | 0.051 | -.0457655 | .0001503 |
| _cons | 3.829225 | 1.313654 | 2.91 | 0.005 | 1.190675 | 6.467776 |

## Entity fixed effects model

```
. xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster
>  stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.0176                                         min =         23
     between = 0.0700                                         avg =       23.0
     overall = 0.0669                                         max =         23

                                                F(7,50)           =       2.82
corr(u_i, Xb)  = 0.1141                         Prob > F          =     0.0149

                             (Std. Err. adjusted for 51 clusters in stateid)
------------------------------------------------------------------------------
             |               Robust
        lrob |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |   .0154532   .0561198     0.28   0.784    -.0972668    .1281731
 incarc_rate |   .0000174   .0003304     0.05   0.958    -.0006463    .0006811
     density |   .0887945   .1733513     0.51   0.611    -.2593917    .4369808
      avginc |  -.0081818   .0200511    -0.41   0.685    -.0484556     .032092
         pop |   .0223849   .0235101     0.95   0.346    -.0248365    .0696064
      pm1029 |   .0085865   .0294279     0.29   0.772    -.0505213    .0676942
      pw1064 |   .0118002    .015639     0.75   0.454    -.0196117    .0432122
       _cons |   3.769828    .948678     3.97   0.000     1.864352    5.675304
-------------+----------------------------------------------------------------
     sigma_u |  .91198136
     sigma_e |  .21716752
         rho |  .94633832   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

## Time fixed effects model

```
. reg lrob i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
```

| Source | SS | df | MS |
|---|---|---|---|
| Model | 685.988457 | 29 | 23.6547744 |
| Residual | 382.044665 | 1,143 | .334247301 |
| Total | 1068.03312 | 1,172 | .91129106 |

| | | |
|---|---|---|
| Number of obs | = | 1,173 |
| F(29, 1143) | = | 70.77 |
| Prob > F | = | 0.0000 |
| R-squared | = | 0.6423 |
| Adj R-squared | = | 0.6332 |
| Root MSE | = | .57814 |

| lrob | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.3045825 | .0462802 | -6.58 | 0.000 | -.3953861 | -.2137789 |
| incarc_rate | .0017045 | .0001579 | 10.80 | 0.000 | .0013947 | .0020142 |
| density | -.0246581 | .0191617 | -1.29 | 0.198 | -.0622541 | .012938 |
| avginc | .1039027 | .0092436 | 11.24 | 0.000 | .0857664 | .122039 |
| pop | .0684996 | .0034539 | 19.83 | 0.000 | .0617229 | .0752764 |
| pm1029 | -.1146884 | .0214405 | -5.35 | 0.000 | -.1567556 | -.0726212 |
| pw1064 | -.0263125 | .0023454 | -11.22 | 0.000 | -.0309143 | -.0217106 |
| year | | | | | | |
| 78 | -.0564502 | .1146202 | -0.49 | 0.622 | -.2813399 | .1684395 |
| 79 | .0009148 | .1147648 | 0.01 | 0.994 | -.2242585 | .2260882 |
| 80 | .0992307 | .1149578 | 0.86 | 0.388 | -.1263214 | .3247827 |
| 81 | .0808994 | .1153016 | 0.70 | 0.483 | -.1453271 | .3071259 |
| 82 | -.0480384 | .1161647 | -0.41 | 0.679 | -.2759584 | .1798816 |
| 83 | -.2616468 | .1175192 | -2.23 | 0.026 | -.4922243 | -.0310693 |
| 84 | -.4497909 | .1194535 | -3.77 | 0.000 | -.6841636 | -.2154182 |
| 85 | -.5341622 | .1217517 | -4.39 | 0.000 | -.773044 | -.2952803 |
| 86 | -.5696617 | .1247018 | -4.57 | 0.000 | -.8143319 | -.3249915 |
| 87 | -.7120616 | .127871 | -5.57 | 0.000 | -.9629498 | -.4611733 |
| 88 | -.7912225 | .1313728 | -6.02 | 0.000 | -1.048981 | -.5334637 |
| 89 | -.8514952 | .1348028 | -6.32 | 0.000 | -1.115984 | -.5870065 |
| 90 | -.8023459 | .1378638 | -5.82 | 0.000 | -1.07284 | -.5318515 |
| 91 | -.7347585 | .1412127 | -5.20 | 0.000 | -1.011824 | -.4576933 |
| 92 | -.8246658 | .1445841 | -5.70 | 0.000 | -1.108346 | -.5409859 |
| 93 | -.8762286 | .1471162 | -5.96 | 0.000 | -1.164877 | -.5875806 |
| 94 | -.9537233 | .1501133 | -6.35 | 0.000 | -1.248252 | -.6591948 |
| 95 | -1.010542 | .1533692 | -6.59 | 0.000 | -1.311458 | -.7096249 |
| 96 | -1.105306 | .1563898 | -7.07 | 0.000 | -1.41215 | -.798463 |
| 97 | -1.225538 | .1589937 | -7.71 | 0.000 | -1.537491 | -.9135859 |
| 98 | -1.419219 | .1615214 | -8.79 | 0.000 | -1.73613 | -1.102307 |
| 99 | -1.569353 | .1636283 | -9.59 | 0.000 | -1.890399 | -1.248308 |
| _cons | 6.761699 | .4831371 | 14.00 | 0.000 | 5.813764 | 7.709634 |

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,  1143) =    7.63
            Prob > F =    0.0000
```

## Entity and time fixed effects model

```
. xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(
> cluster stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.2358                                         min =         23
     between = 0.1121                                         avg =       23.0
     overall = 0.1132                                         max =         23

                                                F(29,50)          =      41.37
corr(u_i, Xb)  = 0.1309                         Prob > F          =     0.0000

                               (Std. Err. adjusted for 51 clusters in stateid)
------------------------------------------------------------------------------
             |               Robust
        lrob |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |    .026934   .0520319     0.52   0.607    -.0775751    .1314431
 incarc_rate |   .0000214   .0003254     0.07   0.948    -.0006321     .000675
     density |  -.0337849   .2104399    -0.16   0.873     -.456466    .3888962
      avginc |   .0138673    .025474     0.54   0.589    -.0372988    .0650334
         pop |  -.0005204   .0266397    -0.02   0.984    -.0540278     .052987
      pm1029 |   .1102775   .0599431     1.84   0.072    -.0101219    .2306768
      pw1064 |  -.0166585   .0213251    -0.78   0.438    -.0594912    .0261743
             |
        year |
         78  |    .034536   .0232761     1.48   0.144    -.0122154    .0812874
         79  |   .1405983   .0294281     4.78   0.000     .0814903    .1997064
         80  |   .2477349   .0363831     6.81   0.000     .1746572    .3208125
         81  |   .2793348     .03921     7.12   0.000     .2005793    .3580904
         82  |    .223016   .0483961     4.61   0.000     .1258095    .3202225
         83  |   .1292142   .0671987     1.92   0.060    -.0057585    .2641868
         84  |    .088944   .0876657     1.01   0.315    -.0871378    .2650258
         85  |   .1247653   .1075021     1.16   0.251     -.091159    .3406897
         86  |   .2026717   .1297037     1.56   0.124    -.0578459    .4631892
         87  |   .1719957   .1430273     1.20   0.235    -.1152831    .4592744
         88  |    .209481   .1604197     1.31   0.198    -.1127314    .5316934
         89  |   .2672178   .1820959     1.47   0.149    -.0985325    .6329681
         90  |   .3783714   .2078715     1.82   0.075    -.0391507    .7958935
         91  |   .4958913   .2154793     2.30   0.026     .0630884    .9286942
         92  |   .4941518    .228088     2.17   0.035     .0360236    .9522799
         93  |   .5119961   .2378979     2.15   0.036     .0341641    .9898281
         94  |   .5283531   .2499965     2.11   0.040     .0262204    1.030486
         95  |   .5296875   .2565767     2.06   0.044      .014338    1.045037
```

| | | | | | | |
|---|---|---|---|---|---|---|
| 96 | .4714356 | .2681631 | 1.76 | 0.085 | -.067186 | 1.010057 |
| 97 | .4040287 | .2741137 | 1.47 | 0.147 | -.1465448 | .9546023 |
| 98 | .30818 | .2827632 | 1.09 | 0.281 | -.2597667 | .8761266 |
| 99 | .2317005 | .2926609 | 0.79 | 0.432 | -.3561261 | .8195272 |
| _cons | 3.491577 | 1.235401 | 2.83 | 0.007 | 1.010202 | 5.972952 |
| sigma_u | .89542889 | | | | | |
| sigma_e | .19345683 | | | | | |
| rho | .95540429 | (fraction of variance due to u_i) | | | | |

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,    50) =   30.55
            Prob > F =    0.0000
```

## Random effects model

```
. xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, re

Random-effects GLS regression                   Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.0091                                         min =         23
     between = 0.4264                                         avg =       23.0
     overall = 0.4034                                         max =         23

                                                Wald chi2(7)      =      65.15
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------
        lrob |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |   .0004736   .0249693     0.02   0.985    -.0484654    .0494126
 incarc_rate |    .000193   .0000943     2.05   0.041     8.26e-06    .0003778
     density |   .2242059   .0485076     4.62   0.000     .1291326    .3192791
      avginc |  -.0052941   .0078335    -0.68   0.499    -.0206474    .0100592
         pop |   .0443882   .0088126     5.04   0.000     .0271158    .0616606
      pm1029 |    .025615   .0082529     3.10   0.002     .0094395    .0417904
      pw1064 |   .0004343   .0050627     0.09   0.932    -.0094884     .010357
       _cons |   3.982001   .3855551    10.33   0.000     3.226326    4.737675
-------------+----------------------------------------------------------------
     sigma_u |  .47914767
     sigma_e |  .21716752
         rho |  .82958368   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

## Hausman test

```
. hausman rob_fixed rob_random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   rob_fixed    rob_random     Difference          S.E.
-------------+----------------------------------------------------------------
       shall |    .0154532     .0004736        .0149796        .0011633
 incarc_rate |    .0000174      .000193       -.0001756        .0000819
     density |    .0887945     .2242059       -.1354113        .0857501
      avginc |   -.0081818    -.0052941       -.0028877               .
         pop |    .0223849     .0443882       -.0220033        .0077196
      pm1029 |    .0085865      .025615       -.0170285         .002539
      pw1064 |    .0118002     .0004343        .0113659        .0032307
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       47.69
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

# Murder rate

## Pooled OLS

```
. reg lmur i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster st
> ateid)

Linear regression                               Number of obs     =      1,173
                                                F(7, 50)          =     157.13
                                                Prob > F          =     0.0000
                                                R-squared         =     0.5864
                                                Root MSE          =     .45373

                                 (Std. Err. adjusted for 51 clusters in stateid)
```

| lmur | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.2542154 | .0945201 | -2.69 | 0.010 | -.4440646 | -.0643662 |
| incarc_rate | .0021666 | .0004879 | 4.44 | 0.000 | .0011866 | .0031466 |
| density | .0146634 | .0425025 | 0.35 | 0.732 | -.0707054 | .1000322 |
| avginc | -.0429304 | .0264155 | -1.63 | 0.110 | -.0959876 | .0101267 |
| pop | .0381904 | .0109585 | 3.48 | 0.001 | .0161795 | .0602013 |
| pm1029 | .0986517 | .0360213 | 2.74 | 0.009 | .0263009 | .1710025 |
| pw1064 | -.0173228 | .0104159 | -1.66 | 0.103 | -.0382438 | .0035982 |
| _cons | 1.257466 | 1.15766 | 1.09 | 0.283 | -1.067763 | 3.582695 |

## Entity fixed effects model

```
. xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster
>  stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.1516                                         min =         23
     between = 0.2687                                         avg =       23.0
     overall = 0.2237                                         max =         23

                                                F(7,50)           =     167.99
corr(u_i, Xb)  = -0.8985                        Prob > F          =     0.0000

                                (Std. Err. adjusted for 51 clusters in stateid)
------------------------------------------------------------------------------
             |               Robust
        lmur |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |  -.0544046     .04098    -1.33   0.190    -.1367153    .0279062
 incarc_rate |  -.0003342   .0003546    -0.94   0.350    -.0010464     .000378
     density |  -.5950535   .2162465    -2.75   0.008    -1.029397   -.1607096
      avginc |   .0268815   .0138196     1.95   0.057     -.000876    .0546389
         pop |  -.0240397    .021711    -1.11   0.273    -.0676475    .0195682
      pm1029 |   .0385241   .0223326     1.73   0.091    -.0063324    .0833805
      pw1064 |   .0060979    .012149     0.50   0.618     -.018304    .0304999
       _cons |   .8244557   .8986162     0.92   0.363    -.9804681    2.629379
-------------+----------------------------------------------------------------
     sigma_u |  1.3378415
     sigma_e |  .21948634
         rho |  .97378977   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

## Time fixed effects model

```
. reg lmur i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
```

| Source | SS | df | MS | | | |
|---|---|---|---|---|---|---|
| | | | | Number of obs | = | 1,173 |
| | | | | F(29, 1143) | = | 63.78 |
| Model | 358.409941 | 29 | 12.3589635 | Prob > F | = | 0.0000 |
| Residual | 221.491973 | 1,143 | .193781254 | R-squared | = | 0.6181 |
| | | | | Adj R-squared | = | 0.6084 |
| Total | 579.901914 | 1,172 | .494796855 | Root MSE | = | .44021 |

| lmur | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| 1.shall | -.1572912 | .0352385 | -4.46 | 0.000 | -.2264305 | -.0881519 |
| incarc_rate | .0025273 | .0001202 | 21.03 | 0.000 | .0022915 | .0027632 |
| density | -.0308574 | .01459 | -2.11 | 0.035 | -.0594836 | -.0022312 |
| avginc | -.0252763 | .0070382 | -3.59 | 0.000 | -.0390855 | -.011467 |
| pop | .0353773 | .0026299 | 13.45 | 0.000 | .0302174 | .0405372 |
| pm1029 | .0338878 | .0163252 | 2.08 | 0.038 | .0018572 | .0659185 |
| pw1064 | -.0183529 | .0017859 | -10.28 | 0.000 | -.0218568 | -.014849 |
| year | | | | | | |
| 78 | .0188918 | .0872737 | 0.22 | 0.829 | -.1523428 | .1901264 |
| 79 | .0434645 | .0873838 | 0.50 | 0.619 | -.1279861 | .214915 |
| 80 | .028653 | .0875307 | 0.33 | 0.743 | -.1430859 | .2003919 |
| 81 | .0302399 | .0877925 | 0.34 | 0.731 | -.1420126 | .2024924 |
| 82 | -.1020717 | .0884496 | -1.15 | 0.249 | -.2756136 | .0714702 |
| 83 | -.1997911 | .089481 | -2.23 | 0.026 | -.3753565 | -.0242257 |
| 84 | -.2952942 | .0909538 | -3.25 | 0.001 | -.4737493 | -.1168392 |
| 85 | -.2635098 | .0927037 | -2.84 | 0.005 | -.4453982 | -.0816213 |
| 86 | -.2061783 | .09495 | -2.17 | 0.030 | -.3924741 | -.0198825 |
| 87 | -.2496642 | .097363 | -2.56 | 0.010 | -.4406945 | -.0586339 |
| 88 | -.2594935 | .1000293 | -2.59 | 0.010 | -.4557552 | -.0632318 |
| 89 | -.285943 | .102641 | -2.79 | 0.005 | -.487329 | -.0845571 |
| 90 | -.2379492 | .1049717 | -2.27 | 0.024 | -.443908 | -.0319904 |
| 91 | -.2472001 | .1075216 | -2.30 | 0.022 | -.4581619 | -.0362382 |
| 92 | -.3037408 | .1100886 | -2.76 | 0.006 | -.5197392 | -.0877424 |
| 93 | -.256046 | .1120166 | -2.29 | 0.022 | -.4758272 | -.0362648 |
| 94 | -.4028251 | .1142986 | -3.52 | 0.000 | -.6270838 | -.1785664 |
| 95 | -.4333408 | .1167778 | -3.71 | 0.000 | -.6624636 | -.204218 |
| 96 | -.5149928 | .1190777 | -4.32 | 0.000 | -.7486282 | -.2813574 |
| 97 | -.6240055 | .1210604 | -5.15 | 0.000 | -.8615309 | -.38648 |
| 98 | -.6937025 | .1229849 | -5.64 | 0.000 | -.935004 | -.452401 |
| 99 | -.7861529 | .1245892 | -6.31 | 0.000 | -1.030602 | -.5417038 |
| _cons | 2.31711 | .3678683 | 6.30 | 0.000 | 1.595337 | 3.038883 |

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,  1143) =    4.30
            Prob > F =    0.0000
```

## Entity and time fixed effects model

```
. xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(
> cluster stateid)

Fixed-effects (within) regression               Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.2902                                         min =         23
     between = 0.2269                                         avg =       23.0
     overall = 0.1671                                         max =         23

                                                F(29,50)          =      73.03
corr(u_i, Xb)  = -0.8442                        Prob > F          =     0.0000

                                (Std. Err. adjusted for 51 clusters in stateid)
------------------------------------------------------------------------------
             |               Robust
        lmur |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |    -.01479   .0383104    -0.39   0.701    -.0917387    .0621587
 incarc_rate |  -.0001319   .0003846    -0.34   0.733    -.0009043    .0006405
     density |  -.5271852   .2777033    -1.90   0.063    -1.084969    .0305982
      avginc |   .0558863   .0170487     3.28   0.002     .0216428    .0901297
         pop |  -.0329134    .021151    -1.56   0.126    -.0753965    .0095697
      pm1029 |   .0780333    .030753     2.54   0.014      .016264    .1398026
      pw1064 |  -.0064515   .0170785    -0.38   0.707    -.0407547    .0278517
             |
        year |
         78  |   .0019082   .0310208     0.06   0.951    -.0603989    .0642153
         79  |   .0639332   .0283689     2.25   0.029     .0069526    .1209138
         80  |   .0969238   .0374363     2.59   0.013     .0217307    .1721168
         81  |   .1109209    .041413     2.68   0.010     .0277405    .1941014
         82  |    .033358   .0428697     0.78   0.440    -.0527483    .1194643
         83  |  -.0183519   .0532469    -0.34   0.732    -.1253014    .0885976
         84  |  -.1201608   .0587061    -2.05   0.046    -.2380754   -.0022461
         85  |  -.0685141   .0748448    -0.92   0.364    -.2188442    .0818161
         86  |   .0081437   .0782371     0.10   0.918    -.1490002    .1652876
         87  |  -.0060021   .0891811    -0.07   0.947    -.1851276    .1731235
         88  |   .0085964   .0981875     0.09   0.931     -.188619    .2058119
         89  |   .0142446   .1107892     0.13   0.898    -.2082821    .2367714
         90  |   .1026794   .1306271     0.79   0.436    -.1596929    .3650518
         91  |   .1505547   .1412168     1.07   0.291    -.1330875    .4341969
         92  |   .1161402   .1533539     0.76   0.452    -.1918803    .4241606
         93  |   .2047573    .155237     1.32   0.193    -.1070453      .51656
         94  |   .0972101   .1692349     0.57   0.568    -.2427081    .4371284
         95  |   .1112431   .1773458     0.63   0.533    -.2449663    .4674525
```

```
          96 |   .0423713   .1878634     0.23   0.822    -.3349635    .4197061
          97 |  -.0617392   .2006374    -0.31   0.760    -.4647312    .3412528
          98 |  -.1232831   .2103051    -0.59   0.560    -.5456934    .2991273
          99 |  -.1896207   .2281332    -0.83   0.410    -.6478398    .2685983
             |
       _cons |   .5193232     1.0979     0.47   0.638    -1.685874    2.724521
-------------+----------------------------------------------------------------
     sigma_u |  1.1513355
     sigma_e |   .2027687
         rho |  .96991623   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
. testparm i.year

 ( 1)  78.year = 0
 ( 2)  79.year = 0
 ( 3)  80.year = 0
 ( 4)  81.year = 0
 ( 5)  82.year = 0
 ( 6)  83.year = 0
 ( 7)  84.year = 0
 ( 8)  85.year = 0
 ( 9)  86.year = 0
 (10)  87.year = 0
 (11)  88.year = 0
 (12)  89.year = 0
 (13)  90.year = 0
 (14)  91.year = 0
 (15)  92.year = 0
 (16)  93.year = 0
 (17)  94.year = 0
 (18)  95.year = 0
 (19)  96.year = 0
 (20)  97.year = 0
 (21)  98.year = 0
 (22)  99.year = 0

       F( 22,    50) =   20.37
            Prob > F =    0.0000
```

## Random effects model

```
. xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, re

Random-effects GLS regression                   Number of obs     =      1,173
Group variable: stateid                         Number of groups  =         51

R-sq:                                           Obs per group:
     within  = 0.0835                                         min =         23
     between = 0.4737                                         avg =       23.0
     overall = 0.4136                                         max =         23

                                                Wald chi2(7)      =     155.03
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------
        lmur |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       shall |  -.0898712   .0256421    -3.50   0.000    -.1401288   -.0396136
 incarc_rate |   .0004356   .0000929     4.69   0.000     .0002535    .0006176
     density |   .0478661   .0376065     1.27   0.203    -.0258414    .1215735
      avginc |   .0152264   .0080026     1.90   0.057    -.0004585    .0309112
         pop |   .0014712   .0074722     0.20   0.844    -.0131741    .0161165
      pm1029 |   .0746036   .0084021     8.88   0.000     .0581358    .0910714
      pw1064 |   -.009669   .0044636    -2.17   0.030    -.0184176   -.0009205
       _cons |   .8816771   .3542234     2.49   0.013     .1874121    1.575942
-------------+----------------------------------------------------------------
     sigma_u |  .32150357
     sigma_e |  .21948634
         rho |  .68209954   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

## Hausman test

```
. hausman mur_fixed mur_random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   mur_fixed    mur_random     Difference          S.E.
-------------+----------------------------------------------------------------
       shall |   -.0544046    -.0898712        .0354666               .
 incarc_rate |   -.0003342     .0004356       -.0007698         .0000854
     density |   -.5950535     .0478661       -.6429195         .0921965
      avginc |    .0268815     .0152264        .0116551               .
         pop |   -.0240397     .0014712       -.0255109         .0091851
      pm1029 |    .0385241     .0746036       -.0360795         .0023585
      pw1064 |    .0060979     -.009669         .015767         .0041132
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =      126.73
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

# Codes

```
/* Import data */
use "C:\Users\hht180000\Downloads\guns.dta", clear

/* Data transformation */
xtset stateid year
gen lvio = ln(vio)
gen lrob = ln(rob)
gen lmur = ln(mur)

/* Violent crime rate */
/* Pooled OLS */
reg lvio i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster stateid)
/* Entity fixed effects model */
xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster stateid)
/* Time fixed effects model */
reg lvio i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
```

```
testparm i.year
/* Entity and time fixed effects model */
xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(cluster stateid)
testparm i.year
/* Random effects model */
xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, re
/* Hausman test */
xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, fe
estimates store vio_fixed
xtreg lvio shall incarc_rate density avginc pop pm1029 pw1064, re
estimates store vio_random
hausman vio_fixed vio_random

/* Robbery rate */
/* Pooled OLS */
reg lrob i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster stateid)
/* Entity fixed effects model */
xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster stateid)
/* Time fixed effects model */
reg lrob i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
testparm i.year
/* Entity and time fixed effects model */
xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(cluster stateid)
testparm i.year
/* Random effects model */
xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, re
/* Hausman test */
xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, fe
estimates store rob_fixed
xtreg lrob shall incarc_rate density avginc pop pm1029 pw1064, re
estimates store rob_random
hausman rob_fixed rob_random

/* Murder rate */
/* Pooled OLS */
reg lmur i.shall incarc_rate density avginc pop pm1029 pw1064, vce(cluster stateid)
/* Entity fixed effects model */
xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, fe vce(cluster stateid)
/* Time fixed effects model */
reg lmur i.shall incarc_rate density avginc pop pm1029 pw1064 i.year
testparm i.year
/* Entity and time fixed effects model */
xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064 i.year, fe vce(cluster stateid)
testparm i.year
```

```
/* Random effects model */
xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, re
/* Hausman test */
xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, fe
estimates store mur_fixed
xtreg lmur shall incarc_rate density avginc pop pm1029 pw1064, re
estimates store mur_random
hausman mur_fixed mur_random
```

**Group Project**

**Members:**


**Mahdi Shirvin**
**Savrin Darash**
**Derek Tallent**
**Quan Tran**
**Huy Truong**