

# Econ 613 Assignment 2

Xiaolin Ding

04/26/21

```
library(bayesm)
library(plyr)
library(dplyr)

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:plyr':
##
##   arrange, count, desc, failwith, id, mutate, rename, summarise,
##   summarize

## The following objects are masked from 'package:stats':
##
##   filter, lag

## The following objects are masked from 'package:base':
##
##   intersect, setdiff, setequal, union

library(fastDummies)
library(gmm)

## Loading required package: sandwich

library(tidyr)
library(tidyverse)

## -- Attaching packages ----- tidyverse 1.3.0 --
## v ggplot2 3.3.3      v purrr  0.3.4
## v tibble  3.1.0      v stringr 1.4.0
## v readr   1.4.0      v forcats 0.5.1

## -- Conflicts ----- tidyverse_conflicts() --
## x dplyr::arrange() masks plyr::arrange()
## x purrr::compact() masks plyr::compact()
## x dplyr::count() masks plyr::count()
## x dplyr::failwith() masks plyr::failwith()
## x dplyr::filter() masks stats::filter()
## x dplyr::id() masks plyr::id()
## x dplyr::lag() masks stats::lag()
## x dplyr::mutate() masks plyr::mutate()
## x dplyr::rename() masks plyr::rename()
## x dplyr::summarise() masks plyr::summarise()
## x dplyr::summarize() masks plyr::summarize()
```

## Exercise 1 Links to the datasets

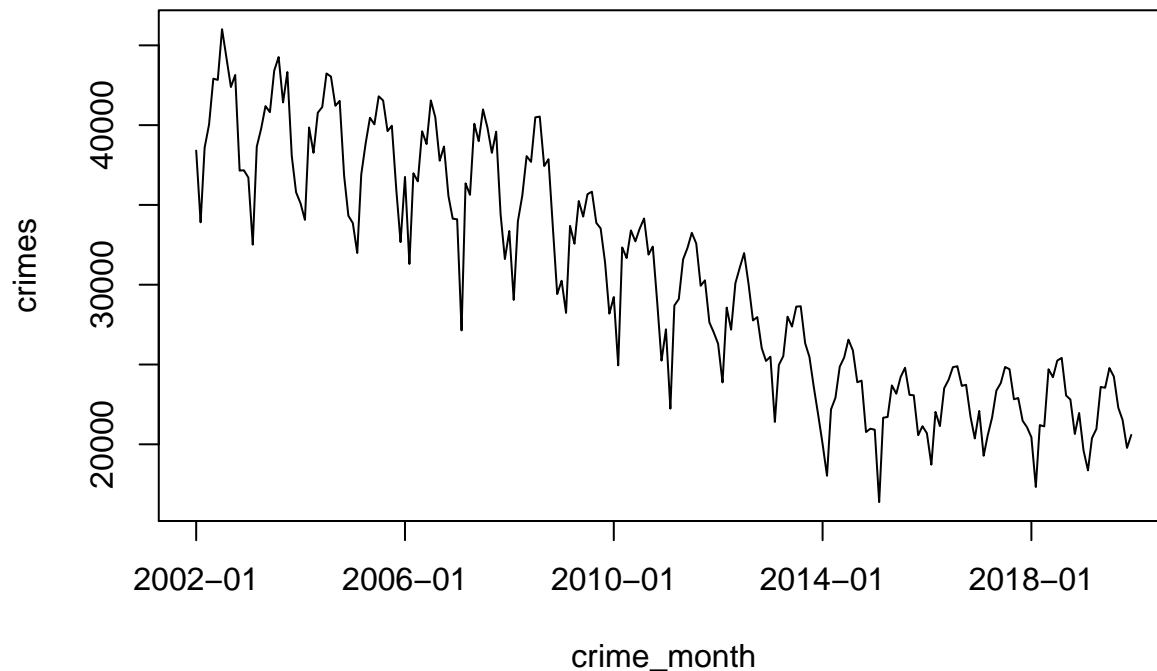
```
pop = read.csv("file:///Users/DXL/Desktop/Econ613/population.csv")
cri = read.csv("file:///Users/DXL/Desktop/Econ613/crime_long.csv")
off = read.csv("file:///Users/DXL/Desktop/Econ613/officers.csv")
```

## Exercise 2 Data Manipulation

- Total Crimes Per Month

```
sum1 = cri %>% group_by(crime_month) %>%
  summarise(cripermon=sum(crimes))
month = as.Date(sum1 %>% pull(crime_month))
cripermon = sum1 %>% pull(cripermon)
plot(month,cripermon,col=1,type="l",xaxt='n',main='Total Crimes Per Month',
      xlab='crime_month',ylab='crimes',lwd=1)
axis.Date(1,at=seq(min(month),max(month),by='48 mon'),format='%Y-%m')
```

### Total Crimes Per Month



- Merged data df1

```
df1 = full_join(cri, pop,
                by=c('crime_month'='month','district'='district'))
df1[1:10,]
```

##	crime_month	district	crime_type	crimes	period	tot_pop	tot_white	tot_black
## 1	2002-01-01	1	drug	104	NA	NA	NA	NA
## 2	2002-01-01	1	other	97	NA	NA	NA	NA
## 3	2002-01-01	1	other	174	NA	NA	NA	NA

```
## 4    2002-01-01      1    property    658    NA    NA    NA    NA
## 5    2002-01-01      1    property    201    NA    NA    NA    NA
## 6    2002-01-01      1     violent    182    NA    NA    NA    NA
## 7    2002-01-01      1     violent     60    NA    NA    NA    NA
## 8    2002-01-01      2      drug     161    NA    NA    NA    NA
## 9    2002-01-01      2     other     112    NA    NA    NA    NA
## 10   2002-01-01      2     other     158    NA    NA    NA    NA
##      tot_hisp p50_inc
## 1      NA      NA
## 2      NA      NA
## 3      NA      NA
## 4      NA      NA
## 5      NA      NA
## 6      NA      NA
## 7      NA      NA
## 8      NA      NA
## 9      NA      NA
## 10     NA      NA
```

- Panel data df7 of unit over time with the following variables
  - Total crimes per resident
  - Violent crimes per resident
  - Property crimes per resident
  - Median income
  - Share of black, Hispanic, and white residents

```
sum2 = df1 %>% group_by(crime_month,district) %>%
  summarise(cribydis=sum(crimes),popbydis=sum(tot_pop),white=sum(tot_white),
            black=sum(tot_black),hisp=sum(tot_hisp),
            med=quantile(p50_inc,1/2,na.rm=TRUE))
```

## `summarise()` has grouped output by 'crime\_month'. You can override using the `.groups` argument.

```
sum3 = df1 %>% group_by(crime_month,district,crime_type) %>%
  summarise(cribytype=sum(crimes))
```

## `summarise()` has grouped output by 'crime\_month', 'district'. You can override using the `.groups` argument.

```
popbydis = sum2 %>% pull(popbydis)
index1 = which(is.na(popbydis)==FALSE)
popbydis = popbydis[!is.na(popbydis)]
df2 = data.frame(matrix(ncol=0,nrow=length(popbydis)))
crimonth = sum2 %>% pull(crime_month)
df2$crimonth = crimonth[c(index1)]
dis = sum2 %>% pull(district)
df2$dis = dis[c(index1)]
cribydis = sum2 %>% pull(cribydis)
df2$cribydis = cribydis[c(index1)]
df2$popbydis = popbydis
white = sum2 %>% pull(white)
df2$white = white[c(index1)]
black = sum2 %>% pull(black)
df2$black = black[c(index1)]
hisp = sum2 %>% pull(hisp)
df2$hisp = hisp[c(index1)]
med = sum2 %>% pull(med)
```

```

df2$med = med[c(index1)]
crimon = sum3 %>% pull(crime_month)
df3 = data.frame(matrix(ncol=0,nrow=length(crimon)))
df3$crimon = crimon
df3$dis = sum3 %>% pull(district)
df3$type = sum3 %>% pull(crime_type)
df3$cribytype = sum3 %>% pull(cribytype)
df4 = full_join(df3, df2,
               by=c('crimon'='crimonth','dis'='dis'))
index2 = which(is.na(df4$cribydis)==FALSE)
df5 = df4[c(index2),]
df5$criperres = df5$cribydis/df5$popbydis
df5$typeperres = df5$cribytype/df5$popbydis
df5$shareofb = df5$black/df5$popbydis
df5$shareofh = df5$hispan/df5$popbydis
df5$shareofw = df5$white/df5$popbydis
df6 = df5[,c(1:3,5,10:15)]
df6 = subset(df6, df6$type=='violent' | df6$type=='property')
df7 = spread(df6, type, typeperres)
colnames(df7) = c('month','district','total_crime','median_income',
                  'crime_per_resident','share_of_black',
                  'share_of_hispanic','share_of_white',
                  'property_per_resident','violent_per_resident')
df7[1:10,]

```

```

##      month district total_crime median_income crime_per_resident
## 1  2005-01-01      1      1549      91084.91      0.005032881
## 2  2005-01-01      2      1351      29890.17      0.004445015
## 3  2005-01-01      3      1707      28047.56      0.003101364
## 4  2005-01-01      4      1839      39010.22      0.002109833
## 5  2005-01-01      5      1411      33146.90      0.002709876
## 6  2005-01-01      6      1742      34672.25      0.002778354
## 7  2005-01-01      7      1970      23960.59      0.003929688
## 8  2005-01-01      8      2383      49069.15      0.001376175
## 9  2005-01-01      9      1533      36323.73      0.001418394
## 10 2005-01-01     10      1395      29147.49      0.001700259
##      share_of_black share_of_hispanic share_of_white property_per_resident
## 1      0.1287430      0.06610002      0.587648160      0.0025473071
## 2      0.9466730      0.01652980      0.016582438      0.0016746947
## 3      0.9130473      0.01743631      0.040913658      0.0011010114
## 4      0.6209012      0.28418956      0.079714742      0.0008191521
## 5      0.9417751      0.03393203      0.011333082      0.0008968903
## 6      0.9745227      0.01011499      0.003449816      0.0011706726
## 7      0.9679541      0.01636506      0.003700290      0.0012726605
## 8      0.2110942      0.56535677      0.208151253      0.0006774039
## 9      0.1215997      0.61083549      0.151658031      0.0006236121
## 10     0.3373888      0.61905656      0.035867553      0.0005606590
##      violent_per_resident
## 1      0.0006888126
## 2      0.0012009107
## 3      0.0009683813
## 4      0.0007067195
## 5      0.0008354331
## 6      0.0009425988

```

```
## 7          0.0014202732
## 8          0.0003638231
## 9          0.0004200592
## 10         0.0005375014
```

## Exercise 3 Panel Data: Introduction

- Create data df9 by merging the data 'off' with the previous panel data df7

```
df8 = full_join(off, df7,
                by=c('month'='month', 'unit'='district'))
df9 = df8[,c(1:7,9:11)]
df9 = df9[rowSums(is.na(df9[,1:10]))== 0,]
df9[1:10,]
```

```
##      NUID      month unit tenure arrest total_crime median_income share_of_black
## 1      1 2007-03-01   14     18      2       1353      61849.46      0.072232
## 2      1 2007-04-01   14     19      0       1200      61849.46      0.072232
## 3      1 2007-05-01   14     20      1       1423      61849.46      0.072232
## 4      1 2007-06-01   14     21      1       1480      61849.46      0.072232
## 5      1 2007-07-01   14     22      0       1569      61849.46      0.072232
## 6      1 2007-08-01   14     23      0       1581      61849.46      0.072232
## 7      1 2007-09-01   14     24      1       1435      61849.46      0.072232
## 8      1 2007-10-01   14     25      0       1538      61849.46      0.072232
## 9      1 2007-11-01   14     26      0       1325      61849.46      0.072232
## 10     1 2007-12-01   14     27      2       1223      61849.46      0.072232
##      share_of_hispanic share_of_white
## 1          0.4608716      0.4173754
## 2          0.4608716      0.4173754
## 3          0.4608716      0.4173754
## 4          0.4608716      0.4173754
## 5          0.4608716      0.4173754
## 6          0.4608716      0.4173754
## 7          0.4608716      0.4173754
## 8          0.4608716      0.4173754
## 9          0.4608716      0.4173754
## 10         0.4608716      0.4173754
```

- Estimate  $\beta$  and  $\gamma$

```
X1 = as.matrix(df9[,c(4,6:10)])
Y1 = as.matrix(df9[,5])
coef1 = solve(t(X1)%*%X1)%*%t(X1)%*%Y1
coef1[1:6,1]
```

```
##      tenure      total_crime      median_income      share_of_black
## 2.878869e-05 -1.364283e-05      7.210106e-07      5.028186e-01
## share_of_hispanic      share_of_white
## 5.172976e-01      5.151714e-01
```

The estimated  $\beta$  is `coef1[1,1]` and the estimated  $\gamma$  are  $-1.3642833 \times 10^{-5}$ ,  $7.210106 \times 10^{-7}$ ,  $0.5028186$ ,  $0.5172976$ ,  $0.5151714$ .

## Exercise 4 Panel Data: More controls

- Create data df10 with district and month dummies

```
df10 = dummy_cols(df9, select_columns=c('unit','month'))
df10[1:10,]
```

```
##      NUID      month unit tenure arrest total_crime median_income share_of_black
## 1      1 2007-03-01   14     18      2       1353      61849.46      0.072232
## 2      1 2007-04-01   14     19      0       1200      61849.46      0.072232
## 3      1 2007-05-01   14     20      1       1423      61849.46      0.072232
## 4      1 2007-06-01   14     21      1       1480      61849.46      0.072232
## 5      1 2007-07-01   14     22      0       1569      61849.46      0.072232
## 6      1 2007-08-01   14     23      0       1581      61849.46      0.072232
## 7      1 2007-09-01   14     24      1       1435      61849.46      0.072232
## 8      1 2007-10-01   14     25      0       1538      61849.46      0.072232
## 9      1 2007-11-01   14     26      0       1325      61849.46      0.072232
## 10     1 2007-12-01   14     27      2       1223      61849.46      0.072232
##      share_of_hispanic share_of_white unit_1 unit_2 unit_3 unit_4 unit_5 unit_6
## 1      0.4608716      0.4173754      0      0      0      0      0      0
## 2      0.4608716      0.4173754      0      0      0      0      0      0
## 3      0.4608716      0.4173754      0      0      0      0      0      0
## 4      0.4608716      0.4173754      0      0      0      0      0      0
## 5      0.4608716      0.4173754      0      0      0      0      0      0
## 6      0.4608716      0.4173754      0      0      0      0      0      0
## 7      0.4608716      0.4173754      0      0      0      0      0      0
## 8      0.4608716      0.4173754      0      0      0      0      0      0
## 9      0.4608716      0.4173754      0      0      0      0      0      0
## 10     0.4608716      0.4173754      0      0      0      0      0      0
##      unit_7 unit_8 unit_9 unit_10 unit_11 unit_12 unit_13 unit_14 unit_15 unit_16
## 1      0      0      0      0      0      0      0      1      0      0
## 2      0      0      0      0      0      0      0      1      0      0
## 3      0      0      0      0      0      0      0      1      0      0
## 4      0      0      0      0      0      0      0      1      0      0
## 5      0      0      0      0      0      0      0      1      0      0
## 6      0      0      0      0      0      0      0      1      0      0
## 7      0      0      0      0      0      0      0      1      0      0
## 8      0      0      0      0      0      0      0      1      0      0
## 9      0      0      0      0      0      0      0      1      0      0
## 10     0      0      0      0      0      0      0      1      0      0
##      unit_17 unit_18 unit_19 unit_20 unit_21 unit_22 unit_23 unit_24 unit_25
## 1      0      0      0      0      0      0      0      0      0
## 2      0      0      0      0      0      0      0      0      0
## 3      0      0      0      0      0      0      0      0      0
## 4      0      0      0      0      0      0      0      0      0
## 5      0      0      0      0      0      0      0      0      0
## 6      0      0      0      0      0      0      0      0      0
## 7      0      0      0      0      0      0      0      0      0
## 8      0      0      0      0      0      0      0      0      0
## 9      0      0      0      0      0      0      0      0      0
## 10     0      0      0      0      0      0      0      0      0
##      month_2007-01-01 month_2007-02-01 month_2007-03-01 month_2007-04-01
## 1      0      0      1      0
## 2      0      0      0      1
```

## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2007-05-01	month_2007-06-01	month_2007-07-01	month_2007-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	1	0	0	0
## 4	0	1	0	0
## 5	0	0	1	0
## 6	0	0	0	1
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2007-09-01	month_2007-10-01	month_2007-11-01	month_2007-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	1	0	0	0
## 8	0	1	0	0
## 9	0	0	1	0
## 10	0	0	0	1
##	month_2008-01-01	month_2008-02-01	month_2008-03-01	month_2008-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2008-05-01	month_2008-06-01	month_2008-07-01	month_2008-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2008-09-01	month_2008-10-01	month_2008-11-01	month_2008-12-01
## 1	0	0	0	0

## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-01-01	month_2009-02-01	month_2009-03-01	month_2009-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-05-01	month_2009-06-01	month_2009-07-01	month_2009-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-09-01	month_2009-10-01	month_2009-11-01	month_2009-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-01-01	month_2010-02-01	month_2010-03-01	month_2010-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-05-01	month_2010-06-01	month_2010-07-01	month_2010-08-01



## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-09-01	month_2010-10-01	month_2010-11-01	month_2010-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-01-01	month_2011-02-01	month_2011-03-01	month_2011-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-05-01	month_2011-06-01	month_2011-07-01	month_2011-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-09-01	month_2011-10-01	month_2011-11-01	month_2011-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0

##	month_2012-01-01	month_2012-02-01	month_2012-03-01	month_2012-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2012-05-01	month_2012-06-01	month_2012-07-01	month_2012-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2012-09-01	month_2012-10-01	month_2012-11-01	month_2012-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2013-01-01	month_2013-02-01	month_2013-03-01	month_2013-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2013-05-01	month_2013-06-01	month_2013-07-01	month_2013-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0

## 10	0	0	0	0
##	month_2013-09-01	month_2013-10-01	month_2013-11-01	month_2013-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-01-01	month_2014-02-01	month_2014-03-01	month_2014-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-05-01	month_2014-06-01	month_2014-07-01	month_2014-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-09-01	month_2014-10-01	month_2014-11-01	month_2014-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-01-01	month_2015-02-01	month_2015-03-01	month_2015-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0

## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-05-01	month_2015-06-01	month_2015-07-01	month_2015-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-09-01	month_2015-10-01	month_2015-11-01	month_2015-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-01-01	month_2016-02-01	month_2016-03-01	month_2016-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-05-01	month_2016-06-01	month_2016-07-01	month_2016-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-09-01	month_2016-10-01	month_2016-11-01	month_2016-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0

```
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-01-01 month_2017-02-01 month_2017-03-01 month_2017-04-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-05-01 month_2017-06-01 month_2017-07-01 month_2017-08-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-09-01 month_2017-10-01 month_2017-11-01 month_2017-12-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
```

- Estimate  $\beta$ ,  $\gamma$ ,  $\psi$ , and  $\kappa$  with district and year and month dummies, whereas the base group dummies are excluded

```
X2 = as.matrix(df10[,c(4,6:34,36:166)])
Y2 = as.matrix(df10[,5])
coef2 = solve(t(X2)%*%X2)%*%t(X2)%*%Y2
coef2[1:6,1]
```

```
##      tenure      total_crime      median_income      share_of_black
##      -3.057654e-06      -3.154716e-06      -1.399981e-06      2.921666e-01
## share_of_hispanic      share_of_white
##      6.526680e-01      5.273245e-01
```

The estimated  $\beta$  is  $-3.0576539 \times 10^{-6}$ , the estimated  $\gamma$  are  $-3.154716 \times 10^{-6}$ ,  $-1.3999809 \times 10^{-6}$ , 0.2921666, 0.652668, 0.5273245, the estimated  $\psi$  are 0.2373476, 0.2415874, 0.2381178, 0.1438174, 0.241982, 0.2552244, 0.2357544, 0.0293969, 0.0461598, 0.0150121, 0.201642, 0.0842541, 0.0886341, 0.0494662, 0.2304053, 0.0698951, 0.0776787, 0.1592691, 0.1245693, 0.1322237, 0.2700504, 0.2079346, 0.1174384, 0.1446851, and the estimated  $\kappa$  are 0.0067746, 0.0104332, 0.0119061, 0.0021393, 0.0156336, -0.0090527, 0.0033869, -0.003256, 0.0090704, 0.0115942, 0.0100144, -0.0014133, -0.0089205,  $-4.915844 \times 10^{-4}$ ,  $-2.4393325 \times 10^{-4}$ , 0.0144694, 0.0251773,

0.0073657, 0.0059242, 0.0069588, 0.0157022, 0.0029276, 0.0053058, 0.0183348, 0.0012871, 0.0017783, -0.0020449, 0.0020809, 0.0050933, 0.0109603, 0.012053, 0.0018908, 0.002023, 0.0052753, 0.0019425, -0.0023136, 0.0092471, 0.0116102, -0.0018615, 0.0141911, 0.0034682, 0.0011102, -0.0066715, 0.0166472, 0.00929, 0.0044686, -0.0017094, 0.0031957,  $-5.1523367 \times 10^{-4}$ , 0.0029628, 0.0029337, 0.0062398, 0.0065709, 0.0071183, 0.010871, 0.0068533, -0.0039762, 0.0178219,  $7.0270812 \times 10^{-4}$ , 0.0080445, -0.0026028, 0.0111669, 0.0091963, 0.0140341, 0.0133939, 0.0068052, 0.0094394, 0.0039216, 0.0117029, -0.0052146, 0.0131121, -0.0071067, 0.0136071, 0.0023584, -0.0059566, 0.0133309, 0.0235331, 0.0165834, 0.0268663, 0.0065925, 0.0127283, 0.0011173, 0.0042966, 0.0136876, -0.0043429, 0.0134174, 0.0058303, -0.0084629, 0.003986, 0.0080348, 0.0151915, 0.0086063, 0.0110643, 0.0082572, 0.0019381, 0.003424, 0.0055423, 0.001851, 0.0144963, 0.0068015, 0.0033093, 0.0029972, 0.0013176, 0.0045188, 0.0091113, 0.0017915, 0.0128181, 0.0030544, 0.005143, 0.0036937, -0.0042581, 0.0202257, 0.019912, 0.0048231,  $-9.5898066 \times 10^{-4}$ , -0.0093592, 0.0085057, 0.0131568, -0.0036378, -0.0023411, 0.0103822, 0.0048672, 0.0165671, 0.0045999, 0.0184974, -0.0021624, 0.0037606, 0.0072453, 0.0016982,  $5.1556835 \times 10^{-4}$ , -0.0064252.

## Exercise 5 Panel Data: Individual fixed effects

- Create data df11 with mean differences, df12 with means, and df13 with first differences

```
df11 = df10 %>% group_by(NUID) %>%
  mutate(across(!month & !unit, ~.x-mean(.x)))
df12 = df10 %>% group_by(NUID) %>%
  summarise(across(!month & !unit, list(mean)))
df13 = df10 %>% group_by(NUID) %>%
  mutate(across(!month & !unit, ~.x-lag(.x)))
df13 = df13[rowSums(is.na(df13[,1:10]))== 0,]
df11 = as.data.frame(df11)
df12 = as.data.frame(df12)
df13 = as.data.frame(df13)
df11[1:10,]
```

##	NUID	month	unit	tenure	arrest	total_crime	median_income			
## 1	1	2007-03-01	14	-64.73077	1.5153846	292.6615	2442.263			
## 2	1	2007-04-01	14	-63.73077	-0.4846154	139.6615	2442.263			
## 3	1	2007-05-01	14	-62.73077	0.5153846	362.6615	2442.263			
## 4	1	2007-06-01	14	-61.73077	0.5153846	419.6615	2442.263			
## 5	1	2007-07-01	14	-60.73077	-0.4846154	508.6615	2442.263			
## 6	1	2007-08-01	14	-59.73077	-0.4846154	520.6615	2442.263			
## 7	1	2007-09-01	14	-58.73077	0.5153846	374.6615	2442.263			
## 8	1	2007-10-01	14	-57.73077	-0.4846154	477.6615	2442.263			
## 9	1	2007-11-01	14	-56.73077	-0.4846154	264.6615	2442.263			
## 10	1	2007-12-01	14	-55.73077	1.5153846	162.6615	2442.263			
##	share_of_black	share_of_hispanic	share_of_white	unit_1	unit_2	unit_3				
## 1	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 2	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 3	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 4	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 5	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 6	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 7	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 8	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 9	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
## 10	-0.0603778	0.04996568	0.01021265	0	0	-0.07692308				
##	unit_4	unit_5	unit_6	unit_7	unit_8	unit_9	unit_10	unit_11	unit_12	unit_13

## 1	0	0	0	0	0	0	0	0	0	0
## 2	0	0	0	0	0	0	0	0	0	0
## 3	0	0	0	0	0	0	0	0	0	0
## 4	0	0	0	0	0	0	0	0	0	0
## 5	0	0	0	0	0	0	0	0	0	0
## 6	0	0	0	0	0	0	0	0	0	0
## 7	0	0	0	0	0	0	0	0	0	0
## 8	0	0	0	0	0	0	0	0	0	0
## 9	0	0	0	0	0	0	0	0	0	0
## 10	0	0	0	0	0	0	0	0	0	0
##	unit_14	unit_15	unit_16	unit_17	unit_18	unit_19	unit_20	unit_21		
## 1	0.1461538	0	-0.06923077	0	0	0	0	0		
## 2	0.1461538	0	-0.06923077	0	0	0	0	0		
## 3	0.1461538	0	-0.06923077	0	0	0	0	0		
## 4	0.1461538	0	-0.06923077	0	0	0	0	0		
## 5	0.1461538	0	-0.06923077	0	0	0	0	0		
## 6	0.1461538	0	-0.06923077	0	0	0	0	0		
## 7	0.1461538	0	-0.06923077	0	0	0	0	0		
## 8	0.1461538	0	-0.06923077	0	0	0	0	0		
## 9	0.1461538	0	-0.06923077	0	0	0	0	0		
## 10	0.1461538	0	-0.06923077	0	0	0	0	0		
##	unit_22	unit_23	unit_24	unit_25	month_2007-01-01	month_2007-02-01				
## 1	0	0	0	0		0			0	
## 2	0	0	0	0		0			0	
## 3	0	0	0	0		0			0	
## 4	0	0	0	0		0			0	
## 5	0	0	0	0		0			0	
## 6	0	0	0	0		0			0	
## 7	0	0	0	0		0			0	
## 8	0	0	0	0		0			0	
## 9	0	0	0	0		0			0	
## 10	0	0	0	0		0			0	
##	month_2007-03-01	month_2007-04-01	month_2007-05-01	month_2007-06-01						
## 1	0.992307692	-0.007692308	-0.007692308	-0.007692308						
## 2	-0.007692308	0.992307692	-0.007692308	-0.007692308						
## 3	-0.007692308	-0.007692308	0.992307692	-0.007692308						
## 4	-0.007692308	-0.007692308	-0.007692308	0.992307692						
## 5	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 6	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 7	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 8	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 9	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 10	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
##	month_2007-07-01	month_2007-08-01	month_2007-09-01	month_2007-10-01						
## 1	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 2	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 3	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 4	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 5	0.992307692	-0.007692308	-0.007692308	-0.007692308						
## 6	-0.007692308	0.992307692	-0.007692308	-0.007692308						
## 7	-0.007692308	-0.007692308	0.992307692	-0.007692308						
## 8	-0.007692308	-0.007692308	-0.007692308	0.992307692						
## 9	-0.007692308	-0.007692308	-0.007692308	-0.007692308						
## 10	-0.007692308	-0.007692308	-0.007692308	-0.007692308						

[illegible]



[illegible]

[illegible]

[illegible]

[illegible]

21

```
## 5      -0.007692308      -0.007692308      -0.007692308      -0.007692308
## 6      -0.007692308      -0.007692308      -0.007692308      -0.007692308
## 7      -0.007692308      -0.007692308      -0.007692308      -0.007692308
## 8      -0.007692308      -0.007692308      -0.007692308      -0.007692308
## 9      -0.007692308      -0.007692308      -0.007692308      -0.007692308
## 10     -0.007692308      -0.007692308      -0.007692308      -0.007692308
##      month_2017-11-01 month_2017-12-01
## 1      -0.007692308      -0.007692308
## 2      -0.007692308      -0.007692308
## 3      -0.007692308      -0.007692308
## 4      -0.007692308      -0.007692308
## 5      -0.007692308      -0.007692308
## 6      -0.007692308      -0.007692308
## 7      -0.007692308      -0.007692308
## 8      -0.007692308      -0.007692308
## 9      -0.007692308      -0.007692308
## 10     -0.007692308      -0.007692308
```

```
df12[1:10,]
```

```
##      NUID  tenure_1  arrest_1  total_crime_1  median_income_1  share_of_black_1
## 1      1  82.73077  0.4846154    1060.3385      59407.20      0.13260980
## 2      2  78.23140  0.4958678    1269.9587      27940.01      0.93349592
## 3      6 157.04167  0.3333333     596.6667      52332.72      0.10655149
## 4      7 199.16667  0.4772727     990.4924      57487.19      0.11121455
## 5     16  63.38806  0.4626866    1533.8657      51768.31      0.71489015
## 6     17 246.95238  0.7380952     485.6190      63652.04      0.09979825
## 7     18 157.39000  0.4400000    1284.2000      70194.66      0.10567584
## 8     19 119.11765  0.5882353     948.3382      55060.06      0.03325003
## 9     23  24.84615  0.4615385     656.9231      55060.06      0.03325003
## 10    25  31.85185  0.7407407    1531.0370      26337.89      0.84344077
##      share_of_hispanic_1  share_of_white_1  unit_1_1  unit_2_1  unit_3_1  unit_4_1
## 1      0.41090590      0.40716270  0.0000000      0  0.07692308      0
## 2      0.03704857      0.01631036  0.0000000      0  0.00000000      0
## 3      0.18344178      0.54034104  0.0000000      0  0.00000000      0
## 4      0.33564607      0.46544887  0.0000000      0  0.00000000      0
## 5      0.02726117      0.18193889  0.3283582      0  0.00000000      0
## 6      0.09368892      0.71092904  0.0000000      0  0.00000000      0
## 7      0.25022095      0.57018921  0.0000000      0  0.00000000      0
## 8      0.43260344      0.38627632  0.0000000      0  0.00000000      0
## 9      0.43260344      0.38627632  0.0000000      0  0.00000000      0
## 10     0.11737796      0.02479407  0.0000000      0  0.00000000      0
##      unit_5_1  unit_6_1  unit_7_1  unit_8_1  unit_9_1  unit_10_1  unit_11_1  unit_12_1
## 1      0  0.0000000      0      0      0      0      0  0.0000000
## 2      0  0.0000000      0      0      0      0      0  0.0000000
## 3      0  0.0000000      0      0      0      0      0  0.0000000
## 4      0  0.0000000      0      0      0      0      0  0.6136364
## 5      0  0.6716418      0      0      0      0      0  0.0000000
## 6      0  0.0000000      0      0      0      0      0  0.0000000
## 7      0  0.0000000      0      0      0      0      0  0.0000000
## 8      0  0.0000000      0      0      0      0      0  0.0000000
## 9      0  0.0000000      0      0      0      0      0  0.0000000
## 10     0  0.0000000      0      0      0      0      1  0.0000000
##      unit_13_1  unit_14_1  unit_15_1  unit_16_1  unit_17_1  unit_18_1  unit_19_1
## 1      0  0.8538462      0  0.06923077      0      0.00  0.0000000
```

## 2	0	0.0000000	1	0.00000000	0	0.00	0.0000000
## 3	0	0.0000000	0	0.00000000	0	0.00	0.0000000
## 4	0	0.0000000	0	0.38636364	0	0.00	0.0000000
## 5	0	0.0000000	0	0.00000000	0	0.00	0.0000000
## 6	0	0.0000000	0	0.00000000	0	0.00	0.2619048
## 7	0	0.0000000	0	0.00000000	0	0.37	0.3300000
## 8	0	0.0000000	0	0.00000000	1	0.00	0.0000000
## 9	0	0.0000000	0	0.00000000	1	0.00	0.0000000
## 10	0	0.0000000	0	0.00000000	0	0.00	0.0000000
##	unit_20_1	unit_21_1	unit_22_1	unit_23_1	unit_24_1	unit_25_1	
## 1	0	0	0	0.0000000	0	0.0	
## 2	0	0	0	0.0000000	0	0.0	
## 3	1	0	0	0.0000000	0	0.0	
## 4	0	0	0	0.0000000	0	0.0	
## 5	0	0	0	0.0000000	0	0.0	
## 6	0	0	0	0.7380952	0	0.0	
## 7	0	0	0	0.0000000	0	0.3	
## 8	0	0	0	0.0000000	0	0.0	
## 9	0	0	0	0.0000000	0	0.0	
## 10	0	0	0	0.0000000	0	0.0	
##	month_2007-01-01_1	month_2007-02-01_1	month_2007-03-01_1	month_2007-04-01_1			
## 1	0.000000000	0.000000000	0.007692308	0.007692308			
## 2	0.000000000	0.000000000	0.008264463	0.008264463			
## 3	0.041666667	0.041666667	0.041666667	0.041666667			
## 4	0.007575758	0.007575758	0.007575758	0.007575758			
## 5	0.000000000	0.000000000	0.000000000	0.000000000			
## 6	0.011904762	0.011904762	0.011904762	0.011904762			
## 7	0.010000000	0.010000000	0.010000000	0.010000000			
## 8	0.014705882	0.014705882	0.014705882	0.014705882			
## 9	0.000000000	0.000000000	0.000000000	0.000000000			
## 10	0.000000000	0.000000000	0.000000000	0.000000000			
##	month_2007-05-01_1	month_2007-06-01_1	month_2007-07-01_1	month_2007-08-01_1			
## 1	0.007692308	0.007692308	0.007692308	0.007692308			
## 2	0.008264463	0.008264463	0.008264463	0.008264463			
## 3	0.041666667	0.041666667	0.041666667	0.041666667			
## 4	0.007575758	0.007575758	0.007575758	0.007575758			
## 5	0.000000000	0.000000000	0.000000000	0.000000000			
## 6	0.011904762	0.011904762	0.011904762	0.011904762			
## 7	0.010000000	0.010000000	0.010000000	0.010000000			
## 8	0.014705882	0.014705882	0.014705882	0.014705882			
## 9	0.000000000	0.000000000	0.000000000	0.000000000			
## 10	0.000000000	0.000000000	0.000000000	0.000000000			
##	month_2007-09-01_1	month_2007-10-01_1	month_2007-11-01_1	month_2007-12-01_1			
## 1	0.007692308	0.007692308	0.007692308	0.007692308			
## 2	0.008264463	0.008264463	0.008264463	0.008264463			
## 3	0.041666667	0.041666667	0.041666667	0.041666667			
## 4	0.007575758	0.007575758	0.007575758	0.007575758			
## 5	0.000000000	0.000000000	0.000000000	0.000000000			
## 6	0.011904762	0.011904762	0.011904762	0.011904762			
## 7	0.010000000	0.010000000	0.010000000	0.010000000			
## 8	0.014705882	0.014705882	0.014705882	0.014705882			
## 9	0.000000000	0.000000000	0.000000000	0.000000000			
## 10	0.000000000	0.000000000	0.000000000	0.000000000			
##	month_2008-01-01_1	month_2008-02-01_1	month_2008-03-01_1	month_2008-04-01_1			

[illegible]



[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

```
## 6      0.000000000      0.000000000      0.000000000      0.000000000
## 7      0.010000000      0.010000000      0.010000000      0.010000000
## 8      0.000000000      0.000000000      0.000000000      0.000000000
## 9      0.076923077      0.076923077      0.076923077      0.076923077
## 10     0.037037037      0.037037037      0.037037037      0.037037037
```

```
df13[1:10,]
```

```
##      NUID      month unit tenure arrest total_crime median_income share_of_black
## 1      1 2007-04-01   14      1     -2      -153           0           0
## 2      1 2007-05-01   14      1      1       223           0           0
## 3      1 2007-06-01   14      1      0        57           0           0
## 4      1 2007-07-01   14      1     -1        89           0           0
## 5      1 2007-08-01   14      1      0        12           0           0
## 6      1 2007-09-01   14      1      1     -146           0           0
## 7      1 2007-10-01   14      1     -1       103           0           0
## 8      1 2007-11-01   14      1      0     -213           0           0
## 9      1 2007-12-01   14      1      2     -102           0           0
## 10     1 2008-01-01   14      1     -1        53           0           0
##      share_of_hispanic share_of_white unit_1 unit_2 unit_3 unit_4 unit_5 unit_6
## 1              0              0      0      0      0      0      0      0
## 2              0              0      0      0      0      0      0      0
## 3              0              0      0      0      0      0      0      0
## 4              0              0      0      0      0      0      0      0
## 5              0              0      0      0      0      0      0      0
## 6              0              0      0      0      0      0      0      0
## 7              0              0      0      0      0      0      0      0
## 8              0              0      0      0      0      0      0      0
## 9              0              0      0      0      0      0      0      0
## 10             0              0      0      0      0      0      0      0
##      unit_7 unit_8 unit_9 unit_10 unit_11 unit_12 unit_13 unit_14 unit_15 unit_16
## 1          0      0      0      0      0      0      0      0      0      0
## 2          0      0      0      0      0      0      0      0      0      0
## 3          0      0      0      0      0      0      0      0      0      0
## 4          0      0      0      0      0      0      0      0      0      0
## 5          0      0      0      0      0      0      0      0      0      0
## 6          0      0      0      0      0      0      0      0      0      0
## 7          0      0      0      0      0      0      0      0      0      0
## 8          0      0      0      0      0      0      0      0      0      0
## 9          0      0      0      0      0      0      0      0      0      0
## 10         0      0      0      0      0      0      0      0      0      0
##      unit_17 unit_18 unit_19 unit_20 unit_21 unit_22 unit_23 unit_24 unit_25
## 1          0      0      0      0      0      0      0      0      0
## 2          0      0      0      0      0      0      0      0      0
## 3          0      0      0      0      0      0      0      0      0
## 4          0      0      0      0      0      0      0      0      0
## 5          0      0      0      0      0      0      0      0      0
## 6          0      0      0      0      0      0      0      0      0
## 7          0      0      0      0      0      0      0      0      0
## 8          0      0      0      0      0      0      0      0      0
## 9          0      0      0      0      0      0      0      0      0
## 10         0      0      0      0      0      0      0      0      0
##      month_2007-01-01 month_2007-02-01 month_2007-03-01 month_2007-04-01
## 1              0              0              -1              1
## 2              0              0              0              -1
```

## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2007-05-01	month_2007-06-01	month_2007-07-01	month_2007-08-01
## 1	0	0	0	0
## 2	1	0	0	0
## 3	-1	1	0	0
## 4	0	-1	1	0
## 5	0	0	-1	1
## 6	0	0	0	-1
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2007-09-01	month_2007-10-01	month_2007-11-01	month_2007-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	1	0	0	0
## 7	-1	1	0	0
## 8	0	-1	1	0
## 9	0	0	-1	1
## 10	0	0	0	-1
##	month_2008-01-01	month_2008-02-01	month_2008-03-01	month_2008-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	1	0	0	0
##	month_2008-05-01	month_2008-06-01	month_2008-07-01	month_2008-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2008-09-01	month_2008-10-01	month_2008-11-01	month_2008-12-01
## 1	0	0	0	0

## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-01-01	month_2009-02-01	month_2009-03-01	month_2009-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-05-01	month_2009-06-01	month_2009-07-01	month_2009-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2009-09-01	month_2009-10-01	month_2009-11-01	month_2009-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-01-01	month_2010-02-01	month_2010-03-01	month_2010-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-05-01	month_2010-06-01	month_2010-07-01	month_2010-08-01



## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2010-09-01	month_2010-10-01	month_2010-11-01	month_2010-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-01-01	month_2011-02-01	month_2011-03-01	month_2011-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-05-01	month_2011-06-01	month_2011-07-01	month_2011-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2011-09-01	month_2011-10-01	month_2011-11-01	month_2011-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0

##	month_2012-01-01	month_2012-02-01	month_2012-03-01	month_2012-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2012-05-01	month_2012-06-01	month_2012-07-01	month_2012-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2012-09-01	month_2012-10-01	month_2012-11-01	month_2012-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2013-01-01	month_2013-02-01	month_2013-03-01	month_2013-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2013-05-01	month_2013-06-01	month_2013-07-01	month_2013-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0

## 10	0	0	0	0
##	month_2013-09-01	month_2013-10-01	month_2013-11-01	month_2013-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-01-01	month_2014-02-01	month_2014-03-01	month_2014-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-05-01	month_2014-06-01	month_2014-07-01	month_2014-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2014-09-01	month_2014-10-01	month_2014-11-01	month_2014-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-01-01	month_2015-02-01	month_2015-03-01	month_2015-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0

## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-05-01	month_2015-06-01	month_2015-07-01	month_2015-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2015-09-01	month_2015-10-01	month_2015-11-01	month_2015-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-01-01	month_2016-02-01	month_2016-03-01	month_2016-04-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-05-01	month_2016-06-01	month_2016-07-01	month_2016-08-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0
## 8	0	0	0	0
## 9	0	0	0	0
## 10	0	0	0	0
##	month_2016-09-01	month_2016-10-01	month_2016-11-01	month_2016-12-01
## 1	0	0	0	0
## 2	0	0	0	0
## 3	0	0	0	0
## 4	0	0	0	0
## 5	0	0	0	0
## 6	0	0	0	0
## 7	0	0	0	0

```

## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-01-01 month_2017-02-01 month_2017-03-01 month_2017-04-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-05-01 month_2017-06-01 month_2017-07-01 month_2017-08-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0
##      month_2017-09-01 month_2017-10-01 month_2017-11-01 month_2017-12-01
## 1      0      0      0      0
## 2      0      0      0      0
## 3      0      0      0      0
## 4      0      0      0      0
## 5      0      0      0      0
## 6      0      0      0      0
## 7      0      0      0      0
## 8      0      0      0      0
## 9      0      0      0      0
## 10     0      0      0      0

```

## Within estimator

- Consider the following model

$$A_{ijt} - \bar{A}_{ij} = \beta(\tau_{it} - \bar{\tau}_i) + \gamma(Z_{jt} - \bar{Z}_j) + (\psi_j - \bar{\psi}_j) + (\kappa_t - \bar{\kappa}) + (\epsilon_{ijt} - \bar{\epsilon}_{ij})$$

where  $\bar{\psi}_j$  is the number of periods in which individual  $i$  is on duty in district  $j$  divided by the total number of periods, which measures the average district fixed effects.

```

X3 = as.matrix(df11[,c(4,6:34,36:166)])
Y3 = as.matrix(df11[,5])
coef3 = solve(t(X3)%*%X3)%*%t(X3)%*%Y3
coef3[1,1]

```

```

##      tenure
## -0.0002767571

```

The estimated  $\beta$  is  $-2.7675706 \times 10^{-4}$ .

## Between estimator

- Consider the following model

$$\bar{A}_{ij} = \alpha_i + \beta \bar{\tau}_i + \gamma \bar{Z}_j + \bar{\psi}_j + \bar{\kappa} + \bar{\epsilon}_{ij}$$

- Since there are 10k+ individuals, the calculation amount is too large if I estimate the individual fixed effects for each individual, so I ignore the individual fixed effects and simply consider the following model

$$\bar{A}_{ij} = \beta \bar{\tau}_i + \gamma \bar{Z}_j + \bar{\psi}_j + \bar{\kappa} + \bar{\epsilon}_{ij}$$

```
X4 = as.matrix(df12[,c(2,4:32,34:164)])
Y4 = as.matrix(df12[,3])
coef4 = solve(t(X4)%*%X4,tol=1e-100)%*%t(X4)%*%Y4
coef4[1,1]
```

```
##      tenure_1
## -1.756059e-05
```

The estimated  $\beta$  is  $-1.7560586 \times 10^{-5}$ .

## First difference estimator

- Consider the following model

$$A_{ij} - A_{i,j-1} = \beta(\tau_{it} - \tau_{i,t-1}) + \gamma(Z_{jt} - Z_{j,t-1}) + (\psi_j - \psi_k) + (\kappa_t - \kappa_{t-1}) + (\epsilon_{ijt} - \epsilon_{ij,t-1}),$$

where  $\psi_k$  is the indicator for district in period  $t-1$ .

```
X5 = as.matrix(df13[,c(4,6:34,36:166)])
Y5 = as.matrix(df13[,5])
coef5 = solve(t(X5)%*%X5,tol=1e-100)%*%t(X5)%*%Y5
coef5[1,1]
```

```
##      tenure
## 0.005430383
```

The estimated  $\beta$  is 0.0054304. The within and between estimators are negative with small absolute value, while the first difference estimator is positive with small absolute value.

## GMM

- Since there are 10k+ individuals, the calculation amount is too large if I estimate the individual fixed effects for each individual, so I use the data df10 and only consider district and year and month fixed effects.
- Estimate

$$\min_{\beta} [(Y - X\beta)'X]I[X'(Y - X\beta)]$$

- Obtain

$$\hat{\beta}_1 = (X'XX'X)^{-1}X'XX'Y$$

```
coef6 = solve(t(X2)%*%X2)%*%t(X2)%*%X2,tol=1e-100)%*%t(X2)%*%X2)%*%t(X2)%*%Y2
coef6[1:6,1]
```

```
##      tenure      total_crime      median_income      share_of_black
## -0.006430752      0.044062993      0.001673600      174.105950560
## share_of_hispanic      share_of_white
## 94.058096948      -68.634474816
```

- Matrix of variance/covariance

$$\hat{S}_n = \frac{1}{N} X' (Y - X\hat{\beta}_1)(Y - X\hat{\beta}_1)' X$$

```
s = t(X2)%*%(Y2-X2*%coef6)%*%t(Y2-X2*%coef6)%*%X2/nrow(X2)
s[1:6,1:6]
```

```
##                tenure    total_crime median_income share_of_black
## tenure          23526143.12   137065741.2    6778134879 -1.902191e+04
## total_crime     137065741.24   798559174.4    39490114336 -1.108236e+05
## median_income   6778134879.42  39490114336.1  1952853564595 -5.480417e+06
## share_of_black  -19021.91     -110823.6      -5480417    1.538004e+01
## share_of_hispanic 257208.55    1498523.6      74104550   -2.079643e+02
## share_of_white   -61835.01    -360257.2     -17815331   4.999629e+01
##                share_of_hispanic share_of_white
## tenure          257208.5516   -6.183501e+04
## total_crime     1498523.6044   -3.602572e+05
## median_income   74104550.2584  -1.781533e+07
## share_of_black  -207.9643     4.999629e+01
## share_of_hispanic 2812.0308   -6.760349e+02
## share_of_white  -676.0349     1.625242e+02
```

- Solve the problem

$$\min_{\beta} [(Y - X\beta)' X] \hat{S}_n [X' (Y - X\beta)]$$

- Obtain

$$\hat{\beta}_{GMM} = (X' X \hat{S}_n X' X)^{-1} X' X \hat{S}_n X' Y$$

```
coef7 = solve(t(X2)%*%X2*%s*%t(X2)%*%X2,tol=1e-100)%*%
t(X2)%*%X2*%s*%t(X2)%*%Y2
coef7[1:6,1]
```

```
##                tenure    total_crime    median_income    share_of_black
##      3.432696e-02   -1.257924e-02   -9.303011e-05    1.142793e+01
## share_of_hispanic share_of_white
##      -5.762788e+00    1.587799e+01
```

The estimated  $\beta$  is 0.034327, the estimated  $\gamma$  are -0.0125792,  $-9.3030114 \times 10^{-5}$ , 11.427927, -5.7627884, 15.8779875, the estimated  $\psi$  are 260.233486, -194.1593003, -660.3874518, -614.0392293, -1134.5037234, -513.4710327, -811.0630493, -821.7088625, 594.6329814, 433.3865776, -839.8880365, -25.5199352, 3194.3315104, 267.3792742, 47.4652703, 123.4081324, 263.0510671, 203.7918916, 454.2880195, 271.6729841, 238.1857325, 760.9020156, 3522.4804661, -454.6756343, and the estimated  $\kappa$  are -4648.7402747,  $-1.5720909 \times 10^4$ ,  $-1.0770185 \times 10^4$ ,  $-1.8773271 \times 10^4$ , 6882.0080465, 4187.1431704, 92.7673602,  $-1.5869528 \times 10^4$ , -837.183258, 6060.3290497, 3650.0219531, 7982.0851386, 6442.1367284, -7160.672517,  $1.1831375 \times 10^4$ , -8527.9742489,  $1.7217455 \times 10^4$ , 5935.9088468, 808.8681615, 373.3567247,  $1.1302311 \times 10^4$ , -1675.9619547, 2807.2671541, -309.080995, -6919.2121571, -392.2783251, -4130.8748702, -299.2683967, 3138.6946618, 1165.8274145, -3815.8554014, -2795.6676286, -6459.2994004, 9270.0084298, 2032.4076731, 5215.3853754, 2980.3530223, 3987.1701401,  $-1.1225375 \times 10^4$ ,  $-1.2298408 \times 10^4$ , 3602.9920122, 6937.6344949, 3771.5645188, 1062.0216998, -1487.8646396, 1923.7791699, -184.4182187, -2692.3040992,  $-1.7145734 \times 10^4$ ,  $1.330129 \times 10^4$ , 3773.5661489, -8906.4649896,  $-1.5512831 \times 10^4$ , 5175.6766344, 3582.3241896, 6536.2838298, 5452.4518203,  $1.359897 \times 10^4$ ,  $-1.1998475 \times 10^4$ ,  $1.0685452 \times 10^4$ , -2682.5329117, 6895.6899574, -288.7476584, 517.0154226,  $1.1897068 \times 10^4$ , 8721.337217,  $-1.350147 \times 10^4$ , 469.8279665, 1845.0446036, 1467.1897827, -2383.1464035, -3843.3332761, 4646.9455575, 2722.2626014,  $1.4488496 \times 10^4$ , -8519.5777973, 3515.4986753,  $1.0638952 \times 10^4$ , -2470.6275489, 9809.2188499, -321.4306651, 5076.001216, 5040.6569102, -1168.1721286, 4164.9269253, 9967.9296517, -7758.7770479, 3534.7615851, 3104.609609, -2675.6784481, 1467.1180117, 4234.7989251, 3786.0010486, -5014.2312015, -619.4009564, -2268.4093885, 8540.2972403, -6512.4650211,  $-1.0868295 \times 10^4$ ,  $-1.3514536 \times 10^4$ ,  $-1.2087499 \times 10^4$ ,  $1.2970387 \times 10^4$ , 3072.4528395, 6285.0464968, 479.1908025, -3870.3300715,  $-1.0804468 \times 10^4$ ,

-71.6723671, -4847.5109113, 8145.4557554, -1981.7509394,  $-1.4132138 \times 10^4$ , 1469.1382734, 3900.1817863,  $1.2036269 \times 10^4$ ,  $-1.1020757 \times 10^4$ , 3480.653435, -648.8760578, -8180.6809538, 3847.4282321,  $-2.2202234 \times 10^4$ ,  $-1.0812708 \times 10^4$ , -452.2407115, -3444.4031514, -3720.6591747, -8306.2290921,  $-1.1364297 \times 10^4$ , -8486.3543727, 9746.6072566, 9060.8262699, -3131.2230012.