Problem Set 5 R Solutions and a Guide to Panel Data

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We will use Question 2i as our guiding example for implementing panel data in R for the purpose of this course. The short of it is that we will implement it entirely using the familiar lm_robust function from *estimatr*. I know I directed some people to *plm* before the strike so apologies if it led to frustration during the problem set. This is why I write my own notes and didn't share the econometrics-with-R website before; it's pretty sloppy, often inaccurate, and I usually have to spend a day figuring out the differences between R and Stata.

Just for exposition, *plm* is a good package and can even handle robust standard errors. However by default it clusters standard errors to the level of the individual fixed effects. In general, we do want to use clustered standard errors whenever we include fixed effects which is why they've made it automatic, but this problem set does ask us to consider fixed-effects models without clustering so it cannot be used. Further, *lm_robust* is much more compatible with *linearHypothesis* when we run F-tests for a subset of covariates (such as fixed effects).

Question 1

Let's load our data and create the log transformations we'll need:

```
guns <- read.dta13("handguns.dta") %>% mutate(lvio = log(vio),
    lrob = log(rob), lmur = log(mur))
```

Regression (i): Regress ln(vio) against shall

```
lm_robust(lvio ~ shall, data = guns, se_type = "stata")
```

```
##               Estimate Std. Error    t value     Pr(>|t|)   CI Lower
## (Intercept)  6.1349189 0.01930393 317.806773 0.000000e+00  6.0970448
## shall       -0.4429646 0.04752832  -9.320014 5.596578e-20 -0.5362148
##               CI Upper   DF
## (Intercept)  6.1727931 1171
## shall       -0.3497144 1171
```

Regression (ii): Regress ln(vio) against shall, incarc_rate, density, avginc, pop, pb1064, pw1064, pm1029

```
lm_robust(lvio ~ shall + incarc_rate + density + avginc + pop +
    pb1064 + pw1064 + pm1029, data = guns, se_type = "stata")
```

```
##                 Estimate   Std. Error     t value     Pr(>|t|)
## (Intercept)  2.981738245 0.6090197820   4.8959629 1.116039e-06
## shall       -0.368386948 0.0347879106 -10.5895106 4.419970e-25
## incarc_rate  0.001612633 0.0001806945   8.9246392 1.701409e-18
## density      0.026688475 0.0143493879   1.8599033 6.315131e-02
## avginc       0.001205122 0.0072778184   0.1655884 8.685096e-01
## pop          0.042709834 0.0031466432  13.5731416 4.578376e-39
## pb1064       0.080852602 0.0199924337   4.0441601 5.596777e-05
## pw1064       0.031200509 0.0097270734   3.2075947 1.374974e-03
## pm1029       0.008870883 0.0120603987   0.7355381 4.621600e-01
##                 CI Lower     CI Upper   DF
## (Intercept)  1.786838934  4.176637556 1164
## shall       -0.436640971 -0.300132925 1164
```

```
## incarc_rate  0.001258110  0.001967156 1164
## density     -0.001465083  0.054842032 1164
## avginc      -0.013073987  0.015484232 1164
## pop          0.036536107  0.048883560 1164
## pb1064       0.041627365  0.120077839 1164
## pw1064       0.012115951  0.050285067 1164
## pm1029      -0.014791669  0.032533434 1164
```

1a: Interpret the coefficient on shall in regression (ii). Is this estimate large or small in a "real-world" sense?

The coefficient of -0.37 means that holding constant the control variables (the incarceration rate in the previous year, the population density, state income, state population, percentage of blacks aged 10–64, percentage of whites aged 10-64, and percentage of male aged 10-29), having a "shall-carry""" law results in a reduction in the violent crime rate of 37%. This is a very large effect – a reduction in violent crimes of 37% is very significant in a political or real-world sense.

1b: Does adding the control variables in regression (ii) change your conclusions about the effect of a shall-carry law, relative to regression (i)?

Adding the control variables reduces the estimated coefficient, suggesting that the original coefficient probably was subject to some omitted variable bias. In both (i) and (ii), the effect of the shall-carry law is statistically significant at the 5% level. In (i) the estimated effect is a crime reduction of 44%, in (ii) the estimated reduction is 37%. Both estimated effects are very large. Still, in a real-world sense the difference between them is substantial also (7% of violent crimes is a lot of crime).

1c: Suggest a variable which varies across states but plausibly varies little, or not at all, over time, and which plausibly could cause omitted variable bias in regression (ii)

Here is one:

Severity of punishment. Laws on violent crime are almost entirely state laws and there is considerable variation across states. Severity of punishment: (i) arguably affects the crime rate and (ii) could be correlated with shall-carry laws (Texas has the death penalty, it also has a shall-carry law). If so, the OLS estimate on shall arguably overstates the effect of having a shall-carry, which is, in part, picking up the effect of tough laws.

Question 2

2i: Dependent variable ln(vio)

Running each regression in order

Regression 1: no controls, no fixed effects, no clustering

```r
# 1
mod.2i.1 <- lm_robust(lvio ~ shall, data = guns, se_type = "stata")
summary(mod.2i.1)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall, data = guns, se_type = "stata")
##
```

```
## Standard error type:  HC1
##
## Coefficients:
##             Estimate Std. Error t value  Pr(>|t|) CI Lower CI Upper   DF
## (Intercept)    6.135    0.01930  317.81 0.000e+00   6.0970   6.1728 1171
## shall         -0.443    0.04753   -9.32 5.597e-20  -0.5362  -0.3497 1171
##
## Multiple R-squared:  0.08664 ,   Adjusted R-squared:  0.08586
## F-statistic: 86.86 on 1 and 1171 DF,  p-value: < 2.2e-16
```

This is the same as the first regression in Question 1. No fixed effects so we're treating this panel data like any data we do OLS on.

Regression 2: yes controls, no fixed effects, no clustering

```r
mod.2i.2 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029, data = guns, se_type = "stata")
summary(mod.2i.2)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029, data = guns, se_type = "stata")
##
## Standard error type:  HC1
##
## Coefficients:
##              Estimate Std. Error  t value  Pr(>|t|)  CI Lower  CI Upper
## (Intercept)  2.981738  0.6090198   4.8960 1.116e-06  1.786839  4.176638
## shall       -0.368387  0.0347879 -10.5895 4.420e-25 -0.436641 -0.300133
## incarc_rate  0.001613  0.0001807   8.9246 1.701e-18  0.001258  0.001967
## density      0.026688  0.0143494   1.8599 6.315e-02 -0.001465  0.054842
## avginc       0.001205  0.0072778   0.1656 8.685e-01 -0.013074  0.015484
## pop          0.042710  0.0031466  13.5731 4.578e-39  0.036536  0.048884
## pb1064       0.080853  0.0199924   4.0442 5.597e-05  0.041627  0.120078
## pw1064       0.031201  0.0097271   3.2076 1.375e-03  0.012116  0.050285
## pm1029       0.008871  0.0120604   0.7355 4.622e-01 -0.014792  0.032533
##               DF
## (Intercept) 1164
## shall       1164
## incarc_rate 1164
## density     1164
## avginc      1164
## pop         1164
## pb1064      1164
## pw1064      1164
## pm1029      1164
##
## Multiple R-squared:  0.5643 ,    Adjusted R-squared:  0.5613
## F-statistic: 95.67 on 8 and 1164 DF,  p-value: < 2.2e-16
```

Again, this is the same as the second regression in Question 1. Don't forget to include the *se_type = 'stata'* argument!

Regression 3: yes controls, state fixed effects, no clustering

Now we're exploiting the panel structure of the data by including fixed effects. *lm_robust* already includes a *fixed_effects* argument that handles these:

```
mod.2i.3 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029, fixed_effects = ~state,
    se_type = "stata", data = guns)
summary(mod.2i.3)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029, data = guns, fixed_effects = ~state,
##     se_type = "stata")
##
## Standard error type:  HC1
##
## Coefficients:
##               Estimate Std. Error t value  Pr(>|t|)   CI Lower   CI Upper
## shall       -4.614e-02  1.994e-02 -2.3136 2.087e-02 -0.0852721 -0.0070109
## incarc_rate -7.101e-05  9.731e-05 -0.7297 4.657e-01 -0.0002619  0.0001199
## density     -1.723e-01  1.049e-01 -1.6428 1.007e-01 -0.3780724  0.0334925
## avginc      -9.204e-03  6.733e-03 -1.3669 1.719e-01 -0.0224155  0.0040080
## pop          1.152e-02  9.704e-03  1.1876 2.353e-01 -0.0075162  0.0305655
## pb1064       1.043e-01  1.656e-02  6.2990 4.305e-10  0.0717976  0.1367633
## pw1064       4.086e-02  5.386e-03  7.5867 6.903e-14  0.0302935  0.0514287
## pm1029      -5.027e-02  7.791e-03 -6.4528 1.634e-10 -0.0655588 -0.0349863
##               DF
## shall       1114
## incarc_rate 1114
## density     1114
## avginc      1114
## pop         1114
## pb1064      1114
## pw1064      1114
## pm1029      1114
##
## Multiple R-squared:  0.9411 ,    Adjusted R-squared:  0.938
## Multiple R-squared (proj. model):  0.2178 ,  Adjusted R-squared (proj. model):  0.1771
## F-statistic (proj. model):  28.1 on 8 and 1114 DF,  p-value: < 2.2e-16
```

These give us exactly the same estimates and standard errors as Stata. I'll just flag here that when we read this regression output, make sure you get the decimal points correct. The coefficient on *shall* here is -4.614e-02, which means -0.04614 (move the decimal point to the left twice). I don't want you guys to lose points for something as silly as decimal places.

So the only downide here is that it omits the estimates on the fixed effects regressors, which makes it (as far as I know) impossible to do the F-test we want to do. So for that reason, we'll want to run this same model slightly differently by explicitly including the fixed effects in the right-hand side of the formula: "+ factor(state)". "factor" here just creates dummy variables for each state. If we did not use "factor" then it would treat *state* as one continuous variable taking on values from 1-50, which is not an implementation of fixed effects.

```
mod.2i.3 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state),
```

```r
    se_type = "stata", data = guns)
summary(mod.2i.3)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029 + factor(state), data = guns,
##     se_type = "stata")
##
## Standard error type:  HC1
##
## Coefficients:
##                                Estimate Std. Error   t value
## (Intercept)                   4.037e+00  3.846e-01  10.49648
## shall                        -4.614e-02  1.994e-02  -2.31364
## incarc_rate                  -7.101e-05  9.731e-05  -0.72971
## density                      -1.723e-01  1.049e-01  -1.64275
## avginc                       -9.204e-03  6.733e-03  -1.36686
## pop                           1.152e-02  9.704e-03   1.18758
## pb1064                        1.043e-01  1.656e-02   6.29896
## pw1064                        4.086e-02  5.386e-03   7.58672
## pm1029                       -5.027e-02  7.791e-03  -6.45284
## factor(state)Alaska           5.596e-02  7.884e-02   0.70988
## factor(state)Arizona          2.404e-01  8.723e-02   2.75595
## factor(state)Arkansas        -1.273e-01  7.145e-02  -1.78133
## factor(state)California       2.442e-01  2.377e-01   1.02739
## factor(state)Colorado        -1.051e-01  1.180e-01  -0.89052
## factor(state)Connecticut     -9.557e-02  1.412e-01  -0.67658
## factor(state)Delaware         9.760e-02  8.245e-02   1.18377
## factor(state)District of Columbia  2.759e+00  1.005e+00   2.74624
## factor(state)Florida          6.771e-01  1.201e-01   5.63622
## factor(state)Georgia          2.253e-02  5.466e-02   0.41225
## factor(state)Hawaii          -1.128e+00  2.586e-01  -4.36118
## factor(state)Idaho           -5.030e-01  1.236e-01  -4.07041
## factor(state)Illinois         4.086e-01  1.128e-01   3.62044
## factor(state)Indiana         -2.057e-01  1.160e-01  -1.77303
## factor(state)Iowa            -6.291e-01  1.317e-01  -4.77677
## factor(state)Kansas          -1.808e-01  1.010e-01  -1.79093
## factor(state)Kentucky        -4.256e-01  1.091e-01  -3.90056
## factor(state)Louisiana        3.685e-01  5.736e-02   6.42495
## factor(state)Maine           -1.132e+00  1.508e-01  -7.50545
## factor(state)Maryland         3.961e-01  6.342e-02   6.24620
## factor(state)Massachusetts    2.869e-01  1.571e-01   1.82596
## factor(state)Michigan         2.449e-01  1.051e-01   2.33142
## factor(state)Minnesota       -5.760e-01  1.290e-01  -4.46351
## factor(state)Mississippi     -3.930e-01  7.799e-02  -5.03909
## factor(state)Missouri         1.455e-01  9.317e-02   1.56196
## factor(state)Montana         -9.910e-01  1.228e-01  -8.07170
## factor(state)Nebraska        -4.432e-01  1.204e-01  -3.68281
## factor(state)Nevada           3.226e-01  9.154e-02   3.52438
## factor(state)New Hampshire   -1.277e+00  1.466e-01  -8.71041
## factor(state)New Jersey       1.222e-01  1.427e-01   0.85633
## factor(state)New Mexico       3.818e-01  7.856e-02   4.85967
## factor(state)New York         4.354e-01  1.728e-01   2.51994
```

```
## factor(state)North Carolina       -9.656e-02  5.689e-02  -1.69737
## factor(state)North Dakota         -1.843e+00  1.136e-01 -16.22255
## factor(state)Ohio                 -1.885e-01  1.339e-01  -1.40800
## factor(state)Oklahoma             -4.115e-02  6.814e-02  -0.60389
## factor(state)Oregon                4.947e-03  1.194e-01   0.04144
## factor(state)Pennyslvania         -3.250e-01  1.439e-01  -2.25800
## factor(state)Rhode Island         -1.004e-01  1.670e-01  -0.60090
## factor(state)South Carolina        3.341e-01  5.764e-02   5.79513
## factor(state)South Dakota         -1.025e+00  1.041e-01  -9.84327
## factor(state)Tennessee             4.468e-02  8.020e-02   0.55709
## factor(state)Texas                 5.265e-02  1.592e-01   0.33067
## factor(state)Utah                 -3.039e-01  1.120e-01  -2.71439
## factor(state)Vermont              -1.255e+00  1.498e-01  -8.37706
## factor(state)Virginia             -6.018e-01  6.013e-02 -10.00759
## factor(state)Washington           -1.322e-01  1.077e-01  -1.22768
## factor(state)West Virginia        -9.691e-01  1.273e-01  -7.61364
## factor(state)Wisconsin            -7.812e-01  1.201e-01  -6.50498
## factor(state)Wyoming              -4.804e-01  1.293e-01  -3.71510
##                                    Pr(>|t|)   CI Lower   CI Upper   DF
## (Intercept)                       1.212e-24  3.2821852  4.7913662 1114
## shall                             2.087e-02 -0.0852721 -0.0070109 1114
## incarc_rate                       4.657e-01 -0.0002619  0.0001199 1114
## density                           1.007e-01 -0.3780724  0.0334925 1114
## avginc                            1.719e-01 -0.0224155  0.0040080 1114
## pop                               2.353e-01 -0.0075162  0.0305655 1114
## pb1064                            4.305e-10  0.0717976  0.1367633 1114
## pw1064                            6.903e-14  0.0302935  0.0514287 1114
## pm1029                            1.634e-10 -0.0655588 -0.0349863 1114
## factor(state)Alaska               4.779e-01 -0.0987211  0.2106508 1114
## factor(state)Arizona              5.948e-03  0.0692506  0.4115726 1114
## factor(state)Arkansas             7.513e-02 -0.2674677  0.0129161 1114
## factor(state)California           3.045e-01 -0.2222089  0.7106903 1114
## factor(state)Colorado             3.734e-01 -0.3366259  0.1264526 1114
## factor(state)Connecticut          4.988e-01 -0.3727071  0.1815767 1114
## factor(state)Delaware             2.368e-01 -0.0641709  0.2593666 1114
## factor(state)District of Columbia 6.125e-03  0.7879023  4.7309053 1114
## factor(state)Florida              2.201e-08  0.4414163  0.9128763 1114
## factor(state)Georgia              6.802e-01 -0.0847081  0.1297720 1114
## factor(state)Hawaii               1.413e-05 -1.6354309 -0.6204919 1114
## factor(state)Idaho                5.024e-05 -0.7454639 -0.2605340 1114
## factor(state)Illinois             3.073e-04  0.1871443  0.6299893 1114
## factor(state)Indiana              7.650e-02 -0.4332429  0.0219301 1114
## factor(state)Iowa                 2.019e-06 -0.8875645 -0.3707156 1114
## factor(state)Kansas               7.358e-02 -0.3789507  0.0172826 1114
## factor(state)Kentucky             1.017e-04 -0.6396215 -0.2114882 1114
## factor(state)Louisiana            1.951e-10  0.2559922  0.4810864 1114
## factor(state)Maine                1.250e-13 -1.4279067 -0.8360551 1114
## factor(state)Maryland             5.973e-10  0.2716935  0.5205617 1114
## factor(state)Massachusetts        6.812e-02 -0.0213909  0.5952020 1114
## factor(state)Michigan             1.991e-02  0.0387974  0.4510353 1114
## factor(state)Minnesota            8.882e-06 -0.8292149 -0.3228040 1114
## factor(state)Mississippi          5.454e-07 -0.5460035 -0.2399664 1114
## factor(state)Missouri             1.186e-01 -0.0372820  0.3283517 1114
## factor(state)Montana              1.784e-15 -1.2319122 -0.7501145 1114
```

```
## factor(state)Nebraska            2.417e-04 -0.6793814 -0.2070935 1114
## factor(state)Nevada              4.417e-04  0.1430070  0.5022155 1114
## factor(state)New Hampshire       1.077e-17 -1.5647192 -0.9893848 1114
## factor(state)New Jersey          3.920e-01 -0.1578117  0.4022392 1114
## factor(state)New Mexico          1.344e-06  0.2276388  0.5359302 1114
## factor(state)New York            1.188e-02  0.0963949  0.7744876 1114
## factor(state)North Carolina      8.991e-02 -0.2081738  0.0150594 1114
## factor(state)North Dakota        2.722e-53 -2.0662922 -1.6203927 1114
## factor(state)Ohio                1.594e-01 -0.4511528  0.0741758 1114
## factor(state)Oklahoma            5.460e-01 -0.1748345  0.0925422 1114
## factor(state)Oregon              9.670e-01 -0.2292791  0.2391732 1114
## factor(state)Pennyslvania        2.414e-02 -0.6073424 -0.0425854 1114
## factor(state)Rhode Island        5.480e-01 -0.4281338  0.2273812 1114
## factor(state)South Carolina      8.879e-09  0.2209491  0.4471531 1114
## factor(state)South Dakota        5.600e-22 -1.2288430 -0.8203665 1114
## factor(state)Tennessee           5.776e-01 -0.1126851  0.2020461 1114
## factor(state)Texas               7.410e-01 -0.2597820  0.3650913 1114
## factor(state)Utah                6.742e-03 -0.5235926 -0.0842291 1114
## factor(state)Vermont             1.616e-16 -1.5483595 -0.9606847 1114
## factor(state)Virginia            1.233e-22 -0.7197493 -0.4837837 1114
## factor(state)Washington          2.198e-01 -0.3434125  0.0790674 1114
## factor(state)West Virginia       5.664e-14 -1.2189054 -0.7193911 1114
## factor(state)Wisconsin           1.171e-10 -1.0168624 -0.5455824 1114
## factor(state)Wyoming             2.132e-04 -0.7341196 -0.2266814 1114
##
## Multiple R-squared:  0.9411 ,    Adjusted R-squared:  0.938
## F-statistic: 364.9 on 58 and 1114 DF,  p-value: < 2.2e-16
```

The output is now much longer since we're including 50 fixed effects. But scroll up to the top and you'll find the estimates and standard errors on the main regressors are exactly the same.

Now let's do hypothesis testing on the fixed effects. We'll want to refer to the fixed effects by name so that we can use our familiar *linearHypothesis* function from the *car* package. But there are 50 of them, too many to type out manually. So let's first pull the vector of coefficients:

```
mod.2i.3$coefficients
```

```
##                       (Intercept)                             shall
##                       4.036775691                      -0.046141523
##                       incarc_rate                           density
##                      -0.000071008                      -0.172289988
##                            avginc                               pop
##                      -0.009203729                       0.011524661
##                            pb1064                            pw1064
##                       0.104280401                       0.040861070
##                            pm1029               factor(state)Alaska
##                      -0.050272536                       0.055964866
##              factor(state)Arizona             factor(state)Arkansas
##                       0.240411594                      -0.127275803
##           factor(state)California             factor(state)Colorado
##                       0.244240711                      -0.105086645
##          factor(state)Connecticut             factor(state)Delaware
##                      -0.095565202                       0.097597850
## factor(state)District of Columbia              factor(state)Florida
##                       2.759403816                       0.677146315
##              factor(state)Georgia               factor(state)Hawaii
```

```
##                     0.022531955                     -1.127961420
##              factor(state)Idaho            factor(state)Illinois
##                    -0.502998956                      0.408566818
##            factor(state)Indiana                factor(state)Iowa
##                    -0.205656410                     -0.629140037
##             factor(state)Kansas            factor(state)Kentucky
##                    -0.180834078                     -0.425554844
##          factor(state)Louisiana               factor(state)Maine
##                     0.368539270                     -1.131980906
##           factor(state)Maryland       factor(state)Massachusetts
##                     0.396127607                      0.286905573
##           factor(state)Michigan           factor(state)Minnesota
##                     0.244916361                     -0.576009440
##        factor(state)Mississippi            factor(state)Missouri
##                    -0.392984941                      0.145534836
##            factor(state)Montana            factor(state)Nebraska
##                    -0.991013338                     -0.443237440
##             factor(state)Nevada       factor(state)New Hampshire
##                     0.322611270                     -1.277051983
##         factor(state)New Jersey          factor(state)New Mexico
##                     0.122213752                      0.381784511
##           factor(state)New York      factor(state)North Carolina
##                     0.435441260                     -0.096557172
##       factor(state)North Dakota                factor(state)Ohio
##                    -1.843342441                     -0.188488494
##           factor(state)Oklahoma              factor(state)Oregon
##                    -0.041146116                      0.004947080
##       factor(state)Pennyslvania        factor(state)Rhode Island
##                    -0.324963870                     -0.100376301
##     factor(state)South Carolina        factor(state)South Dakota
##                     0.334051082                     -1.024604778
##          factor(state)Tennessee               factor(state)Texas
##                     0.044680502                      0.052654625
##               factor(state)Utah             factor(state)Vermont
##                    -0.303910876                     -1.254522082
##           factor(state)Virginia          factor(state)Washington
##                    -0.601766471                     -0.132172552
##      factor(state)West Virginia           factor(state)Wisconsin
##                    -0.969148238                     -0.781222394
##            factor(state)Wyoming
##                    -0.480400511
```

We only need their names rather than the actual estimates:

```
coef.names <- names(mod.2i.3$coefficients)
coef.names
```

```
##  [1] "(Intercept)"
##  [2] "shall"
##  [3] "incarc_rate"
##  [4] "density"
##  [5] "avginc"
##  [6] "pop"
##  [7] "pb1064"
##  [8] "pw1064"
```

```
##  [9] "pm1029"
## [10] "factor(state)Alaska"
## [11] "factor(state)Arizona"
## [12] "factor(state)Arkansas"
## [13] "factor(state)California"
## [14] "factor(state)Colorado"
## [15] "factor(state)Connecticut"
## [16] "factor(state)Delaware"
## [17] "factor(state)District of Columbia"
## [18] "factor(state)Florida"
## [19] "factor(state)Georgia"
## [20] "factor(state)Hawaii"
## [21] "factor(state)Idaho"
## [22] "factor(state)Illinois"
## [23] "factor(state)Indiana"
## [24] "factor(state)Iowa"
## [25] "factor(state)Kansas"
## [26] "factor(state)Kentucky"
## [27] "factor(state)Louisiana"
## [28] "factor(state)Maine"
## [29] "factor(state)Maryland"
## [30] "factor(state)Massachusetts"
## [31] "factor(state)Michigan"
## [32] "factor(state)Minnesota"
## [33] "factor(state)Mississippi"
## [34] "factor(state)Missouri"
## [35] "factor(state)Montana"
## [36] "factor(state)Nebraska"
## [37] "factor(state)Nevada"
## [38] "factor(state)New Hampshire"
## [39] "factor(state)New Jersey"
## [40] "factor(state)New Mexico"
## [41] "factor(state)New York"
## [42] "factor(state)North Carolina"
## [43] "factor(state)North Dakota"
## [44] "factor(state)Ohio"
## [45] "factor(state)Oklahoma"
## [46] "factor(state)Oregon"
## [47] "factor(state)Pennyslvania"
## [48] "factor(state)Rhode Island"
## [49] "factor(state)South Carolina"
## [50] "factor(state)South Dakota"
## [51] "factor(state)Tennessee"
## [52] "factor(state)Texas"
## [53] "factor(state)Utah"
## [54] "factor(state)Vermont"
## [55] "factor(state)Virginia"
## [56] "factor(state)Washington"
## [57] "factor(state)West Virginia"
## [58] "factor(state)Wisconsin"
## [59] "factor(state)Wyoming"
```

Clearly, we only want the names that begin with "factor(state)" since those are the fixed effects. We can do this by observing that the fixed effects begin with variable 10 ("factor(state)Alaska") and go on to variable

59 (“factor(state)Wyoming”) so that we can manually define state coefficients as follows:

```
state.coefficients <- coef.names[10:59]
state.coefficients
```

```
##  [1] "factor(state)Alaska"
##  [2] "factor(state)Arizona"
##  [3] "factor(state)Arkansas"
##  [4] "factor(state)California"
##  [5] "factor(state)Colorado"
##  [6] "factor(state)Connecticut"
##  [7] "factor(state)Delaware"
##  [8] "factor(state)District of Columbia"
##  [9] "factor(state)Florida"
## [10] "factor(state)Georgia"
## [11] "factor(state)Hawaii"
## [12] "factor(state)Idaho"
## [13] "factor(state)Illinois"
## [14] "factor(state)Indiana"
## [15] "factor(state)Iowa"
## [16] "factor(state)Kansas"
## [17] "factor(state)Kentucky"
## [18] "factor(state)Louisiana"
## [19] "factor(state)Maine"
## [20] "factor(state)Maryland"
## [21] "factor(state)Massachusetts"
## [22] "factor(state)Michigan"
## [23] "factor(state)Minnesota"
## [24] "factor(state)Mississippi"
## [25] "factor(state)Missouri"
## [26] "factor(state)Montana"
## [27] "factor(state)Nebraska"
## [28] "factor(state)Nevada"
## [29] "factor(state)New Hampshire"
## [30] "factor(state)New Jersey"
## [31] "factor(state)New Mexico"
## [32] "factor(state)New York"
## [33] "factor(state)North Carolina"
## [34] "factor(state)North Dakota"
## [35] "factor(state)Ohio"
## [36] "factor(state)Oklahoma"
## [37] "factor(state)Oregon"
## [38] "factor(state)Pennyslvania"
## [39] "factor(state)Rhode Island"
## [40] "factor(state)South Carolina"
## [41] "factor(state)South Dakota"
## [42] "factor(state)Tennessee"
## [43] "factor(state)Texas"
## [44] "factor(state)Utah"
## [45] "factor(state)Vermont"
## [46] "factor(state)Virginia"
## [47] "factor(state)Washington"
## [48] "factor(state)West Virginia"
## [49] "factor(state)Wisconsin"
## [50] "factor(state)Wyoming"
```

Alternatively, let's use a new function (no new packages needed; it's standard in R) intuitively called *startsWith*. startsWith takes in a vector of strings/words as its first argument and a string of interest as its second argument. Then it outputs a vector that (obviously) outputs TRUE if it does begin with that string of interest and FALSE otherwise:

```
startsWith(coef.names, "factor(state)")
```

```
##  [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE
## [12]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [23]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [34]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [45]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [56]  TRUE  TRUE  TRUE  TRUE
```

We use this as an index to select the coefficient names for which this is true:

```
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
state.coefficients
```

```
##  [1] "factor(state)Alaska"
##  [2] "factor(state)Arizona"
##  [3] "factor(state)Arkansas"
##  [4] "factor(state)California"
##  [5] "factor(state)Colorado"
##  [6] "factor(state)Connecticut"
##  [7] "factor(state)Delaware"
##  [8] "factor(state)District of Columbia"
##  [9] "factor(state)Florida"
## [10] "factor(state)Georgia"
## [11] "factor(state)Hawaii"
## [12] "factor(state)Idaho"
## [13] "factor(state)Illinois"
## [14] "factor(state)Indiana"
## [15] "factor(state)Iowa"
## [16] "factor(state)Kansas"
## [17] "factor(state)Kentucky"
## [18] "factor(state)Louisiana"
## [19] "factor(state)Maine"
## [20] "factor(state)Maryland"
## [21] "factor(state)Massachusetts"
## [22] "factor(state)Michigan"
## [23] "factor(state)Minnesota"
## [24] "factor(state)Mississippi"
## [25] "factor(state)Missouri"
## [26] "factor(state)Montana"
## [27] "factor(state)Nebraska"
## [28] "factor(state)Nevada"
## [29] "factor(state)New Hampshire"
## [30] "factor(state)New Jersey"
## [31] "factor(state)New Mexico"
## [32] "factor(state)New York"
## [33] "factor(state)North Carolina"
## [34] "factor(state)North Dakota"
## [35] "factor(state)Ohio"
## [36] "factor(state)Oklahoma"
## [37] "factor(state)Oregon"
```

```
## [38] "factor(state)Pennyslvania"
## [39] "factor(state)Rhode Island"
## [40] "factor(state)South Carolina"
## [41] "factor(state)South Dakota"
## [42] "factor(state)Tennessee"
## [43] "factor(state)Texas"
## [44] "factor(state)Utah"
## [45] "factor(state)Vermont"
## [46] "factor(state)Virginia"
## [47] "factor(state)Washington"
## [48] "factor(state)West Virginia"
## [49] "factor(state)Wisconsin"
## [50] "factor(state)Wyoming"
```

Exactly what we wanted. Now we just use this vector of variable names as the hypothesis argument in linearHypothesis. By default, this will jointly test the hypotheses that all these variables are equal to zero:

```
linearHypothesis(mod.2i.3, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
## factor(state)Florida = 0
## factor(state)Georgia = 0
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
```

```
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lvio ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state)
##
##   Res.Df Df      F    Pr(>F)
## 1   1164
## 2   1114 50 210.38 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Conveniently as usual, the output begins with the set of hypotheses we want to test so we know we're running the right test. The F-statistic is 210.38, exactly as Stata has it.

Regression 4: yes controls, state and year fixed effects, no clustering

Again, we have the option to use the *fixed_effects* argument in *lm_robust* for the case with multiple fixed effects:

```r
mod.2i.4 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029, fixed_effects = ~state +
    year, se_type = "stata", data = guns)
summary(mod.2i.4)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029, data = guns, fixed_effects = ~state +
##     year, se_type = "stata")
##
## Standard error type:  HC1
##
## Coefficients:
##               Estimate Std. Error t value  Pr(>|t|)   CI Lower  CI Upper
## shall       -2.799e-02  1.937e-02 -1.4450 1.488e-01 -6.601e-02 0.0100196
## incarc_rate  7.599e-05  8.292e-05  0.9165 3.596e-01 -8.671e-05 0.0002387
## density     -9.155e-02  6.487e-02 -1.4114 1.584e-01 -2.188e-01 0.0357256
## avginc       9.586e-04  7.197e-03  0.1332 8.941e-01 -1.316e-02 0.0150800
```

```
## pop         -4.754e-03  6.703e-03 -0.7093 4.783e-01 -1.791e-02 0.0083976
## pb1064       2.919e-02  2.104e-02  1.3874 1.656e-01 -1.209e-02 0.0704637
## pw1064       9.250e-03  8.518e-03  1.0859 2.777e-01 -7.464e-03 0.0259639
## pm1029       7.333e-02  1.878e-02  3.9052 9.992e-05  3.648e-02 0.1101670
##               DF
## shall       1092
## incarc_rate 1092
## density     1092
## avginc      1092
## pop         1092
## pb1064      1092
## pw1064      1092
## pm1029      1092
##
## Multiple R-squared:  0.9562 ,    Adjusted R-squared:  0.953
## Multiple R-squared (proj. model):  0.05635 , Adjusted R-squared (proj. model):  -0.01278
## F-statistic (proj. model): 7.823 on 8 and 1092 DF,  p-value: 2.935e-10
```

Note that once again, it's important to have the "~" to begin the "fixed_effects" argument (not sure why) and to separate the fixed effects dimensions with a "+" (with the individual fixed effects going first). Again, exactly the estiamtes and standard errors we wanted. Since we'll again be testing the fixed effects jointly for significance, we'll need to include the fixed effects as regressors explicitly:

```r
# 4
mod.2i.4 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), se_type = "stata", data = guns)
summary(mod.2i.4)
```

```
##
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029 + factor(state) + factor(year),
##     data = guns, se_type = "stata")
##
## Standard error type:  HC1
##
## Coefficients:
##                                Estimate Std. Error  t value  Pr(>|t|)
## (Intercept)                   3.972e+00  4.490e-01   8.8463 3.571e-18
## shall                        -2.799e-02  1.937e-02  -1.4450 1.488e-01
## incarc_rate                   7.599e-05  8.292e-05   0.9165 3.596e-01
## density                      -9.155e-02  6.487e-02  -1.4114 1.584e-01
## avginc                        9.586e-04  7.197e-03   0.1332 8.941e-01
## pop                          -4.754e-03  6.703e-03  -0.7093 4.783e-01
## pb1064                        2.919e-02  2.104e-02   1.3874 1.656e-01
## pw1064                        9.250e-03  8.518e-03   1.0859 2.777e-01
## pm1029                        7.333e-02  1.878e-02   3.9052 9.992e-05
## factor(state)Alaska          -1.474e-01  6.964e-02  -2.1166 3.452e-02
## factor(state)Arizona          1.394e-01  7.168e-02   1.9441 5.214e-02
## factor(state)Arkansas        -1.565e-01  5.377e-02  -2.9105 3.682e-03
## factor(state)California       5.385e-01  1.820e-01   2.9595 3.148e-03
## factor(state)Colorado        -1.261e-01  1.008e-01  -1.2508 2.113e-01
## factor(state)Connecticut     -1.074e-01  1.213e-01  -0.8853 3.762e-01
## factor(state)Delaware         3.334e-02  7.009e-02   0.4758 6.343e-01
```

```
## factor(state)District of Columbia  1.988e+00  6.311e-01   3.1506 1.674e-03
## factor(state)Florida               8.598e-01  9.898e-02   8.6867 1.341e-17
## factor(state)Georgia               3.073e-02  4.099e-02   0.7498 4.535e-01
## factor(state)Hawaii               -1.010e+00  2.207e-01  -4.5769 5.259e-06
## factor(state)Idaho                -6.831e-01  1.078e-01  -6.3389 3.380e-10
## factor(state)Illinois              4.953e-01  9.159e-02   5.4078 7.834e-08
## factor(state)Indiana              -2.361e-01  9.855e-02  -2.3957 1.676e-02
## factor(state)Iowa                 -7.003e-01  1.122e-01  -6.2410 6.210e-10
## factor(state)Kansas               -2.824e-01  8.373e-02  -3.3733 7.689e-04
## factor(state)Kentucky             -4.660e-01  9.120e-02  -5.1094 3.812e-07
## factor(state)Louisiana             2.727e-01  4.284e-02   6.3651 2.867e-10
## factor(state)Maine                -1.142e+00  1.322e-01  -8.6334 2.077e-17
## factor(state)Maryland              4.707e-01  6.454e-02   7.2929 5.816e-13
## factor(state)Massachusetts         2.664e-01  1.291e-01   2.0642 3.923e-02
## factor(state)Michigan              2.886e-01  8.751e-02   3.2979 1.005e-03
## factor(state)Minnesota            -6.150e-01  1.106e-01  -5.5605 3.381e-08
## factor(state)Mississippi          -5.105e-01  6.878e-02  -7.4220 2.316e-13
## factor(state)Missouri              1.584e-01  7.516e-02   2.1071 3.534e-02
## factor(state)Montana              -1.027e+00  1.052e-01  -9.7619 1.221e-21
## factor(state)Nebraska             -5.439e-01  1.021e-01  -5.3275 1.209e-07
## factor(state)Nevada                3.236e-01  8.258e-02   3.9191 9.442e-05
## factor(state)New Hampshire        -1.309e+00  1.263e-01 -10.3629 4.573e-24
## factor(state)New Jersey            2.104e-01  1.206e-01   1.7449 8.129e-02
## factor(state)New Mexico            2.877e-01  6.740e-02   4.2680 2.144e-05
## factor(state)New York              6.948e-01  1.437e-01   4.8360 1.515e-06
## factor(state)North Carolina       -7.169e-02  4.582e-02  -1.5647 1.180e-01
## factor(state)North Dakota         -2.073e+00  1.038e-01 -19.9742 6.667e-76
## factor(state)Ohio                 -8.862e-02  1.097e-01  -0.8081 4.192e-01
## factor(state)Oklahoma             -9.372e-02  5.191e-02  -1.8054 7.128e-02
## factor(state)Oregon                3.654e-02  1.024e-01   0.3567 7.214e-01
## factor(state)Pennyslvania         -1.519e-01  1.208e-01  -1.2567 2.091e-01
## factor(state)Rhode Island         -2.263e-01  1.258e-01  -1.7989 7.232e-02
## factor(state)South Carolina        2.759e-01  4.844e-02   5.6961 1.575e-08
## factor(state)South Dakota         -1.192e+00  9.250e-02 -12.8901 1.717e-35
## factor(state)Tennessee             9.298e-02  6.804e-02   1.3666 1.720e-01
## factor(state)Texas                 1.200e-01  1.206e-01   0.9956 3.197e-01
## factor(state)Utah                 -7.211e-01  1.210e-01  -5.9581 3.438e-09
## factor(state)Vermont              -1.326e+00  1.291e-01 -10.2764 1.038e-23
## factor(state)Virginia             -5.622e-01  5.714e-02  -9.8381 6.103e-22
## factor(state)Washington           -1.219e-01  9.470e-02  -1.2876 1.982e-01
## factor(state)West Virginia        -9.411e-01  1.031e-01  -9.1282 3.281e-19
## factor(state)Wisconsin            -8.292e-01  1.025e-01  -8.0904 1.572e-15
## factor(state)Wyoming              -6.536e-01  1.071e-01  -6.1012 1.460e-09
## factor(year)78                     5.853e-02  3.441e-02   1.7007 8.929e-02
## factor(year)79                     1.639e-01  3.259e-02   5.0312 5.695e-07
## factor(year)80                     2.171e-01  3.497e-02   6.2066 7.675e-10
## factor(year)81                     2.173e-01  3.560e-02   6.1028 1.445e-09
## factor(year)82                     1.946e-01  3.350e-02   5.8099 8.192e-09
## factor(year)83                     1.586e-01  3.555e-02   4.4621 8.958e-06
## factor(year)84                     1.930e-01  3.908e-02   4.9380 9.124e-07
## factor(year)85                     2.445e-01  4.293e-02   5.6949 1.586e-08
## factor(year)86                     3.241e-01  4.758e-02   6.8115 1.592e-11
## factor(year)87                     3.244e-01  5.172e-02   6.2720 5.126e-10
## factor(year)88                     3.867e-01  5.670e-02   6.8210 1.495e-11
```

```
## factor(year)89                     4.422e-01  6.139e-02   7.2028 1.097e-12
## factor(year)90                     5.430e-01  7.697e-02   7.0551 3.057e-12
## factor(year)91                     5.959e-01  8.060e-02   7.3939 2.834e-13
## factor(year)92                     6.275e-01  8.513e-02   7.3709 3.339e-13
## factor(year)93                     6.497e-01  8.836e-02   7.3530 3.793e-13
## factor(year)94                     6.354e-01  9.264e-02   6.8590 1.159e-11
## factor(year)95                     6.277e-01  9.658e-02   6.4994 1.224e-10
## factor(year)96                     5.713e-01  1.011e-01   5.6524 2.019e-08
## factor(year)97                     5.501e-01  1.050e-01   5.2374 1.953e-07
## factor(year)98                     4.933e-01  1.105e-01   4.4649 8.841e-06
## factor(year)99                     4.329e-01  1.160e-01   3.7309 2.006e-04
##                                     CI Lower   CI Upper   DF
## (Intercept)                        3.091e+00  4.8530018 1092
## shall                             -6.601e-02  0.0100196 1092
## incarc_rate                       -8.671e-05  0.0002387 1092
## density                           -2.188e-01  0.0357256 1092
## avginc                            -1.316e-02  0.0150800 1092
## pop                               -1.791e-02  0.0083976 1092
## pb1064                            -1.209e-02  0.0704637 1092
## pw1064                            -7.464e-03  0.0259639 1092
## pm1029                             3.648e-02  0.1101670 1092
## factor(state)Alaska               -2.840e-01 -0.0107541 1092
## factor(state)Arizona              -1.292e-03  0.2800054 1092
## factor(state)Arkansas             -2.620e-01 -0.0509951 1092
## factor(state)California            1.815e-01  0.8955929 1092
## factor(state)Colorado             -3.238e-01  0.0716814 1092
## factor(state)Connecticut          -3.453e-01  0.1306034 1092
## factor(state)Delaware             -1.042e-01  0.1708617 1092
## factor(state)District of Columbia  7.500e-01  3.2266616 1092
## factor(state)Florida               6.656e-01  1.0540259 1092
## factor(state)Georgia              -4.969e-02  0.1111637 1092
## factor(state)Hawaii               -1.443e+00 -0.5770525 1092
## factor(state)Idaho                -8.945e-01 -0.4716518 1092
## factor(state)Illinois              3.156e-01  0.6749862 1092
## factor(state)Indiana              -4.295e-01 -0.0427243 1092
## factor(state)Iowa                 -9.205e-01 -0.4801470 1092
## factor(state)Kansas               -4.467e-01 -0.1181500 1092
## factor(state)Kentucky             -6.449e-01 -0.2870351 1092
## factor(state)Louisiana             1.886e-01  0.3567818 1092
## factor(state)Maine                -1.401e+00 -0.8822160 1092
## factor(state)Maryland              3.440e-01  0.5973223 1092
## factor(state)Massachusetts         1.318e-02  0.5196924 1092
## factor(state)Michigan              1.169e-01  0.4603109 1092
## factor(state)Minnesota            -8.320e-01 -0.3979957 1092
## factor(state)Mississippi          -6.455e-01 -0.3755413 1092
## factor(state)Missouri              1.089e-02  0.3058613 1092
## factor(state)Montana              -1.233e+00 -0.8202736 1092
## factor(state)Nebraska             -7.442e-01 -0.3435620 1092
## factor(state)Nevada                1.616e-01  0.4856771 1092
## factor(state)New Hampshire        -1.557e+00 -1.0609113 1092
## factor(state)New Jersey           -2.620e-02  0.4470395 1092
## factor(state)New Mexico            1.554e-01  0.4199063 1092
## factor(state)New York              4.129e-01  0.9767127 1092
## factor(state)North Carolina       -1.616e-01  0.0182109 1092
```

```
## factor(state)North Dakota          -2.276e+00 -1.8690888 1092
## factor(state)Ohio                  -3.038e-01  0.1265583 1092
## factor(state)Oklahoma              -1.956e-01  0.0081342 1092
## factor(state)Oregon                -1.644e-01  0.2374939 1092
## factor(state)Pennyslvania          -3.889e-01  0.0852368 1092
## factor(state)Rhode Island          -4.731e-01  0.0205370 1092
## factor(state)South Carolina         1.809e-01  0.3709622 1092
## factor(state)South Dakota          -1.374e+00 -1.0108516 1092
## factor(state)Tennessee             -4.052e-02  0.2264865 1092
## factor(state)Texas                 -1.165e-01  0.3565820 1092
## factor(state)Utah                  -9.586e-01 -0.4836416 1092
## factor(state)Vermont               -1.579e+00 -1.0729863 1092
## factor(state)Virginia              -6.743e-01 -0.4500362 1092
## factor(state)Washington            -3.078e-01  0.0638812 1092
## factor(state)West Virginia         -1.143e+00 -0.7387812 1092
## factor(state)Wisconsin             -1.030e+00 -0.6280844 1092
## factor(state)Wyoming               -8.638e-01 -0.4434093 1092
## factor(year)78                     -8.998e-03  0.1260507 1092
## factor(year)79                      1.000e-01  0.2278873 1092
## factor(year)80                      1.485e-01  0.2857014 1092
## factor(year)81                      1.474e-01  0.2871053 1092
## factor(year)82                      1.289e-01  0.2603645 1092
## factor(year)83                      8.888e-02  0.2284073 1092
## factor(year)84                      1.163e-01  0.2696730 1092
## factor(year)85                      1.602e-01  0.3287086 1092
## factor(year)86                      2.307e-01  0.4174481 1092
## factor(year)87                      2.229e-01  0.4258390 1092
## factor(year)88                      2.755e-01  0.4979918 1092
## factor(year)89                      3.217e-01  0.5626788 1092
## factor(year)90                      3.920e-01  0.6940776 1092
## factor(year)91                      4.378e-01  0.7540942 1092
## factor(year)92                      4.605e-01  0.7945618 1092
## factor(year)93                      4.764e-01  0.8231231 1092
## factor(year)94                      4.536e-01  0.8171923 1092
## factor(year)95                      4.382e-01  0.8171777 1092
## factor(year)96                      3.730e-01  0.7696754 1092
## factor(year)97                      3.440e-01  0.7562098 1092
## factor(year)98                      2.765e-01  0.7100695 1092
## factor(year)99                      2.052e-01  0.6605369 1092
##
## Multiple R-squared:  0.9562 ,    Adjusted R-squared:  0.953
## F-statistic: 479.8 on 80 and 1092 DF,  p-value: < 2.2e-16
```

Now we want to test the state FEs separately from the

```r
## F-statistic:
coef.names <- mod.2i.4$coefficients %>% names
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2i.4, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
```

```
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
## factor(state)Florida = 0
## factor(state)Georgia = 0
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lvio ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
```

```
##   Res.Df Df      F    Pr(>F)
## 1   1142
## 2   1092 50 309.29 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
linearHypothesis(mod.2i.4, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lvio ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df    F    Pr(>F)
## 1   1114
## 2   1092 22 13.9 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Regression 5: yes controls, state and year fixed effects, yes clustering

lm_robust includes a “clusters” argument. Always choose the individual dimension for clustering. And once again, do not forget the “se_type = ‘stata’ ” argument:

```r
# 5
mod.2i.5 <- lm_robust(lvio ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), clusters = state, se_type = "stata", data = guns)
summary(mod.2i.5)
```

```
##
```

```
## Call:
## lm_robust(formula = lvio ~ shall + incarc_rate + density + avginc +
##     pop + pb1064 + pw1064 + pm1029 + factor(state) + factor(year),
##     data = guns, clusters = state, se_type = "stata")
##
## Standard error type:  stata
##
## Coefficients:
##                                  Estimate Std. Error  t value  Pr(>|t|)
## (Intercept)                     3.972e+00  1.1097648  3.57913 7.778e-04
## shall                          -2.799e-02  0.0416385 -0.67230 5.045e-01
## incarc_rate                     7.599e-05  0.0002126  0.35746 7.222e-01
## density                        -9.155e-02  0.1266662 -0.72280 4.732e-01
## avginc                          9.586e-04  0.0168665  0.05684 9.549e-01
## pop                            -4.754e-03  0.0155742 -0.30528 7.614e-01
## pb1064                          2.919e-02  0.0506622  0.57609 5.671e-01
## pw1064                          9.250e-03  0.0242941  0.38076 7.050e-01
## pm1029                          7.333e-02  0.0536612  1.36645 1.779e-01
## factor(state)Alaska            -1.474e-01  0.1280179 -1.15139 2.550e-01
## factor(state)Arizona            1.394e-01  0.1626619  0.85673 3.957e-01
## factor(state)Arkansas          -1.565e-01  0.0916509 -1.70763 9.391e-02
## factor(state)California        5.385e-01  0.4638773  1.16095 2.512e-01
## factor(state)Colorado          -1.261e-01  0.2620806 -0.48097 6.326e-01
## factor(state)Connecticut       -1.074e-01  0.2988469 -0.35927 7.209e-01
## factor(state)Delaware           3.334e-02  0.1198122  0.27830 7.819e-01
## factor(state)District of Columbia  1.988e+00  1.2841751  1.54834 1.278e-01
## factor(state)Florida            8.598e-01  0.2471365  3.47910 1.052e-03
## factor(state)Georgia            3.073e-02  0.0549982  0.55883 5.788e-01
## factor(state)Hawaii            -1.010e+00  0.5318146 -1.89929 6.330e-02
## factor(state)Idaho             -6.831e-01  0.2410346 -2.83403 6.613e-03
## factor(state)Illinois           4.953e-01  0.2358775  2.09974 4.082e-02
## factor(state)Indiana           -2.361e-01  0.2436553 -0.96895 3.372e-01
## factor(state)Iowa              -7.003e-01  0.2618793 -2.67423 1.009e-02
## factor(state)Kansas            -2.824e-01  0.1962850 -1.43890 1.564e-01
## factor(state)Kentucky          -4.660e-01  0.2167101 -2.15027 3.639e-02
## factor(state)Louisiana          2.727e-01  0.0840986  3.24279 2.111e-03
## factor(state)Maine             -1.142e+00  0.2883486 -3.95941 2.381e-04
## factor(state)Maryland           4.707e-01  0.1408361  3.34208 1.580e-03
## factor(state)Massachusetts      2.664e-01  0.3224811  0.82620 4.126e-01
## factor(state)Michigan           2.886e-01  0.2151058  1.34168 1.858e-01
## factor(state)Minnesota         -6.150e-01  0.2797847 -2.19818 3.259e-02
## factor(state)Mississippi       -5.105e-01  0.1683598 -3.03221 3.841e-03
## factor(state)Missouri           1.584e-01  0.1845778  0.85805 3.950e-01
## factor(state)Montana           -1.027e+00  0.2074646 -4.94843 8.880e-06
## factor(state)Nebraska          -5.439e-01  0.2245000 -2.42260 1.908e-02
## factor(state)Nevada             3.236e-01  0.1887725  1.71445 9.264e-02
## factor(state)New Hampshire     -1.309e+00  0.3161359 -4.13970 1.334e-04
## factor(state)New Jersey         2.104e-01  0.2901715  0.72515 4.717e-01
## factor(state)New Mexico         2.877e-01  0.1363345  2.10995 3.989e-02
## factor(state)New York           6.948e-01  0.3355115  2.07088 4.355e-02
## factor(state)North Carolina    -7.169e-02  0.0749761 -0.95613 3.436e-01
## factor(state)North Dakota      -2.073e+00  0.2262214 -9.16225 2.804e-12
## factor(state)Ohio              -8.862e-02  0.2822928 -0.31393 7.549e-01
## factor(state)Oklahoma          -9.372e-02  0.1048261 -0.89406 3.756e-01
```

```
## factor(state)Oregon                3.654e-02  0.2537003  0.14401 8.861e-01
## factor(state)Pennyslvania         -1.519e-01  0.3235810 -0.46929 6.409e-01
## factor(state)Rhode Island         -2.263e-01  0.2767852 -0.81749 4.175e-01
## factor(state)South Carolina        2.759e-01  0.0743856  3.70928 5.219e-04
## factor(state)South Dakota         -1.192e+00  0.1791106 -6.65707 2.065e-08
## factor(state)Tennessee             9.298e-02  0.1433209  0.64878 5.195e-01
## factor(state)Texas                 1.200e-01  0.2922980  0.41064 6.831e-01
## factor(state)Utah                 -7.211e-01  0.2614627 -2.75803 8.100e-03
## factor(state)Vermont              -1.326e+00  0.2916528 -4.54721 3.476e-05
## factor(state)Virginia             -5.622e-01  0.1355022 -4.14867 1.296e-04
## factor(state)Washington           -1.219e-01  0.2486475 -0.49040 6.260e-01
## factor(state)West Virginia        -9.411e-01  0.2600945 -3.61818 6.906e-04
## factor(state)Wisconsin            -8.292e-01  0.2514955 -3.29701 1.803e-03
## factor(state)Wyoming              -6.536e-01  0.2461306 -2.65554 1.059e-02
## factor(year)78                     5.853e-02  0.0165213  3.54247 8.693e-04
## factor(year)79                     1.639e-01  0.0250116  6.55490 2.983e-08
## factor(year)80                     2.171e-01  0.0341749  6.35191 6.194e-08
## factor(year)81                     2.173e-01  0.0400829  5.42014 1.716e-06
## factor(year)82                     1.946e-01  0.0476286  4.08647 1.585e-04
## factor(year)83                     1.586e-01  0.0607288  2.61235 1.184e-02
## factor(year)84                     1.930e-01  0.0787452  2.45079 1.779e-02
## factor(year)85                     2.445e-01  0.0943093  2.59228 1.247e-02
## factor(year)86                     3.241e-01  0.1113838  2.90967 5.388e-03
## factor(year)87                     3.244e-01  0.1278176  2.53772 1.432e-02
## factor(year)88                     3.867e-01  0.1428701  2.70694 9.267e-03
## factor(year)89                     4.422e-01  0.1570114  2.81645 6.933e-03
## factor(year)90                     5.430e-01  0.2005249  2.70813 9.238e-03
## factor(year)91                     5.959e-01  0.2086882  2.85568 6.238e-03
## factor(year)92                     6.275e-01  0.2219437  2.82737 6.733e-03
## factor(year)93                     6.497e-01  0.2297025  2.82862 6.710e-03
## factor(year)94                     6.354e-01  0.2385238  2.66396 1.037e-02
## factor(year)95                     6.277e-01  0.2478471  2.53254 1.451e-02
## factor(year)96                     5.713e-01  0.2591432  2.20474 3.210e-02
## factor(year)97                     5.501e-01  0.2672680  2.05829 4.479e-02
## factor(year)98                     4.933e-01  0.2808721  1.75628 8.516e-02
## factor(year)99                     4.329e-01  0.2926991  1.47892 1.454e-01
##                                    CI Lower  CI Upper DF
## (Intercept)                        1.742969  6.201025 50
## shall                             -0.111627  0.055640 50
## incarc_rate                       -0.000351  0.000503 50
## density                           -0.345971  0.162862 50
## avginc                            -0.032919  0.034836 50
## pop                               -0.036036  0.026527 50
## pb1064                            -0.072572  0.130944 50
## pw1064                            -0.039546  0.058046 50
## pm1029                            -0.034456  0.181107 50
## factor(state)Alaska               -0.404530  0.109733 50
## factor(state)Arizona              -0.187359  0.466073 50
## factor(state)Arkansas             -0.340592  0.027580 50
## factor(state)California           -0.393187  1.470263 50
## factor(state)Colorado             -0.652458  0.400351 50
## factor(state)Connecticut          -0.707617  0.492886 50
## factor(state)Delaware             -0.207306  0.273994 50
## factor(state)District of Columbia -0.590998  4.567685 50
```

```
## factor(state)Florida              0.363425  1.356201 50
## factor(state)Georgia             -0.079732  0.141202 50
## factor(state)Hawaii              -2.078254  0.058108 50
## factor(state)Idaho               -1.167231 -0.198967 50
## factor(state)Illinois             0.021508  0.969056 50
## factor(state)Indiana             -0.725485  0.253307 50
## factor(state)Iowa                -1.226325 -0.174325 50
## factor(state)Kansas              -0.676685  0.111815 50
## factor(state)Kentucky            -0.901260 -0.030710 50
## factor(state)Louisiana            0.103797  0.441631 50
## factor(state)Maine               -1.720856 -0.562525 50
## factor(state)Maryland             0.187808  0.753563 50
## factor(state)Massachusetts       -0.381287  0.914157 50
## factor(state)Michigan            -0.143449  0.720656 50
## factor(state)Minnesota           -1.176981 -0.053053 50
## factor(state)Mississippi         -0.848663 -0.172342 50
## factor(state)Missouri            -0.212358  0.529113 50
## factor(state)Montana             -1.443329 -0.609919 50
## factor(state)Nebraska            -0.994794 -0.092951 50
## factor(state)Nevada              -0.055520  0.702802 50
## factor(state)New Hampshire       -1.943684 -0.673729 50
## factor(state)New Jersey          -0.372408  0.793245 50
## factor(state)New Mexico           0.013824  0.561495 50
## factor(state)New York             0.020911  1.368700 50
## factor(state)North Carolina      -0.222281  0.078907 50
## factor(state)North Dakota        -2.527077 -1.618319 50
## factor(state)Ohio                -0.655622  0.478381 50
## factor(state)Oklahoma            -0.304270  0.116829 50
## factor(state)Oregon              -0.473036  0.546108 50
## factor(state)Pennyslvania        -0.801783  0.498080 50
## factor(state)Rhode Island        -0.782208  0.329671 50
## factor(state)South Carolina       0.126509  0.425325 50
## factor(state)South Dakota        -1.552107 -0.832598 50
## factor(state)Tennessee           -0.194885  0.380852 50
## factor(state)Texas               -0.467069  0.707126 50
## factor(state)Utah                -1.246286 -0.195959 50
## factor(state)Vermont             -1.912009 -0.740405 50
## factor(state)Virginia            -0.834318 -0.289990 50
## factor(state)Washington          -0.621359  0.377487 50
## factor(state)West Virginia       -1.463483 -0.418653 50
## factor(state)Wisconsin           -1.334327 -0.324039 50
## factor(state)Wyoming             -1.147978 -0.159242 50
## factor(year)78                    0.025342  0.091710 50
## factor(year)79                    0.113711  0.214186 50
## factor(year)80                    0.148434  0.285718 50
## factor(year)81                    0.136746  0.297764 50
## factor(year)82                    0.098968  0.290298 50
## factor(year)83                    0.036667  0.280622 50
## factor(year)84                    0.034824  0.351153 50
## factor(year)85                    0.055051  0.433902 50
## factor(year)86                    0.100369  0.547811 50
## factor(year)87                    0.067636  0.581094 50
## factor(year)88                    0.099778  0.673704 50
## factor(year)89                    0.126847  0.757581 50
```

```
## factor(year)90                        0.140282  0.945814 50
## factor(year)91                        0.176783  1.015108 50
## factor(year)92                        0.181730  1.073304 50
## factor(year)93                        0.188370  1.111113 50
## factor(year)94                        0.156330  1.114508 50
## factor(year)95                        0.129867  1.125499 50
## factor(year)96                        0.050838  1.091847 50
## factor(year)97                        0.013292  1.086939 50
## factor(year)98                       -0.070858  1.057439 50
## factor(year)99                       -0.155026  1.020781 50
##
## Multiple R-squared:  0.9562 ,    Adjusted R-squared:  0.953
## F-statistic:    NA on 80 and 50 DF,  p-value: NA
```

This time, we only want to test the year fixed effects:

```r
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2i.5, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lvio ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1114
## 2   1092 22 20.675 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

2ii: Dependent variable ln(rob)

I'll suppress the regression output so that we don't just produce a massive document full of fixed effects estimates, but the results do indeed match up exactly with the Stata solutions:

```
# 1
mod.2ii.1 <- lm_robust(lrob ~ shall, data = guns, se_type = "stata")
# summary(mod.2ii.1)

# 2
mod.2ii.2 <- lm_robust(lrob ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029, data = guns, se_type = "stata")
# summary(mod.2ii.2)

# 3
mod.2ii.3 <- lm_robust(lrob ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state),
    se_type = "stata", data = guns)
# summary(mod.2ii.3) F-statistic:
coef.names <- names(mod.2ii.3$coefficients)
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
linearHypothesis(mod.2ii.3, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
## factor(state)Florida = 0
## factor(state)Georgia = 0
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
```

```
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lrob ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state)
##
##   Res.Df Df      F    Pr(>F)
## 1   1164
## 2   1114 50 190.47 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# 4
mod.2ii.4 <- lm_robust(lrob ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), se_type = "stata", data = guns)
# summary(mod.2ii.4) F-statistic:
coef.names <- mod.2ii.4$coefficients %>% names
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2ii.4, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
## factor(state)Florida = 0
## factor(state)Georgia = 0
```

```
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lrob ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1142
## 2   1092 50 243.39 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
linearHypothesis(mod.2ii.4, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
```

```
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lrob ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1114
## 2   1092 22 12.392 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# 5
mod.2ii.5 <- lm_robust(lrob ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), clusters = state, se_type = "stata", data = guns)
# summary(mod.2ii.5)
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2ii.5, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
```

```
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lrob ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df     F    Pr(>F)
## 1   1114
## 2   1092 22 24.73 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

2iii: Dependent variable ln(mur)

```r
# 1
mod.2iii.1 <- lm_robust(lmur ~ shall, data = guns, se_type = "stata")
# summary(mod.2iii.1)

# 2
mod.2iii.2 <- lm_robust(lmur ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029, data = guns, se_type = "stata")
# summary(mod.2iii.2)

# 3
mod.2iii.3 <- lm_robust(lmur ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state),
    se_type = "stata", data = guns)
# summary(mod.2iii.3) F-statistic:
coef.names <- names(mod.2iii.3$coefficients)
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
linearHypothesis(mod.2iii.3, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
```

```
## factor(state)Florida = 0
## factor(state)Georgia = 0
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lmur ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state)
##
##   Res.Df Df      F    Pr(>F)
## 1   1164
## 2   1114 50 88.219 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# 4
mod.2iii.4 <- lm_robust(lmur ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), se_type = "stata", data = guns)
# summary(mod.2iii.4) F-statistic:
coef.names <- mod.2iii.4$coefficients %>% names
state.coefficients <- coef.names[startsWith(coef.names, "factor(state)")]
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2iii.4, state.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(state)Alaska = 0
## factor(state)Arizona = 0
## factor(state)Arkansas = 0
## factor(state)California = 0
## factor(state)Colorado = 0
## factor(state)Connecticut = 0
## factor(state)Delaware = 0
## factor(state)District of Columbia = 0
## factor(state)Florida = 0
## factor(state)Georgia = 0
## factor(state)Hawaii = 0
## factor(state)Idaho = 0
## factor(state)Illinois = 0
## factor(state)Indiana = 0
## factor(state)Iowa = 0
## factor(state)Kansas = 0
## factor(state)Kentucky = 0
## factor(state)Louisiana = 0
## factor(state)Maine = 0
## factor(state)Maryland = 0
## factor(state)Massachusetts = 0
## factor(state)Michigan = 0
## factor(state)Minnesota = 0
## factor(state)Mississippi = 0
## factor(state)Missouri = 0
## factor(state)Montana = 0
## factor(state)Nebraska = 0
## factor(state)Nevada = 0
## factor(state)New Hampshire = 0
## factor(state)New Jersey = 0
## factor(state)New Mexico = 0
## factor(state)New York = 0
## factor(state)North Carolina = 0
## factor(state)North Dakota = 0
## factor(state)Ohio = 0
## factor(state)Oklahoma = 0
## factor(state)Oregon = 0
## factor(state)Pennyslvania = 0
## factor(state)Rhode Island = 0
## factor(state)South Carolina = 0
## factor(state)South Dakota = 0
```

```
## factor(state)Tennessee = 0
## factor(state)Texas = 0
## factor(state)Utah = 0
## factor(state)Vermont = 0
## factor(state)Virginia = 0
## factor(state)Washington = 0
## factor(state)West Virginia = 0
## factor(state)Wisconsin = 0
## factor(state)Wyoming = 0
##
## Model 1: restricted model
## Model 2: lmur ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1142
## 2   1092 50 106.69 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
linearHypothesis(mod.2iii.4, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lmur ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1114
## 2   1092 22 9.7281 < 2.2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# 5
mod.2iii.5 <- lm_robust(lmur ~ shall + incarc_rate + density +
    avginc + pop + pb1064 + pw1064 + pm1029 + factor(state) +
    factor(year), clusters = state, se_type = "stata", data = guns)
# summary(mod.2iii.5)
year.coefficients <- coef.names[startsWith(coef.names, "factor(year)")]
linearHypothesis(mod.2iii.5, year.coefficients, test = "F")
```

```
## Linear hypothesis test
##
## Hypothesis:
## factor(year)78 = 0
## factor(year)79 = 0
## factor(year)80 = 0
## factor(year)81 = 0
## factor(year)82 = 0
## factor(year)83 = 0
## factor(year)84 = 0
## factor(year)85 = 0
## factor(year)86 = 0
## factor(year)87 = 0
## factor(year)88 = 0
## factor(year)89 = 0
## factor(year)90 = 0
## factor(year)91 = 0
## factor(year)92 = 0
## factor(year)93 = 0
## factor(year)94 = 0
## factor(year)95 = 0
## factor(year)96 = 0
## factor(year)97 = 0
## factor(year)98 = 0
## factor(year)99 = 0
##
## Model 1: restricted model
## Model 2: lmur ~ shall + incarc_rate + density + avginc + pop + pb1064 +
##     pw1064 + pm1029 + factor(state) + factor(year)
##
##   Res.Df Df      F    Pr(>F)
## 1   1114
## 2   1092 22 18.751 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Question 3

3a: What measures of firm performance would you include in an equation? What are some of the timing issues?

Potential measures of firm performance include: stock prices, percentage change in stock prices (i.e., returns), firm's value (i.e., market capitalization), ROA, ROE, Net Income, and so on. Some of the timing issues can be that the previous day market performance and firm's performance can influence the performance of the firm today. So, we may need to include lagged values of these performance measures.

3b: What other factors might you control for in the equation?

Firm's performance could be influenced by other factors in addition to overall market performance. Some of these factors that you need to control for can include i) firm specific factors such as size of the firm, management quality, leverage, corporate social responsibility, etc. and ii) other macroeconomic factors like inflation, GDP, interest rates, and so on.

3c: Write an equation that allows you to estimate the effects of the overall stock market performance on the percentage change in firm's stock price. How would you estimate this equation? Why would you choose this method?

An unobserved effects model is:

$$\log\left(\frac{P_{i,t}}{P_{i,t-1}}\right) = \beta_0 + \alpha_i + \lambda_t + \beta_1 \log\left(\frac{SP_{i,t}}{SP_{i,t-1}}\right) + \beta_2 \log(SIZE_{i,t}) + ... + u_{i,t}$$

The outcome variable is the percentage change in stock prices or rate of return for firm i at time t and the ratio in the RHS is for the broad market. β_1 is the percentage change in firm performance given a one percentage-point increase in the market index. It is likely that α_i and λ_t are correlated with firm size, and other control factors. So fixed effects (i.e., time and firm) estimation is appropriate.

3d: Implement your strategy discussed above using data from Yahoo Finance for any ten US companies of your choice as well as the stock price for the S&P500

I don't think it's worth our time to go through this exercise since I'm doing multiple problem sets. Just a reminder here that the answer entails creating lagged and differenced variables, which we learned how to do in the context of time series (see: R guide to PS8 practice questions and R solutions to PS8 when I post them on Friday).