Introduction to Panel Data Models

Preparing your workfile

We add the basic libraries needed for this week's work:

```
library(tidyverse)    # for almost all data handling tasks
library(ggplot2)      # to produce nice graphiscs
library(stargazer)    # to produce nice results tables
library(haven)        # to import stata file
library(AER)          # access to HS robust standard errors
source("stargazer_HC.r")  # includes the robust regression display
```

As we are using panel methods we also require an additional package `plm`.

```
# install.packages("plm") # only exwcute this if plm is not installed yet
library(plm)
```

Introduction

The data are an extract from the Understanding Society Survey (formerly the British Household Survey Panel).

Data Upload - and understanding data structure

Upload the data, which are saved in a STATA datafile (extension `.dta`). There is a function which loads STATA file. It is called `read_dta` and is supplied by the `haven` package.

```
data_USoc <- read_dta("20222_USoc_extract.dta")
data_USoc <- as.data.frame(data_USoc)    # ensure data frame structure
names(data_USoc)
```

```
##  [1] "pidp"    "age"     "jbhrs"   "paygu"   "wave"    "cpi"     "year"
##  [8] "region"  "urate"   "male"    "race"    "educ"    "degree"  "mfsize9"
```

Let us ensure that categorical variables are stored as `factor` variables. It is easiest to work with these in R.

```
data_USoc$region <- as_factor(data_USoc$region)
data_USoc$male <- as_factor(data_USoc$male)
data_USoc$degree <- as_factor(data_USoc$degree)
data_USoc$race <- as_factor(data_USoc$race)
```

The pay information (`paygu`) is provided as a measure of the (usual) gross pay per month. As workers work for varying numbers of hours per week (`jbhrs`) we divide the monthly pay by the approximate monthly hours (`4*jbhrs`). We shall also adjust for increasing price levels (as measured by `cpi`). These two adjustments leave us with an inflation adjusted hourly wage. We call this variable `hrpay` and also calculate the natural log of this variable (`lnhrpay`).

```
data_USoc <- data_USoc %>%
              mutate(hrpay = paygu/(jbhrs*4)/(cpi/100)) %>%
              mutate(lnhrpay = log(hrpay))
```

As we wanted to save these additional variables we assign the result of the operation to `data_USoc`.

We will also use the logarithm of the unemployment rate

```
data_USoc <- data_USoc %>%
              mutate(lnurate=log(urate))
```

Understanding the Panel Structure

To explain the meaning of these let us just pick out all the observations that pertain to one particular individual (`pidp == 272395767`). The following command does the following in words: "Take `data_USoc` filter/keep all observations which belong to individual pidp == 272395767, then select a list of variables (we don't need to see all 14 variables) and print the result":

```
data_USoc %>% filter(pidp == 272395767) %>%
              select(c("pidp","male","wave","year","paygu","age","educ")) %>%
              print()
```

```
##        pidp   male wave year    paygu age educ
## 1 272395767 female    1 2009 774.8302  40   11
## 2 272395767 female    2 2010 812.2778  41   11
## 3 272395767 female    3 2011 772.1625  42   11
```

The same person (female) was observed three years in a row (from 2009 to 2011). Their gross monthly income changed, as did, of course, their age, but not their education. This particular person was observed in three consequitive waves. Let's se whether this is a commom pattern.

In the context of this exercise we will ignore the second wave and only look at waves 1 and 3.

```
data_USoc <- data_USoc %>%
  filter(wave != 2) %>%
  filter(!is.na(lnhrpay))
```

[MARTYN, I end up with slightly more obs. Fromn your code I cannot see how you cleaned the data before. For instance for the POLS I get 131 more obs than you.]

The code below figures how many waves we have for each individual (1 or 2) and then saves this in a new variable ('n_wave). This information will be used later as we may want to know whether only using observations for which we have both waves makes a difference to the analysis.

```
data_USoc <- data_USoc %>%
                group_by(pidp) %>%
                mutate(n_wave = n())
```

Now we need to let R know that we are dealing with panel data. This is why we loaded up the `plm` library which contains the `plm.data` function. Using the `index = c("pidp","wave")` we let the function know what identifies the individuals and what identifies the wave.

```
#pdata_USoc <- plm.data(data_USoc, index = c("pidp","wave")) # defines the panel dimensions
pdata_USoc <- pdata.frame(data_USoc, index = c("pidp","wave")) # defines the panel dimensions
```

We saved the output in `pdata_USoc` and we will use this for any panel data estimations.

Some data descriptions

We will use the `lnhrpay` and the `urate` variables below. We therefore will have a look at these variables.

```r
stargazer(pdata_USoc[,c("lnhrpay","urate","year")],type = "text")
```

```
##
## =================================================================
## Statistic   N      Mean    St. Dev.  Min   Pctl(25) Pctl(75)  Max
## -----------------------------------------------------------------
## lnhrpay   39,934   2.284    0.635   -7.816  1.888    2.678   8.868
## urate     39,934   7.877    1.303   5.800   6.400    9.000   10.800
## year      39,934 2,010.393  1.146   2,009   2,009    2,011   2,013
## -----------------------------------------------------------------
```

Let us look at some summary statistics grouped by region

```r
pdata_USoc %>% group_by(region) %>%
              summarise(n = n(), mean_lnhrpay = mean(lnhrpay),mean_urate = mean(urate))
```

```
## # A tibble: 12 x 4
##    region                       n mean_lnhrpay mean_urate
##    <fct>                    <int>        <dbl>      <dbl>
##  1 north east                1576         2.21       9.88
##  2 north west                4280         2.24       8.44
##  3 yorkshire and the humber  3247         2.20       9.00
##  4 east midlands             3107         2.20       9.15
##  5 west midlands             3454         2.23       7.67
##  6 east of england           3724         2.32       6.58
##  7 london                    5736         2.42       9.30
##  8 south east                5125         2.39       6.10
##  9 south west                3119         2.25       6.11
## 10 wales                     1831         2.14       8.45
## 11 scotland                  3020         2.27       7.76
## 12 northern ireland          1715         2.24       6.78
```

Below we will want to use the mean `lnhrpay` and mean `lnurate` as calculated for every region-wave. The following will group the data by region-wave (as we have 12 regions and 2 waves we will 24 such groups). This is similar to the above command but note that we start with `pdata_USoc <-` to ensure that the calculated average wage and unemployment rate values are added as variables to the data frame. Also, instead of `summarise` (which displays the calculated statistics) we use the `mutate` function as we want the calculated series to be saved in the data frame.

```r
pdata_USoc <- pdata_USoc %>%
              group_by(region,wave) %>%
              mutate(mean_lnhrpay = mean(lnhrpay),mean_urate = mean(urate))
```

Estimating Models

We start by estimating a model which does not use the panel nature of the data.

```r
POLS0 <- lm(lnhrpay~lnurate, data = pdata_USoc)
stargazer_HC(POLS0)
```

```
##
## =========================================================
##                               Dependent variable:
##                       -------------------------------------
##                                     lnhrpay
```

```
## ------------------------------------------------------------
## lnurate                                  -0.102***
##                                           (0.019)
##
## Constant                                 2.493***
##                                           (0.038)
##
## ------------------------------------------------------------
## Observations                              39,934
## R2                                         0.001
## Adjusted R2                                0.001
## Residual Std. Error                0.634 (df = 39932)
## F Statistic                 30.049*** (df = 1; 39932)
## ============================================================
## Note:                              *p<0.1; **p<0.05; ***p<0.01
##                         Robust standard errors in parenthesis
```

Let's add the predicted model values to the data frame. As our explanatory variable only has 24 different values we will only get 24 different predicted values.

```
pdata_USoc$pred_POLS0 <- POLS0$fitted.values
```

Here we basically used all observations available, whether they were from wave 1 or 3. We **pooled** the observations and hence we could use our normal `lm` function to estimate this model. The `plm` package we imported earlier has a few panel specific tricks up its sleeve and we could estimate this model with the `plm` function.

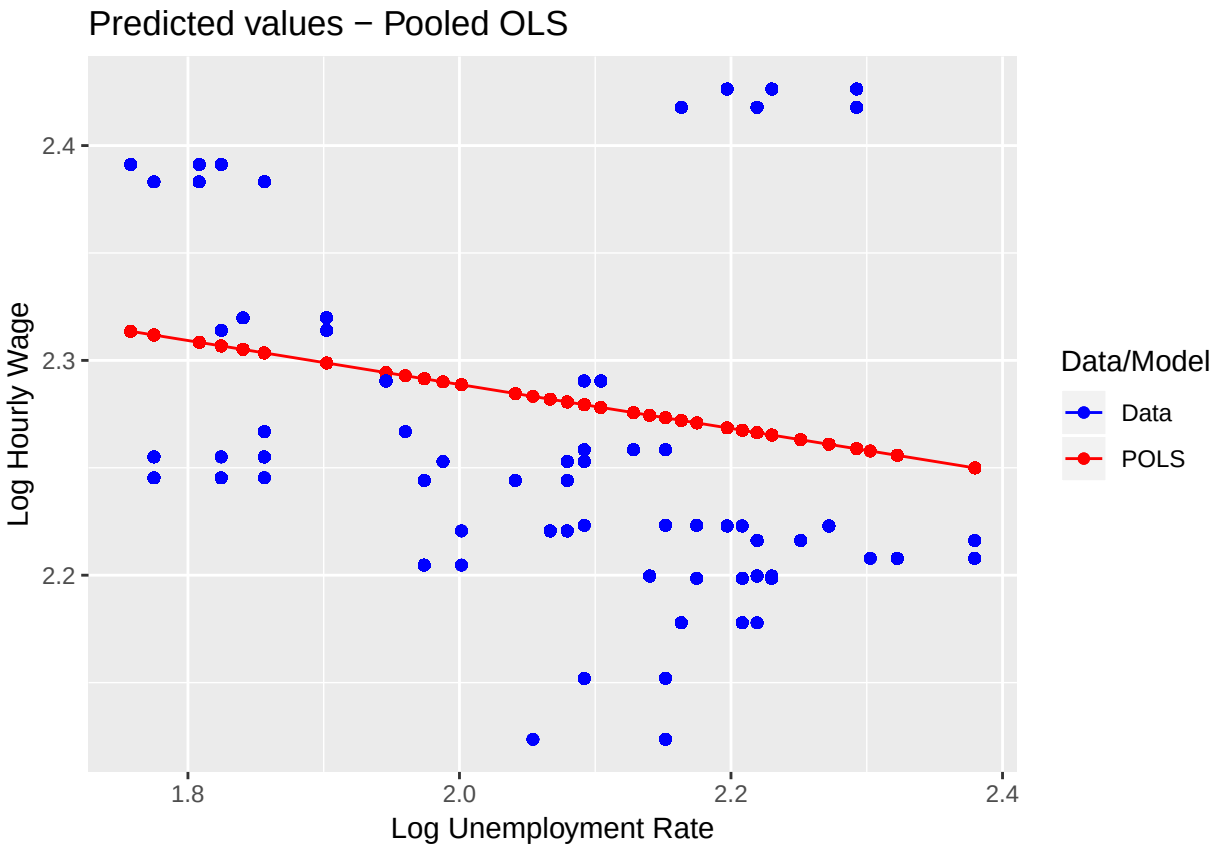
```
POLS0a <- plm(lnhrpay~lnurate, data = pdata_USoc, model = "pooling")
stargazer_HC(POLS0a)
```

```
##
## ================================================
##                         Dependent variable:
##                     ---------------------------
##                                lnhrpay
## ------------------------------------------------
## lnurate                       -0.102***
##                                (0.019)
##
## Constant                      2.493***
##                                (0.038)
##
## ------------------------------------------------
## Observations                   39,934
## R2                              0.001
## Adjusted R2                     0.001
## F Statistic           30.049*** (df = 1; 39932)
## ================================================
## Note:                   *p<0.1; **p<0.05; ***p<0.01
##                 Robust standard errors in parenthesis
```

Now we plot the predicted values and compare them against the

```
# pdf("Lecture6plot_R.pdf",width = 5.5, height = 4) # uncomment to save as pdf
ggplot(pdata_USoc, aes(x=lnurate,y=pred_POLS0)) +
  geom_point(aes(colour = "red")) +
  geom_line(aes(colour = "red")) +
```

```
  geom_point(aes(y = mean_lnhrpay,colour = "blue")) +
  ggtitle("Predicted values - Pooled OLS") +
  ylab("Log Hourly Wage") +
  xlab("Log Unemployment Rate") +
  scale_colour_manual(name="Data/Model", values = c(red = "red", blue = "blue"),labels=c("Data", "POLS")
```




```
# dev.off() # uncomment to save as pdf
```

Now we will include a dummy variable for `wave == 3`. The `wave` variable is a factor variable with two levels (1 and 3) for waves 1 and 3.

```
POLS1 <- lm(lnhrpay~lnurate+wave, data = pdata_USoc)
stargazer_HC(POLS1)
```

```
##
## ===================================================
##                             Dependent variable:
##                         -----------------------
##                                   lnhrpay
## ---------------------------------------------------
## lnurate                          -0.097***
##                                   (0.019)
##
## wave3                            -0.019***
##                                   (0.006)
##
## Constant                         2.491***
```

```
##                                    (0.038)
##
## ------------------------------------------------------------
## Observations                        39,934
## R2                                   0.001
## Adjusted R2                          0.001
## Residual Std. Error          0.634 (df = 39931)
## F Statistic               19.596*** (df = 2; 39931)
## ============================================================
## Note:                          *p<0.1; **p<0.05; ***p<0.01
##                      Robust standard errors in parenthesis
```

The first wave is the base category of `wave` and hence is not included. So far we have used the standard `lm` function to estimate this model.

Alternatively this could be estimated using the `plm` package

```
POLS1a <- plm(lnhrpay~lnurate+wave, data = pdata_USoc, model = "pooling")
stargazer_HC(POLS1a)
```

```
##
## ================================================
##                        Dependent variable:
##              ----------------------------------
##                              lnhrpay
## ------------------------------------------------
## lnurate                     -0.097***
##                              (0.019)
##
## wave3                       -0.019***
##                              (0.006)
##
## Constant                    2.491***
##                              (0.038)
##
## ------------------------------------------------
## Observations                 39,934
## R2                            0.001
## Adjusted R2                   0.001
## F Statistic         19.596*** (df = 2; 39931)
## ================================================
## Note:                  *p<0.1; **p<0.05; ***p<0.01
##              Robust standard errors in parenthesis
```

This regression will have observations for individuals for which we only observe one wave (`n_wave == 1`). Let's restrict the analysis to only individuals for which we have two waves (`n_wave == 2`).

```
POLS2 <- lm(lnhrpay~lnurate+wave, data = pdata_USoc, subset = (n_wave ==2))
stargazer_HC(POLS2)
```

```
##
## ============================================================
##                              Dependent variable:
##                          ---------------------------------
##                                    lnhrpay
## ------------------------------------------------------------
## lnurate                           -0.096***
```

```
##                                    (0.022)
##
## wave3                              -0.005
##                                    (0.008)
##
## Constant                          2.544***
##                                    (0.046)
##
## ------------------------------------------------------------
## Observations                        26,156
## R2                                   0.001
## Adjusted R2                          0.001
## Residual Std. Error          0.611 (df = 26153)
## F Statistic               10.027*** (df = 2; 26153)
## ============================================================
## Note:                          *p<0.1; **p<0.05; ***p<0.01
##                     Robust standard errors in parenthesis
```

or using the `plm` function

```
POLS2a <- plm(lnhrpay~lnurate+wave, data = pdata_USoc, subset = (n_wave ==2), model = "pooling")
stargazer_HC(POLS2a)
```

```
##
## ================================================
##                         Dependent variable:
##              ----------------------------------
##                              lnhrpay
## ------------------------------------------------
## lnurate                     -0.096***
##                              (0.022)
##
## wave3                        -0.005
##                              (0.008)
##
## Constant                    2.544***
##                              (0.046)
##
## ------------------------------------------------
## Observations                 26,156
## R2                            0.001
## Adjusted R2                   0.001
## F Statistic         10.027*** (df = 2; 26153)
## ================================================
## Note:                  *p<0.1; **p<0.05; ***p<0.01
##              Robust standard errors in parenthesis
```

Now we estimate a first difference (FD) model. We will only do this using the `plm` function. If we were to use the `lm` function we had to forst calculate differenced series. This happens automatically inside the `plm` function.

```
FD1a <- plm(lnhrpay~lnurate, data = pdata_USoc, subset = (n_wave ==2), model = "fd")
stargazer_HC(FD1a)
```

```
##
## ================================================
```

```
##                          Dependent variable:
##                ------------------------------------
##                               lnhrpay
## ---------------------------------------------------
## lnurate                        0.042
##                               (0.071)
##
## Constant                     -0.011**
##                               (0.005)
##
## ---------------------------------------------------
## Observations                  13,078
## R2                            0.00003
## Adjusted R2                  -0.00005
## F Statistic          0.353 (df = 1; 13076)
## ===================================================
## Note:                  *p<0.1; **p<0.05; ***p<0.01
##                Robust standard errors in parenthesis
```

Now we will show models, `POLS0a`, `POLS1a`, `POLS2a` and `FD1a` in one table.

```
stargazer_HC(POLS0a,POLS1a,POLS2a,FD1a)
```

```
##
## ==========================================================================================================
##                                                         Dependent variable:
##                ------------------------------------------------------------------------------------------
##                                                               lnhrpay
##                         (1)                        (2)                        (3)
## ----------------------------------------------------------------------------------------------------------
## lnurate              -0.102***                  -0.097***                  -0.096***                   0
##                       (0.022)                    (0.022)                    (0.029)                   (0
##
## wave3                                           -0.019***                   -0.005
##                                                  (0.005)                    (0.005)
##
## Constant              2.493***                   2.491***                   2.544***                 -0.
##                       (0.046)                    (0.046)                    (0.058)                   (0
##
## ----------------------------------------------------------------------------------------------------------
## Observations           39,934                     39,934                     26,156                    13
## R2                     0.001                      0.001                      0.001                     0.
## Adjusted R2            0.001                      0.001                      0.001                    -0.
## F Statistic  30.049*** (df = 1; 39932) 19.596*** (df = 2; 39931) 10.027*** (df = 2; 26153) 0.353 (df
## ==========================================================================================================
## Note:                                                                                  *p<0.1; **p<0.0
##                                                                              Robust standard errors in
```