```r
if (!require("plm")) install.packages("plm")
```

```
## Loading required package: plm
```

```
## Loading required package: Formula
```

```r
library(plm)

# I dowload my DataBase with read.csv2
DB_Tobin<-data.frame(read.csv2("DataBase/DB_Tobin.csv", sep = ";",stringsAsFactors=FALSE, header = TRUE
```

Model 1

Test

Analyse and test of my first model. These tests help select the panel model to be estimated. Here is my first model :

Model 1 : Green Initiatives on Tobin's Q

$$TobinsQ_{it+1} = \beta_0 + \beta_1(SP_{it}) + \beta_2(ST_{it}) + \beta_3(AS_{it}) + \beta_9(C_{it}) + \varepsilon_{it} \quad (1)$$

Tests of poolability

Citation from [@Croissant2008] :

> *pooltest tests the hypothesis that the same coeffcients apply to each individual. It is a standard F test, based on the comparison of a model obtained for the full sample and a model based on the estimation of an equation for each individual. The first argument of pooltest is a plm object. The second argument is a pvcm object obtained with model=within. If the first argument is a pooling model, the test applies to all the coefficients (including the intercepts), if it is a within model, different intercepts are assumed.*

```r
# Test of poolability --> error that I cannot understand

# M1_pvcm <- pvcm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2

# M1_plm<-plm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + Ne

# pooltest(M1_pvcm,M1_plm)

# pooltest(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + NetMa
```

Fixed or Random : Hausman Test

Citation from @Torres-Reyna2010 :

> *To decide between fixed or random effects you can run a Hausman test where the null hypothesis is that the preferred model is random effects vs. the alternative the fixed effects (see Green, 2008, chapter 9). It basically tests whether the unique errors (ui) are correlated with the regressors, the null hypothesis is they are not.*

```r
fixed <- plm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + Net

random <- plm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + Ne

phtest(fixed,random)
```

```
##
##  Hausman Test
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +  ...
## chisq = 27.79, df = 6, p-value = 0.0001029
## alternative hypothesis: one model is inconsistent
```

Interpretation : P-Value < 0.05 then Ho is rejected and I have to use the fixed-effect.

Testing for time and companies fixed effects

```r
fixed <- plm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + Net

fixed_time <- plm(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2


# Testing the time-fixed effects. The null is that no time-fixed effects needed
pFtest(fixed_time, fixed)
```

```
##
##  F test for individual effects
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +  ...
## F = 4.7276, df1 = 2, df2 = 692, p-value = 0.009135
## alternative hypothesis: significant effects
```

Interpretation Fixed_time effect : P-Value is < 0.05 meaning that null hypothesis is rejected and that there is a significant time-fixed effect. **So I need to use time fixed effect in my model!!**

Testing for cross-sectional dependence/contemporaneous correlation

Citation from @Torres-Reyna2010 :

> According to Baltagi, cross-sectional dependence is a problem in macro panels with long time series. This is not much of a problem in micro panels (few years and large number of cases). The null hypothesis in the B -P/LM and Pasaran CD tests of independence is that residuals across entities are not correlated. B- P/LM and Pasaran CD (cross-sectional dependence) tests are used to test whether the residuals are correlated across entities*. Cross-sectional dependence can lead to bias in tests results (also called contemporaneous correlation).

```r
pcdtest(fixed_time, test = c("lm"))
```

```
## Warning in pcdres(tres = tres, n = n, w = w, form = paste(deparse(x
## $formula)), : Some pairs of individuals (8.8 percent) do not have any or
## just one time period in common and have been omitted from calculation
```

```
##
##  Breusch-Pagan LM test for cross-sectional dependence in panels
##
```

```
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## chisq = 96787, df = 61773, p-value < 2.2e-16
## alternative hypothesis: cross-sectional dependence
```

```
pcdtest(fixed_time, test = c("cd"))
```

```
## Warning in pcdres(tres = tres, n = n, w = w, form = paste(deparse(x
## $formula)), : Some pairs of individuals (8.8 percent) do not have any or
## just one time period in common and have been omitted from calculation
```

```
##
##  Pesaran CD test for cross-sectional dependence in panels
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## z = 12.299, p-value < 2.2e-16
## alternative hypothesis: cross-sectional dependence
```

```
pcdtest(fixed, test = c("lm"))
```

```
## Warning in pcdres(tres = tres, n = n, w = w, form = paste(deparse(x
## $formula)), : Some pairs of individuals (8.8 percent) do not have any or
## just one time period in common and have been omitted from calculation
```

```
##
##  Breusch-Pagan LM test for cross-sectional dependence in panels
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## chisq = 96675, df = 61773, p-value < 2.2e-16
## alternative hypothesis: cross-sectional dependence
```

```
pcdtest(fixed, test = c("cd"))
```

```
## Warning in pcdres(tres = tres, n = n, w = w, form = paste(deparse(x
## $formula)), : Some pairs of individuals (8.8 percent) do not have any or
## just one time period in common and have been omitted from calculation
```

```
##
##  Pesaran CD test for cross-sectional dependence in panels
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## z = 6.2089, p-value = 5.336e-10
## alternative hypothesis: cross-sectional dependence
```

So HO is rejected meaning that I have cross sectional dependence in my first model. **What should I do?**

Testing for serial correlation

```
pbgtest(fixed_time)
```

```
##
##  Breusch-Godfrey/Wooldridge test for serial correlation in panel
##  models
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## chisq = 49.079, df = 1, p-value = 2.458e-12
## alternative hypothesis: serial correlation in idiosyncratic errors
```

```r
pbgtest(fixed)
```

```
##
##  Breusch-Godfrey/Wooldridge test for serial correlation in panel
##  models
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## chisq = 50.53, df = 1, p-value = 1.174e-12
## alternative hypothesis: serial correlation in idiosyncratic errors
```

Interpretation: HO is rejected as p-value < 0.05 then I have serial correlation....

Testing for stationarity

```r
if (!require("tseries")) install.packages("tseries")
```

```
## Loading required package: tseries
```

```r
library(tseries)
PanelSet <- plm.data(DB_Tobin, index = c("Companies", "YearFinancialIndicator"))
```

```
## Warning: use of 'plm.data' is discouraged, better use 'pdata.frame' instead
```

```r
adf.test(PanelSet$TobinsQ, k=2)
```

```
## Warning in adf.test(PanelSet$TobinsQ, k = 2): p-value smaller than printed
## p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  PanelSet$TobinsQ
## Dickey-Fuller = -16.843, Lag order = 2, p-value = 0.01
## alternative hypothesis: stationary
```

Ho : Series has stationarity **Interpretation :** p-value < 0.05 then ho is rejected and my panel data do not have stationarity

Testing for heteroskedasticity

```r
if (!require("lmtest")) install.packages("lmtest")
```

```
## Loading required package: lmtest
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```r
library(lmtest)

bptest(ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore + DebtRatio^2 + NetMargin
```

```
##
##  Breusch-Pagan test
##
## data:  ROA ~ SustainabilityPayLink + SustainableThemedCommitment + AuditScore +     DebtRatio^2 + Ne
## BP = 14173, df = 365, p-value < 2.2e-16
```

Interpretation: p-value < 0.05 then the null hypothesis of homoskedasticity is rejected and heteroskedasticity assumed...

Use the **sandwich estimator** to account for the heteroskedasticity issue? See @MiroshnychenkoGreenpracticesfinancial2017 and @Stock2008

"If hetersokedaticity is detected you can use the sandwich estimaror" [@Torres-Reyna2010]

vcovHC is a function for estimating a robust covariance matrix of parameters for a fixed effects or random effects panel model according to the White method (White 1980, 1984; Arellano 1987). The –vcovHC– function estimates three heteroskedasticity-consistent covariance estimators:

- "white1" - for general heteroskedasticity but no serial correlation. Recommended for random effects.
- "white2" - is "white1" restricted to a common variance within groups. Recommended for random effects.
- "arellano" - both heteroskedasticity and serial correlation. Recommended for fixed effects.

The following options apply*:

- HC0 - heteroskedasticity consistent. The default.
- HC1,HC2, HC3 – Recommended for small samples. HC3 gives less weight to influential observations.
- HC4 - small samples with influential observations
- HAC - heteroskedasticity and autocorrelation consistent (type ?vcovHAC for more details)

```
coeftest(fixed) # Original coefficients
```

```
##
## t test of coefficients:
##
##                               Estimate  Std. Error t value  Pr(>|t|)
## SustainabilityPayLink       -3.8841e-02  3.8132e-02 -1.0186  0.308755
## SustainableThemedCommitment  3.5463e-01  1.2639e-01  2.8059  0.005158 **
## AuditScore                  -6.9733e-03  1.2051e-01 -0.0579  0.953872
## DebtRatio                   -2.9614e-05  3.3954e-05 -0.8722  0.383420
## NetMargin                    2.1156e-01  7.6851e-03 27.5282 < 2.2e-16 ***
## log(Asset)                  -6.8001e-03  3.3122e-03 -2.0531  0.040440 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coeftest(fixed, vcovHC) # Heteroskedasticity consistent coefficients
```

```
##
## t test of coefficients:
##
##                               Estimate  Std. Error t value  Pr(>|t|)
## SustainabilityPayLink       -3.8841e-02  3.8725e-02 -1.0030   0.31621
## SustainableThemedCommitment  3.5463e-01  1.3791e-01  2.5714   0.01033 *
## AuditScore                  -6.9733e-03  6.3383e-02 -0.1100   0.91243
## DebtRatio                   -2.9614e-05  1.9432e-05 -1.5240   0.12797
## NetMargin                    2.1156e-01  3.5452e-02  5.9675 3.842e-09 ***
## log(Asset)                  -6.8001e-03  5.9027e-03 -1.1520   0.24970
## ---
```

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

```
coeftest(fixed, vcovHC(fixed, method = "arellano")) # Heteroskedasticity consistent
```

```
##
## t test of coefficients:
##
##                               Estimate  Std. Error t value  Pr(>|t|)
## SustainabilityPayLink       -3.8841e-02  3.8725e-02 -1.0030   0.31621
## SustainableThemedCommitment  3.5463e-01  1.3791e-01  2.5714   0.01033 *
## AuditScore                  -6.9733e-03  6.3383e-02 -0.1100   0.91243
## DebtRatio                   -2.9614e-05  1.9432e-05 -1.5240   0.12797
## NetMargin                    2.1156e-01  3.5452e-02  5.9675 3.842e-09 ***
## log(Asset)                  -6.8001e-03  5.9027e-03 -1.1520   0.24970
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coeftest(fixed, vcovHC(fixed, type = "HC3")) # Heteroskedasticity consistent coefficients, type 3coeffi
```

```
##
## t test of coefficients:
##
##                               Estimate  Std. Error t value  Pr(>|t|)
## SustainabilityPayLink       -3.8841e-02  3.9543e-02 -0.9822    0.3263
## SustainableThemedCommitment  3.5463e-01  1.4063e-01  2.5217    0.0119 *
## AuditScore                  -6.9733e-03  6.4615e-02 -0.1079    0.9141
## DebtRatio                   -2.9614e-05  3.1047e-05 -0.9538    0.3405
## NetMargin                    2.1156e-01  3.9486e-02  5.3578 1.147e-07 ***
## log(Asset)                  -6.8001e-03  6.5832e-03 -1.0330    0.3020
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# The following shows the HC standard errors of the coefficients
t(sapply(c("HC0", "HC1", "HC2", "HC3", "HC4"), function(x) sqrt(diag(vcovHC(fixed, type = x)))))
```

```
##     SustainabilityPayLink SustainableThemedCommitment AuditScore
## HC0            0.03872470                   0.1379112 0.06338307
## HC1            0.03883477                   0.1383032 0.06356322
## HC2            0.03911290                   0.1392589 0.06398496
## HC3            0.03954350                   0.1406321 0.06461521
## HC4            0.04029676                   0.1430071 0.06569777
##        DebtRatio  NetMargin  log(Asset)
## HC0 1.943172e-05 0.03545174 0.005902691
## HC1 1.948695e-05 0.03555250 0.005919468
## HC2 2.424797e-05 0.03737308 0.006213768
## HC3 3.104699e-05 0.03948605 0.006583227
## HC4 5.425316e-05 0.04437177 0.007538404
```

** What should I do with those estimates?**