MASTER 2 FINANCIAL TECHNOLOGY DATA

UNIVERSITY PARIS 1 PANTHEON SORBONNE

FINANCIAL ECONOMETRICS

ASSIGNMENT 02

- Julien DOS REIS
- [redacted]
- [redacted]

<u>Consider three series over a given period</u>

For our analysis we chose three different series:

- *CAC40* (series of prices of indexes)
- *Long term (10 years) government bond yield*
- *CPI* (macroeconomic series)

The periods of analysis are 01.01.2019 to 01.07.2022. We chose a monthly frequency.

<u>Justify the choice of the set of stocks, of the period and of the frequency</u>

According to the assignment it is required to use 3 series with at least one series of prices of indexes and at least one macroeconomic series. So, firstly we chose the CAC40, as it is a free float market capitalization weighted index that reflects the performance of the 40 largest and most actively traded shares listed on Euronext Paris, and is the most widely used indicator of the Paris stock market. Then we chose french CPI which measures the monthly change in prices paid by french consumers and Long term government bond yield to analyze the case of France.

We chose a period starting from 1 January 2019 and up to 1 July 2022, a period in which different changes occurred and observed on the different variables so we want to analyze if a change in one of these variables has affected the other one, knowing that those 3 variables have a link between them. We chose a monthly frequency, as with higher frequency data we could obtain more reliable estimates, compared to yearly data.

1. **Data preparation**

We import the necessary libraries and the series of prices of indexes and macroeconomic series. For the index we extract the close prices since we are going to use only this variable for our study.

2. **We perform Unit root test to investigate whether our series are stationary or not**

In order to verify if we have a stochastic process, we will apply ADF test under those two hypothesis:

H0: ρ= 1 => existence if unit root, our series is not stationary

H1: ρ <1 no unit root, our series in stationary

And we have 3 models to test for each series.

1) CAC40:

Model 03: with trend and drift

critical value for ρ is 3.45

$\Delta Xt = b0 + b1\ t + \rho Xt\text{-}1 + \phi j \sum \Delta Xt{-}j + \varepsilon t$

H0: b1 = 0 the trend is not significant

H1: b1 =/= 0 the trend is significant

```
Call:
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max
-0.17656 -0.03517  0.01650  0.03793  0.14128

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
z.lag.1    -0.0019316  0.0012836  -1.505    0.140
z.diff.lag  0.0004087  0.1563219   0.003    0.998

Residual standard error: 0.06766 on 39 degrees of freedom
Multiple R-squared:  0.05726,   Adjusted R-squared:  0.008919
F-statistic: 1.184 on 2 and 39 DF,  p-value: 0.3167


Value of test-statistic is: -1.5049
```

According to the ADF test t-stat for ρ = 2.77 < 3.45, so we accept that there is a unit root; t-stat for b1 =2.67 < 2.79, so the trend is not significant.

Model 02: with a drift only

critical value for ρ = 2.89 and for b0 = 2.54

$\Delta X_t = b_0 + \rho X_{t-1} + \phi_j \sum \Delta X_{t-j} + \varepsilon$

H0: b0 = 0 the drift is not significant

H1: b0 =/= 0 the drift is significant

According to the ADF test ρ = 0.701 < 2.89, so there is a unit root; for b0 =0.649 <2.54 the drift is not significant.

```
lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.18375 -0.03461  0.01530  0.04415  0.13288 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.20170    0.31066   0.649    0.520
z.lag.1     -0.02585    0.03686  -0.701    0.487
z.diff.lag   0.01949    0.16021   0.122    0.904

Residual standard error: 0.06817 on 38 degrees of freedom
Multiple R-squared:  0.01278,	Adjusted R-squared:  -0.03918 
F-statistic: 0.2459 on 2 and 38 DF,  p-value: 0.7832


Value of test-statistic is: -0.7013 1.3263
```

Model 01: without a trend and drift

$\Delta X_t = \rho X_{t-1} + \phi_j \sum_{j=1} \Delta X_{t-j} + \varepsilon$

critical value for ρ =1.95

t stat for ρ =1.50<1.95 there is a unit root.

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.17656 -0.03517  0.01650  0.03793  0.14128 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
z.lag.1    -0.0019316  0.0012836  -1.505    0.140
z.diff.lag  0.0004087  0.1563219   0.003    0.998

Residual standard error: 0.06766 on 39 degrees of freedom
Multiple R-squared:  0.05726,	Adjusted R-squared:  0.008919 
F-statistic: 1.184 on 2 and 39 DF,  p-value: 0.3167


Value of test-statistic is: -1.5049
```

To make the series stationary we differentiate the series and perform an ADF test one more time.

After the first differentiation, t value of ρ = 4.215 >1.95 => we reject h0 there is no unit root. CAC40 is stationary after the first difference I(1).

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.18944 -0.05266 -0.00369  0.02414  0.13448 

Coefficients:
           Estimate Std. Error t value Pr(>|t|)    
z.lag.1    -0.94001    0.22302  -4.215 0.000148 ***
z.diff.lag -0.01652    0.15979  -0.103 0.918180    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.07048 on 38 degrees of freedom
Multiple R-squared:  0.4762,	Adjusted R-squared:  0.4487 
F-statistic: 17.27 on 2 and 38 DF,  p-value: 4.611e-06


Value of test-statistic is: -4.215
```

We do the same thing for the other series by respecting the different critical values.

2) CPI

Model 03: with trend and drift

critical value for ρ is 3.45

$\Delta X_t = b_0 + b_1 t + \rho X_{t-1} + \phi_j \sum \Delta X_{t-j} + \varepsilon_t$

```
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.64050 -0.17131 -0.00517  0.11702  0.65672 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  0.946346   0.245743   3.851 0.000451 ***
z.lag.1     -0.604325   0.153393  -3.940 0.000348 ***
tt           0.007063   0.004195   1.684 0.100652    
z.diff.lag   0.285220   0.157442   1.812 0.078173 .  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.272 on 37 degrees of freedom
Multiple R-squared:  0.298,	Adjusted R-squared:  0.2411 
F-statistic: 5.236 on 3 and 37 DF,  p-value: 0.004104


Value of test-statistic is: -3.9397 5.2591 7.8455
```

H0: b1 = 0 the trend is not significant

H1: b1 =/= 0 the trend is significant

According to the ADF test ρ = 3.94 > 3.45, so we reject h0, there is no unit root.

If rejection of ρ=0 , the series is I(0); one can test for significance of b0 and b1 by referring to the usual threshold 1.96. b1 =1.68 <1.96 we accept h0 the trend is not significant; b0=3.85 > 1.96 we reject h0 the drift is significant. We can test again for model 2 to be sure.

Model 02: with a drift only

ΔXt =b0 + ρXt-1 + ϕj ∑ ΔXt−j +ε

H0: b0 = 0 the drift is not significant

H1: b0 =/= 0 the drift is significant

According to ADF test ρ= 3.50>2.89 - there is no UR; b0= 3.49 > 2.54 the drift is significant our serie is stationary with a drift

```
lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.61113 -0.11837 -0.02851  0.15330  0.71826 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept)   0.8611     0.2462   3.498  0.00121 **
z.lag.1      -0.4708     0.1344  -3.502  0.00120 **
z.diff.lag    0.2156     0.1555   1.386  0.17379   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2785 on 38 degrees of freedom
Multiple R-squared:  0.2442,	Adjusted R-squared:  0.2044 
F-statistic:  6.14 on 2 and 38 DF,  p-value: 0.004893


Value of test-statistic is: -3.502 6.1731
```

3) Treasury bond

Model 03: with trend and drift

ΔXt =b0 +b1 t+ ρXt-1 + ϕj ∑ ΔXt−j +εt

H0: b1 = 0 the trend is not significant

H1: b1 =/= 0 the trend is significant

According to the ADF test ρ =2.47 < 3.45 there is no unit root; b1= 2.20 > 1.96 trend not significant; b0 = 2.41 >1.96 the drift not significant.

```
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.35213 -0.10578 -0.01241  0.09287  0.31750 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)  
(Intercept)  1.445564   0.598067   2.417   0.0207 *
z.lag.1     -0.260960   0.105547  -2.472   0.0181 *
tt          -0.008803   0.003993  -2.205   0.0338 *
z.diff.lag   0.268535   0.178681   1.503   0.1414  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1529 on 37 degrees of freedom
Multiple R-squared:  0.1492,	Adjusted R-squared:  0.08018 
F-statistic: 2.162 on 3 and 37 DF,  p-value: 0.1089


Value of test-statistic is: -2.4725 2.678 3.0684
```

Model 02: with a drift only

ΔXt =b0 + ρXt-1 + ϕj ∑ ΔXt−j +ε

H0: b0 = 0 the drift is not significant

H1: b0 =/= 0 the drift is significant

According to the ADF test ρ= 1.08 < 3.45 there is no unit root.

```
lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.35645 -0.13496 -0.00895  0.09204  0.32698 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.26655    0.28103   0.948    0.349
z.lag.1     -0.06086    0.05654  -1.076    0.289
z.diff.lag   0.15938    0.18020   0.884    0.382

Residual standard error: 0.1605 on 38 degrees of freedom
Multiple R-squared:  0.03739,	Adjusted R-squared:  -0.01327 
F-statistic: 0.7381 on 2 and 38 DF,  p-value: 0.4848


Value of test-statistic is: -1.0763 1.4404
```

Model 01: without a trend and drift

$\Delta Xt = \rho Xt\text{-}1 + \phi j\ j\text{=}1 \sum \Delta Xt\text{−}j + \varepsilon$

According to the ADF test p-value > 0.05, so there is unit root.

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.30786 -0.11501 -0.02318  0.10244  0.36243 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
z.lag.1    -0.007466   0.005297  -1.409    0.167
z.diff.lag  0.099059   0.168381   0.588    0.560

Residual standard error: 0.1603 on 39 degrees of freedom
Multiple R-squared:  0.07213,	Adjusted R-squared:  0.02455 
F-statistic: 1.516 on 2 and 39 DF,  p-value: 0.2323


Value of test-statistic is: -1.4094
```

To make the series stationary we differentiate the series and perform an ADF test one more time.

After the first differentiation, t value of ρ = 4.473 >1.95 => we reject h0 there is no unit root. Treasury bond series is stationary after the first difference I(1).

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.33881 -0.13384 -0.06468  0.08193  0.30908 

Coefficients:
           Estimate Std. Error t value Pr(>|t|)    
z.lag.1     -0.9454     0.2113  -4.473 6.77e-05 ***
z.diff.lag   0.1331     0.1725   0.772    0.445    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1628 on 38 degrees of freedom
Multiple R-squared:  0.4143,	Adjusted R-squared:  0.3835 
F-statistic: 13.44 on 2 and 38 DF,  p-value: 3.848e-05


Value of test-statistic is: -4.4734
```

As a result of the ADF test, we can see that two series (CAC40 and Treasury bond) are I(1), whereas CPI is I(0). So we do the cointegration test on our 2 series with I(1).

3. Test for cointegration (rank test and estimation of the potential cointegration relationship(s)

To perform a cointegration test we firstly bind series into a system:

	CAC40_ts	Bond_ts
1	8.641146	5.6624
2	8.730845	5.6157
3	8.746088	5.4348
4	8.767130	5.3328
5	8.768148	5.5032
6	8.771299	5.3232
7	8.786073	5.3990

We identify the order of a VAR using the VARselect function.

```
> lagselect$selection
AIC(n)  HQ(n)  SC(n) FPE(n)
     6      1      1      6
```

We choose to base our selection on AIC criteria, so lag is equal 5 (6-1). Next we perform a Johansen test using "trace" and "maxEigen" approaches:

```
Test type: trace statistic , with linear trend in cointegration

Eigenvalues (lambda):
[1] 2.054942e-01 1.651096e-01 2.775558e-17

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 1 |  6.86 10.49 12.25 16.26
r = 0  | 15.60 22.76 25.32 30.45

Eigenvectors, normalised to first column:
(These are the cointegration relations)

            CAC40_ts.l5   Bond_ts.l5    trend.l5
CAC40_ts.l5  1.00000000  1.000000000  1.00000000
Bond_ts.l5   0.10530473 -0.497989980 -0.12274296
trend.l5     0.02747451  0.008081439  0.03950895

Weights W:
(This is the loading matrix)

           CAC40_ts.l5 Bond_ts.l5     trend.l5
CAC40_ts.d  -0.4968190  0.1608728 1.223024e-15
Bond_ts.d    0.4746064  0.7671947 2.551531e-15
```

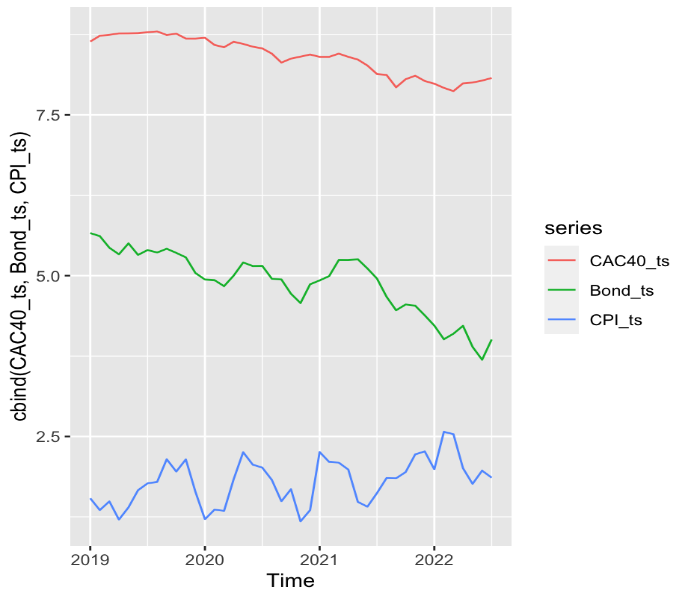
```
Test type: maximal eigenvalue statistic (lambda max) , with linear trend in cointegration

Eigenvalues (lambda):
[1] 2.054942e-01 1.651096e-01 2.775558e-17

Values of teststatistic and critical values of test:

         test 10pct  5pct  1pct
r <= 1 | 6.86 10.49 12.25 16.26
r = 0  | 8.74 16.85 18.96 23.65

Eigenvectors, normalised to first column:
(These are the cointegration relations)

            CAC40_ts.l5   Bond_ts.l5    trend.l5
CAC40_ts.l5  1.00000000  1.000000000  1.00000000
Bond_ts.l5   0.10530473 -0.497989980 -0.12274296
trend.l5     0.02747451  0.008081439  0.03950895

Weights W:
(This is the loading matrix)

           CAC40_ts.l5 Bond_ts.l5     trend.l5
CAC40_ts.d  -0.4968190  0.1608728 1.223024e-15
Bond_ts.d    0.4746064  0.7671947 2.551531e-15
```

From both approaches we see that there is no cointegration in our series:

- for "trace" approach: r=0: test = 15.60 < 30.45 (critical value); r<=1: test = 6.86 < 16.26;
- for "maxEigen" approach: r=0: test = 8.74 < 23.65; r<=1: test = 6.86 < 16.26;

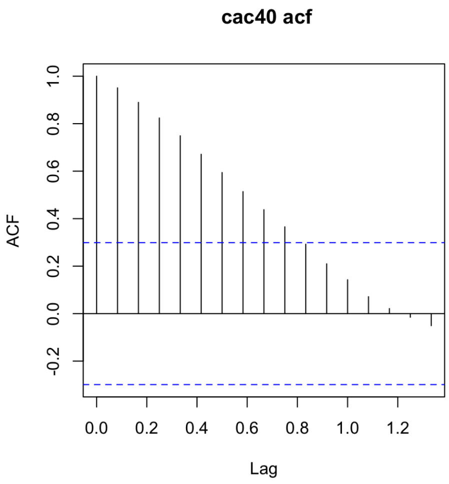
As there is no cointegration, we turn to a VAR model in the first difference.

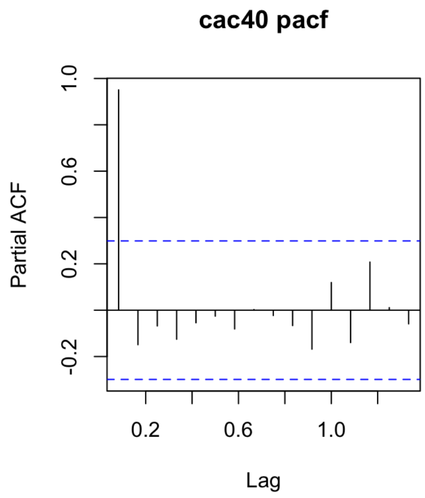
First, we plot out series:



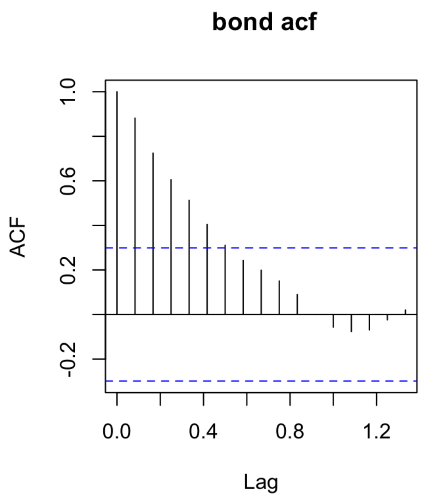
In next step we plot both ACF and PACF:

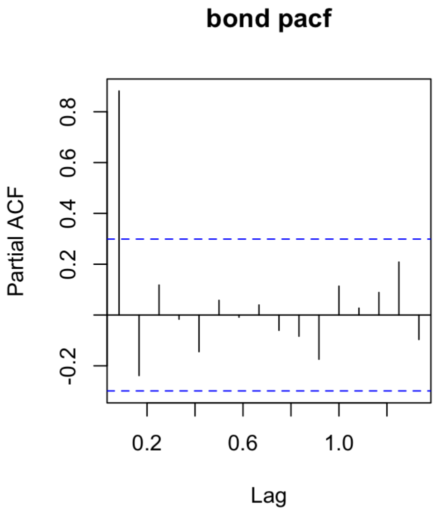
1) **CAC40:** we can notice there is a slow decrease which means we have a long memory (we have a random walk).



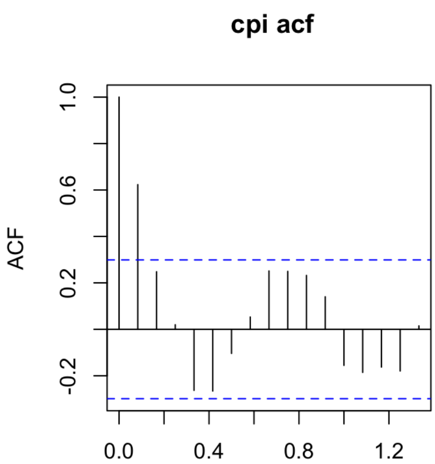


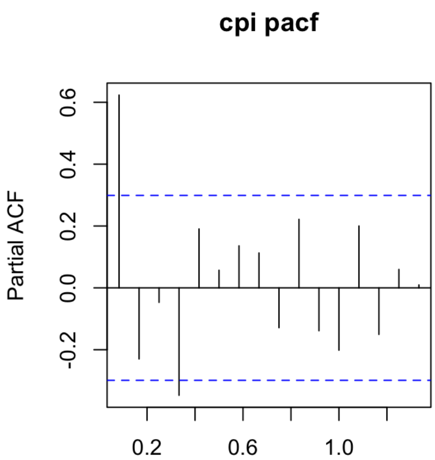
2) **Bond:** for bond series we have a long memory as well





3) **CPI:** we can see that series fading rapidly, which means that we have a short memory and there is no autocorrelation (PACF)





4. VAR Model:

We will first estimate a standard VAR which reflects a key economic response.

In order to construct our VAR model, all the series need to be stationary, so we apply the first differentiation on our 2 series (CAC40 and Treasury bonds series).

we bind our new data set with the 3 series.

```
diffcac40 <- diff(CAC40_closing$Close)
diffcac40_ts <- ts(diffcac40,start = c(2019,1,1), end =c(2022,7,1)
diffbond<-diff(LT_gov_bond$IRLTLT01FRM156N)
diffbond_ts <- ts(diffbond,start = c(2019,1,1), end =c(2022,7,1),
DATA <- cbind(diffbond_ts,diffcac40_ts,CPI_ts)
```

1) Order of the VAR

Next we estimate the order of VAR: we identify the order of a VAR using the VARselect function. We choose to base our selection on AIC criteria, so lag is equal 5 .

```
> lagselect$selection
AIC(n)  HQ(n)  SC(n) FPE(n)
     5      2      1      5
```

2) Estimation

Then we estimate a VAR model with the following code: VAR(DATA,p= 6,type="const", season=NULL, exogen = NULL)

we can clearly see in our result that the constant is not significant, in that case we are going to estimate a VAR model without a constant,

<u>interpretation:</u>

Our results suggest that the CAC40 is impacted by the interest rate of treasury bonds, and the coefficient is negative, which means that If interest rates rise individuals will see a higher return on their savings. This removes the need for individuals to take on added risk by investing in stocks, resulting in less demand for stocks, so that will hurt the performance of CAC40. We see that the inflation impacts the CAC40 at the level of 10%. We can accept this since it is compatible with reality because we know that Stock markets usually aren't affected too much by the inflation data.

```
Estimation results for equation diffbond_ts:
============================================
diffbond_ts = diffbond_ts.l1 + diffcac40_ts.l1 + CPI_ts.l
ond_ts.l3 + diffcac40_ts.l3 + CPI_ts.l3 + diffbond_ts.l4
40_ts.l5 + CPI_ts.l5

                 Estimate Std. Error t value Pr(>|t|)
diffbond_ts.l1   1.015e-01  2.069e-01   0.491   0.6284
diffcac40_ts.l1  2.439e-04  1.286e-04   1.897   0.0705 .
CPI_ts.l1        1.657e-01  9.258e-02   1.790   0.0867 .
diffbond_ts.l2  -4.152e-01  2.134e-01  -1.945   0.0641 .
diffcac40_ts.l2  1.477e-04  1.107e-04   1.334   0.1952
CPI_ts.l2       -3.621e-01  1.351e-01  -2.681   0.0133 *
diffbond_ts.l3   1.698e-01  2.212e-01   0.768   0.4503
diffcac40_ts.l3  1.069e-04  1.218e-04   0.878   0.3891
CPI_ts.l3        1.878e-01  1.550e-01   1.212   0.2379
diffbond_ts.l4  -1.833e-02  2.187e-01  -0.084   0.9339
diffcac40_ts.l4  5.538e-05  1.024e-04   0.541   0.5939
CPI_ts.l4       -1.024e-01  1.512e-01  -0.677   0.5051
diffbond_ts.l5   1.436e-01  2.745e-01   0.523   0.6058
diffcac40_ts.l5  3.855e-05  1.021e-04   0.378   0.7092
```

```
Estimation results for equation diffcac40_ts:
=============================================
diffcac40_ts = diffbond_ts.l1 + diffcac40_ts.l1 + CPI_ts.l1
bond_ts.l3 + diffcac40_ts.l3 + CPI_ts.l3 + diffbond_ts.l4 +
c40_ts.l5 + CPI_ts.l5

                 Estimate Std. Error t value Pr(>|t|)
diffbond_ts.l1   2.844e+02  3.226e+02   0.882  0.38713
diffcac40_ts.l1  1.267e-01  2.005e-01   0.632  0.53350
CPI_ts.l1        7.918e+01  1.444e+02   0.548  0.58867
diffbond_ts.l2  -8.235e+02  3.328e+02  -2.474  0.02115 *
diffcac40_ts.l2 -2.007e-01  1.726e-01  -1.163  0.25691
CPI_ts.l2       -1.963e+02  2.106e+02  -0.932  0.36105
diffbond_ts.l3   3.117e+02  3.449e+02   0.904  0.37544
diffcac40_ts.l3  3.886e-01  1.900e-01   2.046  0.05236 .
CPI_ts.l3        1.970e+02  2.417e+02   0.815  0.42335
diffbond_ts.l4  -1.342e+03  3.411e+02  -3.936  0.00066 ***
diffcac40_ts.l4  5.603e-02  1.597e-01   0.351  0.72889
CPI_ts.l4       -4.765e+02  2.357e+02  -2.022  0.05501 .
diffbond_ts.l5   5.276e+02  4.280e+02   1.233  0.23020
diffcac40_ts.l5  9.768e-02  1.592e-01   0.613  0.54563
```

Now for the interest rate and the other 2 variables, we can see that the interest rate of treasury bonds is affected by the CPI but not instantly (a lag of 2 months). Now for CPI from our model we can see that it is only impacted by his previous values and the coefficient is positive.

```
Estimation results for equation CPI_ts:
=======================================
CPI_ts = diffbond_ts.l1 + diffcac40_ts.l1 + CPI_ts.l1 + dif
s.l3 + diffcac40_ts.l3 + CPI_ts.l3 + diffbond_ts.l4 + diffca
s.l5 + CPI_ts.l5

                 Estimate Std. Error t value Pr(>|t|)
diffbond_ts.l1   5.434e-01  4.364e-01   1.245    0.226
diffcac40_ts.l1 -2.896e-04  2.712e-04  -1.068    0.297
CPI_ts.l1        9.217e-01  1.953e-01   4.719 9.37e-05 ***
diffbond_ts.l2   4.017e-02  4.502e-01   0.089    0.930
diffcac40_ts.l2 -3.670e-05  2.335e-04  -0.157    0.876
CPI_ts.l2       -2.608e-01  2.849e-01  -0.915    0.370
diffbond_ts.l3  -1.825e-01  4.665e-01  -0.391    0.699
diffcac40_ts.l3 -1.612e-05  2.570e-04  -0.063    0.951
CPI_ts.l3        4.774e-01  3.270e-01   1.460    0.158
diffbond_ts.l4  -5.778e-01  4.614e-01  -1.252    0.223
diffcac40_ts.l4  3.057e-04  2.161e-04   1.415    0.171
CPI_ts.l4       -5.362e-01  3.189e-01  -1.681    0.106
diffbond_ts.l5  -5.159e-01  5.791e-01  -0.891    0.382
diffcac40_ts.l5  1.315e-04  2.154e-04   0.610    0.548
```

Autocorrelation :

One assumption is that the residuals should, as much as possible, be **non-autocorrelated**. This is again on our assumption that the residuals are white noise and thus uncorrelated with the previous periods. To do this, we run the serial.test() command.

```
        Portmanteau Test (asymptotic)

data:  Residuals of VAR object var
Chi-squared = 30.641, df = 0, p-value < 2.2e-16
```

According to the results, p-value is so weak (< 5%), that we reject H0. We thus deduce that there is an autocorrelation of the residuals of the VAR model.

Heteroscedasticity :

Another aspect to consider is the presence of heteroscedasticity, we check it using the "arch.test" function. In time series, there is what we call *ARCH effects* which are essentially clustered volatility areas in a time series.

```
        ARCH (multivariate)

data:  Residuals of VAR object var
Chi-squared = 132, df = 540, p-value = 1
```

The results of the ARCH test signify no degree of heteroscedasticity as we fail to reject the null hypothesis, so we conclude that there are no ARCH effects in this model.

Normality : Next we perform a “normality.test” function to check residuals distribution.

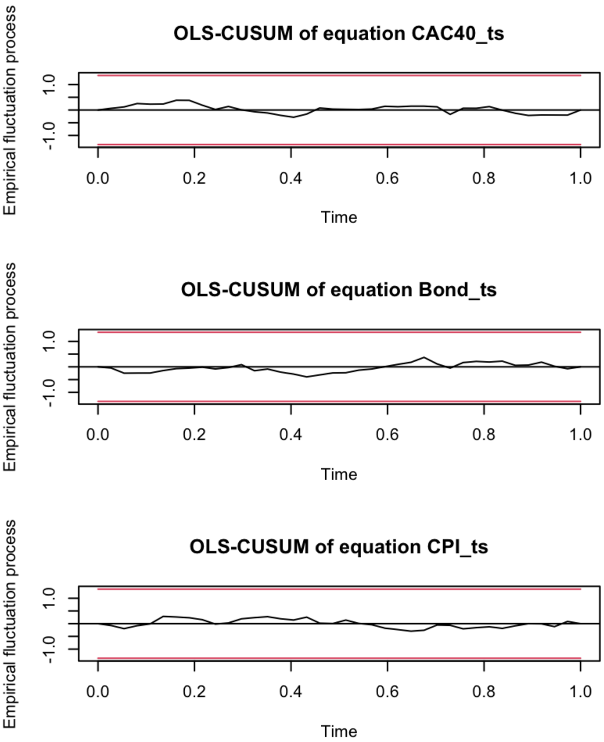
```
        JB-Test (multivariate)

data:  Residuals of VAR object var
Chi-squared = 3.6201, df = 6, p-value = 0.7279

$Skewness

        Skewness only (multivariate)

data:  Residuals of VAR object var
Chi-squared = 3.413, df = 3, p-value = 0.3322

$Kurtosis

        Kurtosis only (multivariate)

data:  Residuals of VAR object var
Chi-squared = 0.20709, df = 3, p-value = 0.9764
```

The results suggest that we accept h0 which say that our residuals are not normally distributed, but this will not really affect our VAR model because it is not a necessary condition.

Stability :

The stability test is some test for the presence of structural breaks. We know that if we are unable to test for structural breaks and if there happened to be one, the whole estimation may be thrown off.

To check the stability we applied “stability” function



According to the results of the test, there seems to be no structural breaks evident. As such, our model passes, so it is stable.

Causality test

We use the Granger causality test, that is a statistical hypothesis test for determining whether one time series is useful for forecasting another. If the probability value is less than any α level, then the hypothesis would be rejected at that level.

CAC40: we may reject the null hypothesis of the test because the p-value is smaller than 0.05, and infer that knowing the values of CAC40 is valuable for forecasting the future values of Bond and CPI.

```
$Granger

        Granger causality H0: CAC40_ts do not Granger-cause Bond_ts
        CPI_ts

data:  VAR object var
F-Test = 1.992, df1 = 12, df2 = 54, p-value = 0.04313
```

Bond: we may reject the null hypothesis, the results suggest that Bond can be used to predict future values of CAC40 and CPI (p-value = 0.018<0.05)

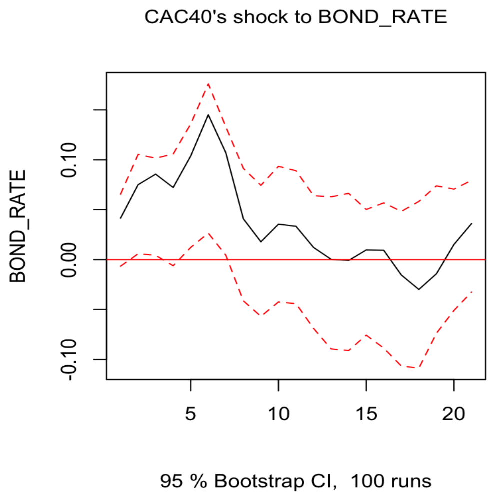
```
$Granger

        Granger causality H0: Bond_ts do not Granger-cause CAC40_ts CPI_ts

data:  VAR object var
F-Test = 2.3249, df1 = 12, df2 = 54, p-value = 0.0176
```

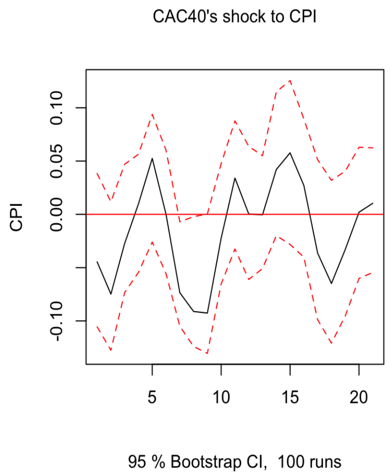
CPI: for the CPI we reject the null hypothesis as well, as p-value = 0.0007 < 0.05. So the values of CPI are valuable for forecasting the future values of Bond and CAC40.

```
$Granger

        Granger causality H0: CPI_ts do not Granger-cause CAC40_ts Bond_ts

data:  VAR object var
F-Test = 3.5111, df1 = 12, df2 = 54, p-value = 0.0007166
```

Impulse response function

We implement the “irf” function to investigate different impulse responses.
On the first graph we see how Bond yield would react to the impulse (increase) of CAC40 prices. The reaction is relatively positive: in the first period bond yield significantly increases and then slowly goes down; Nevertheless, there is also a big room for error that means that it could have no effect at all.
The second graph suggests the impact of CAC40 impulse on CPI - we can see that reaction is not permanent and CPI value increases and decreases. There is a big room for error as well, so it could have no effect at all.


CAC40's shock to BOND_RATE
BOND_RATE
-0.10
0.00
0.10
5
10
15
20
95 % Bootstrap CI, 100 runs


CAC40's shock to CPI
CPI
-0.10
0.00
0.05
0.10
5
10
15
20
95 % Bootstrap CI, 100 runs