Inspeção

gpetrini

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Pacotes

```
library(MASS)
library(urca)
library(MTS)  # pacote estatístico geral
library(vars)
library(lmtest)
library(xts)
library(dplyr)
```

Dados

```
df <- read.csv(
    "../data/raw_data.csv",
    encoding="UTF-8",
    row.names=1,
    stringsAsFactors=FALSE
    )
df <- df[,c( # Subset das colunas com ordenação de Choleski
    "Exportações.FOB",
    "Taxa.de.câmbio",
    "Importações.FOB",
    "Índice.da.Produção.Física.Industrial.com.ajuste.sazonal..Média.2012...100.",
    "ICMS.Nominal.milhões.de.reais"
    )]
colnames(df) <- c( # Encurtando nomes
    "Exportacoes",
    "Cambio",
    "Importacoes",
    "Industrial",
    "ICMS"
)
df <- xts::as.xts(df)
df %>% head() %>% knitr::kable()
```

Exportacoes	Cambio	Importacoes	Industrial	ICMS
1262216472	2.3771	1588583185	75.7	2956.254
1345978624	2.4188	1507819585	78.6	2612.978
1443341004	2.3458	1654236906	78.1	2603.101
1614508483	2.3196	1752896831	78.2	2964.823
1491268802	2.4796	1666945463	78.0	2848.264
1670856204	2.7132	1537291228	77.4	2934.246

Testes de quebra estrutural

Teste de Chow

H_0 : Não há quebra estrutural

ICMS

```
df_ <- df %>% as.data.frame()
result = strucchange::breakpoints(df_$ICMS~1)
result$breakpoints %>% unique() %>% na.omit() %>% c() -> breaks

for(i in breaks){
  print(paste0("Testando para i = ", index(df)[i]))
  strucchange::sctest(df_$ICMS~1, point=i, type="Chow") %>% print()
}
```

```
## [1] "Testando para i = 2004-08-31"
##
##  Chow test
##
## data:  df_$ICMS ~ 1
## F = 119.01, p-value < 2.2e-16
##
## [1] "Testando para i = 2007-08-31"
##
##  Chow test
##
## data:  df_$ICMS ~ 1
## F = 462.15, p-value < 2.2e-16
##
## [1] "Testando para i = 2010-05-31"
##
##  Chow test
##
## data:  df_$ICMS ~ 1
## F = 844.4, p-value < 2.2e-16
##
## [1] "Testando para i = 2013-03-31"
##
##  Chow test
```

```
##
## data:  df_$ICMS ~ 1
## F = 469.43, p-value < 2.2e-16
##
## [1] "Testando para i = 2017-07-31"
##
##  Chow test
##
## data:  df_$ICMS ~ 1
## F = 102.8, p-value < 2.2e-16
```

Industrial

```
result = breakpoints(Industrial~1, data=df_)
result$breakpoints %>% unique() %>% na.omit() %>% c() -> breaks

for(i in breaks){
  print(paste0("Testando para i = ", index(df)[i]))
  strucchange::sctest(Industrial~1, data=df_, point=i, type="Chow") %>% print()
}
```

```
## [1] "Testando para i = 2004-08-31"
##
##  Chow test
##
## data:  Industrial ~ 1
## F = 99.441, p-value < 2.2e-16
##
## [1] "Testando para i = 2007-04-30"
##
##  Chow test
##
## data:  Industrial ~ 1
## F = 63.34, p-value = 9.592e-14
##
## [1] "Testando para i = 2009-12-31"
##
##  Chow test
##
## data:  Industrial ~ 1
## F = 11.659, p-value = 0.0007625
##
## [1] "Testando para i = 2014-11-30"
##
##  Chow test
##
## data:  Industrial ~ 1
## F = 52.766, p-value = 6.661e-12
```

Cambio

```
result = breakpoints(Cambio~1, data=df_)
result$breakpoints %>% unique() %>% na.omit() %>% c() -> breaks

for(i in breaks){
  print(paste0("Testando para i = ", index(df)[i]))
  strucchange::sctest(Cambio~1, data=df_, point=i, type="Chow") %>% print()
}
```

```
## [1] "Testando para i = 2005-04-30"
##
##  Chow test
##
## data:  Cambio ~ 1
## F = 8.5344, p-value = 0.003853
##
## [1] "Testando para i = 2009-07-31"
##
##  Chow test
##
## data:  Cambio ~ 1
## F = 8.6445, p-value = 0.003636
##
## [1] "Testando para i = 2012-03-31"
##
##  Chow test
##
## data:  Cambio ~ 1
## F = 88.997, p-value < 2.2e-16
##
## [1] "Testando para i = 2014-11-30"
##
##  Chow test
##
## data:  Cambio ~ 1
## F = 332, p-value < 2.2e-16
##
## [1] "Testando para i = 2017-07-31"
##
##  Chow test
##
## data:  Cambio ~ 1
## F = 133.69, p-value < 2.2e-16
```

Exportações

```
result = breakpoints(Exportacoes~1, data=df_)
result$breakpoints %>% unique() %>% na.omit() %>% c() -> breaks

for(i in breaks){
```

```
  print(paste0("Testando para i = ", index(df)[i]))
  strucchange::sctest(Exportacoes~1, data=df_, point=i, type="Chow") %>% print()
}
```

```
## [1] "Testando para i = 2005-04-30"
##
##  Chow test
##
## data:  Exportacoes ~ 1
## F = 343.14, p-value < 2.2e-16
##
## [1] "Testando para i = 2010-05-31"
##
##  Chow test
##
## data:  Exportacoes ~ 1
## F = 84.963, p-value < 2.2e-16
##
## [1] "Testando para i = 2013-12-31"
##
##  Chow test
##
## data:  Exportacoes ~ 1
## F = 6.0666, p-value = 0.01455
```

Importações

```
result = breakpoints(Importacoes~1, data=df_)
result$breakpoints %>% unique() %>% na.omit() %>% c() -> breaks

for(i in breaks){
  print(paste0("Testando para i = ", index(df)[i]))
  strucchange::sctest(Importacoes~1, data=df_, point=i, type="Chow") %>% print()
}
```

```
## [1] "Testando para i = 2004-08-31"
##
##  Chow test
##
## data:  Importacoes ~ 1
## F = 145.65, p-value < 2.2e-16
##
## [1] "Testando para i = 2007-04-30"
##
##  Chow test
##
## data:  Importacoes ~ 1
## F = 383.63, p-value < 2.2e-16
##
## [1] "Testando para i = 2010-06-30"
##
```

```
##  Chow test
##
## data:  Importacoes ~ 1
## F = 193.31, p-value < 2.2e-16
##
## [1] "Testando para i = 2014-12-31"
##
##  Chow test
##
## data:  Importacoes ~ 1
## F = 1.3749, p-value = 0.2423
```

Testes de raíz unitária

ADF

```
for (serie in colnames(df)) {
  print(paste0("Testando para a série ", serie))
  print("H0: Há raíz unitária")
  urca::ur.df(
    y = df[,serie],
    type = "drift",
    lags = 12,
    selectlags = "AIC"
    ) %>% summary() %>% print()
}
```

```
## [1] "Testando para a série Exportacoes"
## [1] "H0: Há raíz unitária"
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.352e+09 -2.397e+08  1.980e+07  2.483e+08  1.009e+09
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   3.882e+08  1.402e+08   2.769 0.006181 **
## z.lag.1      -9.086e-02  3.473e-02  -2.616 0.009605 **
## z.diff.lag1  -4.459e-01  7.053e-02  -6.322 1.76e-09 ***
## z.diff.lag2  -1.934e-01  7.714e-02  -2.508 0.012985 *
## z.diff.lag3  -2.998e-02  7.927e-02  -0.378 0.705762
```

```
## z.diff.lag4  -1.395e-01  7.946e-02  -1.756 0.080736 .
## z.diff.lag5  -1.826e-01  7.838e-02  -2.330 0.020842 *
## z.diff.lag6  -2.419e-01  7.626e-02  -3.172 0.001764 **
## z.diff.lag7  -2.781e-01  7.580e-02  -3.668 0.000316 ***
## z.diff.lag8  -2.299e-01  7.691e-02  -2.989 0.003166 **
## z.diff.lag9  -1.071e-01  7.806e-02  -1.372 0.171813
## z.diff.lag10 -1.492e-01  7.899e-02  -1.889 0.060464 .
## z.diff.lag11 -1.153e-01  7.822e-02  -1.474 0.142011
## z.diff.lag12  3.095e-01  6.928e-02   4.468 1.35e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 412300000 on 192 degrees of freedom
## Multiple R-squared:  0.4874, Adjusted R-squared:  0.4527
## F-statistic: 14.04 on 13 and 192 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: -2.616 3.927
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.46 -2.88 -2.57
## phi1  6.52  4.63  3.81
##
## [1] "Testando para a série Cambio"
## [1] "H0: Há raíz unitária"
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.42990 -0.04906 -0.00903  0.04549  0.47307
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.002745   0.025687  -0.107   0.9150
## z.lag.1      0.003351   0.009524   0.352   0.7253
## z.diff.lag1  0.365422   0.073396   4.979 1.37e-06 ***
## z.diff.lag2 -0.147585   0.076721  -1.924   0.0558 .
## z.diff.lag3  0.134226   0.072869   1.842   0.0669 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1015 on 201 degrees of freedom
## Multiple R-squared:  0.1216, Adjusted R-squared:  0.1042
## F-statistic: 6.959 on 4 and 201 DF,  p-value: 2.887e-05
```

```
##
##
## Value of test-statistic is: 0.3518 0.4142
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.46 -2.88 -2.57
## phi1  6.52  4.63  3.81
##
## [1] "Testando para a série Importacoes"
## [1] "H0: Há raíz unitária"
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.504e+09 -2.941e+08 -4.047e+07  2.382e+08  2.643e+09
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.288e+08  1.102e+08   2.077 0.039093 *
## z.lag.1      -4.213e-02  2.189e-02  -1.925 0.055729 .
## z.diff.lag1  -4.964e-01  7.093e-02  -6.998 4.23e-11 ***
## z.diff.lag2  -1.359e-01  7.898e-02  -1.721 0.086796 .
## z.diff.lag3   2.998e-01  7.960e-02   3.766 0.000220 ***
## z.diff.lag4  -7.356e-02  8.192e-02  -0.898 0.370362
## z.diff.lag5  -1.419e-01  8.139e-02  -1.743 0.082847 .
## z.diff.lag6  -5.049e-02  8.194e-02  -0.616 0.538529
## z.diff.lag7  -4.779e-02  8.183e-02  -0.584 0.559943
## z.diff.lag8  -1.609e-01  8.119e-02  -1.982 0.048914 *
## z.diff.lag9  -1.787e-01  8.185e-02  -2.183 0.030253 *
## z.diff.lag10 -8.851e-03  8.018e-02  -0.110 0.912214
## z.diff.lag11  1.316e-01  7.939e-02   1.657 0.099089 .
## z.diff.lag12  2.604e-01  7.073e-02   3.681 0.000301 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 527600000 on 192 degrees of freedom
## Multiple R-squared:  0.4717, Adjusted R-squared:  0.4359
## F-statistic: 13.19 on 13 and 192 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: -1.9248 2.1616
##
## Critical values for test statistics:
##       1pct  5pct 10pct
```

```
## tau2 -3.46 -2.88 -2.57
## phi1  6.52  4.63  3.81
##
## [1] "Testando para a série Industrial"
## [1] "H0: Há raíz unitária"
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.5230  -1.2415   0.3347   1.3411   8.3871
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.22348    1.78397   1.807 0.072257 .
## z.lag.1     -0.03490    0.01936  -1.803 0.072905 .
## z.diff.lag  -0.23553    0.06851  -3.438 0.000711 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.345 on 203 degrees of freedom
## Multiple R-squared:  0.0764, Adjusted R-squared:  0.0673
## F-statistic: 8.396 on 2 and 203 DF,  p-value: 0.0003139
##
##
## Value of test-statistic is: -1.8028 1.6332
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.46 -2.88 -2.57
## phi1  6.52  4.63  3.81
##
## [1] "Testando para a série ICMS"
## [1] "H0: Há raíz unitária"
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -1780.23  -178.84   -26.46   175.96  1880.17
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.525e+02  8.595e+01   2.938 0.003710 **
## z.lag.1       1.715e-04  9.849e-03   0.017 0.986122
## z.diff.lag1  -6.238e-01  7.245e-02  -8.611 2.61e-15 ***
## z.diff.lag2  -5.541e-01  8.119e-02  -6.825 1.12e-10 ***
## z.diff.lag3  -4.362e-01  8.766e-02  -4.976 1.44e-06 ***
## z.diff.lag4  -4.206e-01  8.999e-02  -4.674 5.55e-06 ***
## z.diff.lag5  -3.581e-01  9.155e-02  -3.912 0.000127 ***
## z.diff.lag6  -3.596e-01  9.117e-02  -3.945 0.000112 ***
## z.diff.lag7  -4.312e-01  9.248e-02  -4.663 5.82e-06 ***
## z.diff.lag8  -3.687e-01  9.433e-02  -3.908 0.000129 ***
## z.diff.lag9  -3.914e-01  9.327e-02  -4.197 4.14e-05 ***
## z.diff.lag10 -4.092e-01  9.207e-02  -4.445 1.49e-05 ***
## z.diff.lag11 -4.343e-01  8.700e-02  -4.991 1.34e-06 ***
## z.diff.lag12  1.296e-01  7.728e-02   1.677 0.095077 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 400.5 on 192 degrees of freedom
## Multiple R-squared:  0.4771, Adjusted R-squared:  0.4417
## F-statistic: 13.48 on 13 and 192 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: 0.0174 17.2312
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.46 -2.88 -2.57
## phi1  6.52  4.63  3.81
```

Zivot Andrews

```
for (serie in colnames(df)) {
  print(paste0("Testando para a série ", serie))
  print("H0: Há raíz unitária com quebra estrutural")
  print("H1: Série estacionária com quebra")
  urca::ur.za(
    y = df[,serie],
    lag = 12,
    model = "both"
    ) %>% summary() %>% print()
}
```

```
## [1] "Testando para a série Exportacoes"
## [1] "H0: Há raíz unitária com quebra estrutural"
## [1] "H1: Série estacionária com quebra"
##
## ################################
```

```
## # Zivot-Andrews Unit Root Test #
## ################################
##
##
## Call:
## lm(formula = testmat)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.347e+09 -2.400e+08  1.334e+07  2.297e+08  1.020e+09
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.055e+08  2.225e+08   1.373  0.17131
## y.l1         7.843e-01  7.484e-02  10.481  < 2e-16 ***
## trend        1.058e+07  7.232e+06   1.462  0.14528
## y.dl1       -3.511e-01  9.290e-02  -3.780  0.00021 ***
## y.dl2       -1.144e-01  9.501e-02  -1.205  0.22989
## y.dl3        3.910e-02  9.389e-02   0.416  0.67757
## y.dl4       -7.397e-02  9.271e-02  -0.798  0.42591
## y.dl5       -1.239e-01  8.995e-02  -1.378  0.16997
## y.dl6       -1.918e-01  8.572e-02  -2.237  0.02646 *
## y.dl7       -2.397e-01  8.276e-02  -2.896  0.00423 **
## y.dl8       -2.039e-01  8.169e-02  -2.496  0.01342 *
## y.dl9       -9.137e-02  8.142e-02  -1.122  0.26319
## y.dl10      -1.385e-01  8.156e-02  -1.698  0.09117 .
## y.dl11      -1.115e-01  7.988e-02  -1.396  0.16430
## y.dl12       3.054e-01  6.990e-02   4.369 2.05e-05 ***
## du           1.719e+08  1.659e+08   1.036  0.30164
## dt          -1.149e+07  7.254e+06  -1.584  0.11486
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 409100000 on 189 degrees of freedom
##   (13 observations deleted due to missingness)
## Multiple R-squared:  0.8122, Adjusted R-squared:  0.7963
## F-statistic:  51.1 on 16 and 189 DF,  p-value: < 2.2e-16
##
##
## Teststatistic: -2.8818
## Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82
##
## Potential break point at position: 50
##
## [1] "Testando para a série Cambio"
## [1] "H0: Há raíz unitária com quebra estrutural"
## [1] "H1: Série estacionária com quebra"
##
## ################################
## # Zivot-Andrews Unit Root Test #
## ################################
##
##
## Call:
```

```
## lm(formula = testmat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.45496 -0.04701 -0.00941  0.04169  0.46228
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.3541961  0.1213606   2.919  0.00394 **
## y.l1         0.8861989  0.0356157  24.882  < 2e-16 ***
## trend       -0.0016649  0.0006909  -2.410  0.01692 *
## y.dl1        0.3487806  0.0766557   4.550 9.58e-06 ***
## y.dl2       -0.0961695  0.0792244  -1.214  0.22631
## y.dl3        0.1450471  0.0768160   1.888  0.06053 .
## y.dl4        0.1043571  0.0725657   1.438  0.15206
## y.dl5        0.0845360  0.0720134   1.174  0.24192
## y.dl6        0.1074608  0.0705246   1.524  0.12925
## y.dl7       -0.0552731  0.0704275  -0.785  0.43354
## y.dl8       -0.0612307  0.0713496  -0.858  0.39188
## y.dl9        0.0209444  0.0713066   0.294  0.76929
## y.dl10       0.0129614  0.0716790   0.181  0.85670
## y.dl11       0.0253668  0.0715588   0.354  0.72337
## y.dl12       0.0374462  0.0699241   0.536  0.59292
## du          -0.0076564  0.0284956  -0.269  0.78846
## dt           0.0046904  0.0014855   3.157  0.00185 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0982 on 189 degrees of freedom
##   (13 observations deleted due to missingness)
## Multiple R-squared:  0.9852, Adjusted R-squared:  0.9839
## F-statistic: 784.9 on 16 and 189 DF,  p-value: < 2.2e-16
##
##
## Teststatistic: -3.1953
## Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82
##
## Potential break point at position: 107
##
## [1] "Testando para a série Importacoes"
## [1] "H0: Há raíz unitária com quebra estrutural"
## [1] "H1: Série estacionária com quebra"
##
## ################################
## # Zivot-Andrews Unit Root Test #
## ################################
##
##
## Call:
## lm(formula = testmat)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.335e+09 -2.868e+08 -4.848e+06  2.495e+08  2.356e+09
```

```
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.843e+08  1.062e+08   2.676 0.008102 **
## y.l1         6.844e-01  7.234e-02   9.461  < 2e-16 ***
## trend        1.477e+07  3.566e+06   4.143 5.17e-05 ***
## y.dl1       -3.224e-01  8.804e-02  -3.662 0.000325 ***
## y.dl2       -1.977e-02  9.086e-02  -0.218 0.827955
## y.dl3        3.934e-01  8.948e-02   4.396 1.83e-05 ***
## y.dl4        4.201e-02  9.094e-02   0.462 0.644593
## y.dl5       -2.472e-02  8.883e-02  -0.278 0.781112
## y.dl6        4.720e-02  8.760e-02   0.539 0.590700
## y.dl7        3.831e-02  8.613e-02   0.445 0.657001
## y.dl8       -9.383e-02  8.360e-02  -1.122 0.263124
## y.dl9       -1.315e-01  8.273e-02  -1.589 0.113676
## y.dl10       4.331e-03  8.266e-02   0.052 0.958275
## y.dl11       1.088e-01  8.096e-02   1.344 0.180558
## y.dl12       2.495e-01  6.961e-02   3.584 0.000431 ***
## du          -1.030e+09  2.099e+08  -4.907 1.99e-06 ***
## dt          -1.414e+07  6.318e+06  -2.237 0.026436 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 499300000 on 189 degrees of freedom
##   (13 observations deleted due to missingness)
## Multiple R-squared:  0.9232, Adjusted R-squared:  0.9167
## F-statistic: 141.9 on 16 and 189 DF,  p-value: < 2.2e-16
##
##
## Teststatistic: -4.3632
## Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82
##
## Potential break point at position: 153
##
## [1] "Testando para a série Industrial"
## [1] "H0: Há raíz unitária com quebra estrutural"
## [1] "H1: Série estacionária com quebra"
##
## ################################
## # Zivot-Andrews Unit Root Test #
## ################################
##
##
## Call:
## lm(formula = testmat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.6291  -1.1759   0.1909   1.3077   8.2919
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 11.103978   3.199783   3.470 0.000644 ***
## y.l1         0.859393   0.043424  19.791  < 2e-16 ***
```

```
## trend        0.032260   0.018045   1.788 0.075413 .
## y.dl1       -0.214010   0.075904  -2.819 0.005323 **
## y.dl2       -0.037254   0.076818  -0.485 0.628262
## y.dl3        0.128869   0.076084   1.694 0.091958 .
## y.dl4        0.137208   0.076250   1.799 0.073542 .
## y.dl5        0.078655   0.076967   1.022 0.308118
## y.dl6        0.047921   0.076524   0.626 0.531921
## y.dl7       -0.008838   0.076437  -0.116 0.908069
## y.dl8        0.059272   0.076366   0.776 0.438630
## y.dl9        0.044512   0.076807   0.580 0.562924
## y.dl10       0.008700   0.077668   0.112 0.910926
## y.dl11      -0.004887   0.076886  -0.064 0.949386
## y.dl12      -0.012306   0.072136  -0.171 0.864723
## du           0.900773   0.707460   1.273 0.204493
## dt          -0.063607   0.025042  -2.540 0.011888 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.32 on 189 degrees of freedom
##   (13 observations deleted due to missingness)
## Multiple R-squared:  0.9313, Adjusted R-squared:  0.9255
## F-statistic: 160.2 on 16 and 189 DF,  p-value: < 2.2e-16
##
##
## Teststatistic: -3.238
## Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82
##
## Potential break point at position: 92
##
## [1] "Testando para a série ICMS"
## [1] "H0: Há raíz unitária com quebra estrutural"
## [1] "H1: Série estacionária com quebra"
##
## ################################
## # Zivot-Andrews Unit Root Test #
## ################################
##
##
## Call:
## lm(formula = testmat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1843.55  -169.99   -22.88   178.05  1978.75
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 846.10124  246.39879   3.434 0.000731 ***
## y.l1          0.67903    0.09879   6.873 8.85e-11 ***
## trend        16.04362    4.65901   3.444 0.000707 ***
## y.dl1        -0.38058    0.10852  -3.507 0.000566 ***
## y.dl2        -0.35002    0.10653  -3.286 0.001213 **
## y.dl3        -0.26806    0.10507  -2.551 0.011527 *
## y.dl4        -0.28281    0.10282  -2.751 0.006527 **
```

```
## y.dl5        -0.25036    0.10057  -2.489 0.013664 *
## y.dl6        -0.27694    0.09756  -2.839 0.005025 **
## y.dl7        -0.37360    0.09677  -3.861 0.000155 ***
## y.dl8        -0.33739    0.09672  -3.488 0.000605 ***
## y.dl9        -0.37791    0.09437  -4.005 8.92e-05 ***
## y.dl10       -0.41629    0.09206  -4.522 1.08e-05 ***
## y.dl11       -0.44948    0.08608  -5.222 4.65e-07 ***
## y.dl12        0.09589    0.07615   1.259 0.209485
## du          361.52647  144.83771   2.496 0.013413 *
## dt           -4.97693    2.12753  -2.339 0.020365 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 388.4 on 189 degrees of freedom
##   (13 observations deleted due to missingness)
## Multiple R-squared:  0.9834, Adjusted R-squared:  0.982
## F-statistic: 699.9 on 16 and 189 DF,  p-value: < 2.2e-16
##
##
## Teststatistic: -3.249
## Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82
##
## Potential break point at position: 95
```

KPSS

```
for (serie in colnames(df)) {
  print(paste0("Testando para a série ", serie))
  print("H0: Série é estacionária em terno da tendência (trend stationary)")
  print("H1: Raíz unitária")
  urca::ur.kpss(
    y = df[,serie],
    ) %>% summary() %>% print()
}
```

```
## [1] "Testando para a série Exportacoes"
## [1] "H0: Série é estacionária em terno da tendência (trend stationary)"
## [1] "H1: Raíz unitária"
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 4 lags.
##
## Value of test-statistic is: 1.9863
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
##
## [1] "Testando para a série Cambio"
```

```
## [1] "H0: Série é estacionária em terno da tendência (trend stationary)"
## [1] "H1: Raíz unitária"
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 4 lags.
##
## Value of test-statistic is: 1.6839
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
##
## [1] "Testando para a série Importacoes"
## [1] "H0: Série é estacionária em terno da tendência (trend stationary)"
## [1] "H1: Raíz unitária"
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 4 lags.
##
## Value of test-statistic is: 2.3707
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
##
## [1] "Testando para a série Industrial"
## [1] "H0: Série é estacionária em terno da tendência (trend stationary)"
## [1] "H1: Raíz unitária"
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 4 lags.
##
## Value of test-statistic is: 0.9397
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
##
## [1] "Testando para a série ICMS"
## [1] "H0: Série é estacionária em terno da tendência (trend stationary)"
## [1] "H1: Raíz unitária"
##
## ########################
## # KPSS Unit Root Test #
## ########################
```

```
##
## Test is of type: mu with 4 lags.
##
## Value of test-statistic is: 4.4477
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
```

Phillips-Perron

```
for (serie in colnames(df)) {
  print(paste0("Testando para a série ", serie))
  print("H0: Série é integrada de ordem 1")
  urca::ur.pp(
    x = df[,serie],
    ) %>% summary() %>% print()
}
```

```
## [1] "Testando para a série Exportacoes"
## [1] "H0: Série é integrada de ordem 1"
##
## ###################################
## # Phillips-Perron Unit Root Test #
## ###################################
##
## Test regression with intercept
##
##
## Call:
## lm(formula = y ~ y.l1)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.811e+09 -3.092e+08 -4.519e+06  3.715e+08  1.484e+09
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 5.922e+08  1.356e+08   4.368 1.95e-05 ***
## y.l1        8.484e-01  3.415e-02  24.843  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 522400000 on 216 degrees of freedom
## Multiple R-squared:  0.7408, Adjusted R-squared:  0.7396
## F-statistic: 617.2 on 1 and 216 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic, type: Z-alpha  is: -24.3589
##
##          aux. Z statistics
## Z-tau-mu            3.9067
```

```
##
## [1] "Testando para a série Cambio"
## [1] "H0: Série é integrada de ordem 1"
##
## ###################################
## # Phillips-Perron Unit Root Test #
## ###################################
##
## Test regression with intercept
##
##
## Call:
## lm(formula = y ~ y.l1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.38293 -0.06272 -0.01421  0.05244  0.51597
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.01177    0.02822  -0.417    0.677
## y.l1         1.00889    0.01037  97.298   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.115 on 216 degrees of freedom
## Multiple R-squared:  0.9777, Adjusted R-squared:  0.9776
## F-statistic:  9467 on 1 and 216 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic, type: Z-alpha  is: 0.4412
##
##          aux. Z statistics
## Z-tau-mu            0.1848
##
## [1] "Testando para a série Importacoes"
## [1] "H0: Série é integrada de ordem 1"
##
## ###################################
## # Phillips-Perron Unit Root Test #
## ###################################
##
## Test regression with intercept
##
##
## Call:
## lm(formula = y ~ y.l1)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.005e+09 -3.560e+08 -4.423e+07  3.522e+08  3.083e+09
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) 3.644e+08  1.232e+08   2.958  0.00344 **
## y.l1        9.246e-01  2.482e-02  37.245  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 672500000 on 216 degrees of freedom
## Multiple R-squared:  0.8653, Adjusted R-squared:  0.8646
## F-statistic:  1387 on 1 and 216 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic, type: Z-alpha  is: -9.5787
##
##          aux. Z statistics
## Z-tau-mu            2.4388
##
## [1] "Testando para a série Industrial"
## [1] "H0: Série é integrada de ordem 1"
##
## ###################################
## # Phillips-Perron Unit Root Test #
## ###################################
##
## Test regression with intercept
##
##
## Call:
## lm(formula = y ~ y.l1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.608  -1.288   0.387   1.304  10.953
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.58054    1.66483   2.151   0.0326 *
## y.l1         0.96081    0.01821  52.754   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.396 on 216 degrees of freedom
## Multiple R-squared:  0.928,  Adjusted R-squared:  0.9276
## F-statistic:  2783 on 1 and 216 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic, type: Z-alpha  is: -6.2859
##
##          aux. Z statistics
## Z-tau-mu            1.8762
##
## [1] "Testando para a série ICMS"
## [1] "H0: Série é integrada de ordem 1"
##
## ###################################
## # Phillips-Perron Unit Root Test #
```

```
## ###################################
##
## Test regression with intercept
##
##
## Call:
## lm(formula = y ~ y.l1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1894.74  -224.94    14.17   258.73  2073.08
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 160.40045   96.70859   1.659   0.0986 .
## y.l1          0.98456    0.01177  83.623   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 524.8 on 216 degrees of freedom
## Multiple R-squared:   0.97,  Adjusted R-squared:  0.9699
## F-statistic:  6993 on 1 and 216 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic, type: Z-alpha  is: -1.2048
##
##          aux. Z statistics
## Z-tau-mu            1.4985
```

Testes de cointegração

Procedimento de Johansen

```
# # Desativado: system is computationally singular
# urca::ca.jo( # H0: r = r* < k, vs. H1: r = k
#     x = df %>% as.ts(),
#     ecdet = "const",
#     type = "trace",
#     K = VARselect(df)[["selection"]]["AIC(n)"] %>% as.numeric(), # Ordem do VAR de acordo com o crité
#     #season = 12 # Dummies mensais
# ) %>% summary()
```

Procedimento de Phillips-Ouliares

```
urca::ca.po( # null hypothesis of no-cointegration (unit root in the residuals)
    z = df,
    demean = "constant",
    type = 'Pz'
) %>% summary()
```

```
##
## ########################################
## # Phillips and Ouliaris Unit Root Test #
## ########################################
##
## Test of type Pz
## detrending of series with constant only
##
## Response Exportacoes :
##
## Call:
## lm(formula = Exportacoes ~ zr)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.624e+09 -2.693e+08  4.078e+07  2.640e+08  1.227e+09
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -8.856e+08  1.003e+09  -0.883   0.3781
## zrExportacoes  5.605e-01  6.192e-02   9.052   <2e-16 ***
## zrCambio      -7.483e+07  1.182e+08  -0.633   0.5272
## zrImportacoes  1.001e-02  5.037e-02   0.199   0.8427
## zrIndustrial   2.474e+07  1.009e+07   2.452   0.0150 *
## zrICMS         6.285e+04  3.019e+04   2.082   0.0385 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 491800000 on 212 degrees of freedom
## Multiple R-squared:  0.7744, Adjusted R-squared:  0.7691
## F-statistic: 145.6 on 5 and 212 DF,  p-value: < 2.2e-16
##
##
## Response Cambio :
##
## Call:
## lm(formula = Cambio ~ zr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.37137 -0.05762 -0.00588  0.04382  0.53569
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    4.102e-01  2.278e-01   1.800  0.07320 .
## zrExportacoes -2.407e-11  1.407e-11  -1.711  0.08858 .
## zrCambio       9.793e-01  2.685e-02  36.471  < 2e-16 ***
## zrImportacoes  3.221e-11  1.145e-11   2.814  0.00535 **
## zrIndustrial  -4.540e-03  2.293e-03  -1.980  0.04897 *
## zrICMS         1.585e-06  6.860e-06   0.231  0.81755
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1118 on 212 degrees of freedom
```

```
## Multiple R-squared:  0.9793, Adjusted R-squared:  0.9788
## F-statistic:  2008 on 5 and 212 DF,  p-value: < 2.2e-16
##
##
## Response Importacoes :
##
## Call:
## lm(formula = Importacoes ~ zr)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.302e+09 -3.528e+08 -1.217e+07  3.325e+08  2.875e+09
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -2.761e+09  1.193e+09  -2.314   0.0216 *
## zrExportacoes -5.606e-02  7.368e-02  -0.761   0.4476
## zrCambio      -3.619e+08  1.406e+08  -2.574   0.0107 *
## zrImportacoes  4.632e-01  5.994e-02   7.729 4.29e-13 ***
## zrIndustrial   5.098e+07  1.201e+07   4.246 3.25e-05 ***
## zrICMS         2.326e+05  3.592e+04   6.476 6.46e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 585300000 on 212 degrees of freedom
## Multiple R-squared:  0.8998, Adjusted R-squared:  0.8975
## F-statistic: 380.9 on 5 and 212 DF,  p-value: < 2.2e-16
##
##
## Response Industrial :
##
## Call:
## lm(formula = Industrial ~ zr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.7459  -1.1404   0.3557   1.2454  10.0818
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    2.499e+01  4.635e+00   5.391 1.86e-07 ***
## zrExportacoes  3.205e-10  2.862e-10   1.120    0.264
## zrCambio      -2.551e+00  5.462e-01  -4.670 5.35e-06 ***
## zrImportacoes -7.755e-11  2.329e-10  -0.333    0.739
## zrIndustrial   7.694e-01  4.664e-02  16.497  < 2e-16 ***
## zrICMS         2.362e-04  1.396e-04   1.693    0.092 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.274 on 212 degrees of freedom
## Multiple R-squared:  0.9364, Adjusted R-squared:  0.9349
## F-statistic: 623.8 on 5 and 212 DF,  p-value: < 2.2e-16
##
##
```

```
## Response ICMS :
##
## Call:
## lm(formula = ICMS ~ zr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1677.08  -230.40   -12.25   278.17  2212.46
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -1.333e+03  1.056e+03  -1.262   0.2084
## zrExportacoes  6.935e-08  6.524e-08   1.063   0.2890
## zrCambio       3.005e+02  1.245e+02   2.414   0.0166 *
## zrImportacoes  1.020e-07  5.307e-08   1.922   0.0559 .
## zrIndustrial   7.092e+00  1.063e+01   0.667   0.5054
## zrICMS         8.963e-01  3.181e-02  28.181   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 518.2 on 212 degrees of freedom
## Multiple R-squared:  0.9713, Adjusted R-squared:  0.9707
## F-statistic:  1437 on 5 and 212 DF,  p-value: < 2.2e-16
##
##
##
## Value of test-statistic is: 370.6368
##
## Critical values of Pz are:
##                    10pct     5pct     1pct
## critical values 168.8572 182.0749 209.8054
```