# VAR

gpetrini

19/05/2020

## 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 |

# Estimação

## Ordem do modelo

```
vars::VARselect(
    df %>% log() %>%  diff() %>% na.omit(),
    lag.max = 15,
    type = 'const'
    )$selection -> ordem
ordem %>% knitr::kable(col.names = "Ordem do modelo")
```

| | Ordem do modelo |
|---|---|
| AIC(n) | 14 |
| HQ(n) | 3 |
| SC(n) | 1 |
| FPE(n) | 4 |

```
vars::VAR(
    df %>% log() %>%  diff() %>% na.omit(),
    type = 'const',
    season = 12,
    lag.max = 15,
    ic = "SC"
    ) -> modelo
modelo %>% summary()
```

```
##
## VAR Estimation Results:
## ========================
## Endogenous variables: Exportacoes, Cambio, Importacoes, Industrial, ICMS
## Deterministic variables: const
## Sample size: 217
## Log Likelihood: 1756.032
## Roots of the characteristic polynomial:
## 0.5343 0.5266 0.5266 0.4259 0.2282
## Call:
## vars::VAR(y = df %>% log() %>% diff() %>% na.omit(), type = "const",
##     season = 12L, lag.max = 15, ic = "SC")
##
##
```

```
## Estimation results for equation Exportacoes:
## ============================================
## Exportacoes = Exportacoes.l1 + Cambio.l1 + Importacoes.l1 + Industrial.l1 + ICMS.l1 + const + sd1 + s
##
##                 Estimate Std. Error t value Pr(>|t|)
## Exportacoes.l1 -0.539974   0.070951  -7.610 1.05e-12 ***
## Cambio.l1      -0.217077   0.164626  -1.319 0.188810
## Importacoes.l1  0.073196   0.066936   1.094 0.275481
## Industrial.l1   0.177017   0.229522   0.771 0.441474
## ICMS.l1        -0.048038   0.113232  -0.424 0.671840
## const           0.006747   0.006093   1.107 0.269495
## sd1             0.112353   0.047246   2.378 0.018347 *
## sd2             0.420378   0.031777  13.229  < 2e-16 ***
## sd3             0.253661   0.033545   7.562 1.41e-12 ***
## sd4             0.263475   0.032921   8.003 9.68e-14 ***
## sd5             0.304474   0.032520   9.363  < 2e-16 ***
## sd6             0.248283   0.031394   7.909 1.73e-13 ***
## sd7             0.269706   0.034133   7.902 1.81e-13 ***
## sd8             0.231458   0.031913   7.253 8.77e-12 ***
## sd9             0.211814   0.032070   6.605 3.52e-10 ***
## sd10            0.133320   0.033723   3.953 0.000107 ***
## sd11            0.276756   0.033160   8.346 1.15e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.08888 on 200 degrees of freedom
## Multiple R-Squared: 0.6637,  Adjusted R-squared: 0.6368
## F-statistic: 24.66 on 16 and 200 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation Cambio:
## =======================================
## Cambio = Exportacoes.l1 + Cambio.l1 + Importacoes.l1 + Industrial.l1 + ICMS.l1 + const + sd1 + sd2 +
##
##                 Estimate Std. Error t value Pr(>|t|)
## Exportacoes.l1 -0.036928   0.028706  -1.286   0.1998
## Cambio.l1       0.410045   0.066605   6.156    4e-09 ***
## Importacoes.l1  0.021620   0.027081   0.798   0.4256
## Industrial.l1  -0.069418   0.092861  -0.748   0.4556
## ICMS.l1        -0.022631   0.045812  -0.494   0.6218
## const           0.002313   0.002465   0.938   0.3492
## sd1             0.001034   0.019115   0.054   0.9569
## sd2             0.022089   0.012857   1.718   0.0873 .
## sd3            -0.003364   0.013572  -0.248   0.8045
## sd4             0.028416   0.013319   2.133   0.0341 *
## sd5             0.012957   0.013157   0.985   0.3259
## sd6             0.006085   0.012701   0.479   0.6324
## sd7             0.028359   0.013810   2.054   0.0413 *
## sd8             0.022905   0.012911   1.774   0.0776 .
## sd9             0.008660   0.012975   0.667   0.5053
## sd10            0.016849   0.013644   1.235   0.2183
## sd11            0.019141   0.013416   1.427   0.1552
## ---
```

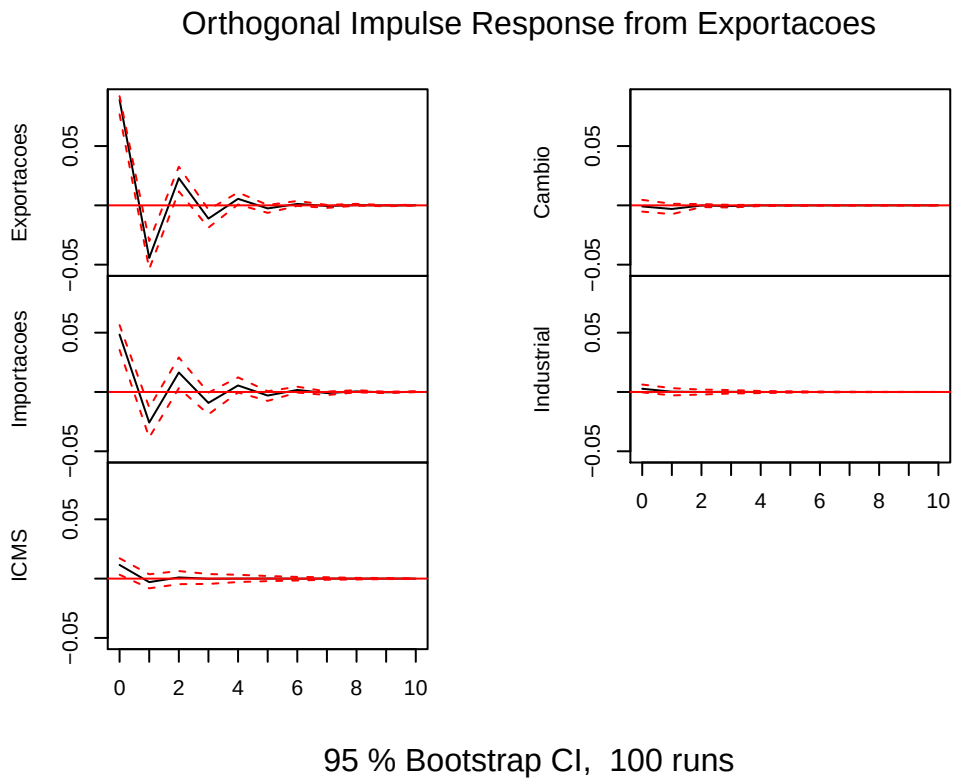
```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.03596 on 200 degrees of freedom
## Multiple R-Squared: 0.2284,  Adjusted R-squared: 0.1666
## F-statistic: 3.699 on 16 and 200 DF,  p-value: 6e-06
##
##
## Estimation results for equation Importacoes:
## ============================================
## Importacoes = Exportacoes.l1 + Cambio.l1 + Importacoes.l1 + Industrial.l1 + ICMS.l1 + const + sd1 + s
##
##                 Estimate Std. Error t value Pr(>|t|)
## Exportacoes.l1 -0.061351   0.075730  -0.810   0.4188
## Cambio.l1      -0.438747   0.175715  -2.497   0.0133 *
## Importacoes.l1 -0.486494   0.071445  -6.809 1.12e-10 ***
## Industrial.l1   0.567441   0.244982   2.316   0.0216 *
## ICMS.l1         0.109200   0.120858   0.904   0.3673
## const           0.007855   0.006503   1.208   0.2285
## sd1            -0.128451   0.050428  -2.547   0.0116 *
## sd2             0.069529   0.033918   2.050   0.0417 *
## sd3             0.013565   0.035804   0.379   0.7052
## sd4            -0.027119   0.035138  -0.772   0.4412
## sd5            -0.014945   0.034710  -0.431   0.6672
## sd6             0.016997   0.033508   0.507   0.6125
## sd7             0.012343   0.036432   0.339   0.7351
## sd8            -0.045315   0.034062  -1.330   0.1849
## sd9             0.006543   0.034230   0.191   0.8486
## sd10           -0.089277   0.035994  -2.480   0.0140 *
## sd11           -0.183345   0.035394  -5.180 5.39e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.09487 on 200 degrees of freedom
## Multiple R-Squared: 0.5207,  Adjusted R-squared: 0.4823
## F-statistic: 13.58 on 16 and 200 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation Industrial:
## ==========================================
## Industrial = Exportacoes.l1 + Cambio.l1 + Importacoes.l1 + Industrial.l1 + ICMS.l1 + const + sd1 + sd
##
##                  Estimate Std. Error t value Pr(>|t|)
## Exportacoes.l1  0.0057460  0.0209208   0.275  0.78386
## Cambio.l1      -0.1407023  0.0485420  -2.899  0.00417 **
## Importacoes.l1 -0.0005420  0.0197369  -0.027  0.97812
## Industrial.l1  -0.2723940  0.0676773  -4.025 8.08e-05 ***
## ICMS.l1         0.0331497  0.0333877   0.993  0.32197
## const           0.0002843  0.0017965   0.158  0.87443
## sd1             0.0011327  0.0139311   0.081  0.93528
## sd2             0.0032366  0.0093700   0.345  0.73014
## sd3            -0.0017824  0.0098911  -0.180  0.85718
## sd4            -0.0083026  0.0097071  -0.855  0.39340
```

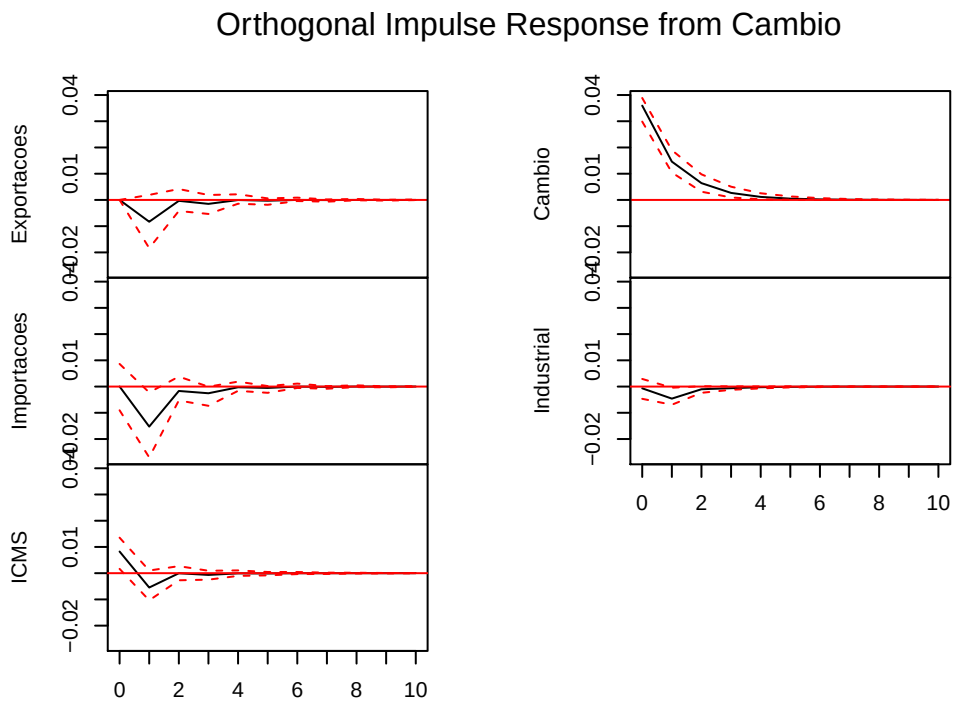
```
## sd5             0.0064338  0.0095888   0.671  0.50302
## sd6            -0.0010466  0.0092568  -0.113  0.91009
## sd7            -0.0035343  0.0100644  -0.351  0.72584
## sd8             0.0074097  0.0094099   0.787  0.43196
## sd9             0.0039912  0.0094562   0.422  0.67342
## sd10           -0.0027633  0.0099435  -0.278  0.78138
## sd11           -0.0072150  0.0097777  -0.738  0.46144
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.02621 on 200 degrees of freedom
## Multiple R-Squared: 0.129,   Adjusted R-squared: 0.05935
## F-statistic: 1.852 on 16 and 200 DF,  p-value: 0.02694
##
##
## Estimation results for equation ICMS:
## =====================================
## ICMS = Exportacoes.l1 + Cambio.l1 + Importacoes.l1 + Industrial.l1 + ICMS.l1 + const + sd1 + sd2 + s
##
##                 Estimate Std. Error t value Pr(>|t|)
## Exportacoes.l1  0.016756   0.038967   0.430 0.667663
## Cambio.l1      -0.030917   0.090414  -0.342 0.732748
## Importacoes.l1 -0.002382   0.036762  -0.065 0.948392
## Industrial.l1   0.466835   0.126055   3.703 0.000275 ***
## ICMS.l1        -0.489211   0.062187  -7.867 2.24e-13 ***
## const           0.010085   0.003346   3.014 0.002915 **
## sd1            -0.042313   0.025948  -1.631 0.104527
## sd2             0.045617   0.017452   2.614 0.009635 **
## sd3             0.089882   0.018423   4.879 2.18e-06 ***
## sd4             0.051304   0.018080   2.838 0.005014 **
## sd5             0.055305   0.017860   3.097 0.002239 **
## sd6             0.043129   0.017242   2.501 0.013171 *
## sd7             0.054599   0.018746   2.913 0.003992 **
## sd8             0.086790   0.017527   4.952 1.56e-06 ***
## sd9             0.088701   0.017613   5.036 1.06e-06 ***
## sd10            0.044474   0.018521   2.401 0.017253 *
## sd11            0.092336   0.018212   5.070 9.03e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.04882 on 200 degrees of freedom
## Multiple R-Squared: 0.4995,  Adjusted R-squared: 0.4594
## F-statistic: 12.47 on 16 and 200 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##             Exportacoes     Cambio Importacoes Industrial      ICMS
## Exportacoes   7.900e-03 -8.198e-05   4.298e-03  2.418e-04 0.0010258
## Cambio       -8.198e-05  1.293e-03  -4.389e-05 -2.665e-05 0.0002862
## Importacoes   4.298e-03 -4.389e-05   9.000e-03  3.082e-04 0.0011457
## Industrial    2.418e-04 -2.665e-05   3.082e-04  6.869e-04 0.0001559
```

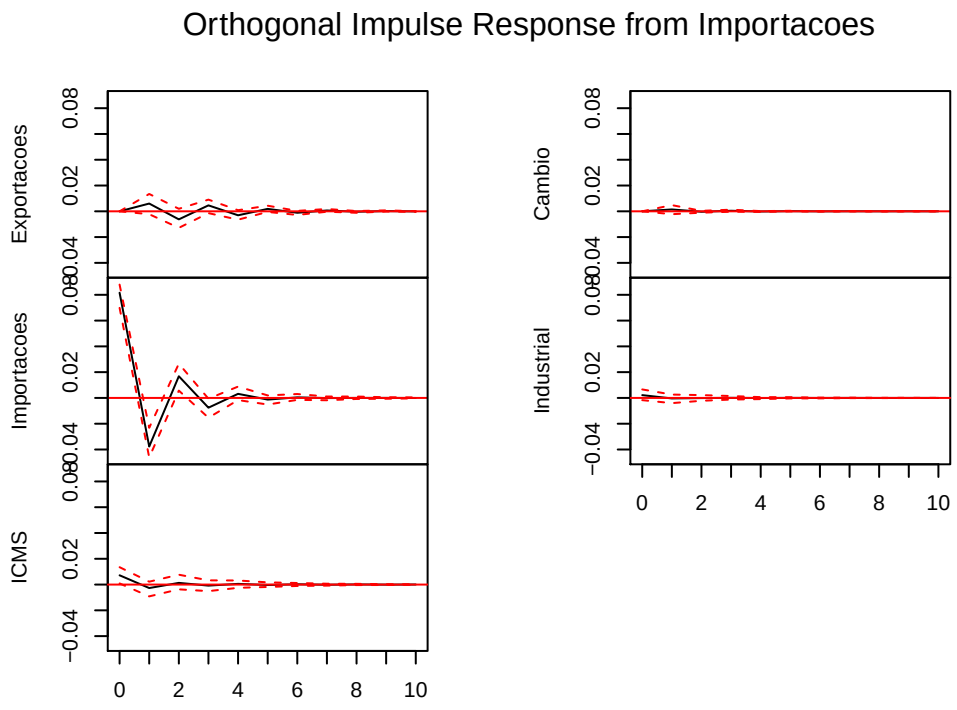
```
## ICMS          1.026e-03  2.862e-04   1.146e-03  1.559e-04 0.0023829
##
## Correlation matrix of residuals:
##             Exportacoes   Cambio Importacoes Industrial   ICMS
## Exportacoes     1.00000 -0.02565     0.50969    0.10380 0.2364
## Cambio         -0.02565  1.00000    -0.01286   -0.02827 0.1630
## Importacoes     0.50969 -0.01286     1.00000    0.12396 0.2474
## Industrial      0.10380 -0.02827     0.12396    1.00000 0.1218
## ICMS            0.23641  0.16301     0.24738    0.12184 1.0000
```

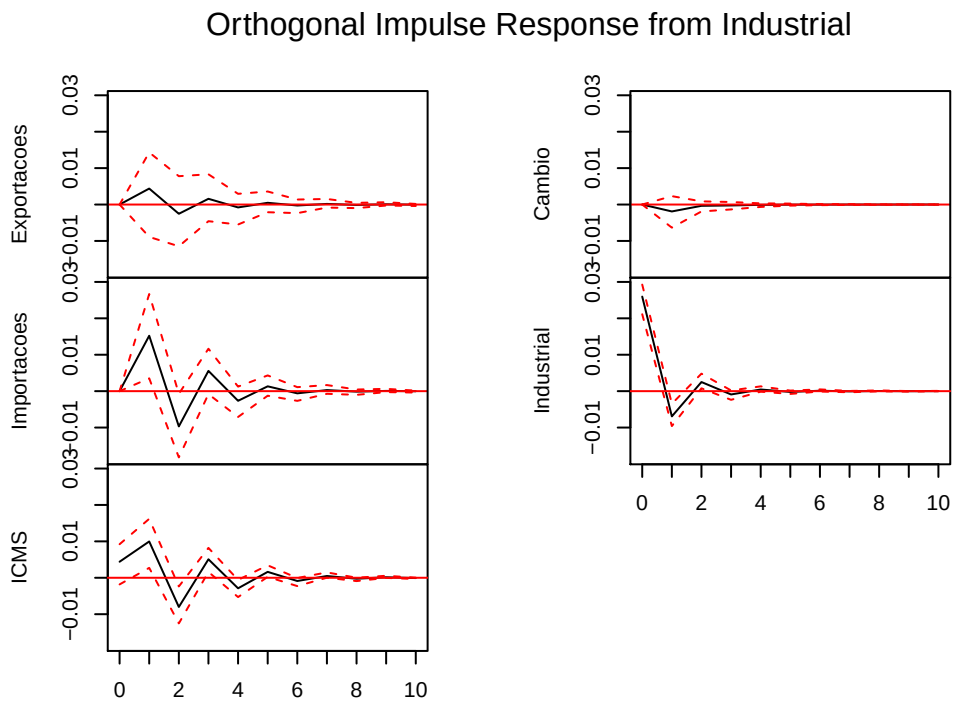
### Respolta ao Impulso

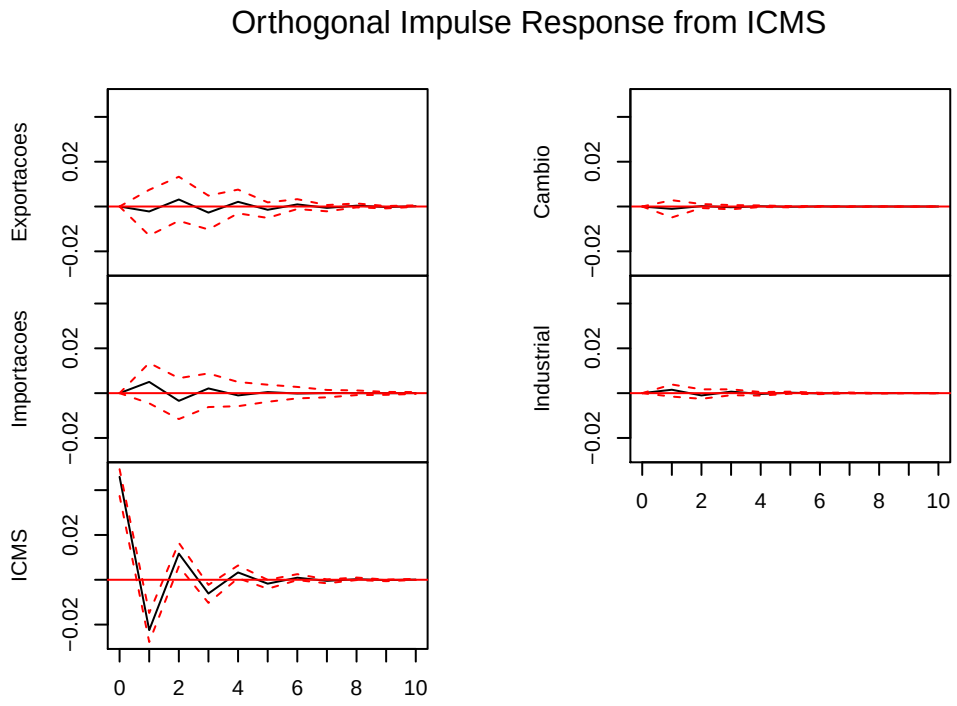
```
vars::irf(modelo) %>% plot()
```




Orthogonal Impulse Response from Cambio
Exportacoes
Importacoes
ICMS
Cambio
Industrial
0.04
0.01
−0.02
0
2
4
6
8
10
95 % Bootstrap CI, 100 runs

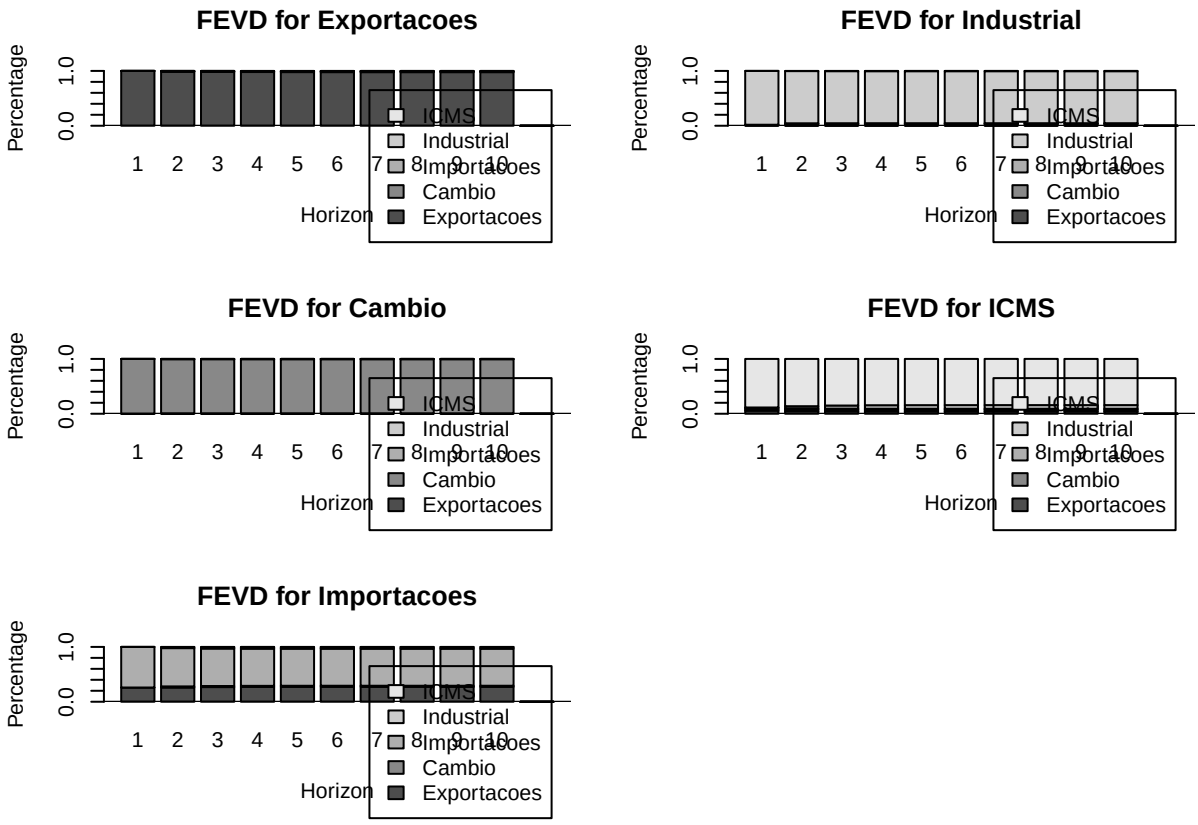

Orthogonal Impulse Response from Importacoes
Exportacoes
Importacoes
ICMS
Cambio
Industrial
0.08
0.02
−0.04
0
2
4
6
8
10
95 % Bootstrap CI, 100 runs


Orthogonal Impulse Response from Industrial
Exportacoes
Importacoes
ICMS
Cambio
Industrial
0.03
0.01
−0.01
0
2
4
6
8
10
95 % Bootstrap CI, 100 runs




## FEVD

```
vars::fevd(modelo) %>% plot()
```




# Pós-Estimação

```
roots(modelo) %>% knitr::kable(col.names = "Raizes")
```

| Raizes |
|---|
| 0.5342792 |
| 0.5265614 |
| 0.5265614 |
| 0.4259314 |
| 0.2281572 |

```
stability(modelo, type = c("OLS-CUSUM"), h=0.15)
```

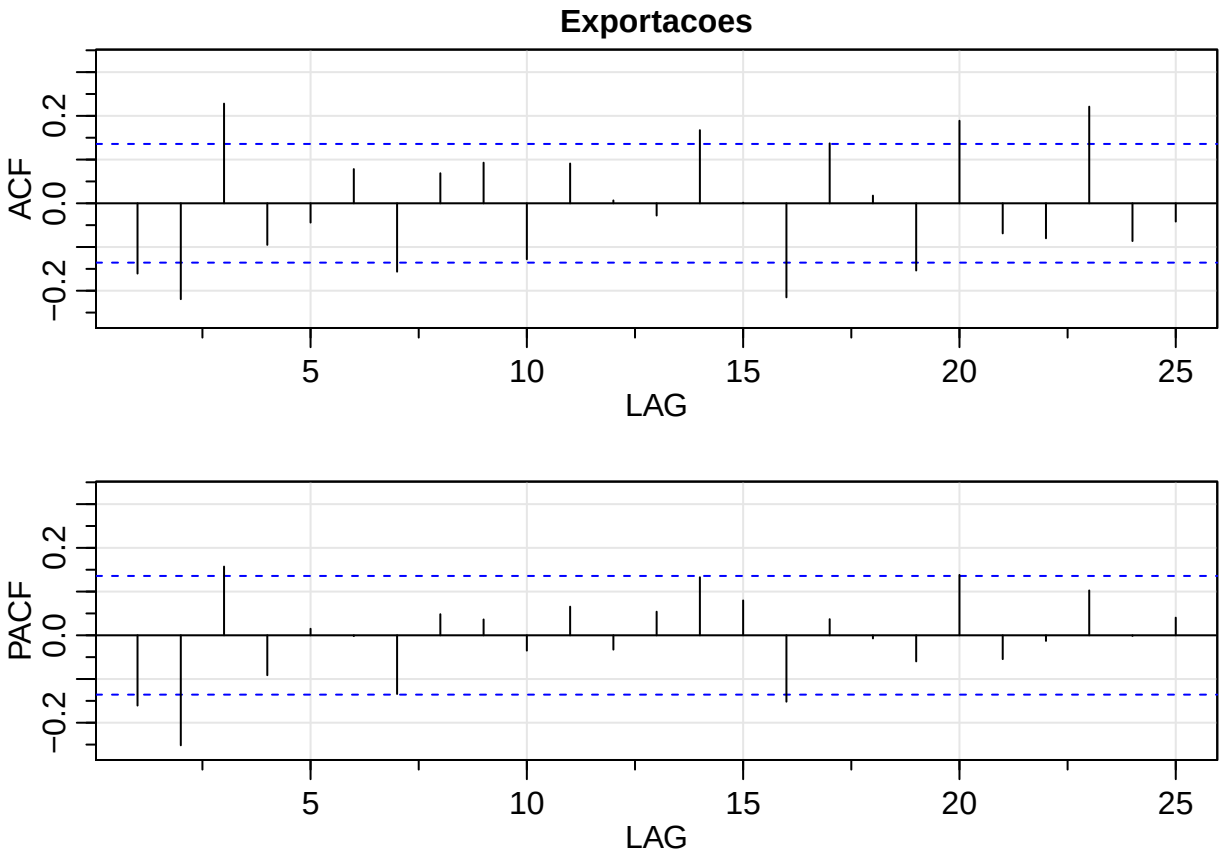
```
## $Exportacoes
##
## Empirical Fluctuation Process: OLS-based CUSUM test
##
## Call: efp(formula = formula, data = data, type = type, h = h, dynamic = dynamic,
##     rescale = rescale)
##
##
```

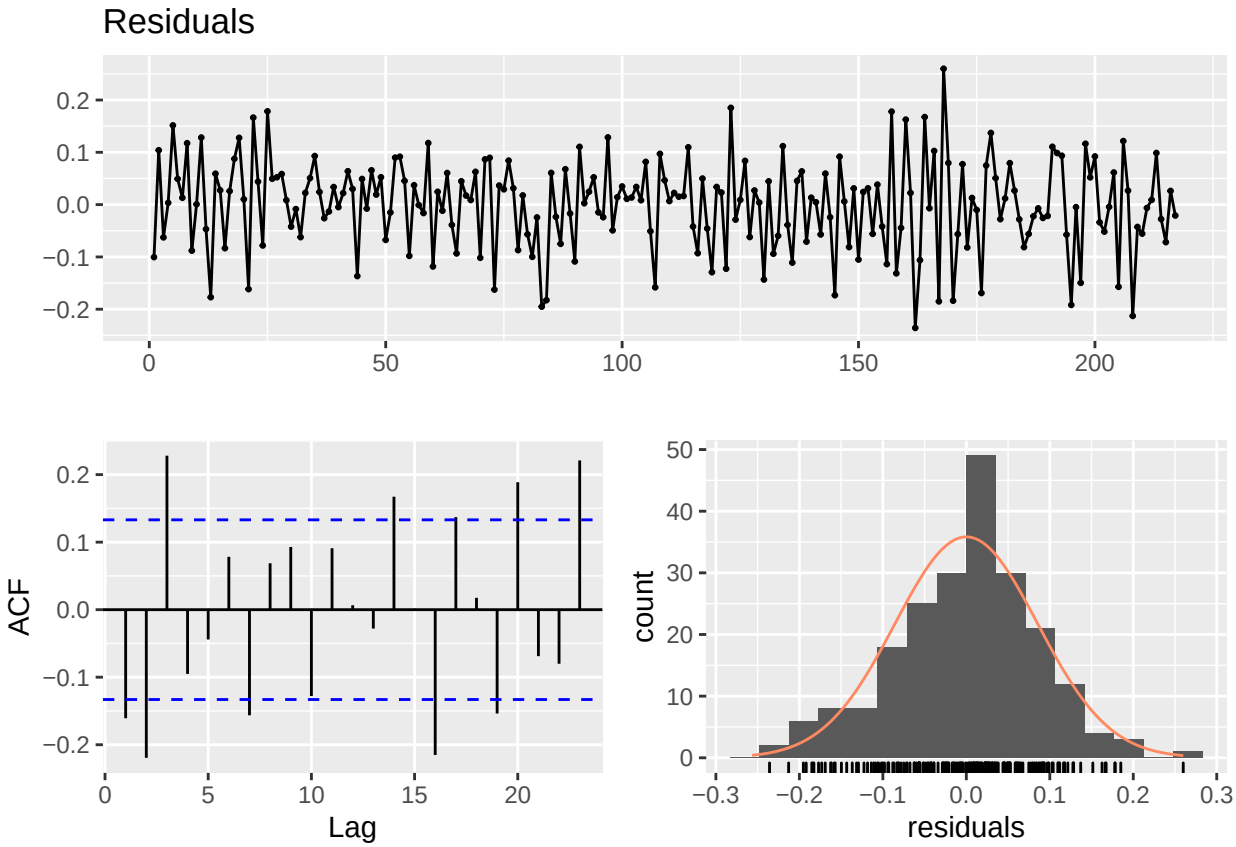
```
## $Cambio
##
## Empirical Fluctuation Process: OLS-based CUSUM test
##
## Call: efp(formula = formula, data = data, type = type, h = h, dynamic = dynamic,
##     rescale = rescale)
##
##
## $Importacoes
##
## Empirical Fluctuation Process: OLS-based CUSUM test
##
## Call: efp(formula = formula, data = data, type = type, h = h, dynamic = dynamic,
##     rescale = rescale)
##
##
## $Industrial
##
## Empirical Fluctuation Process: OLS-based CUSUM test
##
## Call: efp(formula = formula, data = data, type = type, h = h, dynamic = dynamic,
##     rescale = rescale)
##
##
## $ICMS
##
## Empirical Fluctuation Process: OLS-based CUSUM test
##
## Call: efp(formula = formula, data = data, type = type, h = h, dynamic = dynamic,
##     rescale = rescale)
```

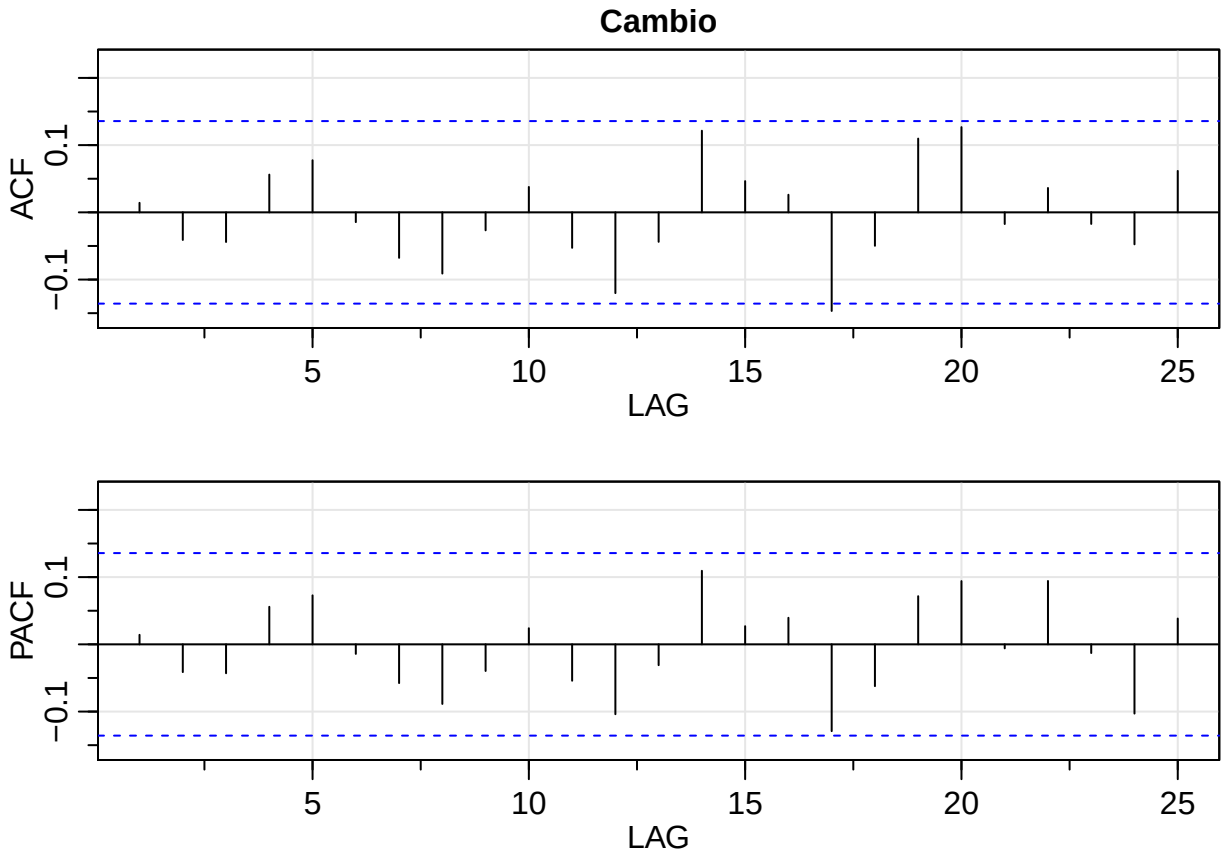
## Resíduos

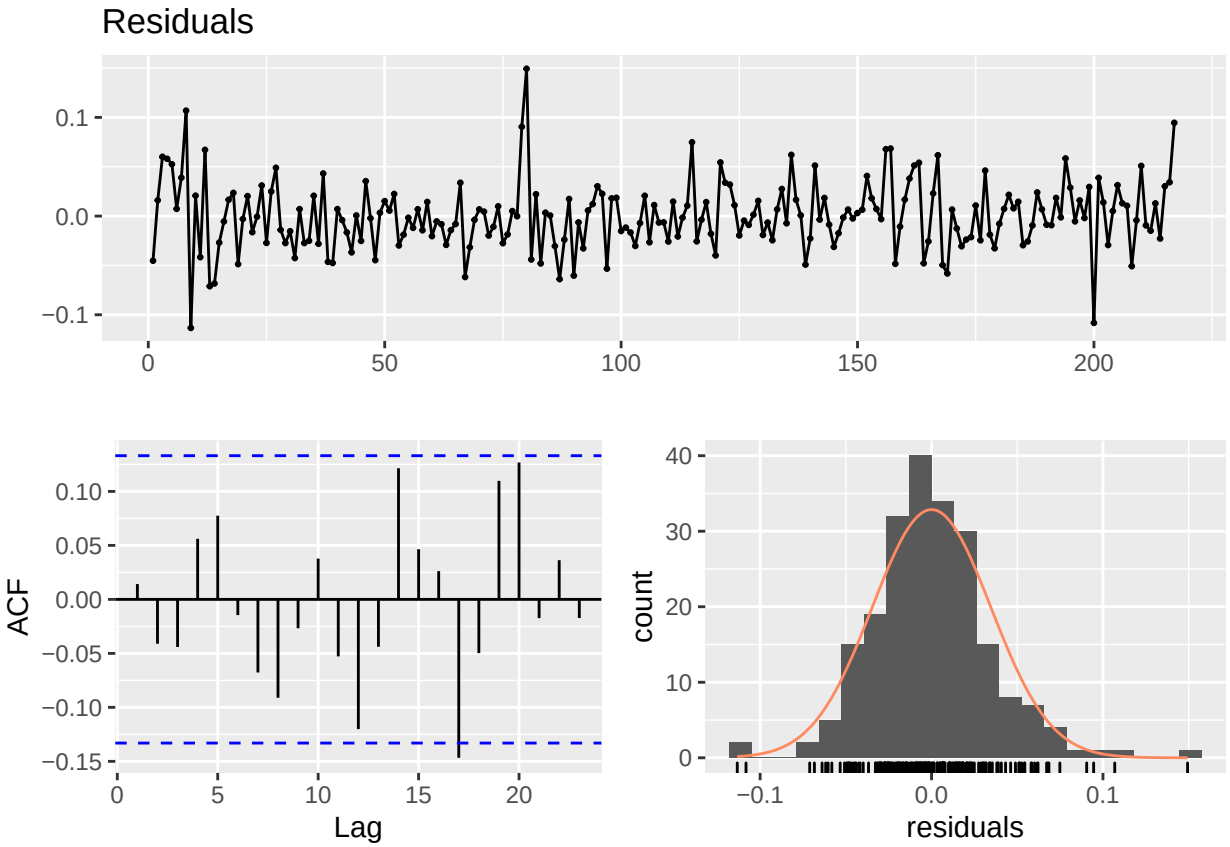
### Correlograma

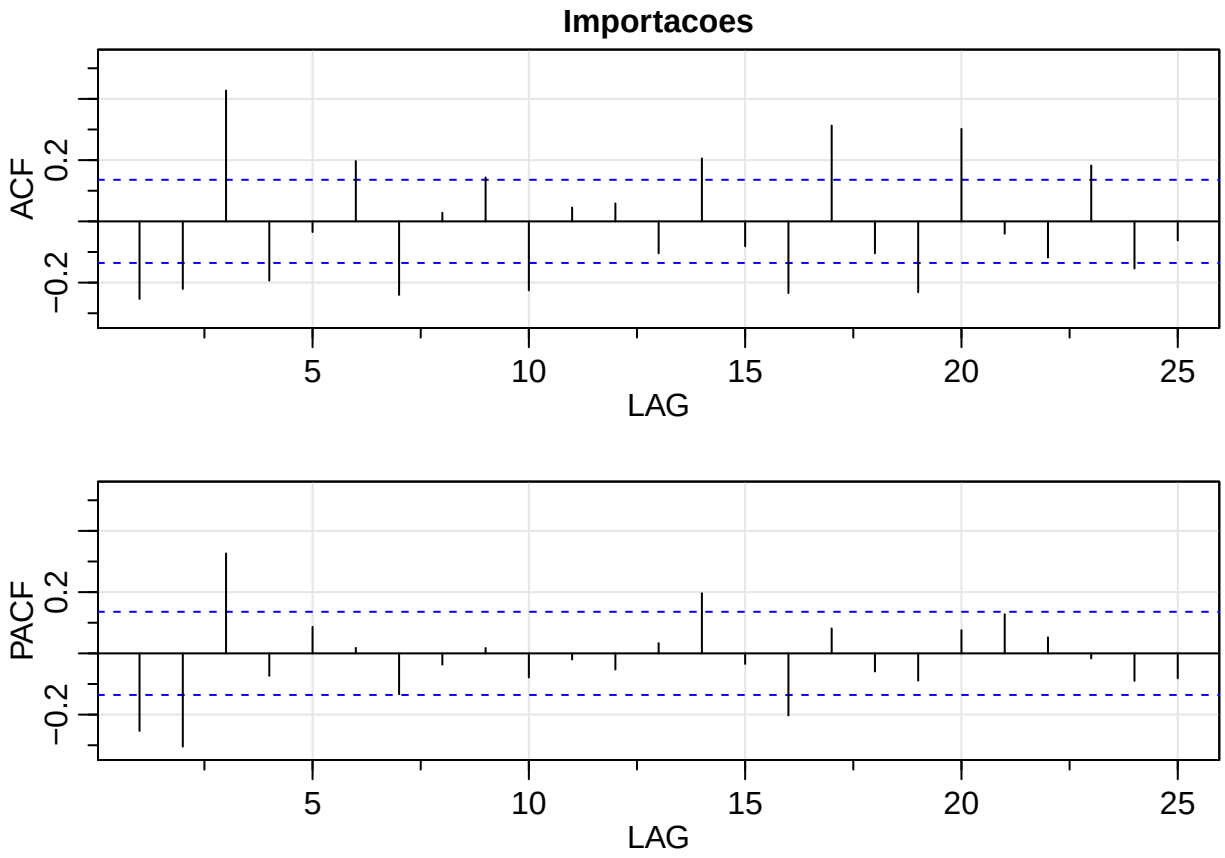
```
for (serie in colnames(df)) {
    astsa::acf2(
        residuals(modelo)[,serie],
        main = serie
    )
    forecast::checkresiduals(
        residuals(modelo)[,serie],
        main = serie
        )
}
```

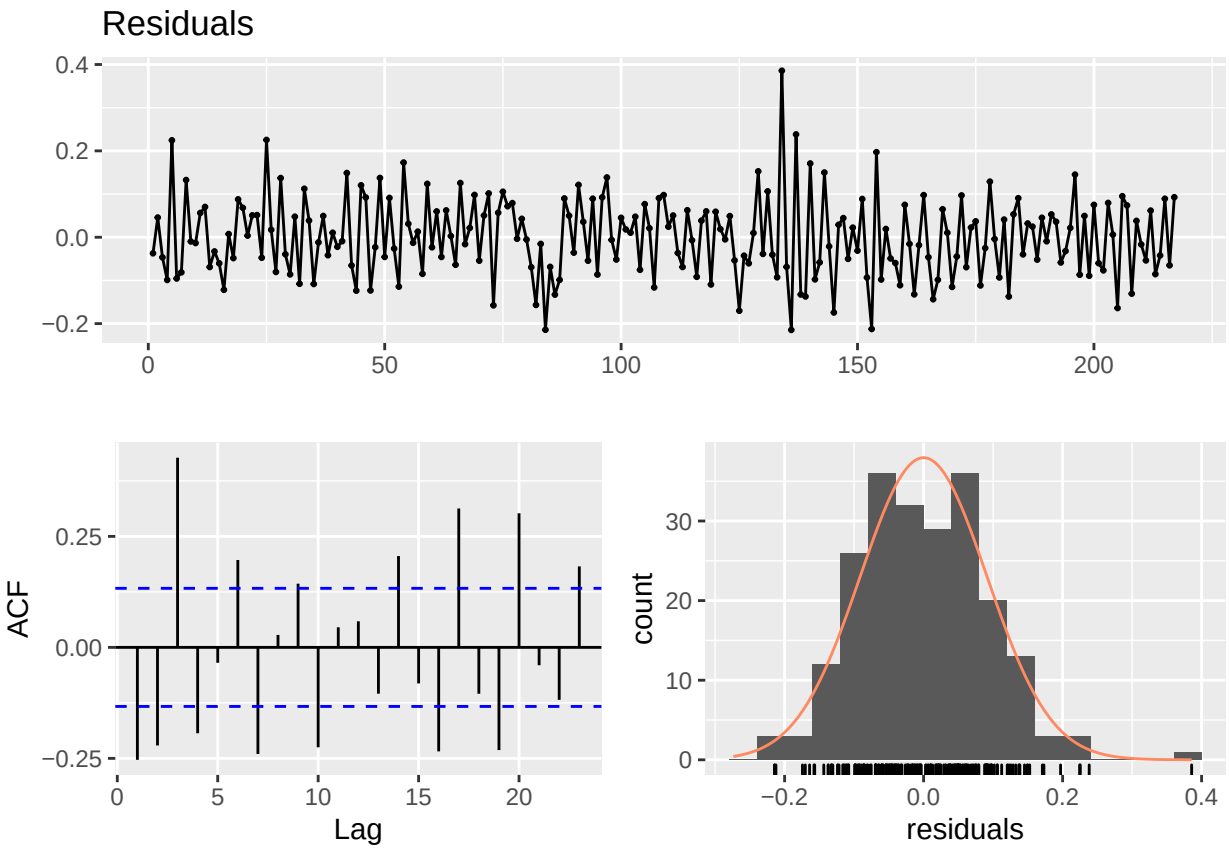

Exportacoes
ACF
0.2
0.0
−0.2
5
10
15
20
25
LAG
PACF
0.2
0.0
−0.2
5
10
15
20
25
LAG

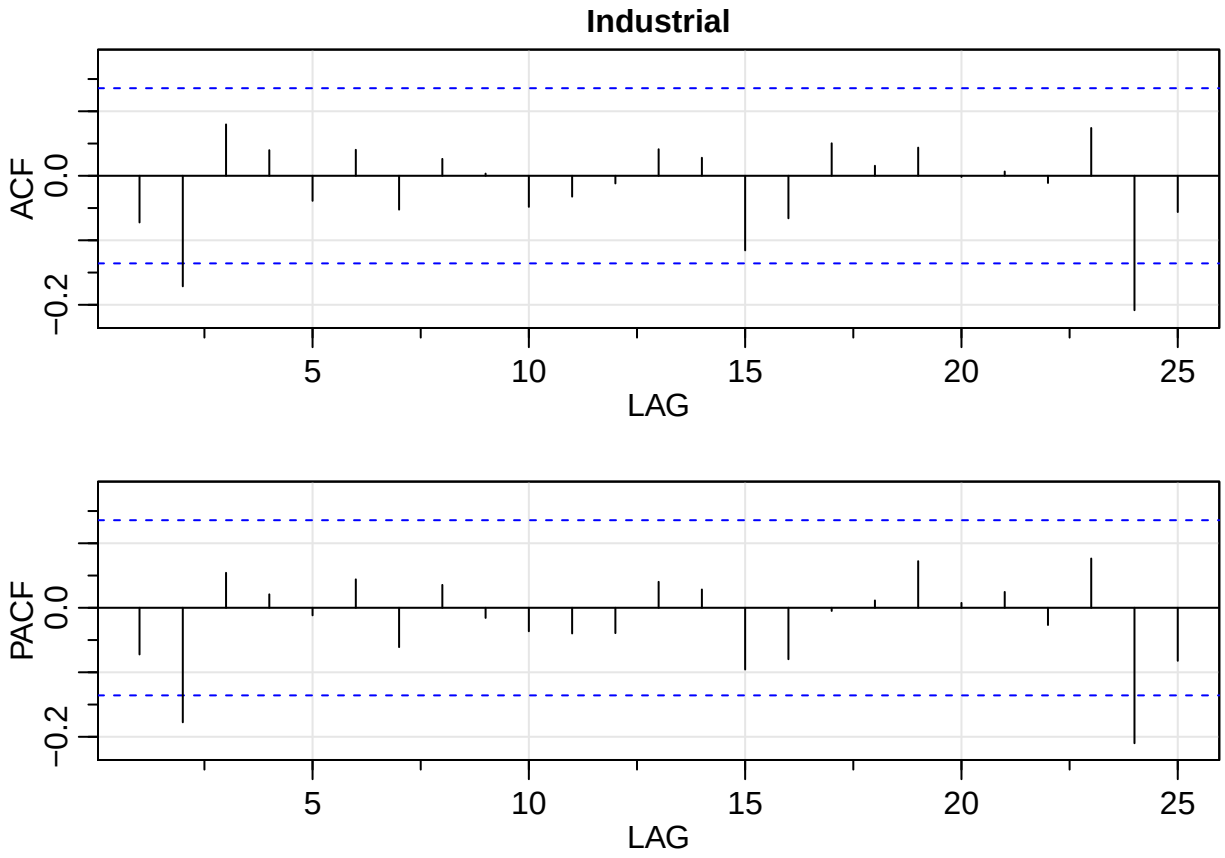

Residuals
0.2
0.1
0.0
−0.1
−0.2
0
50
100
150
200
ACF
Lag
count
residuals
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
5
10
15
20
30
40
50

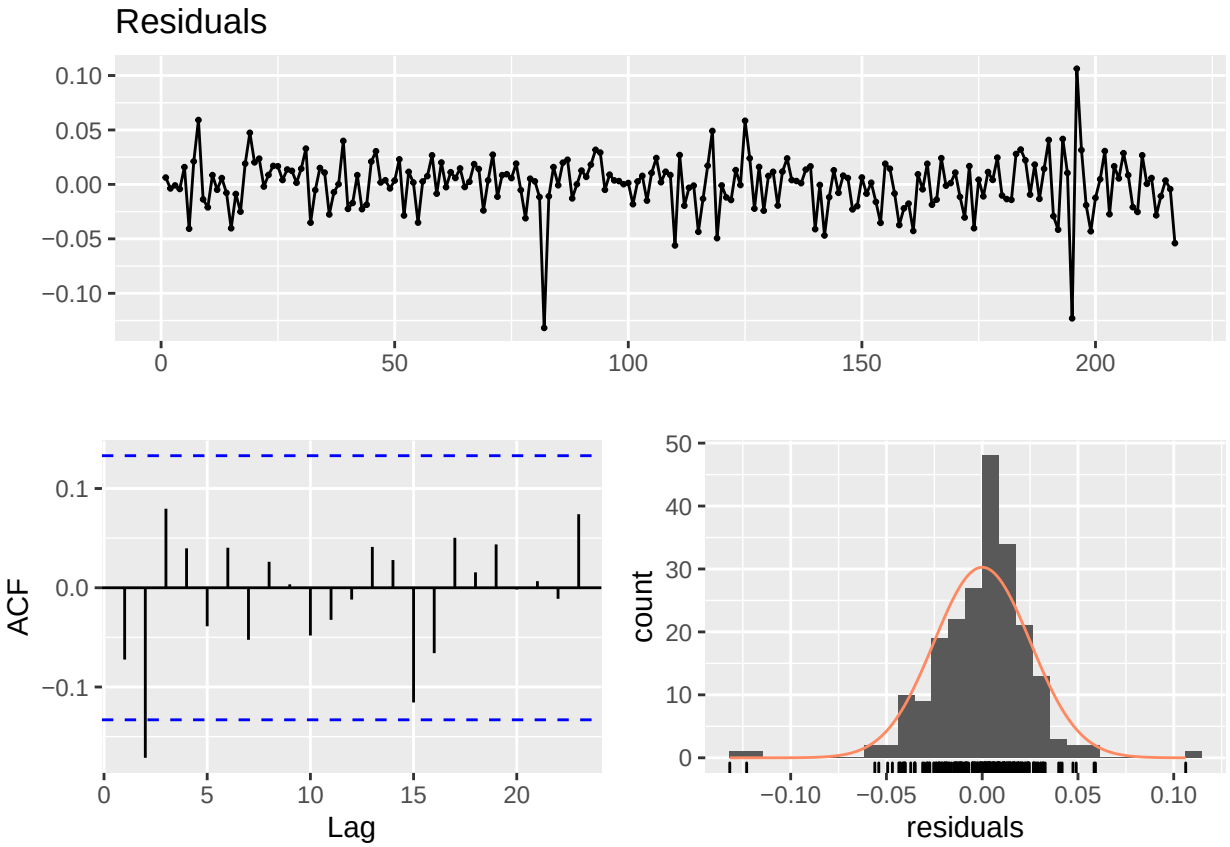

Cambio
ACF
0.1
−0.1
5
10
15
20
25
LAG
PACF
0.1
−0.1
5
10
15
20
25
LAG

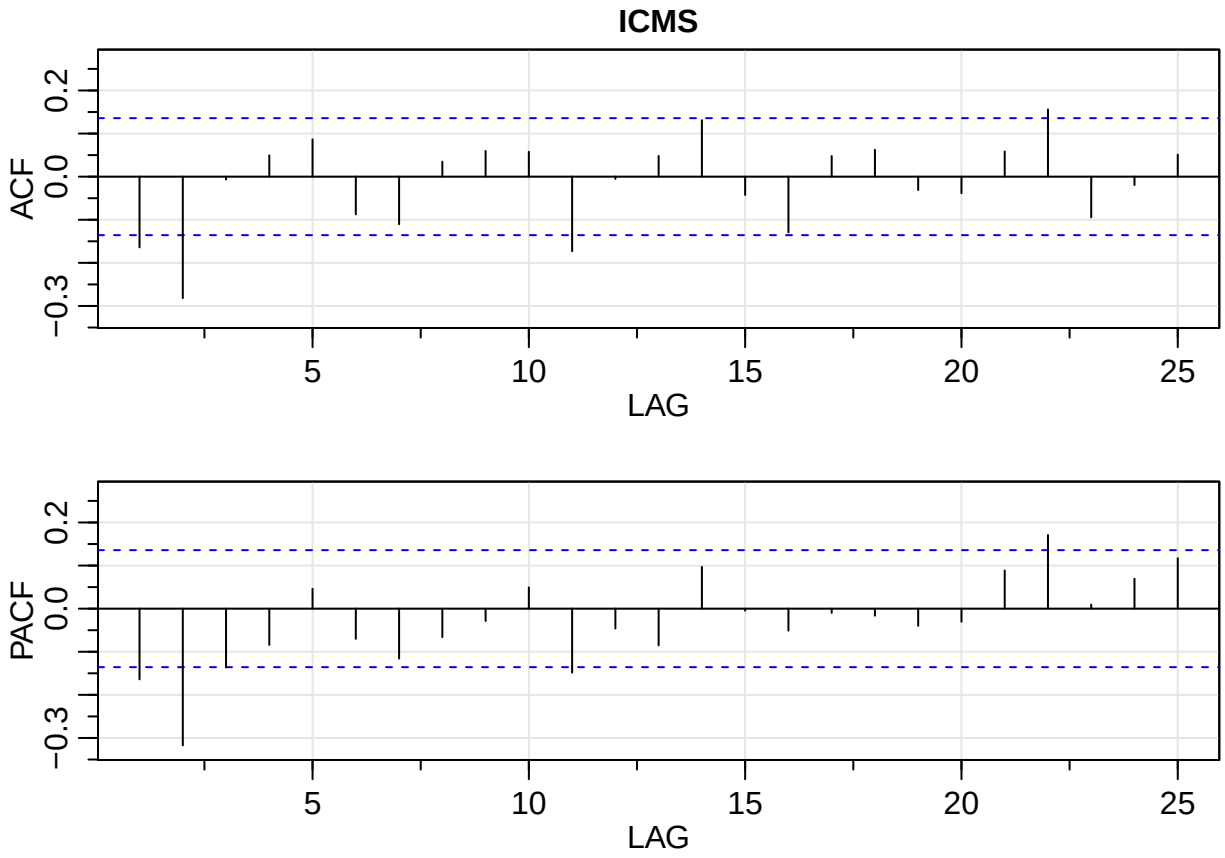

Residuals
0.1
0.0
−0.1
0
50
100
150
200
ACF
0.10
0.05
0.00
−0.05
−0.10
−0.15
0
5
10
15
20
Lag
count
40
30
20
10
0
−0.1
0.0
0.1
residuals

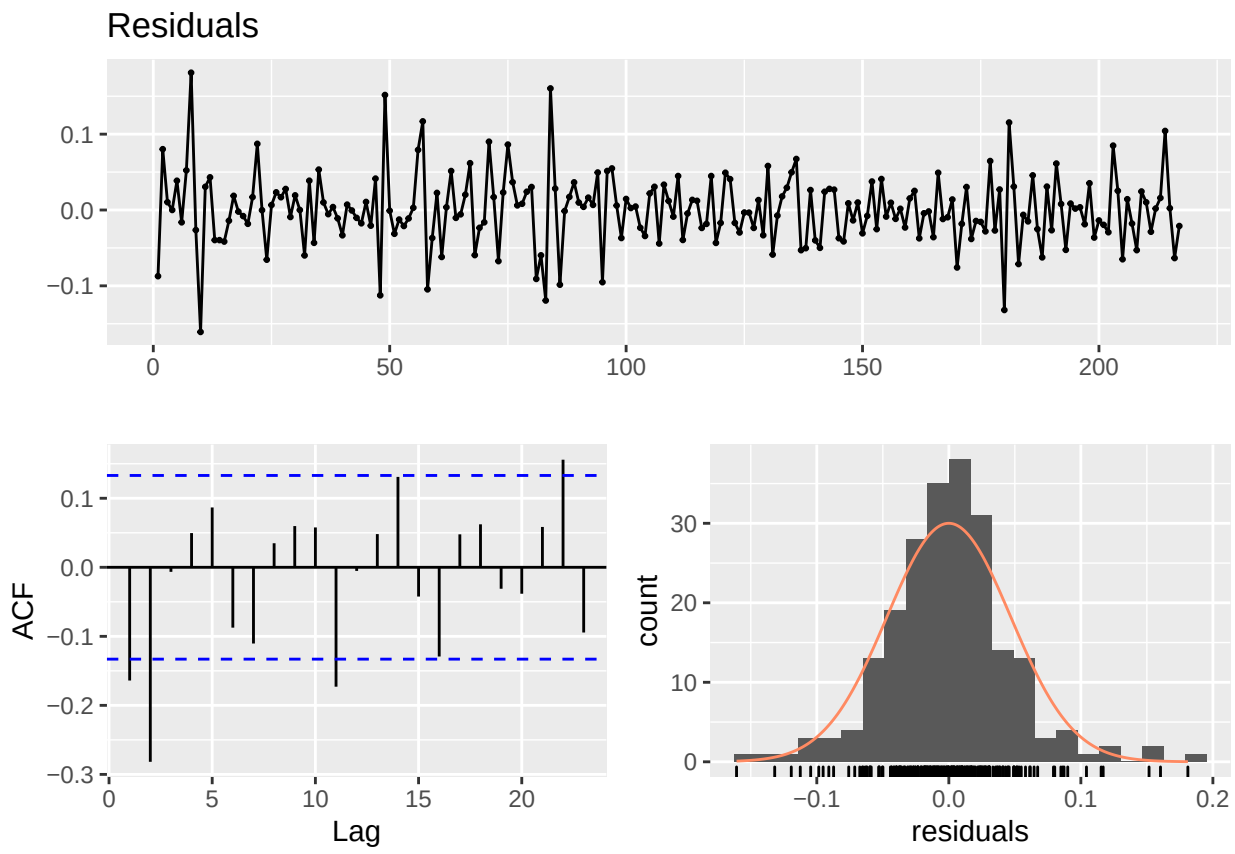

Importacoes
ACF
0.2
−0.2
5
10
15
20
25
LAG
PACF
0.2
−0.2
5
10
15
20
25
LAG


Residuals
0.4
0.2
0.0
−0.2
0
50
100
150
200
ACF
0.25
0.00
−0.25
0
5
10
15
20
Lag
count
30
20
10
0
−0.2
0.0
0.2
0.4
residuals


Industrial
ACF
0.0
−0.2
5
10
15
20
25
LAG
PACF
0.0
−0.2
5
10
15
20
25
LAG


Residuals
0.10
0.05
0.00
−0.05
−0.10
0
50
100
150
200
ACF
0.1
0.0
−0.1
0
5
10
15
20
Lag
count
50
40
30
20
10
0
−0.10
−0.05
0.00
0.05
0.10
residuals


ICMS
ACF
0.2
0.0
−0.3
5
10
15
20
25
LAG
PACF
0.2
0.0
−0.3
5
10
15
20
25
LAG




**Autocorrelação**

```
vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'PT.asymptotic'
    )
```

```
##
##  Portmanteau Test (asymptotic)
##
## data:  Residuals of VAR object modelo
## Chi-squared = 508.04, df = 350, p-value = 6.465e-08
```

```
vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'PT.adjusted'
    )
```

```
##
##  Portmanteau Test (adjusted)
##
```

```
## data:  Residuals of VAR object modelo
## Chi-squared = 525.83, df = 350, p-value = 3.306e-09
```

```
vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'BG'
    )
```

```
##
##  Breusch-Godfrey LM test
##
## data:  Residuals of VAR object modelo
## Chi-squared = 245.77, df = 125, p-value = 6.751e-10
```

### Normalidade

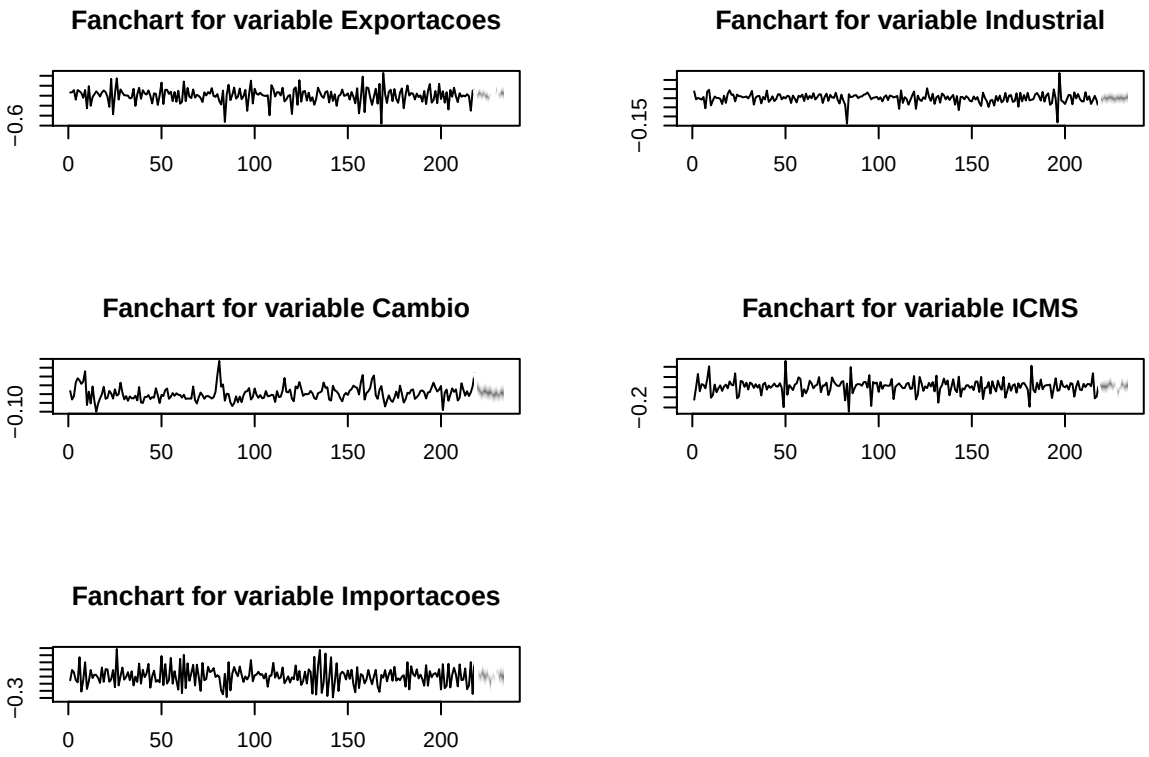
```
vars::normality.test(
    modelo, multivariate.only = FALSE)
```

```
## $Exportacoes
##
##  JB-Test (univariate)
##
## data:  Residual of Exportacoes equation
## Chi-squared = 2.2258, df = 2, p-value = 0.3286
##
##
## $Cambio
##
##  JB-Test (univariate)
##
## data:  Residual of Cambio equation
## Chi-squared = 41.1, df = 2, p-value = 1.189e-09
##
##
## $Importacoes
##
##  JB-Test (univariate)
##
## data:  Residual of Importacoes equation
## Chi-squared = 10.893, df = 2, p-value = 0.004311
##
##
## $Industrial
##
##  JB-Test (univariate)
##
## data:  Residual of Industrial equation
## Chi-squared = 361.83, df = 2, p-value < 2.2e-16
##
```

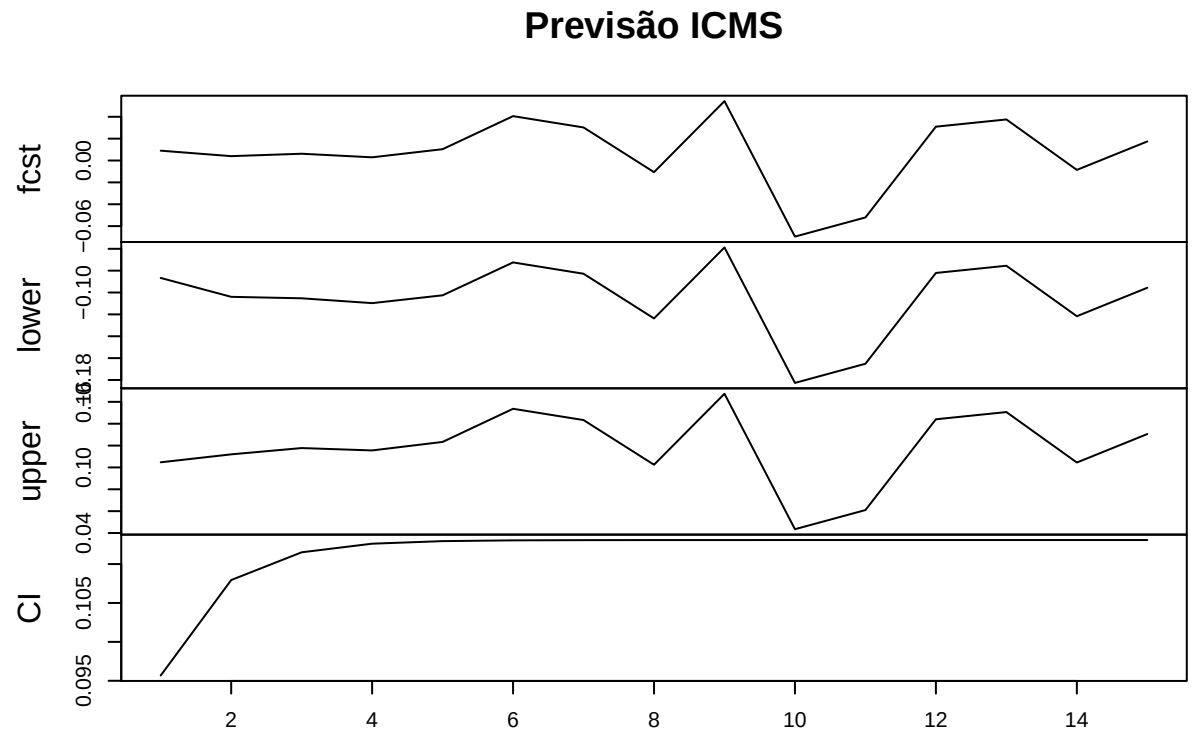
```
##
## $ICMS
##
##  JB-Test (univariate)
##
## data:  Residual of ICMS equation
## Chi-squared = 41.334, df = 2, p-value = 1.058e-09
##
##
## $JB
##
##  JB-Test (multivariate)
##
## data:  Residuals of VAR object modelo
## Chi-squared = 399.36, df = 10, p-value < 2.2e-16
##
##
## $Skewness
##
##  Skewness only (multivariate)
##
## data:  Residuals of VAR object modelo
## Chi-squared = 41.589, df = 5, p-value = 7.133e-08
##
##
## $Kurtosis
##
##  Kurtosis only (multivariate)
##
## data:  Residuals of VAR object modelo
## Chi-squared = 357.77, df = 5, p-value < 2.2e-16
```

# Previsão

```
vars::fanchart(predict(
    modelo,
    n.ahead = 15,
    ci=0.95
    ))
```




```
predict(
    modelo,
    n.ahead = 15,
    ci=0.95
    )$fcst$ICMS %>% plot.ts(
        main = "Previsão ICMS",
        xlab = "",
        ylab = "R$ Milhões"
    )
```

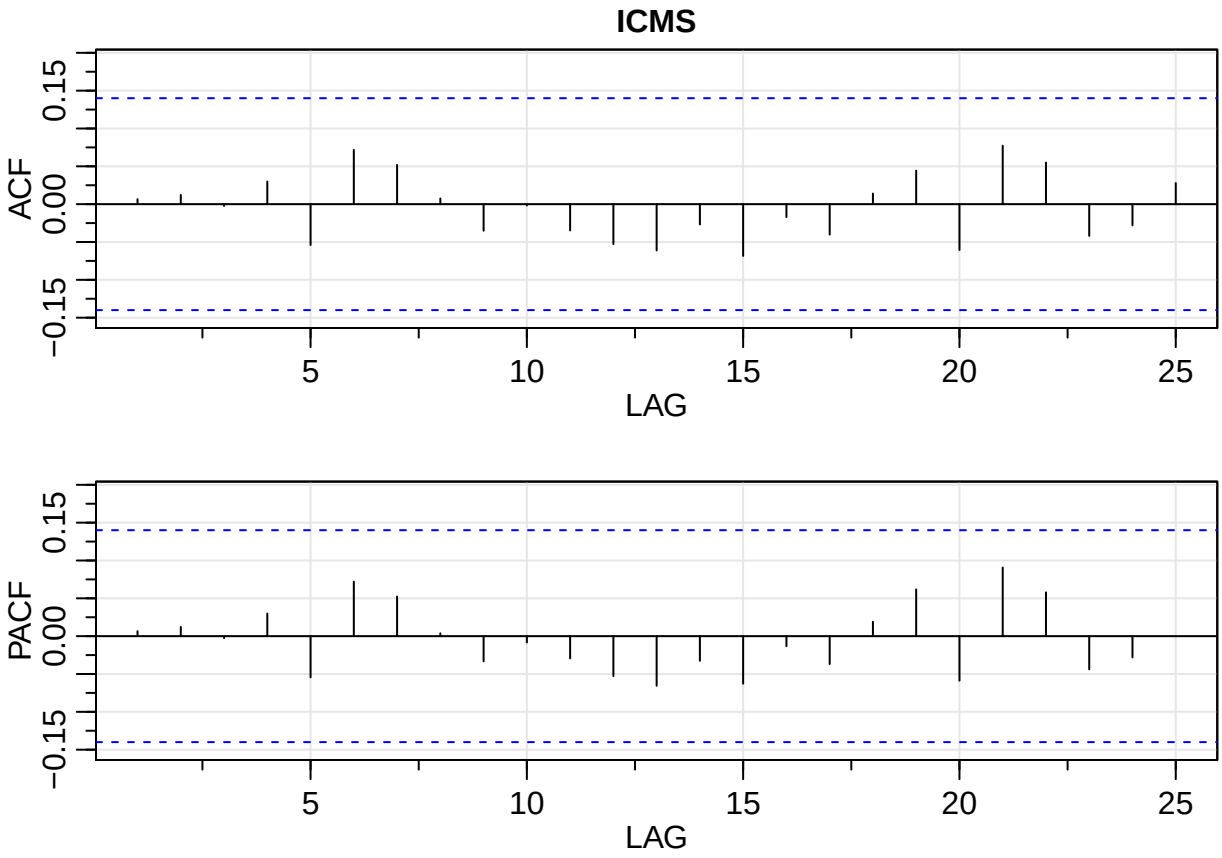


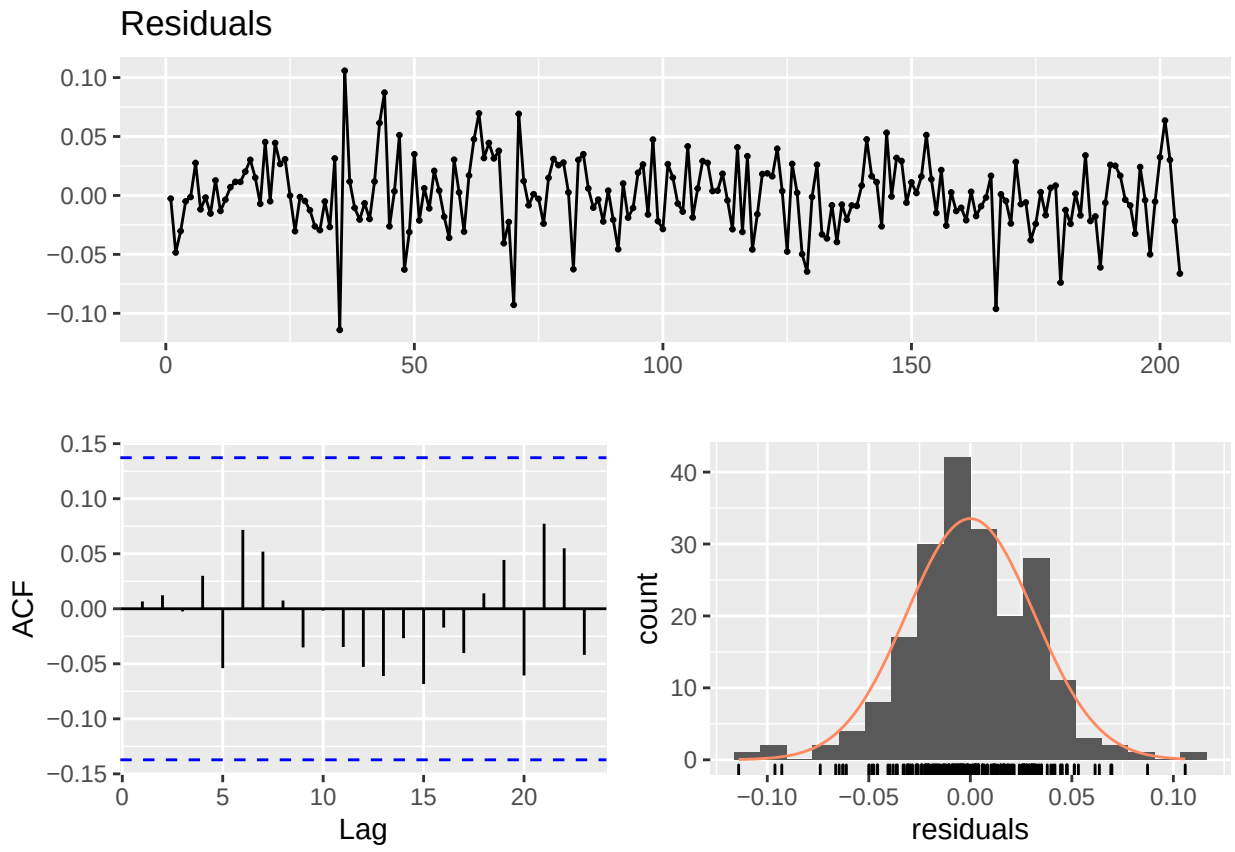

## Comparação

```
comparacao <- data.frame(
    matrix(ncol = 5, nrow = 4)
)
colnames(comparacao) <- c(
    "Critérios",
    "Portmanteau_pvalue",
    "LjungBox_pvalue",
    "BG_pvalue",
    "JB_pvalue"
)

comparacao$Critérios <- c(
    "AIC(n)",
    "HQ(n)",
    "SC(n)",
    "FPE(n)"
)

for (i in 1:length(ordem)) {
    print(paste0("Estimando para VAR(p = ", ordem[i], ")"), quote = FALSE)
    vars::VAR(
```

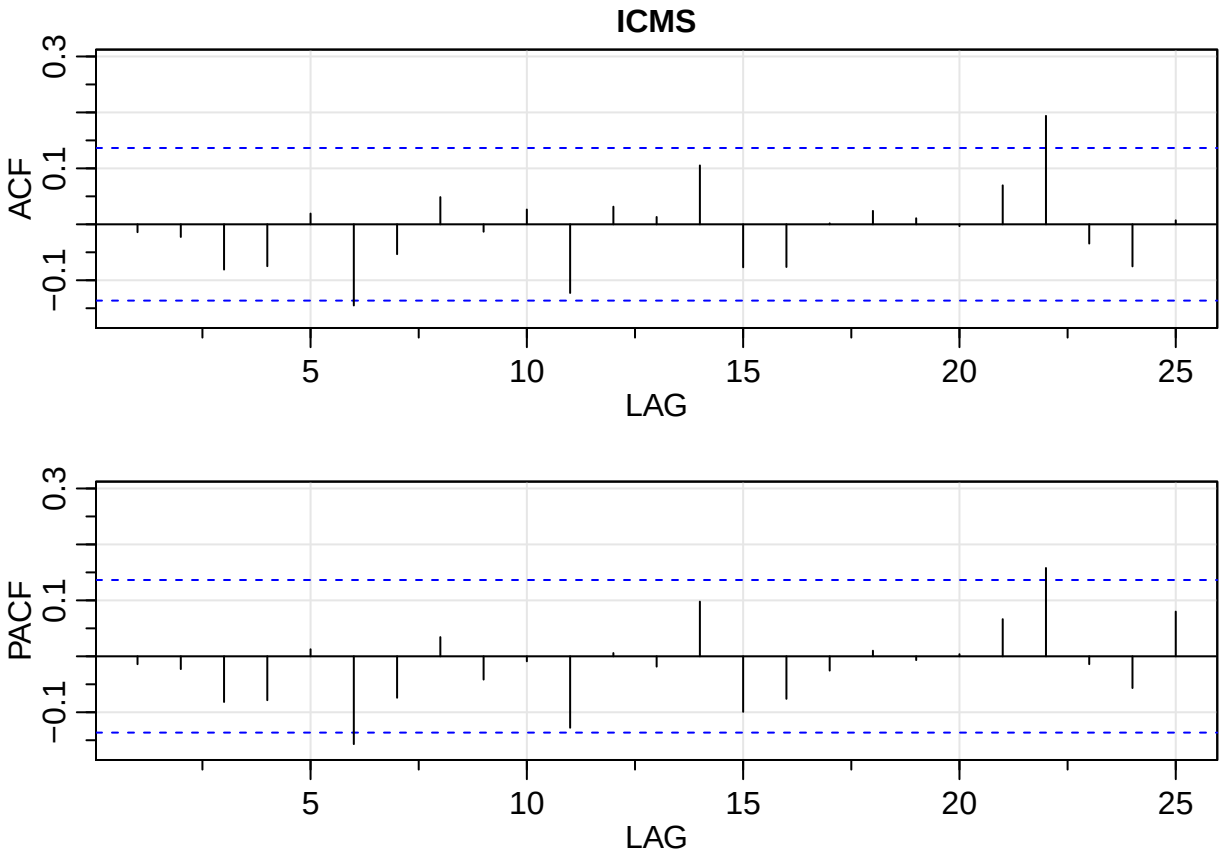
```
    df %>% log() %>%  diff() %>% na.omit(),
    type = 'const',
    season = 12,
    p = ordem[i] %>% as.numeric()
    ) -> modelo
    astsa::acf2(
        residuals(modelo)[,"ICMS"],
        main = "ICMS"
    )
    forecast::checkresiduals(
        residuals(modelo)[,"ICMS"],
        main = "ICMS"
        )

    vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'PT.asymptotic'
    ) -> teste
    comparacao$Portmanteau_pvalue[i]  <- teste$serial$p.value  %>% as.numeric()

    vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'PT.adjusted'
    ) -> teste
    comparacao$LjungBox_pvalue[i]  <- teste$serial$p.value  %>% as.numeric()

    vars::serial.test(
    modelo,
    lags.pt = 15,
    type = 'BG'
    ) -> teste
    comparacao$BG_pvalue[i]  <- teste$serial$p.value  %>% as.numeric()

    vars::normality.test(modelo)$jb.mul$JB$p.value -> teste
    comparacao$JB_pvalue[i]  <- teste %>% as.numeric()

    rownames(comparacao)[i] <- c(paste0("VAR(p = ", ordem[i] %>% as.numeric(), ")" ))
}
```

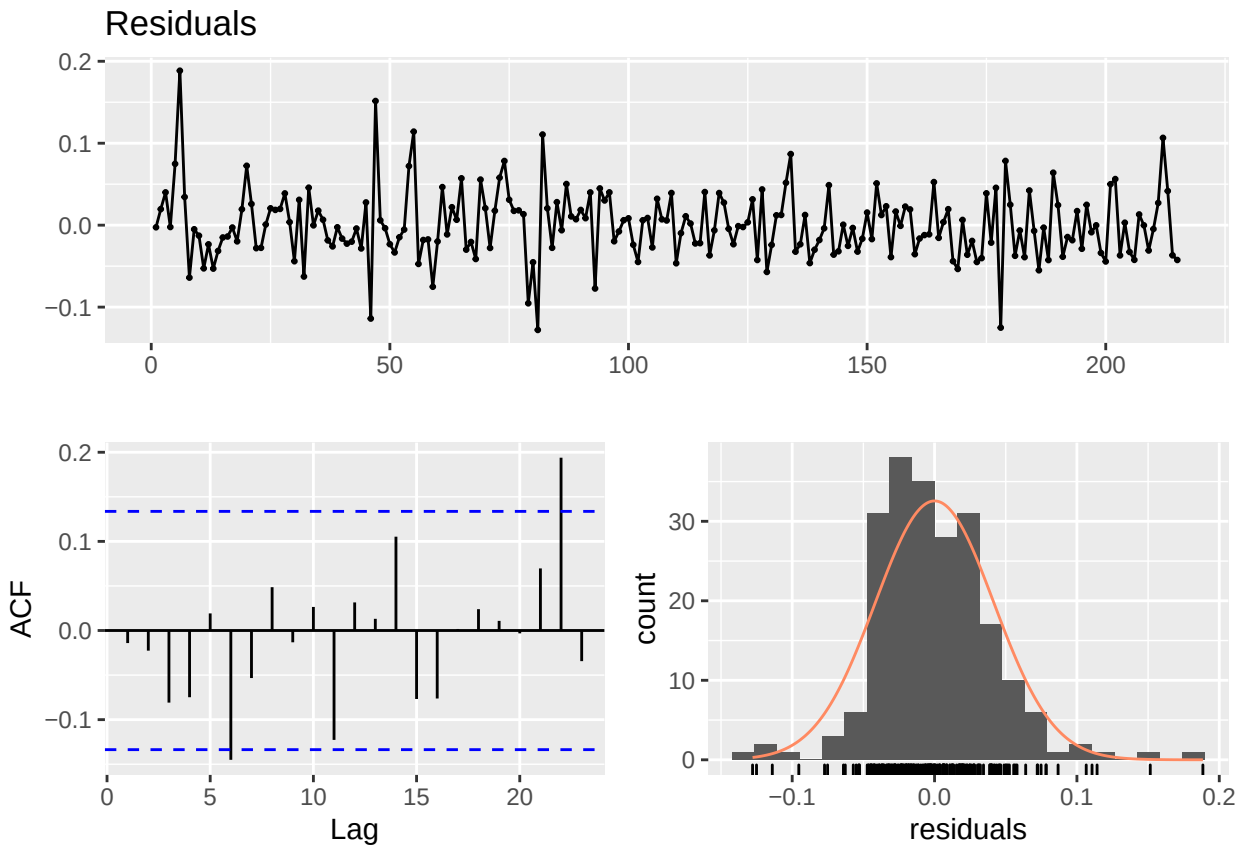
```
## [1] Estimando para VAR(p = 14)
```


ICMS
ACF
0.15
0.00
−0.15
5
10
15
20
25
LAG
PACF
0.15
0.00
−0.15
5
10
15
20
25
LAG

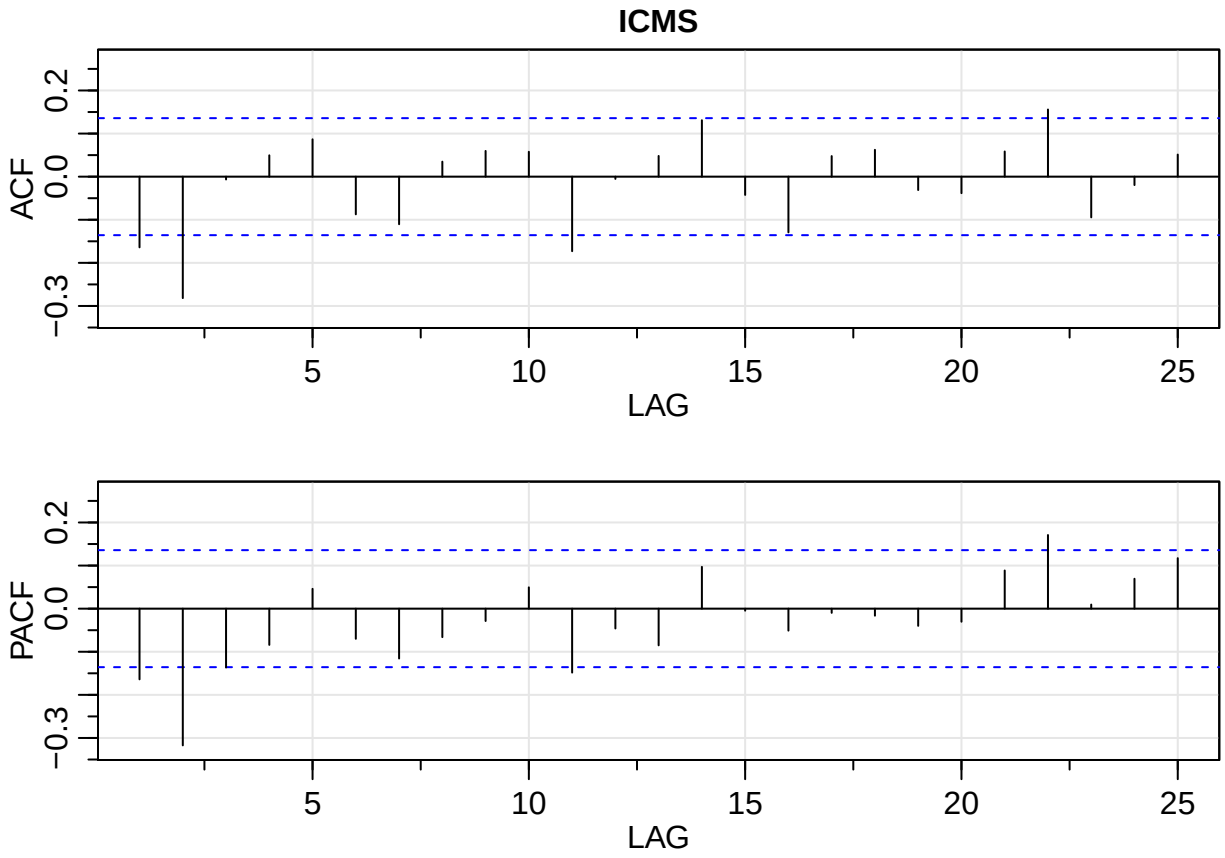


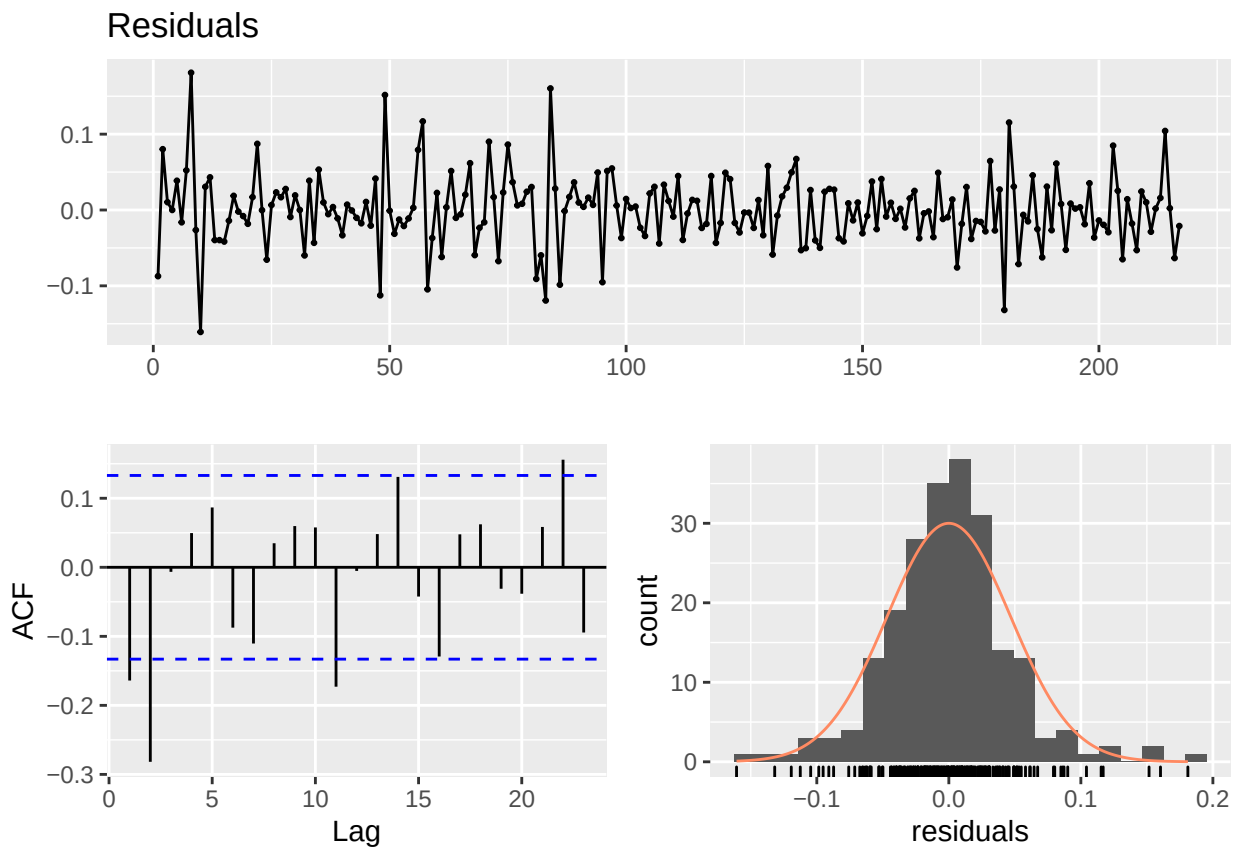

```
## [1] Estimando para VAR(p = 3)
```


ICMS
ACF
0.3
0.1
−0.1
5
10
15
20
25
LAG
PACF
0.3
0.1
−0.1
5
10
15
20
25
LAG

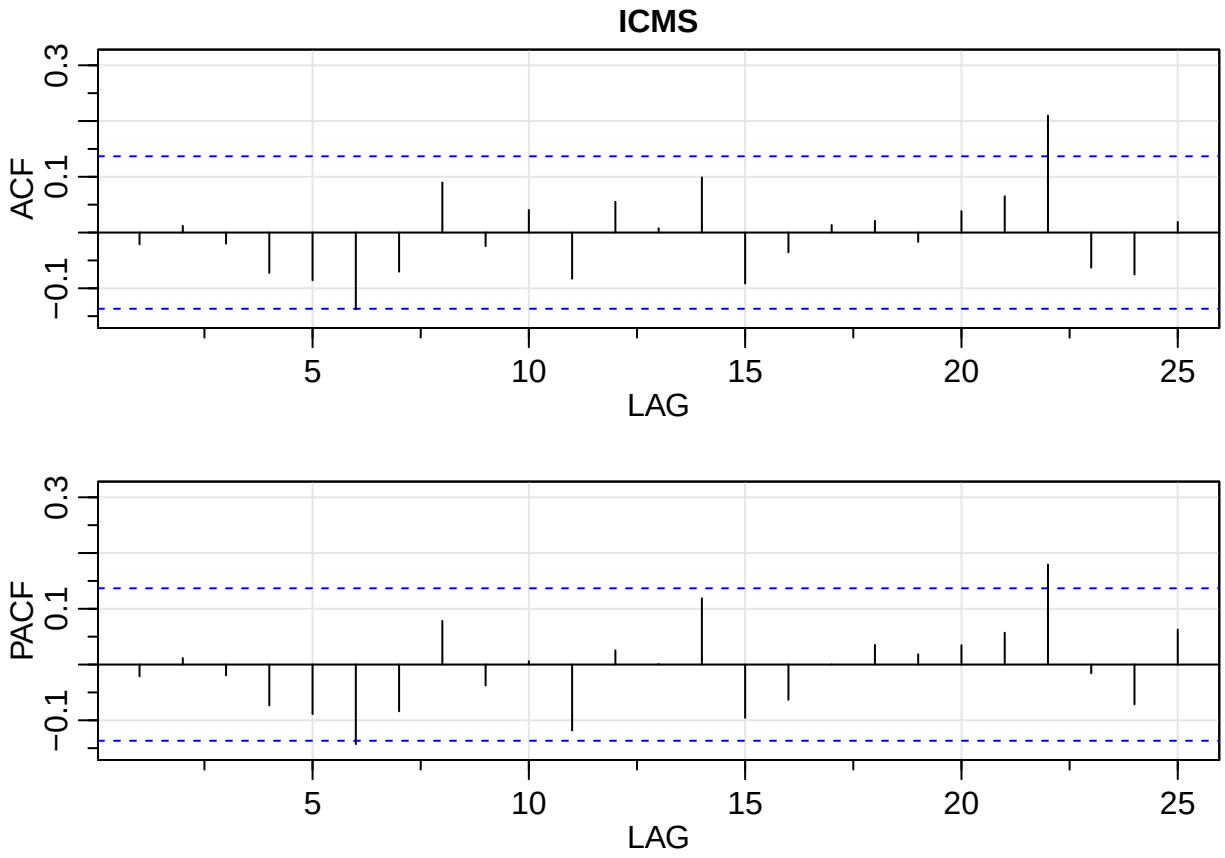


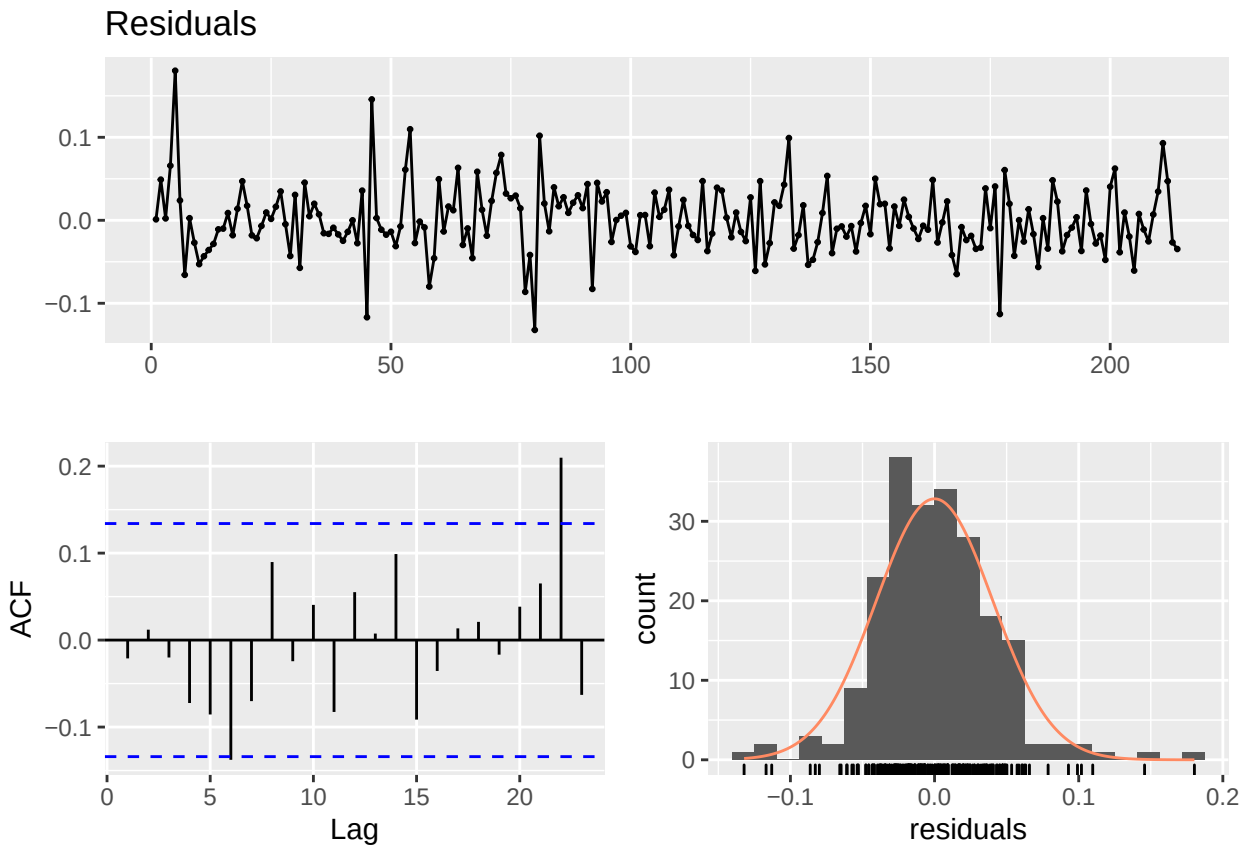

```
## [1] Estimando para VAR(p = 1)
```


ICMS
ACF
0.2
0.0
−0.3
5
10
15
20
25
LAG
PACF
0.2
0.0
−0.3
5
10
15
20
25
LAG




```
## [1] Estimando para VAR(p = 4)
```


ICMS
ACF
0.3
0.1
−0.1
5
10
15
20
25
LAG
PACF
0.3
0.1
−0.1
5
10
15
20
25
LAG




```
comparacao %>% knitr::kable(digits = 3, align = 'c')
```

| | Critérios | Portmanteau_pvalue | LjungBox_pvalue | BG_pvalue | JB_pvalue |
|---|---|---|---|---|---|
| VAR(p = 14) | AIC(n) | 0.000 | 0.000 | 0.00 | 0 |
| VAR(p = 3) | HQ(n) | 0.079 | 0.024 | 0.01 | 0 |
| VAR(p = 1) | SC(n) | 0.000 | 0.000 | 0.00 | 0 |
| VAR(p = 4) | FPE(n) | 0.162 | 0.059 | 0.09 | 0 |