Stress Test Model

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Introdução

Neste estudo, a série denominada “Inadimplência da carteira de crédito das instituições financeiras sob controle privado – Total” será modelada com técnicas de séries temporais univariada e multivariada. Inicialmente, o modelo ARIMA será adotado para estimar a série de inadimplência com base em seus valores defasados e componentes de médias móveis. Em posse do modelo, será realizada a previsão da série para o periodo de dezembro de 2024.

Posteriormente, no caso multivariado, o modelo ARIMAX será adotado para modelar a série de inadimplência com base em variáveis explicativas macroecônomicas.

Upload packages

```
library(readxl)
library(forecast)
library(tseries)
library(lmtest)
library(dplyr)
library(corrplot)
library(ggplot2)
#Library(TSPred)


source("http://www.sthda.com/upload/rquery_cormat.r")
```

Upload database

```
data<-readxl::read_excel("Data_Stress.xlsx")

attach(data)
```

Overview da base de dados

```
glimpse(data)
```

```
## Rows: 192
## Columns: 16
## $ Date                                  <dttm> 2006-01-01, 2006-02-01, 2006-0~
## $ `IBC-BR`                              <dbl> 108.55, 107.80, 119.09, 112.61,~
## $ PIB_Index                             <dbl> 83.7, 80.2, 92.4, 85.7, 95.4, 9~
## $ `Retail Sales`                        <dbl> 52.7, 46.9, 55.1, 52.0, 56.8, 5~
## $ `Business Credit Concessions`         <dbl> 138.9600, 120.1362, 159.5268, 1~
## $ `Business Confidence Index`           <dbl> 93.4, 97.5, 100.4, 104.0, 98.3,~
## $ `Commodity Price Index`               <dbl> 101.81, 97.57, 93.81, 95.29, 99~
## $ `USD/BRL`                             <dbl> 2.2739, 2.1619, 2.1520, 2.1293,~
## $ `Index of Employed Persons - Industry` <dbl> 115.2033, 115.6635, 116.2086, 1~
## $ Selic                                 <dbl> 17.25, 17.25, 16.50, 15.75, 15.~
## $ `Uncertainty Index`                   <dbl> 93.4, 89.0, 92.3, 90.1, 98.0, 9~
## $ Index_Inad                            <dbl> 3.79, 3.94, 4.04, 4.24, 4.33, 4~
## $ IPCA                                  <dbl> 0.59, 0.41, 0.43, 0.21, 0.10, -~
## $ DLSP                                  <dbl> 47.82, 47.78, 47.66, 47.14, 47.~
## $ Cut                                   <dbl> 86.06, 91.73, 89.01, 94.15, 86.~
## $ Juro_Real                             <dbl> 16.66, 16.84, 16.07, 15.54, 15.~
```

Variáveis consideradas na análise

Variavel dependente

- `Taxa_Inad` - Taxa de inadimplência da carteira de crédito das instituições financeiras sob controle privado Total (%)" (Mensal).

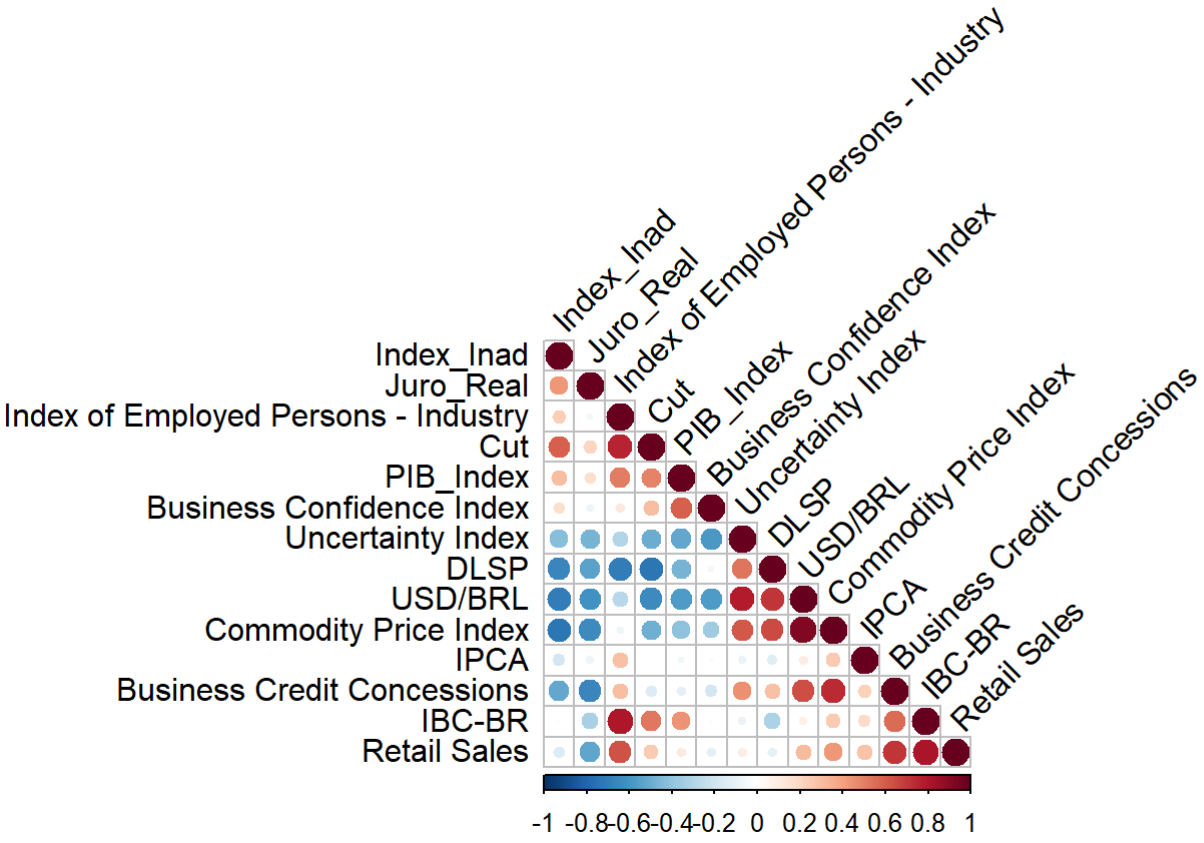
Variáveis explicativas

- `PIB Mensal (Indice)` - Indice do PIB - (Mensal)
- `Retail Sales` - Indice de Vendas no varejo - (Mensal)
- `IPCA` - Índice geral de preços ao consumidor amplo - (Mensal).
- `Business Credit Concessions` - Índice da concessão de crédito para negócios (Mensal)
- `DSLP` - Dívida Líquida do Setor Público (%) - (Mensal).
- `Index of Employed Persons - Industry` - Proxy para taxa de pessoas empregadas - (Mensal)
- `USD/BRL` - Taxa de câmbio - (Mensal)
- `Industrial Production` - Índice de produção industrial - (Mensal)
- `Uncertainy Index` - Índice de incerteza da economia - (Mensal)
- `Taxa Real de Juros` - Taxa real de juros básica da economia (%)- (Mensal)
- `Commodity price index` - Indice de preço de commodities - (Mensal)
- `Business Confidence Index` - Índice de confiança nos negócios. - (Mensal)
- `Cut` : Custo Unitário do Trabalho - (Mensal).

Matriz de correlação

A seguir, será plotado a matriz de correlação, para analisar o grau de correlação entre as variáveis do modelo.

```
tab_cor<- data %>%
        select(
          `IBC-BR`,
          PIB_Index,
          `Retail Sales`,
          `Business Credit Concessions`,
          `Business Confidence Index`,
          `USD/BRL`,
          `Commodity Price Index`,
          `Index of Employed Persons - Industry`,
          `Uncertainty Index`,
          Index_Inad,
          IPCA,
          DLSP,
          Cut, #Custo unitario do Trabalho
          Juro_Real
          )

rquery.cormat(tab_cor)
```



```
## $r
##                                    Index_Inad Juro_Real
## Index_Inad                                  1
## Juro_Real                                0.43         1
## Index of Employed Persons - Industry     0.24    -0.054
## Cut                                      0.59      0.21
## PIB_Index                                 0.3      0.17
## Business Confidence Index                0.17    -0.072
## Uncertainty Index                       -0.43     -0.47
## DLSP                                    -0.66     -0.54
## USD/BRL                                  -0.7     -0.61
## Commodity Price Index                   -0.73     -0.64
## IPCA                                    -0.19    -0.076
## Business Credit Concessions             -0.52     -0.66
## IBC-BR                                 -0.013     -0.33
## Retail Sales                            -0.15     -0.53
##                                    Index of Employed Persons - Industry
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry                                   1
## Cut                                                                 0.76
## PIB_Index                                                           0.51
## Business Confidence Index                                           0.12
## Uncertainty Index                                                   -0.3
## DLSP                                                                -0.7
## USD/BRL                                                            -0.28
## Commodity Price Index                                             -0.068
## IPCA                                                                0.29
## Business Credit Concessions                                          0.3
## IBC-BR                                                               0.8
## Retail Sales                                                        0.63
##                                       Cut PIB_Index Business Confidence Index
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut                                     1
## PIB_Index                            0.49         1
## Business Confidence Index             0.3      0.59                         1
## Uncertainty Index                    -0.5     -0.52                     -0.58
## DLSP                                -0.73     -0.47                    -0.051
## USD/BRL                             -0.64     -0.57                     -0.56
## Commodity Price Index               -0.49     -0.41                     -0.36
## IPCA                               0.0037    -0.051                    -0.022
## Business Credit Concessions          -0.15     -0.12                     -0.19
## IBC-BR                                0.52      0.44                     0.013
## Retail Sales                          0.25      0.11                     -0.12
##                                    Uncertainty Index  DLSP USD/BRL
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index                                  1
## DLSP                                            0.53     1
```

```
## USD/BRL                                          0.78  0.71       1
## Commodity Price Index                            0.61  0.65    0.92
## IPCA                                           -0.081 -0.14     0.1
## Business Credit Concessions                      0.45  0.29    0.64
## IBC-BR                                          -0.09 -0.32   0.088
## Retail Sales                                    0.098 -0.11    0.31
##                                    Commodity Price Index IPCA
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index                               1
## IPCA                                             0.25    1
## Business Credit Concessions                      0.74 0.23
## IBC-BR                                           0.25 0.19
## Retail Sales                                     0.43 0.28
##                                    Business Credit Concessions IBC-BR
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index
## IPCA
## Business Credit Concessions                                 1
## IBC-BR                                                   0.56      1
## Retail Sales                                             0.71   0.82
##                                    Retail Sales
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index
## IPCA
## Business Credit Concessions
## IBC-BR
## Retail Sales                                        1
##
## $p
##                                    Index_Inad Juro_Real
## Index_Inad                                  0
## Juro_Real                               5e-10         0
```

```
## Index of Employed Persons - Industry     0.0012      0.45
## Cut                                     1.6e-20    0.0034
## PIB_Index                               6.9e-06     0.021
## Business Confidence Index                 0.022      0.32
## Uncertainty Index                       3.1e-10   3.4e-12
## DLSP                                    2.5e-26   5.2e-16
## USD/BRL                                 1.4e-31   4.6e-20
## Commodity Price Index                   1.1e-33   1.6e-20
## IPCA                                     0.0039      0.28
## Business Credit Concessions             5.4e-16   8.2e-22
## IBC-BR                                     0.75   2.5e-06
## Retail Sales                               0.04     5e-15
##                                    Index of Employed Persons - Industry
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry                                  0
## Cut                                                             2.7e-36
## PIB_Index                                                       7.9e-14
## Business Confidence Index                                         0.089
## Uncertainty Index                                               3.5e-05
## DLSP                                                            1.1e-28
## USD/BRL                                                         0.00018
## Commodity Price Index                                              0.44
## IPCA                                                            4.3e-05
## Business Credit Concessions                                     2.3e-05
## IBC-BR                                                          1.3e-44
## Retail Sales                                                      1e-22
##                                        Cut PIB_Index
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut                                          0
## PIB_Index                              2.3e-13         0
## Business Confidence Index              2.9e-05   2.5e-19
## Uncertainty Index                      5.2e-14   8.8e-15
## DLSP                                   1.1e-33   2.7e-12
## USD/BRL                                4.3e-25   1.7e-18
## Commodity Price Index                  6.6e-14     1e-09
## IPCA                                      0.82      0.39
## Business Credit Concessions             0.0054      0.03
## IBC-BR                                 1.2e-13   4.6e-10
## Retail Sales                           0.00041      0.12
##                                    Business Confidence Index
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index                                  0
## Uncertainty Index                                    3.7e-18
## DLSP                                                    0.48
## USD/BRL                                              4.9e-16
## Commodity Price Index                                1.6e-06
## IPCA                                                    0.76
## Business Credit Concessions                            0.016
## IBC-BR                                                  0.87
```

```
## Retail Sales                                                0.1
##                                   Uncertainty Index    DLSP USD/BRL
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index                                   0
## DLSP                                          1.2e-15       0
## USD/BRL                                       2.2e-39 1.5e-31       0
## Commodity Price Index                           8e-20 1.3e-24 4.4e-79
## IPCA                                             0.35    0.12   0.078
## Business Credit Concessions                   9.6e-11 3.3e-06 8.6e-26
## IBC-BR                                           0.24 1.8e-05    0.18
## Retail Sales                                     0.18    0.14 1.5e-05
##                                   Commodity Price Index    IPCA
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index                                  0
## IPCA                                            8.5e-05       0
## Business Credit Concessions                     9.8e-40 0.00029
## IBC-BR                                            5e-04  0.0082
## Retail Sales                                      7e-10 0.00012
##                                   Business Credit Concessions  IBC-BR
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index
## IPCA
## Business Credit Concessions                                 0
## IBC-BR                                                8.6e-16       0
## Retail Sales                                          7.1e-31 1.4e-47
##                                   Retail Sales
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
```

```
## Commodity Price Index
## IPCA
## Business Credit Concessions
## IBC-BR
## Retail Sales                                    0
##
## $sym
##                                   Index_Inad Juro_Real
## Index_Inad                        1
## Juro_Real                         .          1
## Index of Employed Persons - Industry
## Cut                               .
## PIB_Index
## Business Confidence Index
## Uncertainty Index                 .          .
## DLSP                              ,          .
## USD/BRL                           ,          ,
## Commodity Price Index             ,          ,
## IPCA
## Business Credit Concessions       .          ,
## IBC-BR                                       .
## Retail Sales                                 .
##                                   Index of Employed Persons - Industry Cut
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry 1
## Cut                               ,                                     1
## PIB_Index                         .                                     .
## Business Confidence Index
## Uncertainty Index                                                       .
## DLSP                              ,                                     ,
## USD/BRL                                                                 ,
## Commodity Price Index                                                   .
## IPCA
## Business Credit Concessions
## IBC-BR                            ,                                     .
## Retail Sales                      ,
##                                   PIB_Index Business Confidence Index
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index                         1
## Business Confidence Index         .         1
## Uncertainty Index                 .         .
## DLSP                              .
## USD/BRL                           .         .
## Commodity Price Index             .         .
## IPCA
## Business Credit Concessions
## IBC-BR                            .
## Retail Sales
##                                   Uncertainty Index DLSP USD/BRL
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
```

```
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index                    1
## DLSP                                 .                 1
## USD/BRL                              ,                 ,    1
## Commodity Price Index                ,                 ,    *
## IPCA
## Business Credit Concessions          .                      ,
## IBC-BR                                                      .
## Retail Sales                                                .
##                                     Commodity Price Index IPCA
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index                1
## IPCA                                                        1
## Business Credit Concessions          ,
## IBC-BR
## Retail Sales                         .
##                                     Business Credit Concessions IBC-BR
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index
## IPCA
## Business Credit Concessions          1
## IBC-BR                               .                           1
## Retail Sales                         ,                           +
##                                     Retail Sales
## Index_Inad
## Juro_Real
## Index of Employed Persons - Industry
## Cut
## PIB_Index
## Business Confidence Index
## Uncertainty Index
## DLSP
## USD/BRL
## Commodity Price Index
## IPCA
## Business Credit Concessions
## IBC-BR
## Retail Sales                         1
```

```
## attr(,"legend")
## [1] 0 ' ' 0.3 '.' 0.6 ',' 0.8 '+' 0.9 '*' 0.95 'B' 1
```

Com base na matriz de correlação acima, destaca-se:

- Uma correlação negativa entre a taxa de inadimplência e indice de crédito para negócios.
- Uma alta correlação positiva entre a taxa de câmbio e o indice de incerteza da economia.
- Uma alta correlação negativa entre a taxa de inadimplência e a taxa de câmbio.

Teste de estacionariedade

A seguir, com base no teste Kpss, será analisado se a série de inadimplência no Brasil é estacionária.

Variável dependente: Taxa de Inadimplência

```
Taxa_Inad<-ts(data$Index_Inad, start=c(2006,1), end=c(2021,12),frequency=12)
```

Teste de estacionariedade

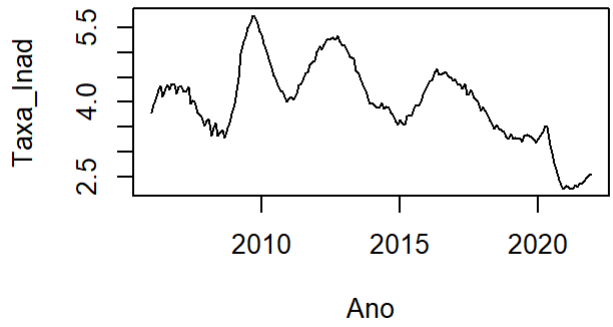
```
ndiffs(Taxa_Inad, alpha=0.05, test="kpss")
```

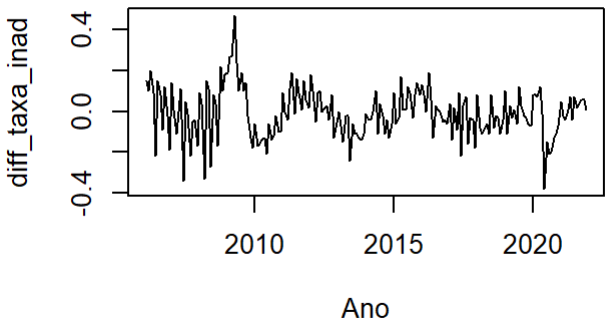
```
## [1] 1
```

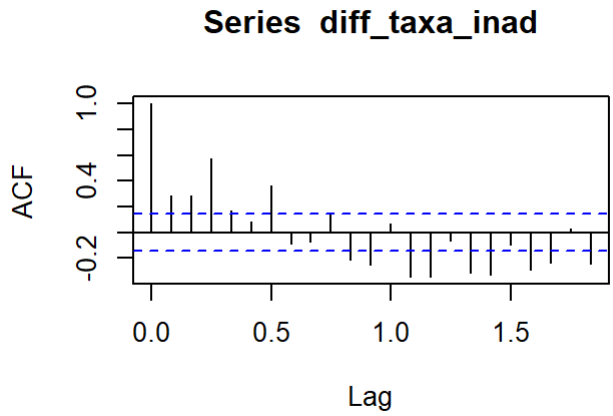
Portanto, a série de inadimplência no Brasil não é estacionária, pois é necessário 1 processo de diferenciação para torna-la estacionária.

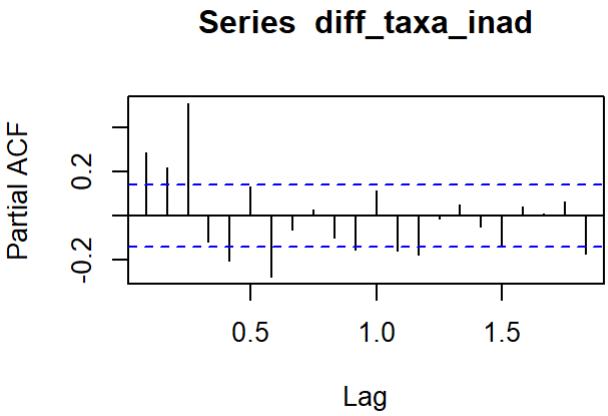
ACF e PACF

```
par(mfrow=c(2,2))

diff_taxa_inad<-diff(Taxa_Inad)

plot.ts(Taxa_Inad, xlab="Ano")

plot.ts(diff_taxa_inad, xlab="Ano")

acf(diff_taxa_inad)

pacf(diff_taxa_inad)
```









Análise univariada

Nesta seção, a série de inadimplência será modelada de forma univariada, ou seja, os valores defasados da própria variável serão utilizados como preditores do valor atual e futuro.

Modelo Arima

A função `auto.arima()` do pacote `forecasts` realiza a estimação iterativa do modelo ARIMA que melhor se adequa a série temporal, com base na minimização do critério de informação de Akaike (AIC).

```
mod_arima<-auto.arima(Taxa_Inad, trace=TRUE, approximation=FALSE)
```

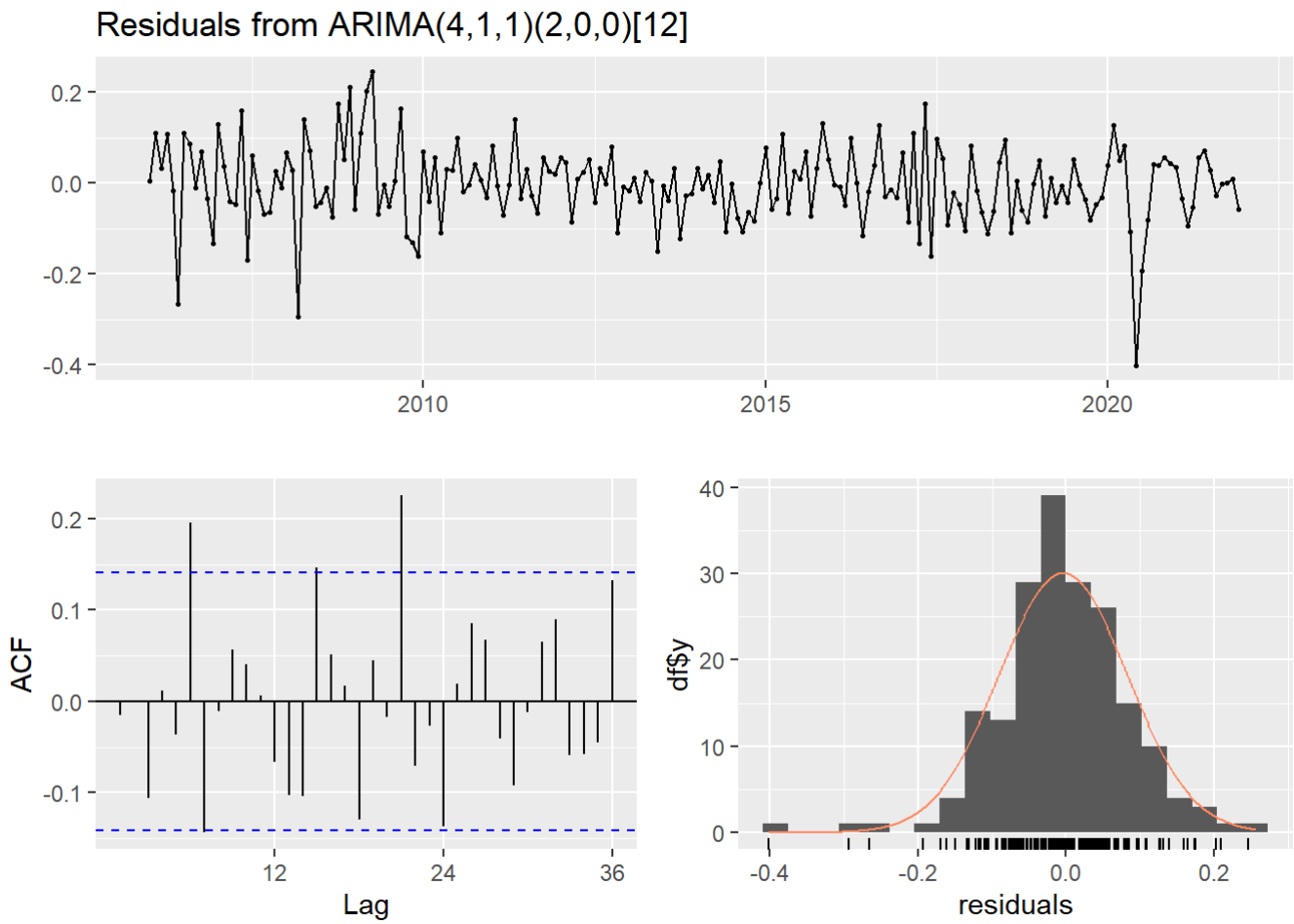
```
##
##  ARIMA(2,1,2)(1,0,1)[12] with drift         : Inf
##  ARIMA(0,1,0)            with drift         : -257.9515
##  ARIMA(1,1,0)(1,0,0)[12] with drift         : -297.9447
##  ARIMA(0,1,1)(0,0,1)[12] with drift         : -275.3359
##  ARIMA(0,1,0)                               : -259.4529
##  ARIMA(1,1,0)            with drift         : -272.5774
##  ARIMA(1,1,0)(2,0,0)[12] with drift         : -308.5957
##  ARIMA(1,1,0)(2,0,1)[12] with drift         : Inf
##  ARIMA(1,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(0,1,0)(2,0,0)[12] with drift         : -257.3619
##  ARIMA(2,1,0)(2,0,0)[12] with drift         : -329.1481
##  ARIMA(2,1,0)(1,0,0)[12] with drift         : -318.1022
##  ARIMA(2,1,0)(2,0,1)[12] with drift         : Inf
##  ARIMA(2,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(3,1,0)(2,0,0)[12] with drift         : -347.139
##  ARIMA(3,1,0)(1,0,0)[12] with drift         : -343.2771
##  ARIMA(3,1,0)(2,0,1)[12] with drift         : Inf
##  ARIMA(3,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(4,1,0)(2,0,0)[12] with drift         : -348.8681
##  ARIMA(4,1,0)(1,0,0)[12] with drift         : -346.0348
##  ARIMA(4,1,0)(2,0,1)[12] with drift         : Inf
##  ARIMA(4,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(5,1,0)(2,0,0)[12] with drift         : -353.8377
##  ARIMA(5,1,0)(1,0,0)[12] with drift         : -352.664
##  ARIMA(5,1,0)(2,0,1)[12] with drift         : Inf
##  ARIMA(5,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(5,1,1)(2,0,0)[12] with drift         : -358.5373
##  ARIMA(5,1,1)(1,0,0)[12] with drift         : -357.3955
##  ARIMA(5,1,1)(2,0,1)[12] with drift         : Inf
##  ARIMA(5,1,1)(1,0,1)[12] with drift         : Inf
##  ARIMA(4,1,1)(2,0,0)[12] with drift         : -368.0166
##  ARIMA(4,1,1)(1,0,0)[12] with drift         : -365.6928
##  ARIMA(4,1,1)(2,0,1)[12] with drift         : Inf
##  ARIMA(4,1,1)(1,0,1)[12] with drift         : Inf
##  ARIMA(3,1,1)(2,0,0)[12] with drift         : -346.7326
##  ARIMA(4,1,2)(2,0,0)[12] with drift         : Inf
##  ARIMA(3,1,2)(2,0,0)[12] with drift         : -354.3713
##  ARIMA(5,1,2)(2,0,0)[12] with drift         : Inf
##  ARIMA(4,1,1)(2,0,0)[12]                    : -369.8603
##  ARIMA(4,1,1)(1,0,0)[12]                    : -367.3849
##  ARIMA(4,1,1)(2,0,1)[12]                    : Inf
##  ARIMA(4,1,1)(1,0,1)[12]                    : Inf
##  ARIMA(3,1,1)(2,0,0)[12]                    : -348.8846
##  ARIMA(4,1,0)(2,0,0)[12]                    : -351.0318
##  ARIMA(5,1,1)(2,0,0)[12]                    : -360.7622
##  ARIMA(4,1,2)(2,0,0)[12]                    : Inf
##  ARIMA(3,1,0)(2,0,0)[12]                    : -349.2598
##  ARIMA(3,1,2)(2,0,0)[12]                    : -356.5737
##  ARIMA(5,1,0)(2,0,0)[12]                    : -356.0387
##  ARIMA(5,1,2)(2,0,0)[12]                    : Inf
##
##  Best model: ARIMA(4,1,1)(2,0,0)[12]
```

Com base na função `auto.arima()` , o modelo implementado para representar a série de inadimplência, será o ARIMA(4,1,1)(2,0,0).

Análise dos resíduos

O teste de Ljung-Box, analisa a correlação dos resíduos do modelo ARIMA estimado.

```
checkresiduals(mod_arima)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(4,1,1)(2,0,0)[12]
## Q* = 46.546, df = 17, p-value = 0.0001428
##
## Model df: 7.   Total lags used: 24
```

```
Box.test(mod_arima$residuals, type="Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  mod_arima$residuals
## X-squared = 0.046353, df = 1, p-value = 0.8295
```

Com base no p-valor, constata-se a ausência de correlação entre os resíduos.

Previsão do modelo (univariado)

```
previsao24<-forecast(mod_arima, h=36) # 36 meses a frente

summary(previsao24$fitted)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   2.216   3.537   4.030   4.015   4.473   5.838
```

Portanto, no período analisado o valor médio e mediano da taxa de inadimplência, foi de 4.12% e 4.08%, respectivamente.

Acurácia do modelo univariado

```
accuracy(previsao24)
```

```
##                       ME       RMSE        MAE        MPE     MAPE      MASE
## Training set -0.00400138 0.08677066 0.06475809 -0.1405619 1.673754 0.1002792
##                      ACF1
## Training set -0.01541723
```

O erro absoluto médio, representado por MAE, é igual a aproximadamente 6,4%.

A raiz do erro médio ao quadrado, representado por RMSE, é igual a aproximadamente 8,6%.

Gráfico da previsão

```
autoplot(previsao24, xlab="Ano", ylab="Taxa de inadimplência dos bancos (%)")
```

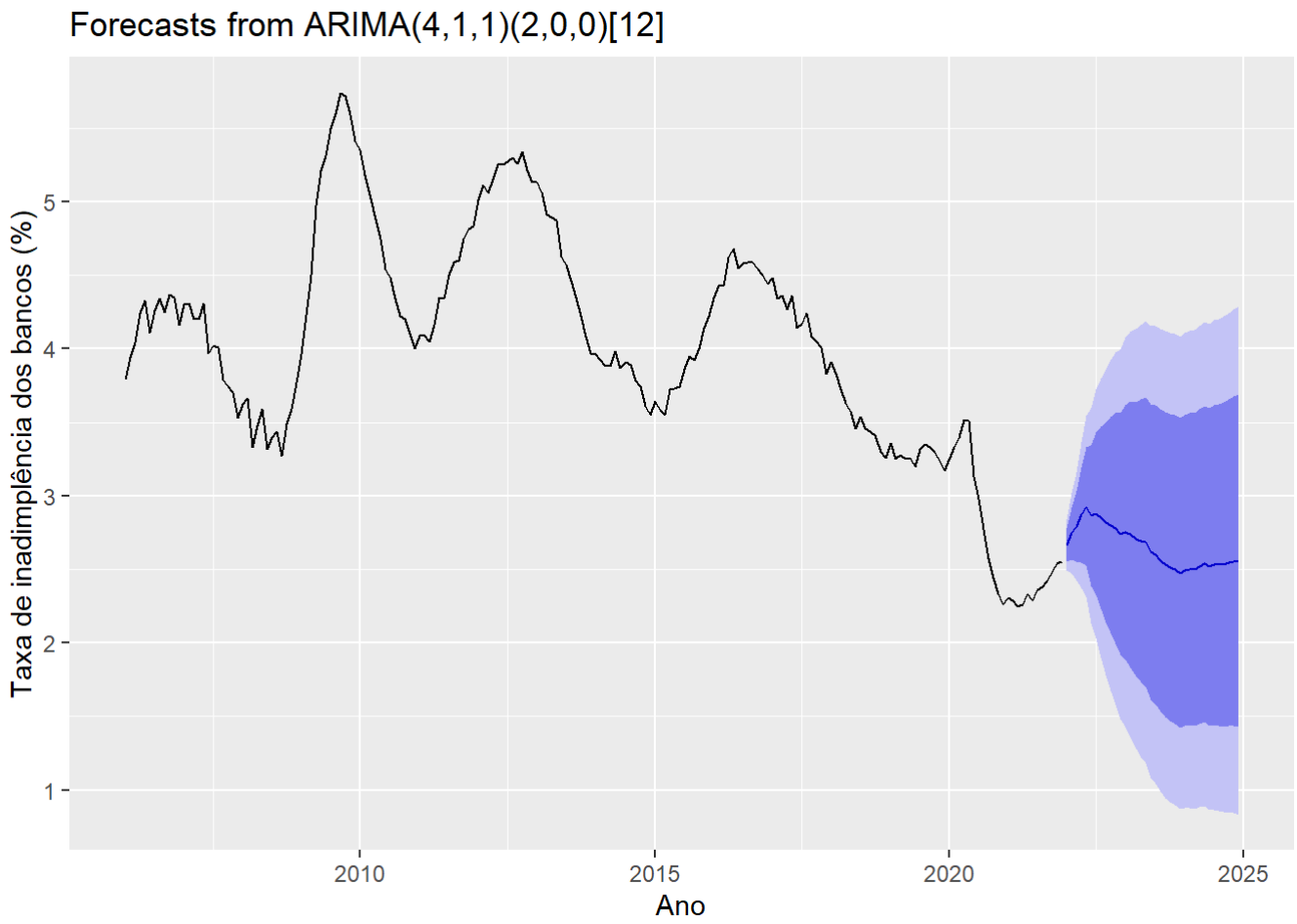
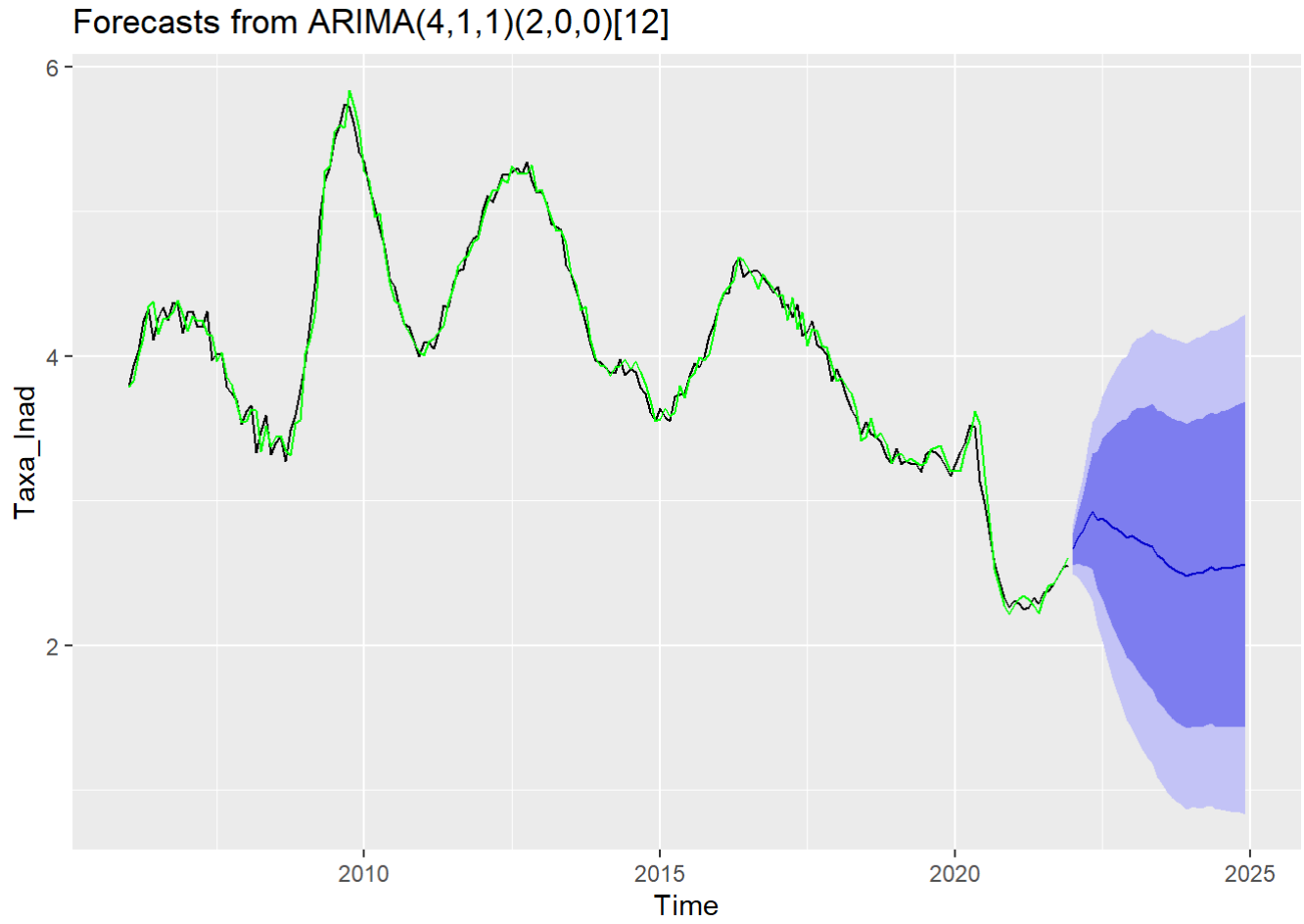


Gráfico dos valores previstos e efetivos

```
previsao24 %>%
  autoplot() +
  geom_line(
    aes(
      x = as.numeric(time(Taxa_Inad)),
      y = as.numeric(mod_arima$fitted)
    ),
    col = "green"
  )
```



Modelo Multivariado

Com base no enunciado, o ano de 2021 será utilizado para validação da previsão. Desta forma, 180 observações (93.75%) da amostra será para treino e 12 observações (6.25%) para teste.

Partição da amostra entre treino e teste.

```
treino<-data[1:180,]
teste<-data[181:192,]
```

Variável Endógena

```
v0<-ts(treino$Index_Inad,
       frequency = 12,
       start=c(2006,1))
```

Variaveis Exógenas

```
v1<-ts(treino$`IBC-BR`,
             frequency=12,
             start=c(2006,01))


v2<-ts(treino$PIB_Index,
             frequency=12,
             start=c(2006,01))

v3<-ts(treino$`Retail Sales`,
             frequency=12,
             start=c(2006,01))

v4<-ts(treino$`Business Credit Concessions`,
             frequency=12,
             start=c(2006,01))

v5<-ts(treino$`Business Confidence Index`,
             frequency=12,
             start=c(2006,01))

v6<-ts(treino$`Commodity Price Index`,
             frequency=12,
             start=c(2006,01))

v7<-ts(treino$`USD/BRL`,
             frequency=12,
             start=c(2006,01))

v8<-ts(treino$`Index of Employed Persons - Industry`,
             frequency=12,
             start=c(2006,01))

v9<-ts(treino$`Uncertainty Index`,
             frequency=12,
             start=c(2006,01))

v10<-ts(treino$IPCA,
             frequency=12,
             start=c(2006,01))

v11<-ts(treino$Juro_Real,
             frequency=12,
             start=c(2006,01))

v12<-ts(treino$Cut,
             frequency=12,
             start=c(2006,01))

v13<-ts(treino$DLSP,
             frequency=12,
             start=c(2006,01))

vxreg<-cbind(
  #v1,  `IBC-BR`
```

```
  #v2,   #Pib Index
  v3,  # Retail Sales
  #v4,  # BCC
 #v5,  #BCI
  #v6,  #CPI
  #v7,  #Cambio
  #v8,  #Emprego
  v9,  #Unc Index
 #v10, #IPCA
  v11,  # Juro Real
  v12  #Cut
 #v13  #DLSP
)
```

Modelo ARIMAX

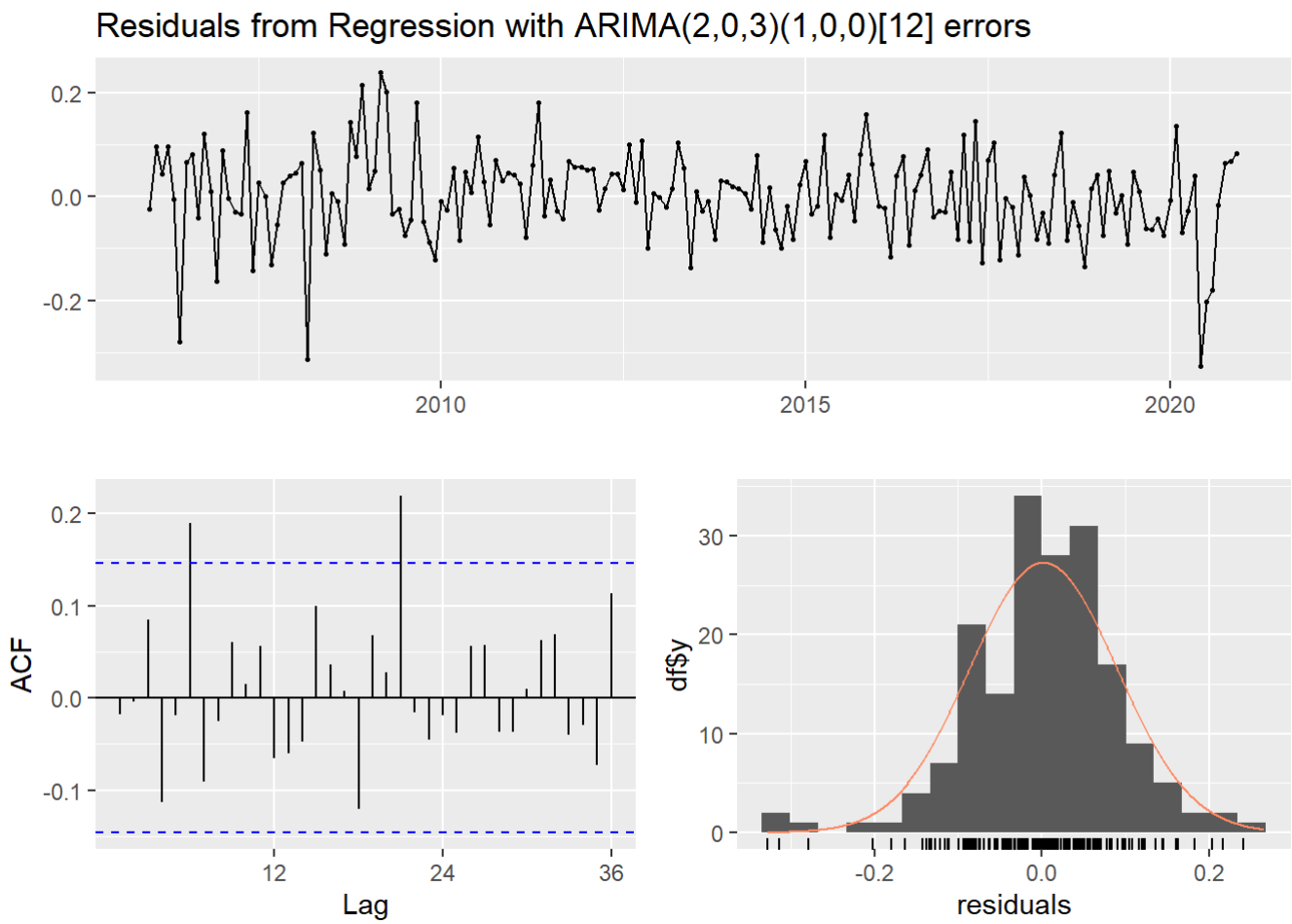
Variaveis exógenas selecionadas: `Retail Sales` , `Uncertainy Index` , `Taxa Real de Juros` e `Custo Unitário do Trabalho` .

```
fit.arima<-auto.arima(v0, xreg=vxreg)


summary(fit.arima)
```

```
## Series: v0
## Regression with ARIMA(2,0,3)(1,0,0)[12] errors
##
## Coefficients:
##          ar1      ar2      ma1     ma2     ma3    sar1  intercept       v3
##       1.8789  -0.9109  -0.8441  0.2418  0.2264  0.4686     3.6340  -0.0015
## s.e.  0.0416   0.0415   0.0954  0.1126  0.0935  0.0786     0.3376   0.0012
##           v9     v11     v12
##       0.0023  0.0057  0.0014
## s.e.  0.0008  0.0129  0.0009
##
## sigma^2 = 0.008192:  log likelihood = 178.45
## AIC=-332.91   AICc=-331.04   BIC=-294.59
##
## Training set error measures:
##                       ME       RMSE        MAE          MPE     MAPE      MASE
## Training set 0.001536118 0.08769797 0.06643007 -0.02138524 1.687056 0.1032114
##                     ACF1
## Training set -0.01783315
```

Análise dos resíduos

```
checkresiduals(fit.arima)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(2,0,3)(1,0,0)[12] errors
## Q* = 32.274, df = 13, p-value = 0.002188
##
## Model df: 11.   Total lags used: 24
```

```
Box.test(fit.arima$residuals, type="Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  fit.arima$residuals
## X-squared = 0.058203, df = 1, p-value = 0.8094
```

Com base no teste de Ljung-Box, constata-se a ausência de correlação dos resíduos.

Variáveis para validação da estimação

```
w0<-ts(teste$Index_Inad,
             frequency=12,
             start=c(2021,01))


w1<-ts(teste$`IBC-BR`,
             frequency=12,
             start=c(2021,01))

w2<-ts(teste$PIB_Index,
             frequency=12,
             start=c(2021,01))

w3<-ts(teste$`Retail Sales`,
             frequency=12,
             start=c(2021,01))

w4<-ts(teste$`Business Credit Concessions`,
             frequency=12,
             start=c(2021,01))

w5<-ts(teste$`Business Confidence Index`,
             frequency=12,
             start=c(2021,01))

w6<-ts(teste$`Commodity Price Index`,
             frequency=12,
             start=c(2021,01))

w7<-ts(teste$`USD/BRL`,
             frequency=12,
             start=c(2021,01))

w8<-ts(teste$`Index of Employed Persons - Industry`,
             frequency=12,
             start=c(2021,01))

w9<-ts(teste$`Uncertainty Index`,
             frequency=12,
             start=c(2021,01))

w10<-ts(teste$IPCA,
             frequency=12,
             start=c(2021,01))

w11<-ts(teste$Juro_Real,
             frequency=12,
             start=c(2021,01))

w12<-ts(teste$Cut,
             frequency=12,
             start=c(2021,01))

w13<-ts(teste$DLSP,
             frequency=12,
```

```
            start=c(2021,01))

wxreg<-cbind(
  #w1,# `IBC-BR`
  #w2,   #Pib Index
  w3,  # Retail Sales
  #w4,  # BCC
 # w5,  #BCI
  #w6,  #CPI
  #w7,  #Cambio
  #w8,  #Emprego
  w9,  #Unc Index
 #w10, #IPCA
  w11,  # Juro Real (Baixo)
  w12#v12  #Cut
 #w13  #DLSP (ALto)
)
```

Raizes ARIMAX

```
autoplot(fit.arima)
```

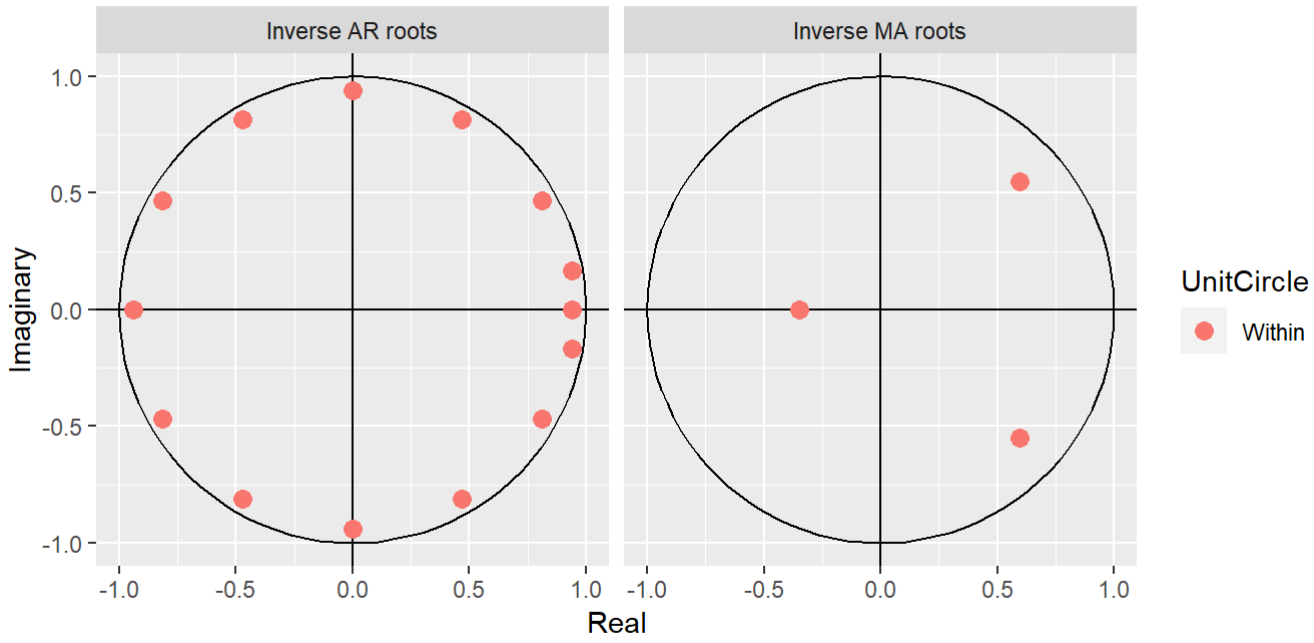
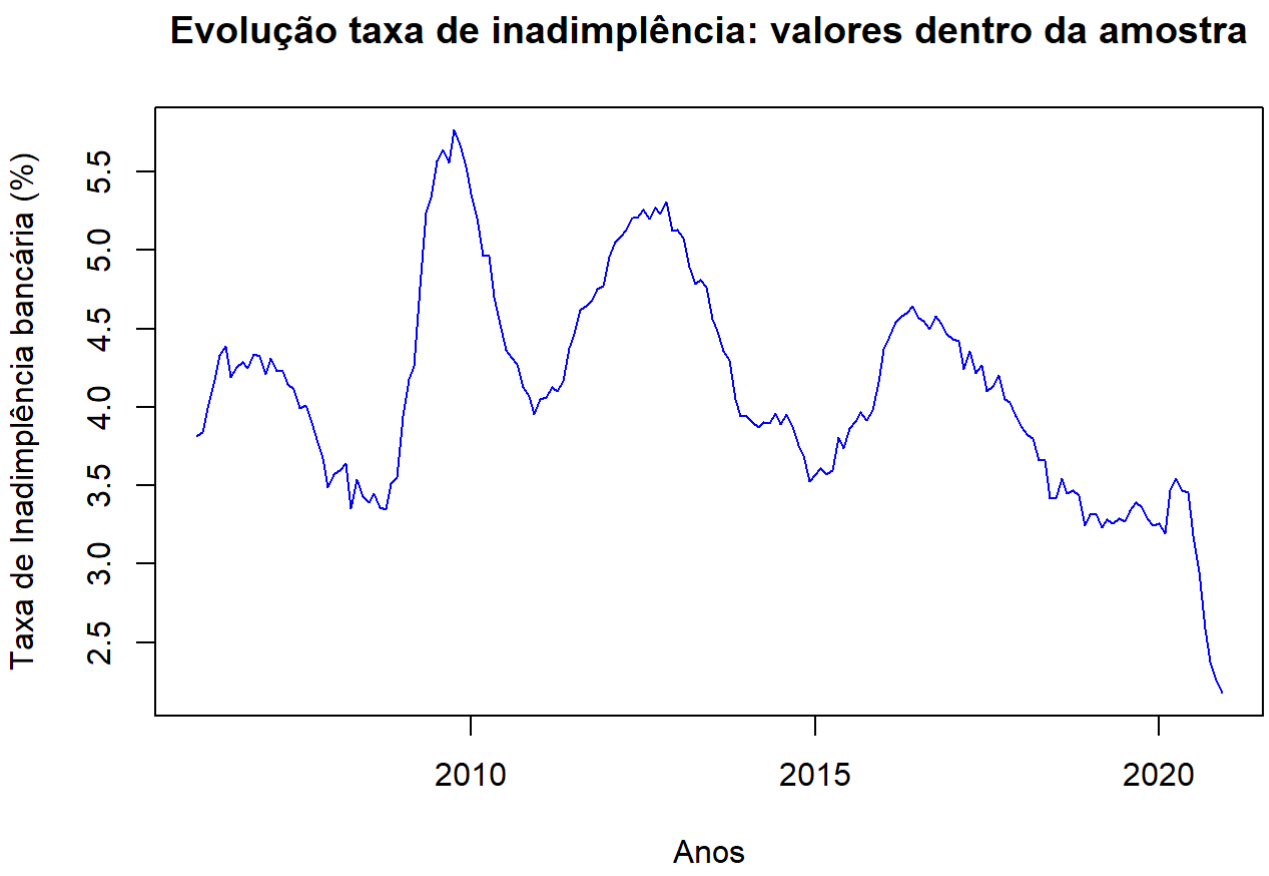


Gráfico (In-Sample)

```
plot.ts(fit.arima$fitted,
       xlab="Anos",
       ylab="Taxa de Inadimplência bancária (%)",
        main="Evolução taxa de inadimplência: valores dentro da amostra",
       col="blue")
```



Previsão fora da amostra

Validação para 2021

```
previsao21<-forecast(fit.arima, xreg = wxreg)
```

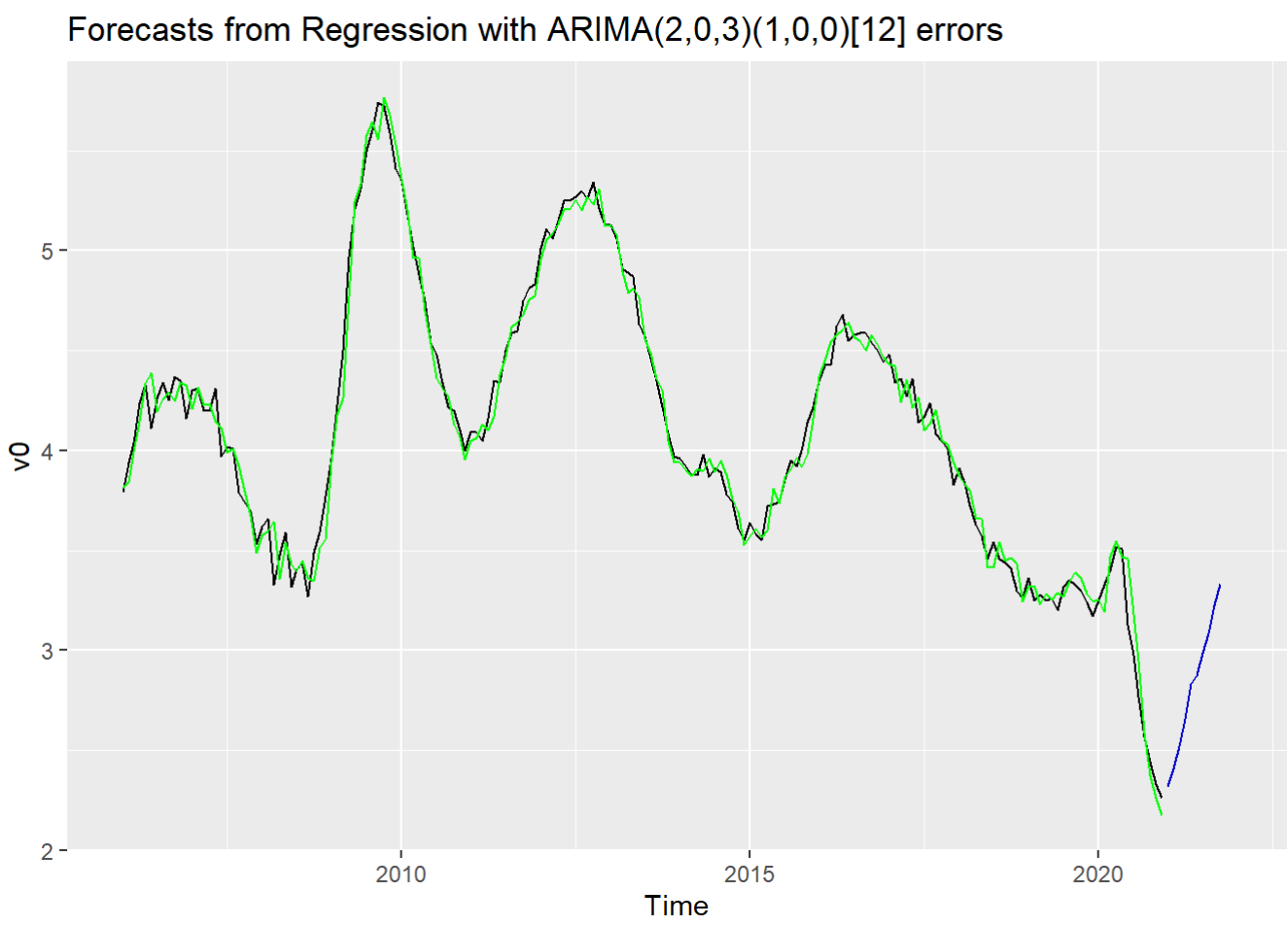
```
## Warning in forecast.forecast_ARIMA(fit.arima, xreg = wxreg): xreg contains
## different column names from the xreg used in training. Please check that the
## regressors are in the same order.
```

```
## Warning in forecast.forecast_ARIMA(fit.arima, xreg = wxreg): Upper prediction
## intervals are not finite.
```

```
previsao21
```

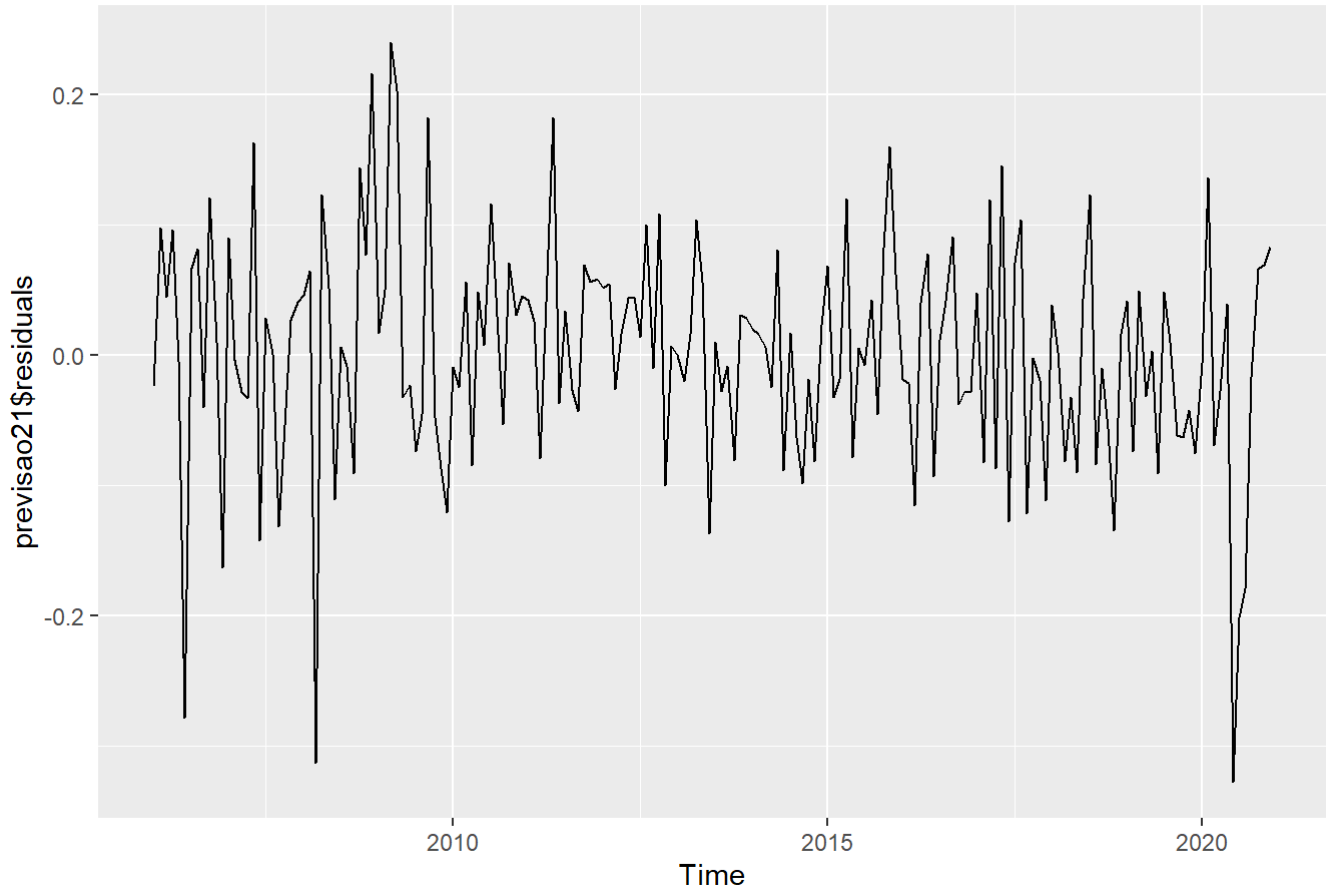
```
##          Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## Jan 2021       2.318783 2.202793 2.434772 2.141392 2.496173
## Feb 2021       2.408203 2.241291 2.575115 2.152933 2.663473
## Mar 2021       2.520090 2.297074 2.743106 2.179016 2.861164
## Apr 2021       2.657047 2.360916 2.953179 2.204154 3.109941
## May 2021       2.831366 2.455591 3.207142 2.256667 3.406066
## Jun 2021       2.877675 2.422321 3.333029 2.181272 3.574079
## Jul 2021       2.989636 2.458978 3.520294 2.178065 3.801208
## Aug 2021       3.086932 2.487996 3.685869 2.170938 4.002926
## Sep 2021       3.227849 2.569383 3.886314 2.220812 4.234885
## Oct 2021       3.331825 2.623490 4.040160 2.248520 4.415130
## Nov 2021             NA       NA       NA       NA       NA
## Dec 2021             NA       NA       NA       NA       NA
```

```
previsao21 %>%
  autoplot() +
  geom_line(
    aes(
      x = as.numeric(time(v0)),
      y = as.numeric(fit.arima$fitted)
    ),
    col = "green"
  )
```



Análise dos resíduos

```
autoplot(previsao21$residuals)
```




```
Box.test(previsao21$residuals, type = "Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  previsao21$residuals
## X-squared = 0.058203, df = 1, p-value = 0.8094
```

Com base no p-valor do teste Ljung-Box, constata-se que os residuos são não correlacionados.

Acurácia

```
accuracy(previsao21, teste$Index_Inad)
```

```
##                       ME       RMSE        MAE          MPE      MAPE
## Training set  0.001536118 0.08769797 0.06643007  -0.02138524  1.687056
## Test set     -0.487940630 0.55819305 0.48794063 -20.64073913 20.640739
##                    MASE        ACF1
## Training set 0.6676577 -0.01783315
## Test set     4.9040636          NA
```

```
previsao24<-forecast(fit.arima, xreg=vxreg, h=36)

fit.prev<-previsao24$fitted[1:36]

summary(fit.prev)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   3.346   3.550   3.957   3.890   4.230   4.389
```

```
round(sd(fit.prev),2) #Desvio Padrão
```

```
## [1] 0.36
```

Portanto, a taxa de inadimplência média no período entre 2022 e 2024, será igual a 3.89% com desvio padrão de 36%.

Acurácia da previsão

```
accuracy(previsao24)
```

```
##                       ME       RMSE        MAE         MPE     MAPE      MASE
## Training set 0.001536118 0.08769797 0.06643007 -0.02138524 1.687056 0.1032114
##                      ACF1
## Training set -0.01783315
```

Neste caso, o MAE, apresentou valor igual a 6.64% e o RMSE igual a 8.7%.

Conclusão

Com base em modelos univariados e multivariados de séries temporais, foi modelada a série de inadimplência dos bancos privados no Brasil. Neste estudo, a série histórica mensal, obtida junto ao SGS do Banco Central do Brasil cobre o período de janeiro de 2006 a dezembro de 2021. Ademais, foi construido um banco de dados contendo 16 variáveis macroecônomicas, totalizando 192 observações. Com base no teste de raiz unitária foi possível constatar que a série de inadimplência no Brasil não é estacionária.

Primeiramente, com base no modelo ARIMA, a série de inadimplência foi estimada utilizando seus termos autoregressivos e de médias móveis. A previsão foi realizada considerando os 36 meses a frente. Em seguida, no modelo multivariado, a amostra foi particionada entre treino e teste, para realização da previsão fora da amostra e testar a validação da estimação.

No modelo ARIMAX, as seguintes variáveis explicativas foram incluidas: Vendas no Varejo, Indice de Incerteza, Taxa Real de Juros e Custo Unitário de Trabalho, pois apresentaram conjuntamente, menor correlação dos resíduos. O valor médio da taxa de inadimplência prevista para o período até dez/24 foi igual a 3.89% com desvio padrão de 36%, o qual pode ser indicio de forte volatidade no período em questão.

Apêndice

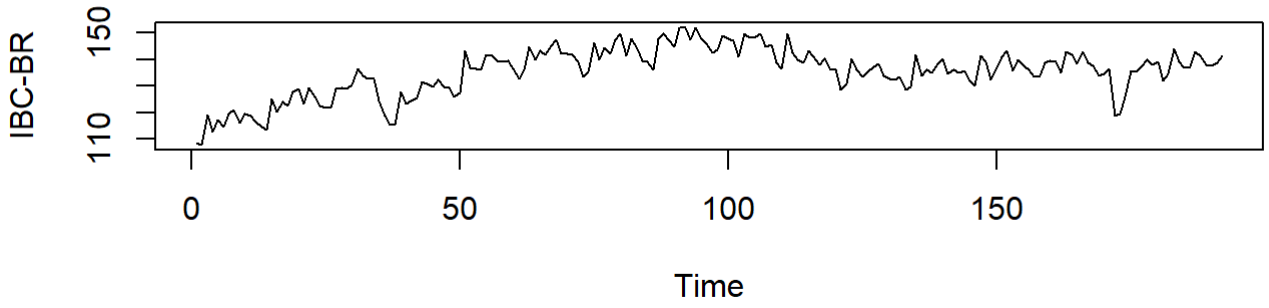
Testes de estacionariedade das variáveis explicativas

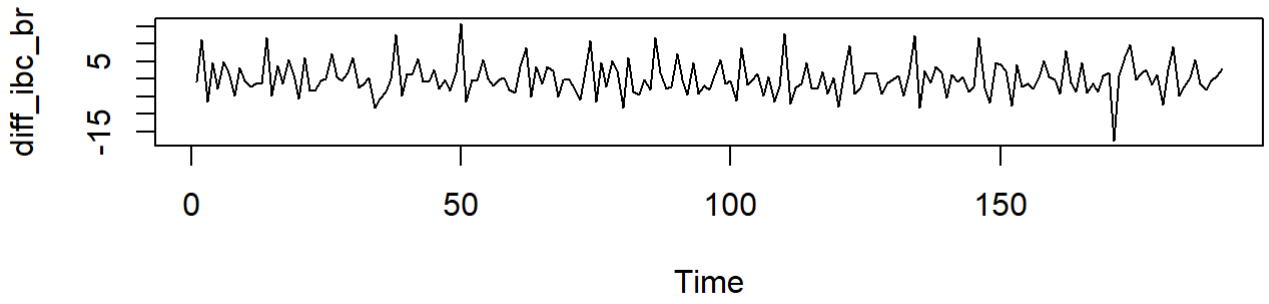
IBC-BR

```
data$`IBC-BR`<-ts(data$`IBC-BR`)

ndiffs(`IBC-BR`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_ibc_br<-diff(`IBC-BR`)

par(mfrow=c(2,1))

plot.ts(`IBC-BR`)

plot.ts(diff_ibc_br)
```



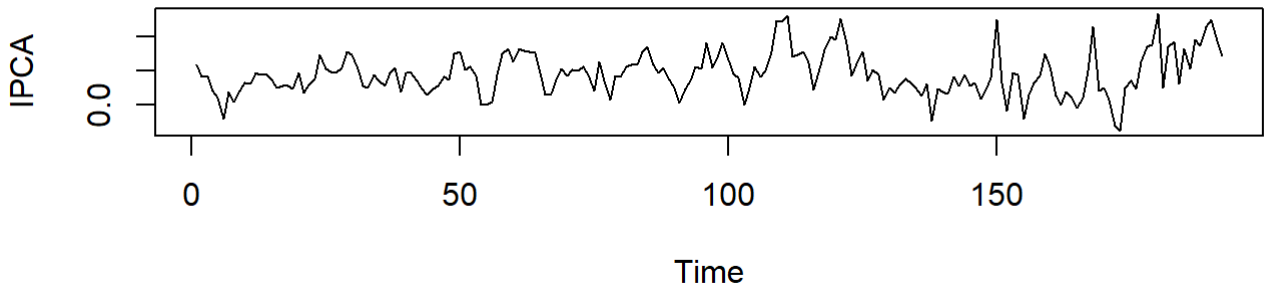


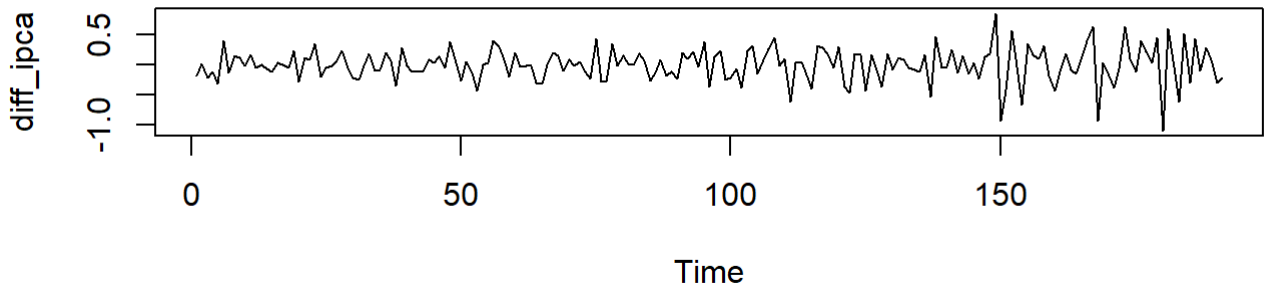
IPCA

```
data$IPCA<-ts(data$IPCA, start=c(2006,1), frequency=12)

ndiffs(IPCA, alpha=0.05, test="kpss")
```

```
## [1] 0
```

```
diff_ipca<-diff(IPCA)

par(mfrow=c(2,1))

plot.ts(IPCA)

plot.ts(diff_ipca)
```



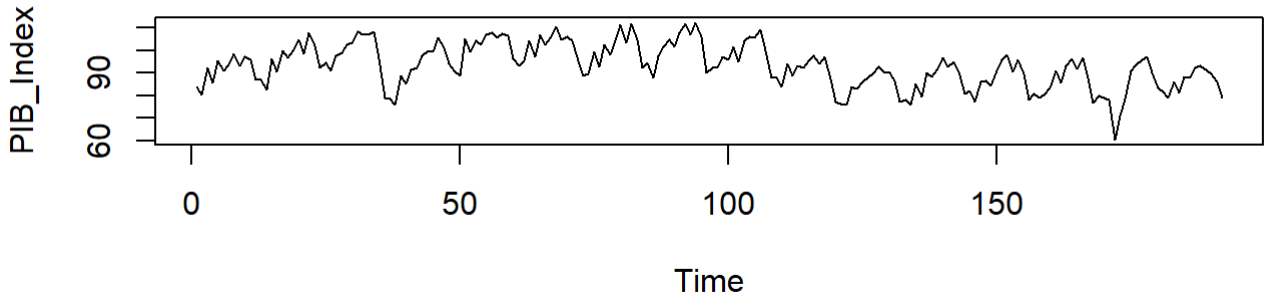


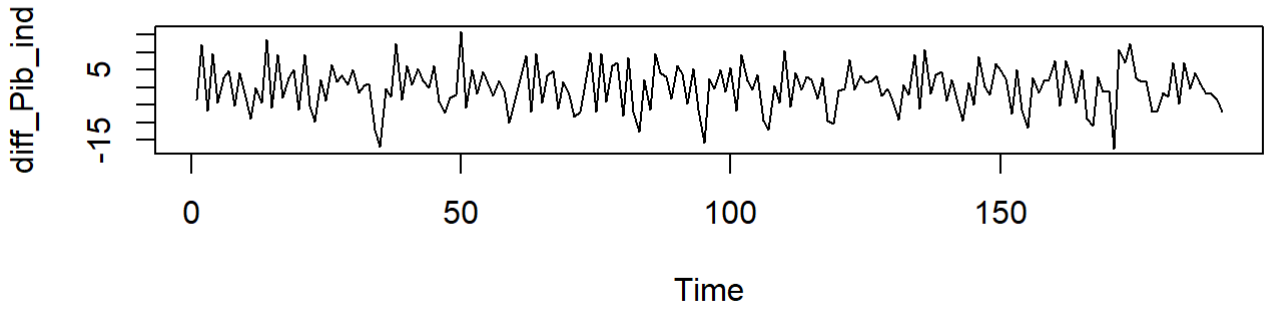
Industrial Production

```
data$PIB_Index<-ts(data$PIB_Index)

ndiffs(PIB_Index, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_Pib_ind<-diff(PIB_Index)

par(mfrow=c(2,1))

plot.ts(PIB_Index)

plot.ts(diff_Pib_ind)
```



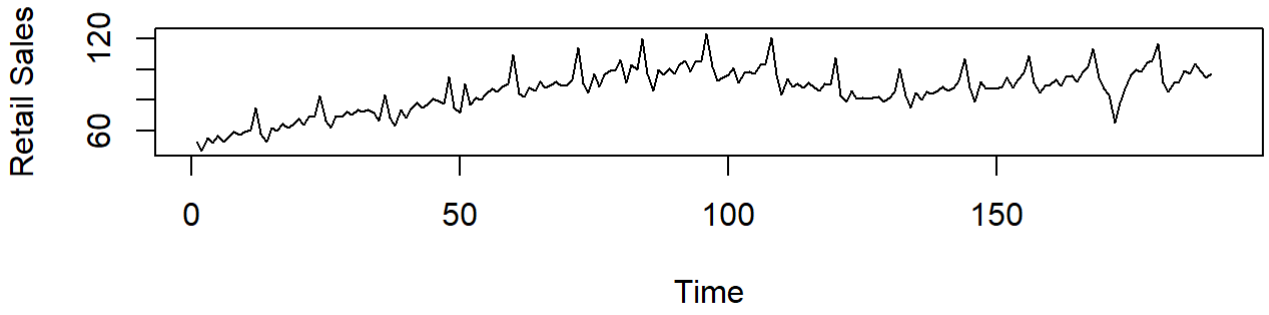


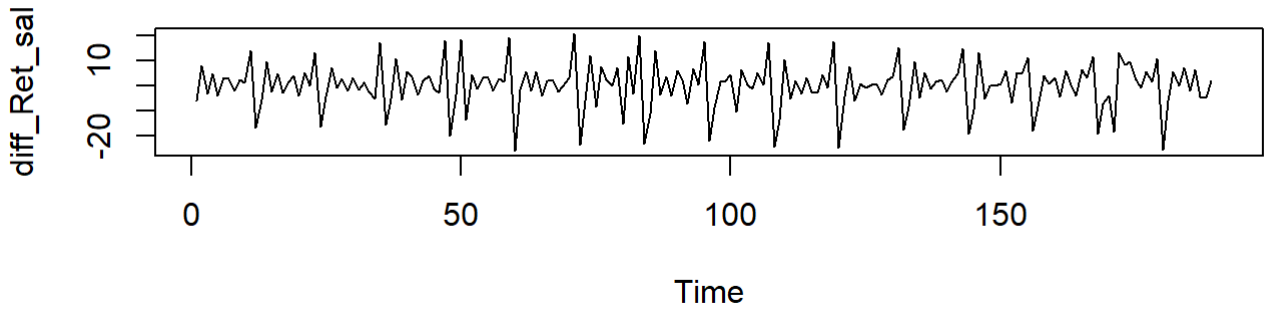
Retail Sales

```
data$`Retail Sales`<-ts(data$`Retail Sales`)

ndiffs(`Retail Sales`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_Ret_sal<-diff(`Retail Sales`)

par(mfrow=c(2,1))

plot.ts(`Retail Sales`)

plot.ts(diff_Ret_sal)
```



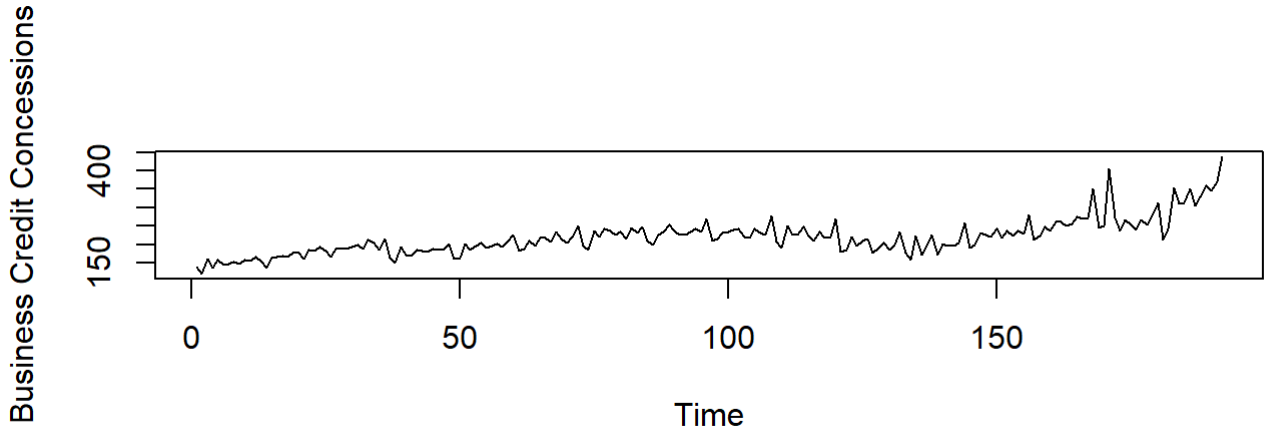


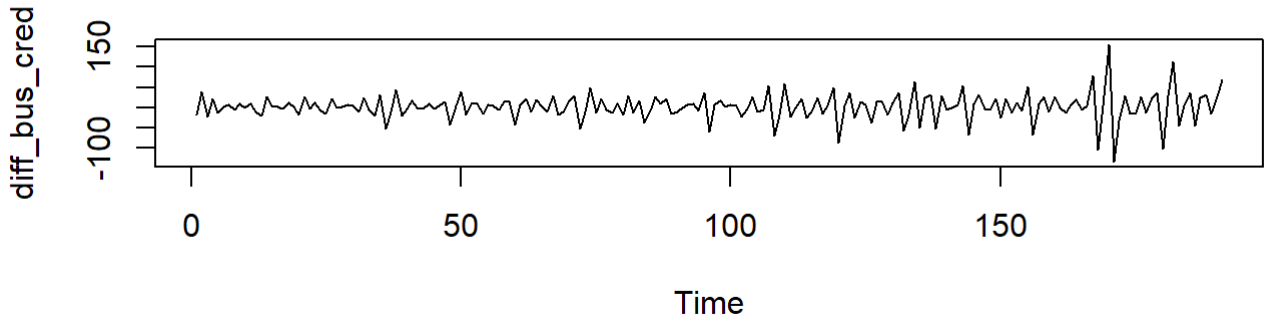
Business Credit Concessions

```
data$`Business Credit Concessions`<-data$`Business Credit Concessions`

ndiffs(`Business Credit Concessions`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_bus_cred<-diff(`Business Credit Concessions`)

par(mfrow=c(2,1))

plot.ts(`Business Credit Concessions`)

plot.ts(diff_bus_cred)
```



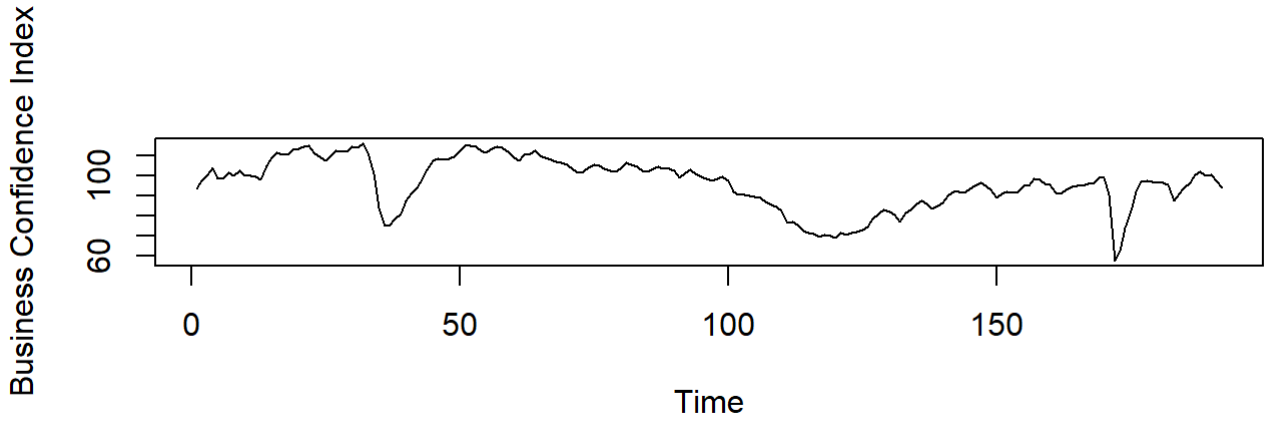


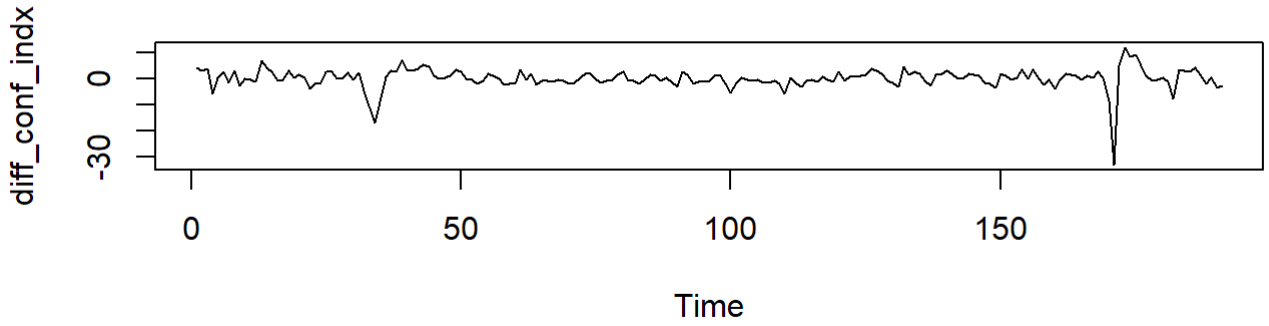
Business Confidence Index

```
data$`Business Confidence Index`<-ts(data$`Business Confidence Index`)

ndiffs(`Business Confidence Index`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_conf_indx<-diff(`Business Confidence Index`)

par(mfrow=c(2,1))

plot.ts(`Business Confidence Index`)

plot.ts(diff_conf_indx)
```



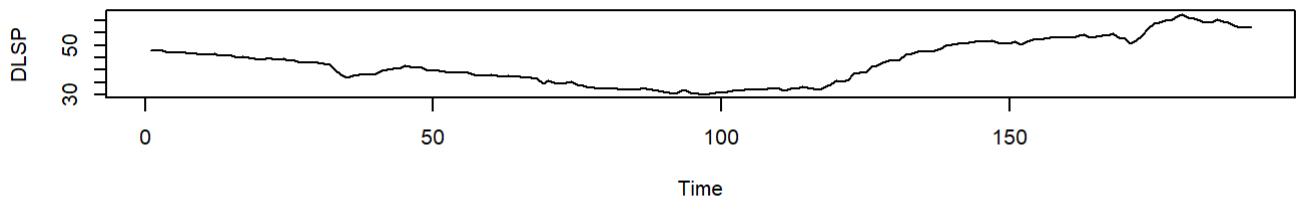


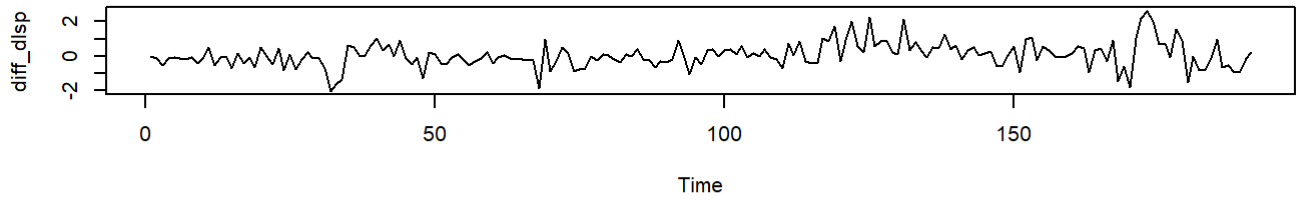
DSLP

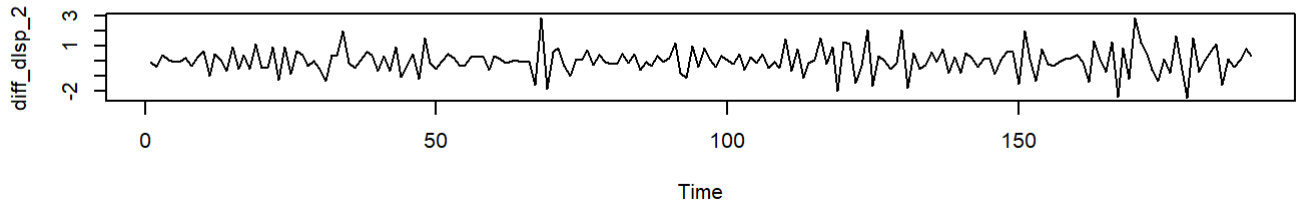
```
data$DLSP<-ts(data$DLSP)

ndiffs(`DLSP`, alpha=0.05, test="kpss")
```

```
## [1] 2
```

```
diff_dlsp<-diff(`DLSP`)

diff_dlsp_2<-diff(diff_dlsp)

par(mfrow=c(3,1))

plot.ts(`DLSP`)

plot.ts(diff_dlsp)

plot.ts(diff_dlsp_2)
```





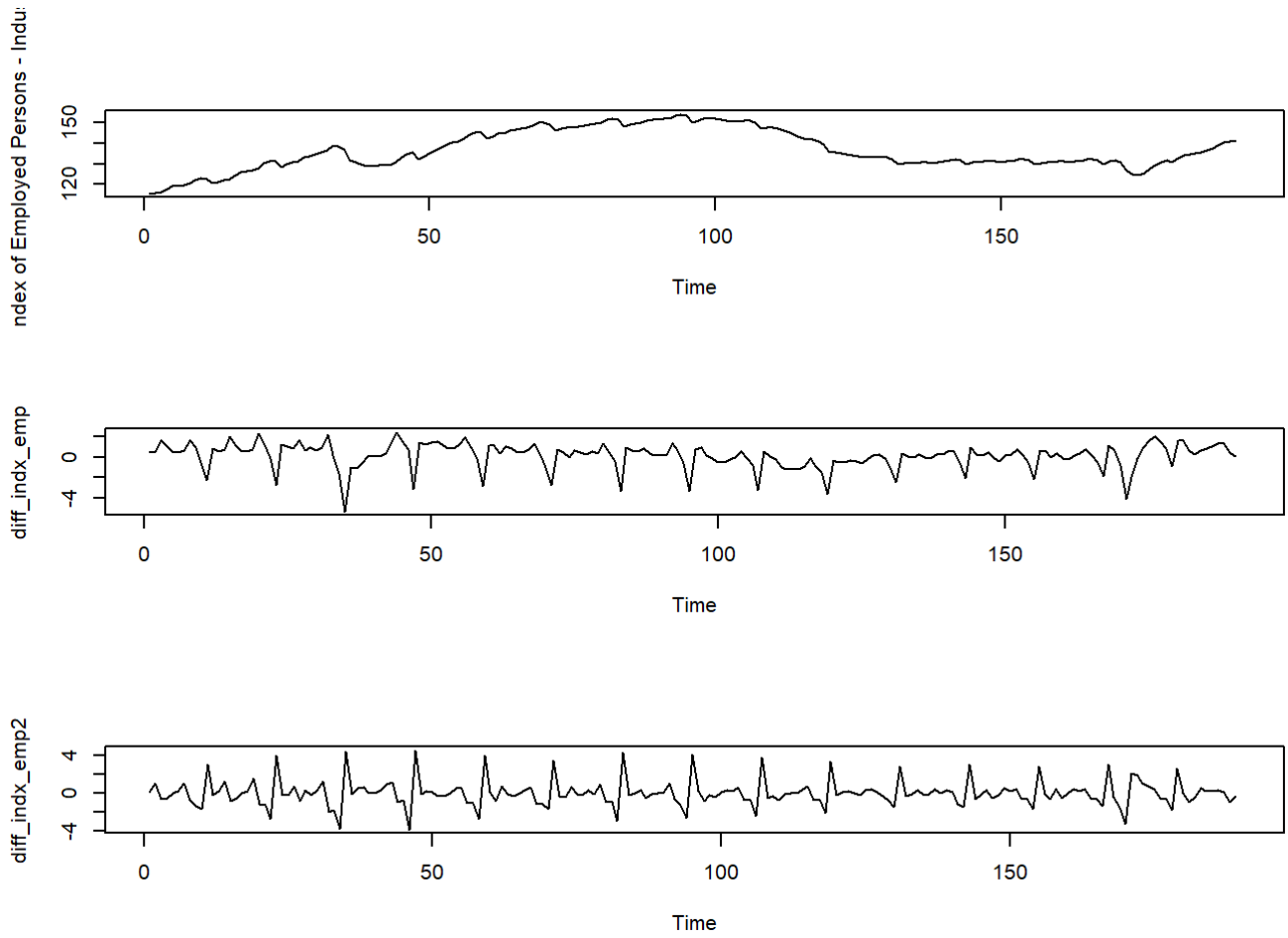


Index of Employed Persons - Industry

```
data$`Index of Employed Persons - Industry`<-ts(data$`Index of Employed Persons - Industry`)

ndiffs(`Index of Employed Persons - Industry`, alpha=0.05, test="kpss")
```

```
## [1] 2
```

```
diff_indx_emp<-diff(`Index of Employed Persons - Industry`)

diff_indx_emp2<-diff(diff_indx_emp)

par(mfrow=c(3,1))

plot.ts(`Index of Employed Persons - Industry`)

plot.ts(diff_indx_emp)

plot.ts(diff_indx_emp2)
```




```
length(diff_indx_emp)
```

```
## [1] 191
```

```
length(diff_indx_emp2)
```

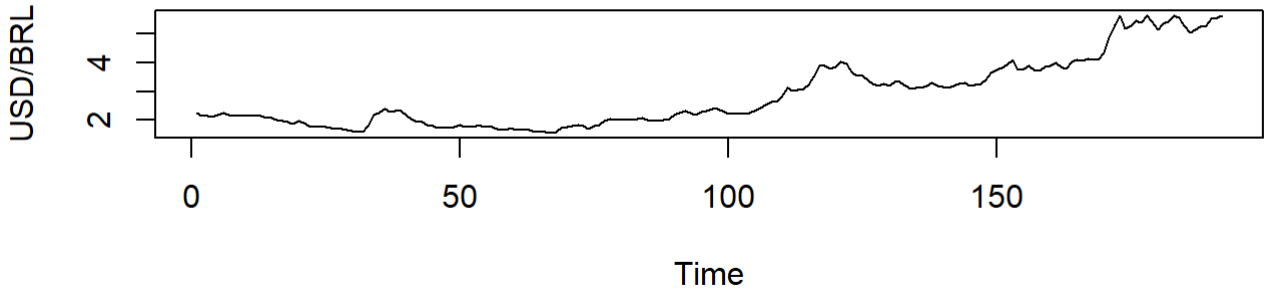
```
## [1] 190
```

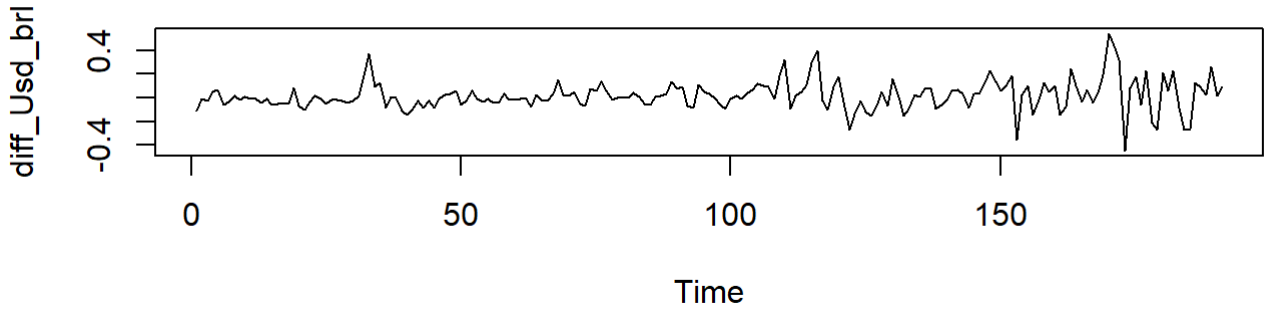
- USD/BRL

```
data$`USD/BRL`<-ts(data$`USD/BRL`)

ndiffs(`USD/BRL`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_Usd_brl<-diff(`USD/BRL`)

par(mfrow=c(2,1))

plot.ts(`USD/BRL`)

plot.ts(diff_Usd_brl)
```






```
length(diff_Usd_brl)
```

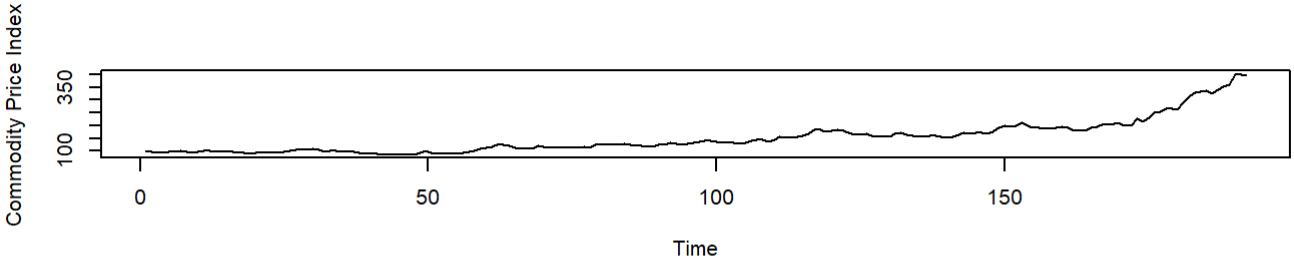
```
## [1] 191
```

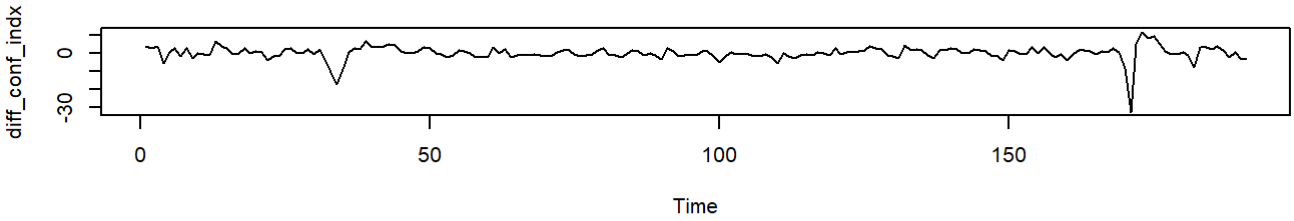
Commodity price index

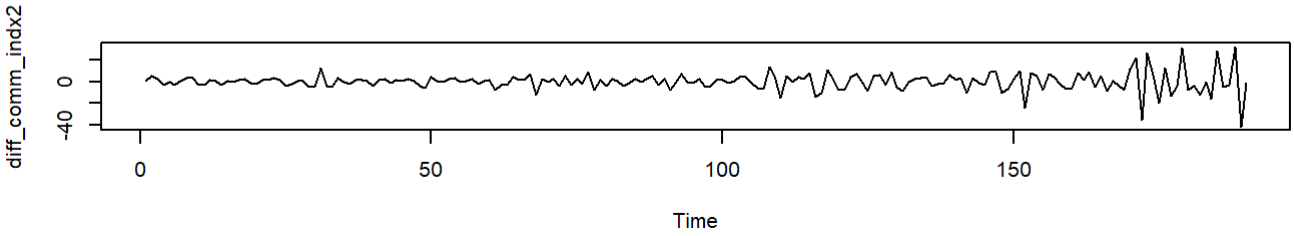
```
data$`Commodity Price Index`<-ts(data$`Commodity Price Index`)

ndiffs(`Commodity Price Index`, alpha=0.05, test="kpss")
```

```
## [1] 2
```

```
diff_comm_indx<-diff(`Commodity Price Index`)

diff_comm_indx2<-diff(diff_comm_indx)

par(mfrow=c(3,1))

plot.ts(`Commodity Price Index`)

plot.ts(diff_conf_indx)

plot.ts(diff_comm_indx2)
```





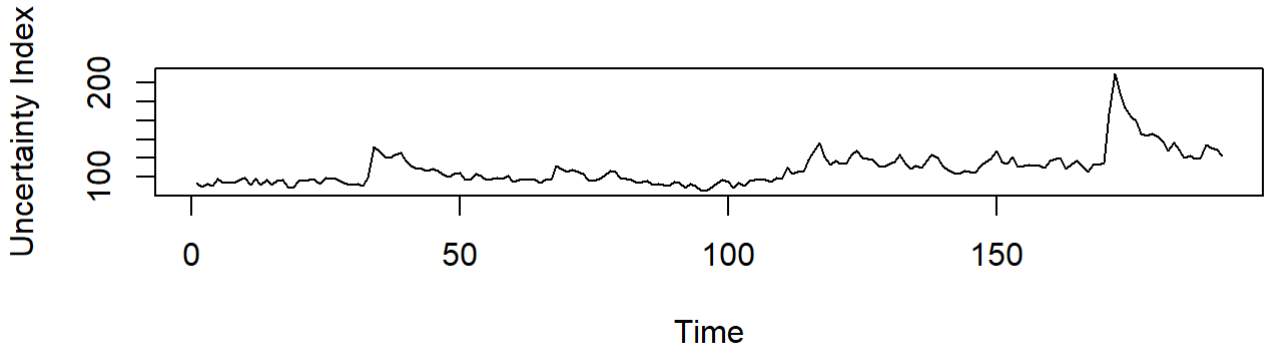


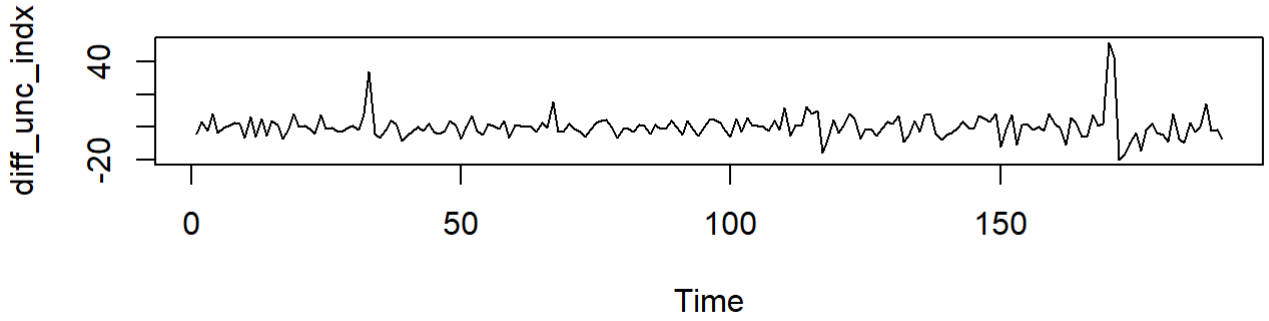
Uncertainy Index

```
data$`Uncertainty Index`<-ts(data$`Uncertainty Index`)

ndiffs(`Uncertainty Index`, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_unc_indx<-diff(`Uncertainty Index`)

par(mfrow=c(2,1))

plot.ts(`Uncertainty Index`)

plot.ts(diff_unc_indx)
```



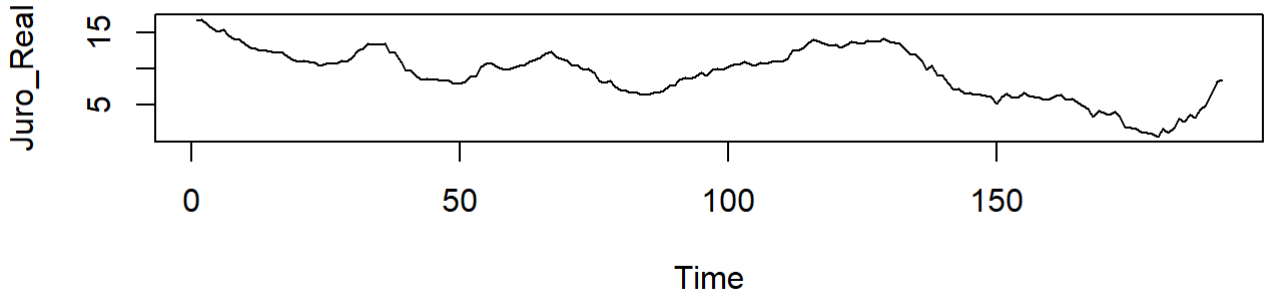


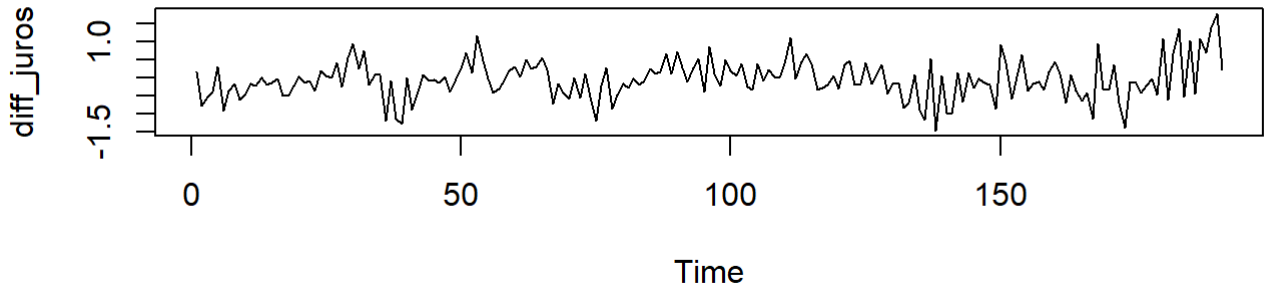
Taxa Real de Juros

```
data$juros<-ts(data$Juro_Real)

ndiffs(Juro_Real, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_juros<-diff(Juro_Real)

par(mfrow=c(2,1))

plot.ts(Juro_Real)

plot.ts(diff_juros)
```



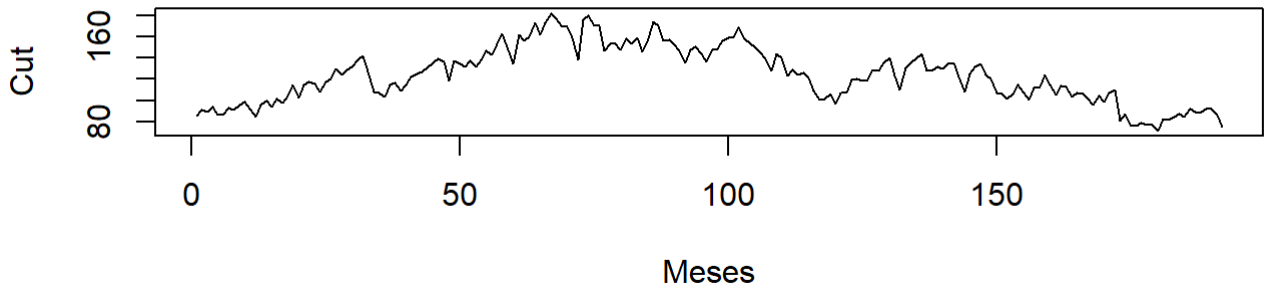


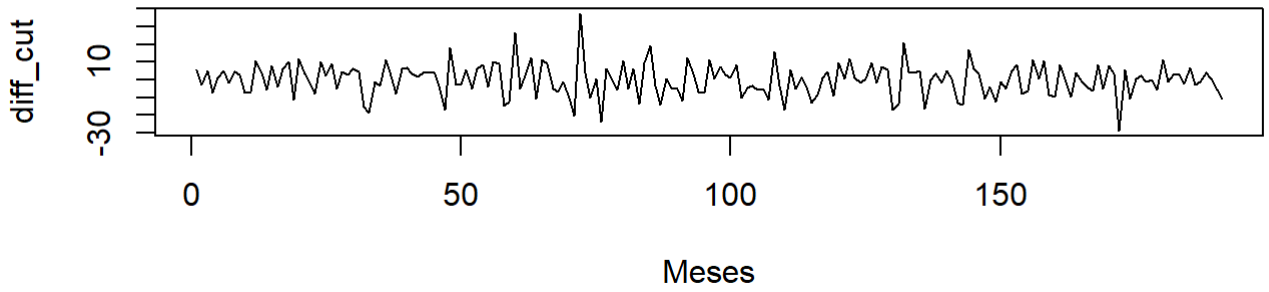
Custo Unitário do trabalho

```
ndiffs(Cut, alpha=0.05, test="kpss")
```

```
## [1] 1
```

```
diff_cut<-diff(Cut)

par(mfrow=c(2,1))

plot.ts(Cut,xlab="Meses")

plot.ts(diff_cut, xlab="Meses")
```


Cut
80
160
0
50
100
150
Meses


diff_cut
-30
10
0
50
100
150
Meses