Econ 144 HW 3

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Contents

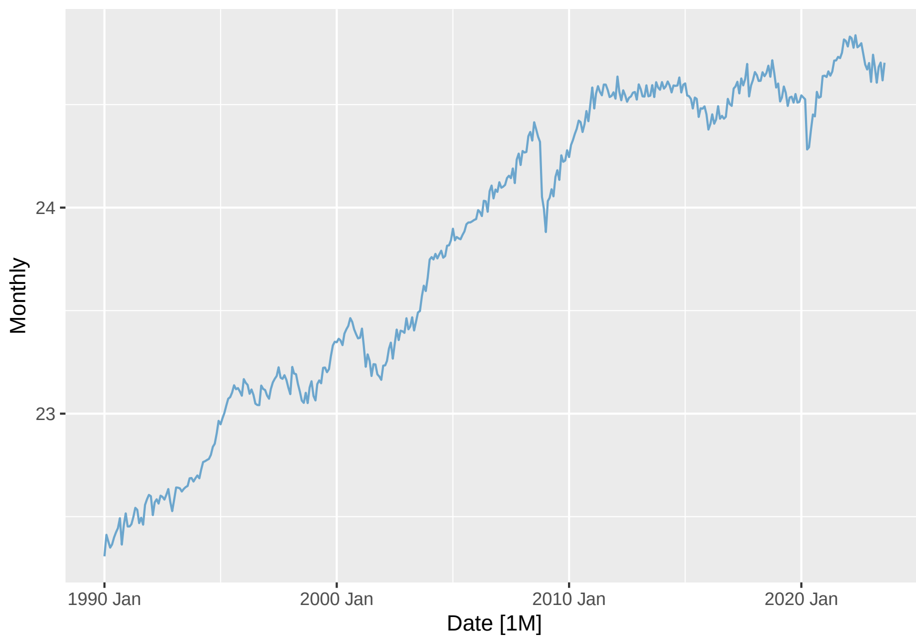
I. Introduction (describe the data, provide some background on the topic, etc.).

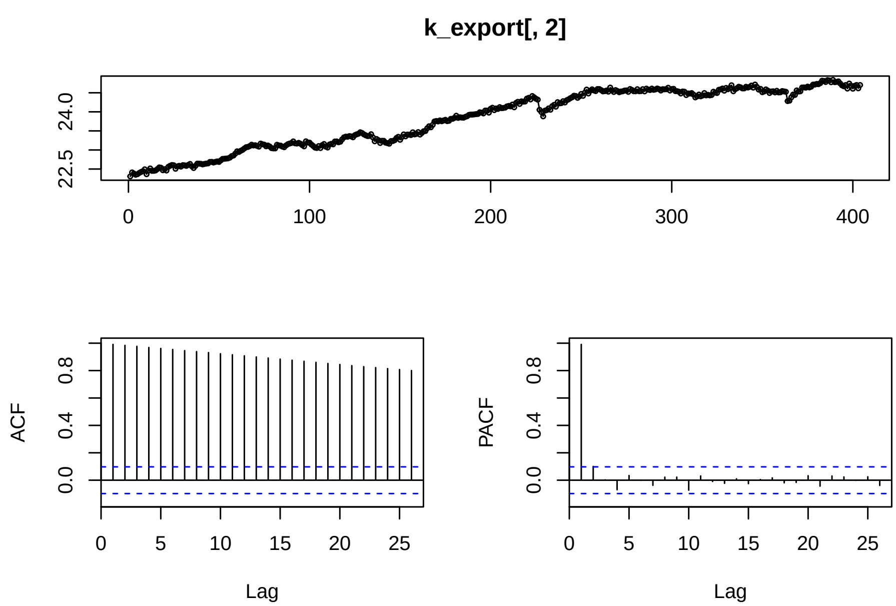
II. (80%) Results (answers and plots).

(a) Produce a time-series plot of your data including the respective ACF and PACF plots.

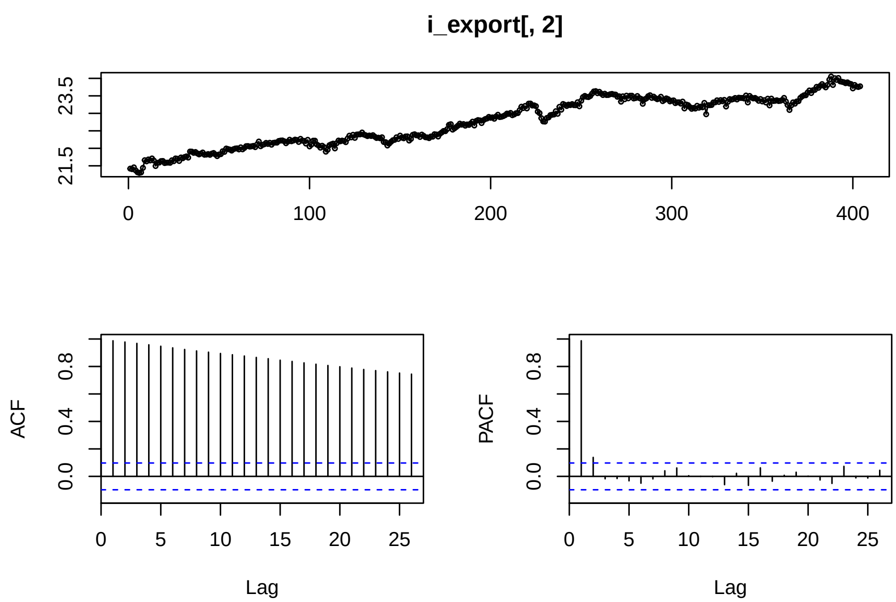
(a) Time Series Plots

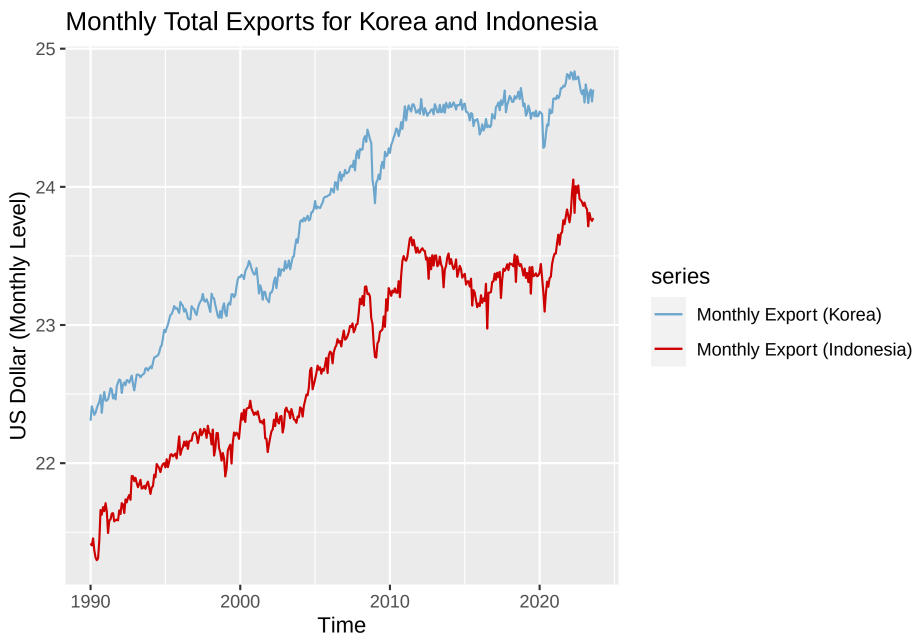
International Trade: Exports: Value (Goods): Total for Korea



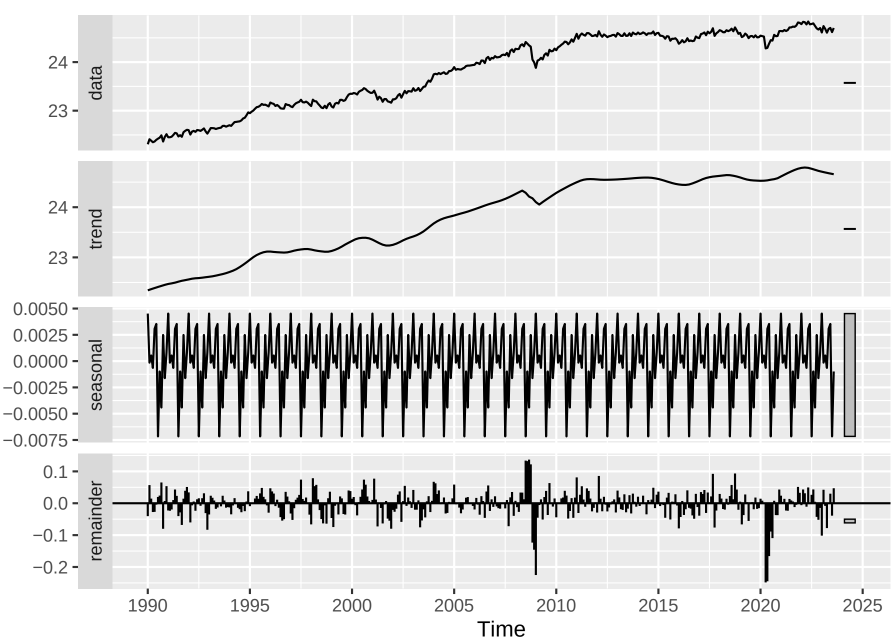


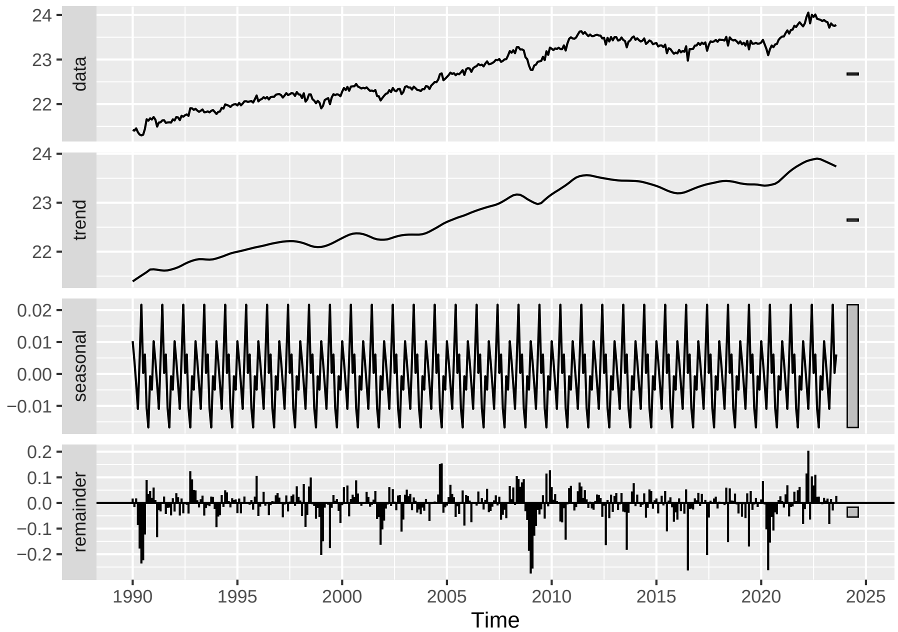

24
23
22
Monthly
1990 Jan
2000 Jan
2010 Jan
2020 Jan
Date [1M]


i_export[, 2]
23.5
21.5
0
100
200
300
400
ACF
0.0
0.4
0.8
Lag
PACF
5
10
15
20
25

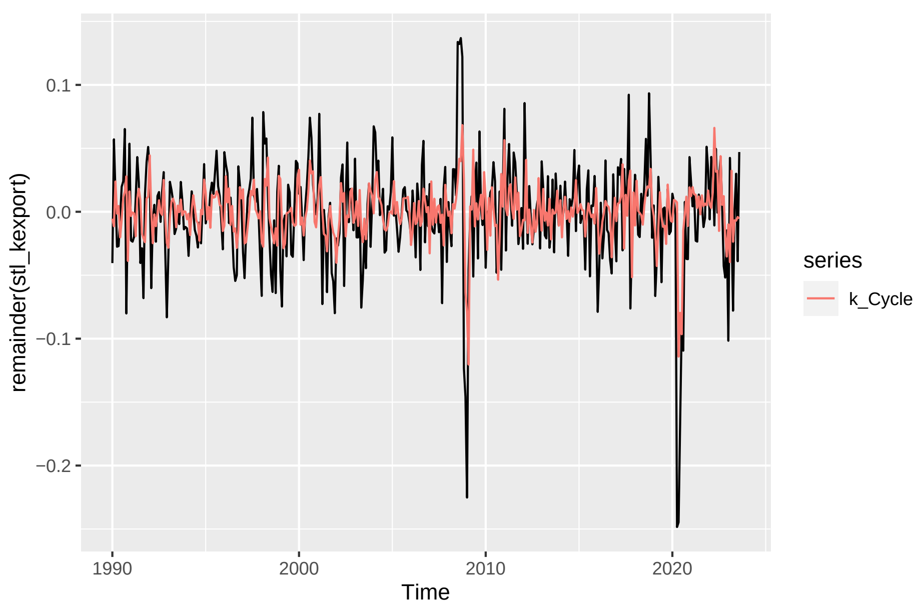


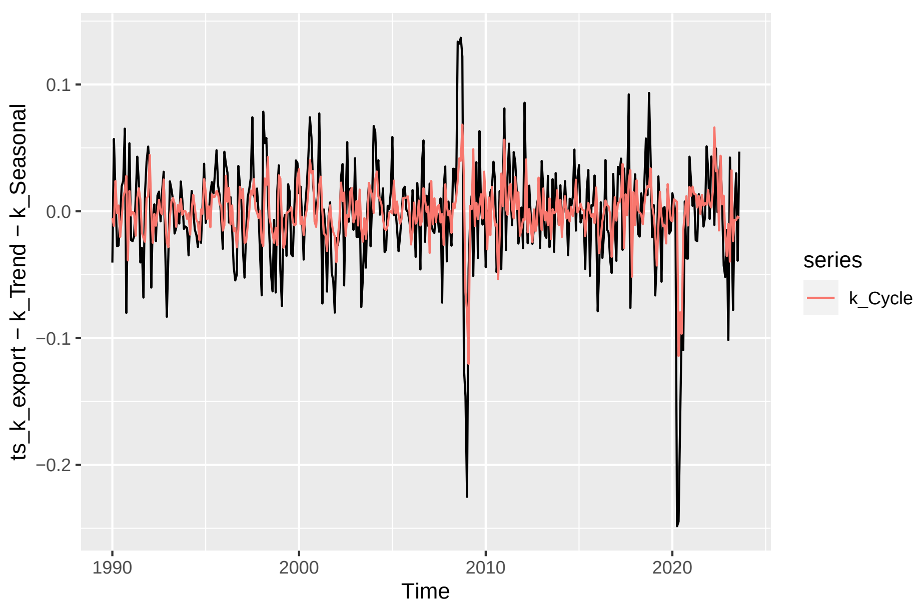
(b) Plot the stl decomposition plot of your data, and discuss the results.

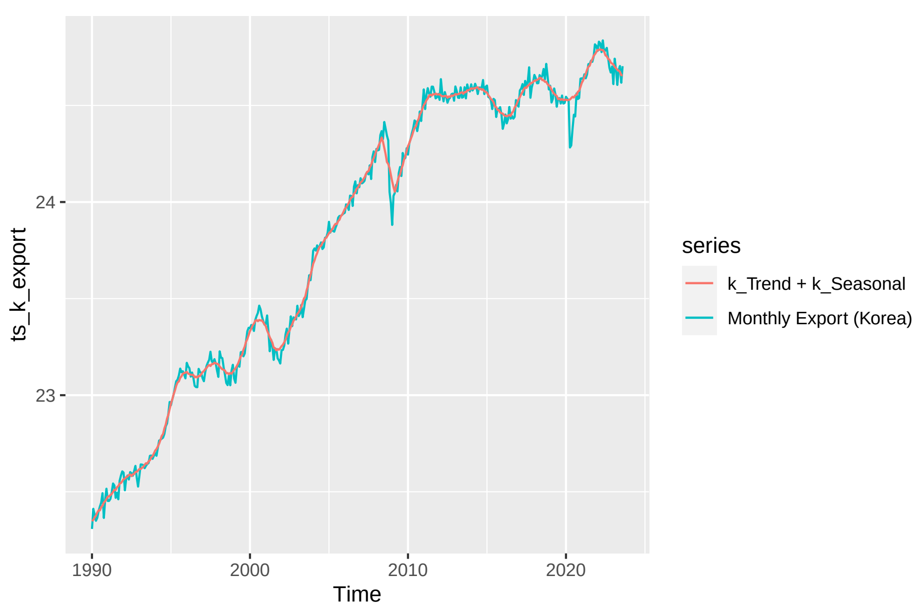


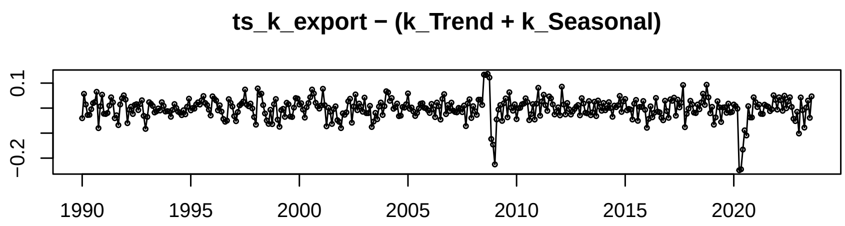


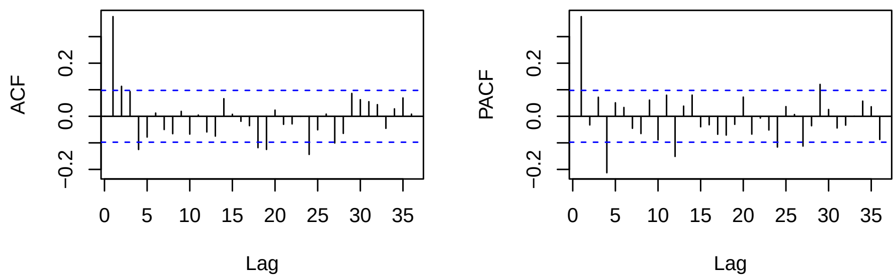
(c) Fit a model that includes, trend, seasonality and cyclical components. Make sure to discuss your model in detail.

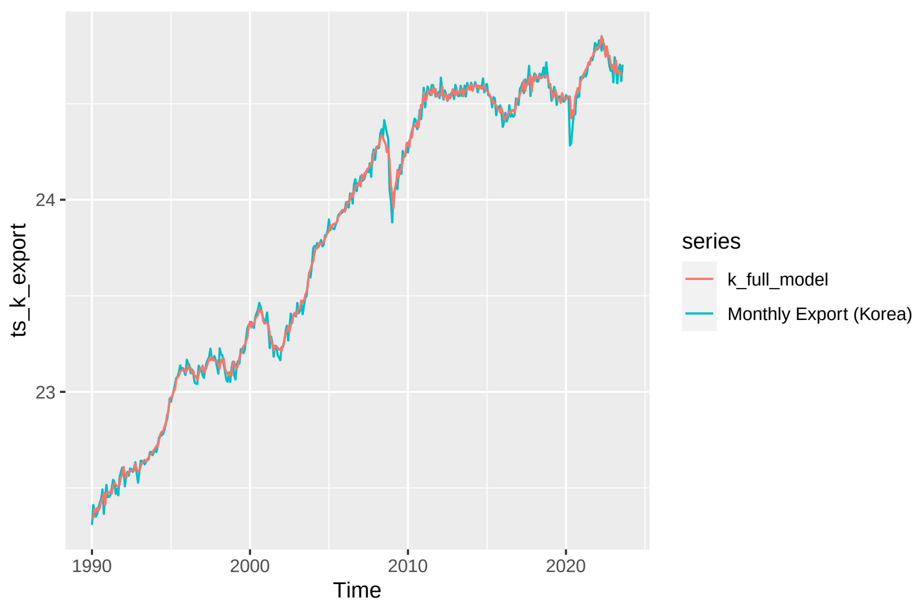


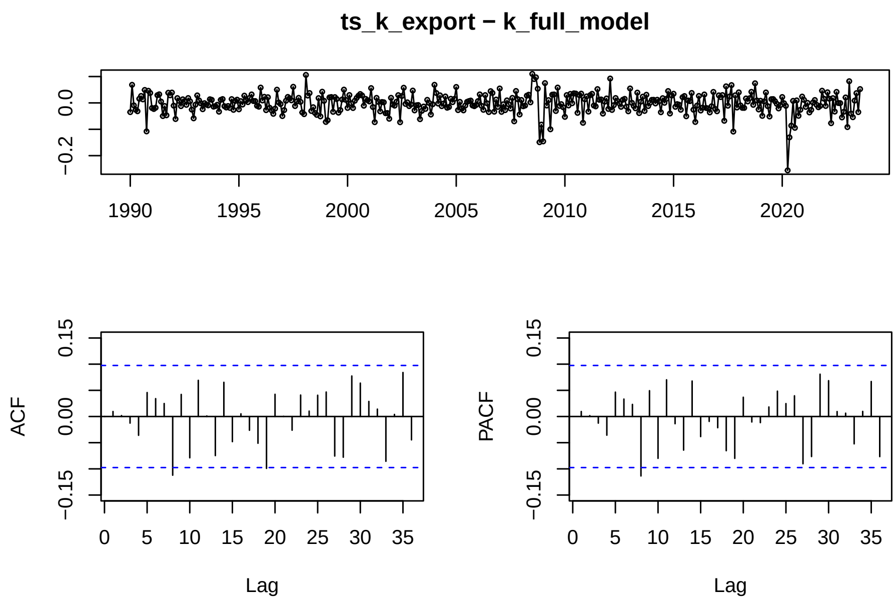

ts_k_export − k_Trend − k_Seasonal
0.1
0.0
−0.1
−0.2
1990
2000
2010
2020
Time
series
k_Cycle

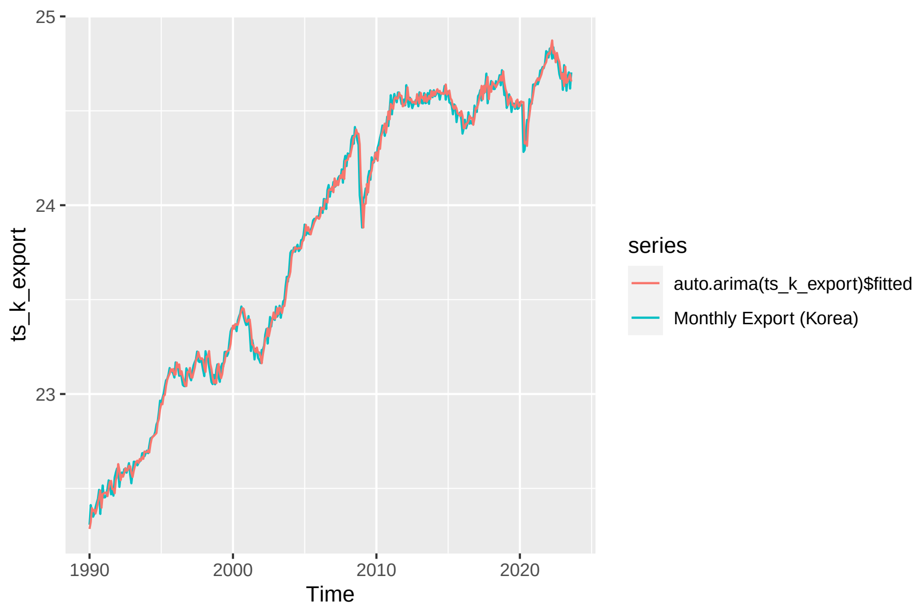

ts_k_export
24
23
1990
2000
2010
2020
Time
series
k_Trend + k_Seasonal
Monthly Export (Korea)

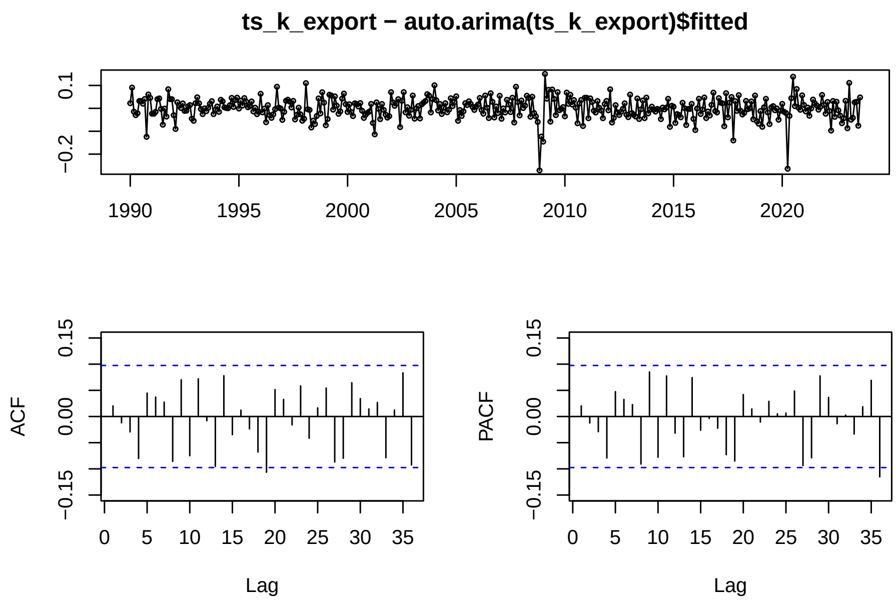

ts_k_export − (k_Trend + k_Seasonal)
0.1
−0.2
1990
1995
2000
2005
2010
2015
2020

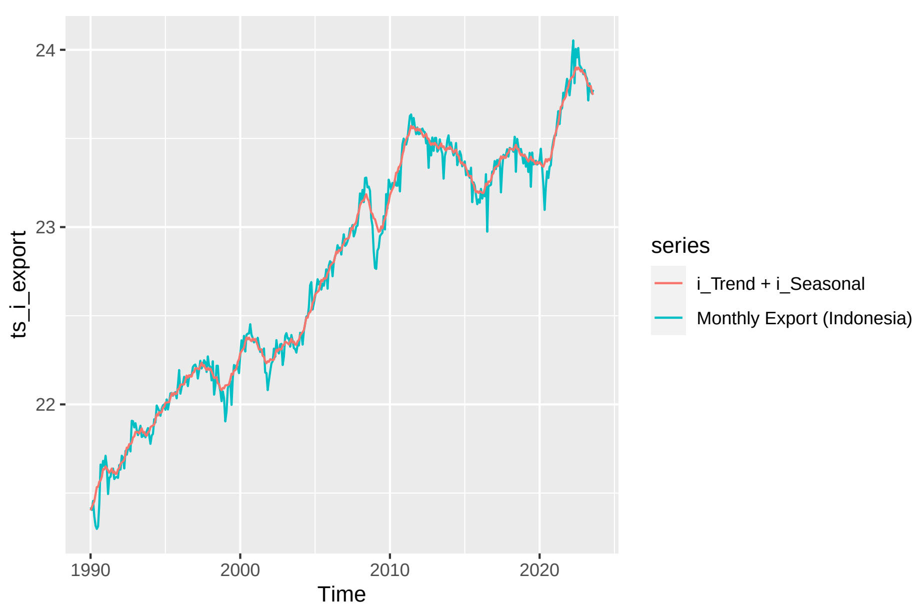

ACF
Lag
PACF
Lag

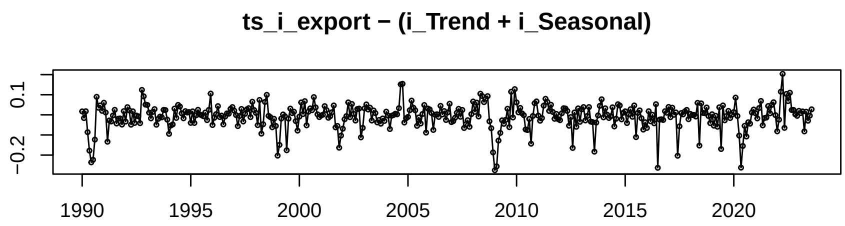

ts_k_export
Time
series
k_full_model
Monthly Export (Korea)

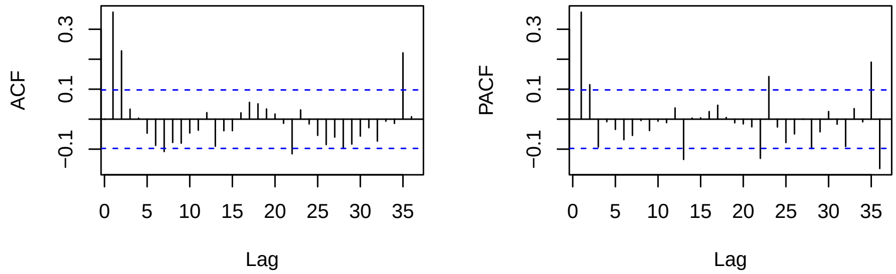

ts_k_export − k_full_model
0.0
−0.2
1990
1995
2000
2005
2010
2015
2020
ACF
PACF
0.15
0.00
−0.15
0
5
10
15
20
25
30
35
Lag

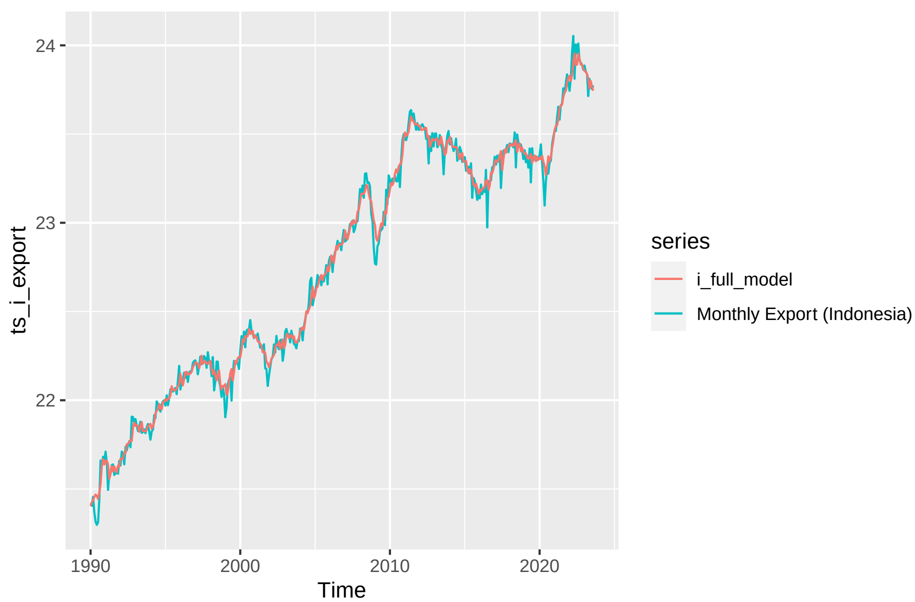

25
24
23
ts_k_export
1990
2000
2010
2020
Time
series
auto.arima(ts_k_export)$fitted
Monthly Export (Korea)

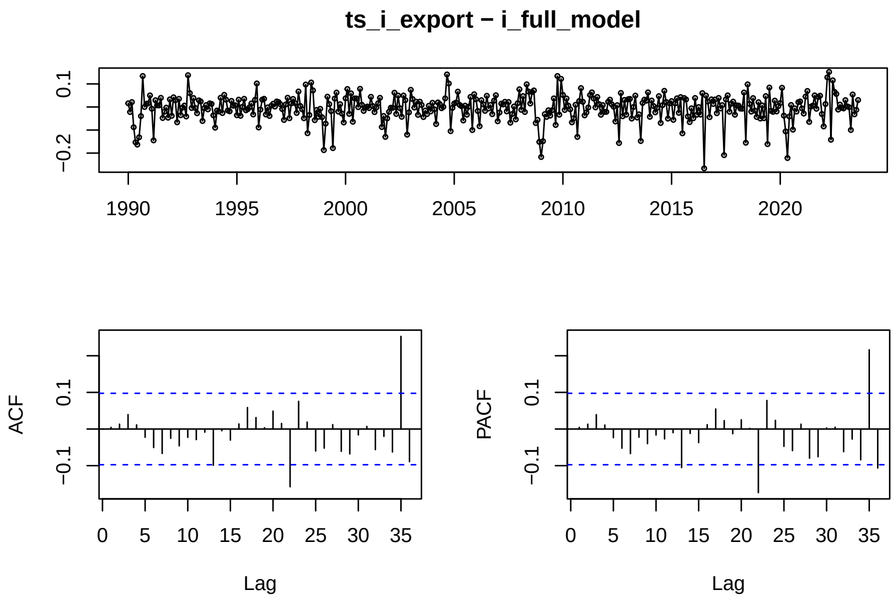

ts_k_export − auto.arima(ts_k_export)$fitted
0.1
−0.2
1990
1995
2000
2005
2010
2015
2020
ACF
PACF
0.15
0.00
−0.15
0
5
10
15
20
25
30
35
Lag

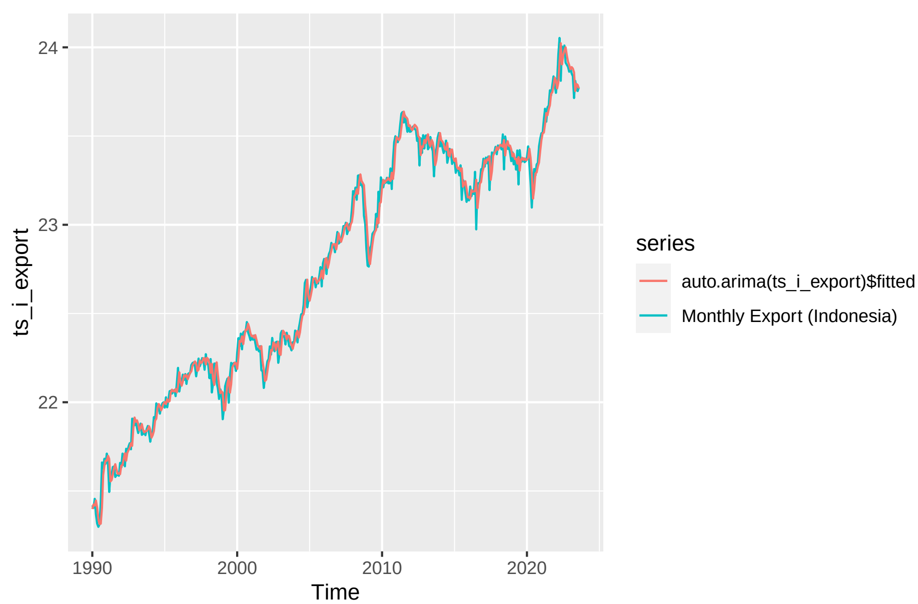

24
23
22
ts_i_export
1990
2000
2010
2020
Time
series
i_Trend + i_Seasonal
Monthly Export (Indonesia)

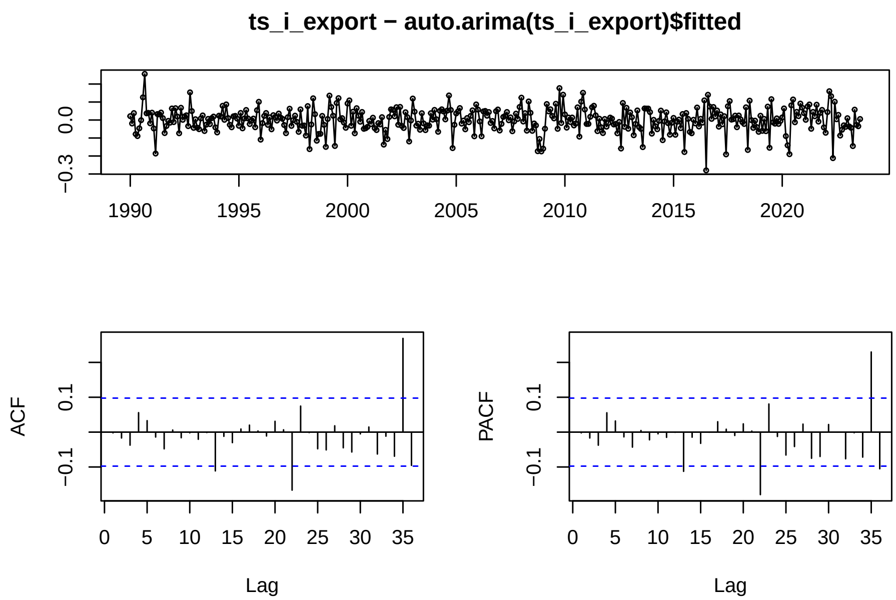

ts_i_export − (i_Trend + i_Seasonal)
0.1
−0.2
1990
1995
2000
2005
2010
2015
2020


ACF
PACF
0.3
0.1
−0.1
0
5
10
15
20
25
30
35
Lag
Lag


ts_i_export
24
23
22
1990
2000
2010
2020
Time
series
i_full_model
Monthly Export (Indonesia)


ts_i_export − i_full_model
ACF
PACF
Lag
Lag

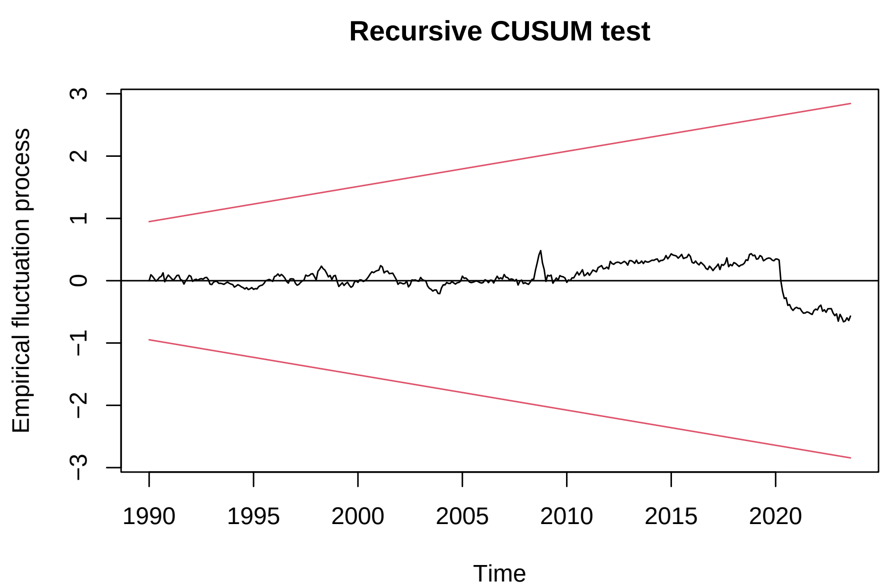

ts_i_export
Time
series
auto.arima(ts_i_export)$fitted
Monthly Export (Indonesia)

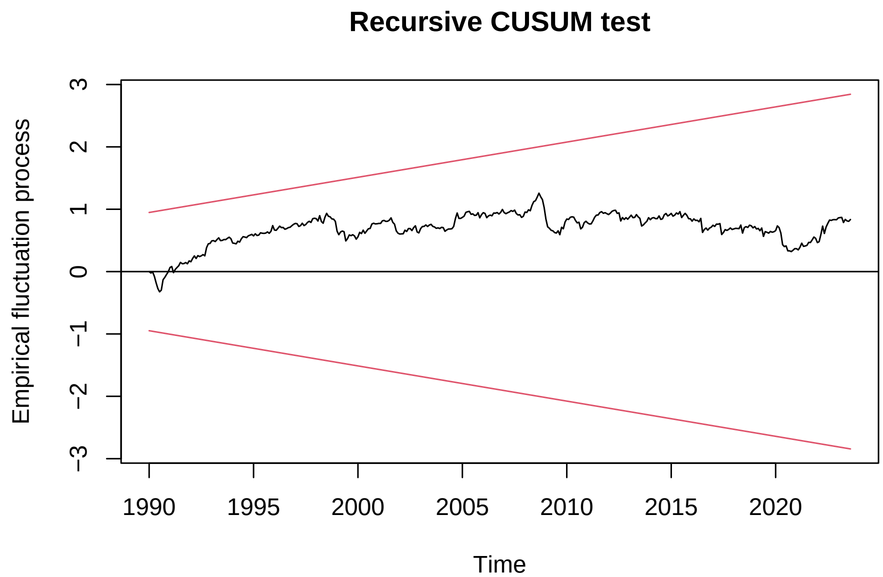


(e) **Plot the respective residuals vs. fitted values and discuss your observations.**

(f) **Plot the ACF and PACF of the respective residuals and interpret the plots.**

(g) **Plot the respective CUSUM and interpret the plot.**





(h) For your model, discuss the associated diagnostic statistics.

```
## [1] 0.1151033
```

```
## [1] 0.03797116
```

```
## [1] 0.181621
```

```
## [1] 0.05794525
```

(i) Use your model to forecast 12-steps ahead. Your forecast should include the respective error bands.

```
##           Jan      Feb      Mar      Apr      May      Jun      Jul      Aug
## 1990 22.34253 22.34347 22.39105 22.37575 22.39685 22.38342 22.39714 22.43124
## 1991 22.47161 22.47584 22.48176 22.46974 22.51041 22.52811 22.51841 22.50694
## 1992 22.60967 22.56877 22.55111 22.57699 22.57565 22.58838 22.58993 22.59025
## 1993 22.58949 22.61322 22.63153 22.63954 22.64590 22.63563 22.64984 22.65835
## 1994 22.70726 22.71967 22.71604 22.75073 22.78171 22.79257 22.79215 22.81888
## 1995 22.97269 22.97219 23.00882 23.01212 23.06286 23.07723 23.08311 23.10578
## 1996 23.10958 23.14024 23.11644 23.12372 23.09579 23.10937 23.07645 23.08340
## 1997 23.13767 23.09964 23.11097 23.12886 23.15141 23.17312 23.16405 23.18634
## 1998 23.13729 23.12084 23.16705 23.15441 23.17450 23.12276 23.10143 23.09756
## 1999 23.15778 23.12993 23.12238 23.13928 23.18129 23.20056 23.20896 23.23816
## 2000 23.36546 23.33385 23.35680 23.35190 23.38008 23.39087 23.39903 23.43006
## 2001 23.36279 23.35683 23.34630 23.30051 23.26872 23.25303 23.21486 23.23688
## 2002 23.21382 23.24078 23.26674 23.31075 23.31543 23.34030 23.31283 23.35077
## 2003 23.41650 23.43783 23.43194 23.47590 23.46542 23.47643 23.50511 23.52055
## 2004 23.67941 23.72247 23.75076 23.74689 23.76574 23.77545 23.76664 23.77510
## 2005 23.83732 23.86881 23.85371 23.87197 23.87472 23.87772 23.88057 23.91251
```

```
## 2006 23.93766 23.95573 23.99070 23.98520 24.00375 24.03239 24.01440 24.03556
## 2007 24.06867 24.13050 24.10671 24.13760 24.13395 24.16028 24.16420 24.17109
## 2008 24.26388 24.27997 24.28039 24.31925 24.33626 24.32320 24.30450 24.29036
## 2009 24.02734 23.95678 24.05739 24.07874 24.15488 24.11834 24.14952 24.16536
## 2010 24.29814 24.27439 24.33597 24.32333 24.38359 24.38602 24.37972 24.40472
## 2011 24.55839 24.51413 24.52400 24.55505 24.57199 24.55824 24.54508 24.58524
## 2012 24.55159 24.54370 24.58933 24.52965 24.55091 24.53786 24.51533 24.54801
## 2013 24.54356 24.57401 24.55167 24.55931 24.55478 24.57886 24.53844 24.57096
## 2014 24.59791 24.56581 24.59017 24.60035 24.58758 24.59444 24.57506 24.59035
## 2015 24.56819 24.55882 24.54589 24.53412 24.50714 24.51248 24.50172 24.49070
## 2016 24.45103 24.41600 24.42655 24.43604 24.44607 24.46039 24.45073 24.46629
## 2017 24.52536 24.54947 24.56571 24.58123 24.62217 24.56419 24.60405 24.59953
## 2018 24.61796 24.65262 24.63351 24.63454 24.64037 24.63234 24.63589 24.64698
## 2019 24.59423 24.56440 24.52831 24.54847 24.57001 24.54491 24.52020 24.52404
## 2020 24.52269 24.53623 24.53701 24.53803 24.42369 24.46530 24.44435 24.53742
## 2021 24.62905 24.64894 24.66134 24.67658 24.68681 24.71233 24.70349 24.73934
## 2022 24.79365 24.78983 24.80638 24.85281 24.81873 24.81094 24.74390 24.79859
## 2023 24.70215 24.65997 24.72506 24.66049 24.67386 24.66705 24.65243 24.65073
##           Sep      Oct      Nov      Dec
## 1990 22.44365 22.47267 22.41218 22.47835
## 1991 22.50819 22.51879 22.55579 22.56650
## 1992 22.58875 22.62793 22.59783 22.58531
## 1993 22.67243 22.67617 22.68476 22.69821
## 1994 22.82455 22.88019 22.89713 22.95301
## 1995 23.11156 23.11709 23.11841 23.10149
## 1996 23.06277 23.08624 23.11827 23.11929
## 1997 23.16335 23.16749 23.15961 23.16276
## 1998 23.08321 23.10239 23.08483 23.14945
## 1999 23.24330 23.26581 23.28081 23.33754
## 2000 23.41671 23.41972 23.37004 23.35502
## 2001 23.23665 23.22996 23.21880 23.22412
## 2002 23.36100 23.40068 23.41168 23.39793
## 2003 23.55888 23.62146 23.63915 23.66381
## 2004 23.78053 23.79970 23.81418 23.82686
## 2005 23.91915 23.93779 23.94618 23.94789
## 2006 24.06947 24.07797 24.07506 24.09156
## 2007 24.18890 24.18784 24.24810 24.25072
## 2008 24.24684 24.26531 24.20154 24.07706
## 2009 24.19581 24.23374 24.23327 24.29481
## 2010 24.37585 24.43368 24.49486 24.48684
## 2011 24.55775 24.57715 24.53764 24.54292
## 2012 24.52800 24.54272 24.57563 24.55608
## 2013 24.56696 24.57799 24.59447 24.57168
## 2014 24.57727 24.58677 24.59890 24.56857
## 2015 24.47289 24.47357 24.45374 24.47860
## 2016 24.46751 24.45360 24.48633 24.52603
## 2017 24.62997 24.64840 24.56398 24.63684
## 2018 24.64246 24.64098 24.64434 24.60760
## 2019 24.50308 24.55490 24.53088 24.52145
## 2020 24.55233 24.58213 24.56413 24.61466
## 2021 24.74207 24.76333 24.77021 24.79276
## 2022 24.74626 24.74943 24.70425 24.68124
## 2023
```

(j) Compare your forecast from (i) to the 12-steps ahead forecasts from auto.arima model. Which model performs best in terms of MAPE?

(k) Combine the four forecasts and comment on the MAPE from this forecasts vs., the individual ones.

(l) Fit an appropriate VAR model using your two variables. Make sure to show the relevant plots and discuss your results from the fit.

```
## $selection
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      4      3      2      4
##
## $criteria
##                    1             2             3             4             5
## AIC(n) -1.153632e+01 -1.160057e+01 -1.163788e+01 -1.164352e+01 -1.163648e+01
## HQ(n)  -1.151228e+01 -1.156050e+01 -1.158178e+01 -1.157139e+01 -1.154832e+01
## SC(n)  -1.147565e+01 -1.149945e+01 -1.149632e+01 -1.146151e+01 -1.141403e+01
## FPE(n)  9.768784e-06  9.160922e-06  8.825425e-06  8.775917e-06  8.837994e-06
##                    6             7             8             9            10
## AIC(n) -1.163025e+01 -1.162121e+01 -1.161691e+01 -1.160734e+01 -1.159786e+01
## HQ(n)  -1.152607e+01 -1.150099e+01 -1.148067e+01 -1.145507e+01 -1.142957e+01
## SC(n)  -1.136735e+01 -1.131786e+01 -1.127312e+01 -1.122311e+01 -1.117318e+01
## FPE(n)  8.893377e-06  8.974432e-06  9.013351e-06  9.100406e-06  9.187576e-06
```

```
## $selection
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      5      4      3      5
##
## $criteria
##                    1             2             3             4             5
## AIC(n) -1.138118e+01 -1.156707e+01 -1.161763e+01 -1.164317e+01 -1.164714e+01
## HQ(n)  -1.135718e+01 -1.152708e+01 -1.156164e+01 -1.157119e+01 -1.155916e+01
## SC(n)  -1.132062e+01 -1.146615e+01 -1.147634e+01 -1.146151e+01 -1.142511e+01
## FPE(n)  1.140823e-05  9.472946e-06  9.005998e-06  8.778924e-06  8.744306e-06
##                    6             7             8             9            10
## AIC(n) -1.163875e+01 -1.163157e+01 -1.162084e+01 -1.161547e+01 -1.160347e+01
## HQ(n)  -1.153477e+01 -1.151159e+01 -1.148487e+01 -1.146351e+01 -1.143551e+01
## SC(n)  -1.137635e+01 -1.132880e+01 -1.127770e+01 -1.123197e+01 -1.117959e+01
## FPE(n)  8.818149e-06  8.881932e-06  8.978015e-06  9.026696e-06  9.136223e-06
```

```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: ts_k_export, ts_i_export
## Deterministic variables: const
## Sample size: 399
## Log Likelihood: 1201.272
## Roots of the characteristic polynomial:
## 0.9948 0.959 0.6848 0.6848 0.5433 0.5433 0.4984 0.4384 0.3065 0.3065
## Call:
## VAR(y = var_model, p = 5)
##
##
```

```
## Estimation results for equation ts_k_export:
## ============================================
## ts_k_export = ts_k_export.l1 + ts_i_export.l1 + ts_k_export.l2 + ts_i_export.l2 + ts_k_export.l3 + ts
##
##                 Estimate Std. Error t value Pr(>|t|)
## ts_k_export.l1  0.76960    0.05146  14.955  < 2e-16 ***
## ts_i_export.l1  0.11293    0.03720   3.035 0.002564 **
## ts_k_export.l2  0.03291    0.06408   0.514 0.607862
## ts_i_export.l2 -0.08086    0.04181  -1.934 0.053831 .
## ts_k_export.l3  0.30419    0.06208   4.900 1.41e-06 ***
## ts_i_export.l3  0.04585    0.04328   1.059 0.290078
## ts_k_export.l4 -0.22034    0.06379  -3.454 0.000613 ***
## ts_i_export.l4 -0.05014    0.04223  -1.187 0.235831
## ts_k_export.l5  0.12071    0.05290   2.282 0.023051 *
## ts_i_export.l5 -0.04223    0.03636  -1.161 0.246204
## const           0.16738    0.08177   2.047 0.041332 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.04675 on 388 degrees of freedom
## Multiple R-Squared: 0.9962,  Adjusted R-squared: 0.9961
## F-statistic: 1.006e+04 on 10 and 388 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation ts_i_export:
## ============================================
## ts_i_export = ts_k_export.l1 + ts_i_export.l1 + ts_k_export.l2 + ts_i_export.l2 + ts_k_export.l3 + ts
##
##                  Estimate Std. Error t value Pr(>|t|)
## ts_k_export.l1  0.340963   0.071322   4.781 2.48e-06 ***
## ts_i_export.l1  0.527181   0.051560  10.225  < 2e-16 ***
## ts_k_export.l2 -0.020720   0.088813  -0.233    0.816
## ts_i_export.l2  0.268193   0.057941   4.629 5.02e-06 ***
## ts_k_export.l3 -0.065357   0.086036  -0.760    0.448
## ts_i_export.l3  0.025513   0.059983   0.425    0.671
## ts_k_export.l4 -0.098087   0.088411  -1.109    0.268
## ts_i_export.l4  0.088736   0.058533   1.516    0.130
## ts_k_export.l5 -0.084219   0.073322  -1.149    0.251
## ts_i_export.l5  0.006996   0.050394   0.139    0.890
## const           0.173761   0.113329   1.533    0.126
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.0648 on 388 degrees of freedom
## Multiple R-Squared: 0.9911,  Adjusted R-squared: 0.9908
## F-statistic:  4309 on 10 and 388 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##             ts_k_export ts_i_export
## ts_k_export   0.0021857   0.0006174
```

```
## ts_i_export   0.0006174   0.0041985
##
## Correlation matrix of residuals:
##             ts_k_export ts_i_export
## ts_k_export      1.0000      0.2038
## ts_i_export      0.2038      1.0000
```

```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: diff_k_export, diff_i_export
## Deterministic variables: const
## Sample size: 399
## Log Likelihood: 1195.396
## Roots of the characteristic polynomial:
## 0.6751 0.6751 0.5684 0.5684 0.4269 0.4233 0.2229 0.2229
## Call:
## VAR(y = var_model1, p = 4)
##
##
## Estimation results for equation diff_k_export:
## ==============================================
## diff_k_export = diff_k_export.l1 + diff_i_export.l1 + diff_k_export.l2 + diff_i_export.l2 + diff_k_e
##
##                   Estimate Std. Error t value Pr(>|t|)
## diff_k_export.l1 -0.222371   0.051379  -4.328 1.91e-05 ***
## diff_i_export.l1  0.116787   0.036845   3.170 0.001647 **
## diff_k_export.l2 -0.189228   0.054291  -3.485 0.000547 ***
## diff_i_export.l2  0.037113   0.040628   0.913 0.361552
## diff_k_export.l3  0.113006   0.055073   2.052 0.040845 *
## diff_i_export.l3  0.084808   0.040136   2.113 0.035234 *
## diff_k_export.l4 -0.111426   0.052382  -2.127 0.034032 *
## diff_i_export.l4  0.038096   0.036057   1.057 0.291374
## const             0.006580   0.002451   2.685 0.007560 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.04686 on 390 degrees of freedom
## Multiple R-Squared: 0.1344,  Adjusted R-squared: 0.1166
## F-statistic: 7.569 on 8 and 390 DF,  p-value: 2.048e-09
##
##
## Estimation results for equation diff_i_export:
## ==============================================
## diff_i_export = diff_k_export.l1 + diff_i_export.l1 + diff_k_export.l2 + diff_i_export.l2 + diff_k_e
##
##                   Estimate Std. Error t value Pr(>|t|)
## diff_k_export.l1  0.341161   0.071605   4.765 2.68e-06 ***
## diff_i_export.l1 -0.450200   0.051350  -8.767  < 2e-16 ***
## diff_k_export.l2  0.311677   0.075664   4.119 4.64e-05 ***
## diff_i_export.l2 -0.168864   0.056621  -2.982  0.00304 **
## diff_k_export.l3  0.231677   0.076754   3.018  0.00271 **
## diff_i_export.l3 -0.133855   0.055936  -2.393  0.01718 *
```

```
## diff_k_export.l4  0.116866   0.073003   1.601  0.11022
## diff_i_export.l4 -0.028087   0.050251  -0.559  0.57653
## const             0.005055   0.003415   1.480  0.13967
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.06531 on 390 degrees of freedom
## Multiple R-Squared: 0.1963,  Adjusted R-squared: 0.1798
## F-statistic: 11.91 on 8 and 390 DF,  p-value: 3.175e-15
##
##
##
## Covariance matrix of residuals:
##               diff_k_export diff_i_export
## diff_k_export     0.0021963     0.0006349
## diff_i_export     0.0006349     0.0042658
##
## Correlation matrix of residuals:
##               diff_k_export diff_i_export
## diff_k_export        1.0000        0.2074
## diff_i_export        0.2074        1.0000
```

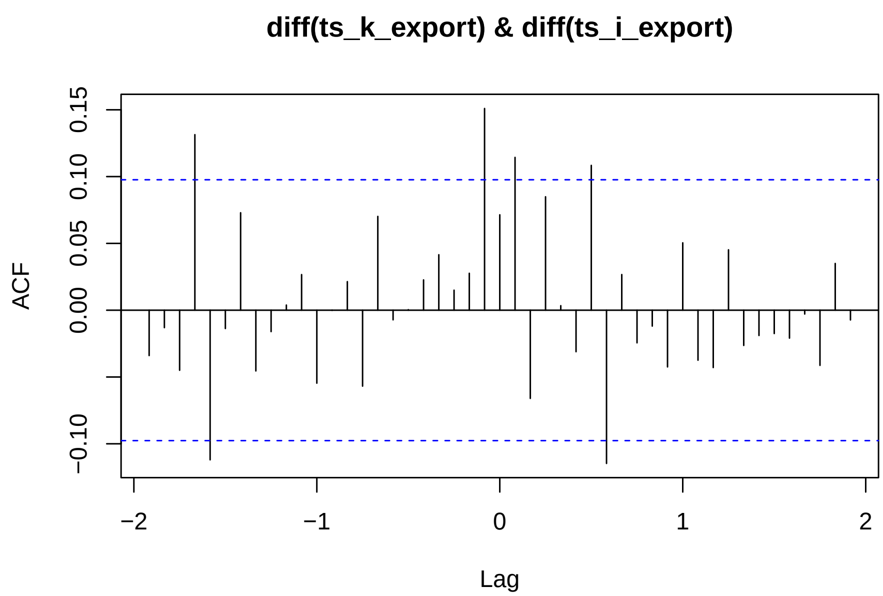
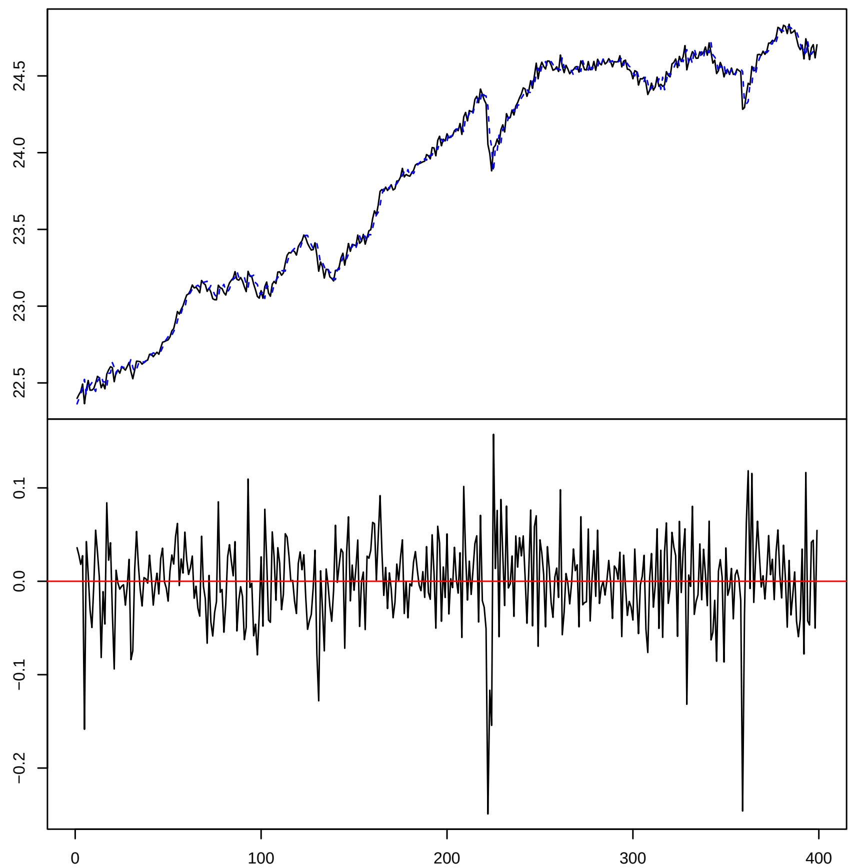
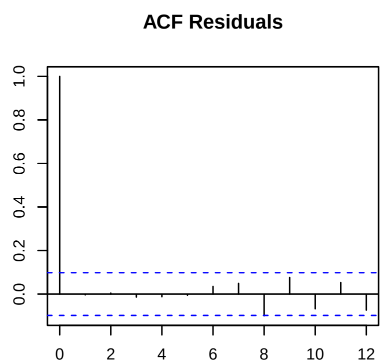
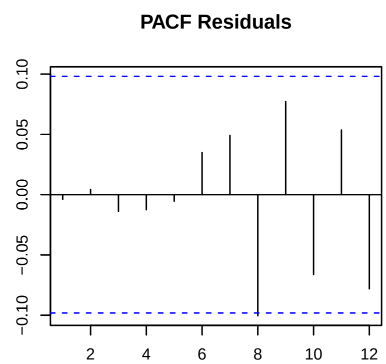


Diagram of fit and residuals for ts_k_export







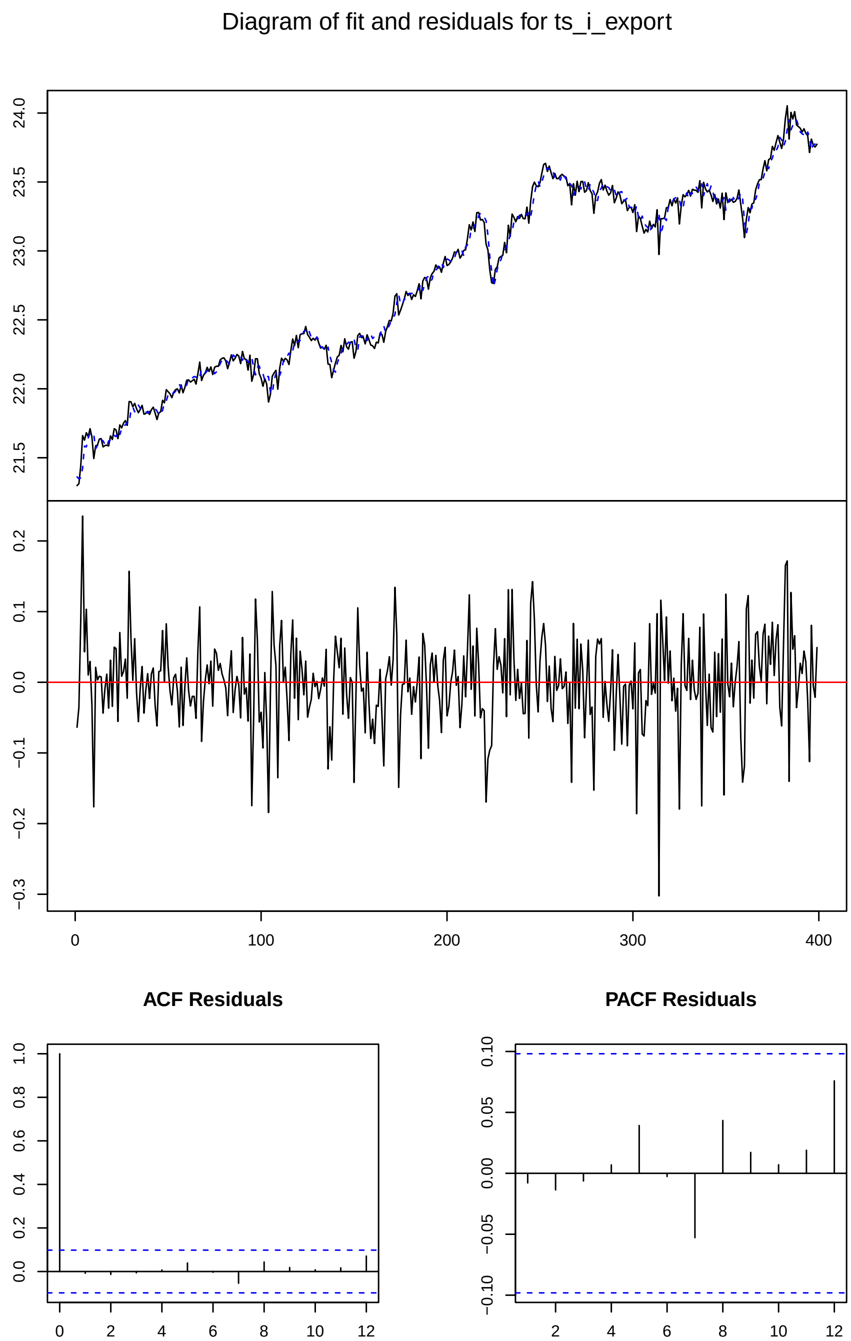


Diagram of fit and residuals for ts_i_export
ACF Residuals
PACF Residuals

Diagram of fit and residuals for diff_k_export

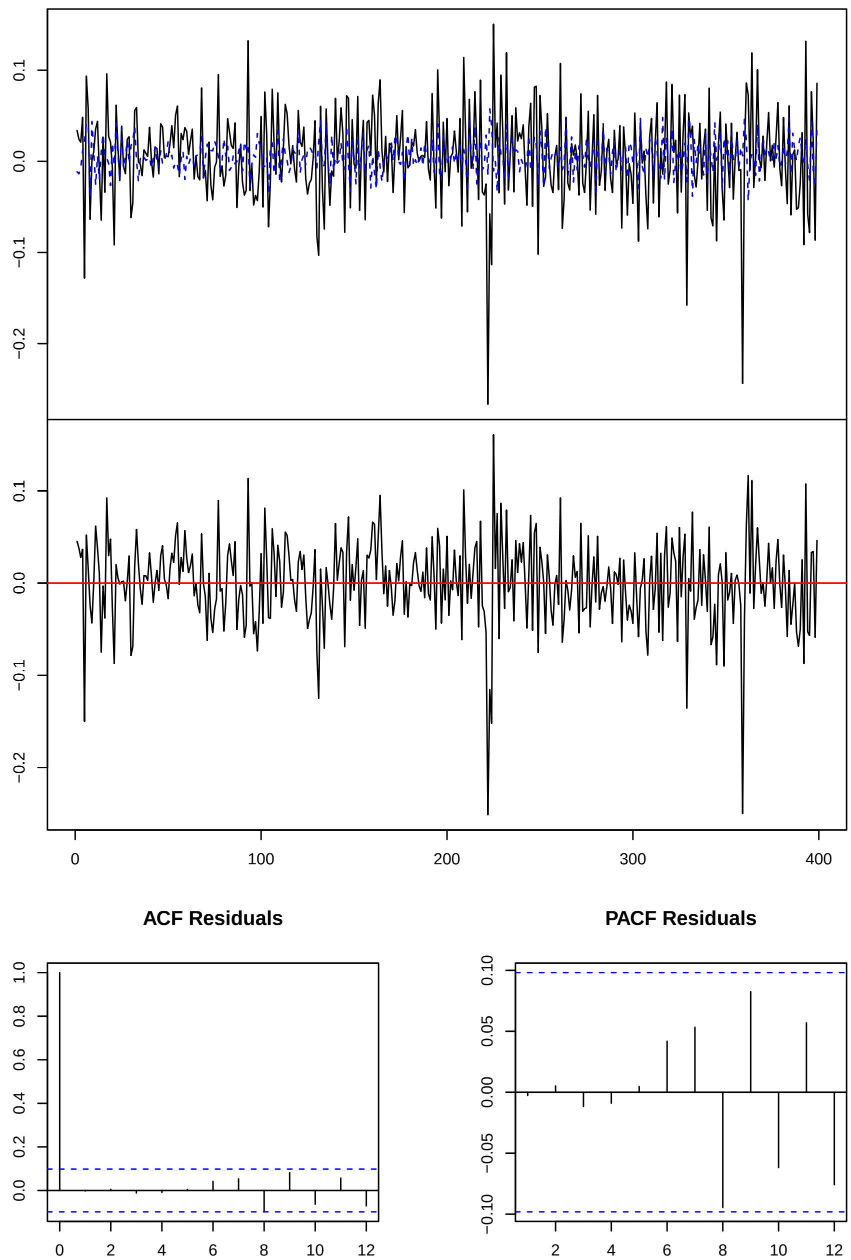
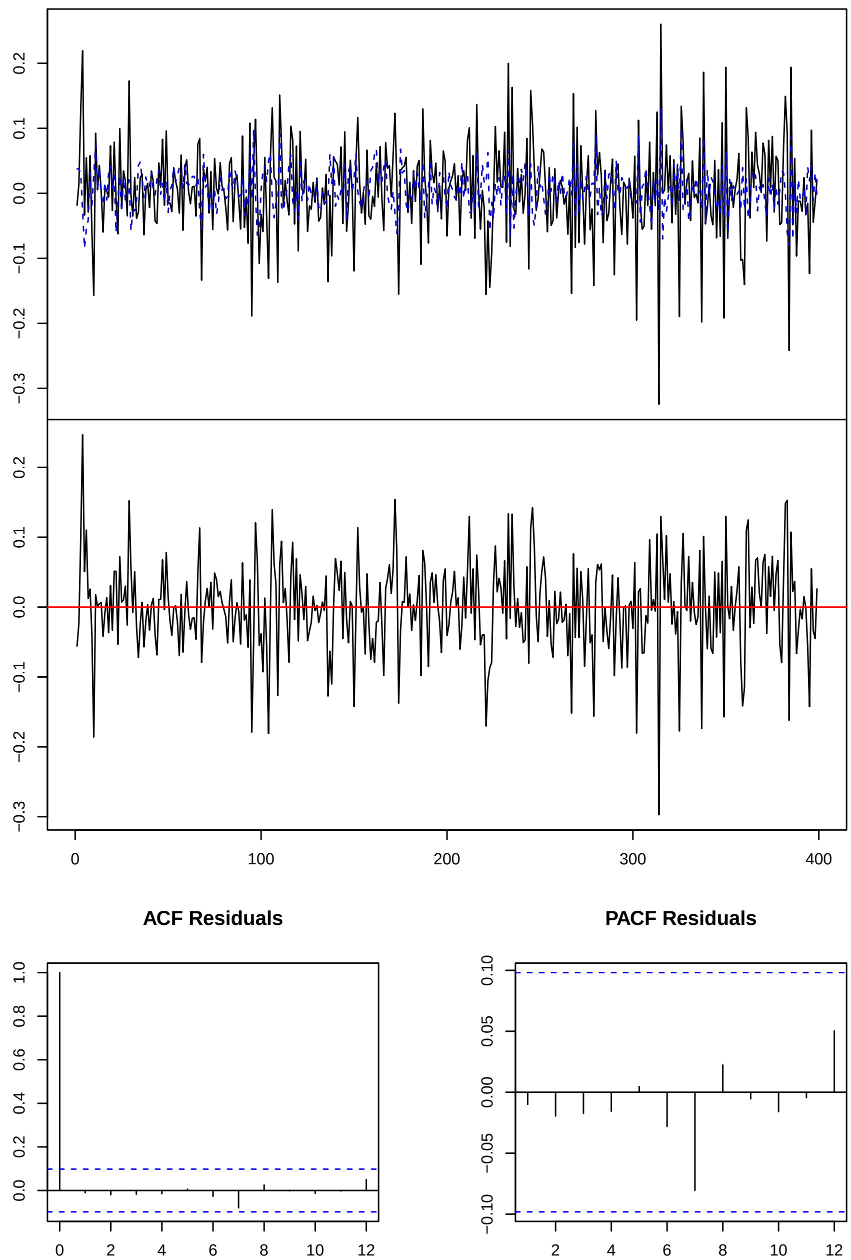
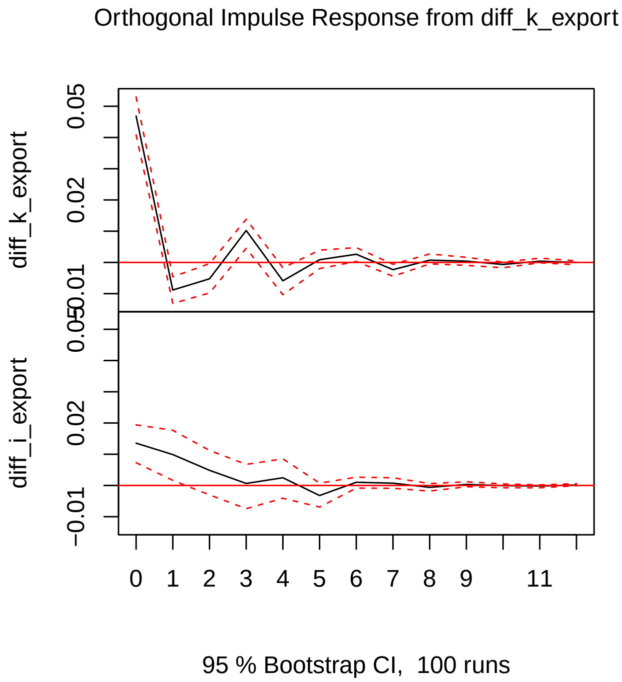
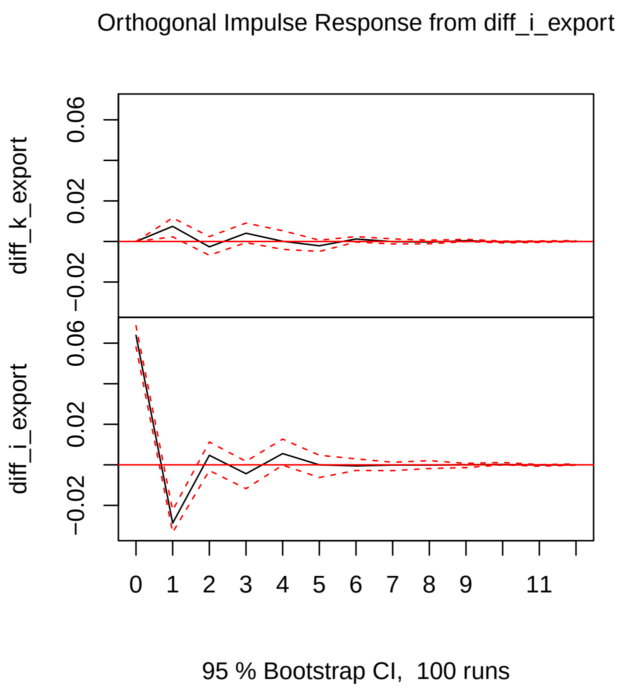


Diagram of fit and residuals for diff_i_export



(m) Compute, plot, and interpret the respective impulse response functions.



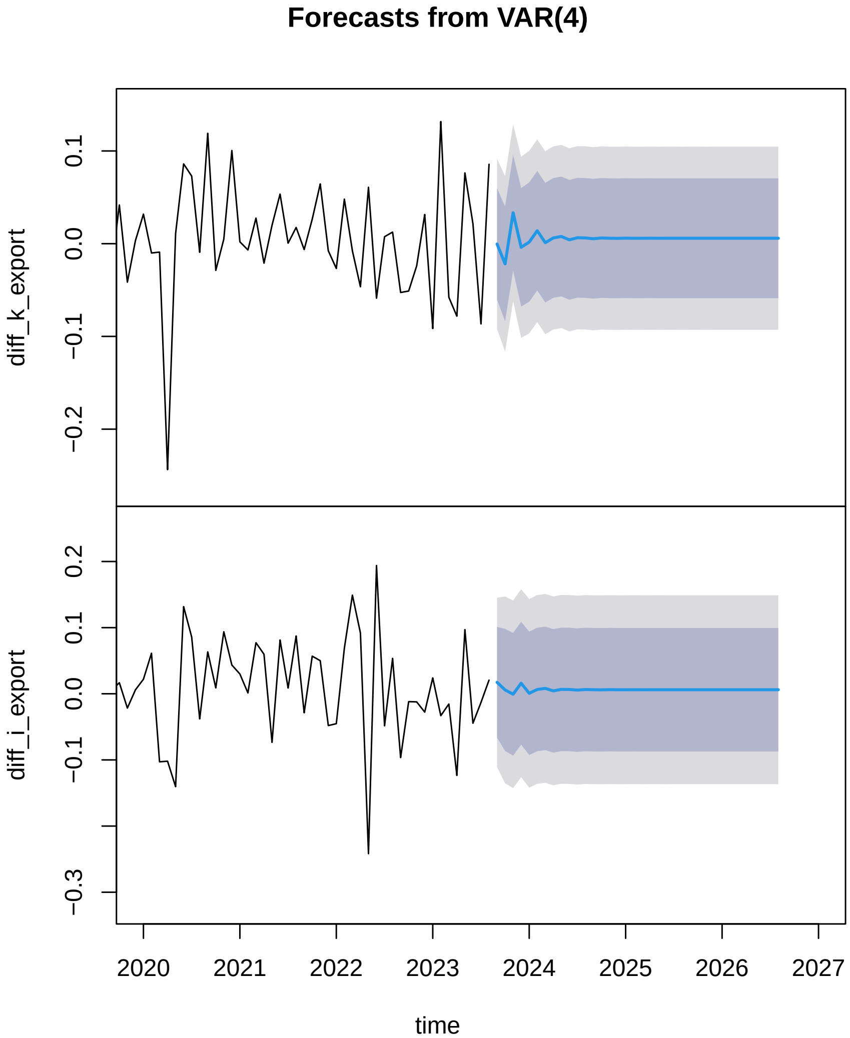


(n) Perform a Granger-Causality test on your variables and discuss your results from the test.

```
## Granger causality test
##
## Model 1: ts_k_export ~ Lags(ts_k_export, 1:4) + Lags(ts_i_export, 1:4)
## Model 2: ts_k_export ~ Lags(ts_k_export, 1:4)
##   Res.Df Df      F  Pr(>F)
## 1    391
## 2    395 -4 2.9467 0.02022 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

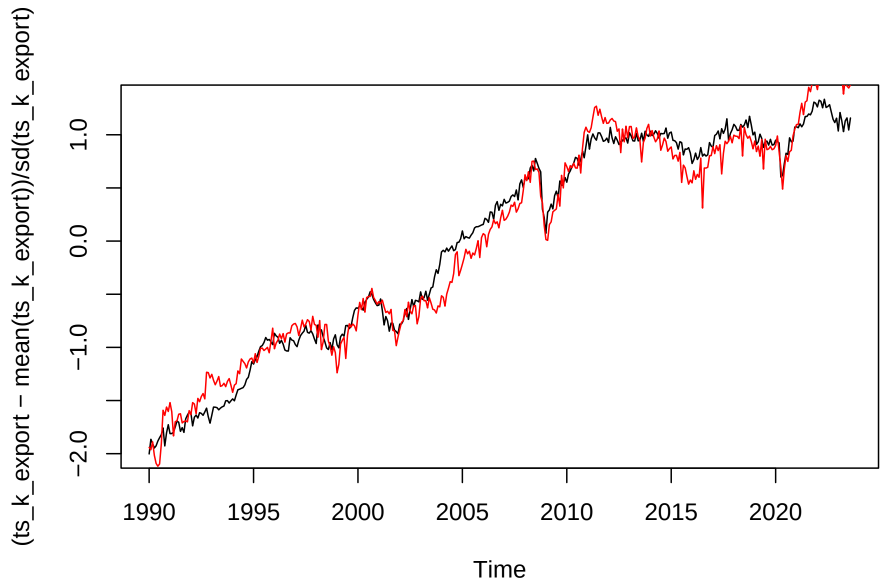
```
## Granger causality test
##
## Model 1: ts_i_export ~ Lags(ts_i_export, 1:4) + Lags(ts_k_export, 1:4)
## Model 2: ts_i_export ~ Lags(ts_i_export, 1:4)
##   Res.Df Df      F    Pr(>F)
## 1    391
## 2    395 -4 10.012 1.008e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

(o) Use your VAR model to forecast 12-steps ahead. Your forecast should include the respective error bands. Comment on the differences between the VAR forecast and the other ones obtained using the different methods.



III. (5%) Conclusions and Future Work.

IV. (5%) References (include the source of your data and any other resources).




```
## Granger causality test
##
## Model 1: ts_k_export ~ Lags(ts_k_export, 1:1) + Lags(ts_i_export, 1:1)
## Model 2: ts_k_export ~ Lags(ts_k_export, 1:1)
##   Res.Df Df      F  Pr(>F)
## 1    400
## 2    401 -1 3.8031 0.05186 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## Granger causality test
##
## Model 1: ts_i_export ~ Lags(ts_i_export, 1:1) + Lags(ts_k_export, 1:1)
## Model 2: ts_i_export ~ Lags(ts_i_export, 1:1)
##   Res.Df Df      F    Pr(>F)
## 1    400
## 2    401 -1 38.398 1.436e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```