VAR_Analysis

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```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
## Warning: package 'vars' was built under R version 4.1.3
```

```
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
## Loading required package: strucchange
```

```
## Warning: package 'strucchange' was built under R version 4.1.3
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
## Loading required package: sandwich
```

```
## Warning: package 'sandwich' was built under R version 4.1.2
```

```
## Loading required package: urca
```

```
## Loading required package: lmtest
```

```
##
## Attaching package: 'xts'
```

```
## The following objects are masked from 'package:dplyr':
##
##     first, last
```

```
## Warning: package 'mgcv' was built under R version 4.1.2
```

```
## Loading required package: nlme
```

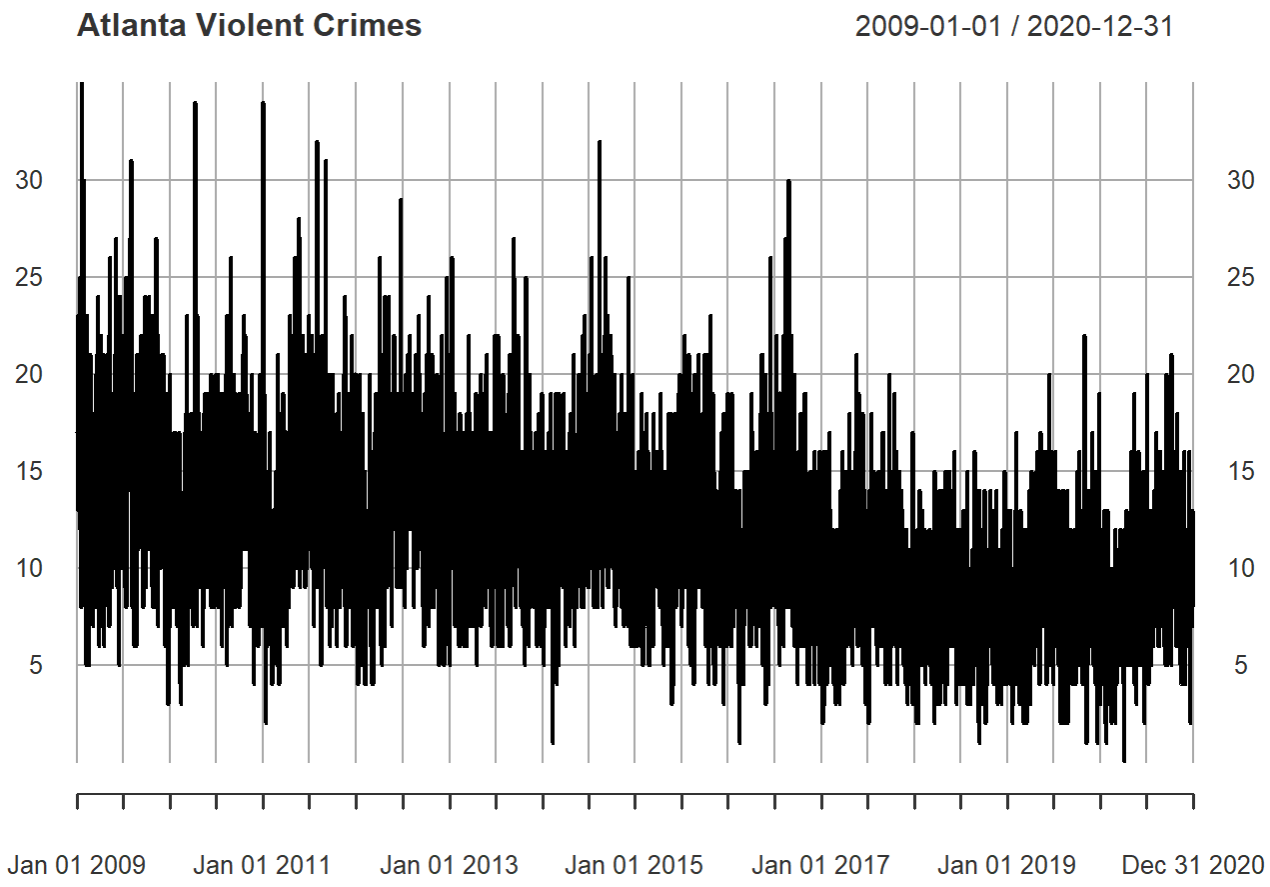
```
##
## Attaching package: 'nlme'
```

```
## The following object is masked from 'package:dplyr':
##
##     collapse
```

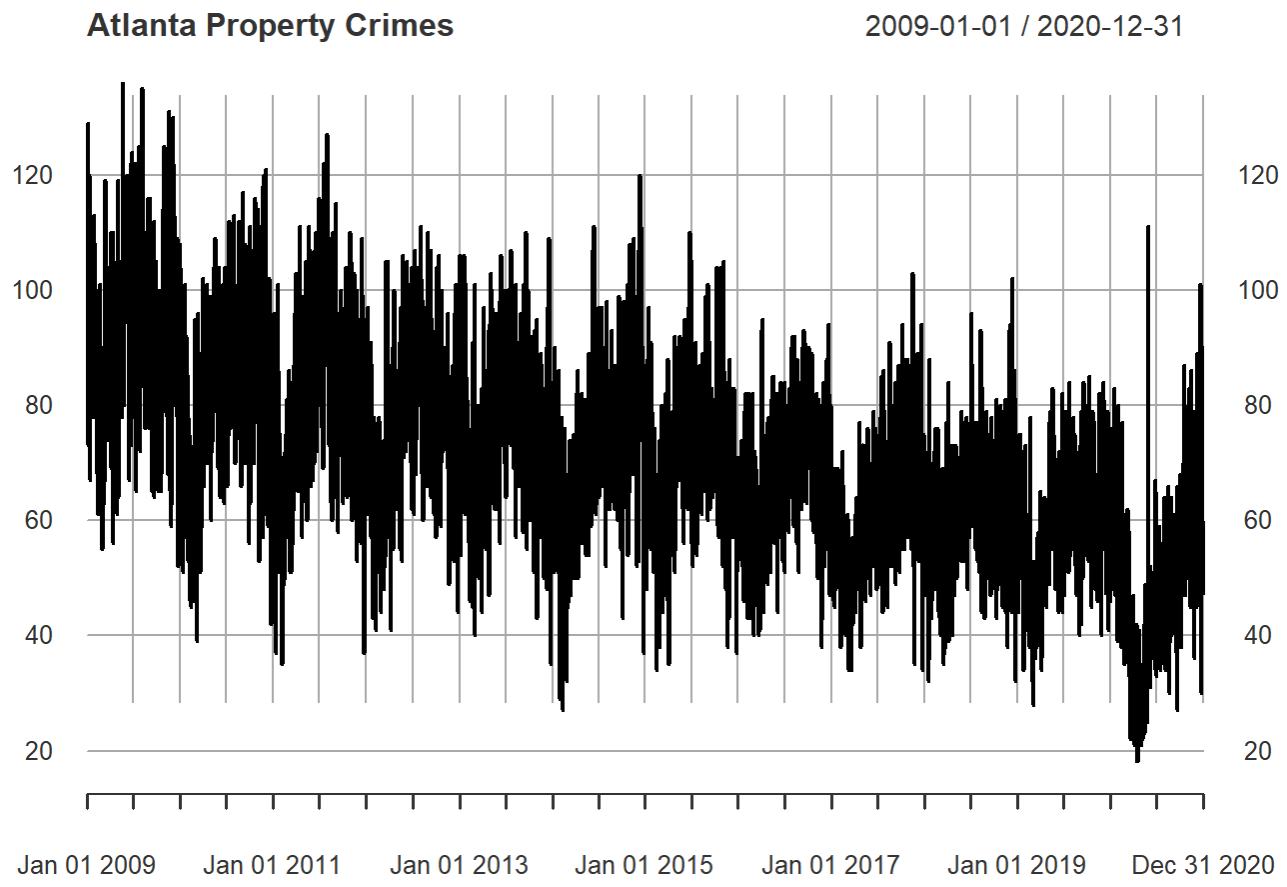
```
## This is mgcv 1.8-38. For overview type 'help("mgcv-package")'.
```

```
atl_violent = read.csv("atl_violent_final_v2.csv")
nyc_violent = read.csv("nyc_violent_final_v3.csv")
atl_property = read.csv("atl_prop_final_v2.csv")
nyc_property = read.csv("nyc_prop_final_v2.csv")
```

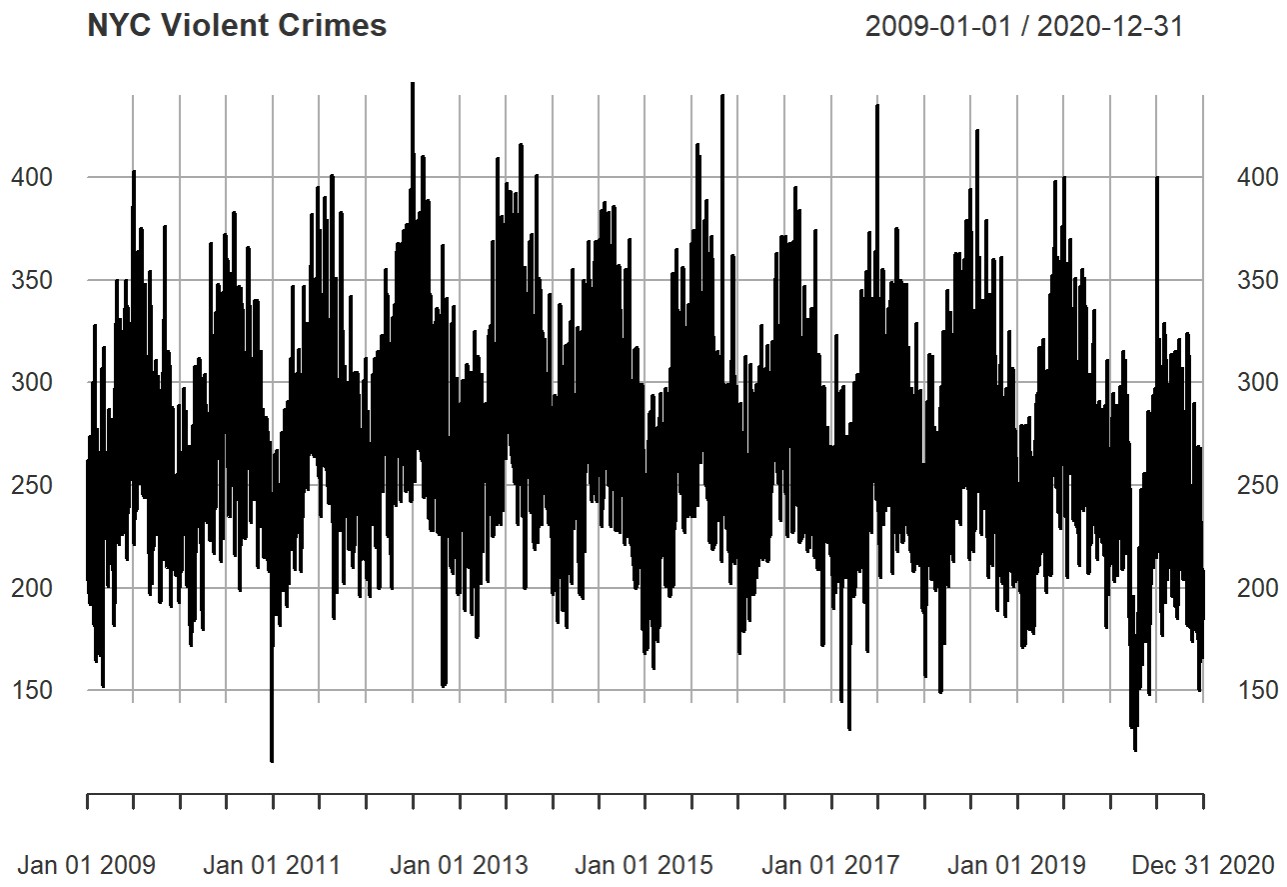
```
#ATL Violent Crimes
atl_violent_crimes<-atl_violent[,2]
datesatl_v<-as.Date(atl_violent[,1],"%m/%d/%Y")
tsatl_v=xts(atl_violent_crimes,datesatl_v)

dlatl_v<-diff(sqrt(tsatl_v+3/8))
plot(tsatl_v,main='Atlanta Violent Crimes')
```



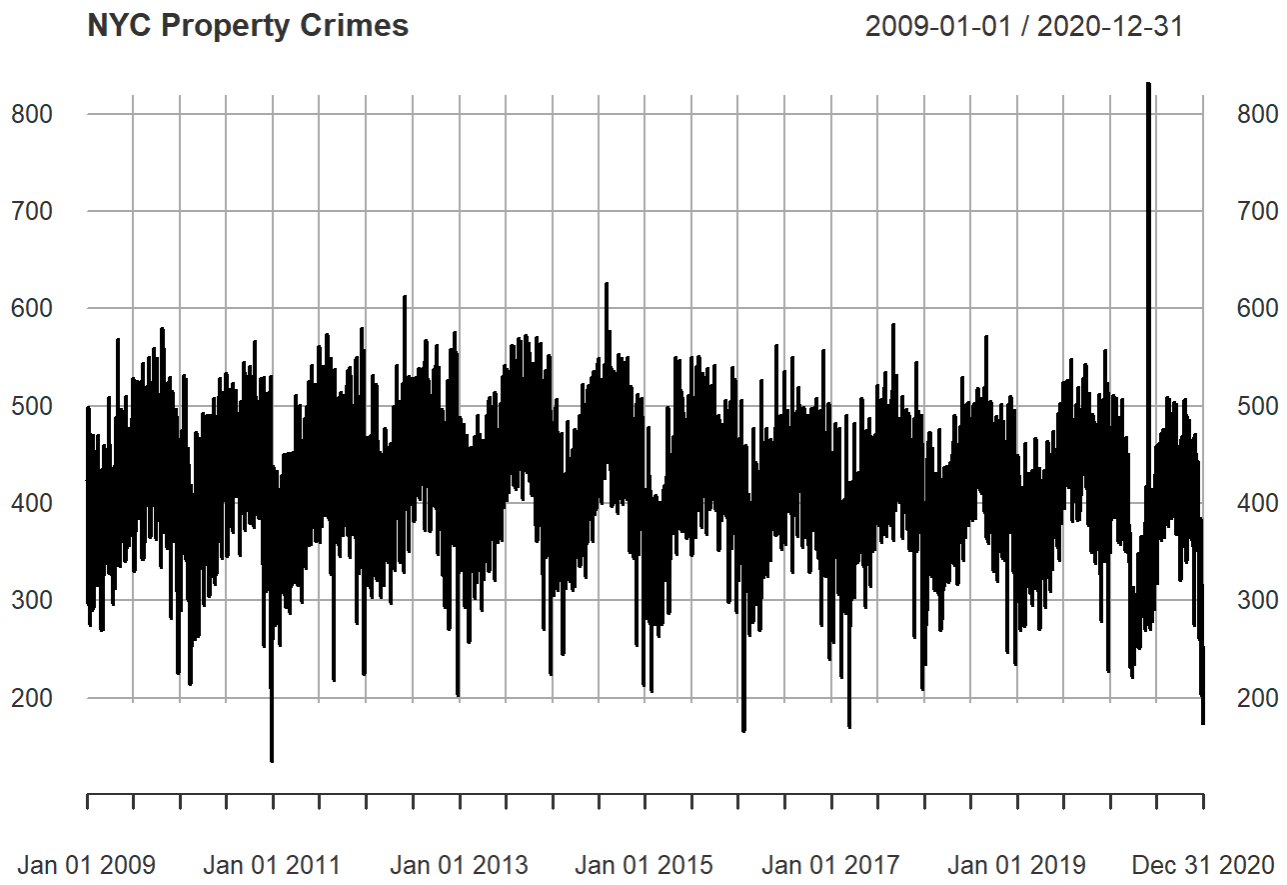

```
#ATL Property Crimes
atl_property_crimes<-atl_property[,2]
datesatl_p<-as.Date(atl_property[,1],"%m/%d/%Y")
tsatl_p=xts(atl_property_crimes,datesatl_p)
dlatl_p<-diff(sqrt(tsatl_p+3/8))
plot(tsatl_p,main='Atlanta Property Crimes')
```



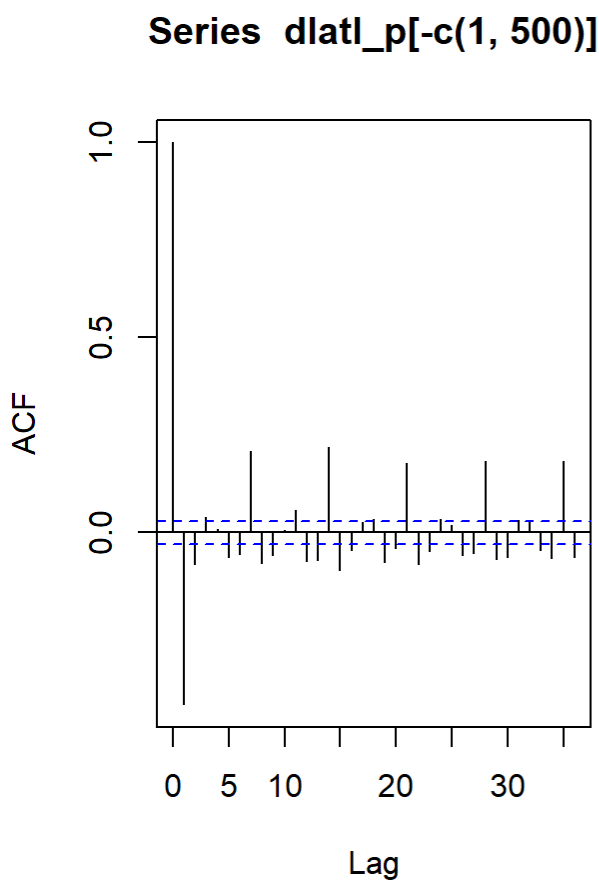

```
#NYC Violent Crimes
nyc_violent_crimes<-nyc_violent[,2]
datesnyc_v<-as.Date(nyc_violent[,1],"%m/%d/%Y")
tsnyc_v=xts(nyc_violent_crimes,datesnyc_v)
dlnyc_v<-diff(sqrt(tsnyc_v+3/8))
plot(tsnyc_v,main='NYC Violent Crimes')
```

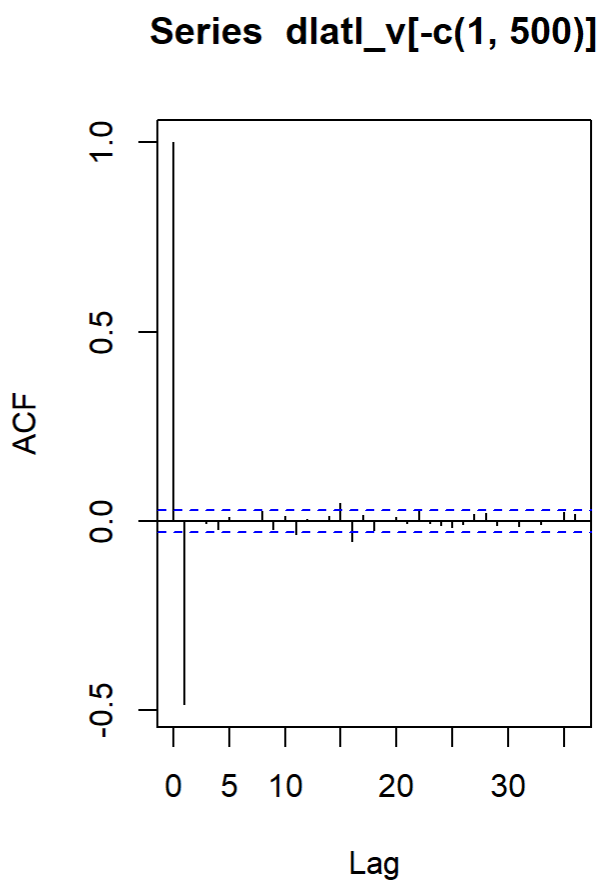



```
#NYC Property Crimes
nyc_property_crimes<-nyc_property[,2]
datesnyc_p<-as.Date(nyc_property[,1],"%m/%d/%Y")
tsnyc_p=xts(nyc_property_crimes,datesnyc_p)
dlnyc_p<-diff(sqrt(tsnyc_p+3/8))
plot(tsnyc_p,main='NYC Property Crimes')
```

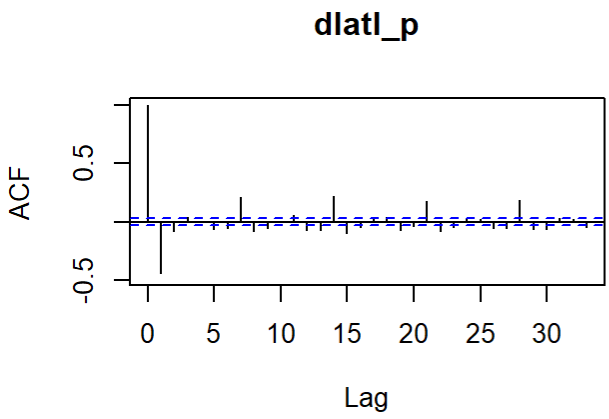


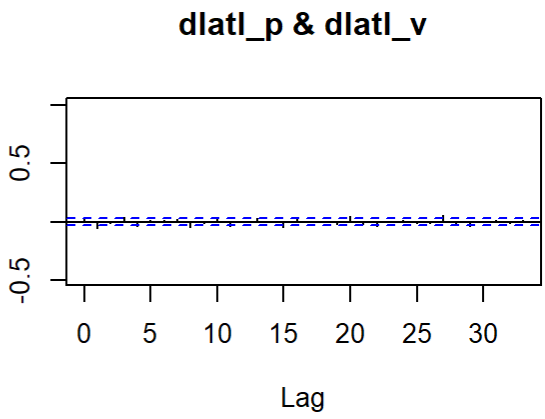

```
## ACF Analysis for both time series together
#ts.merge <- merge(tsatl_p,tsatl_v, join='inner')
#colnames(ts.merge)<-c("tsatl_p","tsatl_p")
par(mfrow = c(1, 2))
acf(dlatl_p[-c(1,500)])
acf(dlatl_v[-c(1,500)])
```

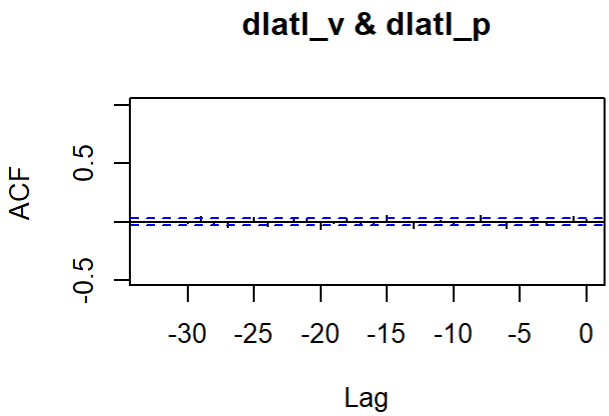


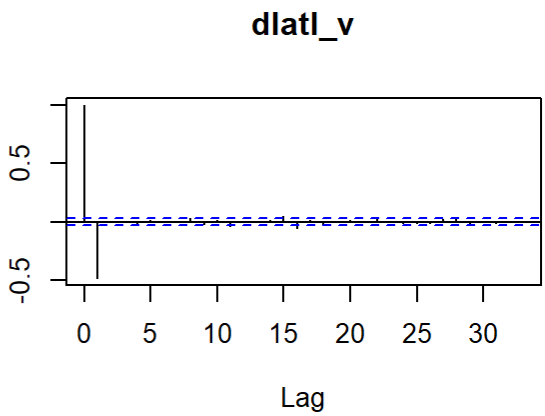



```
dl.merge <- merge(dlatl_p,dlatl_v, join='inner')
colnames(dl.merge)<-c("dlatl_p","dlatl_v")
acf(dl.merge[-c(1, 500)])
```









ATLANTA

```
atl_data_merged <- merge(atl_violent, atl_property, by.x='date', by.y='date', all.x = TRUE, all.
y = TRUE)

names(atl_data_merged)[1] <- "Date"
atl_data_merged=atl_data_merged[order(as.Date(atl_data_merged$Date, format="%m/%d/%Y")),]
names(atl_data_merged)[2] <- "ATL Violent Crimes"
names(atl_data_merged)[3] <- "ATL Property Crimes"

n = nrow(atl_data_merged)
atl_data_merged.train=atl_data_merged[1:(n-877),]
atl_data_merged.test=atl_data_merged[(n-876):n,]

ts_atl_v=ts(atl_data_merged.train[,"ATL Violent Crimes"],start=2009, freq=1)
ts_atl_p=ts(atl_data_merged.train[,"ATL Property Crimes"],start=2009, freq=1)

transts_atl_v= sqrt(ts_atl_v+3/8)
transts_atl_p= sqrt(ts_atl_p+3/8)

ddata.train_atl=cbind(transts_atl_v,transts_atl_p)

VARselect(ddata.train_atl, lag.max = 7)$selection
```

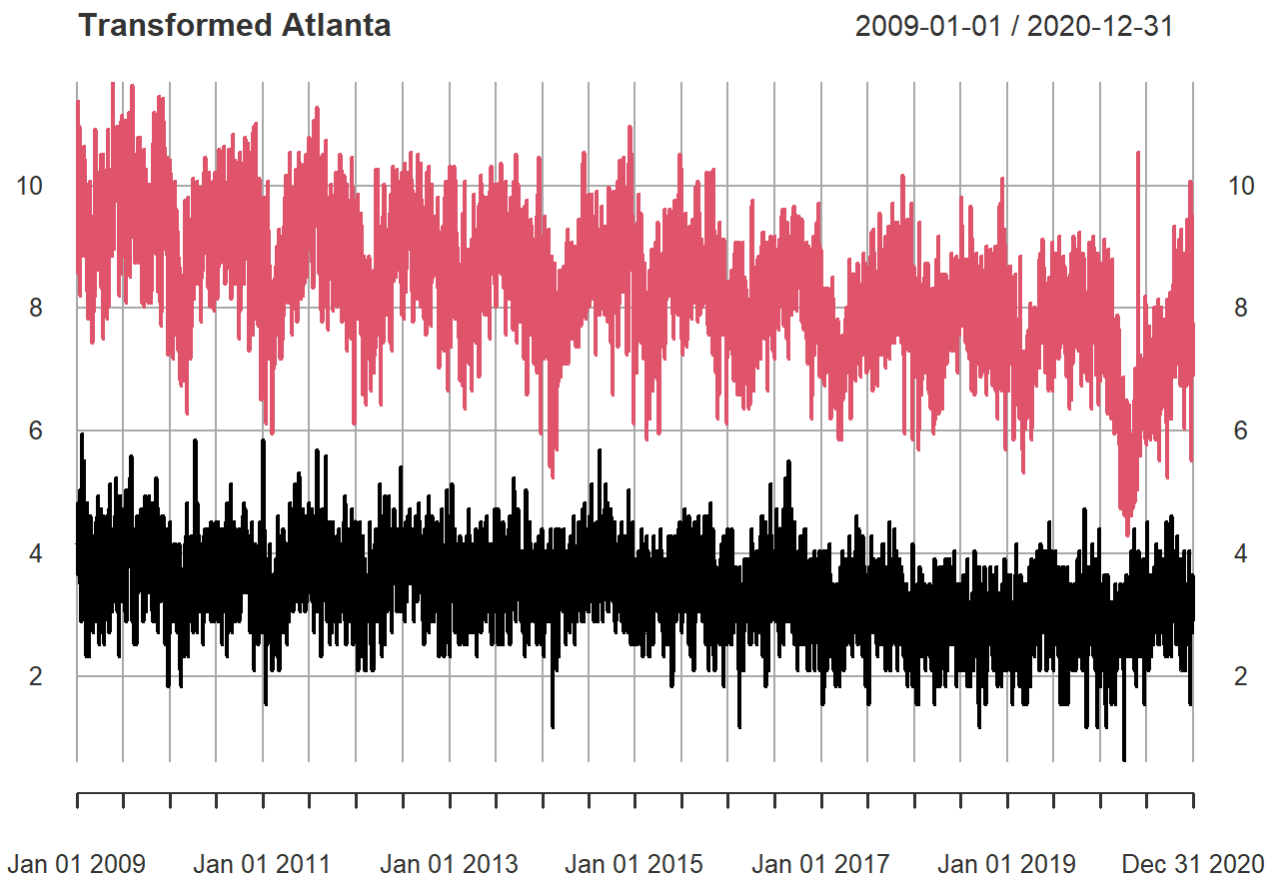
```
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      7      7      7      7
```

```
model.var=VAR(ddata.train_atl, p=7)
summary(model.var)
```

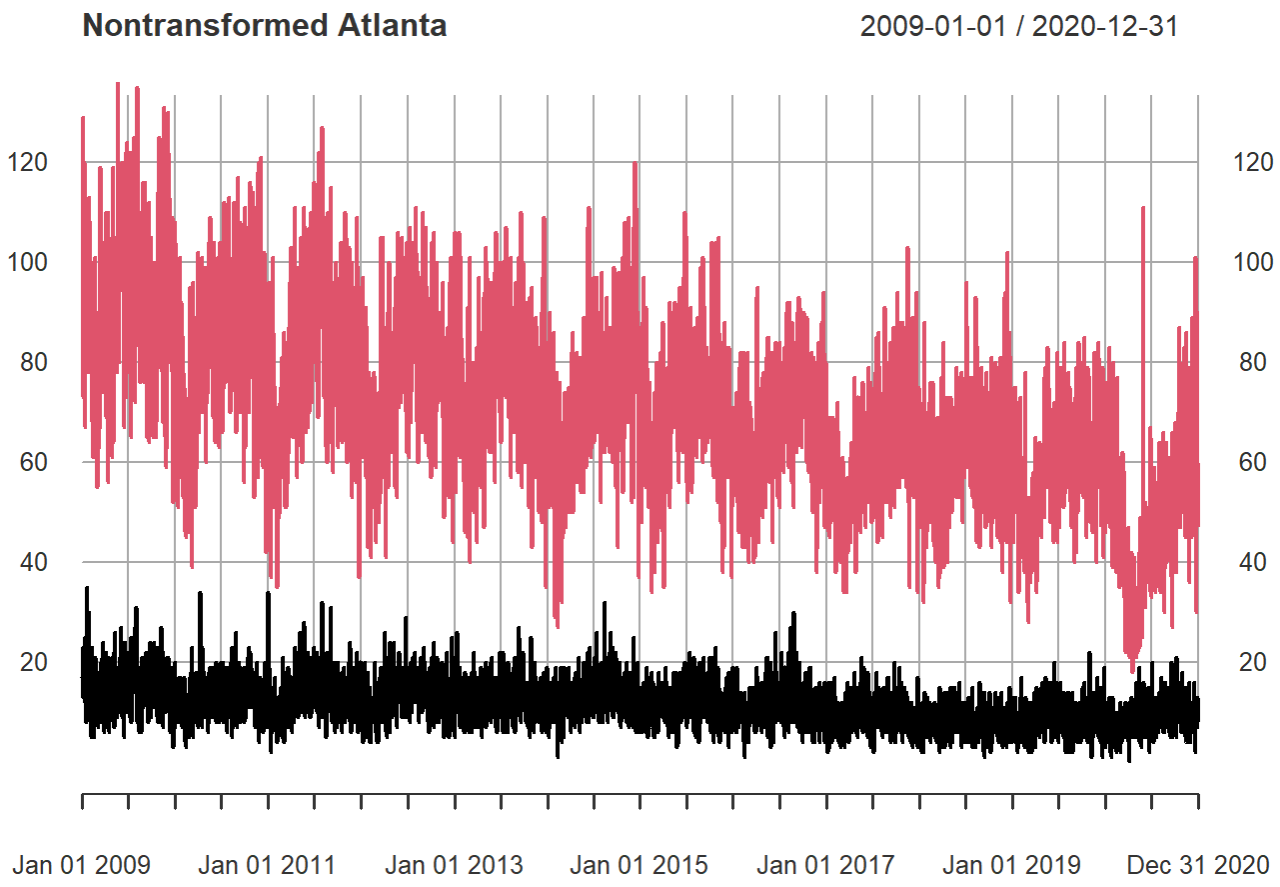
```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: transts_atl_v, transts_atl_p
## Deterministic variables: const
## Sample size: 3499
## Log Likelihood: -6565.665
## Roots of the characteristic polynomial:
## 0.9726 0.8307 0.8307 0.8286 0.8286 0.7989 0.7832 0.7832 0.6997 0.6997 0.6515 0.6515 0.6343 0.
6343
## Call:
## VAR(y = ddata.train_atl, p = 7)
##
##
## Estimation results for equation transts_atl_v:
## ============================================
## transts_atl_v = transts_atl_v.l1 + transts_atl_p.l1 + transts_atl_v.l2 + transts_atl_p.l2 + t
ransts_atl_v.l3 + transts_atl_p.l3 + transts_atl_v.l4 + transts_atl_p.l4 + transts_atl_v.l5 + tr
ansts_atl_p.l5 + transts_atl_v.l6 + transts_atl_p.l6 + transts_atl_v.l7 + transts_atl_p.l7 + con
st
##
##                   Estimate Std. Error t value Pr(>|t|)
## transts_atl_v.l1  0.076752   0.016959   4.526 6.22e-06 ***
## transts_atl_p.l1  0.107181   0.013267   8.079 8.92e-16 ***
## transts_atl_v.l2  0.054075   0.016933   3.193 0.001418 **
## transts_atl_p.l2  0.052992   0.013528   3.917 9.13e-05 ***
## transts_atl_v.l3  0.040409   0.016931   2.387 0.017050 *
## transts_atl_p.l3  0.041027   0.013563   3.025 0.002506 **
## transts_atl_v.l4  0.033571   0.016950   1.981 0.047718 *
## transts_atl_p.l4  0.045001   0.013629   3.302 0.000970 ***
## transts_atl_v.l5  0.068794   0.016949   4.059 5.04e-05 ***
## transts_atl_p.l5  0.002140   0.013532   0.158 0.874340
## transts_atl_v.l6  0.054978   0.016955   3.242 0.001196 **
## transts_atl_p.l6 -0.057633   0.013493  -4.271 1.99e-05 ***
## transts_atl_v.l7  0.070539   0.016805   4.197 2.77e-05 ***
## transts_atl_p.l7  0.004822   0.013375   0.361 0.718471
## const             0.422524   0.115912   3.645 0.000271 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.5587 on 3484 degrees of freedom
## Multiple R-Squared: 0.1988,  Adjusted R-squared: 0.1956
## F-statistic: 61.75 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation transts_atl_p:
## ============================================
## transts_atl_p = transts_atl_v.l1 + transts_atl_p.l1 + transts_atl_v.l2 + transts_atl_p.l2 + t
ransts_atl_v.l3 + transts_atl_p.l3 + transts_atl_v.l4 + transts_atl_p.l4 + transts_atl_v.l5 + tr
ansts_atl_p.l5 + transts_atl_v.l6 + transts_atl_p.l6 + transts_atl_v.l7 + transts_atl_p.l7 + con
st
```

```
##
##                   Estimate Std. Error t value Pr(>|t|)
## transts_atl_v.l1  0.01662    0.02093   0.794 0.427335
## transts_atl_p.l1  0.18200    0.01638  11.114  < 2e-16 ***
## transts_atl_v.l2  0.01314    0.02090   0.629 0.529467
## transts_atl_p.l2  0.07112    0.01670   4.259 2.11e-05 ***
## transts_atl_v.l3  0.07185    0.02090   3.438 0.000593 ***
## transts_atl_p.l3  0.11921    0.01674   7.120 1.30e-12 ***
## transts_atl_v.l4  0.04018    0.02092   1.921 0.054868 .
## transts_atl_p.l4  0.05530    0.01682   3.287 0.001022 **
## transts_atl_v.l5  0.04301    0.02092   2.056 0.039884 *
## transts_atl_p.l5  0.02239    0.01670   1.340 0.180243
## transts_atl_v.l6  0.03446    0.02093   1.646 0.099789 .
## transts_atl_p.l6  0.07891    0.01665   4.738 2.24e-06 ***
## transts_atl_v.l7  0.02521    0.02074   1.215 0.224280
## transts_atl_p.l7  0.26939    0.01651  16.318  < 2e-16 ***
## const             0.88027    0.14307   6.153 8.49e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.6897 on 3484 degrees of freedom
## Multiple R-Squared: 0.4713,  Adjusted R-squared: 0.4692
## F-statistic: 221.9 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##               transts_atl_v transts_atl_p
## transts_atl_v       0.31219       0.03226
## transts_atl_p       0.03226       0.47564
##
## Correlation matrix of residuals:
##               transts_atl_v transts_atl_p
## transts_atl_v       1.00000       0.08371
## transts_atl_p       0.08371       1.00000
```

```
###ATLANTA
atl.vc<-atl_violent[,2]
datesatl.v<-as.Date(atl_violent[,1],"%m/%d/%Y")
xts.atlv=xts(atl.vc,datesatl.v)

atl.pc<-atl_property[,2]
datesatl.p<-as.Date(atl_property[,1],"%m/%d/%Y")
xts.atlp=xts(atl.pc,datesatl.p)

trans.atlv <- sqrt(xts.atlv+3/8)
trans.atlp <- sqrt(xts.atlp+3/8)

transmerge.atl <- merge(trans.atlv, trans.atlp, join='inner')
merge.atl <- merge(xts.atlv, xts.atlp, join='inner')

plot(transmerge.atl, main="Transformed Atlanta")
```




```
plot(merge.atl, main="Nontransformed Atlanta")
```




```
###GRANGER - ATLANTA CRIME CHECK
library(aod)
```

```
##
## Attaching package: 'aod'
```

```
## The following object is masked from 'package:mgcv':
##
##     negbin
```

```
rownames(vcov(model.var))
```

```
##  [1] "transts_atl_v:(Intercept)"      "transts_atl_v:transts_atl_v.l1"
##  [3] "transts_atl_v:transts_atl_p.l1" "transts_atl_v:transts_atl_v.l2"
##  [5] "transts_atl_v:transts_atl_p.l2" "transts_atl_v:transts_atl_v.l3"
##  [7] "transts_atl_v:transts_atl_p.l3" "transts_atl_v:transts_atl_v.l4"
##  [9] "transts_atl_v:transts_atl_p.l4" "transts_atl_v:transts_atl_v.l5"
## [11] "transts_atl_v:transts_atl_p.l5" "transts_atl_v:transts_atl_v.l6"
## [13] "transts_atl_v:transts_atl_p.l6" "transts_atl_v:transts_atl_v.l7"
## [15] "transts_atl_v:transts_atl_p.l7" "transts_atl_p:(Intercept)"
## [17] "transts_atl_p:transts_atl_v.l1" "transts_atl_p:transts_atl_p.l1"
## [19] "transts_atl_p:transts_atl_v.l2" "transts_atl_p:transts_atl_p.l2"
## [21] "transts_atl_p:transts_atl_v.l3" "transts_atl_p:transts_atl_p.l3"
## [23] "transts_atl_p:transts_atl_v.l4" "transts_atl_p:transts_atl_p.l4"
## [25] "transts_atl_p:transts_atl_v.l5" "transts_atl_p:transts_atl_p.l5"
## [27] "transts_atl_p:transts_atl_v.l6" "transts_atl_p:transts_atl_p.l6"
## [29] "transts_atl_p:transts_atl_v.l7" "transts_atl_p:transts_atl_p.l7"
```

```
###GRANGER - DOES ATLANTA PROPERTY LEAD ATLANTA VIOLENT
coef.atl_v = coefficients(model.var)$transts_atl_v[-(7*2+1),1]
var.model = vcov(model.var)[2:15,2:15]
wald.test(b=coef.atl_v, var.model, Terms=c(2,4,6,8,10,12,14))
```

```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 201.9, df = 7, P(> X2) = 0.0
```

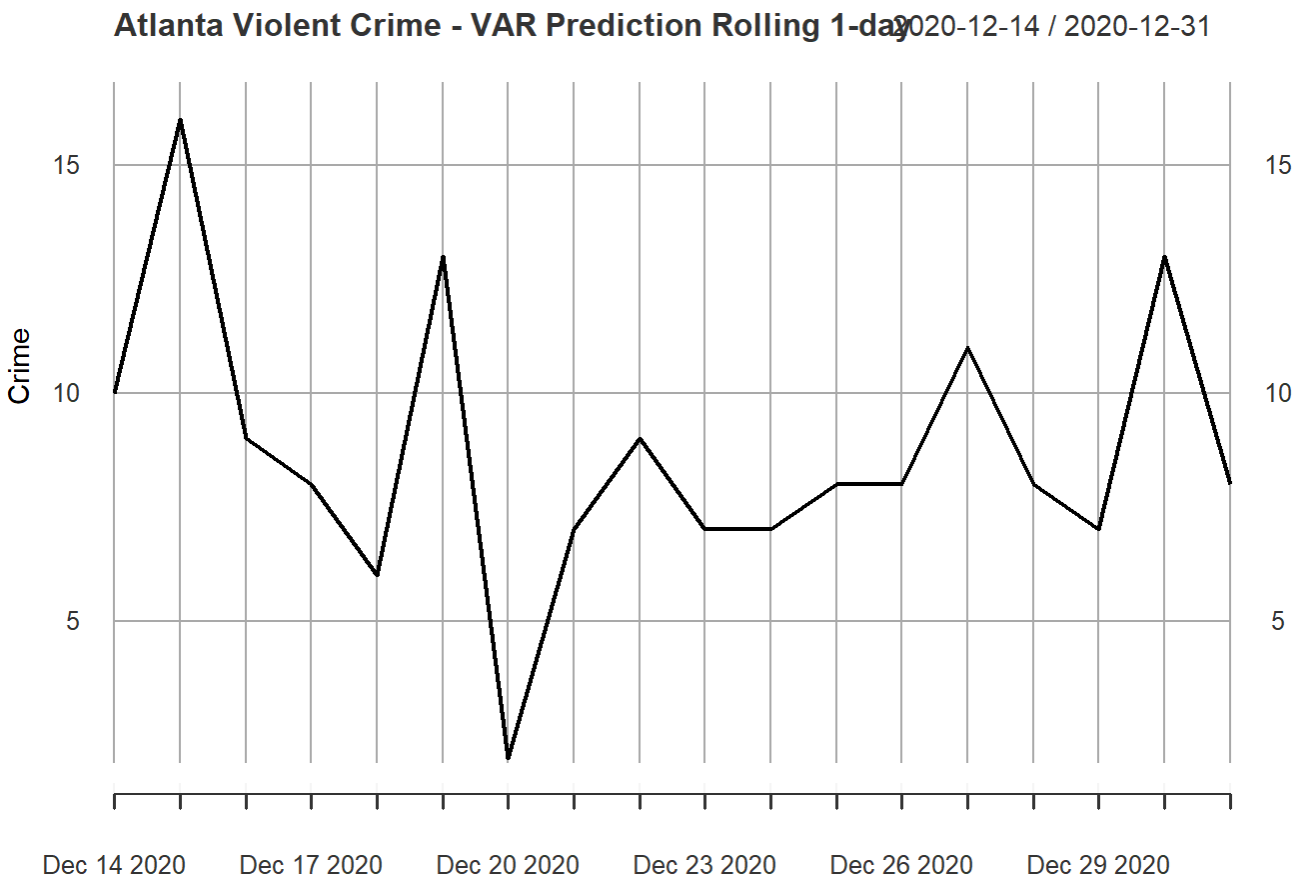
```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN ATLANTA PROPERTY CRIME INFLUENCES CHANGE IN ATLANTA VIOLENT
```

```
###GRANGER - DOES ATLANTA VIOLENT LEAD ATLANTA PROPERTY
coef.atl_p = coefficients(model.var)$transts_atl_p[-(7*2+1),1]
var.model2 = vcov(model.var)[17:30,17:30]
wald.test(b=coef.atl_p, var.model2, Terms=c(1,3,5,7,9,11,13))
```

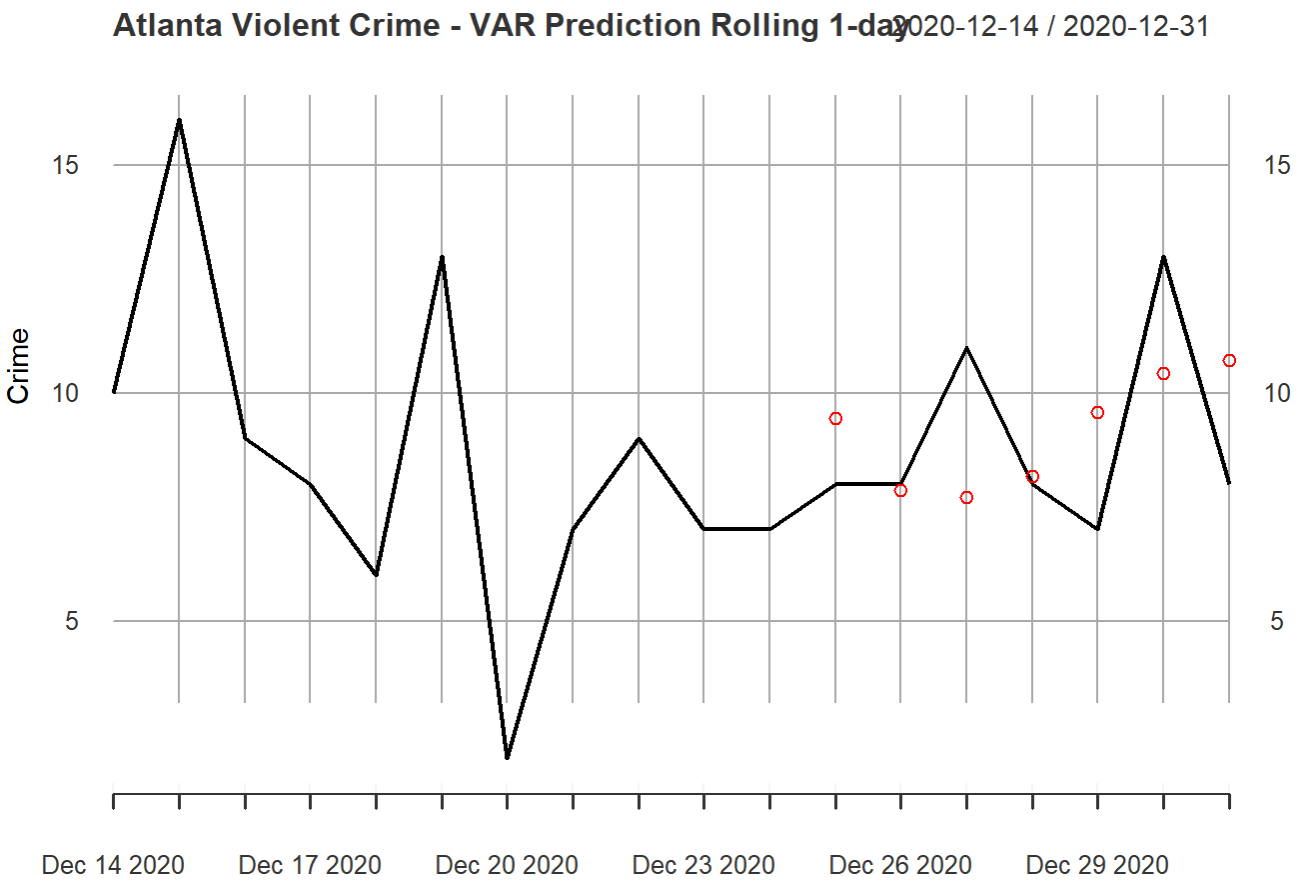
```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 34.3, df = 7, P(> X2) = 1.5e-05
```

```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN ATLANTA VIOLENT CRIME INFLUENCES CHANGE IN ATLANTA PROPERTY CRIME
```

```
###REFORECAST - ATLANTA
n = nrow(merge.atl)
data.train = merge.atl[1:(n-7),]
data.test = merge.atl[(n-7+1):n,]

n2 = length(xts.atlv)
nfit = n2-7

train.atl_v = xts.atlv[1:nfit]
test.atl_v = xts.atlv[(nfit+1):n2]

unrestr.fcst = NULL

for(idx in 1:7){

  nfit=n-(7-idx+1)

  unrestr.bic.pred = VAR(merge.atl[1:nfit],p=7)

    pred.unrestr=predict(unrestr.bic.pred,n.ahead=1)

    unrestr.fcst=c(unrestr.fcst,pred.unrestr[[1]]$xts.atlv[,1])
}

###PLOTTING
n_back = 18

ymin = min(c(ts(xts.atlv[c(n2-n_back+1):n2]), unrestr.fcst))*0.95
ymax = max(c(ts(xts.atlv[c(n2-n_back+1):n2]), unrestr.fcst))*1.05

plot(xts.atlv[c(n2-n_back+1):n2], type="l", xlab="Time", ylab="Crime", main="Atlanta Violent Cri
me - VAR Prediction Rolling 1-day", ylim=c(ymin,ymax))
```




```
points(xts(unrestr.fcst, time(test.atl_v)), col='red')
```




```
###ATLANTA REFORECAST - ACCURACY MEASURE

#Mean Absolute Percentage Error (MAPE)
mean(abs(unrestr.fcst - test.atl_v)/abs(test.atl_v))
```

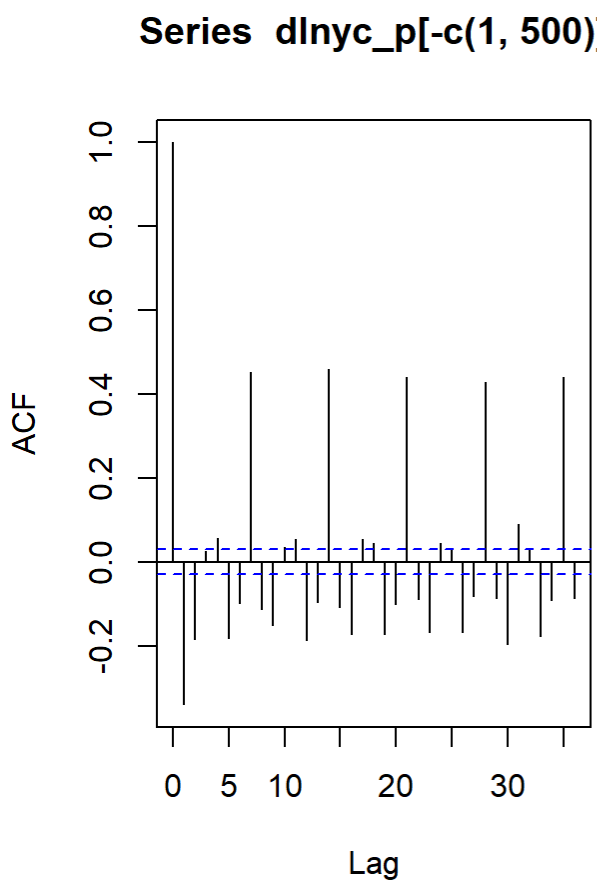
```
## [1] 0.2030456
```

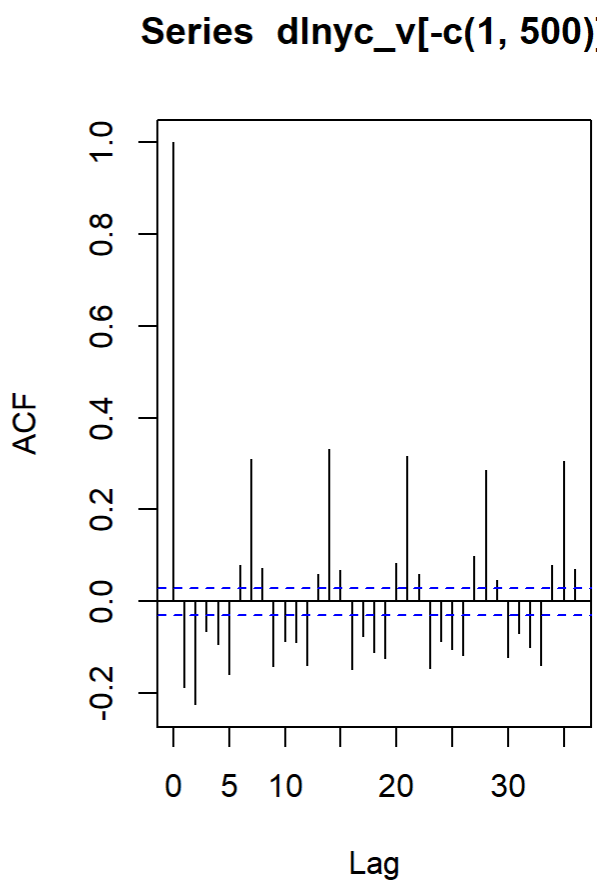
```
#Precision Measure (PM)
sum((unrestr.fcst - test.atl_v)^2)/sum((test.atl_v-mean(test.atl_v))^2)
```

```
## [1] 1.19626
```

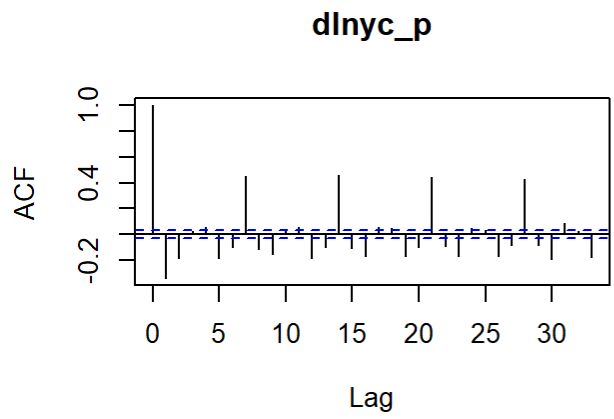
##NYC

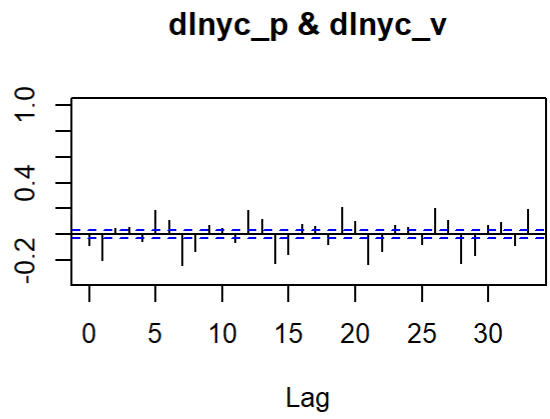
```
par(mfrow = c(1, 2))
acf(dlnyc_p[-c(1,500)])
acf(dlnyc_v[-c(1,500)])
```

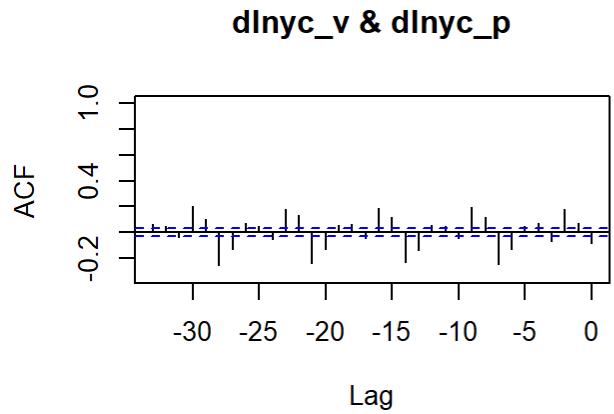


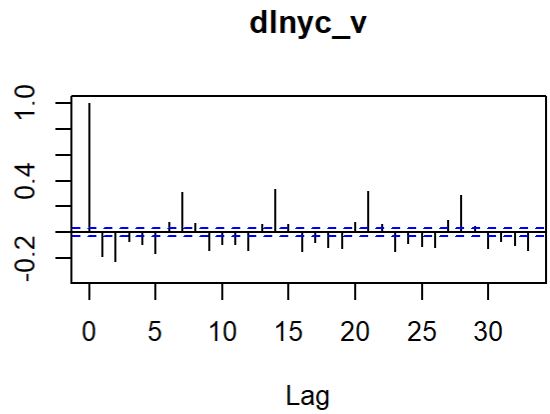



```
dl.merge <- merge(dlnyc_p,dlnyc_v, join='inner')
colnames(dl.merge)<-c("dlnyc_p","dlnyc_v")
acf(dl.merge[-c(1, 500)])
```










```
nyc_data_merged <- merge(nyc_violent, nyc_property, by.x='date', by.y='date', all.x = TRUE, all.
y = TRUE)

names(nyc_data_merged)[1] <- "Date"
nyc_data_merged=nyc_data_merged[order(as.Date(nyc_data_merged$Date, format="%m/%d/%Y")),]
names(nyc_data_merged)[2] <- "NYC Violent Crimes"
names(nyc_data_merged)[3] <- "NYC Property Crimes"

n = nrow(nyc_data_merged)
nyc_data_merged.train=nyc_data_merged[1:(n-877),]
nyc_data_merged.test=nyc_data_merged[(n-876):n,]

ts_nyc_v=ts(nyc_data_merged.train[,"NYC Violent Crimes"],start=2009, freq=1)
ts_nyc_p=ts(nyc_data_merged.train[,"NYC Property Crimes"],start=2009, freq=1)

transts_nyc_v= sqrt(ts_nyc_v+3/8)
transts_nyc_p= sqrt(ts_nyc_p+3/8)

ddata.train_nyc=cbind(transts_nyc_v,transts_nyc_p)

VARselect(ddata.train_nyc, lag.max = 7)$selection
```

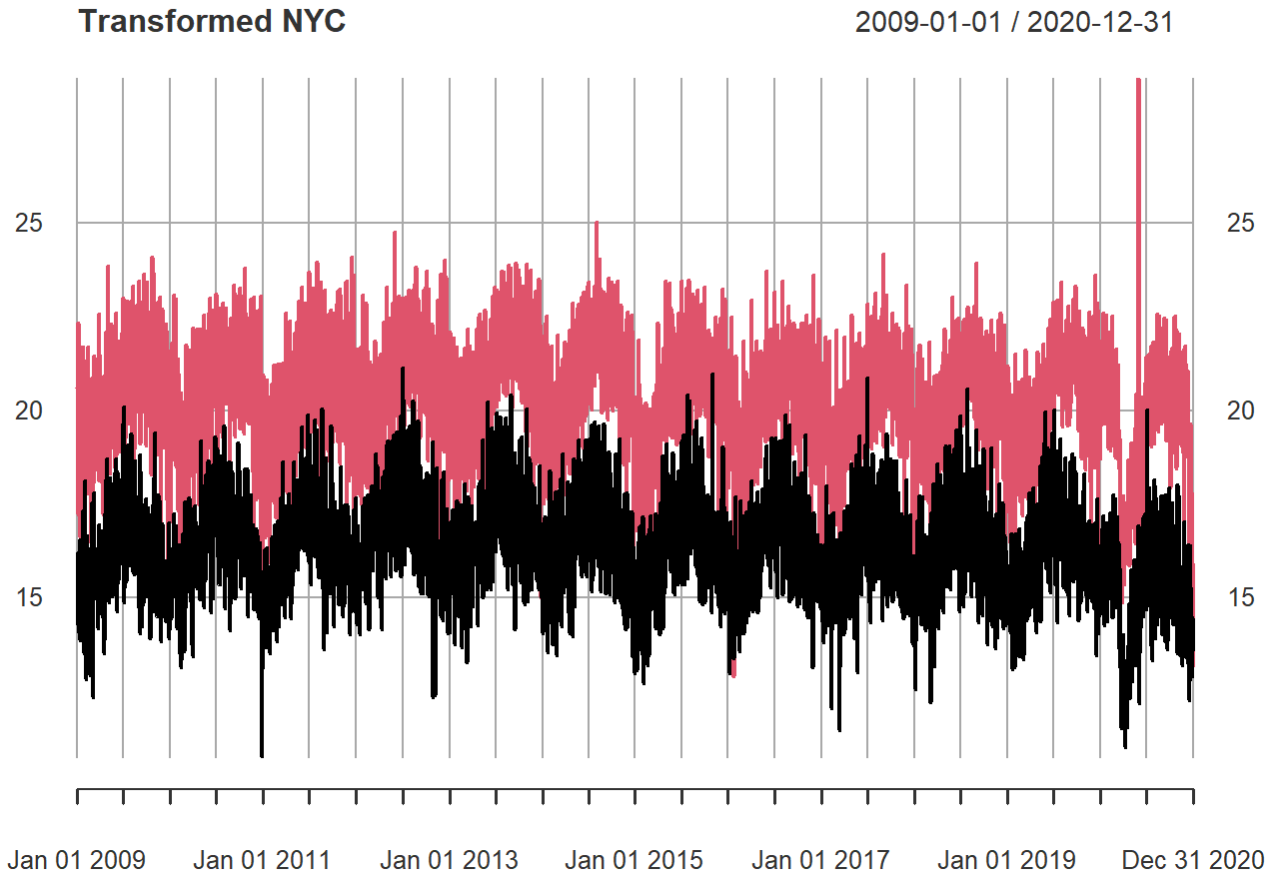
```
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      7      7      7      7
```

```
model.var=VAR(ddata.train_nyc, p=7)
summary(model.var)
```

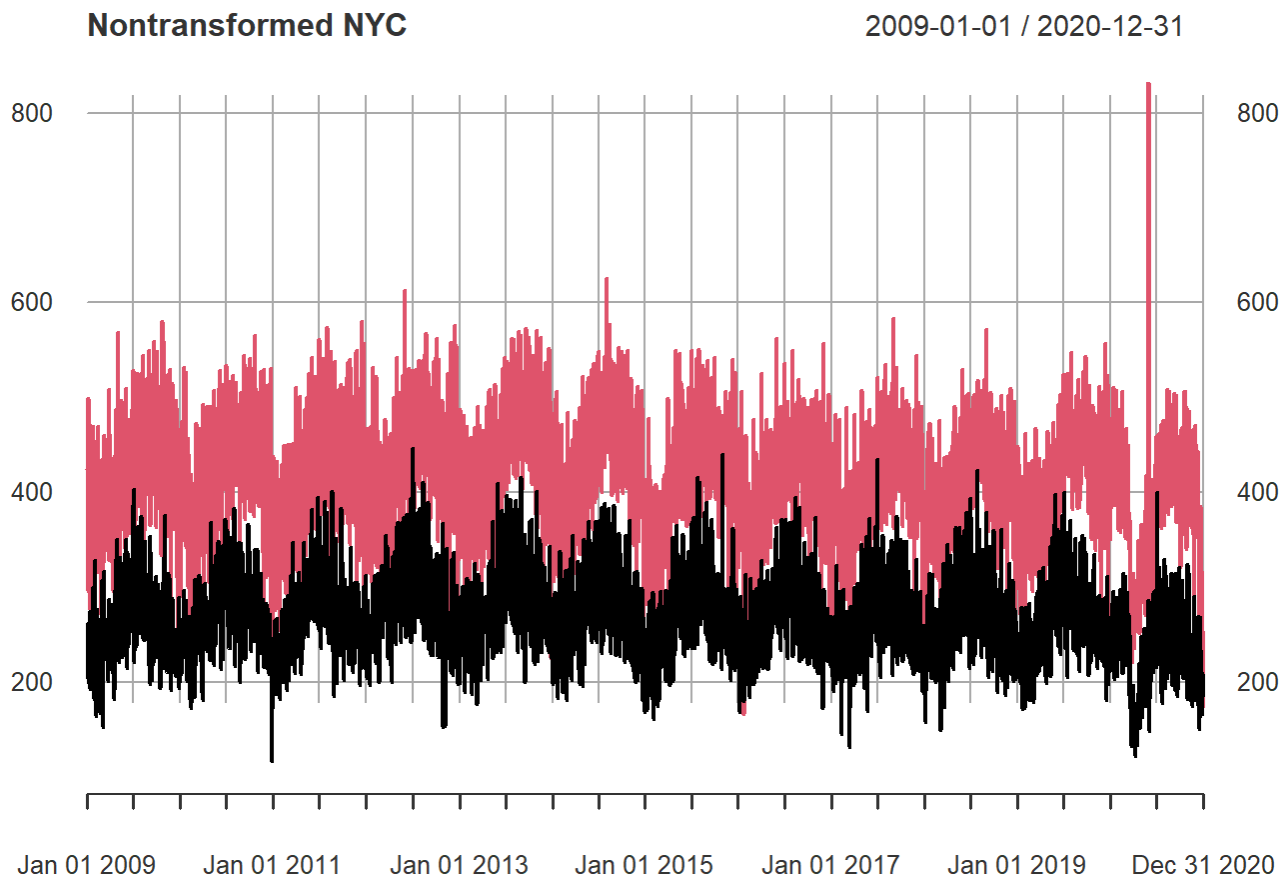
```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: transts_nyc_v, transts_nyc_p
## Deterministic variables: const
## Sample size: 3499
## Log Likelihood: -9713.087
## Roots of the characteristic polynomial:
## 0.9629 0.9629 0.9601 0.9379 0.9379 0.9192 0.8673 0.8673 0.7503 0.7503 0.7323 0.7323 0.6555 0.
6555
## Call:
## VAR(y = ddata.train_nyc, p = 7)
##
##
## Estimation results for equation transts_nyc_v:
## ============================================
## transts_nyc_v = transts_nyc_v.l1 + transts_nyc_p.l1 + transts_nyc_v.l2 + transts_nyc_p.l2 + t
ransts_nyc_v.l3 + transts_nyc_p.l3 + transts_nyc_v.l4 + transts_nyc_p.l4 + transts_nyc_v.l5 + tr
ansts_nyc_p.l5 + transts_nyc_v.l6 + transts_nyc_p.l6 + transts_nyc_v.l7 + transts_nyc_p.l7 + con
st
##
##                   Estimate Std. Error t value Pr(>|t|)
## transts_nyc_v.l1  0.326402   0.016251  20.085  < 2e-16 ***
## transts_nyc_p.l1  0.131753   0.012838  10.263  < 2e-16 ***
## transts_nyc_v.l2 -0.055387   0.017047  -3.249 0.001169 **
## transts_nyc_p.l2  0.137796   0.013299  10.362  < 2e-16 ***
## transts_nyc_v.l3  0.065615   0.017116   3.834 0.000129 ***
## transts_nyc_p.l3  0.011930   0.013315   0.896 0.370341
## transts_nyc_v.l4 -0.029153   0.017125  -1.702 0.088782 .
## transts_nyc_p.l4  0.068909   0.013284   5.187 2.25e-07 ***
## transts_nyc_v.l5  0.005942   0.017126   0.347 0.728642
## transts_nyc_p.l5 -0.024081   0.013236  -1.819 0.068947 .
## transts_nyc_v.l6  0.149813   0.017134   8.744  < 2e-16 ***
## transts_nyc_p.l6 -0.068452   0.013204  -5.184 2.29e-07 ***
## transts_nyc_v.l7  0.234966   0.016005  14.681  < 2e-16 ***
## transts_nyc_p.l7 -0.133523   0.013023 -10.253  < 2e-16 ***
## const             2.368784   0.342789   6.910 5.72e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.9071 on 3484 degrees of freedom
## Multiple R-Squared: 0.504,   Adjusted R-squared: 0.502
## F-statistic: 252.8 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation transts_nyc_p:
## ============================================
## transts_nyc_p = transts_nyc_v.l1 + transts_nyc_p.l1 + transts_nyc_v.l2 + transts_nyc_p.l2 + t
ransts_nyc_v.l3 + transts_nyc_p.l3 + transts_nyc_v.l4 + transts_nyc_p.l4 + transts_nyc_v.l5 + tr
ansts_nyc_p.l5 + transts_nyc_v.l6 + transts_nyc_p.l6 + transts_nyc_v.l7 + transts_nyc_p.l7 + con
st
```

```
##
##                   Estimate Std. Error t value Pr(>|t|)
## transts_nyc_v.l1  0.01506    0.01901   0.792 0.428252
## transts_nyc_p.l1  0.21563    0.01502  14.360  < 2e-16 ***
## transts_nyc_v.l2  0.07041    0.01994   3.531 0.000419 ***
## transts_nyc_p.l2  0.04626    0.01555   2.974 0.002962 **
## transts_nyc_v.l3  0.07413    0.02002   3.703 0.000217 ***
## transts_nyc_p.l3  0.05456    0.01557   3.503 0.000466 ***
## transts_nyc_v.l4  0.02754    0.02003   1.375 0.169188
## transts_nyc_p.l4  0.07033    0.01554   4.527 6.19e-06 ***
## transts_nyc_v.l5  0.15435    0.02003   7.705 1.69e-14 ***
## transts_nyc_p.l5 -0.06541    0.01548  -4.225 2.45e-05 ***
## transts_nyc_v.l6  0.03350    0.02004   1.671 0.094713 .
## transts_nyc_p.l6  0.01553    0.01544   1.005 0.314848
## transts_nyc_v.l7 -0.24173    0.01872 -12.912  < 2e-16 ***
## transts_nyc_p.l7  0.43629    0.01523  28.641  < 2e-16 ***
## const             2.50337    0.40095   6.244 4.79e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 1.061 on 3484 degrees of freedom
## Multiple R-Squared: 0.5041,  Adjusted R-squared: 0.5021
## F-statistic:   253 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##               transts_nyc_v transts_nyc_p
## transts_nyc_v        0.8228        0.1872
## transts_nyc_p        0.1872        1.1257
##
## Correlation matrix of residuals:
##               transts_nyc_v transts_nyc_p
## transts_nyc_v        1.0000        0.1945
## transts_nyc_p        0.1945        1.0000
```

```
###NYC
nyc.vc<-nyc_violent[,2]
datesnyc.v<-as.Date(nyc_violent[,1],"%m/%d/%Y")
xts.nycv=xts(nyc.vc,datesnyc.v)

nyc.pc<-nyc_property[,2]
datesnyc.p<-as.Date(nyc_property[,1],"%m/%d/%Y")
xts.nycp=xts(nyc.pc,datesnyc.p)

trans.nycv <- sqrt(xts.nycv+3/8)
trans.nycp <- sqrt(xts.nycp+3/8)

transmerge.nyc <- merge(trans.nycv, trans.nycp, join='inner')
merge.nyc <- merge(xts.nycv, xts.nycp, join='inner')

plot(transmerge.nyc, main="Transformed NYC")
```




```
plot(merge.nyc, main="Nontransformed NYC")
```




```
###GRANGER - NYC CRIME CHECK
library(aod)
rownames(vcov(model.var))
```

```
##  [1] "transts_nyc_v:(Intercept)"      "transts_nyc_v:transts_nyc_v.l1"
##  [3] "transts_nyc_v:transts_nyc_p.l1" "transts_nyc_v:transts_nyc_v.l2"
##  [5] "transts_nyc_v:transts_nyc_p.l2" "transts_nyc_v:transts_nyc_v.l3"
##  [7] "transts_nyc_v:transts_nyc_p.l3" "transts_nyc_v:transts_nyc_v.l4"
##  [9] "transts_nyc_v:transts_nyc_p.l4" "transts_nyc_v:transts_nyc_v.l5"
## [11] "transts_nyc_v:transts_nyc_p.l5" "transts_nyc_v:transts_nyc_v.l6"
## [13] "transts_nyc_v:transts_nyc_p.l6" "transts_nyc_v:transts_nyc_v.l7"
## [15] "transts_nyc_v:transts_nyc_p.l7" "transts_nyc_p:(Intercept)"
## [17] "transts_nyc_p:transts_nyc_v.l1" "transts_nyc_p:transts_nyc_p.l1"
## [19] "transts_nyc_p:transts_nyc_v.l2" "transts_nyc_p:transts_nyc_p.l2"
## [21] "transts_nyc_p:transts_nyc_v.l3" "transts_nyc_p:transts_nyc_p.l3"
## [23] "transts_nyc_p:transts_nyc_v.l4" "transts_nyc_p:transts_nyc_p.l4"
## [25] "transts_nyc_p:transts_nyc_v.l5" "transts_nyc_p:transts_nyc_p.l5"
## [27] "transts_nyc_p:transts_nyc_v.l6" "transts_nyc_p:transts_nyc_p.l6"
## [29] "transts_nyc_p:transts_nyc_v.l7" "transts_nyc_p:transts_nyc_p.l7"
```

```
###GRANGER - DOES NYC PROPERTY LEAD NYC VIOLENT
coef.nyc_v = coefficients(model.var)$transts_nyc_v[-(7*2+1),1]
var.model = vcov(model.var)[2:15,2:15]
wald.test(b=coef.nyc_v, var.model, Terms=c(2,4,6,8,10,12,14))
```

```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 466.1, df = 7, P(> X2) = 0.0
```

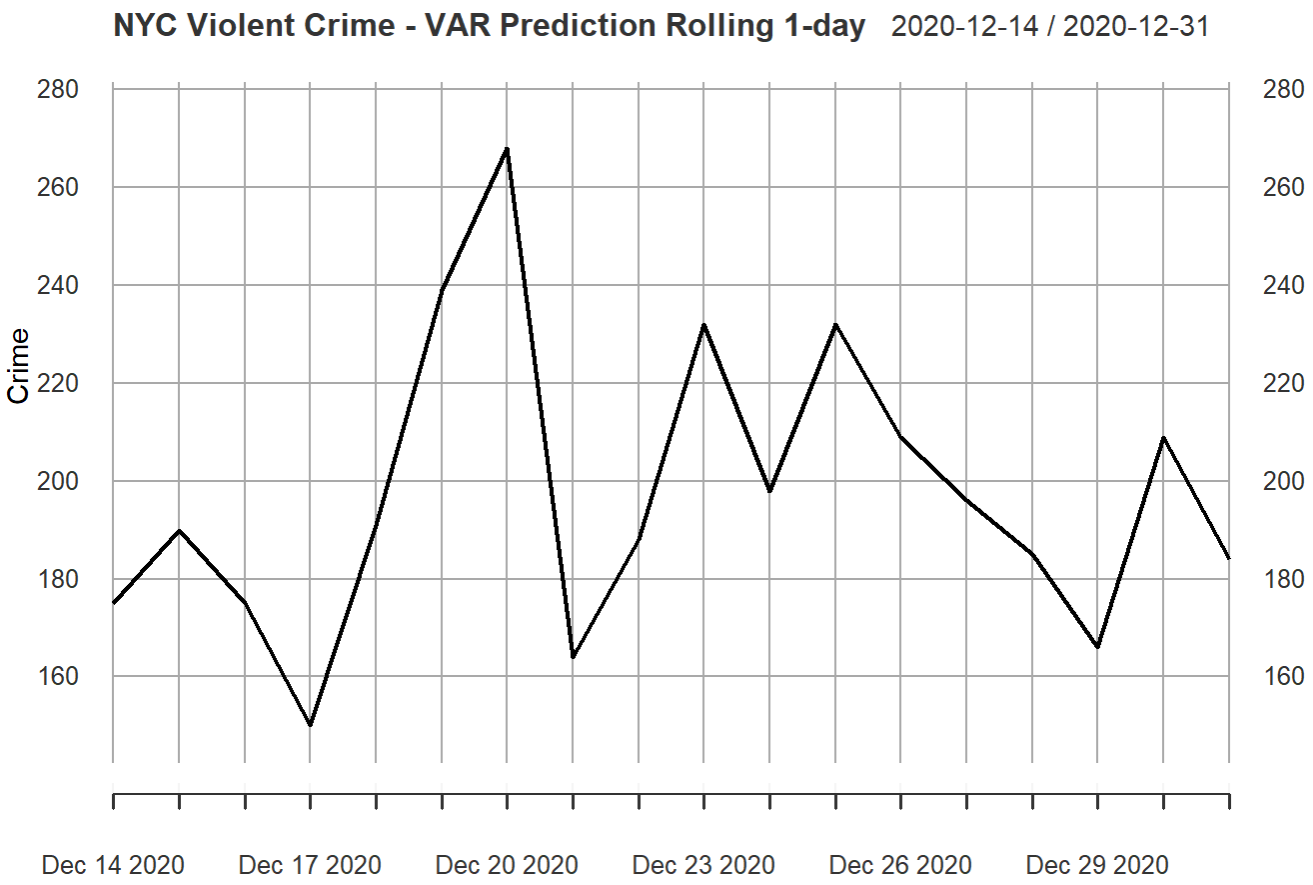
```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN NYC PROPERTY CRIME INFLUENCES CHANGE IN NYC VIOLENT
```

```
###GRANGER - DOES NYC VIOLENT LEAD NYC PROPERTY
coef.nyc_p = coefficients(model.var)$transts_nyc_p[-(7*2+1),1]
var.model2 = vcov(model.var)[17:30,17:30]
wald.test(b=coef.nyc_p, var.model2, Terms=c(1,3,5,7,9,11,13))
```

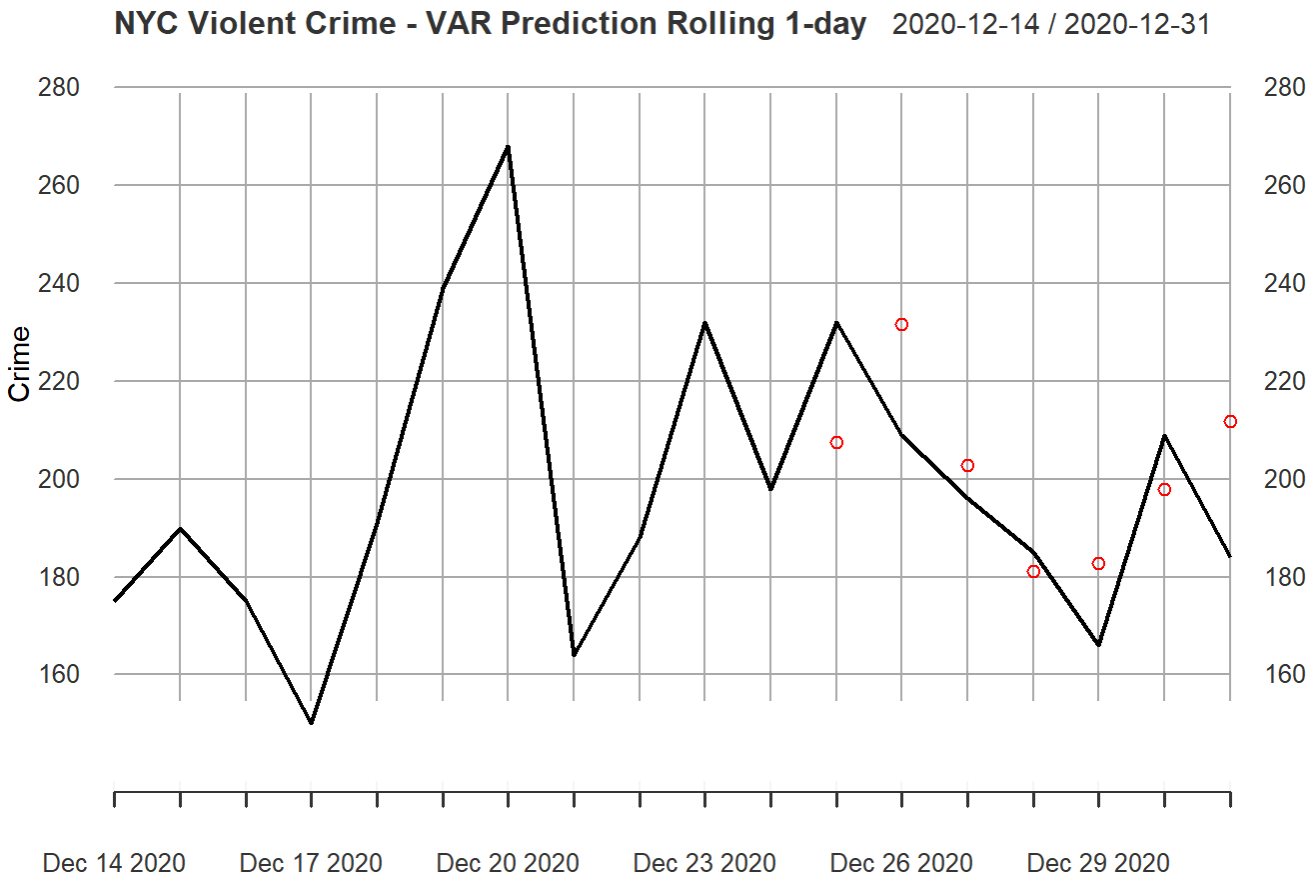
```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 356.8, df = 7, P(> X2) = 0.0
```

```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN NYC VIOLENT CRIME INFLUENCES CHANGE IN NYC PROPERTY CRIME
```

```
###REFORECAST - NYC
n = nrow(merge.nyc)
data.train = merge.nyc[1:(n-7),]
data.test = merge.nyc[(n-7+1):n,]

n2 = length(xts.nycv)
nfit = n2-7

train.nyc_v = xts.nycv[1:nfit]
test.nyc_v = xts.nycv[(nfit+1):n2]

unrestr.fcst = NULL

for(idx in 1:7){

  nfit=n-(7-idx+1)

  unrestr.bic.pred = VAR(merge.nyc[1:nfit],p=7)

    pred.unrestr=predict(unrestr.bic.pred,n.ahead=1)

    unrestr.fcst=c(unrestr.fcst,pred.unrestr[[1]]$xts.nycv[,1])
}

###PLOTTING
n_back = 18

ymin = min(c(ts(xts.nycv[c(n2-n_back+1):n2]), unrestr.fcst))*0.95
ymax = max(c(ts(xts.nycv[c(n2-n_back+1):n2]), unrestr.fcst))*1.05

plot(xts.nycv[c(n2-n_back+1):n2], type="l", xlab="Time", ylab="Crime", main="NYC Violent Crime -
VAR Prediction Rolling 1-day", ylim=c(ymin,ymax))
```




```
points(xts(unrestr.fcst, time(test.nyc_v)), col='red')
```




```
###NYC REFORECAST - ACCURACY MEASURE

#Mean Absolute Percentage Error (MAPE)
mean(abs(unrestr.fcst - test.nyc_v)/abs(test.nyc_v))
```

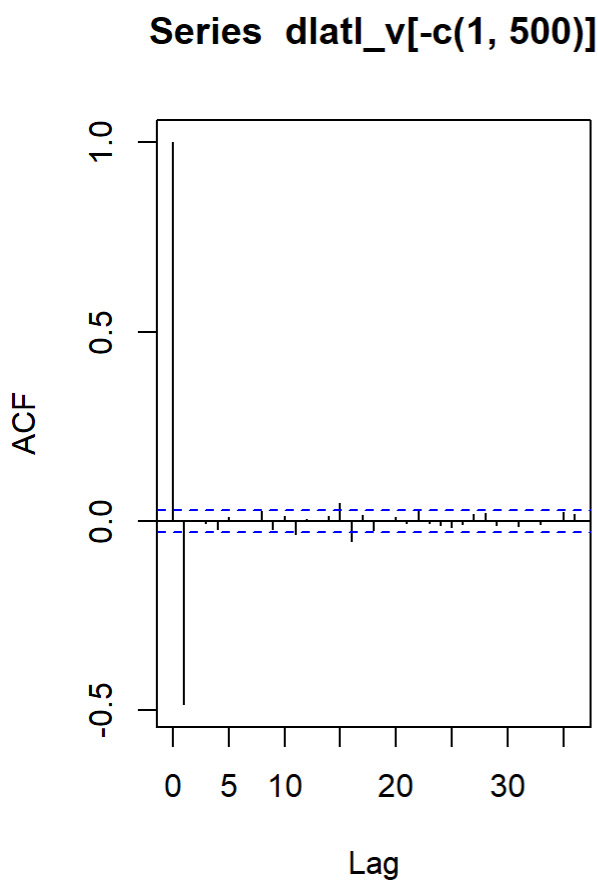
```
## [1] 0.08187034
```

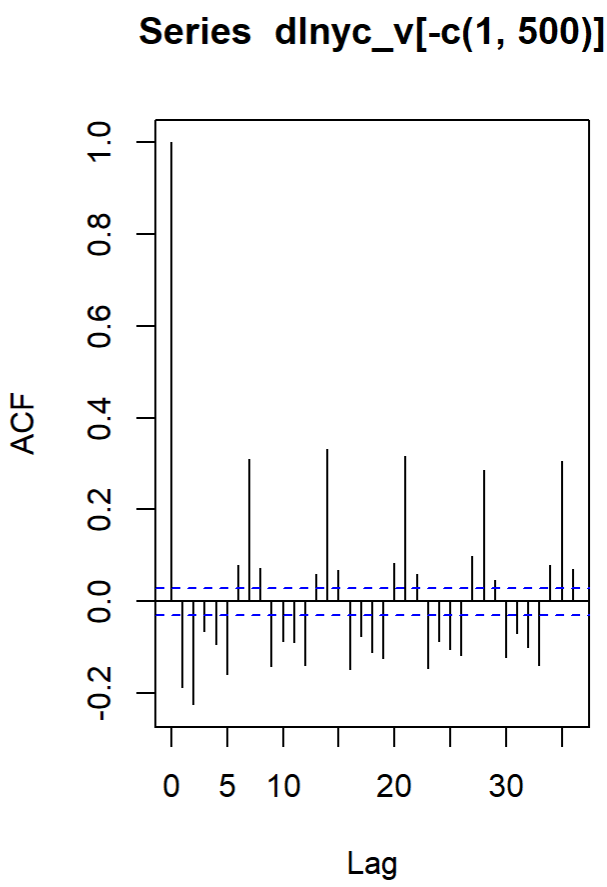
```
#Precision Measure (PM)
sum((unrestr.fcst - test.nyc_v)^2)/sum((test.nyc_v-mean(test.nyc_v))^2)
```

```
## [1] 0.839868
```

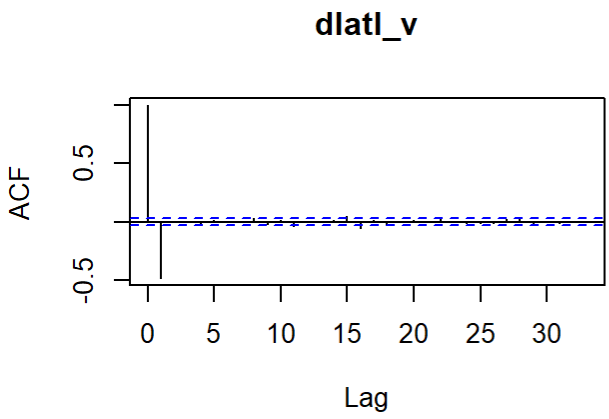
##NYC-ATLANTA

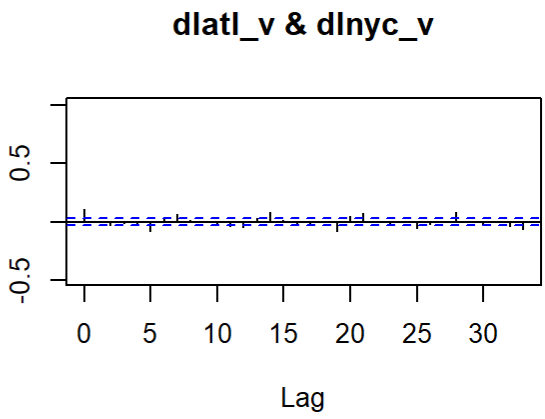
```
par(mfrow = c(1, 2))
acf(dlatl_v[-c(1,500)])
acf(dlnyc_v[-c(1,500)])
```

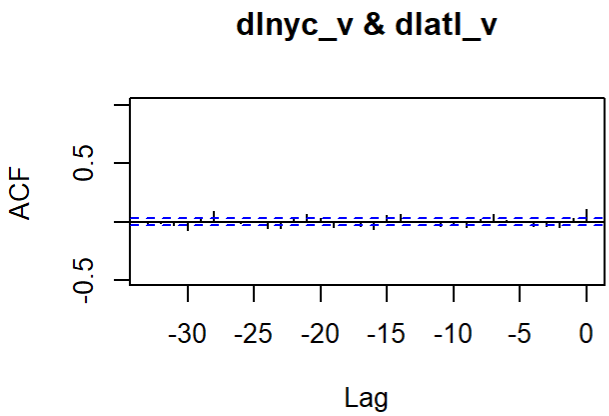


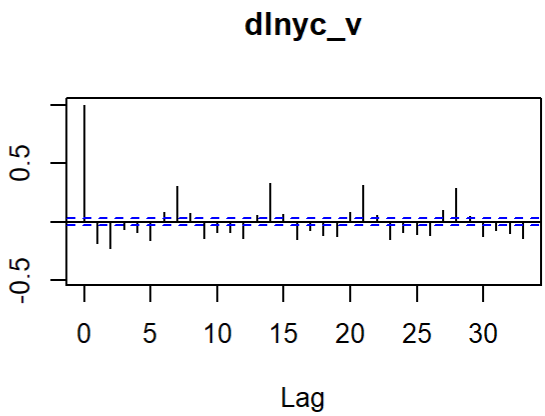



```
dl.merge <- merge(dlatl_v,dlnyc_v, join='inner')
colnames(dl.merge)<-c("dlatl_v","dlnyc_v")
acf(dl.merge[-c(1, 500)])
```










```
both_data_merged <- merge(nyc_violent, atl_violent, by.x='date', by.y='date', all.x = TRUE, all.
y = TRUE)

names(both_data_merged)[1] <- "Date"
both_data_merged=both_data_merged[order(as.Date(both_data_merged$Date, format="%m/%d/%Y")),]
names(both_data_merged)[2] <- "NYC Violent Crimes"
names(both_data_merged)[3] <- "ATL Violent Crimes"

n = nrow(both_data_merged)
both_data_merged.train=both_data_merged[1:(n-877),]
both_data_merged.test=both_data_merged[(n-876):n,]

ts_nyc_v=ts(both_data_merged.train[,"NYC Violent Crimes"],start=2009, freq=1)
ts_atl_v=ts(both_data_merged.train[,"ATL Violent Crimes"],start=2009, freq=1)

transts_nyc_v= sqrt(ts_nyc_v+3/8)
transts_atl_v= sqrt(ts_atl_v+3/8)

ddata.train_both=cbind(transts_nyc_v,transts_atl_v)

VARselect(ddata.train_both, lag.max = 7)$selection
```

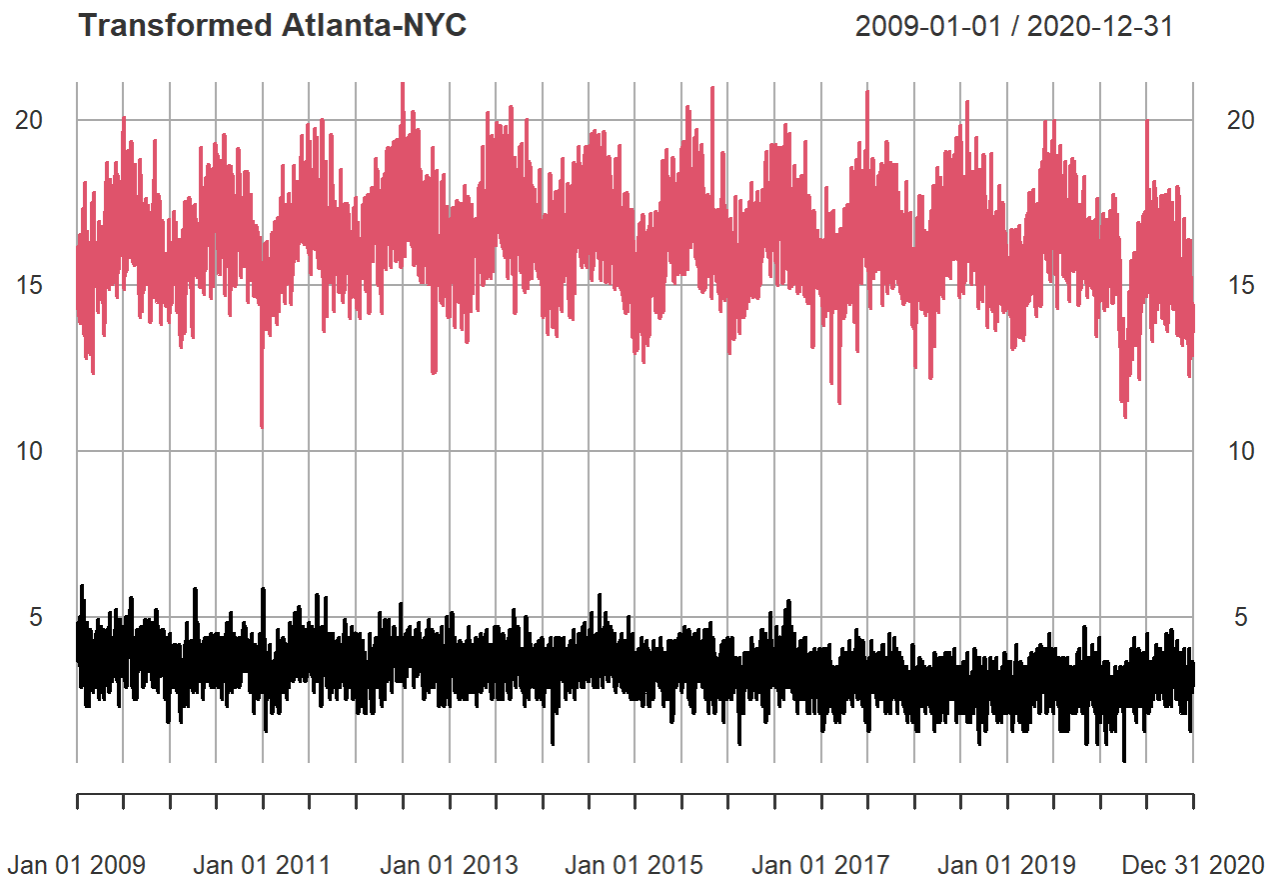
```
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      7      7      7      7
```

```
model.var=VAR(ddata.train_both, p=7)
summary(model.var)
```

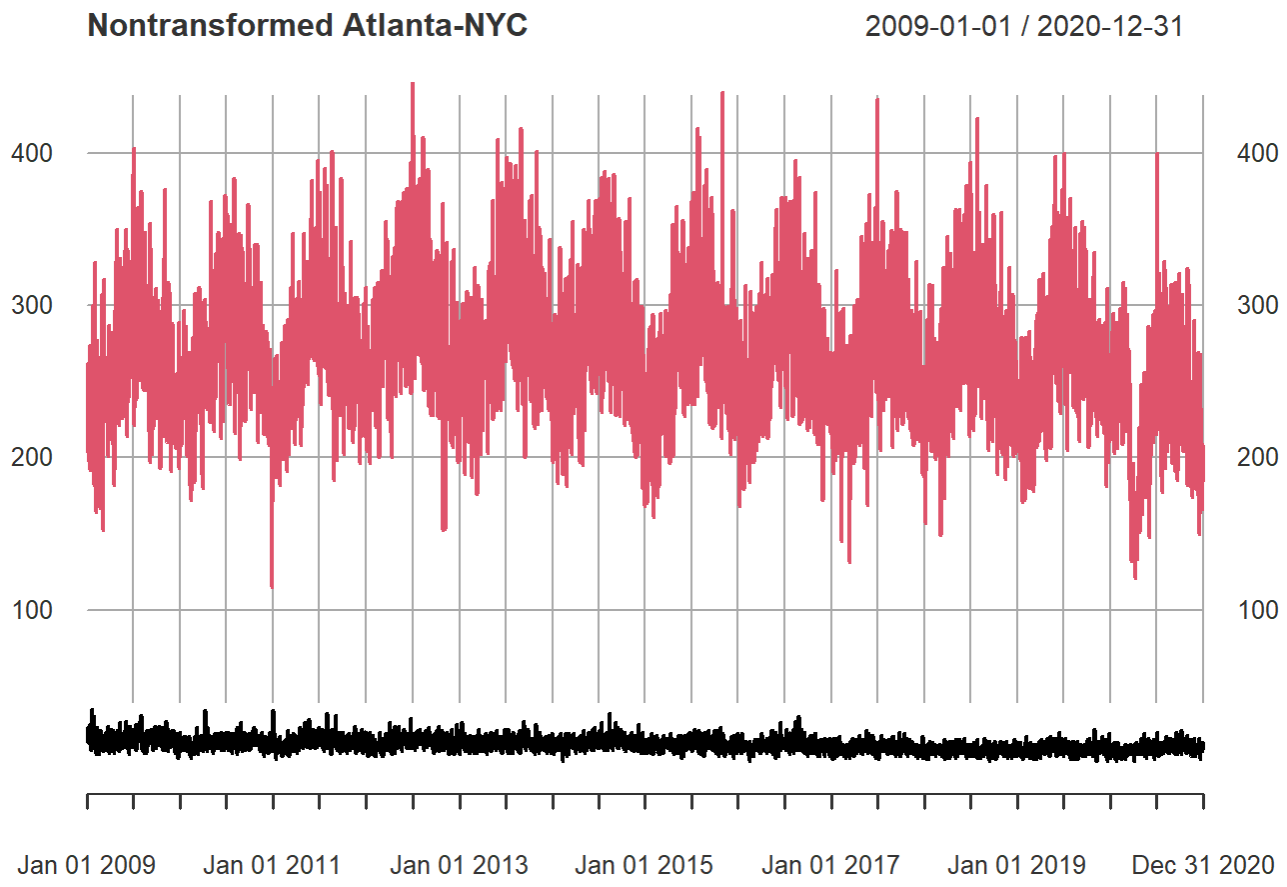
```
##
## VAR Estimation Results:
## ========================
## Endogenous variables: transts_nyc_v, transts_atl_v
## Deterministic variables: const
## Sample size: 3499
## Log Likelihood: -7757.088
## Roots of the characteristic polynomial:
## 0.9584 0.9194 0.9194 0.8774 0.837 0.837 0.7275 0.7275 0.6891 0.6891 0.6523 0.6523 0.646 0.646
## Call:
## VAR(y = ddata.train_both, p = 7)
##
##
## Estimation results for equation transts_nyc_v:
## ============================================
## transts_nyc_v = transts_nyc_v.l1 + transts_atl_v.l1 + transts_nyc_v.l2 + transts_atl_v.l2 + t
ransts_nyc_v.l3 + transts_atl_v.l3 + transts_nyc_v.l4 + transts_atl_v.l4 + transts_nyc_v.l5 + tr
ansts_atl_v.l5 + transts_nyc_v.l6 + transts_atl_v.l6 + transts_nyc_v.l7 + transts_atl_v.l7 + con
st
##
##                   Estimate Std. Error t value Pr(>|t|)
## transts_nyc_v.l1  0.392041   0.016404  23.899  < 2e-16 ***
## transts_atl_v.l1  0.100941   0.028949   3.487 0.000495 ***
## transts_nyc_v.l2 -0.072475   0.017410  -4.163 3.22e-05 ***
## transts_atl_v.l2 -0.020102   0.029025  -0.693 0.488623
## transts_nyc_v.l3  0.050370   0.017462   2.885 0.003944 **
## transts_atl_v.l3 -0.041989   0.028972  -1.449 0.147351
## transts_nyc_v.l4 -0.028467   0.017463  -1.630 0.103152
## transts_atl_v.l4 -0.006674   0.028983  -0.230 0.817906
## transts_nyc_v.l5 -0.029519   0.017441  -1.693 0.090635 .
## transts_atl_v.l5  0.078935   0.028958   2.726 0.006446 **
## transts_nyc_v.l6  0.193454   0.017429  11.099  < 2e-16 ***
## transts_atl_v.l6  0.007426   0.029025   0.256 0.798077
## transts_nyc_v.l7  0.287445   0.016403  17.524  < 2e-16 ***
## transts_atl_v.l7  0.033498   0.028964   1.157 0.247551
## const             2.853150   0.331443   8.608  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.9621 on 3484 degrees of freedom
## Multiple R-Squared: 0.4419,  Adjusted R-squared: 0.4397
## F-statistic: 197.1 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation transts_atl_v:
## ============================================
## transts_atl_v = transts_nyc_v.l1 + transts_atl_v.l1 + transts_nyc_v.l2 + transts_atl_v.l2 + t
ransts_nyc_v.l3 + transts_atl_v.l3 + transts_nyc_v.l4 + transts_atl_v.l4 + transts_nyc_v.l5 + tr
ansts_atl_v.l5 + transts_nyc_v.l6 + transts_atl_v.l6 + transts_nyc_v.l7 + transts_atl_v.l7 + con
st
##
```

```
##                   Estimate Std. Error t value Pr(>|t|)
## transts_nyc_v.l1  0.038193   0.009659   3.954 7.83e-05 ***
## transts_atl_v.l1  0.105984   0.017045   6.218 5.64e-10 ***
## transts_nyc_v.l2 -0.005654   0.010251  -0.552 0.581254
## transts_atl_v.l2  0.088705   0.017090   5.190 2.22e-07 ***
## transts_nyc_v.l3 -0.001812   0.010282  -0.176 0.860136
## transts_atl_v.l3  0.085533   0.017059   5.014 5.60e-07 ***
## transts_nyc_v.l4 -0.012695   0.010282  -1.235 0.217042
## transts_atl_v.l4  0.084378   0.017065   4.945 7.99e-07 ***
## transts_nyc_v.l5 -0.038931   0.010269  -3.791 0.000152 ***
## transts_atl_v.l5  0.106078   0.017050   6.221 5.51e-10 ***
## transts_nyc_v.l6  0.040141   0.010262   3.912 9.35e-05 ***
## transts_atl_v.l6  0.069687   0.017090   4.078 4.65e-05 ***
## transts_nyc_v.l7  0.035232   0.009658   3.648 0.000268 ***
## transts_atl_v.l7  0.081401   0.017054   4.773 1.89e-06 ***
## const             0.438560   0.195152   2.247 0.024685 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.5665 on 3484 degrees of freedom
## Multiple R-Squared: 0.1765,  Adjusted R-squared: 0.1732
## F-statistic: 53.32 on 14 and 3484 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##               transts_nyc_v transts_atl_v
## transts_nyc_v       0.92563       0.07548
## transts_atl_v       0.07548       0.32090
##
## Correlation matrix of residuals:
##               transts_nyc_v transts_atl_v
## transts_nyc_v        1.0000        0.1385
## transts_atl_v        0.1385        1.0000
```

```
###ATLANTA-NYC
transmerge.atlnyc <- merge(trans.atlv, trans.nycv, join='inner')
merge.atlnyc <- merge(xts.atlv, xts.nycv, join='inner')

plot(transmerge.atlnyc, main="Transformed Atlanta-NYC")
```




```
plot(merge.atlnyc, main="Nontransformed Atlanta-NYC")
```




```
###GRANGER - ATLANTA-NYC CHECK
library(aod)
rownames(vcov(model.var))
```

```
##  [1] "transts_nyc_v:(Intercept)"      "transts_nyc_v:transts_nyc_v.l1"
##  [3] "transts_nyc_v:transts_atl_v.l1" "transts_nyc_v:transts_nyc_v.l2"
##  [5] "transts_nyc_v:transts_atl_v.l2" "transts_nyc_v:transts_nyc_v.l3"
##  [7] "transts_nyc_v:transts_atl_v.l3" "transts_nyc_v:transts_nyc_v.l4"
##  [9] "transts_nyc_v:transts_atl_v.l4" "transts_nyc_v:transts_nyc_v.l5"
## [11] "transts_nyc_v:transts_atl_v.l5" "transts_nyc_v:transts_nyc_v.l6"
## [13] "transts_nyc_v:transts_atl_v.l6" "transts_nyc_v:transts_nyc_v.l7"
## [15] "transts_nyc_v:transts_atl_v.l7" "transts_atl_v:(Intercept)"
## [17] "transts_atl_v:transts_nyc_v.l1" "transts_atl_v:transts_atl_v.l1"
## [19] "transts_atl_v:transts_nyc_v.l2" "transts_atl_v:transts_atl_v.l2"
## [21] "transts_atl_v:transts_nyc_v.l3" "transts_atl_v:transts_atl_v.l3"
## [23] "transts_atl_v:transts_nyc_v.l4" "transts_atl_v:transts_atl_v.l4"
## [25] "transts_atl_v:transts_nyc_v.l5" "transts_atl_v:transts_atl_v.l5"
## [27] "transts_atl_v:transts_nyc_v.l6" "transts_atl_v:transts_atl_v.l6"
## [29] "transts_atl_v:transts_nyc_v.l7" "transts_atl_v:transts_atl_v.l7"
```

```
###GRANGER - DOES ATLANTA VIOLENT LEAD NYC VIOLENT
coef.nyc_v = coefficients(model.var)$transts_nyc_v[-(7*2+1),1]
var.model = vcov(model.var)[2:15,2:15]
wald.test(b=coef.nyc_v, var.model, Terms=c(2,4,6,8,10,12,14))
```

```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 27.2, df = 7, P(> X2) = 0.00031
```

```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN ATLANTA VIOLENT CRIME INFLUENCES CHANGE IN NYC VIOLENT
```

```
###GRANGER - DOES NYC VIOLENT LEAD ATLANTA VIOLENT
coef.atl_v = coefficients(model.var)$transts_atl_v[-(7*2+1),1]
var.model2 = vcov(model.var)[17:30,17:30]
wald.test(b=coef.atl_v, var.model2, Terms=c(1,3,5,7,9,11,13))
```

```
## Wald test:
## ----------
##
## Chi-squared test:
## X2 = 101.8, df = 7, P(> X2) = 0.0
```

```
###SMALL P-VALUE DO NOT REJECT NULL HYPOTHESIS
###CHANGE IN NYC VIOLENT CRIME INFLUENCES CHANGE IN ATLANTA VIOLENT CRIME
```