ENV 790.30 - Time Series Analysis for Energy Data | Spring 2021

Assignment 3 - Due date 02/15/21

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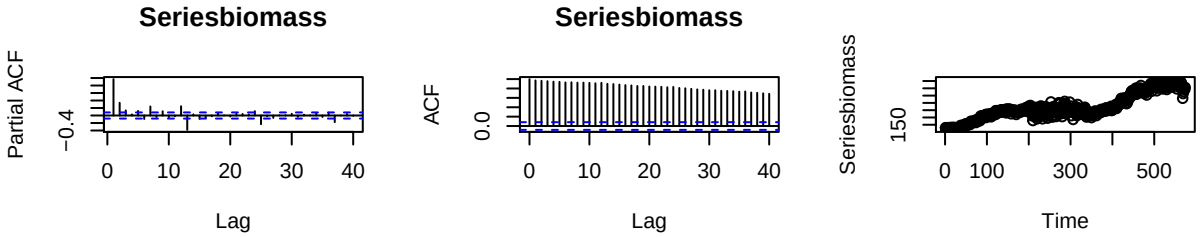
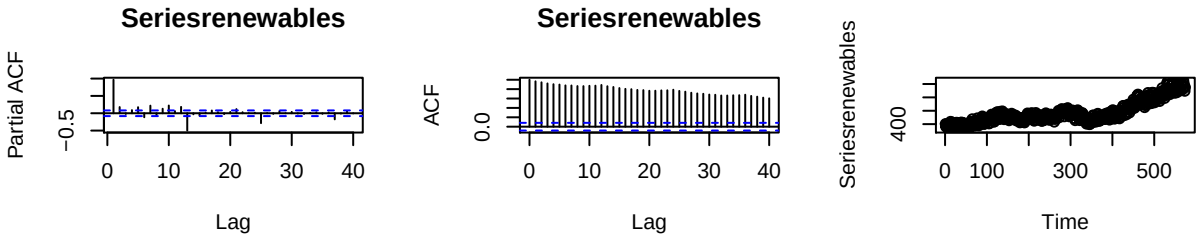
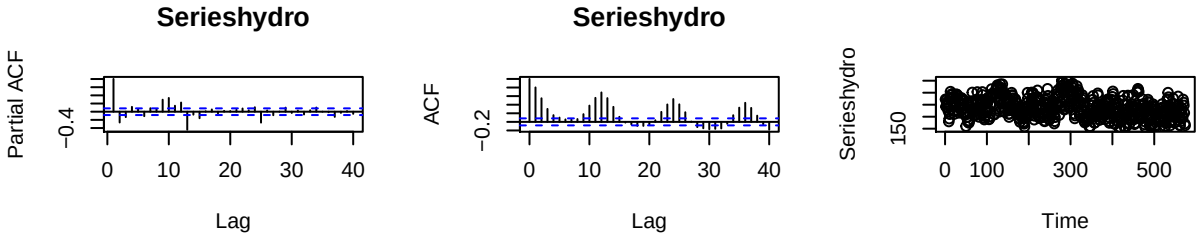
Trend Component

Q1







Q2

Total Renewable Energy Production and Total Biomass Energy Production both appear to have an increasing trend. However, Hydroelectric Power Consumption appears to have a seasonal component to it.

Q3

For biomass production, the intercept value at time 0 (1973) for the trend line is 135.5, with the value growing by a factor of .47 by each additional time period.

Renewables production also has a positive trend line, with an intercept value at time 0 of 330.37 and a positive slope of .84 (the value of production increases by a factor of .84 for each time period).

Hydroelectric Power Consumption has a trend line that crosses the intercept at 258.06 at time 0, and which has a slope of -.07–each additional year causes a slight decrease in the consumption value.

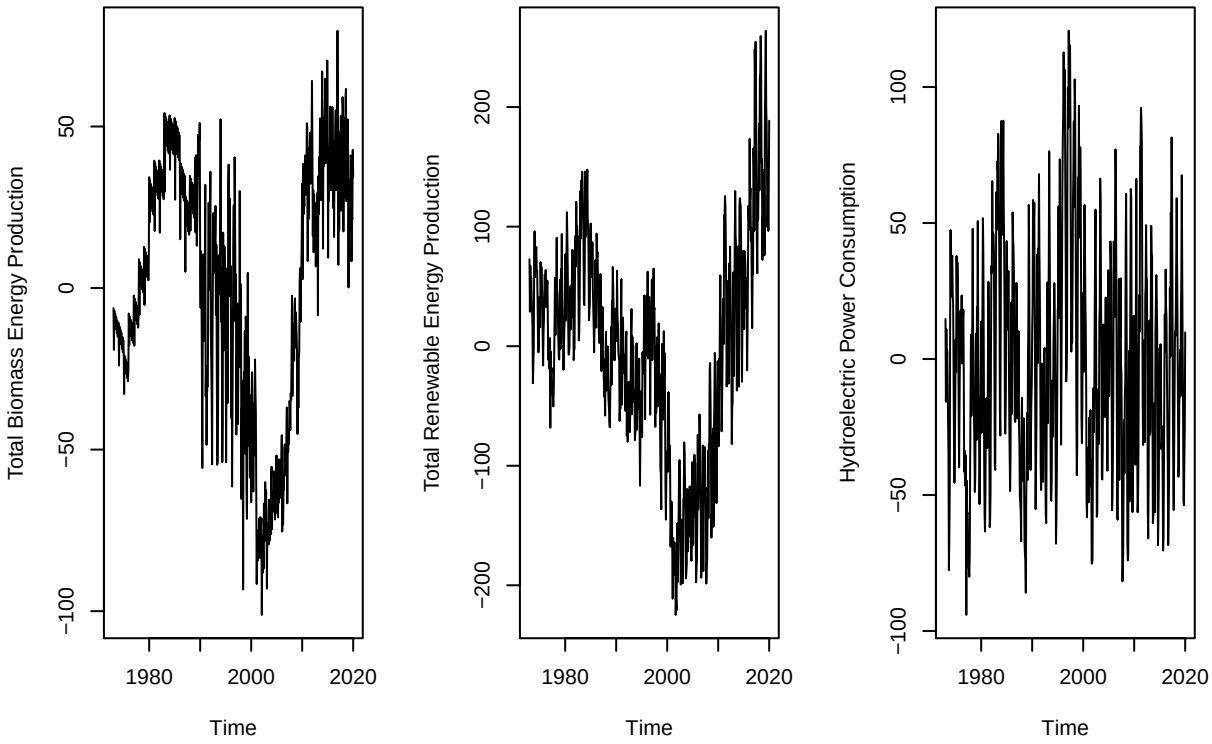
```
##
## Call:
## lm(formula = biomass ~ q)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -101.149  -25.456    4.985   33.353   79.634
##
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1.355e+02  3.296e+00   41.11   <2e-16 ***
## q           4.702e-01  9.934e-03   47.33   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 39.44 on 572 degrees of freedom
## Multiple R-squared:  0.7966, Adjusted R-squared:  0.7962
## F-statistic:  2240 on 1 and 572 DF,  p-value: < 2.2e-16
```

```
##
## Call:
## lm(formula = renewables ~ q)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -224.735  -55.673    5.418   60.453  263.849
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 330.37156    7.86270   42.02   <2e-16 ***
## q             0.84299    0.02369   35.58   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 94.07 on 572 degrees of freedom
## Multiple R-squared:  0.6887, Adjusted R-squared:  0.6882
## F-statistic:  1266 on 1 and 572 DF,  p-value: < 2.2e-16
```

```
##
## Call:
## lm(formula = hydro ~ q)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -94.06 -31.57  -1.63  27.73 120.69
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 258.05622    3.52899  73.125  < 2e-16 ***
## q            -0.07341    0.01063  -6.903 1.36e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 42.22 on 572 degrees of freedom
## Multiple R-squared:  0.07689,    Adjusted R-squared:  0.07528
## F-statistic: 47.64 on 1 and 572 DF,  p-value: 1.361e-11
```

Q4



For Total Biomass Production, the plot has become more dramatic. It has a significant decrease and increase that wasn't visible on the original plot. The original plot looked like a pretty staid and solid upward-growing trend, with a varying plateau in the middle. On this second plot, the period of fluctuations has a clear downward slope, which makes the next period increase all the more remarkable, and is shown to have a steeper slope on this plot.

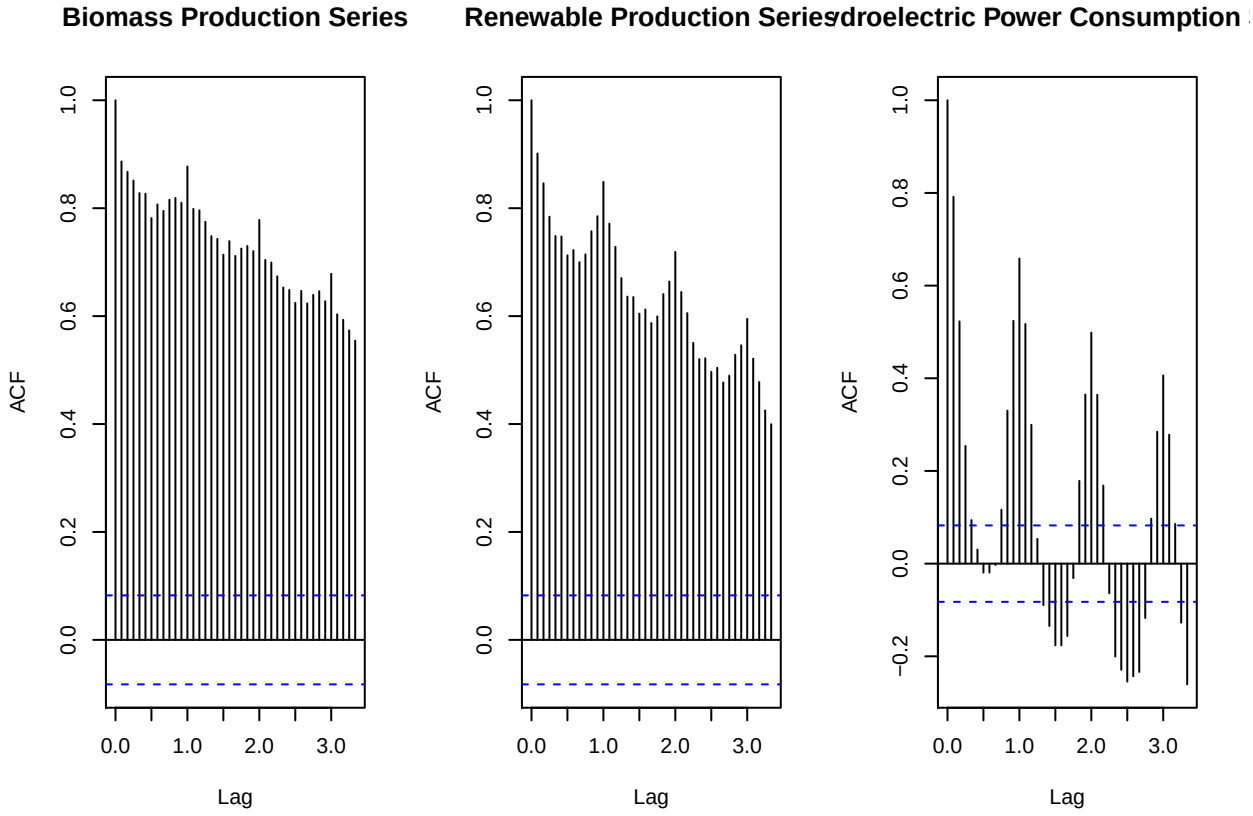
This new plot for Total Renewables shows that the initial part of the series did have a mean over time that hovered around 0, but that the second-half growth is steeper than it initially appeared. The detrended plot actually shows how the trend decreases before it increases, making the growth look even larger than it did on the initial plot.

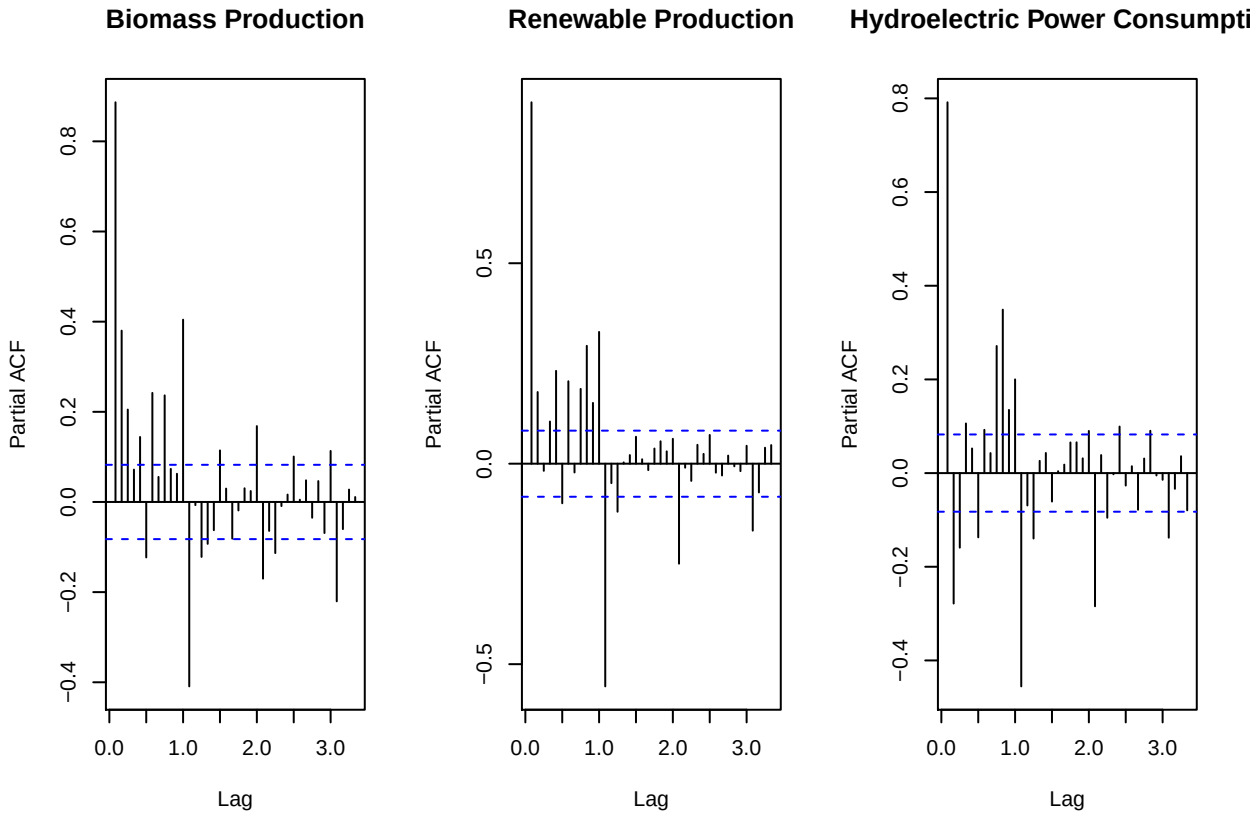
As for the Hydroelectric Consumption, these plots look almost exactly the same. This was expected though, as it did not exhibit a linear trend. This series is much more likely to show a change when accounting for seasonality.

Q5

For Biomass and Renewables, the ACF plots look a litle steeper, with some more firmly pronounced peaks and minimums as the values decrease. However, the overall pattern is the same. The ACF plot for Hydroelectric Power Consumption looks unchanged.

Most of the PACF plots look changed from the original plots.


Biomass Production Series
Renewable Production Series
ydroelectric Power Consumption
ACF
Lag
0.0
0.2
0.4
0.6
0.8
1.0
−0.2
1.0
2.0
3.0



Seasonal Component

Set aside the detrended series and consider the original series again from Q1 to answer Q6 to Q8.

Q6

The Hydroelectric Power Consumption series has a seasonal trend, but the others do not. For the seasonal means model created, there is an intercept value of 238.89 at time 0 in 1973, and each month has values that show correlation with either negative or positive growth. The dummy variable coefficients reveal how much growth or decrease in the consumption value can be attributed to the month–which range from -49.7 in September to +40.89 in May.

```
##
## Call:
## lm(formula = workingts[, 3] ~ dummies)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -92.224 -22.892  -2.692  20.673  98.109
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  238.887      4.872  49.031  < 2e-16 ***
## dummiesJan    13.270      6.854   1.936  0.05337 .
```

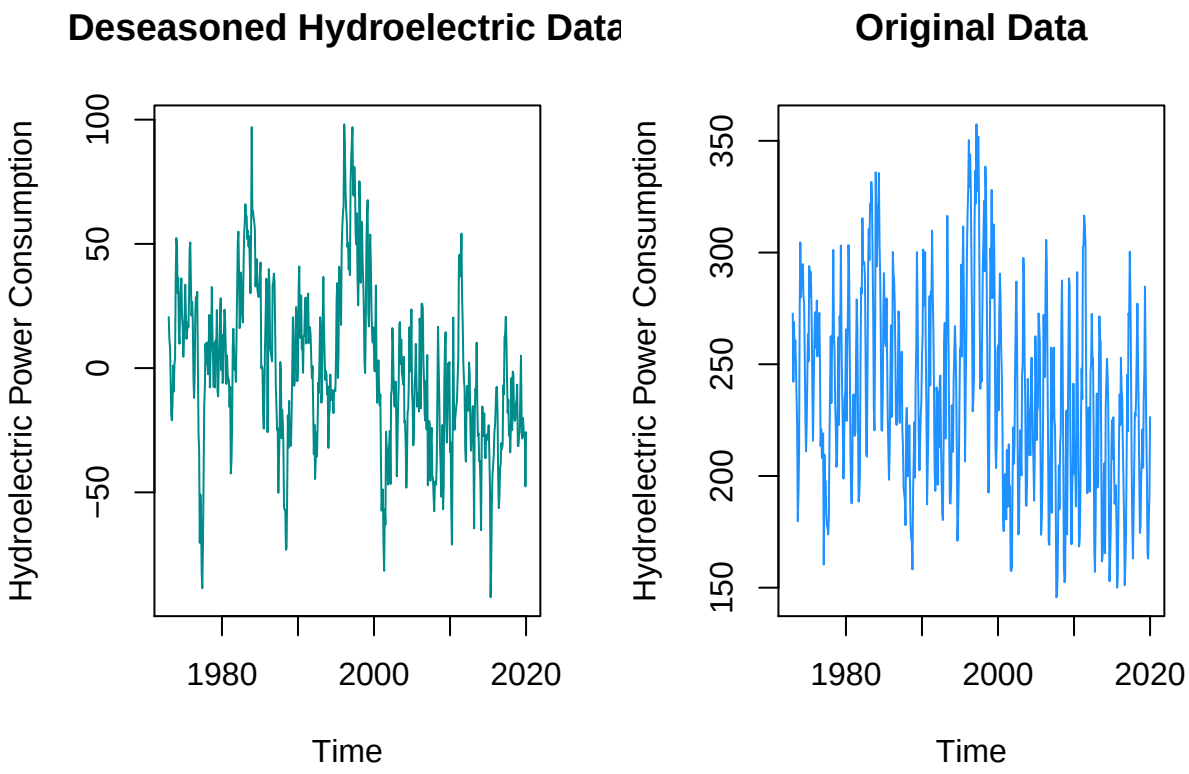
```
## dummiesFeb    -8.224      6.890  -1.194  0.23317
## dummiesMar    21.523      6.890   3.124  0.00188 **
## dummiesApr    18.488      6.890   2.683  0.00751 **
## dummiesMay    40.886      6.890   5.934 5.22e-09 ***
## dummiesJun    32.002      6.890   4.645 4.26e-06 ***
## dummiesJul    10.913      6.890   1.584  0.11379
## dummiesAug   -17.795      6.890  -2.583  0.01006 *
## dummiesSep   -49.739      6.890  -7.219 1.74e-12 ***
## dummiesOct   -48.605      6.890  -7.054 5.21e-12 ***
## dummiesNov   -32.757      6.890  -4.754 2.54e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 33.4 on 553 degrees of freedom
## Multiple R-squared:  0.4339, Adjusted R-squared:  0.4226
## F-statistic: 38.53 on 11 and 553 DF,  p-value: < 2.2e-16

##
## Call:
## lm(formula = workingts[, 1] ~ dummyb)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -153.29  -48.37  -18.09   46.52  182.84
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  280.569     12.693  22.104   <2e-16 ***
## dummybJan     -1.004     17.857  -0.056    0.955
## dummybFeb    -32.703     17.951  -1.822    0.069 .
## dummybMar    -11.626     17.951  -0.648    0.517
## dummybApr    -22.028     17.951  -1.227    0.220
## dummybMay    -16.169     17.951  -0.901    0.368
## dummybJun    -22.041     17.951  -1.228    0.220
## dummybJul     -6.066     17.951  -0.338    0.736
## dummybAug     -2.378     17.951  -0.132    0.895
## dummybSep    -14.600     17.951  -0.813    0.416
## dummybOct     -3.221     17.951  -0.179    0.858
## dummybNov     -9.375     17.951  -0.522    0.602
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 87.02 on 553 degrees of freedom
## Multiple R-squared:  0.01255,    Adjusted R-squared:  -0.007088
## F-statistic: 0.6391 on 11 and 553 DF,  p-value: 0.7956

##
## Call:
## lm(formula = workingts[, 2] ~ dummyr)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -254.41  -98.23  -48.57   33.84  455.14
##
```

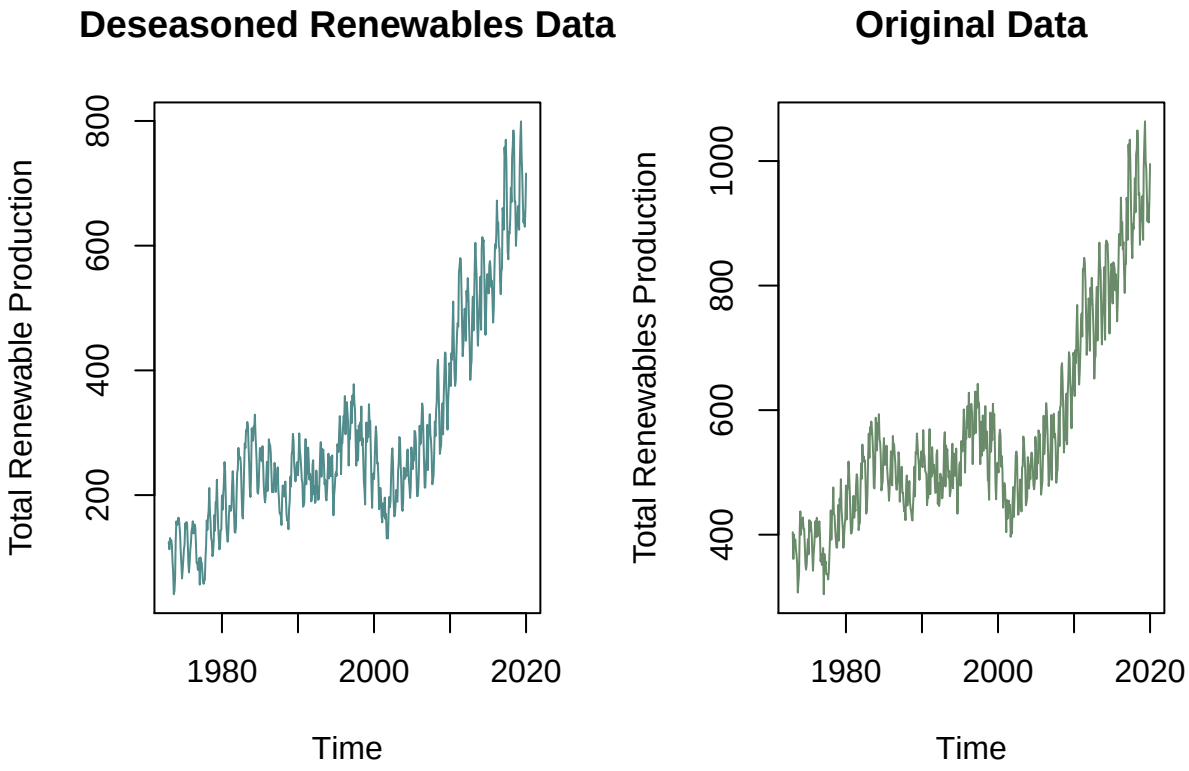
```
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 580.912468  23.379863  24.847   <2e-16 ***
## dummyrJan    12.451386  32.891460   0.379   0.7052
## dummyrFeb   -48.614830  33.064120  -1.470   0.1420
## dummyrMar    12.148872  33.064120   0.367   0.7134
## dummyrApr     1.290170  33.064120   0.039   0.9689
## dummyrMay    27.713191  33.064120   0.838   0.4023
## dummyrJun     9.983596  33.064120   0.302   0.7628
## dummyrJul    -0.001426  33.064120   0.000   1.0000
## dummyrAug   -27.061638  33.064120  -0.818   0.4134
## dummyrSep   -70.419851  33.064120  -2.130   0.0336 *
## dummyrOct   -51.409170  33.064120  -1.555   0.1206
## dummyrNov   -42.516404  33.064120  -1.286   0.1990
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 160.3 on 553 degrees of freedom
## Multiple R-squared:  0.03542,    Adjusted R-squared:  0.01623
## F-statistic: 1.846 on 11 and 553 DF,  p-value: 0.04396
```

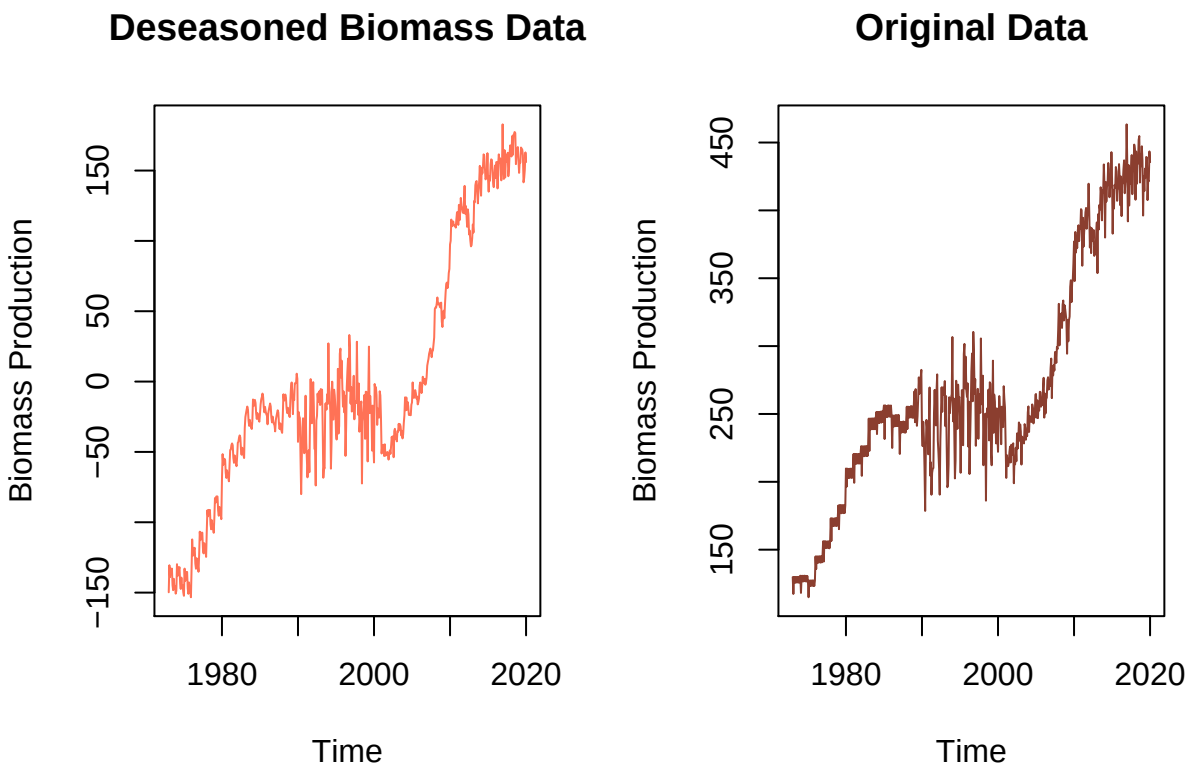
Q7

For Hydroelectric Consumption, the plot looks a lot clearer–it's much easier to pick out trends of increase and decrease. There seems to be much less noise to the plot.

For Biomass and Renewables, the plots did not change at all.

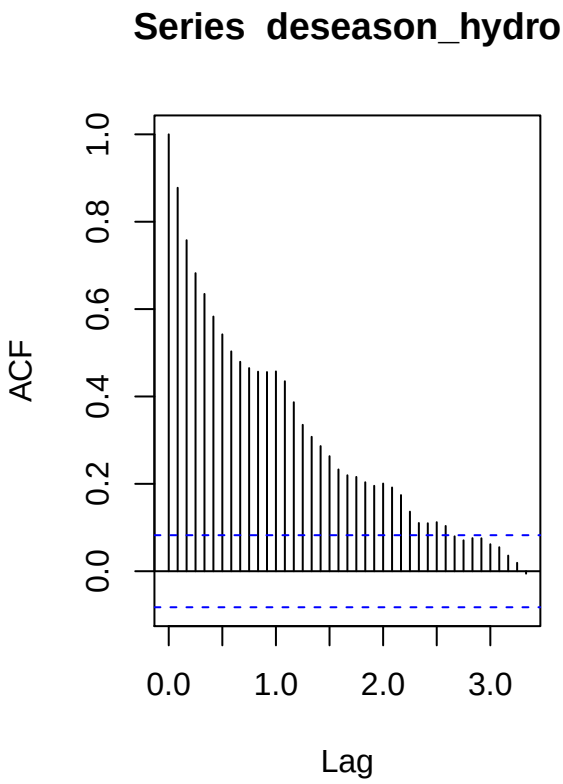

Deseasoned Hydroelectric Data
Hydroelectric Power Consumption
100
50
0
−50
1980
2000
2020
Time
Original Data
Hydroelectric Power Consumption
350
300
250
200
150
1980
2000
2020
Time

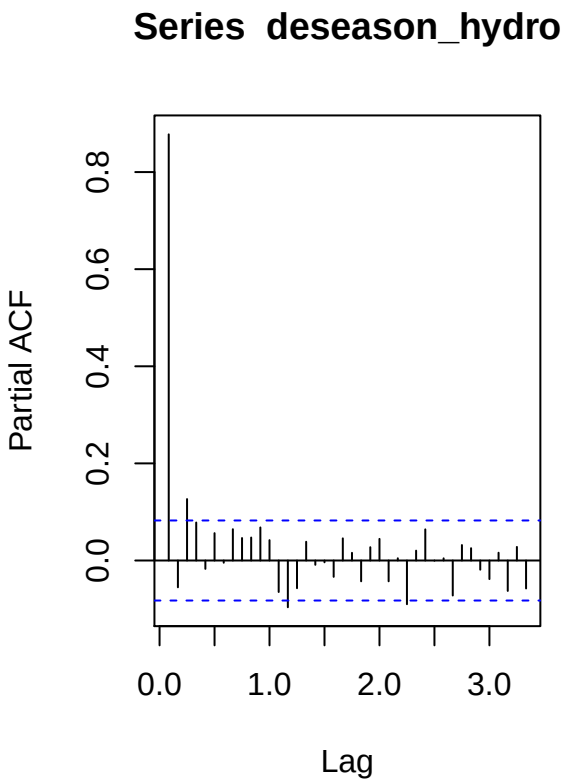

Deseasoned Renewables Data
Total Renewable Production
200
400
600
800
1980
2000
2020
Time
Original Data
Total Renewables Production
400
600
800
1000
1980
2000
2020
Time

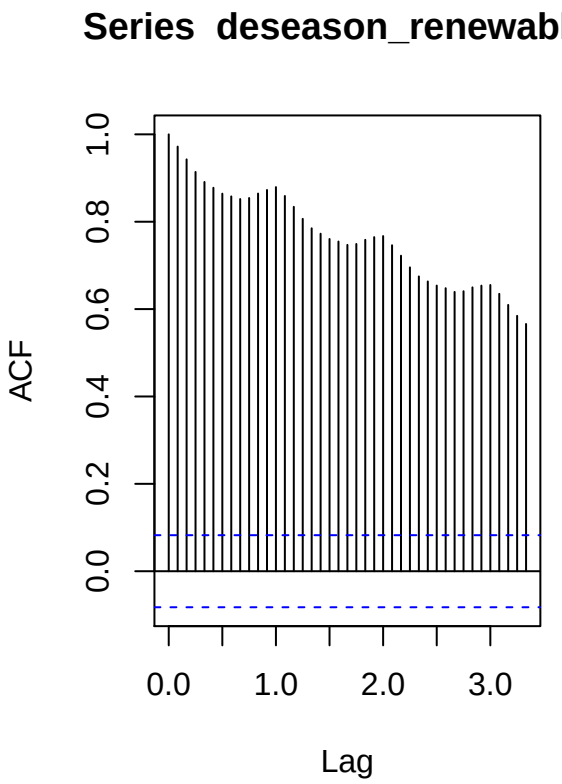


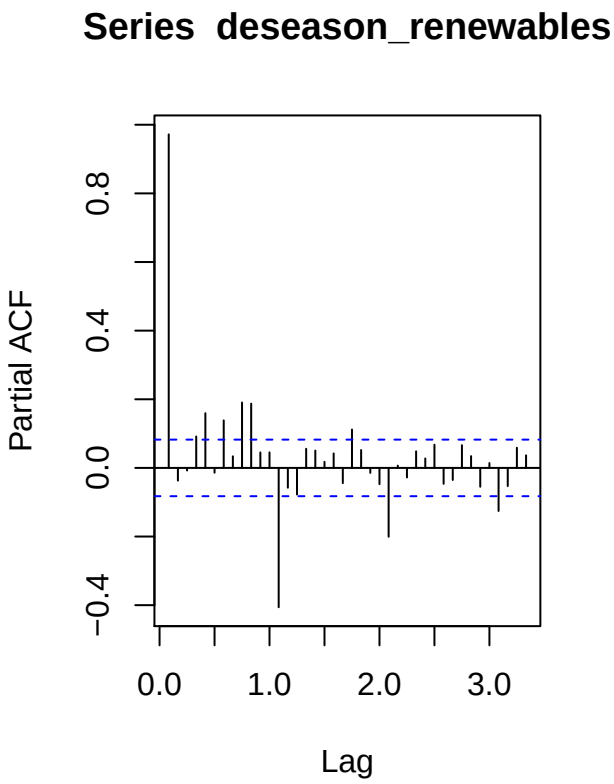
Q8

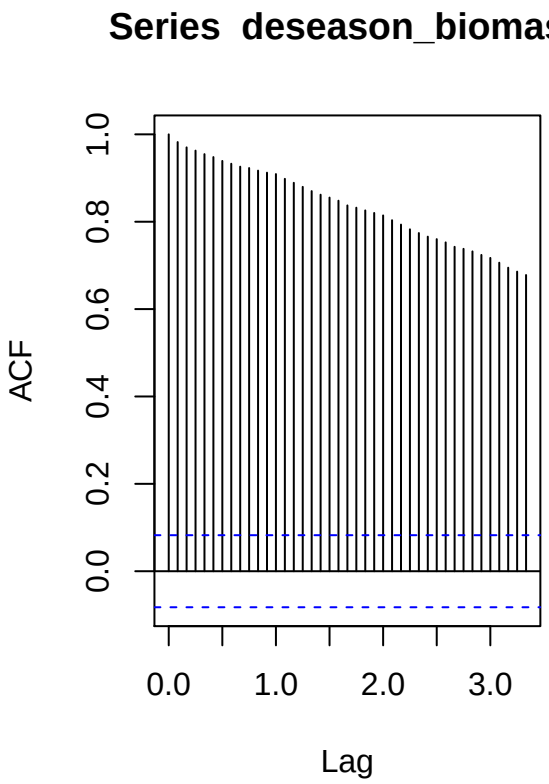
For biomass and renewables, the ACF & PACF for the deseasoned series did not change at all. The hydro plots though changed dramatically. The ACF is no longer swinging wildly, and looks like the other plots that didn't have seasonality in them. It's now just a steadily declining plot as the lag decreases. The PACF also has a lot less variation between the values, and has a much more consistent pattern. The values also seem to be lower overall.

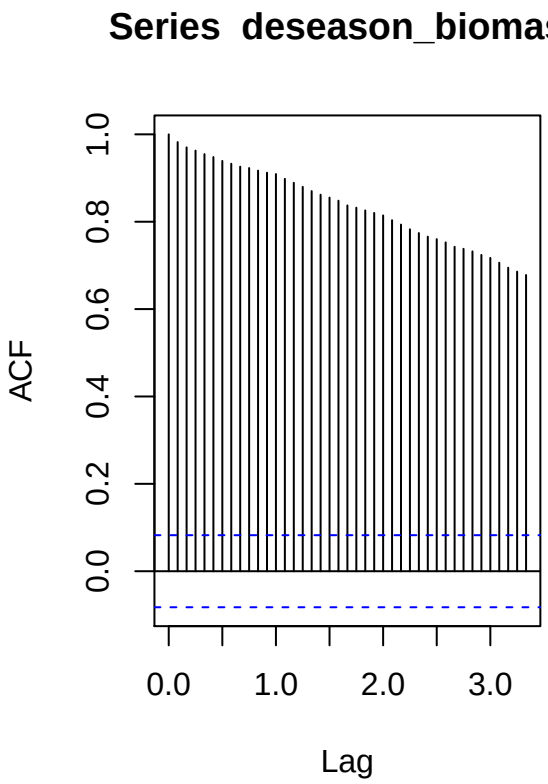

Series deseason_hydro
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
Lag


Series deseason_hydro
Partial ACF
0.0
0.2
0.4
0.6
0.8
0.0
1.0
2.0
3.0
Lag


Series deseason_renewables
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
Lag


Series deseason_renewables
Partial ACF
−0.4
0.0
0.4
0.8
0.0
1.0
2.0
3.0
Lag


Series deseason_biomass
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
Lag


Series deseason_biomass
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
Lag