ENV 790.30 - Time Series Analysis for Energy Data | Spring 2025

Assignment 3 - Due date 02/03/26

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Directions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github.

Once you have the file open on your local machine the first thing you will do is rename the file such that it includes your first and last name (e.g., "LuanaLima_TSA_A03_Sp25.Rmd"). Then change "Student Name" on line 4 with your name.

Then you will start working through the assignment by **creating code and output** that answer each question. Be sure to use this assignment document. Your report should contain the answer to each question and any plots/tables you obtained (when applicable).

Please keep this R code chunk options for the report. It is easier for us to grade when we can see code and output together. And the tidy.opts will make sure that line breaks on your code chunks are automatically added for better visualization.

When you have completed the assignment, **Knit** the text and code into a single PDF file. Submit this pdf using Sakai.

Questions

Consider the same data you used for A2 from the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumpt The data comes from the US Energy Information and Administration and corresponds to the December 2025 Monthly Energy Review. This time you will work only with the following columns: **Total Renewable Energy Production**; and **Hydroelectric Power Consumption**.

Create a data frame structure with these two time series only.

R packages needed for this assignment:"forecast","tseries", and "Kendall". Install these packages, if you haven't done yet. Do not forget to load them before running your script, since they are NOT default packages.\

```
library(readxl)
library(openxlsx)
library(forecast)
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```
library(tseries)
library(Kendall)
library(cowplot)
library(gridGraphics)
```

```
## Loading required package: grid
```

```
library(ggplot2)
```

##Trend Component

Q1

For each series (Total Renewable Production and Hydroelectric Consumption) create three plots arranged in a row (side-by-side): (1) time series plot, (2) ACF, (3) PACF. Use cowplot::plot_grid() to place them in a grid.

```
energy_data <- read_excel(
  path = "../Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.xlsx",
  sheet = "Monthly Data",
  skip = 12,
  col_names = FALSE
)
```

```
## New names:
## * `` -> `...1`
## * `` -> `...2`
## * `` -> `...3`
## * `` -> `...4`
## * `` -> `...5`
## * `` -> `...6`
## * `` -> `...7`
## * `` -> `...8`
## * `` -> `...9`
## * `` -> `...10`
## * `` -> `...11`
## * `` -> `...12`
## * `` -> `...13`
## * `` -> `...14`
```

```
col_line <- read_excel(
  path = "../Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.xlsx",
  sheet = "Monthly Data",
  skip = 10,
  n_max = 1,
  col_names = FALSE
)
```

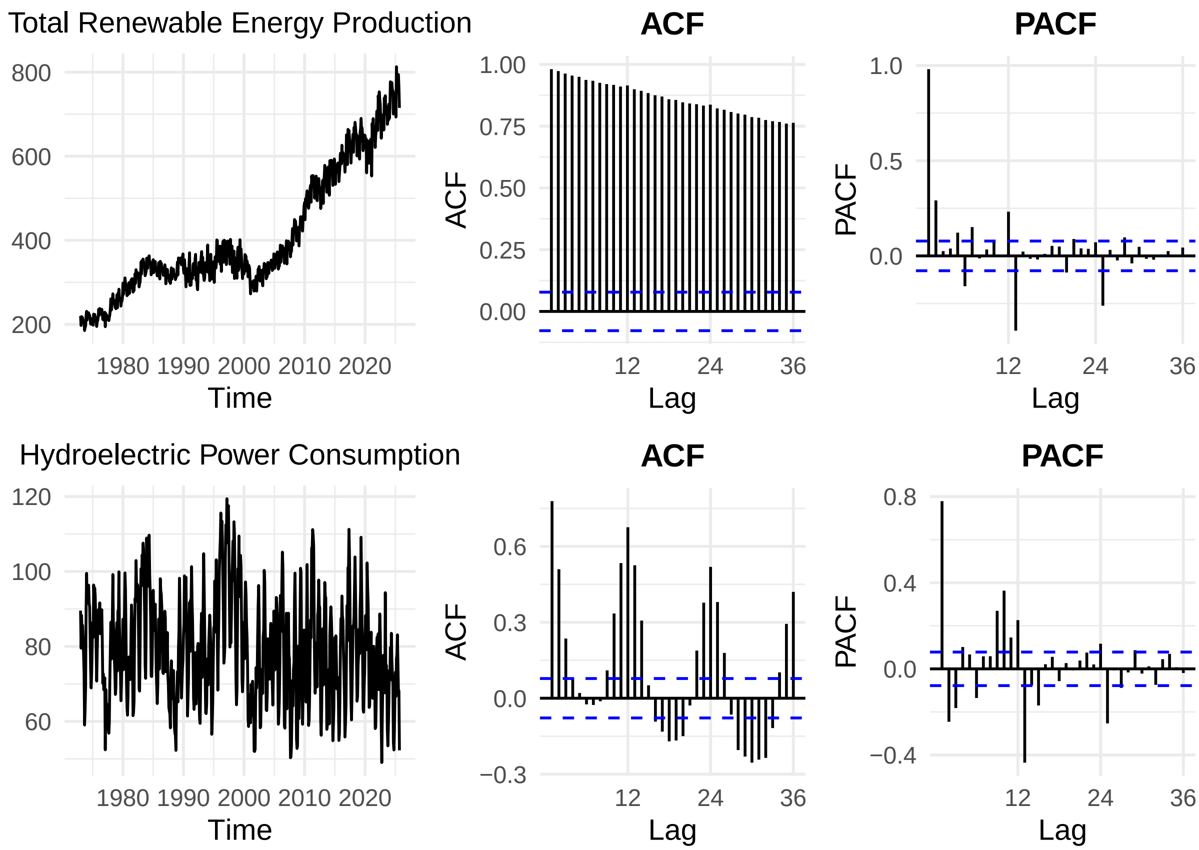
```
## New names:
## * `` -> `...1`
## * `` -> `...2`
## * `` -> `...3`
## * `` -> `...4`
## * `` -> `...5`
## * `` -> `...6`
## * `` -> `...7`
```

```
## * `` -> `...8`
## * `` -> `...9`
## * `` -> `...10`
## * `` -> `...11`
## * `` -> `...12`
## * `` -> `...13`
## * `` -> `...14`
```

```r
colnames(energy_data) <- as.character(col_line[1, ])

two_series_df <- energy_data[, c(
  "Total Renewable Energy Production",
  "Hydroelectric Power Consumption"
)]
two_series_df <- as.data.frame(two_series_df)

start_year <- 1973
start_month <- 1

trp_ts <- ts(as.numeric(two_series_df[["Total Renewable Energy Production"]]),
             start = c(start_year, start_month), frequency = 12)

hyd_ts <- ts(as.numeric(two_series_df[["Hydroelectric Power Consumption"]]),
             start = c(start_year, start_month), frequency = 12)
```

```r
plot_three_clean <- function(x_ts, series_name, lag_max = 36) {
  p_ts <- autoplot(x_ts) +
    labs(title = series_name,
         x = "Time", y = "") +
    theme_minimal(base_size = 11) +
    theme(
      plot.title = element_text(
        hjust = 0.5,
        size = 11,
        face = "plain"
      )
    )

  p_acf <- ggAcf(x_ts, lag.max = lag_max) +
    labs(title = "ACF") +
    theme_minimal(base_size = 11) +
    theme(
      plot.title = element_text(
        hjust = 0.5,
        size = 12,
        face = "bold"
      )
    )

  p_pacf <- ggPacf(x_ts, lag.max = lag_max) +
    labs(title = "PACF") +
    theme_minimal(base_size = 11) +
    theme(
      plot.title = element_text(
```

```
        hjust = 0.5,
        size = 12,
        face = "bold"
      )
    )

  cowplot::plot_grid(p_ts, p_acf, p_pacf, nrow = 1, rel_widths = c(1.2, 1, 1))
}

row_trp <- plot_three_clean(
  trp_ts,
  "Total Renewable Energy Production"
)

row_hyd <- plot_three_clean(
  hyd_ts,
  "Hydroelectric Power Consumption"
)
print(cowplot::plot_grid(row_trp, row_hyd, ncol = 1))
```



Q2

From the plot in Q1, do the series Total Renewable Energy Production and Hydroelectric Power Consumption appear to have a trend? If yes, what kind of trend?

Total Renewable Energy Production shows a clear upward trend over time, which indicates strong long-term growth. Because in the ACF plot, autocorrelations remain high and decay slowly across many lags. In contrast, Hydroelectric Power Consumption does not exhibit a clear long-term trend. The series fluctuates around a relatively stable level over time. Its ACF shows significant correlations at specific lags, which suggests seasonal or cyclical behavior rather than a sustained upward or downward trend.

Q3

Use the *lm()* function to fit a linear trend to the two time series. Ask R to print the summary of the regression. Interpret the regression output, i.e., slope and intercept. Save the regression coefficients for further analysis.

```
nobs <- nrow(two_series_df)

t <- 1:nobs

linear_trp <- lm(two_series_df$`Total Renewable Energy Production` ~ t)
summary(linear_trp)
```

```
##
## Call:
## lm(formula = two_series_df$`Total Renewable Energy Production` ~
##     t)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -154.81  -39.55   12.52   41.49  171.15
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 171.44868    5.11085   33.55   <2e-16 ***
## t             0.74999    0.01397   53.69   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 64.22 on 631 degrees of freedom
## Multiple R-squared:  0.8204, Adjusted R-squared:  0.8201
## F-statistic:  2883 on 1 and 631 DF,  p-value: < 2.2e-16
```

```
trp_beta0 <- as.numeric(linear_trp$coefficients[1])
trp_beta1 <- as.numeric(linear_trp$coefficients[2])

linear_hyd <- lm(two_series_df$`Hydroelectric Power Consumption` ~ t)
summary(linear_hyd)
```

```
##
## Call:
## lm(formula = two_series_df$`Hydroelectric Power Consumption` ~
##     t)
##
## Residuals:
```

```
##      Min      1Q  Median      3Q     Max 
## -30.190 -10.214  -0.715   8.909  39.723 
## 
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 83.223802   1.110552  74.939  < 2e-16 ***
## t           -0.012199   0.003035  -4.019 6.55e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 13.95 on 631 degrees of freedom
## Multiple R-squared:  0.02496,    Adjusted R-squared:  0.02342 
## F-statistic: 16.15 on 1 and 631 DF,  p-value: 6.547e-05
```

```r
hyd_beta0 <- as.numeric(linear_hyd$coefficients[1])
hyd_beta1 <- as.numeric(linear_hyd$coefficients[2])

coef_list <- list(
  trp = c(beta0 = trp_beta0, beta1 = trp_beta1),
  hyd = c(beta0 = hyd_beta0, beta1 = hyd_beta1)
)
coef_list
```

```
## $trp
##      beta0      beta1 
## 171.448682   0.749989 
## 
## $hyd
##       beta0       beta1 
## 83.22380232 -0.01219868
```

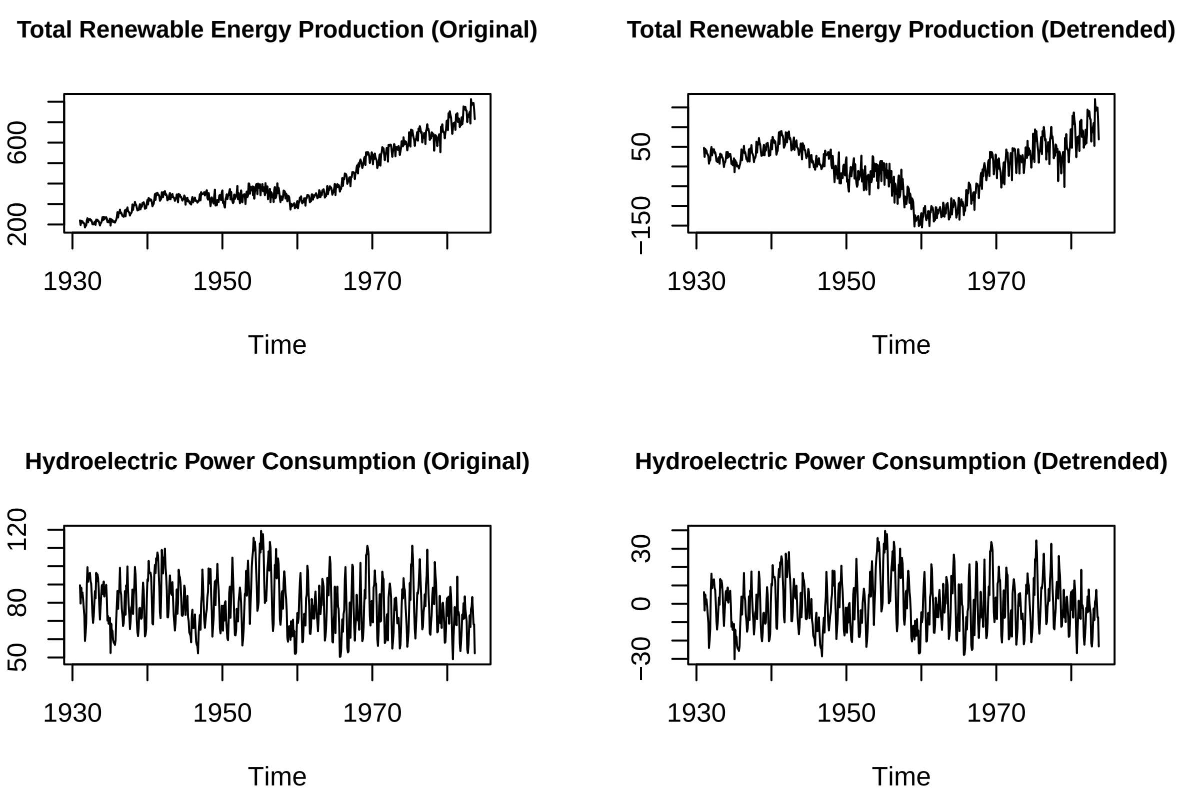
For Total Renewable Energy Production, the intercept (171.45) represents the baseline production level at the start of the sample period. The slope is about 0.75, which means that total renewable energy production increases by roughly 0.75 units per month on average. This shows a clear upward trend over time. For Hydroelectric Power Consumption, the intercept (83.22) represents the baseline level of consumption at the beginning of the sample. The slope is about -0.012, meaning that hydroelectric power consumption decreases slightly by around 0.012 units per month. The decrease is small, but it is consistent over time.

Q4

Use the regression coefficients to detrend each series (subtract fitted linear trend). Plot detrended series and compare with the original time series from Q1. Describe what changed.

```r
fitted_trp <- coef_list$trp["beta0"] + coef_list$trp["beta1"] * t
fitted_hyd <- coef_list$hyd["beta0"] + coef_list$hyd["beta1"] * t

detrend_trp <- two_series_df$`Total Renewable Energy Production` - fitted_trp
detrend_hyd <- two_series_df$`Hydroelectric Power Consumption` - fitted_hyd

ts_trp_det <- ts(detrend_trp, start = c(1931, 1), frequency = 12)
ts_hyd_det <- ts(detrend_hyd, start = c(1931, 1), frequency = 12)
```

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

plot(ts(two_series_df$`Total Renewable Energy Production`,
        start = c(1931, 1), frequency = 12),
     main = "Total Renewable Energy Production (Original)",
     ylab = "", xlab = "Time",
     cex.main = 0.9)

plot(ts_trp_det,
     main = "Total Renewable Energy Production (Detrended)",
     ylab = "", xlab = "Time",
     cex.main = 0.9)

plot(ts(two_series_df$`Hydroelectric Power Consumption`,
        start = c(1931, 1), frequency = 12),
     main = "Hydroelectric Power Consumption (Original)",
     ylab = "", xlab = "Time",
     cex.main = 0.9)

plot(ts_hyd_det,
     main = "Hydroelectric Power Consumption (Detrended)",
     ylab = "", xlab = "Time",
     cex.main = 0.9)
```



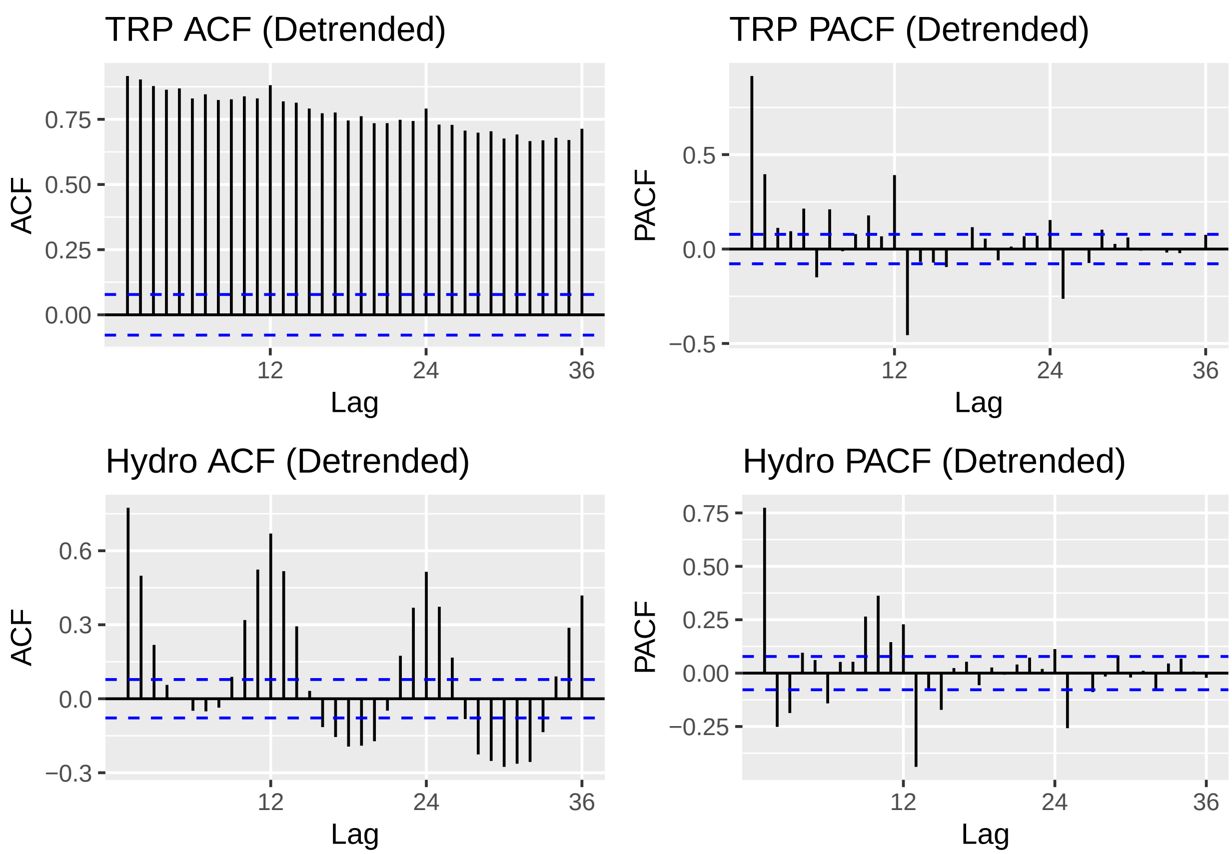
After detrending, the long-term linear trend is removed from both series. For Total Renewable

Energy Production, the strong upward growth visible in the original series disappears, and the detrended series fluctuates around zero. For Hydroelectric Power Consumption, the original series already shows no strong trend, so detrending mainly recenters the data around zero while preserving its variability and seasonal patterns.

Q5

Plot ACF and PACF for the detrended series and compare with the plots from Q1. You may use plot_grid() again to get them side by side to make it easier to compare. Did the plots change? How?

```
p1 <- ggAcf(ts_trp_det, lag.max = 36) + ggtitle("TRP ACF (Detrended)")
p2 <- ggPacf(ts_trp_det, lag.max = 36) + ggtitle("TRP PACF (Detrended)")
p3 <- ggAcf(ts_hyd_det, lag.max = 36) + ggtitle("Hydro ACF (Detrended)")
p4 <- ggPacf(ts_hyd_det, lag.max = 36) + ggtitle("Hydro PACF (Detrended)")

plot_grid(p1, p2, p3, p4, ncol = 2)
```



Seasonal Component

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

Q6

Just by looking at the time series and the acf plots, do the series seem to have a seasonal trend? No need to run any code to answer your question. Just type in you answer below.

> Answer:

Q7

Use function *lm()* to fit a seasonal means model (i.e. using the seasonal dummies) to the two time series. Ask R to print the summary of the regression. Interpret the regression output. From the results, which series have a seasonal trend? Do the results match you answer to Q6?

Q8

Use the regression coefficients from Q7 to deseason the series. Plot the deseason series and compare with the plots from part Q1. Did anything change?

Q9

Plot ACF and PACF for the deseason series and compare with the plots from Q1. You may use plot_grid() again to get them side by side. Did the plots change? How?