itle: "ENV 790.30 - Time Series Analysis for Energy Data | Spring 2023"
ubtitle: "Assignment 4 - Due date 02/17/23"
uthor: "Zhengqi Jiao"
utput: pdf_document
eometry: margin=2.54cm
ditor_options:
chunk_output_type: console

Directions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github. And to do so you will need to fork our repository and link it to your RStudio.

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_A04_Sp23.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).

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

R packages needed for this assignment: "xlsx" or "readxl", "ggplot2", "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.\

```r
#Load/install required package here
library(readxl)
library(ggplot2)
library(forecast)
```

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

```r
library(Kendall)
library(tseries)
library(dplyr)
```

```
##
## 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
```

```r
library(knitr)
library(tidyr)
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2
## --
```

1

```
## v tibble  3.1.8      v stringr 1.5.0
## v readr   2.1.4      v forcats 1.0.0
## v purrr   1.0.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
library(magrittr)
```

```
##
## Attaching package: 'magrittr'
##
## The following object is masked from 'package:purrr':
##
##     set_names
##
## The following object is masked from 'package:tidyr':
##
##     extract
library(lubridate)
```

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

Questions

Consider the same data you used for A3 from the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumption".
The data comes from the US Energy Information and Administration and corresponds to the December 2022
Monthly Energy Review. For this assignment you will work only with the column "Total Renewable Energy
Production".

```
#Importing data set - using xlsx package
energy_data <- read.csv(file="/Users/christine/Documents/TimeSeriesAnalysis/TimeSeriesAnalysis_Jiao/Data
```

```
renewable_data <- energy_data[,c("Month","Total.Renewable.Energy.Production")]
head(renewable_data)
```

```
##           Month Total.Renewable.Energy.Production
## 1   1973 January                            403.981
## 2 1973 February                            360.900
## 3    1973 March                            400.161
## 4    1973 April                            380.470
## 5      1973 May                            392.141
## 6     1973 June                            377.232
```

```
ts_energy_data1 <- ts(renewable_data,frequency=12,start=c(1973,1))
head(ts_energy_data1,20)
```

```
##          Month Total.Renewable.Energy.Production
## Jan 1973     5                            403.981
## Feb 1973     4                            360.900
## Mar 1973     8                            400.161
```

```
## Apr 1973     1                        380.470
## May 1973     9                        392.141
## Jun 1973     7                        377.232
## Jul 1973     6                        367.325
## Aug 1973     2                        353.757
## Sep 1973    12                        307.006
## Oct 1973    11                        323.453
## Nov 1973    10                        337.817
## Dec 1973     3                        406.694
## Jan 1974    17                        437.467
## Feb 1974    16                        399.942
## Mar 1974    20                        423.474
## Apr 1974    13                        422.323
## May 1974    21                        427.657
## Jun 1974    19                        409.281
## Jul 1974    18                        409.719
## Aug 1974    14                        386.101
```

```
ed <- energy_data %>%
    separate(Month, c('year', 'month'))


my_date <- paste(ed[,2],ed[,1],sep="-")
my_date <- my(my_date)
```

Stochastic Trend and Stationarity Tests

Q1

Difference the "Total Renewable Energy Production" series using function diff(). Function diff() is from package base and take three main arguments: * *x* vector containing values to be differenced; * *lag* integer indicating with lag to use; * *differences* integer indicating how many times series should be differenced.

Try differencing at lag 1 only once, i.e., make `lag=1` and `differences=1`. Plot the differenced series Do the series still seem to have trend?

```
Difference_energy_data1 <- diff(x=renewable_data$Total.Renewable.Energy.Production,lag = 1, differences
Difference_energy_data1
```

```
##   [1] -43.081   39.261  -19.691   11.671  -14.909   -9.907  -13.568  -46.751
##   [9]  16.447   14.364   68.877   30.773  -37.525   23.532   -1.151    5.334
##  [17] -18.376    0.438  -23.618  -32.191  -10.207    7.930   25.009   16.114
##  [25] -24.478   55.212  -18.122   15.915   -9.661  -13.163  -30.229  -26.273
##  [33]  26.829   14.410   20.500   18.079  -25.602   30.871  -30.113   18.797
##  [41]  -4.173    9.870  -23.296  -41.145   12.202  -17.800    9.448   17.687
##  [49] -74.193   64.638  -17.665    5.622  -20.438    0.418   -1.022   -7.806
##  [57]  13.293   28.800   29.880   38.935  -47.117   41.593    0.920   41.504
##  [65] -43.255   -1.167  -23.044  -16.130  -12.851   -0.358   28.486   40.232
##  [73] -57.309   67.312  -11.867   43.148  -47.397  -17.170  -15.303  -30.307
##  [81]  18.699   17.138   10.369   53.834  -54.645   44.836    8.222   40.100
##  [89] -19.688  -26.437  -41.973  -27.646    0.852    7.312   38.670   13.835
##  [97] -35.338   16.765   -5.788   42.403   16.572   -5.691  -37.276  -46.808
## [105]   9.746    1.510   58.548   37.416  -24.816   55.100  -27.596    8.667
## [113]  -6.821    0.293  -36.064  -49.455    6.126   30.056   53.000   39.349
## [121] -39.003   49.577  -11.395   20.283  -12.248  -18.500  -22.705  -52.115
## [129]  -1.922   32.784   80.738  -17.692  -34.842   43.801  -13.021   27.485
## [137] -40.183   -5.703  -23.565  -53.143    8.710    6.490   46.237   22.858
```

```
## [145]  -43.367   13.164  -12.065   30.031  -35.638  -17.753  -13.665  -21.638
## [153]   21.132   24.200   34.354  -47.896   -6.942   79.416  -18.641    5.175
## [161]  -17.660  -14.120  -30.445  -10.733    9.999   10.208   40.025  -11.081
## [169]  -68.387   45.904  -21.126   31.376  -42.159    0.818  -18.705  -11.785
## [177]    5.454  -19.447   52.372   19.552  -48.469   22.435  -13.105   30.219
## [185]  -32.321  -11.289   -5.388  -10.902   -3.710   26.301   23.229   37.016
## [193]  -47.712   71.281   -2.618   32.603  -16.564  -21.039  -11.943  -25.205
## [201]   23.110   10.265   12.516  -22.569   -2.911   59.574  -37.504   -4.757
## [209]  -22.311   -3.867   -2.040  -50.106   12.850   -0.634   69.361   40.550
## [217] -104.360   53.992  -26.196   47.677  -26.951  -14.103   12.694  -20.507
## [225]  -24.587    0.607   60.838    7.025  -86.412   33.590  -36.829    9.284
## [233]   42.643  -10.904    4.464  -33.179   14.417   25.951   47.282   18.731
## [241]  -87.307   65.977  -15.836    9.626  -30.415  -15.003   10.606  -40.591
## [249]    7.060   13.389   36.617   27.288  -71.457   55.895  -14.667  -21.277
## [257]    2.884   40.866  -53.964  -50.709   42.676    6.629   29.781    3.794
## [265]  -37.883   71.786  -13.881   -2.905   26.525   41.131  -18.994  -82.790
## [273]   59.003   -4.209   31.356   21.008  -35.348   56.622  -71.856   38.837
## [281]   12.712    2.479  -15.219  -81.619   55.485   -7.437   36.826   31.664
## [289]  -66.513   65.704  -25.211   38.471  -34.444    3.411  -44.230  -53.772
## [297]   68.060  -54.807   15.301   49.757  -56.931   50.753  -35.260   56.509
## [305]  -68.101   27.507  -28.711  -50.178   -1.133  -29.892   97.553   42.498
## [313]  -62.932   31.359  -12.908   58.599  -38.302   21.731  -46.607  -64.912
## [321]  -25.448   36.188   22.372  -10.127   -5.191   58.047   10.520   -9.800
## [329]  -49.610   17.149  -22.577  -60.310   24.838   14.651   -5.082  -32.815
## [337]  -40.901   51.713  -30.414   10.152   19.099  -18.549   11.836  -51.434
## [345]   13.449   -8.148   47.556   27.215  -48.186   31.109   29.048   39.138
## [353]    5.923   -8.325  -55.585  -37.767   13.557   10.400   32.843  -18.608
## [361]  -32.754   70.874    1.434   47.973   -8.530  -24.468  -23.094  -54.409
## [369]    4.810    8.887   63.714  -10.271  -40.158   36.599  -21.944   33.851
## [377]    9.187   -7.925  -21.378  -23.091   -6.505   11.857   72.395  -20.104
## [385]  -47.641   35.105  -10.153   53.126   -7.910    2.283  -47.182  -50.488
## [393]   11.645    9.084   42.260   63.725  -61.653   23.934   24.663   33.525
## [401]  -12.761  -30.026  -37.106  -53.374   11.276   26.439   26.206   50.159
## [409] -104.158   86.768   -8.243   27.697  -38.457    6.283  -19.988  -58.730
## [417]   17.275    2.576   44.629   49.748  -55.351   62.213    2.810   61.575
## [425]    6.692  -29.212  -47.045  -67.281   20.198   -0.401   63.012   11.925
## [433]  -81.446   80.079   25.986   41.892   -7.355  -40.150  -27.612  -47.128
## [441]   57.316   14.326   49.618   -7.611  -61.906   73.960  -20.952   57.039
## [449]   36.245  -51.368  -39.561  -36.967   20.260   34.665   43.112   16.798
## [457]  -37.465  108.787   -2.589   21.099   -8.257  -31.739  -49.992  -66.147
## [465]   30.496   27.914   32.435   -6.634  -77.903  101.685  -26.656   42.268
## [473]  -33.516  -28.493  -30.597  -69.271   32.315    4.111   82.107   28.360
## [481]  -86.017   67.440   49.010   41.089  -36.029   -7.987  -72.515  -45.085
## [489]   43.160   18.425   36.945   25.361 -116.778  152.147    7.533   -2.787
## [497]   -1.790  -32.939  -68.073  -44.838   50.537   44.728   19.194   -6.789
## [505]  -58.121   66.523   -3.636   -6.627  -34.899   26.052  -26.214  -49.690
## [513]   32.538   51.814   55.746   -7.236  -11.555   78.663  -49.929   10.728
## [521]  -43.252   11.460  -47.489  -34.546   47.222    0.805  106.142  -15.053
## [529]  -53.016  152.476  -28.740   37.509  -45.529  -65.380  -54.498  -25.090
## [537]   55.394   -8.669   31.551   49.259  -53.997   94.262    6.984   30.485
## [545]  -20.861  -84.818    4.730  -81.372   37.108    3.911   38.682    0.618
## [553]  -69.743  116.877   39.905   34.054  -63.885  -11.597  -45.718  -40.084
## [561]   29.066  -29.485   39.847   29.506    3.893    9.942  -72.242   98.474
## [569]   17.365  -43.802  -40.103  -70.360   53.930   42.131    3.872   12.088
```

```
## [577] -122.748  222.223   -42.219    58.236   -72.312   -38.686    14.363   -43.002
## [585]    34.113    33.693    77.998    12.183   -58.513   137.916   -33.753    43.572
## [593]  -32.592   -54.927   -88.182   -67.142
```

```
names <- colnames(renewable_data)
   plot(Difference_energy_data1,type="l",col="blue")
```
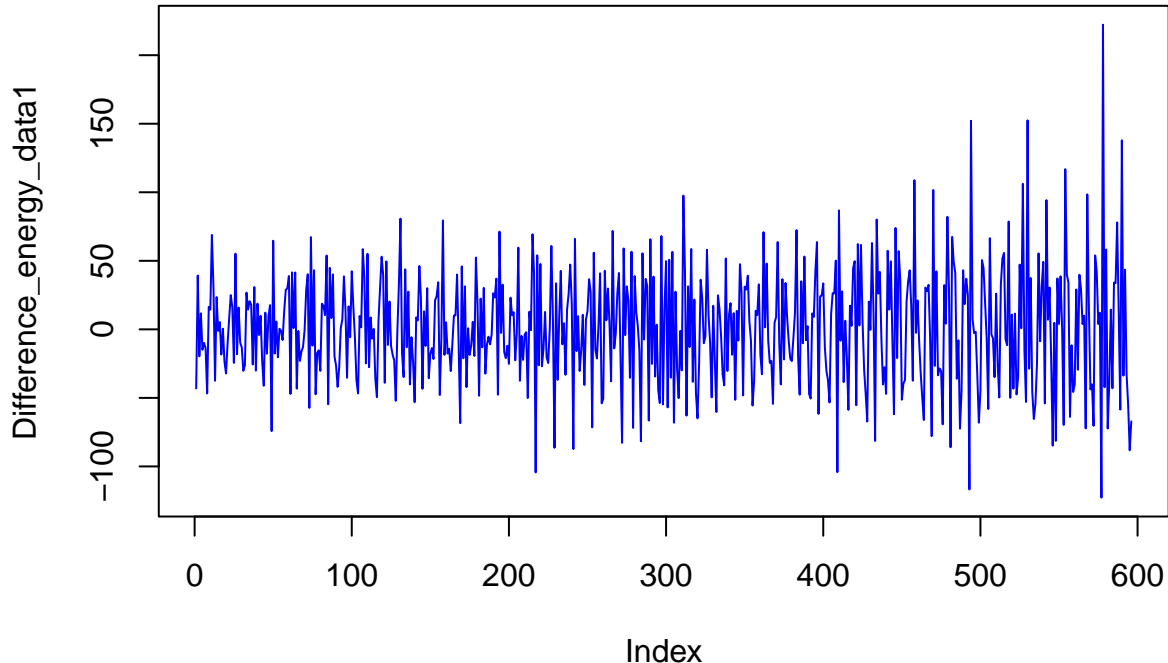

No,there is no trend.

Q2

Now let's compare the differenced series with the detrended series you calculated on A3. In other words, for the "Total Renewable Energy Production" compare the differenced series from Q1 with the series you detrended in A3 using linear regression. (Hint: Just copy and paste part of your code for A3)

Copy and paste part of your code for A3 where you compute regression for Total Energy Production and the detrended Total Energy Production

```
nobs <- nrow(ts_energy_data1)
t <- 1:nobs
iHP <- 1

#Fit a linear trend to TS of iHP
Linear_trend1 <- lm(ts_energy_data1[,iHP+1] ~ t)
summary(Linear_trend1)
```

```
##
## Call:
## lm(formula = ts_energy_data1[, iHP + 1] ~ t)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -238.75  -61.85    8.59   64.48  352.27
##
## Coefficients:
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 312.2475     8.4902   36.78   <2e-16 ***
## t             0.9362     0.0246   38.05   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 103.6 on 595 degrees of freedom
## Multiple R-squared:  0.7088, Adjusted R-squared:  0.7083
## F-statistic:  1448 on 1 and 595 DF,  p-value: < 2.2e-16
```

```r
beta0 <- Linear_trend1$coefficients[1]
beta1 <- Linear_trend1$coefficients[2]
detrend_renewable_data <- renewable_data[,2]-(beta0+beta1*t)

ggplot(renewable_data, aes(x=my_date, y=renewable_data[,2]))+
          geom_line(color="blue")+
          geom_line(aes(y=detrend_renewable_data), col="green")
```
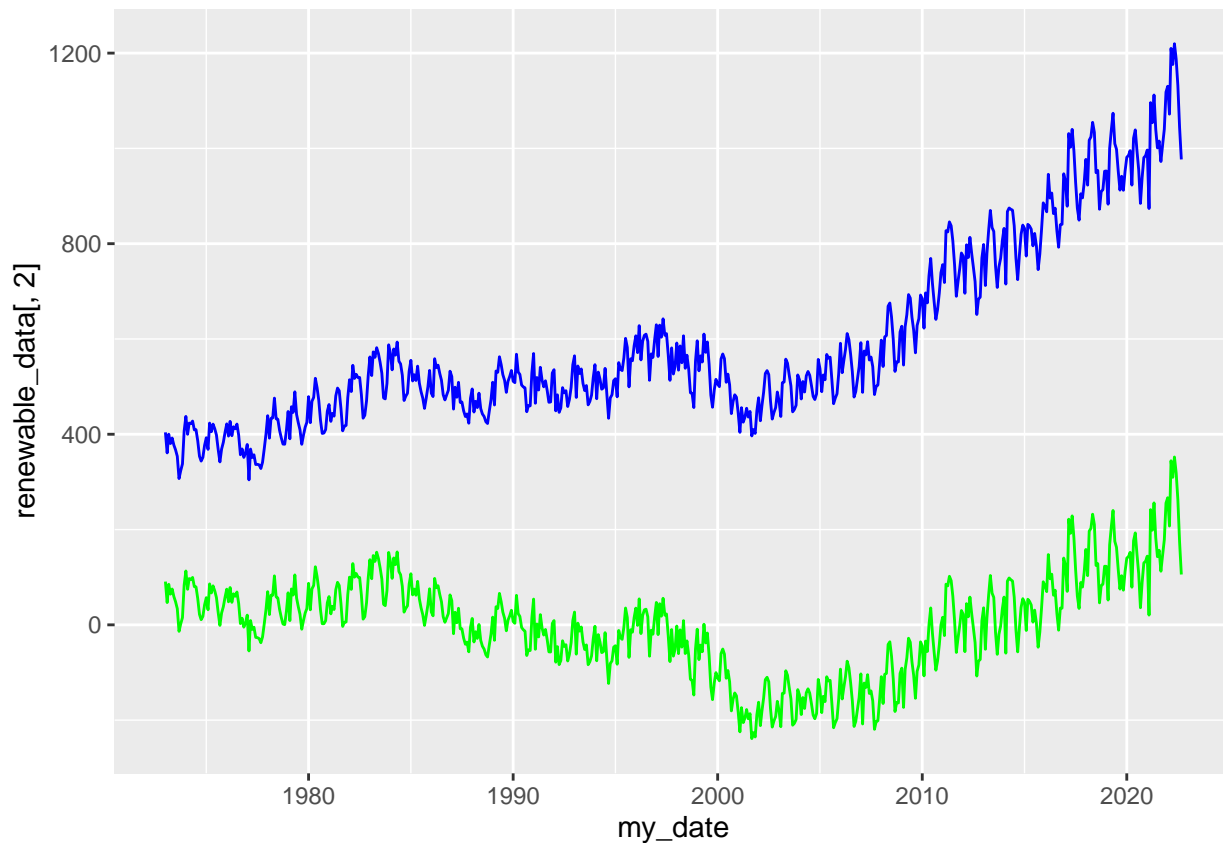


```r
          ylab(paste0("Production",colnames(renewable_data)[iHP+1],sep=""))
```

```
## $y
## [1] "ProductionTotal.Renewable.Energy.Production"
##
## attr(,"class")
## [1] "labels"
```

Q3

Create a data frame with 4 columns: month, original series, detrended by Regression Series and differenced series. Make sure you properly name all columns. Also note that the differenced series will have only 584 rows because you loose the first observation when differencing. Therefore, you need to remove the first observations for the original series and the detrended by regression series to build the new data frame.

```
renewable_data2 <- renewable_data[-1,]
ts_energy_data2 <- ts(renewable_data2,frequency=12,start=c(1973,1))
ts_energy_data2
```

```
##          Month Total.Renewable.Energy.Production
## Jan 1973     4                          360.900
## Feb 1973     8                          400.161
## Mar 1973     1                          380.470
## Apr 1973     9                          392.141
## May 1973     7                          377.232
## Jun 1973     6                          367.325
## Jul 1973     2                          353.757
## Aug 1973    12                          307.006
## Sep 1973    11                          323.453
## Oct 1973    10                          337.817
## Nov 1973     3                          406.694
## Dec 1973    17                          437.467
## Jan 1974    16                          399.942
## Feb 1974    20                          423.474
## Mar 1974    13                          422.323
## Apr 1974    21                          427.657
## May 1974    19                          409.281
## Jun 1974    18                          409.719
## Jul 1974    14                          386.101
## Aug 1974    24                          353.910
## Sep 1974    23                          343.703
## Oct 1974    22                          351.633
## Nov 1974    15                          376.642
## Dec 1974    29                          392.756
## Jan 1975    28                          368.278
## Feb 1975    32                          423.490
## Mar 1975    25                          405.368
## Apr 1975    33                          421.283
## May 1975    31                          411.622
## Jun 1975    30                          398.459
## Jul 1975    26                          368.230
## Aug 1975    36                          341.957
## Sep 1975    35                          368.786
## Oct 1975    34                          383.196
## Nov 1975    27                          403.696
## Dec 1975    41                          421.775
## Jan 1976    40                          396.173
## Feb 1976    44                          427.044
## Mar 1976    37                          396.931
## Apr 1976    45                          415.728
## May 1976    43                          411.555
## Jun 1976    42                          421.425
## Jul 1976    38                          398.129
```

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```
## Aug 1976     48                        356.984
## Sep 1976     47                        369.186
## Oct 1976     46                        351.386
## Nov 1976     39                        360.834
## Dec 1976     53                        378.521
## Jan 1977     52                        304.328
## Feb 1977     56                        368.966
## Mar 1977     49                        351.301
## Apr 1977     57                        356.923
## May 1977     55                        336.485
## Jun 1977     54                        336.903
## Jul 1977     50                        335.881
## Aug 1977     60                        328.075
## Sep 1977     59                        341.368
## Oct 1977     58                        370.168
## Nov 1977     51                        400.048
## Dec 1977     65                        438.983
## Jan 1978     64                        391.866
## Feb 1978     68                        433.459
## Mar 1978     61                        434.379
## Apr 1978     69                        475.883
## May 1978     67                        432.628
## Jun 1978     66                        431.461
## Jul 1978     62                        408.417
## Aug 1978     72                        392.287
## Sep 1978     71                        379.436
## Oct 1978     70                        379.078
## Nov 1978     63                        407.564
## Dec 1978     77                        447.796
## Jan 1979     76                        390.487
## Feb 1979     80                        457.799
## Mar 1979     73                        445.932
## Apr 1979     81                        489.080
## May 1979     79                        441.683
## Jun 1979     78                        424.513
## Jul 1979     74                        409.210
## Aug 1979     84                        378.903
## Sep 1979     83                        397.602
## Oct 1979     82                        414.740
## Nov 1979     75                        425.109
## Dec 1979     89                        478.943
## Jan 1980     88                        424.298
## Feb 1980     92                        469.134
## Mar 1980     85                        477.356
## Apr 1980     93                        517.456
## May 1980     91                        497.768
## Jun 1980     90                        471.331
## Jul 1980     86                        429.358
## Aug 1980     96                        401.712
## Sep 1980     95                        402.564
## Oct 1980     94                        409.876
## Nov 1980     87                        448.546
## Dec 1980    101                        462.381
## Jan 1981    100                        427.043
```

```
## Feb 1981   104                    443.808
## Mar 1981    97                    438.020
## Apr 1981   105                    480.423
## May 1981   103                    496.995
## Jun 1981   102                    491.304
## Jul 1981    98                    454.028
## Aug 1981   108                    407.220
## Sep 1981   107                    416.966
## Oct 1981   106                    418.476
## Nov 1981    99                    477.024
## Dec 1981   113                    514.440
## Jan 1982   112                    489.624
## Feb 1982   116                    544.724
## Mar 1982   109                    517.128
## Apr 1982   117                    525.795
## May 1982   115                    518.974
## Jun 1982   114                    519.267
## Jul 1982   110                    483.203
## Aug 1982   120                    433.748
## Sep 1982   119                    439.874
## Oct 1982   118                    469.930
## Nov 1982   111                    522.930
## Dec 1982   125                    562.279
## Jan 1983   124                    523.276
## Feb 1983   128                    572.853
## Mar 1983   121                    561.458
## Apr 1983   129                    581.741
## May 1983   127                    569.493
## Jun 1983   126                    550.993
## Jul 1983   122                    528.288
## Aug 1983   132                    476.173
## Sep 1983   131                    474.251
## Oct 1983   130                    507.035
## Nov 1983   123                    587.773
## Dec 1983   137                    570.081
## Jan 1984   136                    535.239
## Feb 1984   140                    579.040
## Mar 1984   133                    566.019
## Apr 1984   141                    593.504
## May 1984   139                    553.321
## Jun 1984   138                    547.618
## Jul 1984   134                    524.053
## Aug 1984   144                    470.910
## Sep 1984   143                    479.620
## Oct 1984   142                    486.110
## Nov 1984   135                    532.347
## Dec 1984   149                    555.205
## Jan 1985   148                    511.838
## Feb 1985   152                    525.002
## Mar 1985   145                    512.937
## Apr 1985   153                    542.968
## May 1985   151                    507.330
## Jun 1985   150                    489.577
## Jul 1985   146                    475.912
```

```
## Aug 1985    156                    454.274
## Sep 1985    155                    475.406
## Oct 1985    154                    499.606
## Nov 1985    147                    533.960
## Dec 1985    161                    486.064
## Jan 1986    160                    479.122
## Feb 1986    164                    558.538
## Mar 1986    157                    539.897
## Apr 1986    165                    545.072
## May 1986    163                    527.412
## Jun 1986    162                    513.292
## Jul 1986    158                    482.847
## Aug 1986    168                    472.114
## Sep 1986    167                    482.113
## Oct 1986    166                    492.321
## Nov 1986    159                    532.346
## Dec 1986    173                    521.265
## Jan 1987    172                    452.878
## Feb 1987    176                    498.782
## Mar 1987    169                    477.656
## Apr 1987    177                    509.032
## May 1987    175                    466.873
## Jun 1987    174                    467.691
## Jul 1987    170                    448.986
## Aug 1987    180                    437.201
## Sep 1987    179                    442.655
## Oct 1987    178                    423.208
## Nov 1987    171                    475.580
## Dec 1987    185                    495.132
## Jan 1988    184                    446.663
## Feb 1988    188                    469.098
## Mar 1988    181                    455.993
## Apr 1988    189                    486.212
## May 1988    187                    453.891
## Jun 1988    186                    442.602
## Jul 1988    182                    437.214
## Aug 1988    192                    426.312
## Sep 1988    191                    422.602
## Oct 1988    190                    448.903
## Nov 1988    183                    472.132
## Dec 1988    197                    509.148
## Jan 1989    196                    461.436
## Feb 1989    200                    532.717
## Mar 1989    193                    530.099
## Apr 1989    201                    562.702
## May 1989    199                    546.138
## Jun 1989    198                    525.099
## Jul 1989    194                    513.156
## Aug 1989    204                    487.951
## Sep 1989    203                    511.061
## Oct 1989    202                    521.326
## Nov 1989    195                    533.842
## Dec 1989    209                    511.273
## Jan 1990    208                    508.362
```

```
## Feb 1990    212                        567.936
## Mar 1990    205                        530.432
## Apr 1990    213                        525.675
## May 1990    211                        503.364
## Jun 1990    210                        499.497
## Jul 1990    206                        497.457
## Aug 1990    216                        447.351
## Sep 1990    215                        460.201
## Oct 1990    214                        459.567
## Nov 1990    207                        528.928
## Dec 1990    221                        569.478
## Jan 1991    220                        465.118
## Feb 1991    224                        519.110
## Mar 1991    217                        492.914
## Apr 1991    225                        540.591
## May 1991    223                        513.640
## Jun 1991    222                        499.537
## Jul 1991    218                        512.231
## Aug 1991    228                        491.724
## Sep 1991    227                        467.137
## Oct 1991    226                        467.744
## Nov 1991    219                        528.582
## Dec 1991    233                        535.607
## Jan 1992    232                        449.195
## Feb 1992    236                        482.785
## Mar 1992    229                        445.956
## Apr 1992    237                        455.240
## May 1992    235                        497.883
## Jun 1992    234                        486.979
## Jul 1992    230                        491.443
## Aug 1992    240                        458.264
## Sep 1992    239                        472.681
## Oct 1992    238                        498.632
## Nov 1992    231                        545.914
## Dec 1992    245                        564.645
## Jan 1993    244                        477.338
## Feb 1993    248                        543.315
## Mar 1993    241                        527.479
## Apr 1993    249                        537.105
## May 1993    247                        506.690
## Jun 1993    246                        491.687
## Jul 1993    242                        502.293
## Aug 1993    252                        461.702
## Sep 1993    251                        468.762
## Oct 1993    250                        482.151
## Nov 1993    243                        518.768
## Dec 1993    257                        546.056
## Jan 1994    256                        474.599
## Feb 1994    260                        530.494
## Mar 1994    253                        515.827
## Apr 1994    261                        494.550
## May 1994    259                        497.434
## Jun 1994    258                        538.300
## Jul 1994    254                        484.336
```

```
## Aug 1994   264                    433.627
## Sep 1994   263                    476.303
## Oct 1994   262                    482.932
## Nov 1994   255                    512.713
## Dec 1994   269                    516.507
## Jan 1995   268                    478.624
## Feb 1995   272                    550.410
## Mar 1995   265                    536.529
## Apr 1995   273                    533.624
## May 1995   271                    560.149
## Jun 1995   270                    601.280
## Jul 1995   266                    582.286
## Aug 1995   276                    499.496
## Sep 1995   275                    558.499
## Oct 1995   274                    554.290
## Nov 1995   267                    585.646
## Dec 1995   281                    606.654
## Jan 1996   280                    571.306
## Feb 1996   284                    627.928
## Mar 1996   277                    556.072
## Apr 1996   285                    594.909
## May 1996   283                    607.621
## Jun 1996   282                    610.100
## Jul 1996   278                    594.881
## Aug 1996   288                    513.262
## Sep 1996   287                    568.747
## Oct 1996   286                    561.310
## Nov 1996   279                    598.136
## Dec 1996   293                    629.800
## Jan 1997   292                    563.287
## Feb 1997   296                    628.991
## Mar 1997   289                    603.780
## Apr 1997   297                    642.251
## May 1997   295                    607.807
## Jun 1997   294                    611.218
## Jul 1997   290                    566.988
## Aug 1997   300                    513.216
## Sep 1997   299                    581.276
## Oct 1997   298                    526.469
## Nov 1997   291                    541.770
## Dec 1997   305                    591.527
## Jan 1998   304                    534.596
## Feb 1998   308                    585.349
## Mar 1998   301                    550.089
## Apr 1998   309                    606.598
## May 1998   307                    538.497
## Jun 1998   306                    566.004
## Jul 1998   302                    537.293
## Aug 1998   312                    487.115
## Sep 1998   311                    485.982
## Oct 1998   310                    456.090
## Nov 1998   303                    553.643
## Dec 1998   317                    596.141
## Jan 1999   316                    533.209
```

```
## Feb 1999    320                    564.568
## Mar 1999    313                    551.660
## Apr 1999    321                    610.259
## May 1999    319                    571.957
## Jun 1999    318                    593.688
## Jul 1999    314                    547.081
## Aug 1999    324                    482.169
## Sep 1999    323                    456.721
## Oct 1999    322                    492.909
## Nov 1999    315                    515.281
## Dec 1999    329                    505.154
## Jan 2000    328                    499.963
## Feb 2000    332                    558.010
## Mar 2000    325                    568.530
## Apr 2000    333                    558.730
## May 2000    331                    509.120
## Jun 2000    330                    526.269
## Jul 2000    326                    503.692
## Aug 2000    336                    443.382
## Sep 2000    335                    468.220
## Oct 2000    334                    482.871
## Nov 2000    327                    477.789
## Dec 2000    341                    444.974
## Jan 2001    340                    404.073
## Feb 2001    344                    455.786
## Mar 2001    337                    425.372
## Apr 2001    345                    435.524
## May 2001    343                    454.623
## Jun 2001    342                    436.074
## Jul 2001    338                    447.910
## Aug 2001    348                    396.476
## Sep 2001    347                    409.925
## Oct 2001    346                    401.777
## Nov 2001    339                    449.333
## Dec 2001    353                    476.548
## Jan 2002    352                    428.362
## Feb 2002    356                    459.471
## Mar 2002    349                    488.519
## Apr 2002    357                    527.657
## May 2002    355                    533.580
## Jun 2002    354                    525.255
## Jul 2002    350                    469.670
## Aug 2002    360                    431.903
## Sep 2002    359                    445.460
## Oct 2002    358                    455.860
## Nov 2002    351                    488.703
## Dec 2002    365                    470.095
## Jan 2003    364                    437.341
## Feb 2003    368                    508.215
## Mar 2003    361                    509.649
## Apr 2003    369                    557.622
## May 2003    367                    549.092
## Jun 2003    366                    524.624
## Jul 2003    362                    501.530
```

```
## Aug 2003   372                    447.121
## Sep 2003   371                    451.931
## Oct 2003   370                    460.818
## Nov 2003   363                    524.532
## Dec 2003   377                    514.261
## Jan 2004   376                    474.103
## Feb 2004   380                    510.702
## Mar 2004   373                    488.758
## Apr 2004   381                    522.609
## May 2004   379                    531.796
## Jun 2004   378                    523.871
## Jul 2004   374                    502.493
## Aug 2004   384                    479.402
## Sep 2004   383                    472.897
## Oct 2004   382                    484.754
## Nov 2004   375                    557.149
## Dec 2004   389                    537.045
## Jan 2005   388                    489.404
## Feb 2005   392                    524.509
## Mar 2005   385                    514.356
## Apr 2005   393                    567.482
## May 2005   391                    559.572
## Jun 2005   390                    561.855
## Jul 2005   386                    514.673
## Aug 2005   396                    464.185
## Sep 2005   395                    475.830
## Oct 2005   394                    484.914
## Nov 2005   387                    527.174
## Dec 2005   401                    590.899
## Jan 2006   400                    529.246
## Feb 2006   404                    553.180
## Mar 2006   397                    577.843
## Apr 2006   405                    611.368
## May 2006   403                    598.607
## Jun 2006   402                    568.581
## Jul 2006   398                    531.475
## Aug 2006   408                    478.101
## Sep 2006   407                    489.377
## Oct 2006   406                    515.816
## Nov 2006   399                    542.022
## Dec 2006   413                    592.181
## Jan 2007   412                    488.023
## Feb 2007   416                    574.791
## Mar 2007   409                    566.548
## Apr 2007   417                    594.245
## May 2007   415                    555.788
## Jun 2007   414                    562.071
## Jul 2007   410                    542.083
## Aug 2007   420                    483.353
## Sep 2007   419                    500.628
## Oct 2007   418                    503.204
## Nov 2007   411                    547.833
## Dec 2007   425                    597.581
## Jan 2008   424                    542.230
```

```
## Feb 2008    428                        604.443
## Mar 2008    421                        607.253
## Apr 2008    429                        668.828
## May 2008    427                        675.520
## Jun 2008    426                        646.308
## Jul 2008    422                        599.263
## Aug 2008    432                        531.982
## Sep 2008    431                        552.180
## Oct 2008    430                        551.779
## Nov 2008    423                        614.791
## Dec 2008    437                        626.716
## Jan 2009    436                        545.270
## Feb 2009    440                        625.349
## Mar 2009    433                        651.335
## Apr 2009    441                        693.227
## May 2009    439                        685.872
## Jun 2009    438                        645.722
## Jul 2009    434                        618.110
## Aug 2009    444                        570.982
## Sep 2009    443                        628.298
## Oct 2009    442                        642.624
## Nov 2009    435                        692.242
## Dec 2009    449                        684.631
## Jan 2010    448                        622.725
## Feb 2010    452                        696.685
## Mar 2010    445                        675.733
## Apr 2010    453                        732.772
## May 2010    451                        769.017
## Jun 2010    450                        717.649
## Jul 2010    446                        678.088
## Aug 2010    456                        641.121
## Sep 2010    455                        661.381
## Oct 2010    454                        696.046
## Nov 2010    447                        739.158
## Dec 2010    461                        755.956
## Jan 2011    460                        718.491
## Feb 2011    464                        827.278
## Mar 2011    457                        824.689
## Apr 2011    465                        845.788
## May 2011    463                        837.531
## Jun 2011    462                        805.792
## Jul 2011    458                        755.800
## Aug 2011    468                        689.653
## Sep 2011    467                        720.149
## Oct 2011    466                        748.063
## Nov 2011    459                        780.498
## Dec 2011    473                        773.864
## Jan 2012    472                        695.961
## Feb 2012    476                        797.646
## Mar 2012    469                        770.990
## Apr 2012    477                        813.258
## May 2012    475                        779.742
## Jun 2012    474                        751.249
## Jul 2012    470                        720.652
```

```
## Aug 2012    480                    651.381
## Sep 2012    479                    683.696
## Oct 2012    478                    687.807
## Nov 2012    471                    769.914
## Dec 2012    485                    798.274
## Jan 2013    484                    712.257
## Feb 2013    488                    779.697
## Mar 2013    481                    828.707
## Apr 2013    489                    869.796
## May 2013    487                    833.767
## Jun 2013    486                    825.780
## Jul 2013    482                    753.265
## Aug 2013    492                    708.180
## Sep 2013    491                    751.340
## Oct 2013    490                    769.765
## Nov 2013    483                    806.710
## Dec 2013    497                    832.071
## Jan 2014    496                    715.293
## Feb 2014    500                    867.440
## Mar 2014    493                    874.973
## Apr 2014    501                    872.186
## May 2014    499                    870.396
## Jun 2014    498                    837.457
## Jul 2014    494                    769.384
## Aug 2014    504                    724.546
## Sep 2014    503                    775.083
## Oct 2014    502                    819.811
## Nov 2014    495                    839.005
## Dec 2014    509                    832.216
## Jan 2015    508                    774.095
## Feb 2015    512                    840.618
## Mar 2015    505                    836.982
## Apr 2015    513                    830.355
## May 2015    511                    795.456
## Jun 2015    510                    821.508
## Jul 2015    506                    795.294
## Aug 2015    516                    745.604
## Sep 2015    515                    778.142
## Oct 2015    514                    829.956
## Nov 2015    507                    885.702
## Dec 2015    521                    878.466
## Jan 2016    520                    866.911
## Feb 2016    524                    945.574
## Mar 2016    517                    895.645
## Apr 2016    525                    906.373
## May 2016    523                    863.121
## Jun 2016    522                    874.581
## Jul 2016    518                    827.092
## Aug 2016    528                    792.546
## Sep 2016    527                    839.768
## Oct 2016    526                    840.573
## Nov 2016    519                    946.715
## Dec 2016    533                    931.662
## Jan 2017    532                    878.646
```

```
## Feb 2017    536                        1031.122
## Mar 2017    529                        1002.382
## Apr 2017    537                        1039.891
## May 2017    535                         994.362
## Jun 2017    534                         928.982
## Jul 2017    530                         874.484
## Aug 2017    540                         849.394
## Sep 2017    539                         904.788
## Oct 2017    538                         896.119
## Nov 2017    531                         927.670
## Dec 2017    545                         976.929
## Jan 2018    544                         922.932
## Feb 2018    548                        1017.194
## Mar 2018    541                        1024.178
## Apr 2018    549                        1054.663
## May 2018    547                        1033.802
## Jun 2018    546                         948.984
## Jul 2018    542                         953.714
## Aug 2018    552                         872.342
## Sep 2018    551                         909.450
## Oct 2018    550                         913.361
## Nov 2018    543                         952.043
## Dec 2018    557                         952.661
## Jan 2019    556                         882.918
## Feb 2019    560                         999.795
## Mar 2019    553                        1039.700
## Apr 2019    561                        1073.754
## May 2019    559                        1009.869
## Jun 2019    558                         998.272
## Jul 2019    554                         952.554
## Aug 2019    564                         912.470
## Sep 2019    563                         941.536
## Oct 2019    562                         912.051
## Nov 2019    555                         951.898
## Dec 2019    569                         981.404
## Jan 2020    568                         985.297
## Feb 2020    572                         995.239
## Mar 2020    565                         922.997
## Apr 2020    573                        1021.471
## May 2020    571                        1038.836
## Jun 2020    570                         995.034
## Jul 2020    566                         954.931
## Aug 2020    576                         884.571
## Sep 2020    575                         938.501
## Oct 2020    574                         980.632
## Nov 2020    567                         984.504
## Dec 2020    581                         996.592
## Jan 2021    580                         873.844
## Feb 2021    584                        1096.067
## Mar 2021    577                        1053.848
## Apr 2021    585                        1112.084
## May 2021    583                        1039.772
## Jun 2021    582                        1001.086
## Jul 2021    578                        1015.449
```

```
## Aug 2021    588                                972.447
## Sep 2021    587                               1006.560
## Oct 2021    586                               1040.253
## Nov 2021    579                               1118.251
## Dec 2021    592                               1130.434
## Jan 2022    591                               1071.921
## Feb 2022    595                               1209.837
## Mar 2022    589                               1176.084
## Apr 2022    596                               1219.656
## May 2022    594                               1187.064
## Jun 2022    593                               1132.137
## Jul 2022    590                               1043.955
## Aug 2022    597                                976.813
```

```r
nobs <- nrow(ts_energy_data2)
t <- 1:nobs
iHP <- 1
Linear_trend2 <- lm(ts_energy_data2[,iHP+1] ~ t)
summary(Linear_trend2)
```

```
##
## Call:
## lm(formula = ts_energy_data2[, iHP + 1] ~ t)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -238.66  -62.02    8.58   64.36  351.97
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 312.57277    8.49894   36.78   <2e-16 ***
## t             0.93769    0.02467   38.01   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 103.6 on 594 degrees of freedom
## Multiple R-squared:  0.7087, Adjusted R-squared:  0.7082
## F-statistic:  1445 on 1 and 594 DF,  p-value: < 2.2e-16
```

```r
beta0 <- Linear_trend2$coefficients[1]
beta1 <- Linear_trend2$coefficients[2]
detrend_renewable_data2 <- renewable_data2[,2]-(beta0+beta1*t)
```

```r
chart <- data.frame(Month = c(renewable_data2$Month),
              original_data = c(renewable_data2$Total.Renewable.Energy.Production),
              differenced_data = c(Difference_energy_data1),
              detrended_data = c(detrend_renewable_data2))
chart
```

```
##            Month original_data differenced_data detrended_data
## 1  1973 February       360.900          -43.081     47.38953499
## 2     1973 March       400.161           39.261     85.71284234
## 3     1973 April       380.470          -19.691     65.08414969
## 4       1973 May       392.141           11.671     75.81745704
## 5      1973 June       377.232          -14.909     59.97076439
## 6      1973 July       367.325           -9.907     49.12607174
```

```
## 7      1973 August        353.757      -13.568      34.62037909
## 8   1973 September        307.006      -46.751     -13.06831356
## 9     1973 October        323.453       16.447       2.44099379
## 10    1973 November        337.817       14.364      15.86730114
## 11    1973 December        406.694       68.877      83.80660849
## 12    1974 January        437.467       30.773     113.64191584
## 13    1974 February        399.942      -37.525      75.17922318
## 14      1974 March        423.474       23.532      97.77353053
## 15      1974 April        422.323       -1.151      95.68483788
## 16        1974 May        427.657        5.334     100.08114523
## 17       1974 June        409.281      -18.376      80.76745258
## 18       1974 July        409.719        0.438      80.26775993
## 19     1974 August        386.101      -23.618      55.71206728
## 20   1974 September        353.910      -32.191      22.58337463
## 21     1974 October        343.703      -10.207      11.43868198
## 22    1974 November        351.633        7.930      18.43098933
## 23    1974 December        376.642       25.009      42.50229668
## 24    1975 January        392.756       16.114      57.67860403
## 25    1975 February        368.278      -24.478      32.26291138
## 26      1975 March        423.490       55.212      86.53721873
## 27      1975 April        405.368      -18.122      67.47752608
## 28        1975 May        421.283       15.915      82.45483343
## 29       1975 June        411.622       -9.661      71.85614078
## 30       1975 July        398.459      -13.163      57.75544813
## 31     1975 August        368.230      -30.229      26.58875548
## 32   1975 September        341.957      -26.273      -0.62193717
## 33     1975 October        368.786       26.829      25.26937018
## 34    1975 November        383.196       14.410      38.74167752
## 35    1975 December        403.696       20.500      58.30398487
## 36    1976 January        421.775       18.079      75.44529222
## 37    1976 February        396.173      -25.602      48.90559957
## 38      1976 March        427.044       30.871      78.83890692
## 39      1976 April        396.931      -30.113      47.78821427
## 40        1976 May        415.728       18.797      65.64752162
## 41       1976 June        411.555       -4.173      60.53682897
## 42       1976 July        421.425        9.870      69.46913632
## 43     1976 August        398.129      -23.296      45.23544367
## 44   1976 September        356.984      -41.145       3.15275102
## 45     1976 October        369.186       12.202      14.41705837
## 46    1976 November        351.386      -17.800      -4.32063428
## 47    1976 December        360.834        9.448       4.18967307
## 48    1977 January        378.521       17.687      20.93898042
## 49    1977 February        304.328      -74.193     -54.19171223
## 50      1977 March        368.966       64.638       9.50859512
## 51      1977 April        351.301      -17.665      -9.09409753
## 52        1977 May        356.923        5.622      -4.40979018
## 53       1977 June        336.485      -20.438     -25.78548283
## 54       1977 July        336.903        0.418     -26.30517548
## 55     1977 August        335.881       -1.022     -28.26486813
## 56   1977 September        328.075       -7.806     -37.00856079
## 57     1977 October        341.368       13.293     -24.65325344
## 58    1977 November        370.168       28.800       3.20905391
## 59    1977 December        400.048       29.880      32.15136126
## 60    1978 January        438.983       38.935      70.14866861
```

```
## 61    1978 February      391.866      -47.117    22.09397596
## 62       1978 March      433.459       41.593    62.74928331
## 63       1978 April      434.379        0.920    62.73159066
## 64         1978 May      475.883       41.504   103.29789801
## 65        1978 June      432.628      -43.255    59.10520536
## 66        1978 July      431.461       -1.167    57.00051271
## 67      1978 August      408.417      -23.044    33.01882006
## 68   1978 September      392.287      -16.130    15.95112741
## 69     1978 October      379.436      -12.851     2.16243476
## 70    1978 November      379.078       -0.358     0.86674211
## 71    1978 December      407.564       28.486    28.41504946
## 72     1979 January      447.796       40.232    67.70935681
## 73    1979 February      390.487      -57.309     9.46266416
## 74       1979 March      457.799       67.312    75.83697151
## 75       1979 April      445.932      -11.867    63.03227886
## 76         1979 May      489.080       43.148   105.24258621
## 77        1979 June      441.683      -47.397    56.90789355
## 78        1979 July      424.513      -17.170    38.80020090
## 79      1979 August      409.210      -15.303    22.55950825
## 80   1979 September      378.903      -30.307    -8.68518440
## 81     1979 October      397.602       18.699     9.07612295
## 82    1979 November      414.740       17.138    25.27643030
## 83    1979 December      425.109       10.369    34.70773765
## 84     1980 January      478.943       53.834    87.60404500
## 85    1980 February      424.298      -54.645    32.02135235
## 86       1980 March      469.134       44.836    75.91965970
## 87       1980 April      477.356        8.222    83.20396705
## 88         1980 May      517.456       40.100   122.36627440
## 89        1980 June      497.768      -19.688   101.74058175
## 90        1980 July      471.331      -26.437    74.36588910
## 91      1980 August      429.358      -41.973    31.45519645
## 92   1980 September      401.712      -27.646     2.87150380
## 93     1980 October      402.564        0.852     2.78581115
## 94    1980 November      409.876        7.312     9.16011850
## 95    1980 December      448.546       38.670    46.89242585
## 96     1981 January      462.381       13.835    59.78973320
## 97    1981 February      427.043      -35.338    23.51404055
## 98       1981 March      443.808       16.765    39.34134790
## 99       1981 April      438.020       -5.788    32.61565524
## 100        1981 May      480.423       42.403    74.08096259
## 101       1981 June      496.995       16.572    89.71526994
## 102       1981 July      491.304       -5.691    83.08657729
## 103     1981 August      454.028      -37.276    44.87288464
## 104  1981 September      407.220      -46.808    -2.87280801
## 105    1981 October      416.966        9.746     5.93549934
## 106   1981 November      418.476        1.510     6.50780669
## 107   1981 December      477.024       58.548    64.11811404
## 108    1982 January      514.440       37.416   100.59642139
## 109   1982 February      489.624      -24.816    74.84272874
## 110      1982 March      544.724       55.100   129.00503609
## 111      1982 April      517.128      -27.596   100.47134344
## 112        1982 May      525.795        8.667   108.20065079
## 113       1982 June      518.974       -6.821   100.44195814
## 114       1982 July      519.267        0.293    99.79726549
```

```
## 115    1982 August      483.203    -36.064     62.79557284
## 116 1982 September       433.748    -49.455     12.40288019
## 117    1982 October      439.874      6.126     17.59118754
## 118   1982 November      469.930     30.056     46.70949489
## 119   1982 December      522.930     53.000     98.77180224
## 120    1983 January      562.279     39.349    137.18310958
## 121   1983 February      523.276    -39.003     97.24241693
## 122      1983 March      572.853     49.577    145.88172428
## 123      1983 April      561.458    -11.395    133.54903163
## 124        1983 May      581.741     20.283    152.89433898
## 125       1983 June      569.493    -12.248    139.70864633
## 126       1983 July      550.993    -18.500    120.27095368
## 127     1983 August      528.288    -22.705     96.62826103
## 128 1983 September       476.173    -52.115     43.57556838
## 129    1983 October      474.251     -1.922     40.71587573
## 130   1983 November      507.035     32.784     72.56218308
## 131   1983 December      587.773     80.738    152.36249043
## 132    1984 January      570.081    -17.692    133.73279778
## 133   1984 February      535.239    -34.842     97.95310513
## 134      1984 March      579.040     43.801    140.81641248
## 135      1984 April      566.019    -13.021    126.85771983
## 136        1984 May      593.504     27.485    153.40502718
## 137       1984 June      553.321    -40.183    112.28433453
## 138       1984 July      547.618     -5.703    105.64364188
## 139     1984 August      524.053    -23.565     81.14094923
## 140 1984 September       470.910    -53.143     27.06025658
## 141    1984 October      479.620      8.710     34.83256393
## 142   1984 November      486.110      6.490     40.38487127
## 143   1984 December      532.347     46.237     85.68417862
## 144    1985 January      555.205     22.858    107.60448597
## 145   1985 February      511.838    -43.367     63.29979332
## 146      1985 March      525.002     13.164     75.52610067
## 147      1985 April      512.937    -12.065     62.52340802
## 148        1985 May      542.968     30.031     91.61671537
## 149       1985 June      507.330    -35.638     55.04102272
## 150       1985 July      489.577    -17.753     36.35033007
## 151     1985 August      475.912    -13.665     21.74763742
## 152 1985 September       454.274    -21.638     -0.82805523
## 153    1985 October      475.406     21.132     19.36625212
## 154   1985 November      499.606     24.200     42.62855947
## 155   1985 December      533.960     34.354     76.04486682
## 156    1986 January      486.064    -47.896     27.21117417
## 157   1986 February      479.122     -6.942     19.33148152
## 158      1986 March      558.538     79.416     97.80978887
## 159      1986 April      539.897    -18.641     78.23109622
## 160        1986 May      545.072      5.175     82.46840357
## 161       1986 June      527.412    -17.660     63.87071092
## 162       1986 July      513.292    -14.120     48.81301827
## 163     1986 August      482.847    -30.445     17.43032561
## 164 1986 September       472.114    -10.733      5.75963296
## 165    1986 October      482.113      9.999     14.82094031
## 166   1986 November      492.321     10.208     24.09124766
## 167   1986 December      532.346     40.025     63.17855501
## 168    1987 January      521.265    -11.081     51.15986236
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## 169   1987 February      452.878        -68.387      -18.16483029
## 170      1987 March      498.782         45.904       26.80147706
## 171      1987 April      477.656        -21.126        4.73778441
## 172        1987 May      509.032         31.376       35.17609176
## 173       1987 June      466.873        -42.159       -7.92060089
## 174       1987 July      467.691          0.818       -8.04029354
## 175     1987 August      448.986        -18.705      -27.68298619
## 176  1987 September      437.201        -11.785      -40.40567884
## 177     1987 October      442.655          5.454      -35.88937149
## 178    1987 November      423.208        -19.447      -56.27406414
## 179    1987 December      475.580         52.372       -4.83975679
## 180     1988 January      495.132         19.552       13.77455056
## 181    1988 February      446.663        -48.469      -35.63214209
## 182       1988 March      469.098         22.435      -14.13483474
## 183       1988 April      455.993        -13.105      -28.17752739
## 184         1988 May      486.212         30.219        1.10377995
## 185        1988 June      453.891        -32.321      -32.15491270
## 186        1988 July      442.602        -11.289      -44.38160535
## 187      1988 August      437.214         -5.388      -50.70729800
## 188  1988 September      426.312        -10.902      -62.54699065
## 189     1988 October      422.602         -3.710      -67.19468330
## 190    1988 November      448.903         26.301      -41.83137595
## 191    1988 December      472.132         23.229      -19.54006860
## 192     1989 January      509.148         37.016       16.53823875
## 193    1989 February      461.436        -47.712      -32.11145390
## 194       1989 March      532.717         71.281       38.23185345
## 195       1989 April      530.099         -2.618       34.67616080
## 196         1989 May      562.702         32.603       66.34146815
## 197        1989 June      546.138        -16.564       48.83977550
## 198        1989 July      525.099        -21.039       26.86308285
## 199      1989 August      513.156        -11.943       13.98239020
## 200  1989 September      487.951        -25.205      -12.16030245
## 201     1989 October      511.061         23.110       10.01200490
## 202    1989 November      521.326         10.265       19.33931225
## 203    1989 December      533.842         12.516       30.91761960
## 204     1990 January      511.273        -22.569        7.41092695
## 205    1990 February      508.362         -2.911        3.56223430
## 206       1990 March      567.936         59.574       62.19854164
## 207       1990 April      530.432        -37.504       23.75684899
## 208         1990 May      525.675         -4.757       18.06215634
## 209        1990 June      503.364        -22.311       -5.18653631
## 210        1990 July      499.497         -3.867       -9.99122896
## 211      1990 August      497.457         -2.040      -12.96892161
## 212  1990 September      447.351        -50.106      -64.01261426
## 213     1990 October      460.201         12.850      -52.10030691
## 214    1990 November      459.567         -0.634      -53.67199956
## 215    1990 December      528.928         69.361       14.75130779
## 216     1991 January      569.478         40.550       54.36361514
## 217    1991 February      465.118       -104.360      -50.93407751
## 218       1991 March      519.110         53.992        2.12022984
## 219       1991 April      492.914        -26.196      -25.01346281
## 220         1991 May      540.591         47.677       21.72584454
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## 222        1991 July      499.537        -14.103      -21.20354076
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## 223    1991 August      512.231      12.694    -9.44723341
## 224 1991 September       491.724     -20.507   -30.89192606
## 225    1991 October      467.137     -24.587   -56.41661871
## 226   1991 November      467.744       0.607   -56.74731136
## 227   1991 December      528.582      60.838     3.15299598
## 228    1992 January      535.607       7.025     9.24030333
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## 231     1992 April       445.956     -36.829   -83.22377462
## 232       1992 May       455.240       9.284   -74.87746727
## 233      1992 June       497.883      42.643   -33.17215992
## 234      1992 July       486.979     -10.904   -45.01385257
## 235    1992 August       491.443       4.464   -41.48754522
## 236 1992 September       458.264     -33.179   -75.60423787
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## 239   1992 December      545.914      47.282     9.23268418
## 240    1993 January      564.645      18.731    27.02599153
## 241   1993 February      477.338     -87.307   -61.21870112
## 242     1993 March       543.315      65.977     3.82060623
## 243     1993 April       527.479     -15.836   -12.95308642
## 244       1993 May       537.105       9.626    -4.26477907
## 245      1993 June       506.690     -30.415   -35.61747172
## 246      1993 July       491.687     -15.003   -51.55816437
## 247    1993 August       502.293      10.606   -41.88985702
## 248 1993 September       461.702     -40.591   -83.41854967
## 249    1993 October      468.762       7.060   -77.29624233
## 250   1993 November      482.151      13.389   -64.84493498
## 251   1993 December      518.768      36.617   -29.16562763
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## 253   1994 February      474.599     -71.457   -75.21001293
## 254     1994 March       530.494      55.895   -20.25270558
## 255     1994 April       515.827     -14.667   -35.85739823
## 256       1994 May       494.550     -21.277   -58.07209088
## 257      1994 June       497.434       2.884   -56.12578353
## 258      1994 July       538.300      40.866   -16.19747618
## 259    1994 August       484.336     -53.964   -71.09916883
## 260 1994 September       433.627     -50.709  -122.74586148
## 261    1994 October      476.303      42.676   -81.00755413
## 262   1994 November      482.932       6.629   -75.31624678
## 263   1994 December      512.713      29.781   -46.47293943
## 264    1995 January      516.507       3.794   -43.61663208
## 265   1995 February      478.624     -37.883   -82.43732473
## 266     1995 March       550.410      71.786   -11.58901738
## 267     1995 April       536.529     -13.881   -26.40771003
## 268       1995 May       533.624      -2.905   -30.25040268
## 269      1995 June       560.149      26.525    -4.66309533
## 270      1995 July       601.280      41.131    35.53021201
## 271    1995 August       582.286     -18.994    15.59851936
## 272 1995 September       499.496     -82.790   -68.12917329
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## 274   1995 November      554.290      -4.209   -15.21055859
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## 276    1996 January      606.654      21.008    35.27805611
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## 277   1996 February      571.306        -35.348      -1.00763654
## 278     1996 March       627.928         56.622      54.67667081
## 279     1996 April       556.072        -71.856     -18.11702184
## 280       1996 May       594.909         38.837      19.78228551
## 281      1996 June       607.621         12.712      31.55659286
## 282      1996 July       610.100          2.479      33.09790021
## 283    1996 August       594.881        -15.219      16.94120756
## 284 1996 September       513.262        -81.619     -65.61548509
## 285   1996 October       568.747         55.485     -11.06817774
## 286  1996 November       561.310         -7.437     -19.44287039
## 287  1996 December       598.136         36.826      16.44543696
## 288   1997 January       629.800         31.664      47.17174431
## 289  1997 February       563.287        -66.513     -20.27894834
## 290     1997 March       628.991         65.704      44.48735901
## 291     1997 April       603.780        -25.211      18.33866636
## 292       1997 May       642.251         38.471      55.87197370
## 293      1997 June       607.807        -34.444      20.49028105
## 294      1997 July       611.218          3.411      22.96358840
## 295    1997 August       566.988        -44.230     -22.20410425
## 296 1997 September       513.216        -53.772     -76.91379690
## 297   1997 October       581.276         68.060      -9.79148955
## 298  1997 November       526.469        -54.807     -65.53618220
## 299  1997 December       541.770         15.301     -51.17287485
## 300   1998 January       591.527         49.757      -2.35356750
## 301  1998 February       534.596        -56.931     -60.22226015
## 302     1998 March       585.349         50.753     -10.40695280
## 303     1998 April       550.089        -35.260     -46.60464545
## 304       1998 May       606.598         56.509       8.96666190
## 305      1998 June       538.497        -68.101     -60.07203075
## 306      1998 July       566.004         27.507     -33.50272340
## 307    1998 August       537.293        -28.711     -63.15141605
## 308 1998 September       487.115        -50.178    -114.26710870
## 309   1998 October       485.982         -1.133    -116.33780135
## 310  1998 November       456.090        -29.892    -147.16749400
## 311  1998 December       553.643         97.553     -50.55218665
## 312   1999 January       596.141         42.498      -8.99187930
## 313  1999 February       533.209        -62.932     -72.86157196
## 314     1999 March       564.568         31.359     -42.44026461
## 315     1999 April       551.660        -12.908     -56.28595726
## 316       1999 May       610.259         58.599       1.37535009
## 317      1999 June       571.957        -38.302     -37.86434256
## 318      1999 July       593.688         21.731     -17.07103521
## 319    1999 August       547.081        -46.607     -64.61572786
## 320 1999 September       482.169        -64.912    -130.46542051
## 321   1999 October       456.721        -25.448    -156.85111316
## 322  1999 November       492.909         36.188    -121.60080581
## 323  1999 December       515.281         22.372    -100.16649846
## 324   2000 January       505.154        -10.127    -111.23119111
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## 326     2000 March       558.010         58.047     -60.25057641
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## 328       2000 May       558.730         -9.800     -61.40596171
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## 330      2000 July       526.269         17.149     -95.74234701
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## 331    2000 August      503.692    -22.577  -119.25703966
## 332 2000 September      443.382    -60.310  -180.50473231
## 333    2000 October     468.220     24.838  -156.60442496
## 334    2000 November    482.871     14.651  -142.89111762
## 335    2000 December    477.789     -5.082  -148.91081027
## 336    2001 January     444.974    -32.815  -182.66350292
## 337    2001 February    404.073    -40.901  -224.50219557
## 338    2001 March       455.786     51.713  -173.72688822
## 339    2001 April       425.372    -30.414  -205.07858087
## 340    2001 May         435.524     10.152  -195.86427352
## 341    2001 June        454.623     19.099  -177.70296617
## 342    2001 July        436.074    -18.549  -197.18965882
## 343    2001 August      447.910     11.836  -186.29135147
## 344 2001 September      396.476    -51.434  -238.66304412
## 345    2001 October     409.925     13.449  -226.15173677
## 346    2001 November    401.777     -8.148  -235.23742942
## 347    2001 December    449.333     47.556  -188.61912207
## 348    2002 January     476.548     27.215  -162.34181472
## 349    2002 February    428.362    -48.186  -211.46550737
## 350    2002 March       459.471     31.109  -181.29420002
## 351    2002 April       488.519     29.048  -153.18389267
## 352    2002 May         527.657     39.138  -114.98358532
## 353    2002 June        533.580      5.923  -109.99827797
## 354    2002 July        525.255     -8.325  -119.26097062
## 355    2002 August      469.670    -55.585  -175.78366327
## 356 2002 September      431.903    -37.767  -214.48835593
## 357    2002 October     445.460     13.557  -201.86904858
## 358    2002 November    455.860     10.400  -192.40674123
## 359    2002 December    488.703     32.843  -160.50143388
## 360    2003 January     470.095    -18.608  -180.04712653
## 361    2003 February    437.341    -32.754  -213.73881918
## 362    2003 March       508.215     70.874  -143.80251183
## 363    2003 April       509.649      1.434  -143.30620448
## 364    2003 May         557.622     47.973   -96.27089713
## 365    2003 June        549.092     -8.530  -105.73858978
## 366    2003 July        524.624    -24.468  -131.14428243
## 367    2003 August      501.530    -23.094  -155.17597508
## 368 2003 September      447.121    -54.409  -210.52266773
## 369    2003 October     451.931      4.810  -206.65036038
## 370    2003 November    460.818      8.887  -198.70105303
## 371    2003 December    524.532     63.714  -135.92474568
## 372    2004 January     514.261    -10.271  -147.13343833
## 373    2004 February    474.103    -40.158  -188.22913098
## 374    2004 March       510.702     36.599  -152.56782363
## 375    2004 April       488.758    -21.944  -175.44951628
## 376    2004 May         522.609     33.851  -142.53620893
## 377    2004 June        531.796      9.187  -134.28690159
## 378    2004 July        523.871     -7.925  -143.14959424
## 379    2004 August      502.493    -21.378  -165.46528689
## 380 2004 September      479.402    -23.091  -189.49397954
## 381    2004 October     472.897     -6.505  -196.93667219
## 382    2004 November    484.754     11.857  -186.01736484
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## 385   2005 February          489.404          -47.641  -184.18044279
## 386      2005 March          524.509           35.105  -150.01313544
## 387      2005 April          514.356          -10.153  -161.10382809
## 388        2005 May          567.482           53.126  -108.91552074
## 389       2005 June          559.572           -7.910  -117.76321339
## 390       2005 July          561.855            2.283  -116.41790604
## 391     2005 August          514.673          -47.182  -164.53759869
## 392  2005 September          464.185          -50.488  -215.96329134
## 393    2005 October          475.830           11.645  -205.25598399
## 394   2005 November          484.914            9.084  -197.10967664
## 395   2005 December          527.174           42.260  -155.78736929
## 396    2006 January          590.899           63.725   -93.00006194
## 397   2006 February          529.246          -61.653  -155.59075459
## 398      2006 March          553.180           23.934  -132.59444724
## 399      2006 April          577.843           24.663  -108.86913990
## 400        2006 May          611.368           33.525   -76.28183255
## 401       2006 June          598.607          -12.761   -89.98052520
## 402       2006 July          568.581          -30.026  -120.94421785
## 403     2006 August          531.475          -37.106  -158.98791050
## 404  2006 September          478.101          -53.374  -213.29960315
## 405    2006 October          489.377           11.276  -202.96129580
## 406   2006 November          515.816           26.439  -177.45998845
## 407   2006 December          542.022           26.206  -152.19168110
## 408    2007 January          592.181           50.159  -102.97037375
## 409   2007 February          488.023         -104.158  -208.06606640
## 410      2007 March          574.791           86.768  -122.23575905
## 411      2007 April          566.548           -8.243  -131.41645170
## 412        2007 May          594.245           27.697  -104.65714435
## 413       2007 June          555.788          -38.457  -144.05183700
## 414       2007 July          562.071            6.283  -138.70652965
## 415     2007 August          542.083          -19.988  -159.63222230
## 416  2007 September          483.353          -58.730  -219.29991495
## 417    2007 October          500.628           17.275  -202.96260760
## 418   2007 November          503.204            2.576  -201.32430025
## 419   2007 December          547.833           44.629  -157.63299290
## 420    2008 January          597.581           49.748  -108.82268556
## 421   2008 February          542.230          -55.351  -165.11137821
## 422      2008 March          604.443           62.213  -103.83607086
## 423      2008 April          607.253            2.810  -101.96376351
## 424        2008 May          668.828           61.575   -41.32645616
## 425       2008 June          675.520            6.692   -35.57214881
## 426       2008 July          646.308          -29.212   -65.72184146
## 427     2008 August          599.263          -47.045  -113.70453411
## 428  2008 September          531.982          -67.281  -181.92322676
## 429    2008 October          552.180           20.198  -162.66291941
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## 433   2009 February          545.270          -81.446  -173.32369001
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## 435      2009 April          651.335           25.986   -69.13407531
## 436        2009 May          693.227           41.892   -28.17976796
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## 439    2009 August       618.110        -27.612   -106.10984591
## 440 2009 September       570.982        -47.128   -154.17553856
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## 461       2011 June      837.531         -8.257     92.68191578
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## 465    2011 October      720.149         30.496    -28.45085483
## 466    2011 November     748.063         27.914     -1.47454748
## 467    2011 December     780.498         32.435     30.02275987
## 468    2012 January      773.864         -6.634     22.45106722
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## 470      2012 March      797.646        101.685     44.35768192
## 471      2012 April      770.990        -26.656     16.76398927
## 472        2012 May      813.258         42.268     58.09429662
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## 486       2013 July      825.780         -7.987     57.48859951
## 487     2013 August      753.265        -72.515    -15.96409314
## 488 2013 September       708.180        -45.085    -61.98678579
## 489    2013 October      751.340         43.160    -19.76447844
## 490    2013 November     769.765         18.425     -2.27717109
## 491    2013 December     806.710         36.945     33.73013626
## 492    2014 January      832.071         25.361     58.15344361
```

```
## 493   2014 February    715.293   -116.778   -59.56224904
## 494      2014 March    867.440    152.147    91.64705831
## 495      2014 April    874.973      7.533    98.24236566
## 496        2014 May    872.186     -2.787    94.51767301
## 497       2014 June    870.396     -1.790    91.78998036
## 498       2014 July    837.457    -32.939    57.91328771
## 499     2014 August    769.384    -68.073   -11.09740494
## 500  2014 September    724.546    -44.838   -56.87309759
## 501    2014 October    775.083     50.537    -7.27379024
## 502   2014 November    819.811     44.728    36.51651711
## 503   2014 December    839.005     19.194    54.77282446
## 504    2015 January    832.216     -6.789    47.04613181
## 505   2015 February    774.095    -58.121   -12.01256084
## 506      2015 March    840.618     66.523    53.57274650
## 507      2015 April    836.982     -3.636    48.99905385
## 508        2015 May    830.355     -6.627    41.43436120
## 509       2015 June    795.456    -34.899     5.59766855
## 510       2015 July    821.508     26.052    30.71197590
## 511     2015 August    795.294    -26.214     3.56028325
## 512  2015 September    745.604    -49.690   -47.06740940
## 513    2015 October    778.142     32.538   -15.46710205
## 514   2015 November    829.956     51.814    35.40920530
## 515   2015 December    885.702     55.746    90.21751265
## 516    2016 January    878.466     -7.236    82.04382000
## 517   2016 February    866.911    -11.555    69.55112735
## 518      2016 March    945.574     78.663   147.27643470
## 519      2016 April    895.645    -49.929    96.40974205
## 520        2016 May    906.373     10.728   106.20004940
## 521       2016 June    863.121    -43.252    62.01035675
## 522       2016 July    874.581     11.460    72.53266410
## 523     2016 August    827.092    -47.489    24.10597145
## 524  2016 September    792.546    -34.546   -11.37772120
## 525    2016 October    839.768     47.222    34.90658615
## 526   2016 November    840.573      0.805    34.77389350
## 527   2016 December    946.715    106.142   139.97820084
## 528    2017 January    931.662    -15.053   123.98750819
## 529   2017 February    878.646    -53.016    70.03381554
## 530      2017 March   1031.122    152.476   221.57212289
## 531      2017 April   1002.382    -28.740   191.89443024
## 532        2017 May   1039.891     37.509   228.46573759
## 533       2017 June    994.362    -45.529   181.99904494
## 534       2017 July    928.982    -65.380   115.68135229
## 535     2017 August    874.484    -54.498    60.24565964
## 536  2017 September    849.394    -25.090    34.21796699
## 537    2017 October    904.788     55.394    88.67427434
## 538   2017 November    896.119     -8.669    79.06758169
## 539   2017 December    927.670     31.551   109.68088904
## 540    2018 January    976.929     49.259   158.00219639
## 541   2018 February    922.932    -53.997   103.06750374
## 542      2018 March   1017.194     94.262   196.39181109
## 543      2018 April   1024.178      6.984   202.43811844
## 544        2018 May   1054.663     30.485   231.98542579
## 545       2018 June   1033.802    -20.861   210.18673314
## 546       2018 July    948.984    -84.818   124.43104049
```

28

```
## 547    2018 August     953.714         4.730   128.22334784
## 548 2018 September     872.342       -81.372    45.91365519
## 549    2018 October    909.450        37.108    82.08396253
## 550   2018 November    913.361         3.911    85.05726988
## 551   2018 December    952.043        38.682   122.80157723
## 552    2019 January    952.661         0.618   122.48188458
## 553   2019 February    882.918       -69.743    51.80119193
## 554      2019 March    999.795       116.877   167.74049928
## 555      2019 April   1039.700        39.905   206.70780663
## 556        2019 May   1073.754        34.054   239.82411398
## 557       2019 June   1009.869       -63.885   175.00142133
## 558       2019 July    998.272       -11.597   162.46672868
## 559     2019 August    952.554       -45.718   115.81103603
## 560 2019 September     912.470       -40.084    74.78934338
## 561    2019 October    941.536        29.066   102.91765073
## 562   2019 November    912.051       -29.485    72.49495808
## 563   2019 December    951.898        39.847   111.40426543
## 564    2020 January    981.404        29.506   139.97257278
## 565   2020 February    985.297         3.893   142.92788013
## 566      2020 March    995.239         9.942   151.93218748
## 567      2020 April    922.997       -72.242    78.75249483
## 568        2020 May   1021.471        98.474   176.28880218
## 569       2020 June   1038.836        17.365   192.71610953
## 570       2020 July    995.034       -43.802   147.97641687
## 571     2020 August    954.931       -40.103   106.93572422
## 572 2020 September     884.571       -70.360    35.63803157
## 573    2020 October    938.501        53.930    88.63033892
## 574   2020 November    980.632        42.131   129.82364627
## 575   2020 December    984.504         3.872   132.75795362
## 576    2021 January    996.592        12.088   143.90826097
## 577   2021 February    873.844      -122.748    20.22256832
## 578      2021 March   1096.067       222.223   241.50787567
## 579      2021 April   1053.848       -42.219   198.35118302
## 580        2021 May   1112.084        58.236   255.64949037
## 581       2021 June   1039.772       -72.312   182.39979772
## 582       2021 July   1001.086       -38.686   142.77610507
## 583     2021 August   1015.449        14.363   156.20141242
## 584 2021 September     972.447       -43.002   112.26171977
## 585    2021 October   1006.560        34.113   145.43702712
## 586   2021 November   1040.253        33.693   178.19233447
## 587   2021 December   1118.251        77.998   255.25264182
## 588    2022 January   1130.434        12.183   266.49794917
## 589   2022 February   1071.921       -58.513   207.04725652
## 590      2022 March   1209.837       137.916   344.02556387
## 591      2022 April   1176.084       -33.753   309.33487121
## 592        2022 May   1219.656        43.572   351.96917856
## 593       2022 June   1187.064       -32.592   318.43948591
## 594       2022 July   1132.137       -54.927   262.57479326
## 595     2022 August   1043.955       -88.182   173.45510061
## 596 2022 September     976.813       -67.142   105.37540796
```

Q4

Using ggplot() create a line plot that shows the three series together. Make sure you add a legend to the plot.

```
ed_1 <- chart %>%
    separate(Month, c('year', 'month'))

my_date_chart <- paste(ed_1[,2],ed_1[,1],sep="-")
my_date_chart <- my(my_date_chart)
my_date_chart
```

```
##   [1] "1973-02-01" "1973-03-01" "1973-04-01" "1973-05-01" "1973-06-01"
##   [6] "1973-07-01" "1973-08-01" "1973-09-01" "1973-10-01" "1973-11-01"
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```
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## [596] "2022-09-01"
```

```r
colors <- c("Original Data" = "blue",
            "Differenced Data" = "orange",
            "Detrended Data" = "pink")

ggplot(chart, aes(x = my_date_chart)) +
  geom_line(aes(y = chart[,2], col = "Original Data")) +
  geom_line(aes(y = chart[,3], col = "Differenced Data"))+
  geom_line(aes(y = chart[,4], col = "Detrended Data")) +
  ylab("Energy Production") +
  xlab("Date") +
  scale_color_manual (
    name = "Time Series",
    values = colors)
```
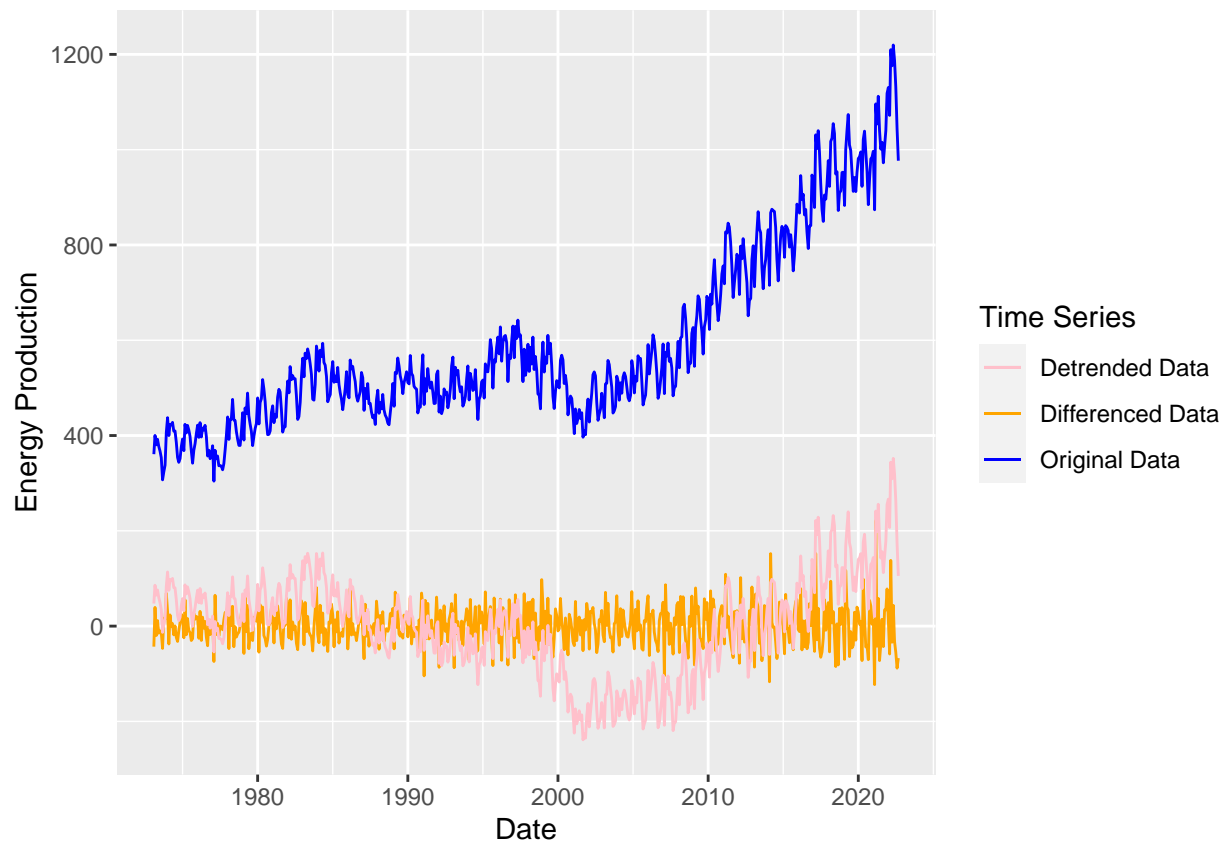
Q5

Plot the ACF for the three series and compare the plots. Add the argument `ylim=c(-0.5,1)` to the Acf() function to make sure all three y axis have the same limits. Which method do you think was more efficient in eliminating the trend? The linear regression or differencing?

```
for(i in 1){
  par(mfrow=c(1,3))  #place plot side by side
  Acf(ts_energy_data2[,2],lag.max=40,main=paste0("Origional series"),ylim=c(-0.5,1))
  Acf(Difference_energy_data1,lag.max=40,main=paste0("Difference data"),ylim=c(-0.5,1))
  Acf(detrend_renewable_data2,lag.max=40,main=paste0("Detrended data"),ylim=c(-0.5,1))
}
```

Origional series	Difference data	Detrended data
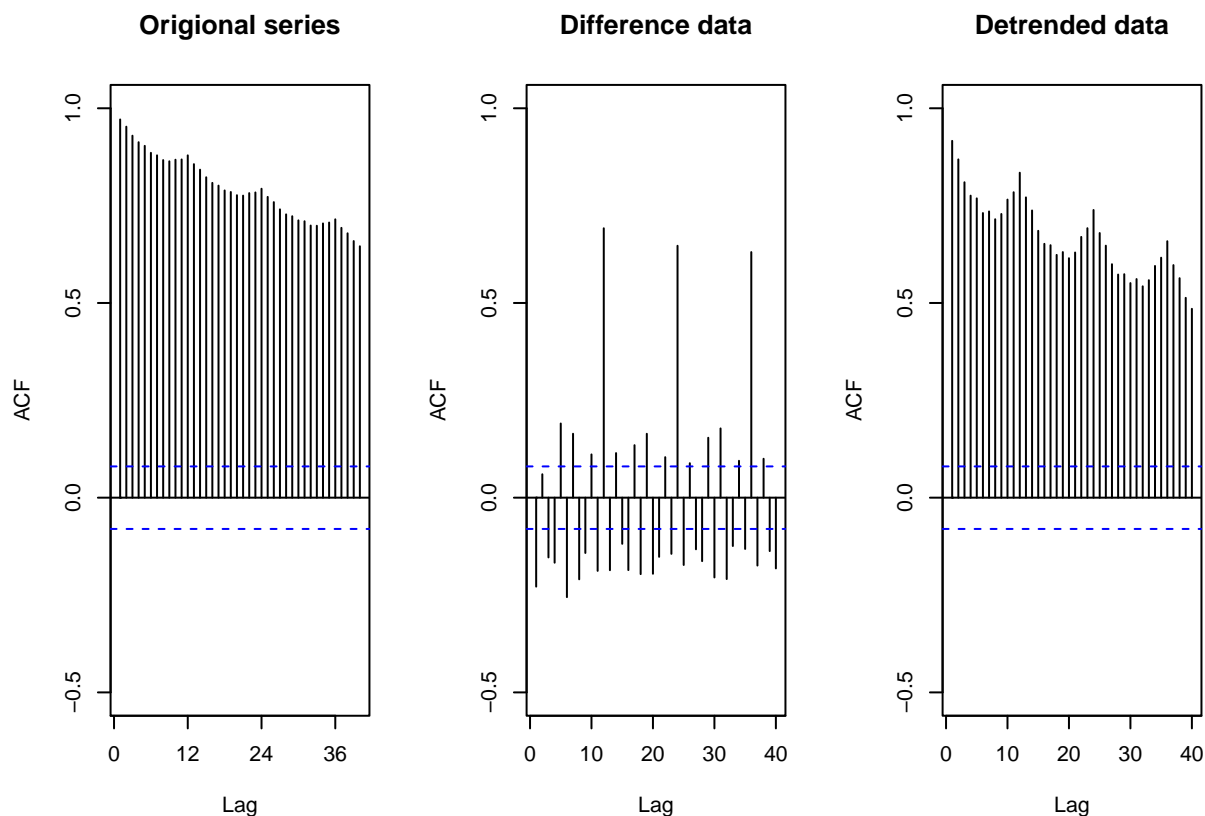
Differencing is the most efficient method in eliminating the trend. Based on diagrams, there are no obvious trend in differenced data. However, there are obvious downward trends in original series and detrended data.

Q6

Compute the Seasonal Mann-Kendall and ADF Test for the original "Total Renewable Energy Production" series. Ask R to print the results. Interpret the results for both test. Whats the conclusion from the Seasonal Mann Kendall test? What's the conclusion for the ADF test? Do they match what you observed in Q2? Recall that having a unit root means the series has a stochastic trend. And when a series has stochastic trend we need to use a different procedure to remove the trend.

```
SMKtest <- SeasonalMannKendall(ts_energy_data1[,2])
print("Results for Seasonal Mann Kendall /n")
```

```
## [1] "Results for Seasonal Mann Kendall /n"
```

```
print(summary(SMKtest))
```

```
## Score =  10577 , Var(Score) = 169001
## denominator =  14553
## tau = 0.727, 2-sided pvalue =< 2.22e-16
## NULL
```

The p-value here is smaller than 0.05, therefore, it is statistically significant and the null hypothesis is rejected. There is trend in the data. Answer matches with what I observed in Q2, because all p-value are smaller than 0.05. Both of them are significant.

```
print(adf.test(ts_energy_data1[,2], alternative = "stationary"))
```

```
##
##  Augmented Dickey-Fuller Test
##
```

```
## data:  ts_energy_data1[, 2]
## Dickey-Fuller = -1.2055, Lag order = 8, p-value = 0.9056
## alternative hypothesis: stationary
```

The p-value here is bigger than 0.05, therefore, the null hypothesis cannot be rejected. The time series is not stationary and with a unit root. Answer do not match with what I observed in Q2, because one p-value is smaller than 0.05 and the other one is bigger than 0.05.

Q7

Aggregate the original "Total Renewable Energy Production" series by year. You can use the same procedure we used in class. Store series in a matrix where rows represent months and columns represent years. And then take the columns mean using function colMeans(). Recall the goal is the remove the seasonal variation from the series to check for trend.

```
iHP=1
energy_data_matrix <- matrix(ts_energy_data1[,2],byrow=FALSE,nrow=12)

## Warning in matrix(ts_energy_data1[, 2], byrow = FALSE, nrow = 12): data length
## [597] is not a sub-multiple or multiple of the number of rows [12]

energy_data_yearly <- colMeans(energy_data_matrix)
```

Q8

Apply the Mann Kendal, Spearman correlation rank test and ADF. Are the results from the test in agreement with the test results for the non-aggregated series, i.e., results for Q6?

```
print(summary(MannKendall(energy_data_yearly)))

## Score =  905 , Var(Score) = 14291.67
## denominator =  1225
## tau = 0.739, 2-sided pvalue =< 2.22e-16
## NULL
```

The p-value here is smaller than 0.05, therefore, it is statistically significant and the null hypothesis is rejected. There is trend in the data. The result here is same with Q6.

```
my_date1 <- my_date[1:597]
library(dplyr)
my_year1 <- c(year(first(my_date1)):year(last(my_date1)))
sp_rho=cor.test(energy_data_yearly,my_year1,method="spearman")
print(sp_rho)

##
##  Spearman's rank correlation rho
##
## data:  energy_data_yearly and my_year1
## S = 2568, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.8766867
```

The p-value here is smaller than 0.05, therefore, it is statistically significant and the null hypothesis is rejected. There is trend in the data.

```
print(adf.test(energy_data_yearly, alternative = "stationary"))
```

```
## 
##  Augmented Dickey-Fuller Test
## 
## data:  energy_data_yearly
## Dickey-Fuller = -1.6251, Lag order = 3, p-value = 0.7247
## alternative hypothesis: stationary
```

The p-value here is bigger than 0.05, therefore, the null hypothesis cannot be rejected. The time series is not stationary and with a unit root. The result here is same with Q6.