

# ChulwalarStudy

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## Introduction

The Prime Minister of Chulwalar personally invited aspiring SMU Data Scientist Students Randy Lisbona and Christopher Farrar to analyze and forecast the islands export data for the year 2015. Randy and Chris were granted access to the islands economic data and chief statistical scientist, in order to answer the following questions.

1. What is the best model for the export data and how we define the best?
2. Which forecast model is the best fit and how we define it
3. All of the different models we could consider could be useful or good. How do we choose among equally good models

## Analysis steps -Import the data

The source files provided by the Chulwalar department of statistical analysis and forecasting were imported into R 3.3.1 for time series analysis, These files were current as of July 18, 2016, reflecting Chulwalar exports data as of December 2015

1. ImportedAsIsDataChulwalar.csv
2. ImportedPlanDataChulwalar.csv
3. ImportedIndicatorsChulwalar.csv

## Transform data into time series

In order to be able to work with the partial data sets later, these need to be split into individual vectors and converted into times series. 1. For details on time series conversion please refer to source file “./Analysis/TransformToTimeseries.R”

## Basic data analysis

### Correlation between As Is and Plan Data

Initial analysis involved checking correlation between As Is and Plan data in order to test how exact the planning is. 1. Correlation is a measure of linear relationship between two variables. 2. The Chulwalar department of statistical analysis and forecasting has done a commendable job in developing the Plan Data!

Table 1: Correlation between As and Plan data

| type                | corr |
|---------------------|------|
| TotalAsIs-TotalPlan | 0.92 |
| EfakAsIs-EfakPlan   | 0.91 |
| WugeAsIs-WugePlan   | 0.88 |

| type                        | corr |
|-----------------------------|------|
| TotalEtelAsIs-TotalEtelPlan | 0.92 |
| BlueEtelAsIs-BlueEtelPlan   | 0.80 |
| RedEtelAsIs-RedEtelPlan     | 0.91 |
| YearAsIs-YearPlan           | 0.96 |

The results show a very high planning accuracy.

```
##
## Call:
## lm(formula = TotalAsIs ~ TotalPlan, data = TotalAsIs)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -770214 -196776   26017  182579  672705
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 8.959e+04  1.521e+05   0.589   0.558
## TotalPlan   9.627e-01  4.959e-02  19.413 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 332600 on 70 degrees of freedom
## Multiple R-squared:  0.8433, Adjusted R-squared:  0.8411
## F-statistic: 376.9 on 1 and 70 DF,  p-value: < 2.2e-16

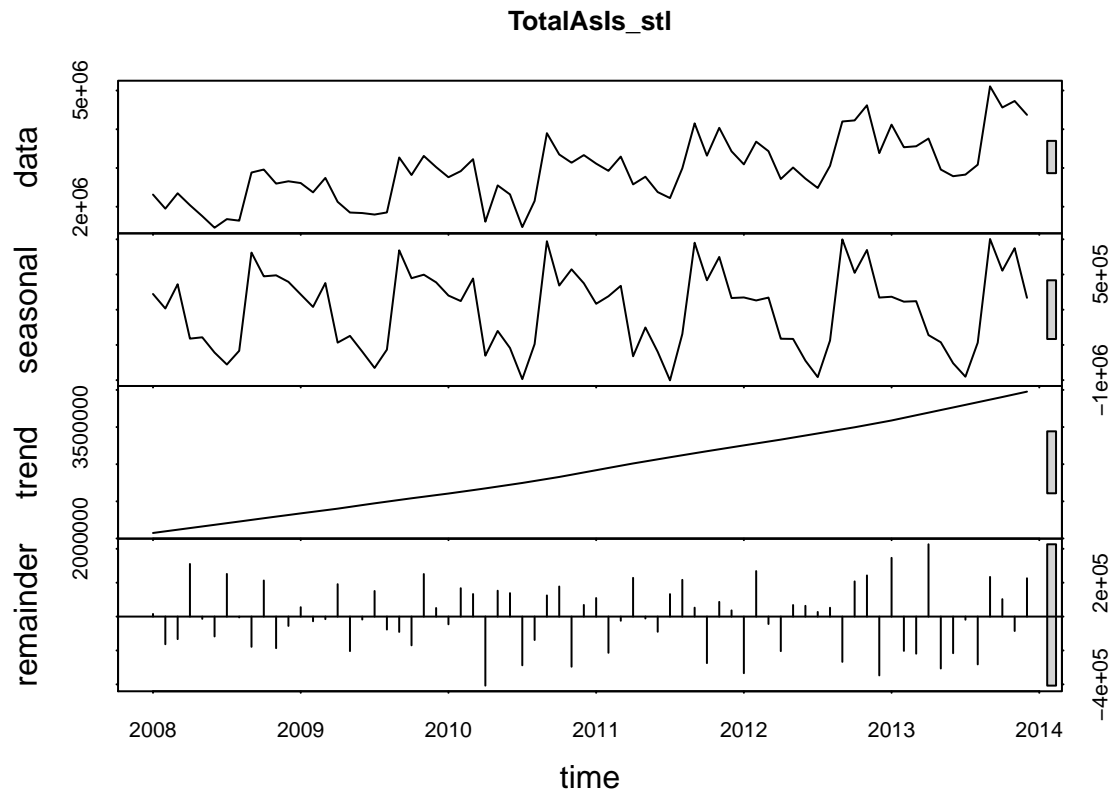
##
## Call:
## tslm(formula = TotalAsIs ~ TotalPlan, data = TotalAsIs)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -770214 -196776   26017  182579  672705
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 8.959e+04  1.521e+05   0.589   0.558
## TotalPlan   9.627e-01  4.959e-02  19.413 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 332600 on 70 degrees of freedom
## Multiple R-squared:  0.8433, Adjusted R-squared:  0.8411
## F-statistic: 376.9 on 1 and 70 DF,  p-value: < 2.2e-16
```

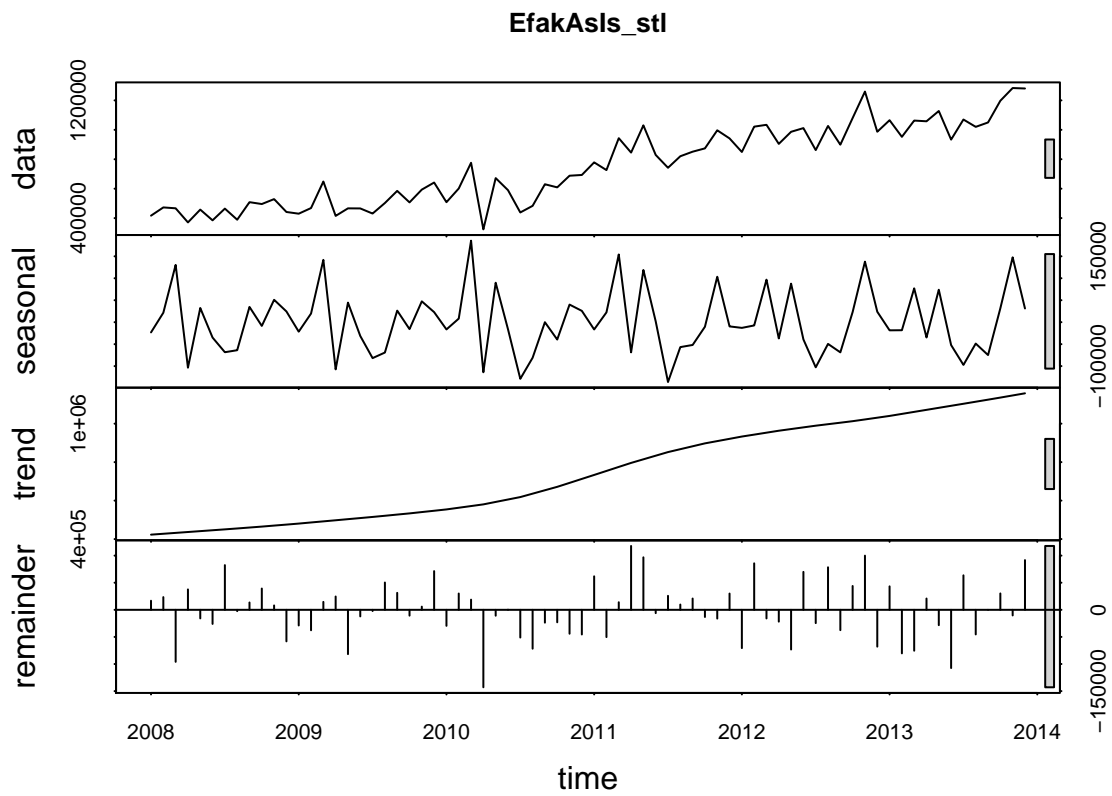
## STL function (Seasonal Decomposition of Time Series by LOESS)

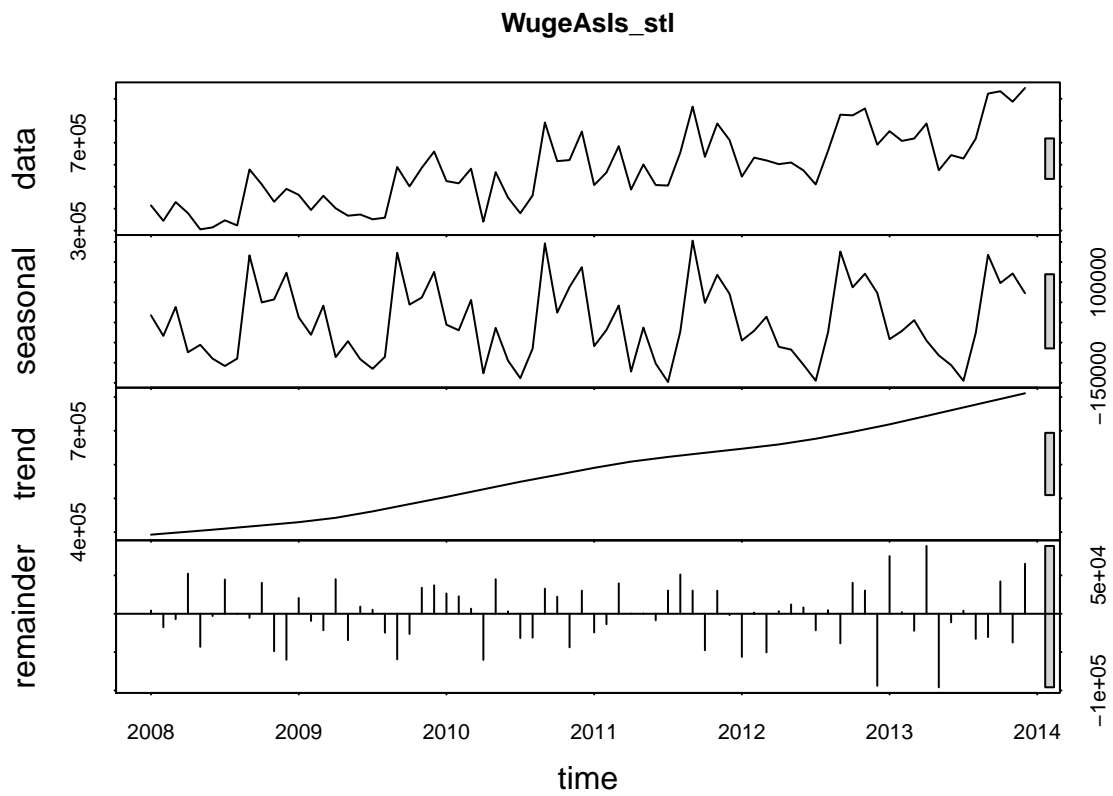
`r.stl()` was used to separate the trend, seasonality and remainder (remaining coincidental) components from one another.

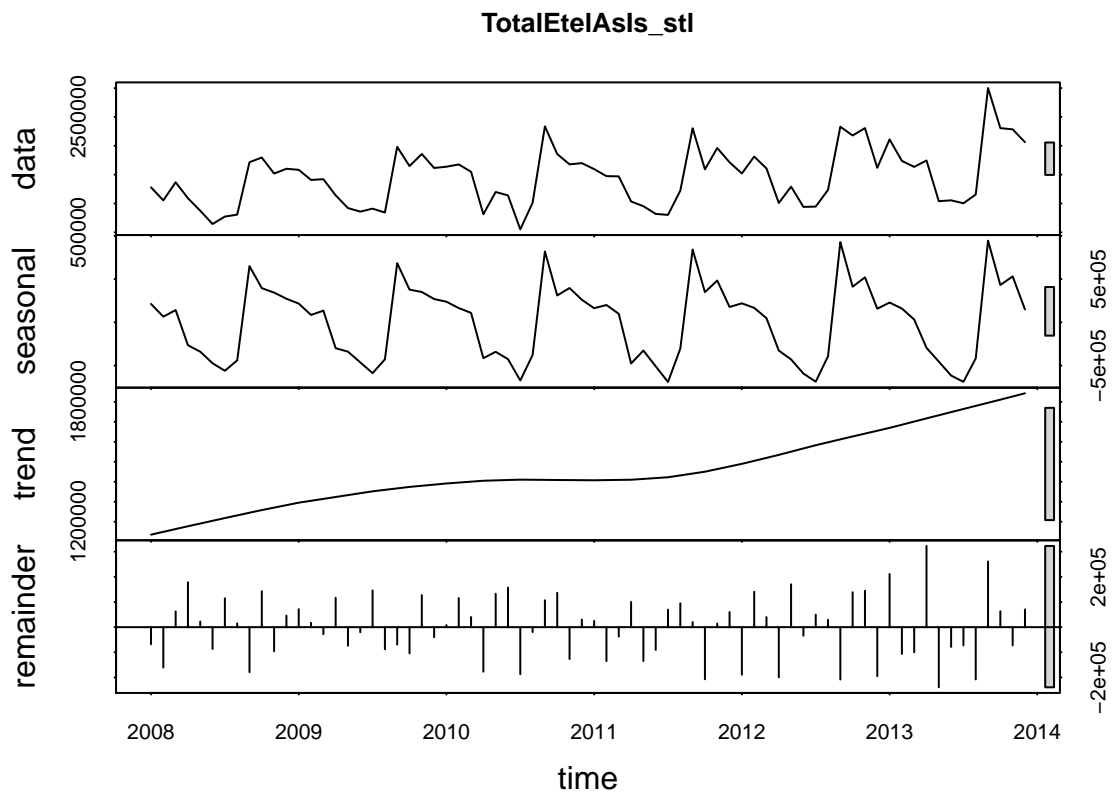
1. The individual time series can be shown graphically and tabularly.
2. The trend of the total exports is almost linear.

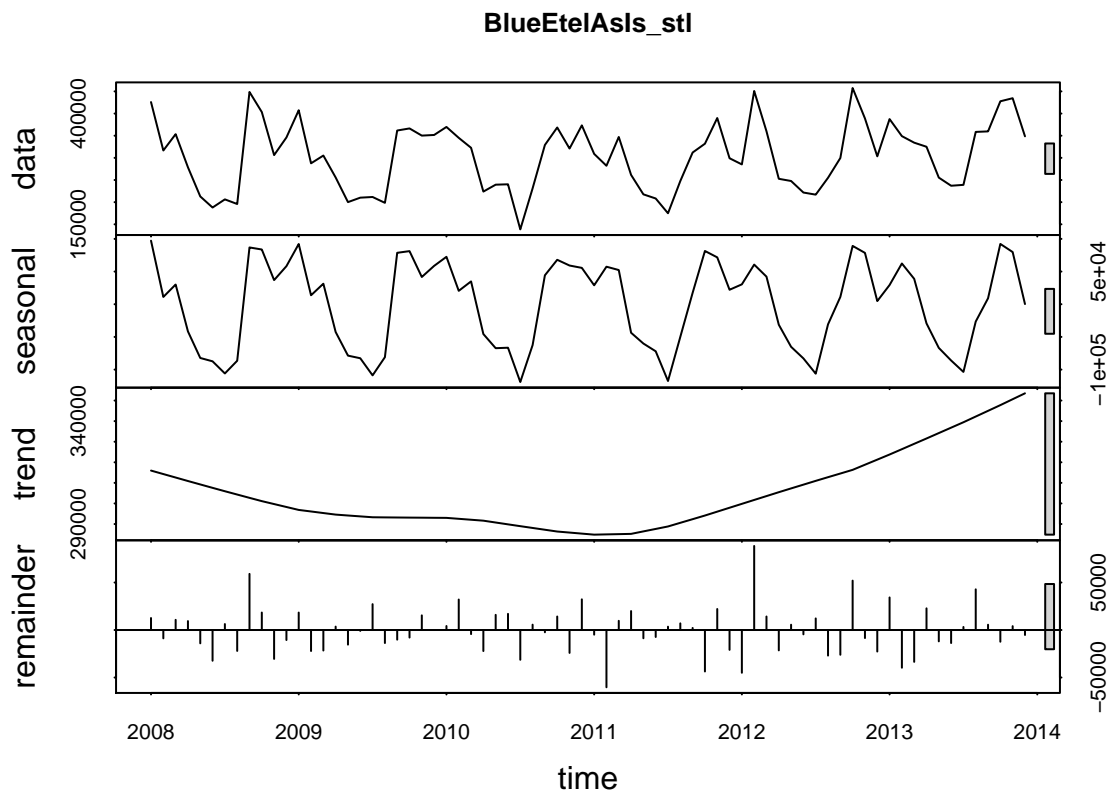
3. A relatively uniform seasonality can be seen.

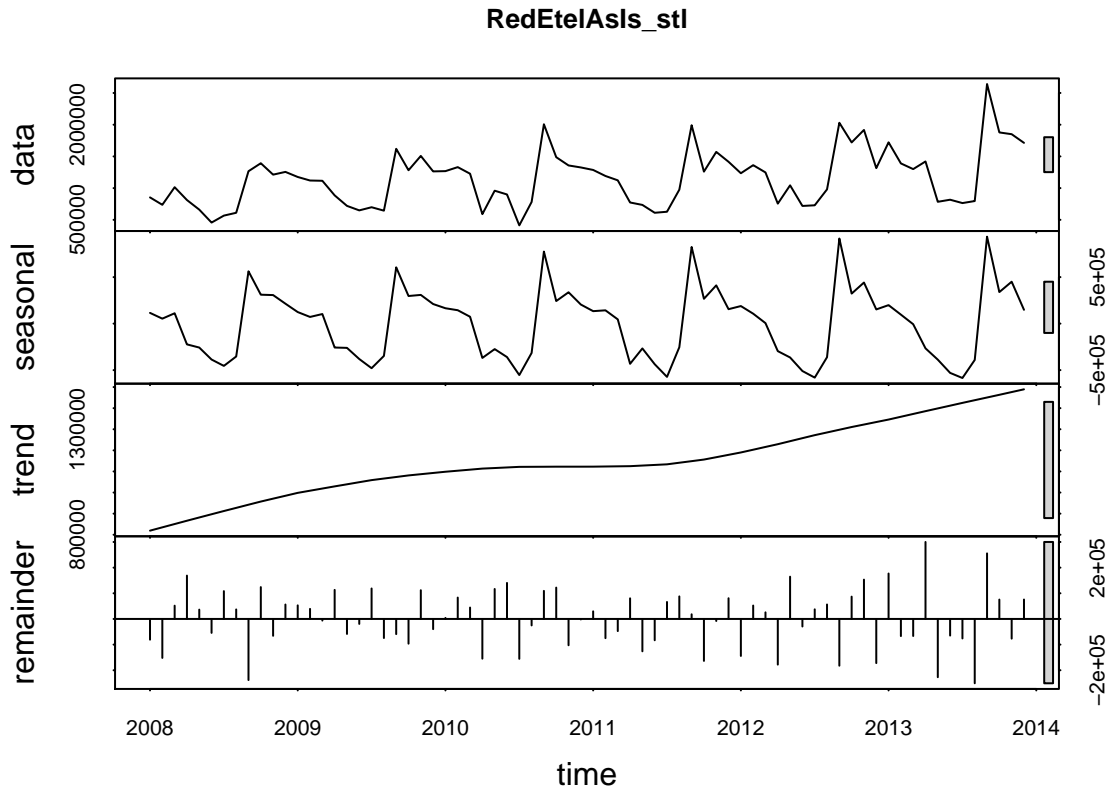






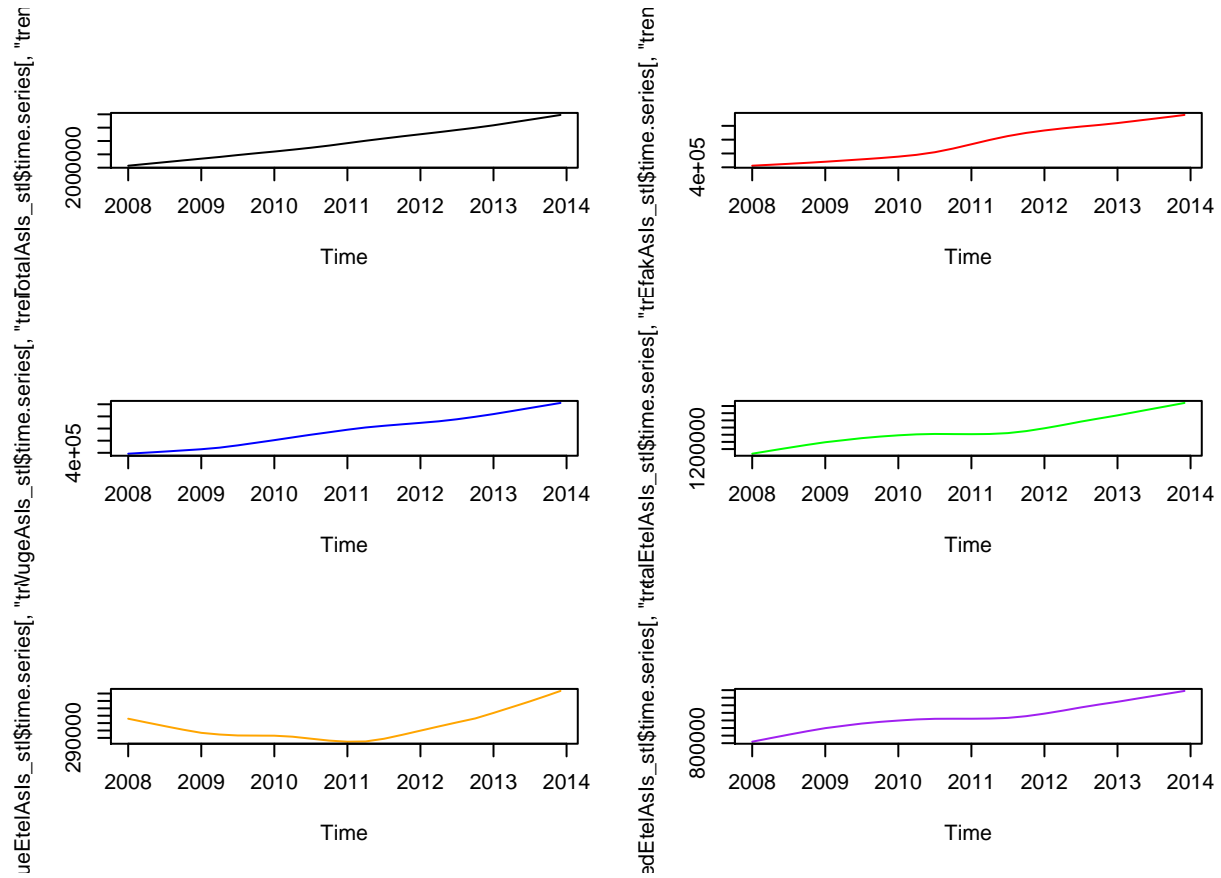






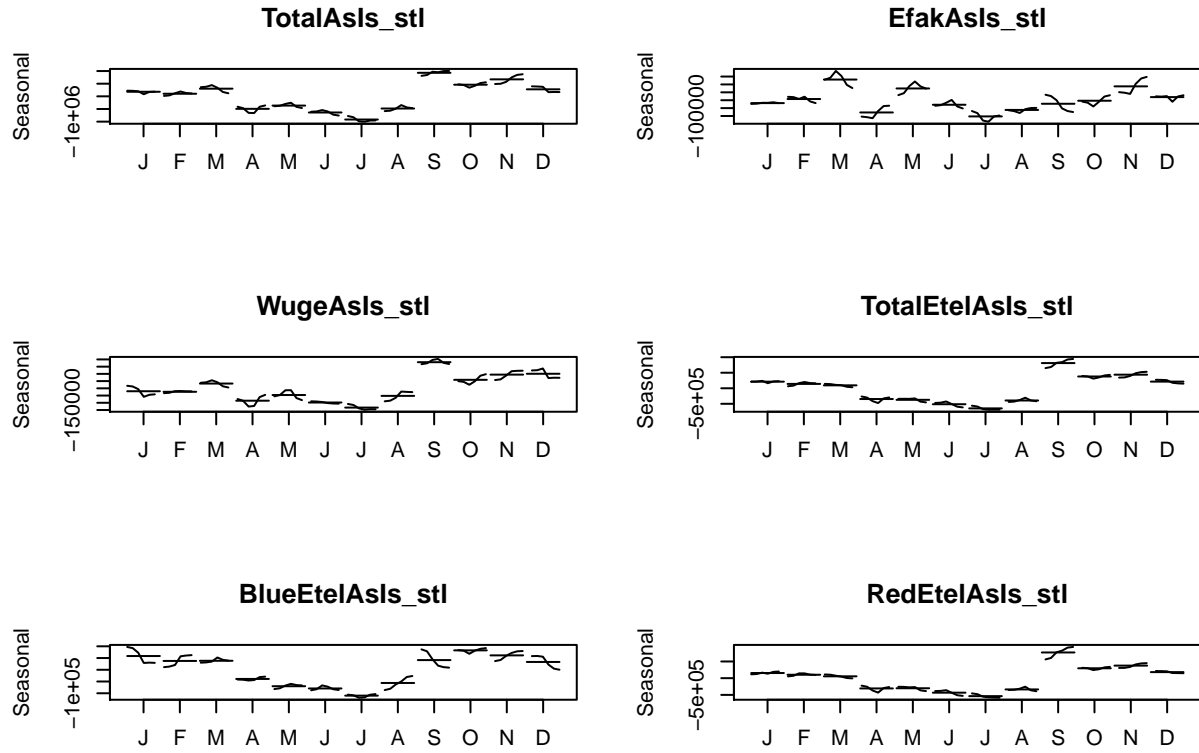
It is interesting to note that the almost linear trend is not seen in the individual segments. The individual trends run partially in opposite directions in the middle of the time scale, which causes the linear trend in the total As Is data.





## Modify seasonal component to a monthly base

The modification of the seasonality component can also be changed into a monthly view. It only makes sense to do this if the seasonality component as the trend looks almost identical and the remainder is then randomly spread.



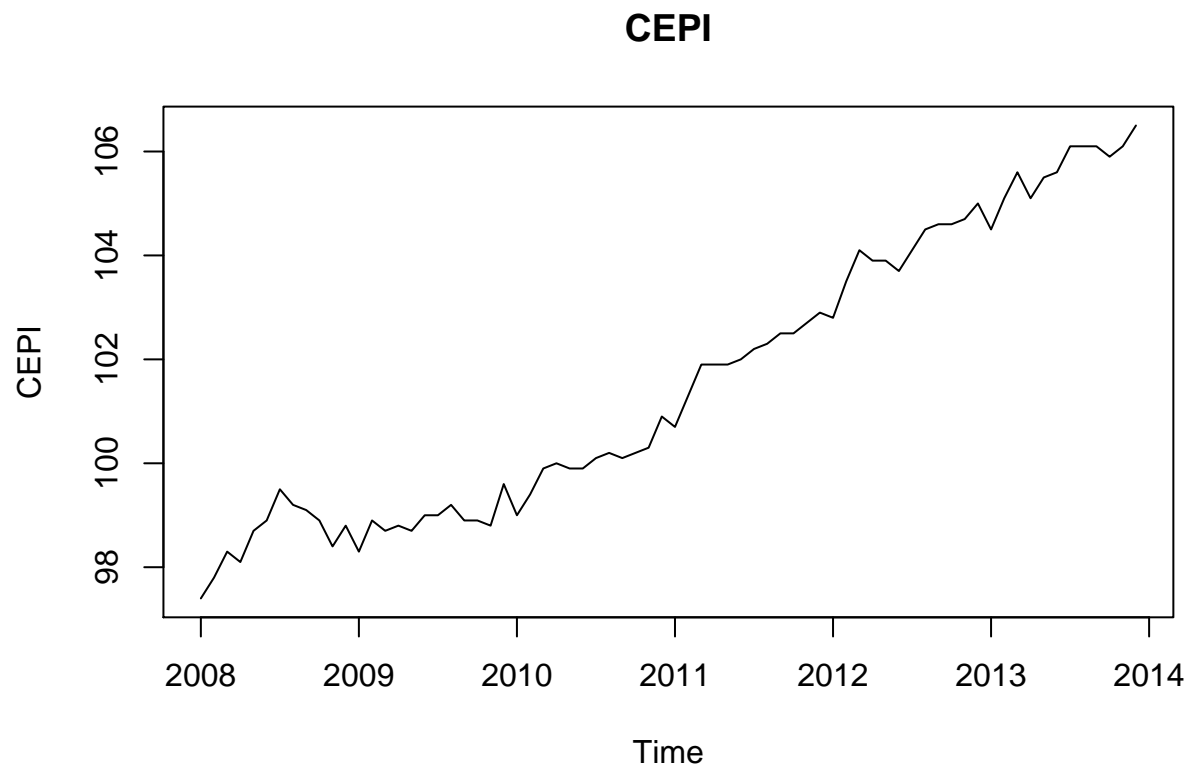
## Correlation with external indicators

The indicators are as follows:

- Monthly Change in Export Price Index (CEPI)
- Monthly Satisfaction Index (SI) government based data
- Average monthly temperatures in Chulwalar
- Monthly births in Chulwalar
- Monthly Satisfaction Index (SI) external index
- Yearly Exports from Urbano
- Yearly number of Globalisation Party members in Chulwalar
- Monthly Average Export Price Index for Chulwalar
- Monthly Producer Price Index (PPI) for Etel in Chulwalar
- National Holidays
- Chulwalar Index (Total value of all companies in Chulwalar)
- Monthly Inflation rate in Chulwalar
- Proposed spending for National Holidays
- Influence of National Holiday

The indicators will be converted into individual vectors and subsequently converted into time series. The correlation of the indicators will then be tested against the As Is exports for Chulwalar.

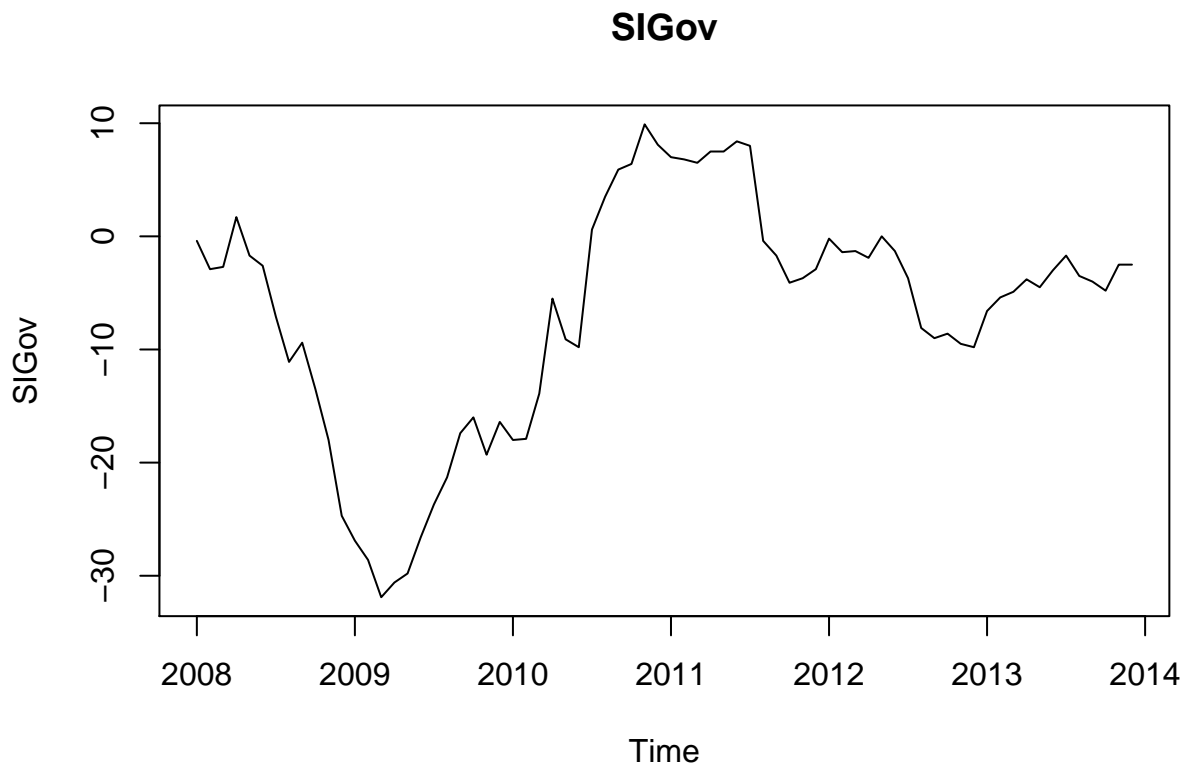
## Monthly Change in Export Price Index (CEPI)



```
## [1] 0.663925
## [1] 0.9303543
## [1] 0.7618551
## [1] 0.339713
## [1] 0.1448837
## [1] 0.3587646
```

## Monthly Satisfaction Index (SI) government based data

```
SIGovVector <- c(ImportedIndicators[16:27,2],ImportedIndicators[16:27,3],ImportedIndicators[16:27,4],Imp
SIGov <- ts(SIGovVector , start=c(2008,1), end=c(2013,12), frequency=12)
plot(SIGov, main="SIGov")
```



```
cor(TotalAsIs, SIGov)
```

```
## [1] 0.2007768
```

```
cor(EfakAsIs , SIGov)
```

```
## [1] 0.37934
```

```
cor(WugeAsIs, SIGov)
```

```
## [1] 0.3030266
```

```
cor(TotalEtelAsIs, SIGov)
```

```
## [1] 0.002556094
```

```
cor(BlueEtelAsIs , SIGov)
```

```
## [1] -0.04146932
```

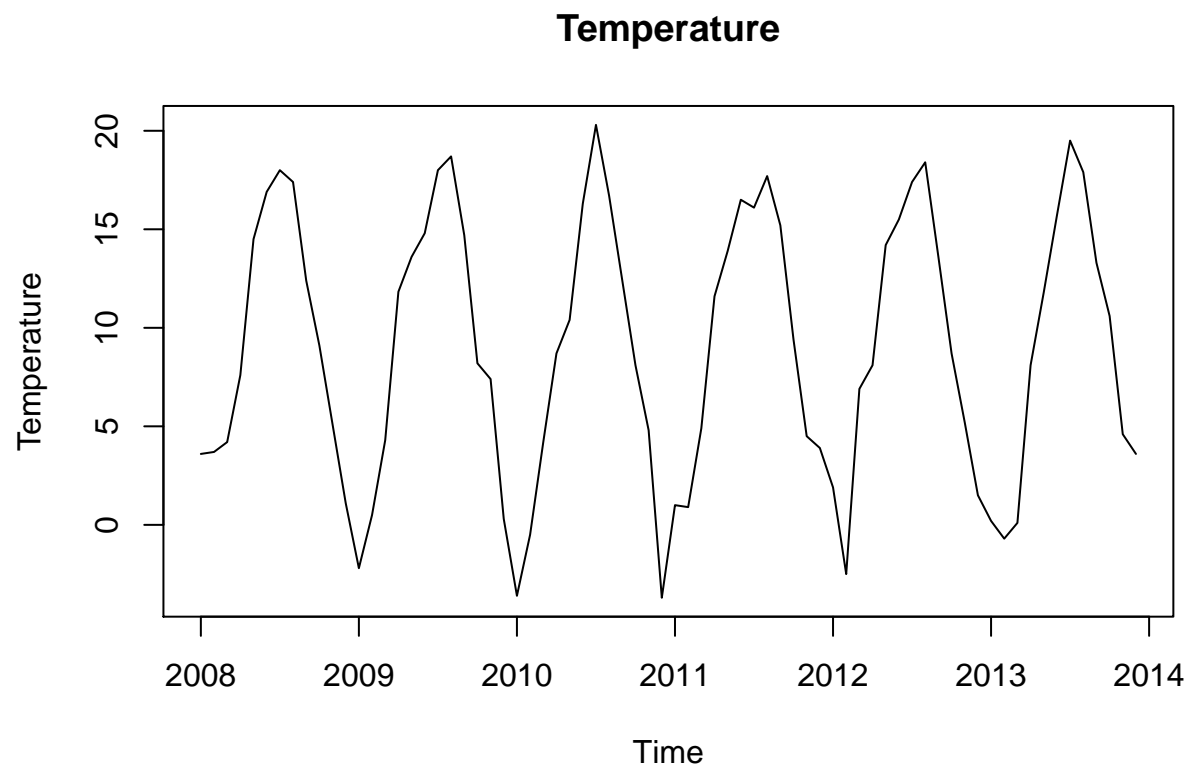
```
cor(RedEtelAsIs , SIGov)
```

```
## [1] 0.009978415
```

## Average monthly temperatures in Chulwalar

```
TemperatureVector <- c(ImportedIndicators[30:41,2],ImportedIndicators[30:41,3],ImportedIndicators[30:41,4])
Temperature <- ts(TemperatureVector, start=c(2008,1), end=c(2013,12), frequency=12)
```

```
plot(Temperature, main="Temperature")
```



```
cor(TotalAsIs, Temperature)
```

```
## [1] -0.3429684
```

```
cor(EfakAsIs , Temperature)
```

```
## [1] -0.07951179
```

```
cor(WugeAsIs, Temperature)
```

```
## [1] -0.2045082
```

```
cor(TotalEtelAsIs, Temperature)
```

```
## [1] -0.453138
```

```
cor(BlueEtelAsIs , Temperature)
```

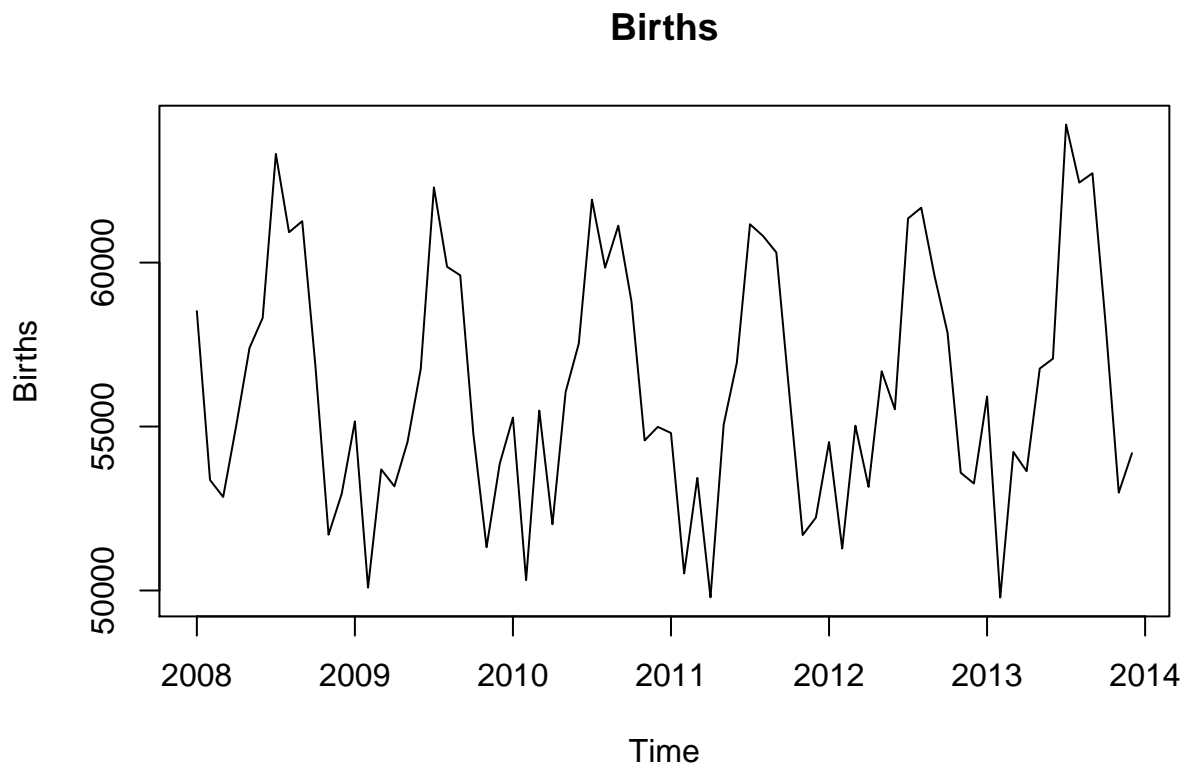
```
## [1] -0.6356067
```

```
cor(RedEtelAsIs , Temperature)
```

```
## [1] -0.4028941
```

## Monthly births in Chulwalar

```
BirthsVector <- c(ImportedIndicators[44:55,2],ImportedIndicators[44:55,3],ImportedIndicators[44:55,4],I
Births <- ts(BirthsVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(Births, main="Births")
```



```
cor(TotalAsIs, Births)
```

```
## [1] -0.1190228
```

```
cor(EfakAsIs , Births)
```

```
## [1] -0.05802961
```

```
cor(WugeAsIs, Births)
```

```
## [1] -0.007371339
```

```
cor(TotalEtelAsIs, Births)
```

```
## [1] -0.1504242
```

```
cor(BlueEtelAsIs , Births)
```

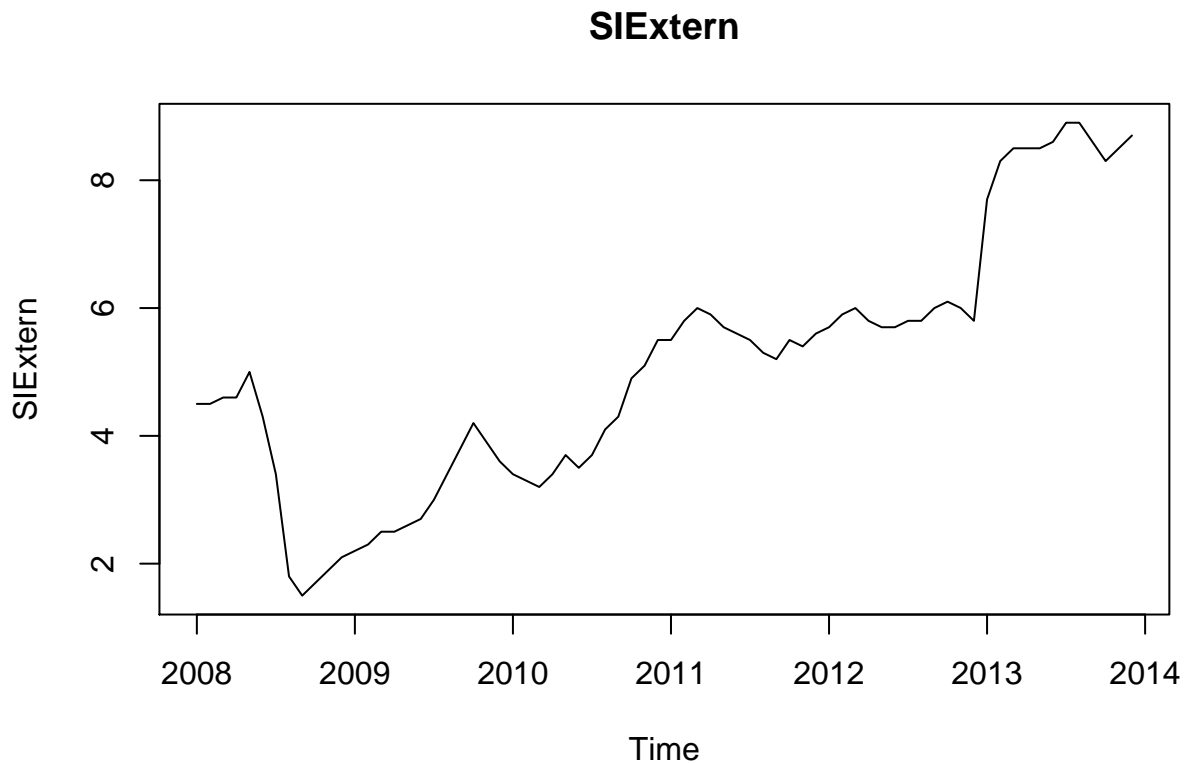
```
## [1] -0.2812913
```

```
cor(RedEtelAsIs , Births)
```

```
## [1] -0.1217222
```

## Monthly Satisfaction Index (SI) external index

```
SIExternVector <- c(ImportedIndicators[58:69,2],ImportedIndicators[58:69,3],ImportedIndicators[58:69,4])
SIExtern <- ts(SIExternVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(SIExtern, main="SIExtern")
```



```
cor(TotalAsIs, SIExtern)
```

```
## [1] 0.5883122
```

```
cor(EfakAsIs , SIExtern)
```

```
## [1] 0.8358147
```

```
cor(WugeAsIs, SIExtern)
```

```
## [1] 0.6786552
```

```
cor(TotalEtelAsIs, SIExtern)
```

```
## [1] 0.2865672
```

```
cor(BlueEtelAsIs , SIExtern)
```

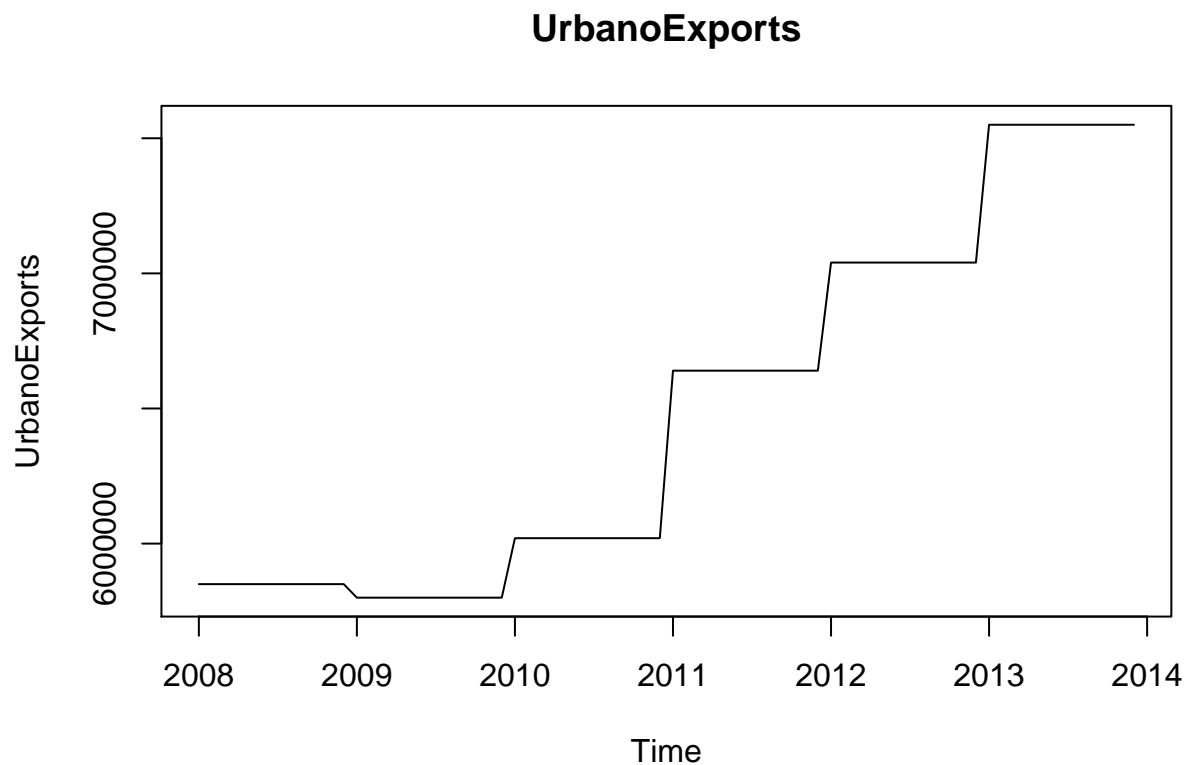
```
## [1] 0.1604768
```

```
cor(RedEtelAsIs , SIExtern)
```

```
## [1] 0.2960946
```

## Yearly exports from Urbano

```
UrbanoExportsVector <- c(ImportedIndicators[72:83,2],ImportedIndicators[72:83,3],ImportedIndicators[72:83,4])
UrbanoExports <- ts(UrbanoExportsVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(UrbanoExports, main="UrbanoExports")
```



```
cor(TotalAsIs, UrbanoExports)
```

```
## [1] 0.638178
```

```
cor(EfakAsIs , UrbanoExports)
```

```
## [1] 0.9163565
```

```
cor(WugeAsIs, UrbanoExports)
```

```
## [1] 0.7118468
```

```
cor(TotalEtelAsIs, UrbanoExports)
```

```
## [1] 0.3182532
```

```
cor(BlueEtelAsIs , UrbanoExports)
```

```
## [1] 0.1655794
```

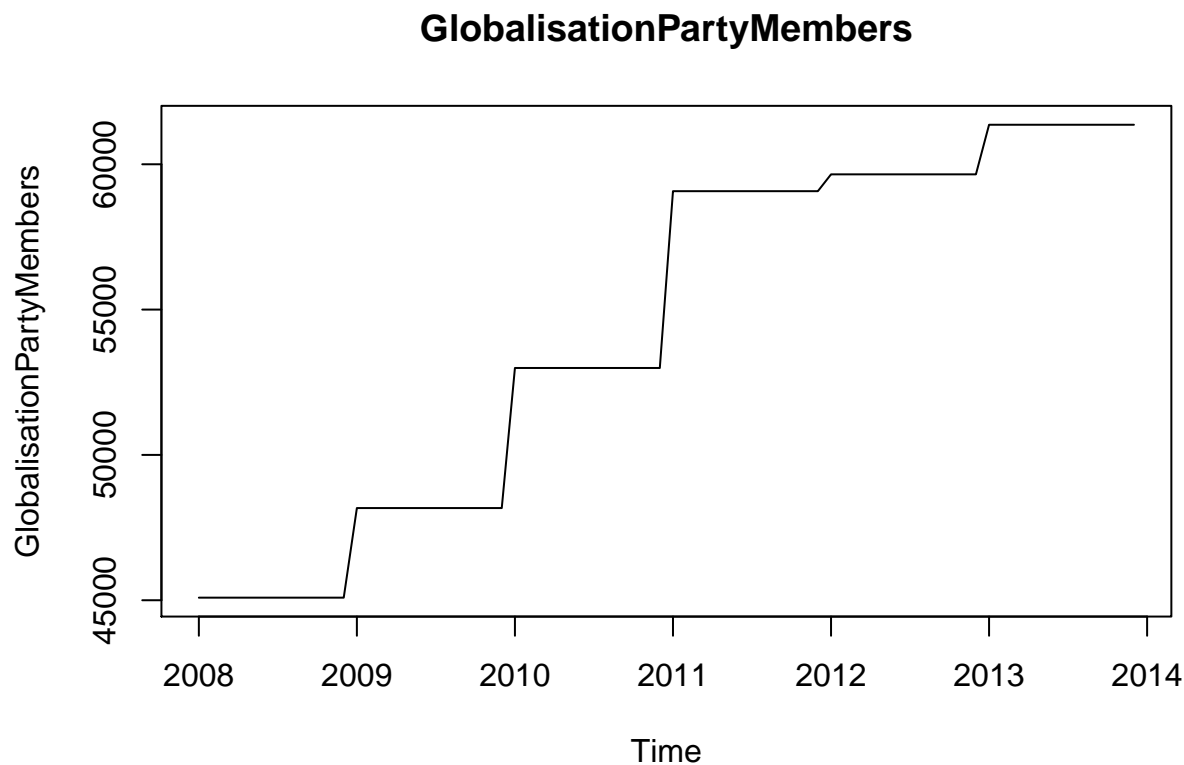
```
cor(RedEtelAsIs , UrbanoExports)
```

```
## [1] 0.3309962
```



## Yearly number of Globalisation Party members in Chulwalar

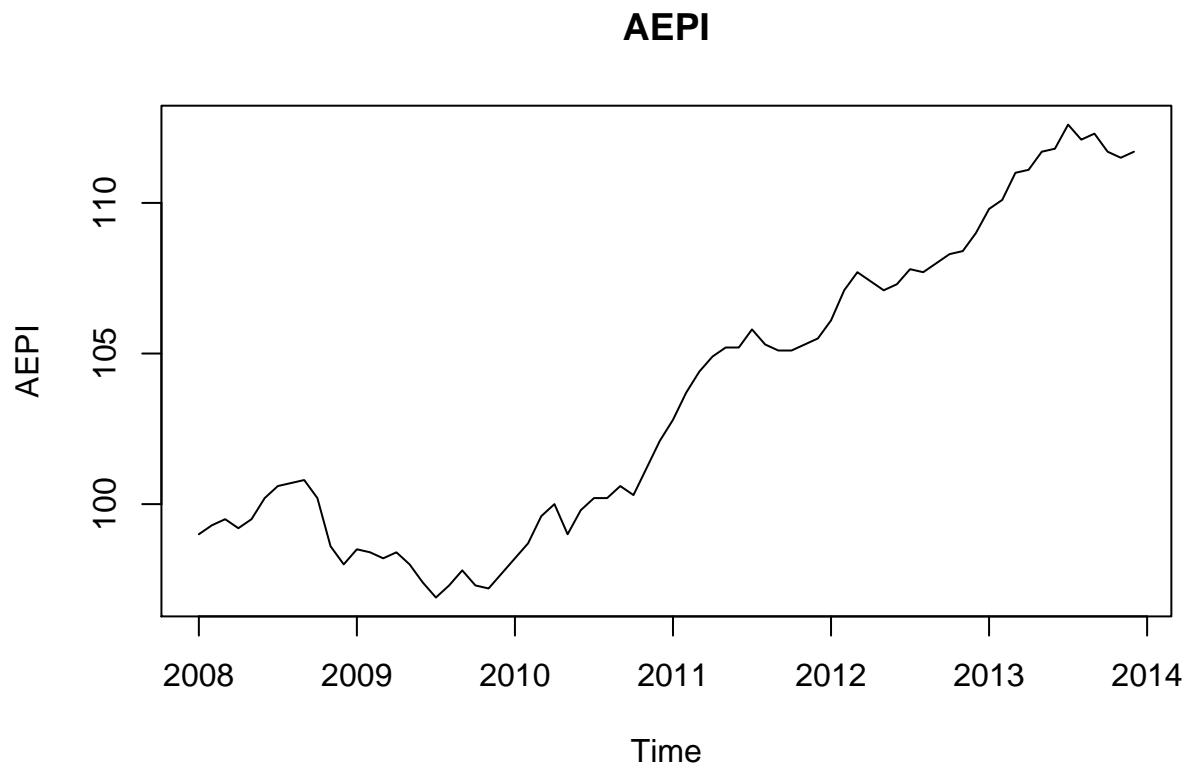
```
GlobalisationPartyMembersVector <- c(ImportedIndicators[86:97,2],ImportedIndicators[86:97,3],ImportedIn  
GlobalisationPartyMembers <- ts(GlobalisationPartyMembersVector, start=c(2008,1), end=c(2013,12), frequ  
plot(GlobalisationPartyMembers, main="GlobalisationPartyMembers")
```



```
cor(TotalAsIs, GlobalisationPartyMembers)  
## [1] 0.630084  
cor(EfakAsIs , GlobalisationPartyMembers)  
## [1] 0.8963942  
cor(WugeAsIs, GlobalisationPartyMembers)  
## [1] 0.7193864  
cor(TotalEtelAsIs, GlobalisationPartyMembers)  
## [1] 0.2994635  
cor(BlueEtelAsIs , GlobalisationPartyMembers)  
## [1] 0.08547266  
cor(RedEtelAsIs , GlobalisationPartyMembers)  
## [1] 0.3234832
```

## Monthly Average Export Price Index for Chulwalar

```
AEPIVector <- c(ImportedIndicators[100:111,2],ImportedIndicators[100:111,3],ImportedIndicators[100:111,4])
AEPI <- ts(AEPIVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(AEPI, main="AEPI")
```



```
cor(TotalAsIs, AEPI)
```

```
## [1] 0.625232
```

```
cor(EfakAsIs , AEPI)
```

```
## [1] 0.9056624
```

```
cor(WugeAsIs, AEPI)
```

```
## [1] 0.7159733
```

```
cor(TotalEtelAsIs, AEPI)
```

```
## [1] 0.3035506
```

```
cor(BlueEtelAsIs , AEPI)
```

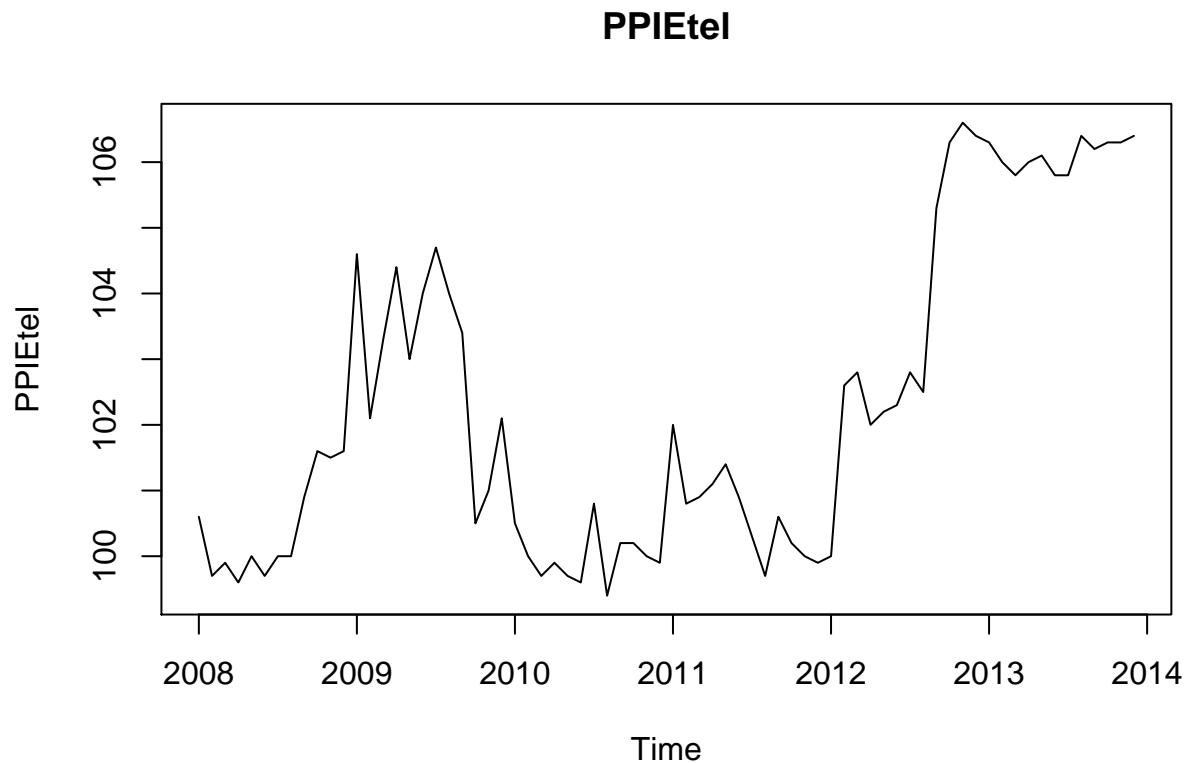
```
## [1] 0.1577964
```

```
cor(RedEtelAsIs , AEPI)
```

```
## [1] 0.3157277
```

## Monthly Producer Price Index (PPI) for Etel in Chulwalar

```
PPIEtelVector <- c(ImportedIndicators[114:125,2],ImportedIndicators[114:125,3],ImportedIndicators[114:125,4])
PPIEtel <- ts(PPIEtelVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(PPIEtel, main="PPIEtel")
```



```
cor(TotalAsIs, PPIEtel)
```

```
## [1] 0.4836129
```

```
cor(EfakAsIs , PPIEtel)
```

```
## [1] 0.5865375
```

```
cor(WugeAsIs, PPIEtel)
```

```
## [1] 0.4920865
```

```
cor(TotalEtelAsIs, PPIEtel)
```

```
## [1] 0.3374707
```

```
cor(BlueEtelAsIs , PPIEtel)
```

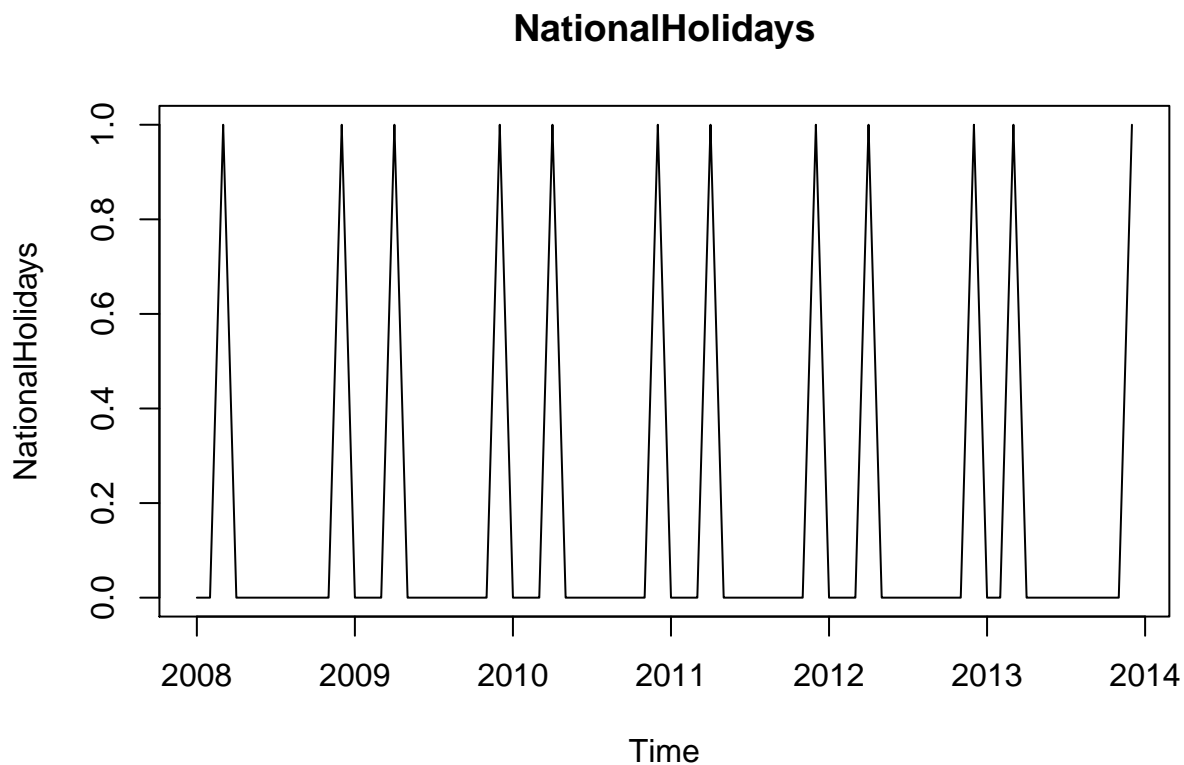
```
## [1] 0.2445472
```

```
cor(RedEtelAsIs , PPIEtel)
```

```
## [1] 0.3391872
```

## National Holidays

```
NationalHolidaysVector <- c(ImportedIndicators[170:181,2],ImportedIndicators[170:181,3],ImportedIndicators[170:181,4])
NationalHolidays <- ts(NationalHolidaysVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(NationalHolidays, main="NationalHolidays")
```



```
cor(TotalAsIs, NationalHolidays)
```

```
## [1] -0.007883708
```

```
cor(EfakAsIs , NationalHolidays)
```

```
## [1] 0.001235706
```

```
cor(WugeAsIs, NationalHolidays)
```

```
## [1] 0.06505569
```

```
cor(TotalEtelAsIs, NationalHolidays)
```

```
## [1] -0.01081446
```

```
cor(BlueEtelAsIs , NationalHolidays)
```

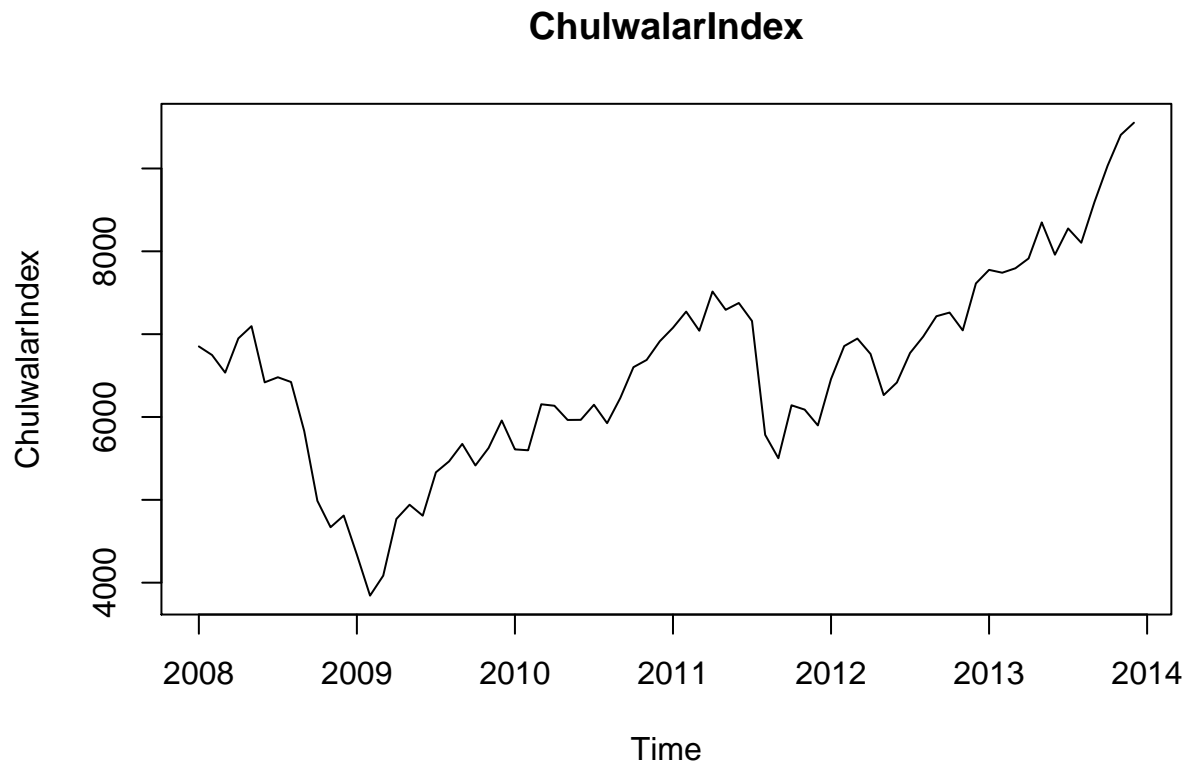
```
## [1] 0.02903763
```

```
cor(RedEtelAsIs , NationalHolidays)
```

```
## [1] -0.01717636
```

## Chulwalar Index (Total value of all companies in Chulwalar)

```
ChulwalarIndexVector <- c(ImportedIndicators[128:139,2],ImportedIndicators[128:139,3],ImportedIndicators[128:139,4])
ChulwalarIndex <- ts(ChulwalarIndexVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(ChulwalarIndex, main="ChulwalarIndex")
```



```
cor(TotalAsIs, ChulwalarIndex)
```

```
## [1] 0.4837017
```

```
cor(EfakAsIs , ChulwalarIndex)
```

```
## [1] 0.7129557
```

```
cor(WugeAsIs, ChulwalarIndex)
```

```
## [1] 0.5721568
```

```
cor(TotalEtelAsIs, ChulwalarIndex)
```

```
## [1] 0.2209171
```

```
cor(BlueEtelAsIs , ChulwalarIndex)
```

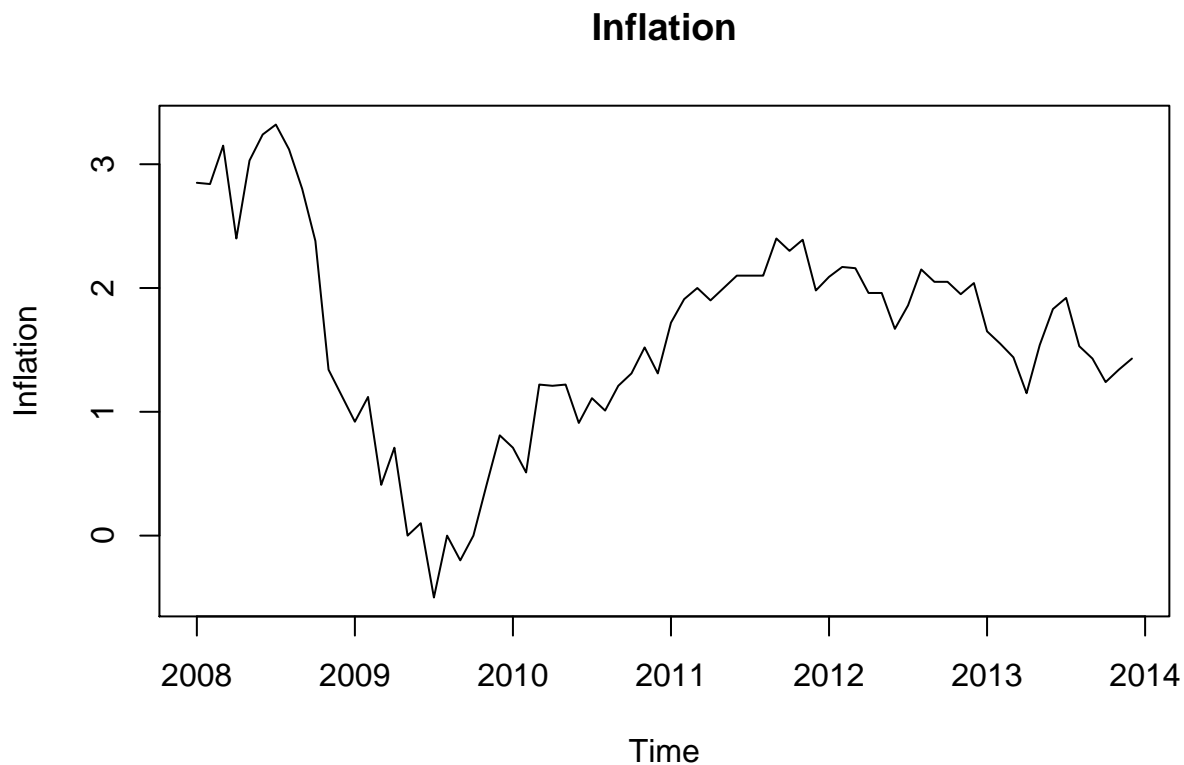
```
## [1] 0.1469233
```

```
cor(RedEtelAsIs , ChulwalarIndex)
```

```
## [1] 0.2242922
```

## Monthly Inflation rate in Chulwalar

```
InflationVector <- c(ImportedIndicators[142:153,2],ImportedIndicators[142:153,3],ImportedIndicators[142:153,4])
Inflation <- ts(InflationVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(Inflation, main="Inflation")
```



```
cor(TotalAsIs, Inflation)
```

```
## [1] 0.002438708
```

```
cor(EfakAsIs , Inflation)
```

```
## [1] 0.1454134
```

```
cor(WugeAsIs, Inflation)
```

```
## [1] 0.03191332
```

```
cor(TotalEtelAsIs, Inflation)
```

```
## [1] -0.08378282
```

```
cor(BlueEtelAsIs , Inflation)
```

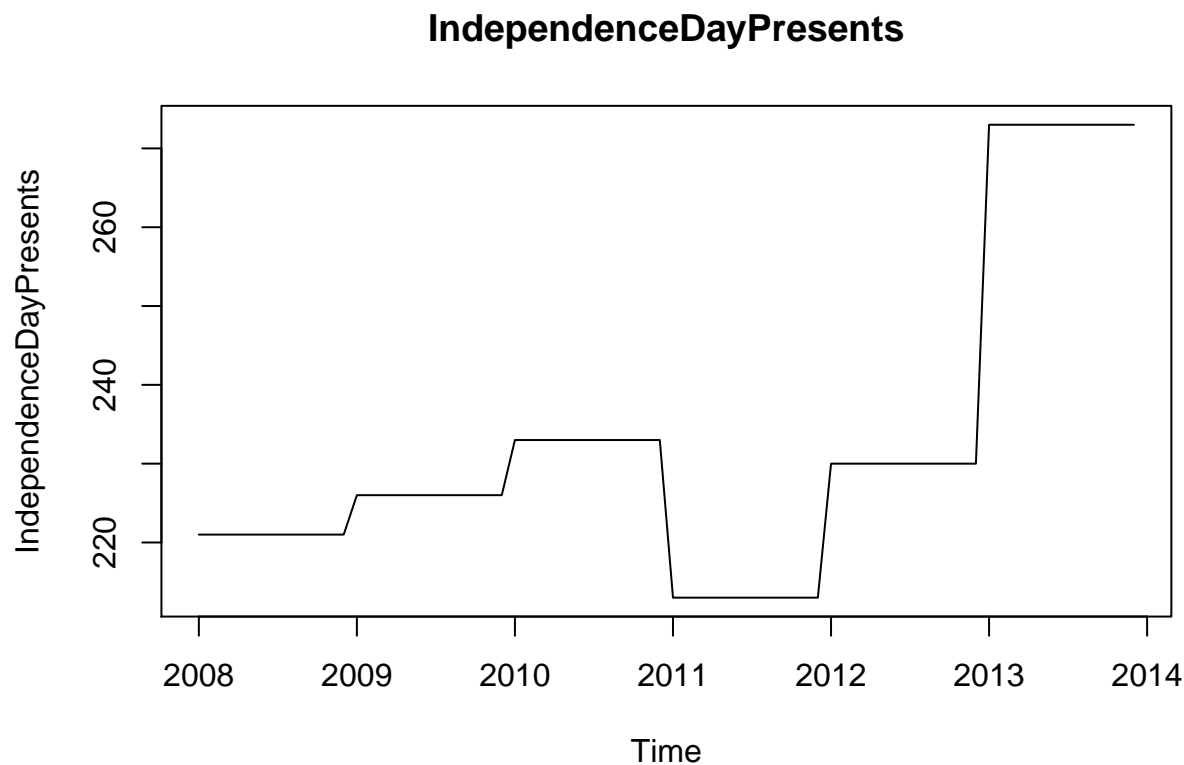
```
## [1] 0.02117817
```

```
cor(RedEtelAsIs , Inflation)
```

```
## [1] -0.0982151
```

## Proposed spending for Independence day presents

```
IndependenceDayPresentsVector <- c(ImportedIndicators[156:167,2],ImportedIndicators[156:167,3],ImportedIndicators[156:167,4])
IndependenceDayPresents <- ts(IndependenceDayPresentsVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(IndependenceDayPresents, main="IndependenceDayPresents")
```



```
cor(TotalAsIs, IndependenceDayPresents)
```

```
## [1] 0.4359522
```

```
cor(EfakAsIs , IndependenceDayPresents)
```

```
## [1] 0.5243145
```

```
cor(WugeAsIs, IndependenceDayPresents)
```

```
## [1] 0.4892437
```

```
cor(TotalEtelAsIs, IndependenceDayPresents)
```

```
## [1] 0.2872013
```

```
cor(BlueEtelAsIs , IndependenceDayPresents)
```

```
## [1] 0.2110373
```

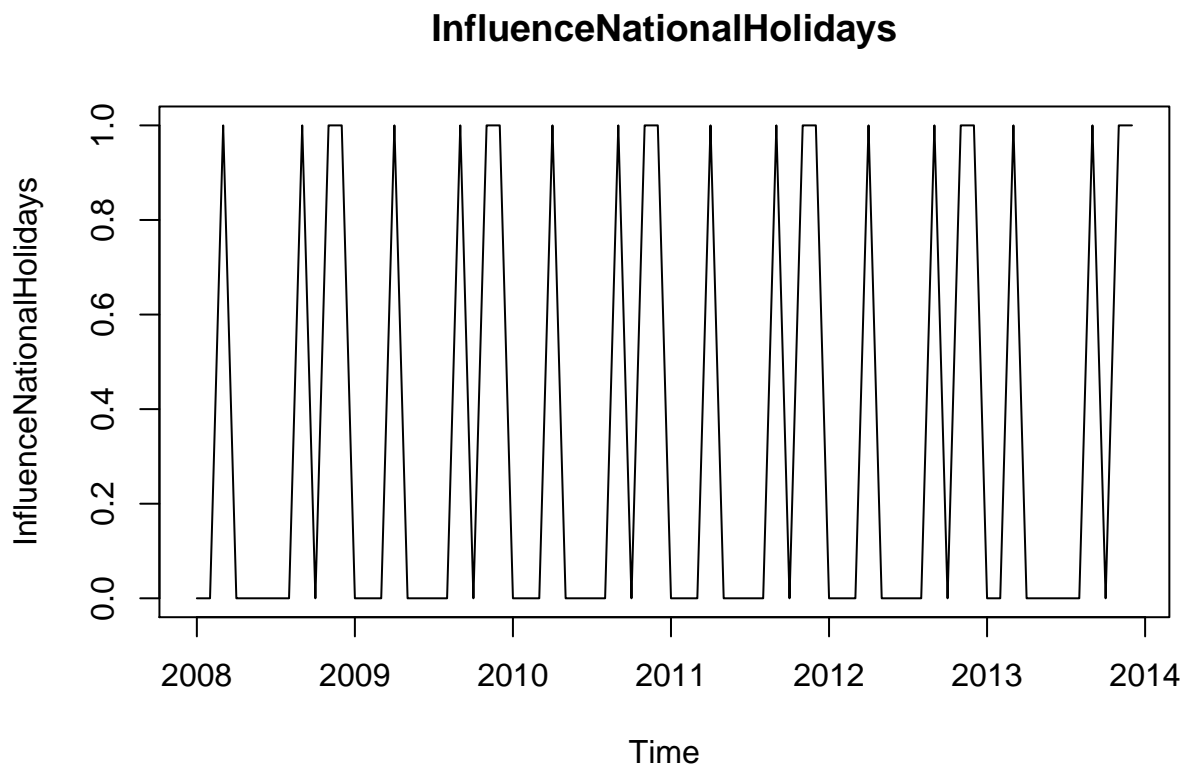
```
cor(RedEtelAsIs , IndependenceDayPresents)
```

```
## [1] 0.2881631
```

## Influence of National Holidays :

This indicator is an experiment where the influence of National Holidays is extended into the months leading up to the holiday. However later tests show that this indicator is no better for forecasting than the original National Holidays indicator.

```
InfluenceNationalHolidaysVector <- c(ImportedIndicators[184:195,2],ImportedIndicators[184:195,3],ImportedIndicators[184:195,4])
InfluenceNationalHolidays <- ts(InfluenceNationalHolidaysVector, start=c(2008,1), end=c(2013,12), frequency=12)
plot(InfluenceNationalHolidays, main="InfluenceNationalHolidays")
```



```
cor(TotalAsIs, InfluenceNationalHolidays)
```

```
## [1] 0.3717463
```

```
cor(EfakAsIs , InfluenceNationalHolidays)
```

```
## [1] 0.09926836
```

```
cor(WugeAsIs, InfluenceNationalHolidays)
```

```
## [1] 0.3712288
```

```
cor(TotalEtelAsIs, InfluenceNationalHolidays)
```

```
## [1] 0.4535836
```

```
cor(BlueEtelAsIs , InfluenceNationalHolidays)
```

```
## [1] 0.2792198
```



```
cor(RedEtelAsIs , InfluenceNationalHolidays)
```

```
## [1] 0.4643512
```

## Check that the data import has worked

```
str(CEPIVector)
```

```
## num [1:72] 97.4 97.8 98.3 98.1 98.7 98.9 99.5 99.2 99.1 98.9 ...
```

```
str(SIGovVector)
```

```
## num [1:72] -0.4 -2.9 -2.7 1.7 -1.7 -2.6 -7.1 -11.1 -9.4 -13.5 ...
```

```
str(TemperatureVector)
```

```
## num [1:72] 3.6 3.7 4.2 7.6 14.5 16.9 18 17.4 12.4 9.1 ...
```

```
str(BirthsVector)
```

```
## num [1:72] 58519 53370 52852 55048 57398 ...
```

```
str(SIExternVector)
```

```
## num [1:72] 4.5 4.5 4.6 4.6 5 4.3 3.4 1.8 1.5 1.7 ...
```

```
str(UrbanoExportsVector)
```

```
## num [1:72] 5850000 5850000 5850000 5850000 5850000 5850000 5850000 5850000 5850000 5850000 ...
```

```
str(GlobalisationPartyMembersVector)
```

```
## num [1:72] 45089 45089 45089 45089 45089 ...
```

```
str(AEPIVector)
```

```
## num [1:72] 99 99.3 99.5 99.2 99.5 ...
```

```
str(PPIEtelVector)
```

```
## num [1:72] 100.6 99.7 99.9 99.6 100 ...
```

```
str(NationalHolidaysVector)
```

```
## num [1:72] 0 0 1 0 0 0 0 0 0 0 ...
```

```
str(ChulwalarIndexVector)
```

```
## num [1:72] 6852 6748 6535 6949 7097 ...
```

```
str(InflationVector)
```

```
## num [1:72] 2.85 2.84 3.15 2.4 3.03 3.24 3.32 3.12 2.8 2.38 ...
```

```
str(IndependenceDayPresentsVector)
```

```
## num [1:72] 221 221 221 221 221 221 221 221 221 221 ...
```

## Forecasting models with smoothing and related approaches

Exponential Smoothing uses past values to calculate a forecast. The strength with which each value influences the forecast is weakened with help of a smoothing parameter. Thus we are dealing with a weighted average, whose values fade out the longer ago they were in the past.

The Akaike's Information Criterion(AIC/AICc) or the Bayesian Information Criterion (BIC) should be at minimum.

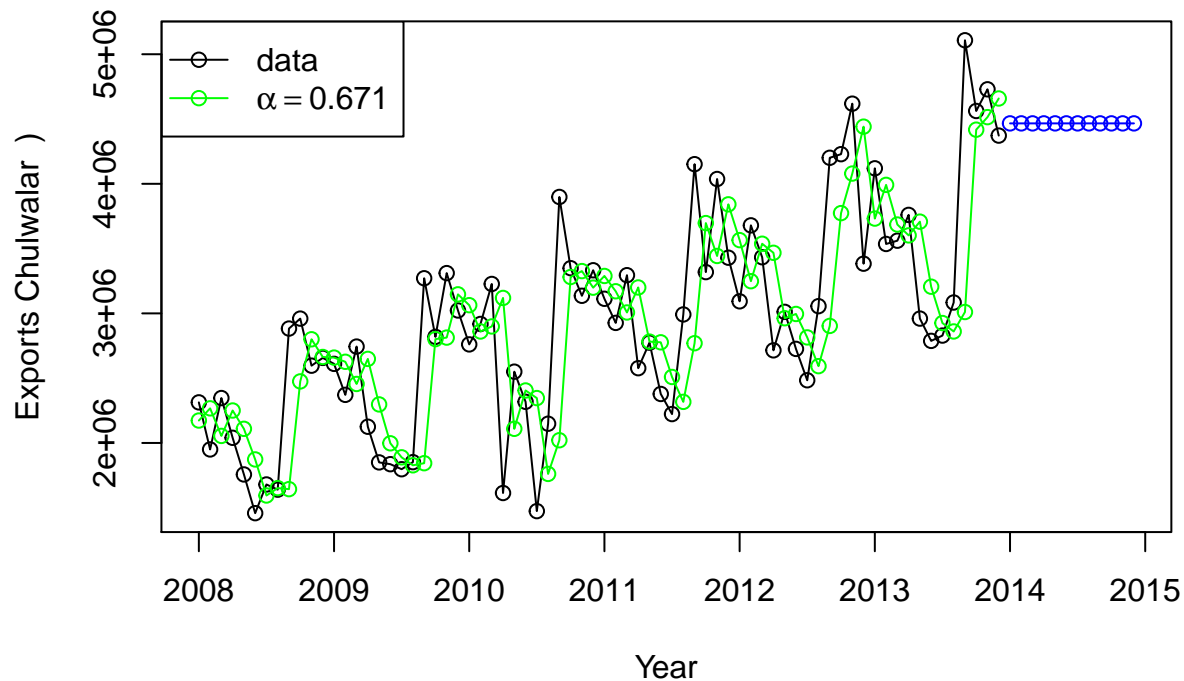
### Simple exponential smoothing

```
Model_ses <- ses(TotalAsIs, h=12)
summary(Model_ses)

##
## Forecast method: Simple exponential smoothing
##
## Model Information:
## Simple exponential smoothing
##
## Call:
## ses(x = TotalAsIs, h = 12)
##
## Smoothing parameters:
##   alpha = 0.671
##
## Initial states:
##   l = 2173226.7433
##
## sigma: 609507
##
##      AIC      AICc      BIC
## 2230.058 2230.232 2234.612
##
## Error measures:
##              ME    RMSE      MAE      MPE      MAPE      MASE
## Training set 47469.84 609507 429997.1 -1.511008 15.02336 1.172074
##              ACF1
## Training set 0.02384493
##
## Forecasts:
##      Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## Jan 2014      4466448 3685333 5247562 3271836 5661059
## Feb 2014      4466448 3525801 5407094 3027853 5905042
## Mar 2014      4466448 3389650 5543245 2819628 6113267
## Apr 2014      4466448 3268880 5664015 2634926 6297969
## May 2014      4466448 3159220 5773675 2467215 6465680
## Jun 2014      4466448 3058072 5874823 2312524 6620371
## Jul 2014      4466448 2963718 5969177 2168221 6764674
## Aug 2014      4466448 2874947 6057948 2032458 6900437
## Sep 2014      4466448 2790873 6142022 1903878 7029017
## Oct 2014      4466448 2710821 6222074 1781448 7151447
## Nov 2014      4466448 2634263 6298632 1664363 7268532
```

```
## Dec 2014      4466448 2560778 6372117 1551977 7380918
```

```
OverallSummary <- GetForecastStats(Model_ses)
plot(Model_ses, plot.conf=FALSE, ylab="Exports Chulwalar )", xlab="Year", main="", fcol="white", type=
lines(fitted(Model_ses), col="green", type="o")
lines(Model_ses$mean, col="blue", type="o")
legend("topleft", lty=1, col=c(1,"green"), c("data", expression(alpha == 0.671)), pch=1)
```



## Holt's linear trend method

Holt added to the model in order to forecast using trends as well. For this it is necessary to add a beta, which determines the trend. If neither alpha nor beta is stated, both parameters will be optimised using ets(). The trend is exponential if the intercepts(level) and the gradient (slope) are multiplied with each other. The values are worse. As the Beta was very low in the optimisation, the forecast is very similar to the ses() model.

```
Model_holt_1 <- holt(TotalAsIs, h=12)
summary(Model_holt_1)
```

```
##
## Forecast method: Holt's method
##
## Model Information:
## Holt's method
##
## Call:
## holt(x = TotalAsIs, h = 12)
```

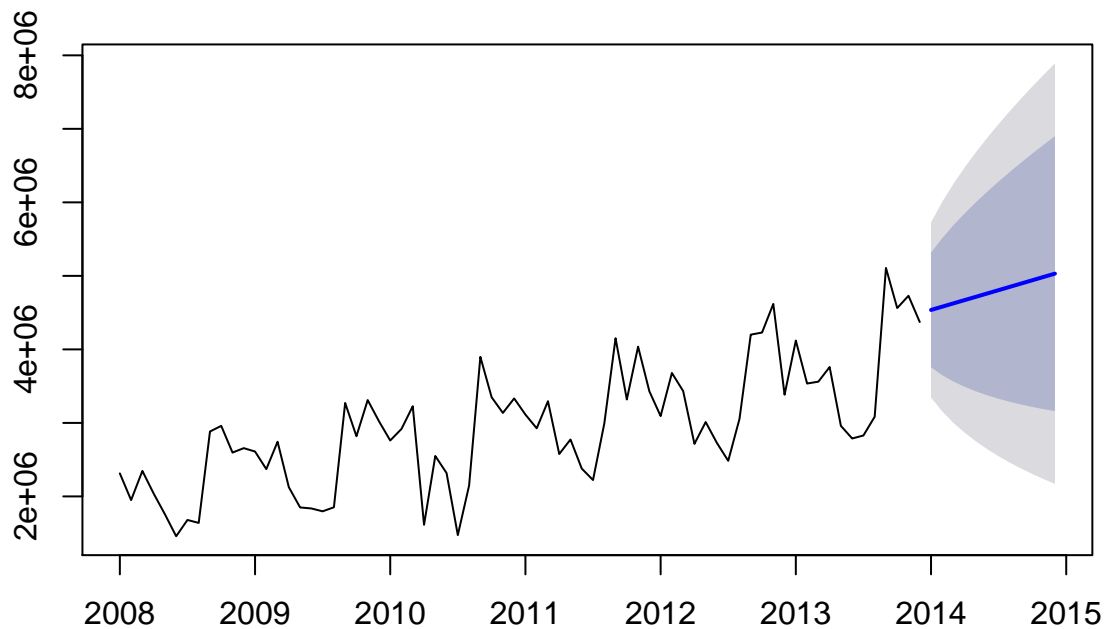
```

##
## Smoothing parameters:
##   alpha = 0.6571
##   beta  = 1e-04
##
## Initial states:
##   l = 2040390.7764
##   b = 45050.7514
##
## sigma: 608119.1
##
##      AIC      AICc      BIC
## 2233.730 2234.327 2242.837
##
## Error measures:
##           ME      RMSE      MAE      MPE      MAPE      MASE
## Training set -16586.9 608119.1 441110.7 -3.88925 15.75307 1.202367
##           ACF1
## Training set 0.03462672
##
## Forecasts:
##      Point Forecast   Lo 80   Hi 80   Lo 95   Hi 95
## Jan 2014      4536367 3757031 5315703 3344475 5728259
## Feb 2014      4581298 3648703 5513894 3155016 6007580
## Mar 2014      4626230 3562188 5690271 2998918 6253541
## Apr 2014      4671161 3490181 5852141 2865008 6477314
## May 2014      4716092 3428721 6003463 2747228 6684956
## Jun 2014      4761024 3375378 6146669 2641862 6880185
## Jul 2014      4805955 3328531 6283379 2546429 7065480
## Aug 2014      4850886 3287035 6414738 2459182 7242591
## Sep 2014      4895818 3250047 6541588 2378829 7412807
## Oct 2014      4940749 3216925 6664573 2304387 7577111
## Nov 2014      4985680 3187164 6784196 2235088 7736273
## Dec 2014      5030612 3160363 6900860 2170314 7890909

```

```
plot(Model_holt_1)
```

## Forecasts from Holt's method



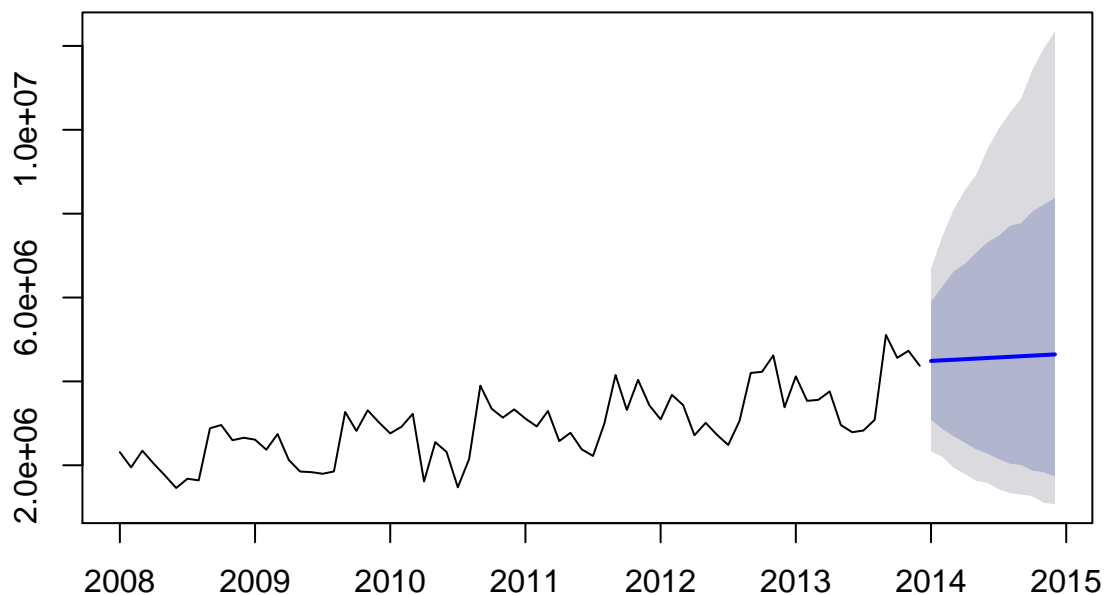
```
# exponential trend
Model_holt_2<- holt(TotalAsIs, exponential=TRUE,h=12)
summary(Model_holt_2)
```

```
##
## Forecast method: Holt's method with exponential trend
##
## Model Information:
## Holt's method with exponential trend
##
## Call:
## holt(x = TotalAsIs, h = 12, exponential = TRUE)
##
## Smoothing parameters:
##   alpha = 0.6637
##   beta  = 1e-04
##
## Initial states:
##   l = 2041538.9468
##   b = 1.0029
##
## sigma: 0.2438
##
##      AIC      AICc      BIC
## 2251.010 2251.607 2260.116
##
```

```
## Error measures:
##           ME      RMSE      MAE      MPE      MAPE      MASE
## Training set 37825.61 609787.5 433018.9 -1.838214 15.18487 1.180311
##           ACF1
## Training set 0.02918287
##
## Forecasts:
##           Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## Jan 2014          4488281 3088776 5895347 2332202 6686602
## Feb 2014          4502175 2865852 6263480 2205796 7452866
## Mar 2014          4516113 2691319 6619824 1941873 8087524
## Apr 2014          4530094 2540182 6802695 1795055 8561230
## May 2014          4544118 2381944 7067397 1625428 8924997
## Jun 2014          4558186 2276516 7316584 1579874 9534915
## Jul 2014          4572297 2149404 7470633 1430581 10018701
## Aug 2014          4586452 2037643 7711148 1337859 10406511
## Sep 2014          4600650 2006342 7776040 1302428 10741609
## Oct 2014          4614893 1872142 8051774 1261109 11434191
## Nov 2014          4629180 1834620 8218030 1106433 11928018
## Dec 2014          4643510 1729264 8373103 1071226 12348352
```

```
plot(Model_holt_2)
```

### Forecasts from Holt's method with exponential trend



## Dampened trends

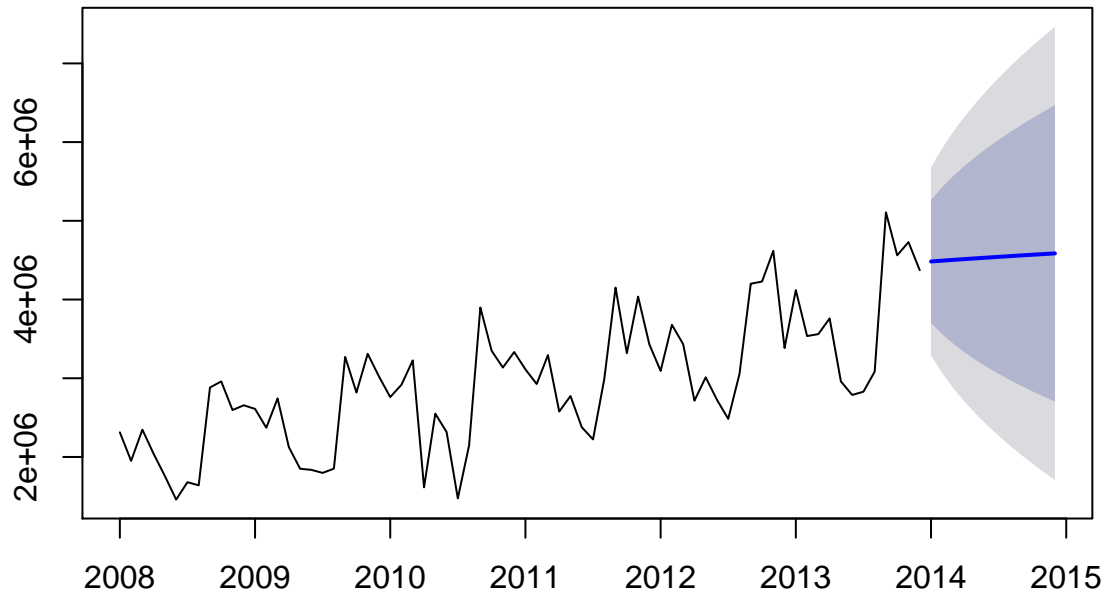
As such simple trends tend to forecast the future too positively, we have added a dampener. This also works for exponential trends. We also plot the level and slope individually for each model.

```
Model_holt_3 <- holt(TotalAsIs, damped=TRUE, h=12)
summary(Model_holt_3)
```

```
##
## Forecast method: Damped Holt's method
##
## Model Information:
## Damped Holt's method
##
## Call:
## holt(x = TotalAsIs, h = 12, damped = TRUE)
##
## Smoothing parameters:
##   alpha = 0.6613
##   beta  = 2e-04
##   phi   = 0.98
##
## Initial states:
##   l = 2040392.5761
##   b = 45053.25
##
## sigma: 608787.2
##
##      AIC      AICc      BIC
## 2235.888 2236.797 2247.272
##
## Error measures:
##           ME      RMSE      MAE      MPE      MAPE      MASE
## Training set 15578.94 608787.2 436909.7 -2.797612 15.46526 1.190916
##           ACF1
## Training set 0.03351419
##
## Forecasts:
##      Point Forecast   Lo 80   Hi 80   Lo 95   Hi 95
## Jan 2014      4483618 3703426 5263811 3290417 5676819
## Feb 2014      4493914 3558436 5429391 3063224 5924603
## Mar 2014      4504003 3435520 5572486 2869899 6138107
## Apr 2014      4513891 3327168 5700614 2698955 6328827
## May 2014      4523581 3229332 5817829 2544198 6502963
## Jun 2014      4533077 3139534 5926619 2401837 6664316
## Jul 2014      4542383 3056128 6028638 2269352 6815413
## Aug 2014      4551503 2977955 6125051 2144969 6958036
## Sep 2014      4560440 2904162 6216719 2027381 7093499
## Oct 2014      4569199 2834101 6304298 1915595 7222803
## Nov 2014      4577783 2767264 6388301 1808834 7346732
## Dec 2014      4586195 2703249 6469141 1706477 7465913
```

```
plot(Model_holt_3)
```

## Forecasts from Damped Holt's method



```
Model_holt_4 <- holt(TotalAsIs, exponential=TRUE, damped=TRUE,h=12)
summary(Model_holt_4)
```

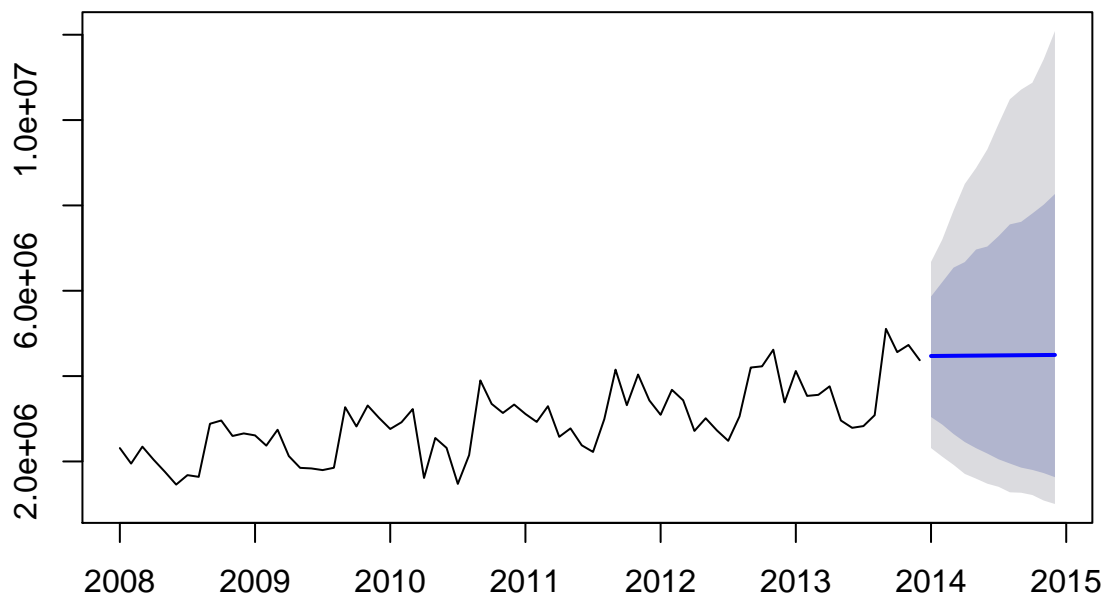
```
##
## Forecast method: Damped Holt's method with exponential trend
##
## Model Information:
## Damped Holt's method with exponential trend
##
## Call:
## holt(x = TotalAsIs, h = 12, damped = TRUE, exponential = TRUE)
##
## Smoothing parameters:
##   alpha = 0.6679
##   beta  = 1e-04
##   phi   = 0.9799
##
## Initial states:
##   l = 2041541.9705
##   b = 1.0019
##
## sigma: 0.2449
##
##      AIC      AICc      BIC
```



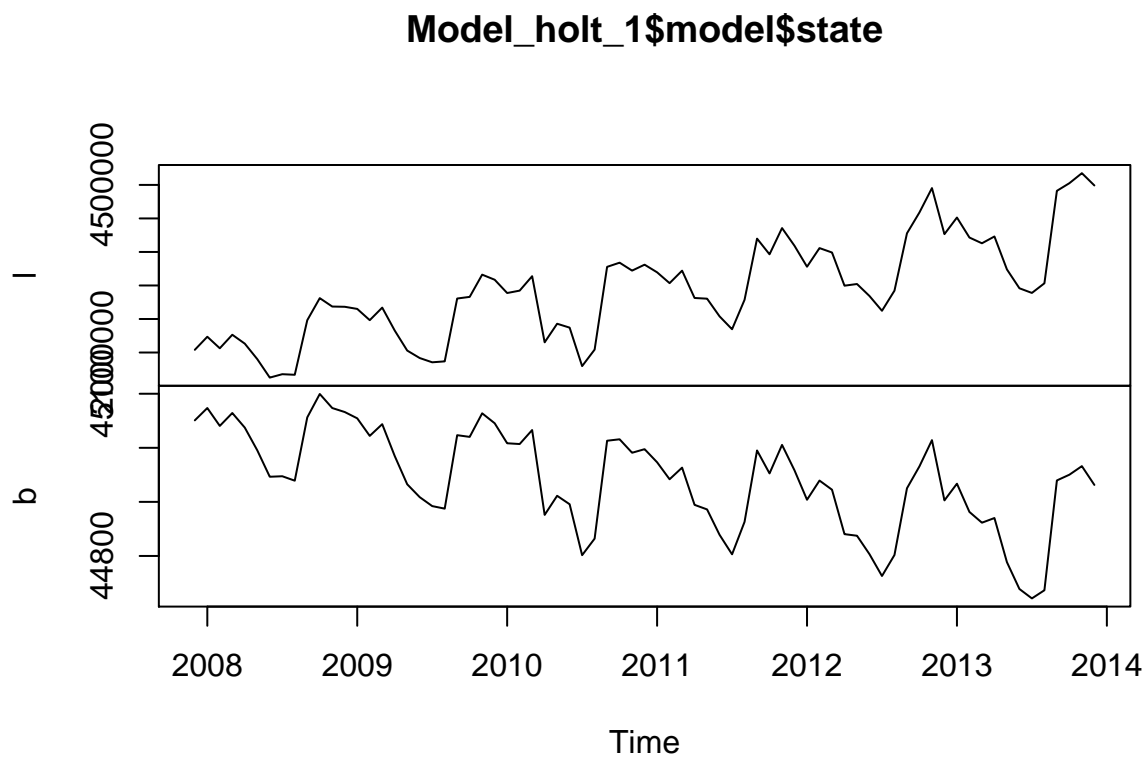
```
## 2253.216 2254.125 2264.600
##
## Error measures:
##           ME      RMSE      MAE      MPE      MAPE      MASE
## Training set 46119.56 609906.7 432069.1 -1.549114 15.11987 1.177722
##           ACF1
## Training set 0.0254941
##
## Forecasts:
##           Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## Jan 2014          4470648 3040929 5864323 2314513 6675597
## Feb 2014          4473164 2863707 6203336 2111849 7199488
## Mar 2014          4475630 2642712 6541923 1920488 7878829
## Apr 2014          4478047 2454945 6672650 1708073 8502659
## May 2014          4480418 2310553 6966096 1596736 8877890
## Jun 2014          4482742 2184766 7036856 1479052 9313377
## Jul 2014          4485020 2049701 7280710 1405349 9912633
## Aug 2014          4487253 1951122 7555157 1276735 10487697
## Sep 2014          4489443 1855882 7615298 1266672 10713430
## Oct 2014          4491589 1801385 7811538 1213268 10875295
## Nov 2014          4493694 1727609 8016311 1084686 11423677
## Dec 2014          4495757 1631264 8267988 1003413 12085156
```

```
plot(Model_holt_4)
```

## Forecasts from Damped Holt's method with exponential trend

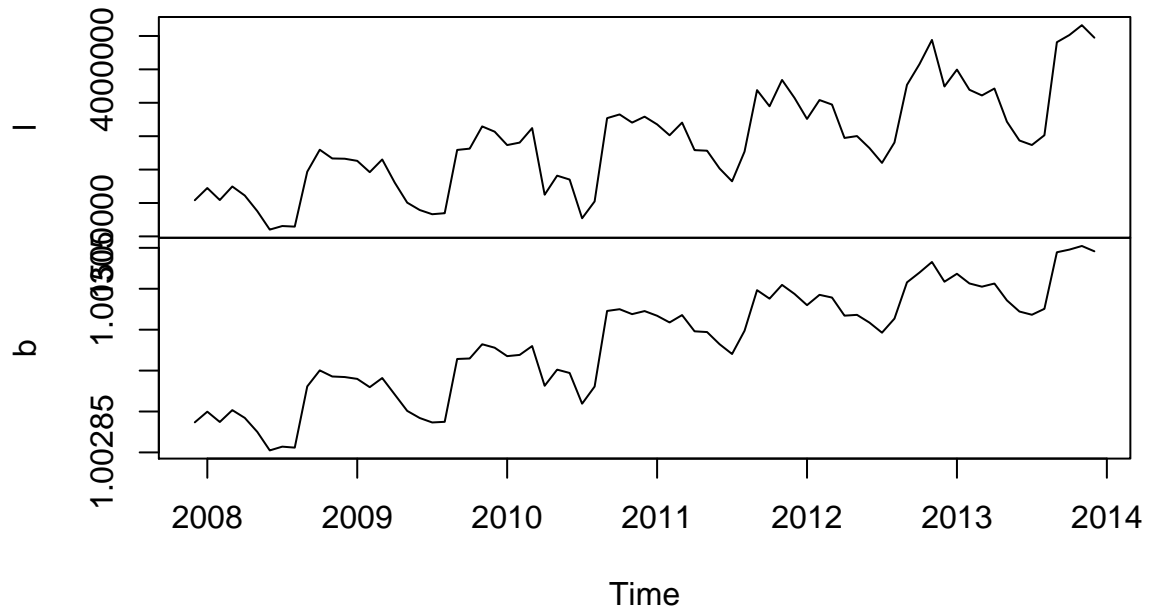


```
# level and slope can be plotted individually for each model.
plot(Model_holt_1$model$state)
```



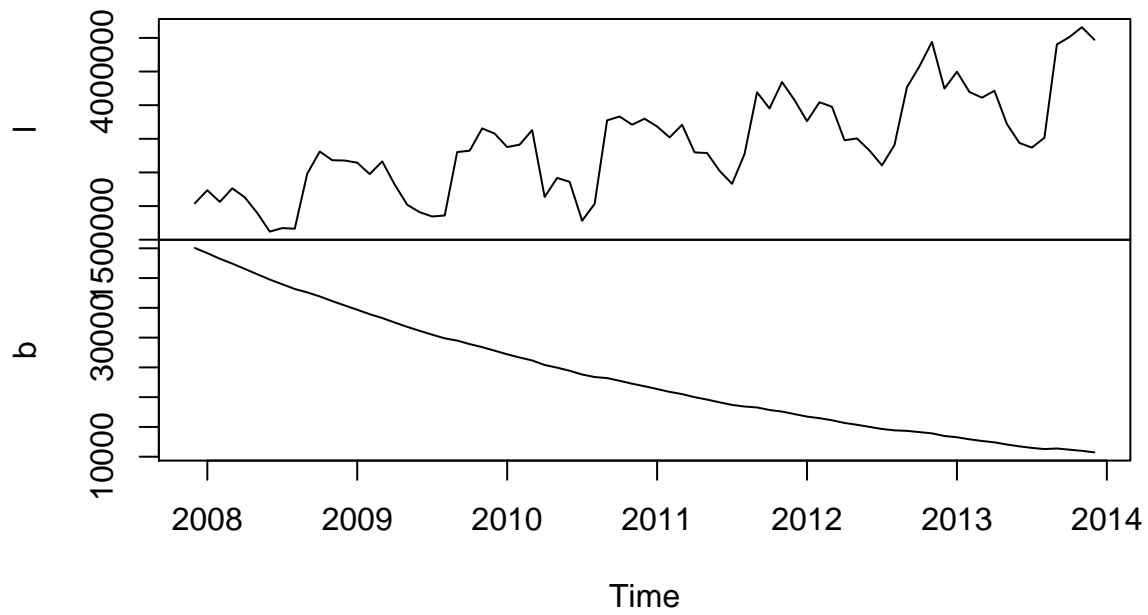
```
plot(Model_holt_2$model$state)
```

### Model\_holt\_2\$model\$state



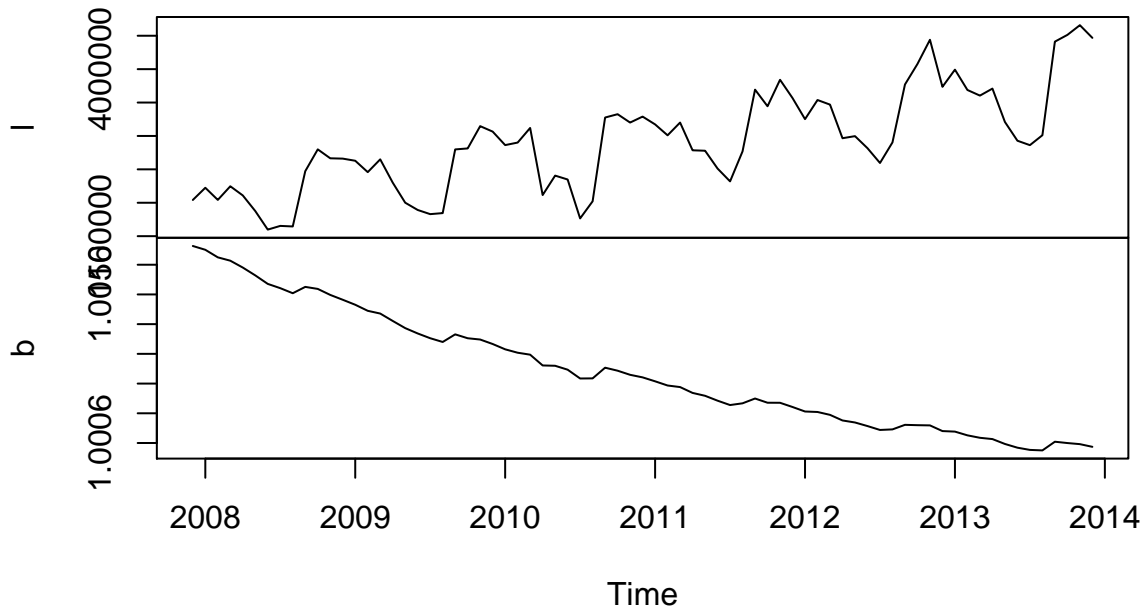
```
plot(Model_holt_3$model$state)
```

### Model\_holt\_3\$model\$state

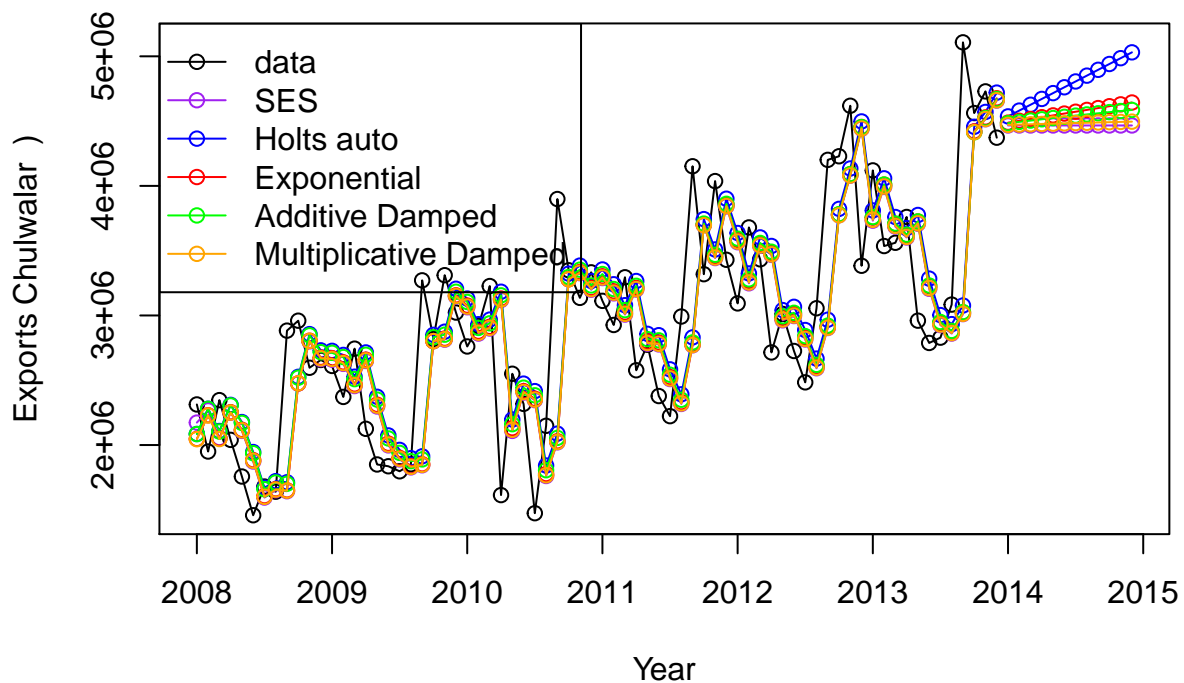


```
plot(Model_holt_4$model$state)
```

## Model\_holt\_4\$model\$state



```
plot(Model_holt_1, plot.conf=FALSE, ylab="Exports Chulwalar  )", xlab="Year", main="", fcol="white", ty
lines(fitted(Model_ses), col="purple", type="o")
lines(fitted(Model_holt_1), col="blue", type="o")
lines(fitted(Model_holt_2), col="red", type="o")
lines(fitted(Model_holt_3), col="green", type="o")
lines(fitted(Model_holt_4), col="orange", type="o")
lines(Model_ses$mean, col="purple", type="o")
lines(Model_holt_1$mean, col="blue", type="o")
lines(Model_holt_2$mean, col="red", type="o")
lines(Model_holt_3$mean, col="green", type="o")
lines(Model_holt_4$mean, col="orange", type="o")
legend("topleft",lty=1, col=c(1,"purple","blue","red","green","orange"), c("data", "SES","Holts auto",
```



## Holt-Winter's seasonal method

Holt and Winters have expanded Holt's model further to include the seasonality aspect. The parameter  $\gamma$ , which is for smoothing the seasonality, was added to achieve this. The values are better than the models without seasonality. This is logical, since the data is strongly influenced by seasonality. In the following model, none of the parameters are given so that they will be optimised automatically. There are two models: one using an additive error model method and one using a multiplicative error model. The additive model gives slightly better results than the multiplicative model.

```
Model_hw_1 <- hw(TotalAsIs ,seasonal="additive",h=12)
summary(Model_hw_1)
```

```
##
## Forecast method: Holt-Winters' additive method
##
## Model Information:
## Holt-Winters' additive method
##
## Call:
## hw(x = TotalAsIs, h = 12, seasonal = "additive")
##
## Smoothing parameters:
##   alpha = 0.0087
##   beta  = 0.0087
##   gamma = 1e-04
##
```

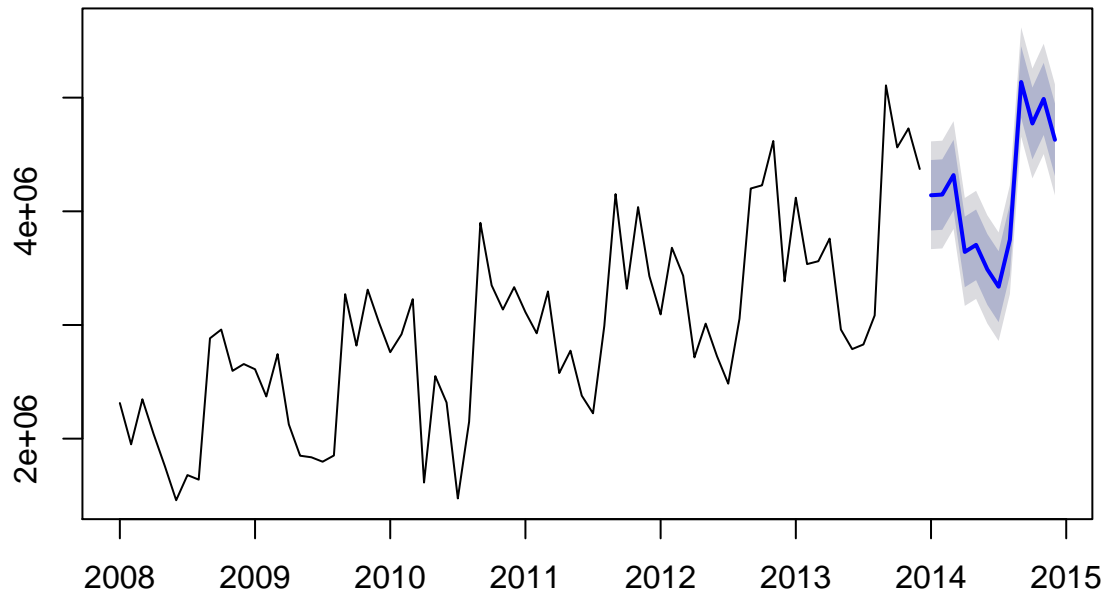
```

## Initial states:
## l = 2047375.0884
## b = 22509.7631
## s=259168.3 654942.6 474529.8 876025.2 -475155 -852844
## -664662.5 -412596.7 -438677.3 273215 138077.9 167976.7
##
## sigma: 241685
##
## AIC AICc BIC
## 2124.856 2134.747 2161.283
##
## Error measures:
## ME RMSE MAE MPE MAPE MASE
## Training set 21615.43 241685 202218.5 -0.08252109 7.329458 0.5512016
## ACF1
## Training set -0.2819072
##
## Forecasts:
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95
## Jan 2014 4141204 3831472 4450936 3667510 4614898
## Feb 2014 4147309 3837472 4457147 3673453 4621165
## Mar 2014 4318537 4008512 4628563 3844394 4792680
## Apr 2014 3642744 3332425 3953063 3168153 4117335
## May 2014 3704865 3394124 4015605 3229628 4180102
## Jun 2014 3488859 3177546 3800173 3012746 3964973
## Jul 2014 3336738 3024677 3648799 2859482 3813994
## Aug 2014 3750478 3437474 4063482 3271780 4229176
## Sep 2014 5137771 4823607 5451935 4657298 5618244
## Oct 2014 4772337 4456775 5087900 4289726 5254949
## Nov 2014 4988809 4671591 5306028 4503665 5473953
## Dec 2014 4629097 4309943 4948252 4140992 5117202

```

```
plot(Model_hw_1)
```

## Forecasts from Holt-Winters' additive method



```
Model_hw_2 <- hw(TotalAsIs ,seasonal="multiplicative",h=12)
summary(Model_hw_2)
```

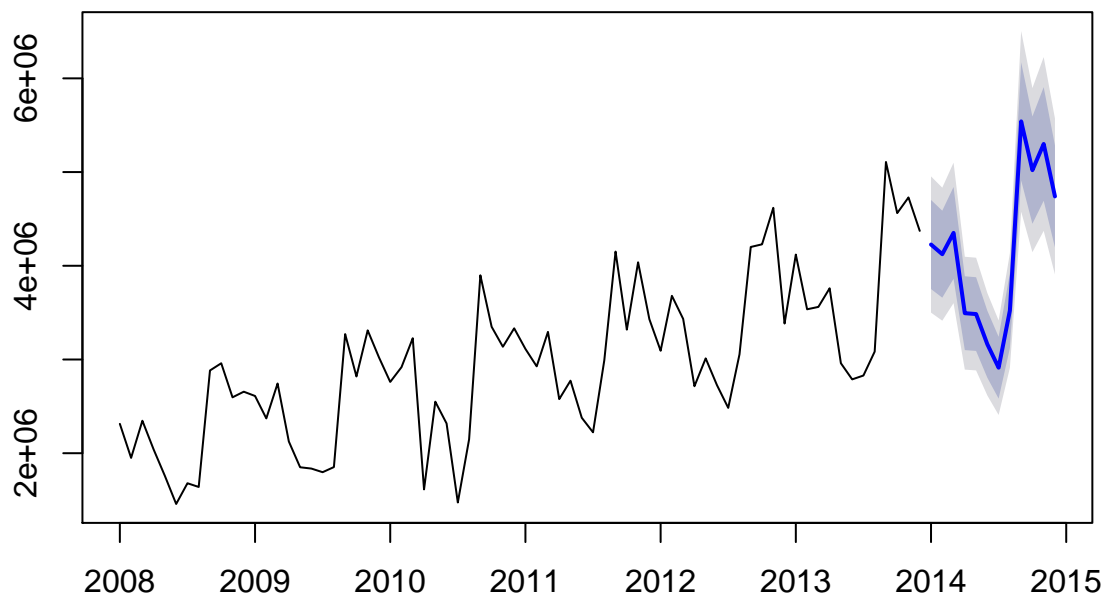
```
##
## Forecast method: Holt-Winters' multiplicative method
##
## Model Information:
## Holt-Winters' multiplicative method
##
## Call:
## hw(x = TotalAsIs, h = 12, seasonal = "multiplicative")
##
## Smoothing parameters:
##   alpha = 0.025
##   beta  = 0.0062
##   gamma = 1e-04
##
## Initial states:
##   l = 2026247.531
##   b = 25395.1259
##   s=1.0933 1.232 1.1763 1.3086 0.8384 0.699
##         0.7653 0.8502 0.8596 1.0793 1.0316 1.0665
##
## sigma: 0.0877
##
##      AIC      AICc      BIC
```



```
## 2128.303 2138.194 2164.729
##
## Error measures:
##           ME      RMSE      MAE      MPE      MAPE      MASE
## Training set 17434.11 235296.6 191805.3 -0.3292809 7.213472 0.5228175
##           ACF1
## Training set -0.3514421
##
## Forecasts:
##           Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## Jan 2014           4226941 3751624 4702258 3500006 4953876
## Feb 2014           4123665 3659738 4587591 3414151 4833179
## Mar 2014           4350808 3860995 4840620 3601704 5099911
## Apr 2014           3494208 3100476 3887940 2892046 4096370
## May 2014           3484738 3091618 3877858 2883513 4085963
## Jun 2014           3162774 2805463 3520085 2616314 3709234
## Jul 2014           2912399 2582802 3241996 2408324 3416474
## Aug 2014           3521645 3122278 3921013 2910865 4132425
## Sep 2014           5540988 4911109 6170867 4577671 6504304
## Oct 2014           5020487 4448200 5592775 4145249 5895725
## Nov 2014           5299729 4693715 5905743 4372911 6226547
## Dec 2014           4740169 4196230 5284108 3908286 5572052
```

```
plot(Model_hw_2)
```

## Forecasts from Holt–Winters' multiplicative method



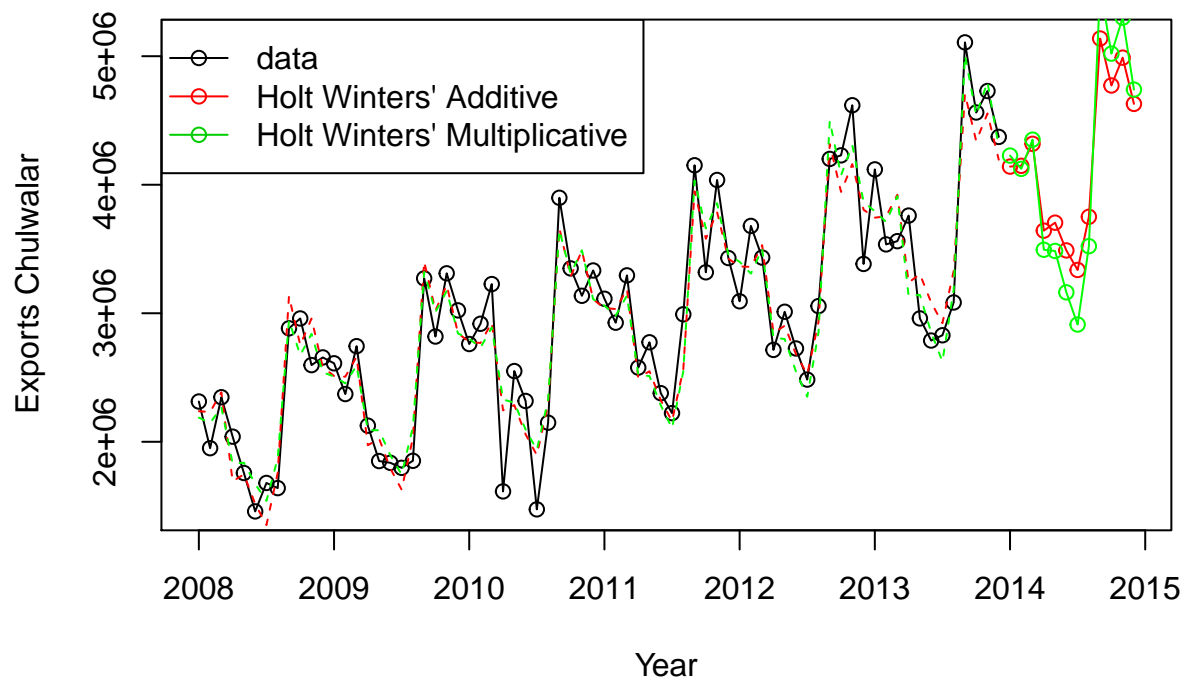
```
plot(Model_hw_1, ylab="Exports Chulwalar ", plot.conf=FALSE, type="o", fcol="white", xlab="Year")
lines(fitted(Model_hw_1), col="red", lty=2)
```

```

lines(fitted(Model_hw_2), col="green", lty=2)
lines(Model_hw_1$mean, type="o", col="red")
lines(Model_hw_2$mean, type="o", col="green")
legend("topleft",lty=1, pch=1, col=1:3, c("data","Holt Winters' Additive","Holt Winters' Multiplicative

```

## Forecasts from Holt–Winters' additive method



```

# In order to use the results later, they need to be converted into point forecasts.
Model_hw_1_df <-as.data.frame(Model_hw_1)
Model_hw_1_PointForecast <- ts(Model_hw_1_df$"Point Forecast", start=c(2014,1), end=c(2014,12), frequen
Model_hw_1_PointForecast

```

```

##          Jan      Feb      Mar      Apr      May      Jun      Jul      Aug
## 2014 4141204 4147309 4318537 3642744 3704865 3488859 3336738 3750478
##          Sep      Oct      Nov      Dec
## 2014 5137771 4772337 4988809 4629097

```

```

Model_hw_2_df <-as.data.frame(Model_hw_2)
Model_hw_2_PointForecast <- ts(Model_hw_2_df$"Point Forecast", start=c(2014,1), end=c(2014,12), frequen
Model_hw_2_PointForecast

```

```

##          Jan      Feb      Mar      Apr      May      Jun      Jul      Aug
## 2014 4226941 4123665 4350808 3494208 3484738 3162774 2912399 3521645
##          Sep      Oct      Nov      Dec
## 2014 5540988 5020487 5299729 4740169

```

```

# Output instruction for the data export of the results for further use in Excel.
#write.csv(Model_hw_1_PointForecast,file='Model_hw_1_PointForecast.csv')
#write.csv(Model_hw_2_PointForecast,file='Model_hw_2_PointForecast.csv')

```

## Conclusion

- The ETS model was preferred over the ARIMA Model. In one sample ETS model, the Mean Absolute Squared Error of .55 was preferred over 15 different ARIMA models with values greater than 1.0. ETS ME of 21,588 was preferred over wide ranging values of -18,789 to 178,628. Based on the review of the data, and the type of data being explored: Error, Trend, Seasonal algorithm “ETS AAA” is the preferred method over autoregressive integrated moving average “ARIMA”. ARIMA is based on assumptions that residuals are uncorrelated and normally distributed. If this doesn’t occur, then forecast intervals are incorrect. “ETS AAA” doesn’t face the same limitations of looking at correlations in data, linearity and stationarity. Also ETS provides an automatic way of selecting the best method. ETS MASE of .55 provides a better value of greater than 0 but less than one.
- Reviewing the different model, to define the best fit is the model that proves the best prediction of error, robust to outliers, good indicator of central tendency and provides the best measure of goodness is the best fit.
- Holt’s-Winters multiplicative method of MASE “.52”, ME 17434.1, and RMSE 241,685 was preferred over other forecast models. When reviewing the different forecast models the root mean square error provided the best indicator for accurate forecasting. Taking into account seasonal fluctuations in the data was important during this case study. Lastly, when comparing “total-as-is” plan to the “total-plan” using linear regression model and time series models provided a better understanding of regression correlation and accuracy. The best fit for forecast is the model that provides the best time series review for your given data and the prediction of bias and error in the data.
- All of the models are equally good when considering the specific data. Based on observation and analysis of the data, any model that provides trend analyses, seasonal interpretation (additive/multiplicative) and greater interpretation of potential error is the one chosen. The model that produces an accurate forecast is a model that contains a low U1 statistic. Important to consider Mean error values as well as taking into account a full range of values in a statistical output

## Recommendation to Chulwalr Prime Minister:

When reviewing the different plots between efak, Wuge, and Etel. The primary export recommended would be Efak. It shows a strong linear progression from 2008 and is resistant to large swings in seasonal, export, and social holidays.