# Final Project

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Change working directory

## Load data (assumes file is in working directory)

```
#load the data
beerData<-read.csv("monthly-beer-production-in-austr.csv")

#cut off the last row which is NA
beerData<-beerData[-nrow(beerData),]
colnames(beerData)<-c("Month", "Production")

#Get a five number summary of the data
summary(beerData$Production)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    64.8   112.9   139.2   136.4   158.8   217.8
```

```
#turn into time series also hold back the last two years of data for forecasting
beerTS<-ts(beerData[1:(nrow(beerData)-24),2], frequency=12, start=c(1956,1))
beer_forecast<-ts(beerData[(nrow(beerData)-23):nrow(beerData), 2], start=c(1993,9), frequency=12)

adf.test(beerTS)
```

```
## Warning in adf.test(beerTS): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  beerTS
## Dickey-Fuller = -4.206, Lag order = 7, p-value = 0.01
## alternative hypothesis: stationary
```

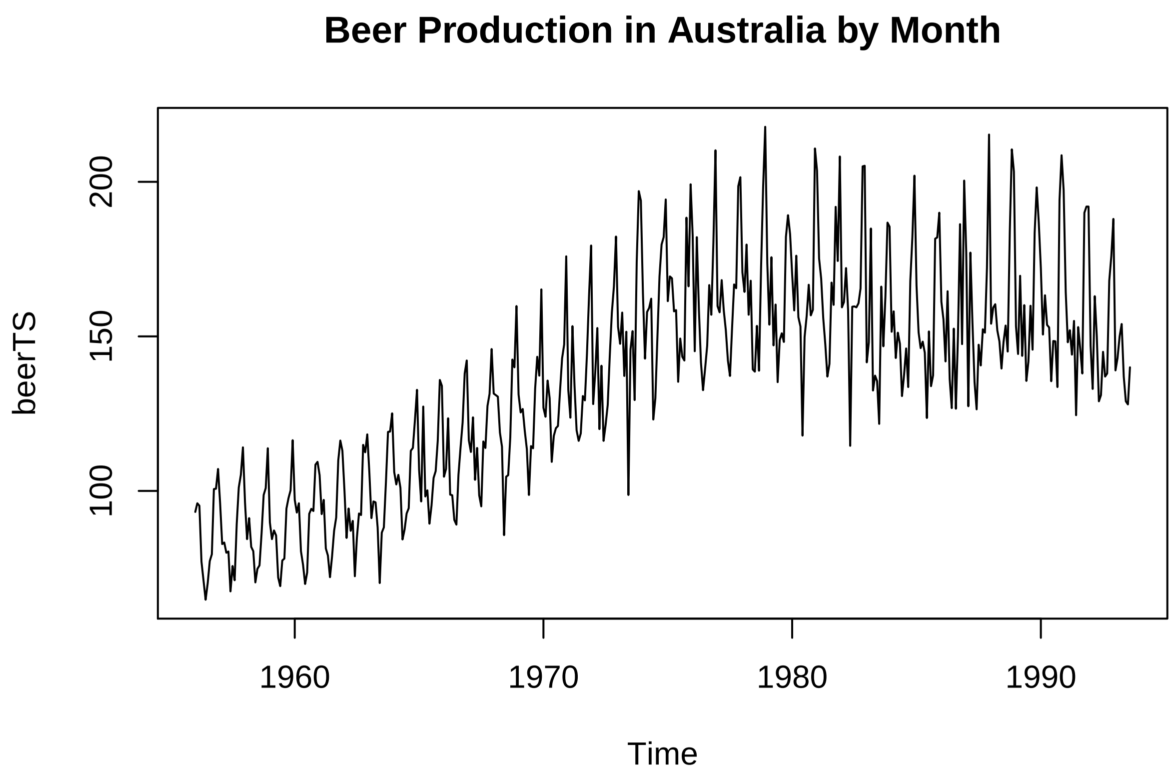
```
pp.test(beerTS)
```

```
## Warning in pp.test(beerTS): p-value smaller than printed p-value
```

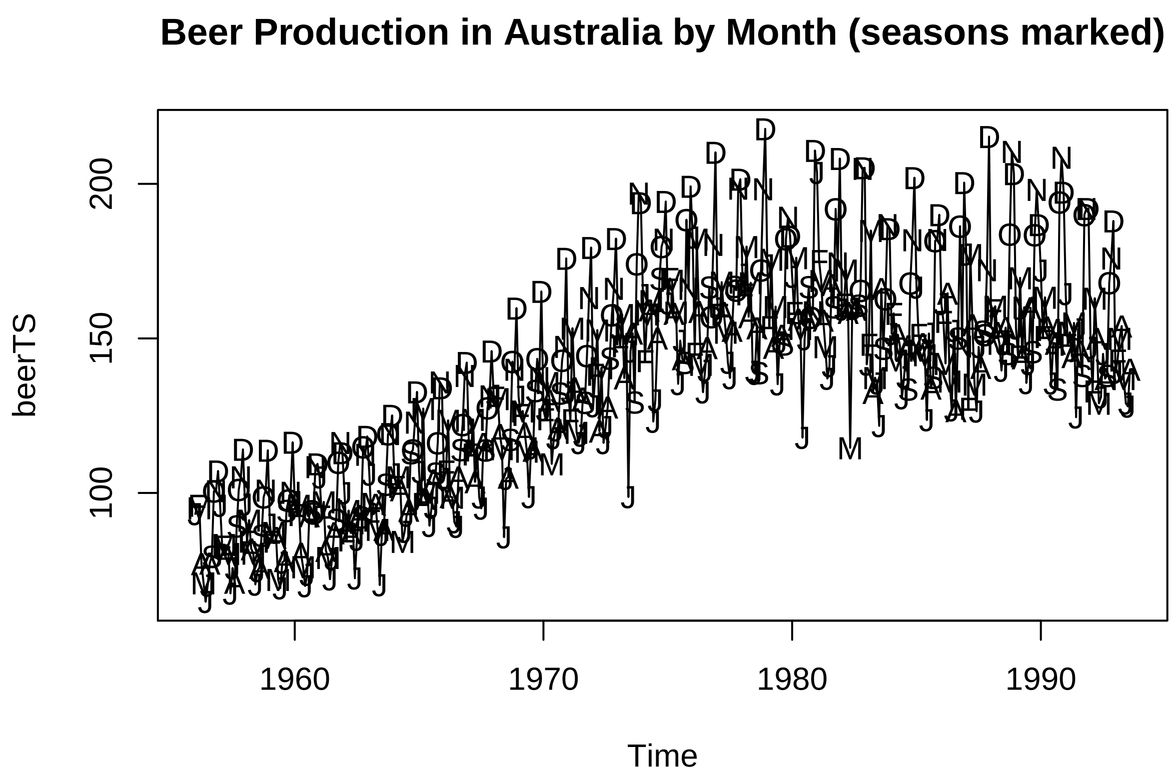
```
##
##  Phillips-Perron Unit Root Test
##
## data:  beerTS
## Dickey-Fuller Z(alpha) = -167.6, Truncation lag parameter = 5,
## p-value = 0.01
## alternative hypothesis: stationary
```

## Plot population data

```r
library(TSA)
par(mfrow=c(1,1))
plot(beerTS, main="Beer Production in Australia by Month")
```




```r
plot(beerTS, main="Beer Production in Australia by Month (seasons marked)", type="l")
points(y=beerTS, x=time(beerTS), pch=as.vector(season(beerTS)))
```

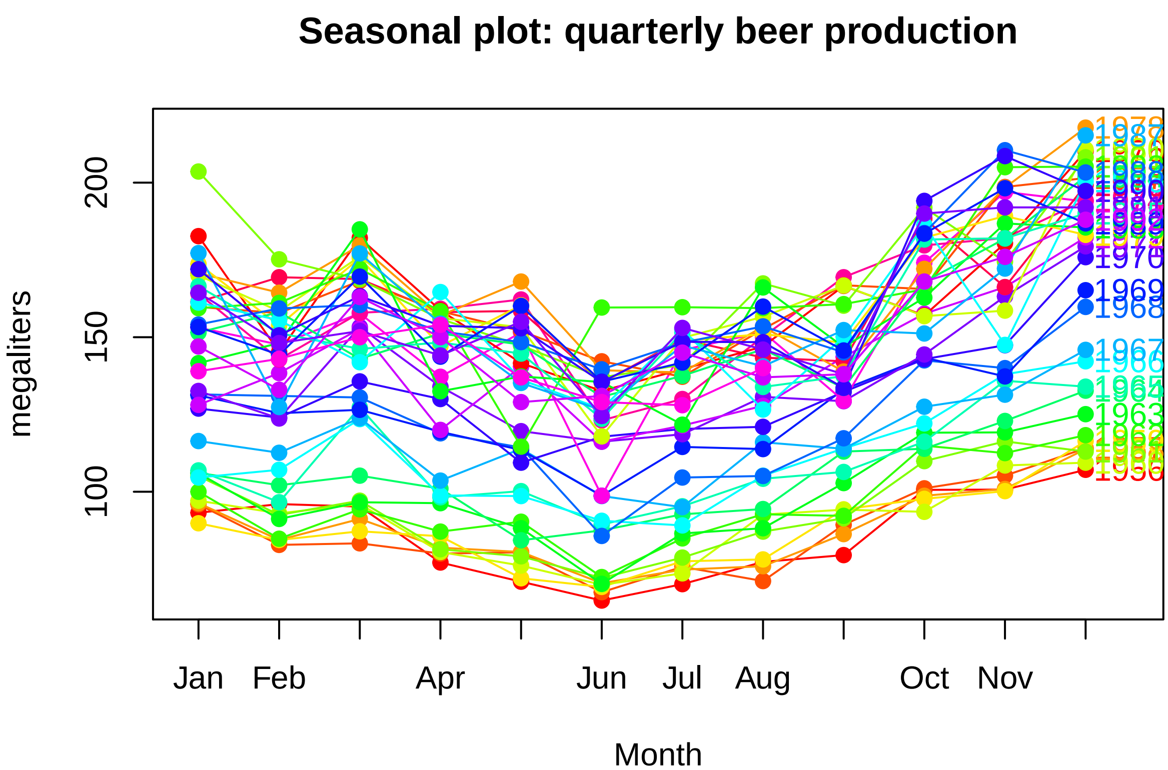



```r
require(fpp)
```

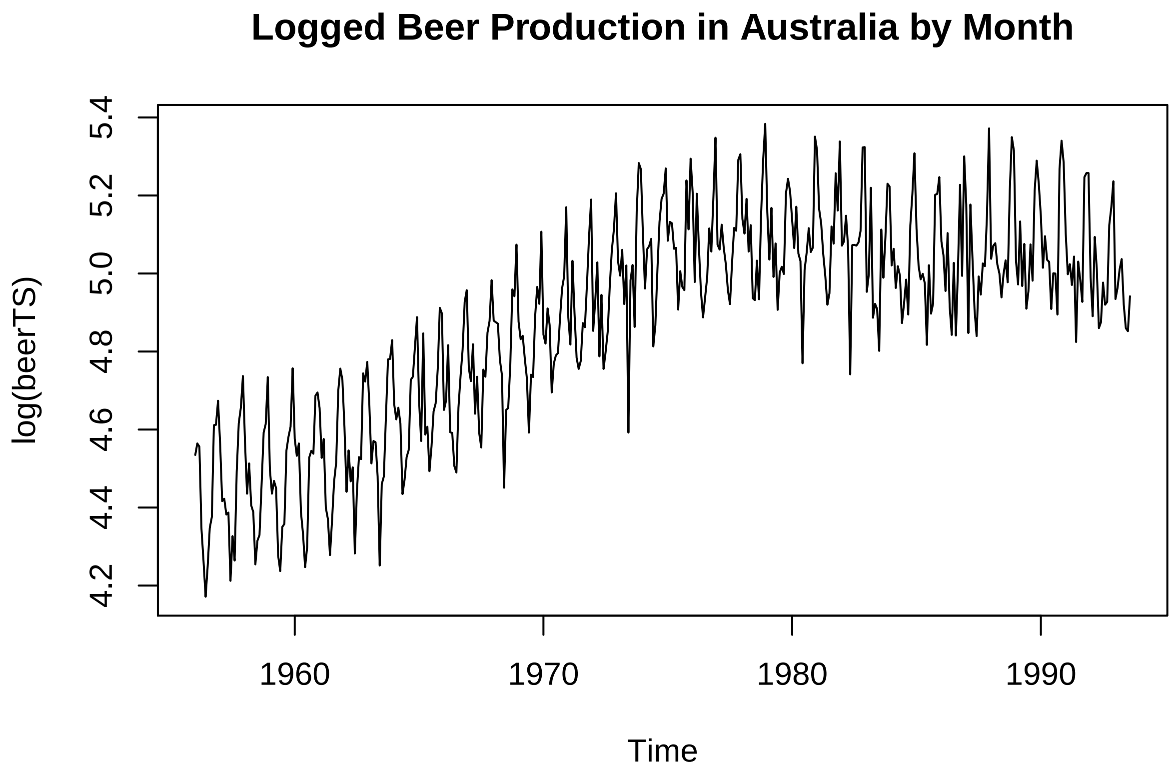
```
## Loading required package: fpp

## Loading required package: forecast

## Loading required package: zoo

##
## Attaching package: 'zoo'

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

## Loading required package: timeDate

##
## Attaching package: 'timeDate'

## The following objects are masked from 'package:TSA':
##
##     kurtosis, skewness

## This is forecast 7.0

##
## Attaching package: 'forecast'
```

```
## The following objects are masked from 'package:TSA':
##
##     fitted.Arima, plot.Arima

## The following object is masked from 'package:nlme':
##
##     getResponse

## Loading required package: fma

## Loading required package: expsmooth

## Loading required package: lmtest
```

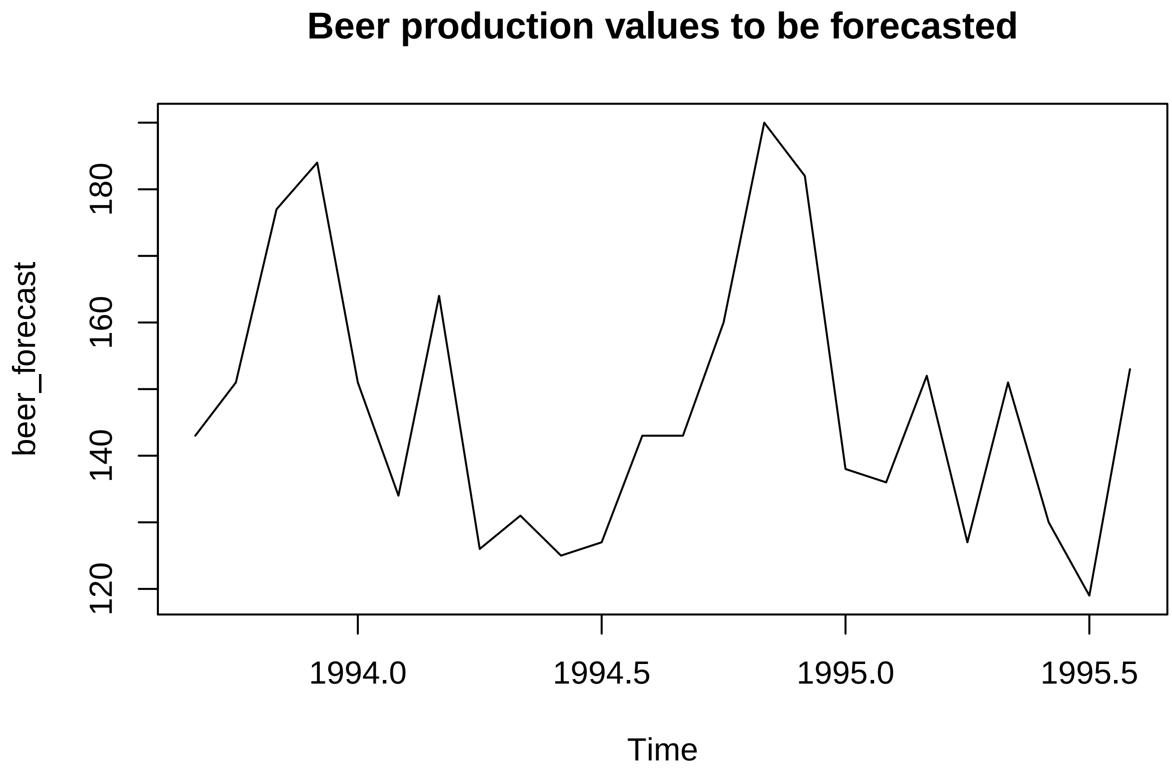
```
seasonplot(beerTS,year.labels=TRUE,ylab="megaliters",main="Seasonal plot: quarterly beer production", col=rain
```




```
plot(log(beerTS), main="Logged Beer Production in Australia by Month")
```




```
plot(beer_forecast, main="Beer production values to be forecasted")
```



```
logBeer<-log(beerTS)
```

## Investigate possible relationship with population data

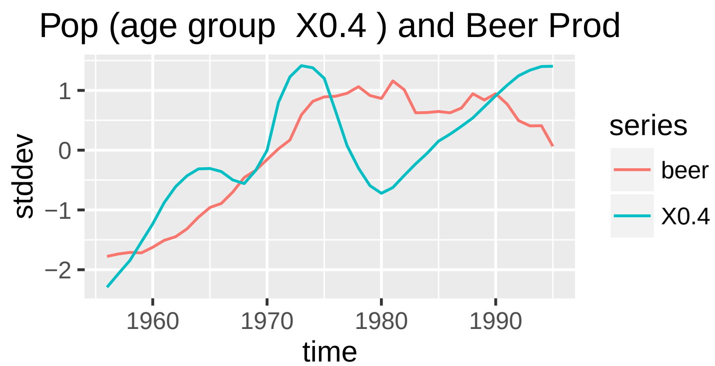
```
#load population data
library(reshape)
```

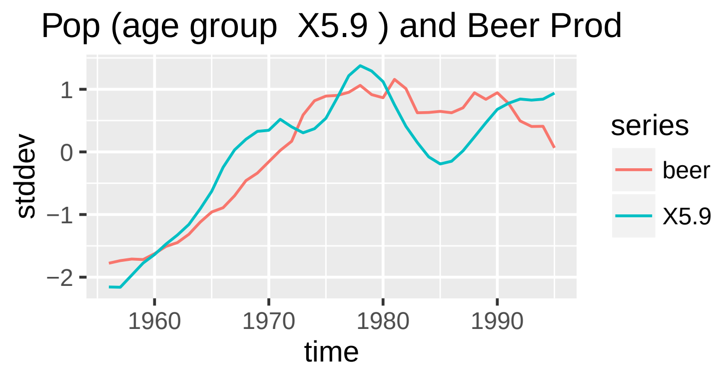
```
## Warning: package 'reshape' was built under R version 3.2.5
```

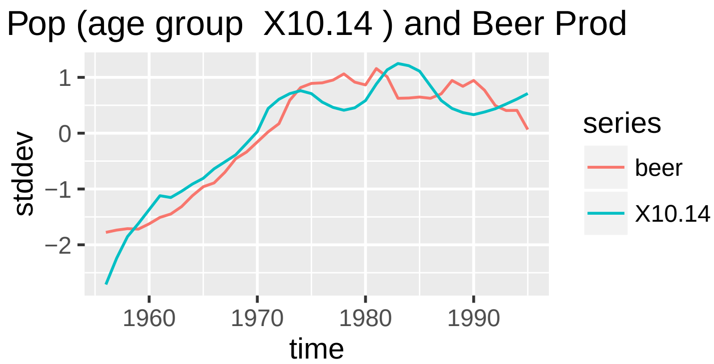
```
library(ggplot2)
```

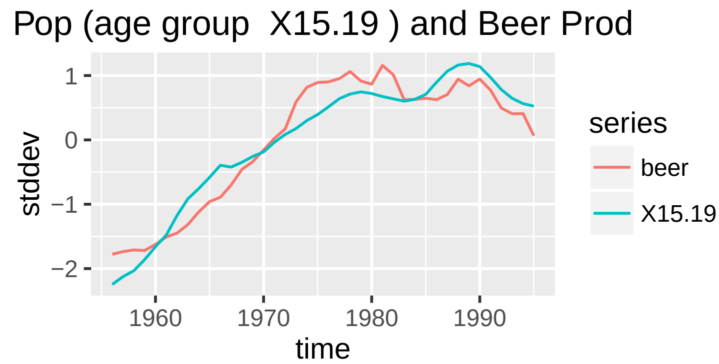
```
## Warning: package 'ggplot2' was built under R version 3.2.5
```

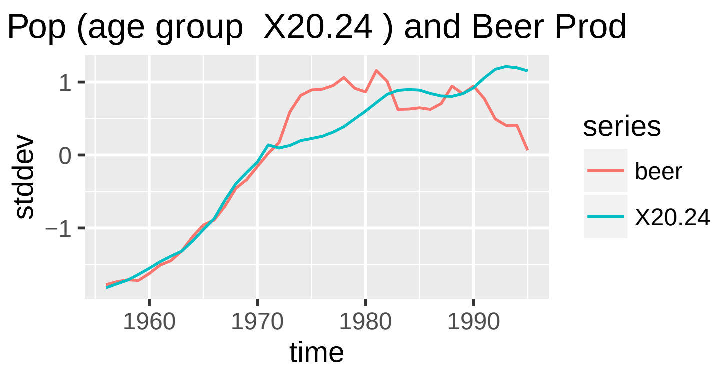
```
#Clean up population data
pop_totalData<-t(read.csv("Pop_total.csv", row.names=1))
dropCols<-colnames(pop_totalData) %in% c("Unspecified","Period not indicated")
rownames(pop_totalData)<-c(1921:2011)
pop_totalDataLong<-pop_totalData[,!dropCols]
pop_totalData<-pop_totalData[paste(1956:1995),!dropCols]

#Aggregate beer data
beerYear<-seq(from=1956, to=1996, by=1)
beerYear<-rep(beerYear, each=12)
beerYear<-beerYear[1:nrow(beerData)]
beerAg<-aggregate(beerData[,2], FUN=mean, by=list(year=beerYear))

#Attach to beer data
beerPop<-data.frame(cbind(beer=beerAg[,2],pop_totalData))
beerPopScale<-scale(beerPop)

beerPopRes<-melt(beerPopScale, variable.name="series")
colnames(beerPopRes)<-c("time", "series", "stddev")

allNames<-colnames(beerPop)[2:length(colnames(beerPop))]

#Plot data for each age group and beer data on same plot
par(mfrow=c(2,2))
for (name in allNames) {
  subset_data<-subset(beerPopRes, beerPopRes$series%in%c("beer", name))
  newPlot<-ggplot(subset_data, aes(time,stddev)) + geom_line(aes(colour = series)) +ggtitle(paste("Pop (age gr
  print(newPlot)
}
```

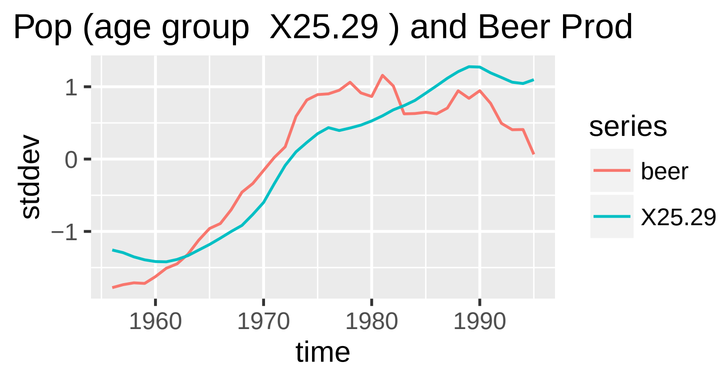


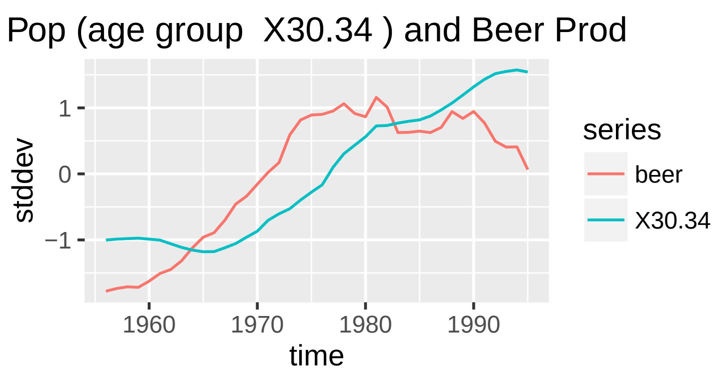



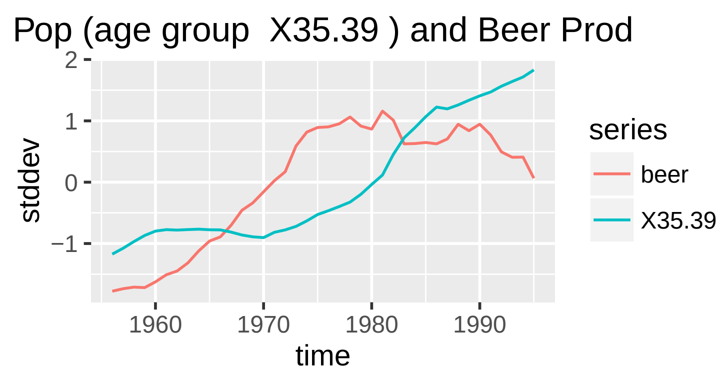

Pop (age group X10.14 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X10.14

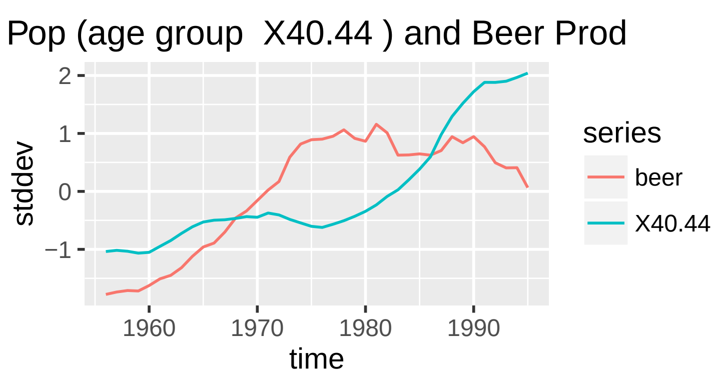

Pop (age group X15.19 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X15.19

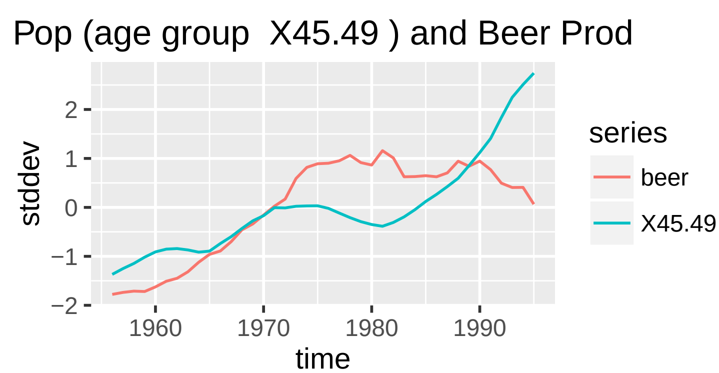

Pop (age group X20.24 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X20.24

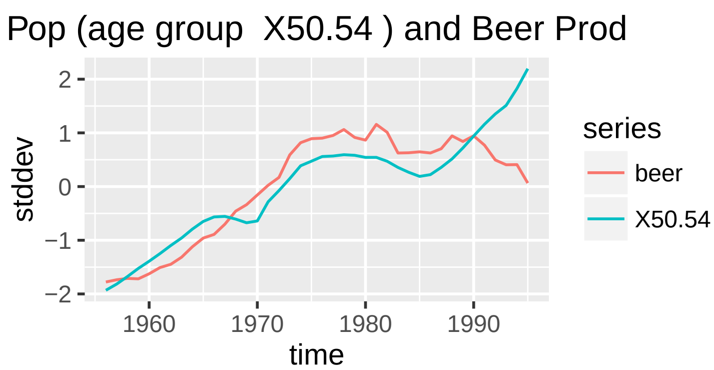

Pop (age group X25.29 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X25.29

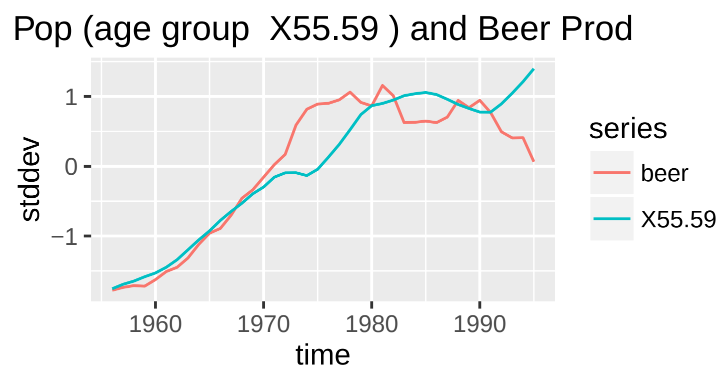

Pop (age group X30.34 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X30.34

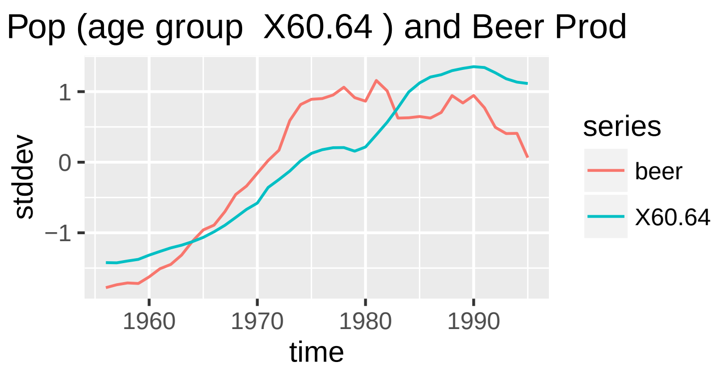

Pop (age group X35.39 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X35.39

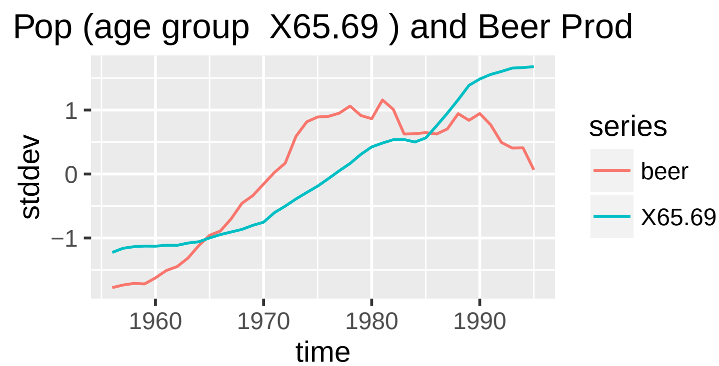

Pop (age group X40.44 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X40.44

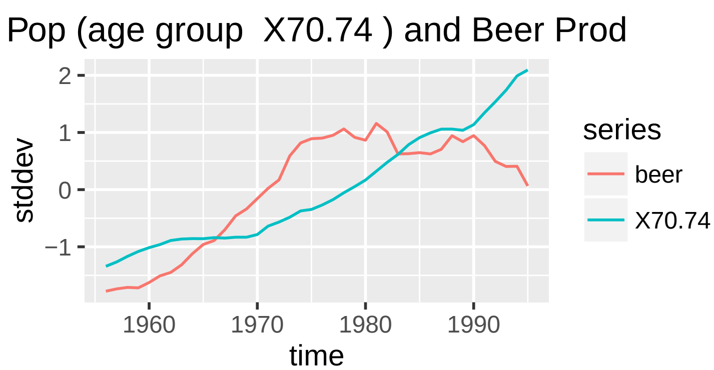

Pop (age group X45.49 ) and Beer Prod
stddev
time
1960
1970
1980
1990
series
beer
X45.49

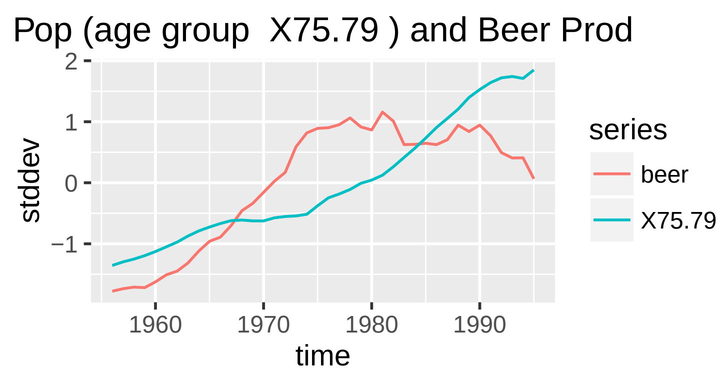

Pop (age group  X50.54 ) and Beer Prod
stddev
2
1
0
−1
−2
1960
1970
1980
1990
time
series
beer
X50.54

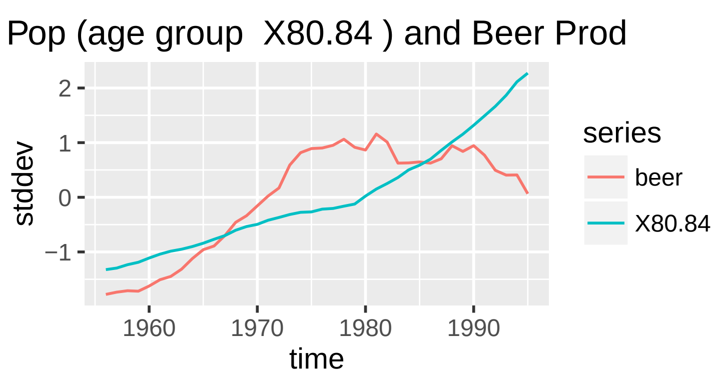

Pop (age group  X55.59 ) and Beer Prod
stddev
1
0
−1
1960
1970
1980
1990
time
series
beer
X55.59

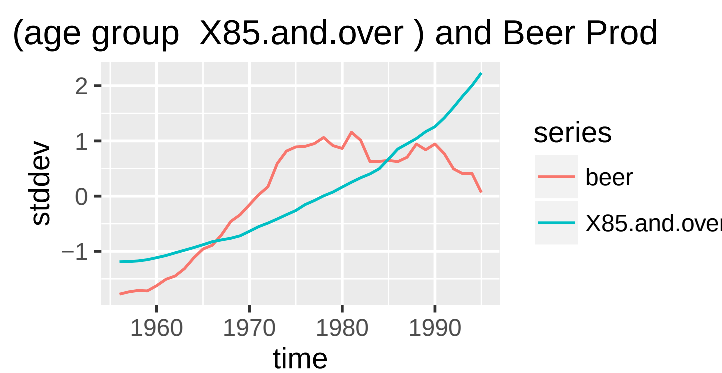

Pop (age group  X60.64 ) and Beer Prod
stddev
1
0
−1
1960
1970
1980
1990
time
series
beer
X60.64

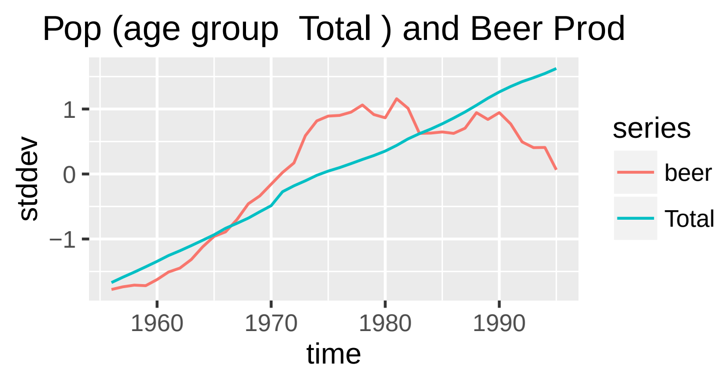

Pop (age group  X65.69 ) and Beer Prod
stddev
1
0
−1
1960
1970
1980
1990
time
series
beer
X65.69


Pop (age group  X70.74 ) and Beer Prod
stddev
2
1
0
−1
1960
1970
1980
1990
time
series
beer
X70.74


Pop (age group  X75.79 ) and Beer Prod
stddev
2
1
0
−1
1960
1970
1980
1990
time
series
beer
X75.79


Pop (age group  X80.84 ) and Beer Prod
stddev
2
1
0
−1
1960
1970
1980
1990
time
series
beer
X80.84

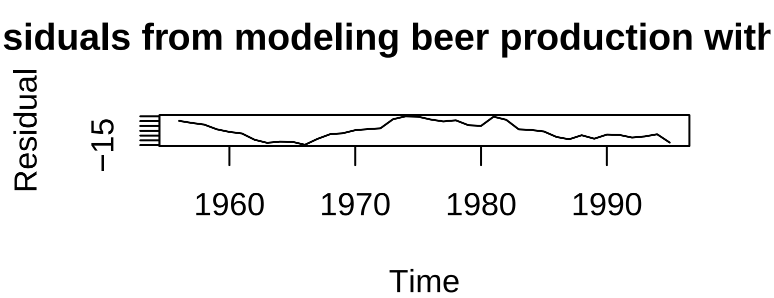

(age group  X85.and.over ) and Beer Prod
stddev
2
1
0
−1
1960
1970
1980
1990
time
series
beer
X85.and.over




```
par(mfrow=c(1,1))

#Make a model based on the 15-19 age group
yearModel1<-lm(beer ~ X15.19, data=beerPop)
summary(yearModel1)
```

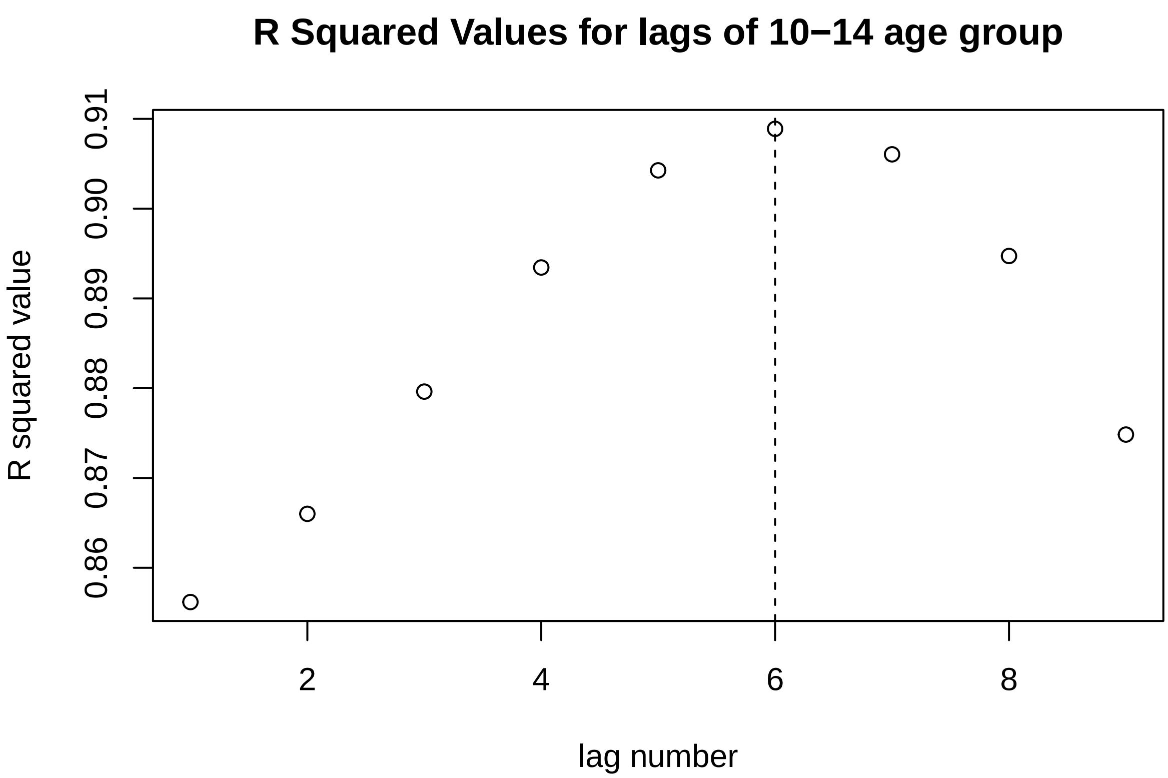
```
##
## Call:
## lm(formula = beer ~ X15.19, data = beerPop)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -14.6061  -6.6167  -0.9743   6.8537  15.0442
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.713e-01  7.188e+00  -0.038     0.97
## X15.19       1.194e-04  6.163e-06  19.374   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.706 on 38 degrees of freedom
## Multiple R-squared:  0.9081, Adjusted R-squared:  0.9057
## F-statistic: 375.4 on 1 and 38 DF,  p-value: < 2.2e-16
```

```
plot(ts(residuals(yearModel1), frequency=1, start=c(1956)), main="Residuals from modeling beer production with
```




## Explore lagged x10.14 data

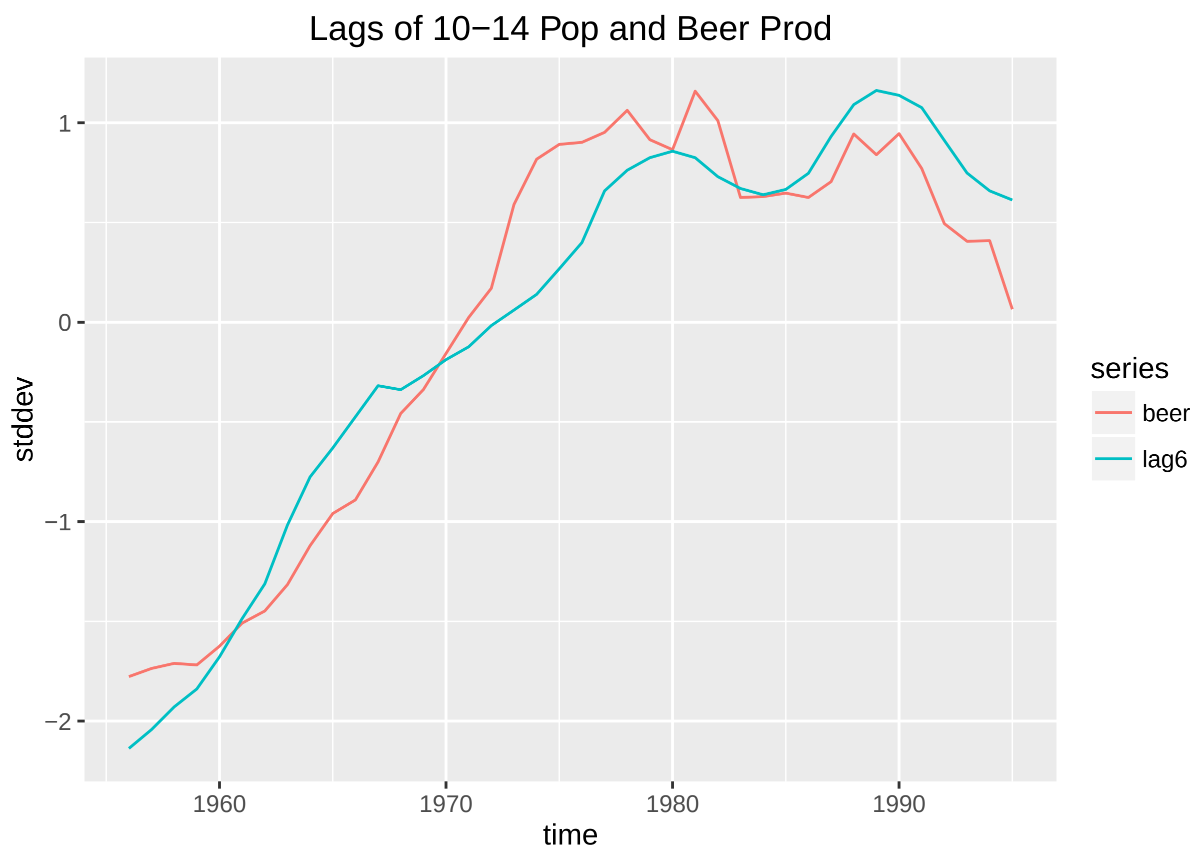
```r
laggedData<-data.frame(beer=beerAg[,2])
models<-list()
modelRsq<-c()
for (lag in 0:8) {
  newColNames<-c(colnames(laggedData), paste("lag", lag, sep=""))
  newLag<-pop_totalDataLong[paste(1956:1995-lag), "10-14"]
  laggedData<-data.frame(laggedData, newLag)
  newModel<-lm(beer ~ newLag, data=laggedData)
  models[[paste("lag", lag, sep="")]]<-newModel
  modelRsq<-c(modelRsq, summary(newModel)$r.squared)
  colnames(laggedData)<-newColNames

}

plot(modelRsq, main="R Squared Values for lags of 10-14 age group", xlab="lag number", ylab="R squared value")
abline(v=6, lty=2)
```



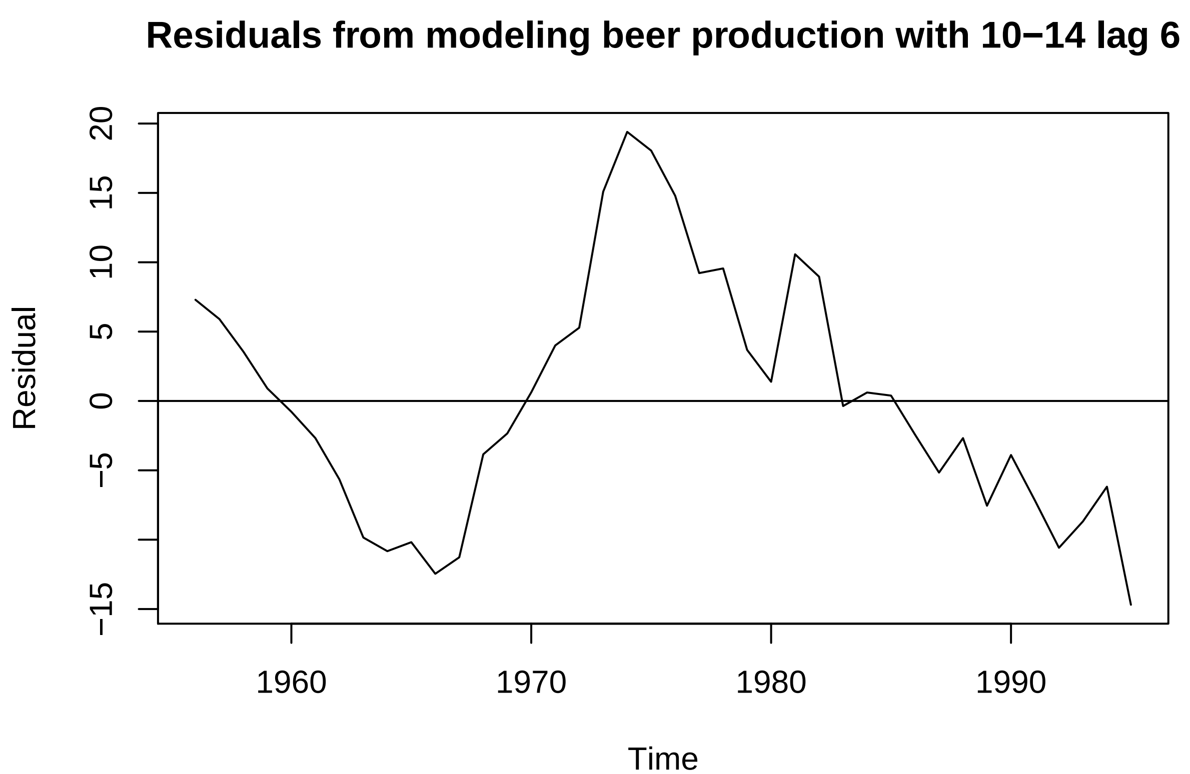

```r
max(modelRsq)
```

```
## [1] 0.9088865
```

```r
lagDataScale<-scale(laggedData)[,c(1,8)]
lagDataMelt<-melt(lagDataScale, variable.name="series")
colnames(lagDataMelt)<-c("time", "series", "stddev")

newPlot<-ggplot(lagDataMelt, aes(time,stddev)) + geom_line(aes(colour = series)) +ggtitle(paste("Lags of 10-14
print(newPlot)
```

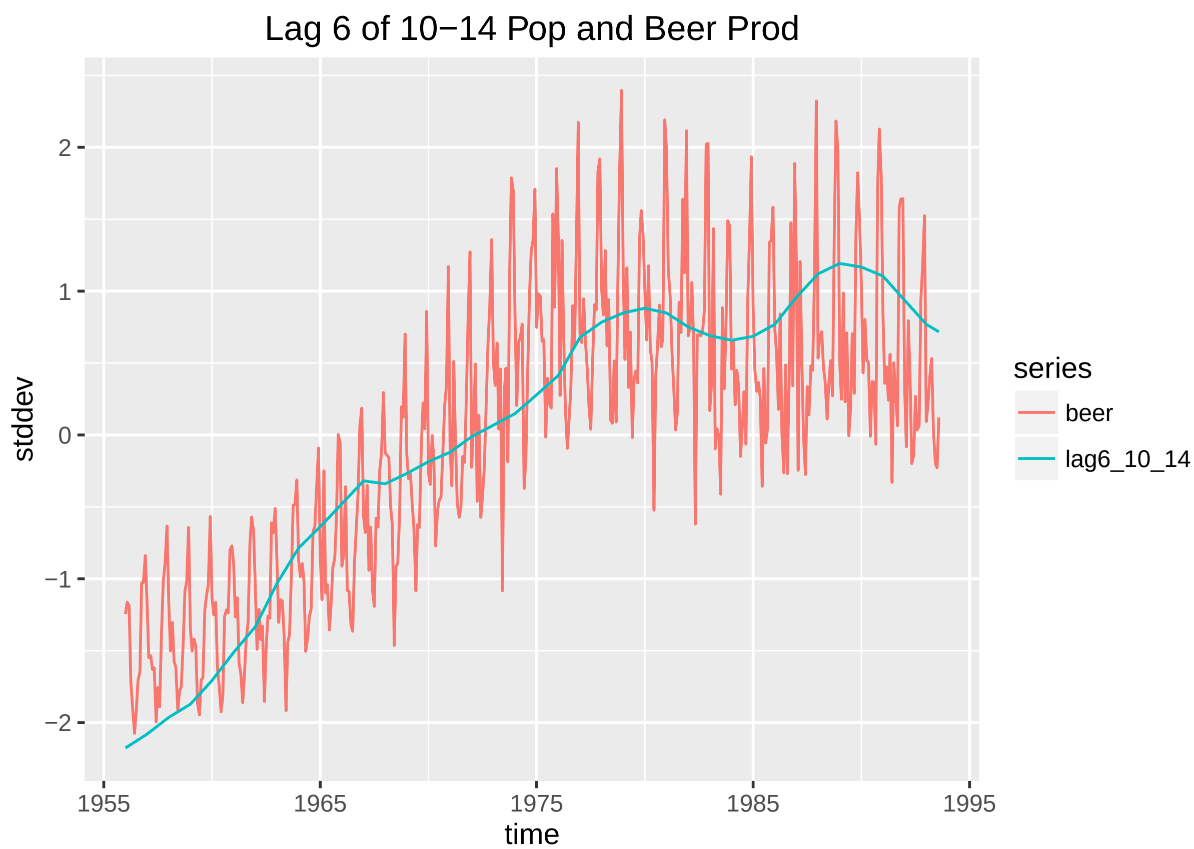



```
plot(ts(residuals(models[["lag6"]]), frequency=1, start=c(1956)), main="Residuals from modeling beer productio
abline(h=0)
```



## Interpolate Monthly Numbers

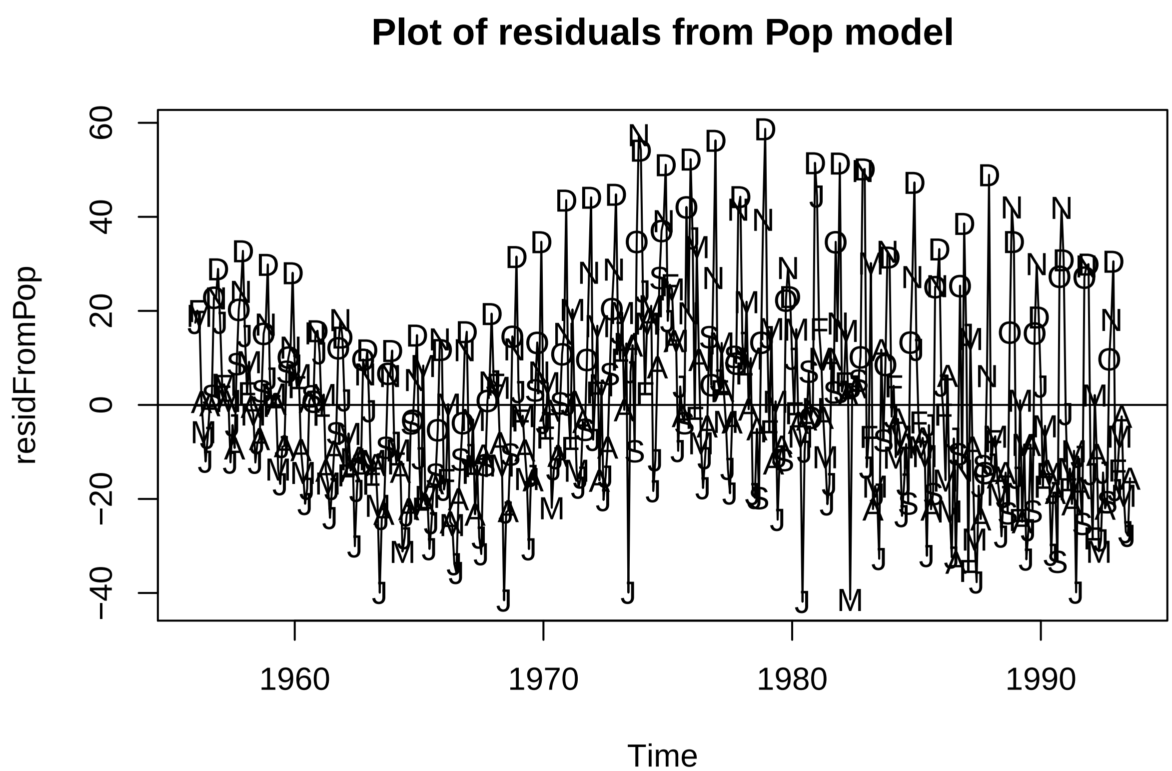
```
library(zoo)

#Create a vector with missing values for zoo to interpolate
withNA<-c()
for (year in 1:nrow(laggedData)) {
  withNA<-c(withNA, laggedData$lag6[year], rep(NA, 11))
}

#Create a vector with missing values for zoo to interpolate
withNALong<-c()
for (year in 1:nrow(pop_totalDataLong)) {
  withNALong<-c(withNALong, pop_totalDataLong[year, "10-14"], rep(NA, 11))
}


#Interpolate values using zoo library
zooSeries<-zoo(withNA, frequency=12)
wAppx<-na.approx(zooSeries, na.rm=FALSE)
monthlyLag6<-wAppx

#Interpolate long series for forecasting
zooSeriesLong<-zoo(withNALong, frequency=12)
wAppxLong<-data.frame(na.approx(zooSeriesLong, na.rm=FALSE))
rownames(wAppxLong)<-round(seq(from=(1921+6), length.out=nrow(wAppxLong), by=1/12),2)
monthlyLag6Long<-wAppxLong

#Reattach to beer numbers for plotting
beerPopMonth<-data.frame(beer=beerTS, lag6_10_14=monthlyLag6[1:length(beerTS)])
rownames(beerPopMonth)<-round(seq(from=1956, length.out=length(beerTS), by=1/12),2)
scaleMonth<-scale(beerPopMonth)
scaleMonthMelt<-melt(scaleMonth, variable.name="series")
colnames(scaleMonthMelt)<-c("time", "series", "stddev")

#Make a pretty plot
newPlot<-ggplot(scaleMonthMelt, aes(time,stddev)) + geom_line(aes(colour = series)) +ggtitle(paste("Lag 6 of 1
print(newPlot)
```




```r
#Try a model
monthlyPopModel<-lm(beer ~ lag6_10_14, data=beerPopMonth)
summary(monthlyPopModel)
```

```
##
## Call:
## lm(formula = beer ~ lag6_10_14, data = beerPopMonth)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -41.862 -14.399  -2.561  13.099  58.717
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 6.919e+00  4.554e+00   1.519    0.129
## lag6_10_14  1.180e-04  4.076e-06  28.946   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 20.25 on 450 degrees of freedom
## Multiple R-squared:  0.6506, Adjusted R-squared:  0.6498
## F-statistic: 837.9 on 1 and 450 DF,  p-value: < 2.2e-16
```

```r
residFromPop<-ts(residuals(monthlyPopModel), frequency=12, start=c(1956,1))
plot(residFromPop, type="l", main="Plot of residuals from Pop model")
points(y=residFromPop, x=time(residFromPop), pch=as.vector(season(residFromPop)))
abline(h=0)
```

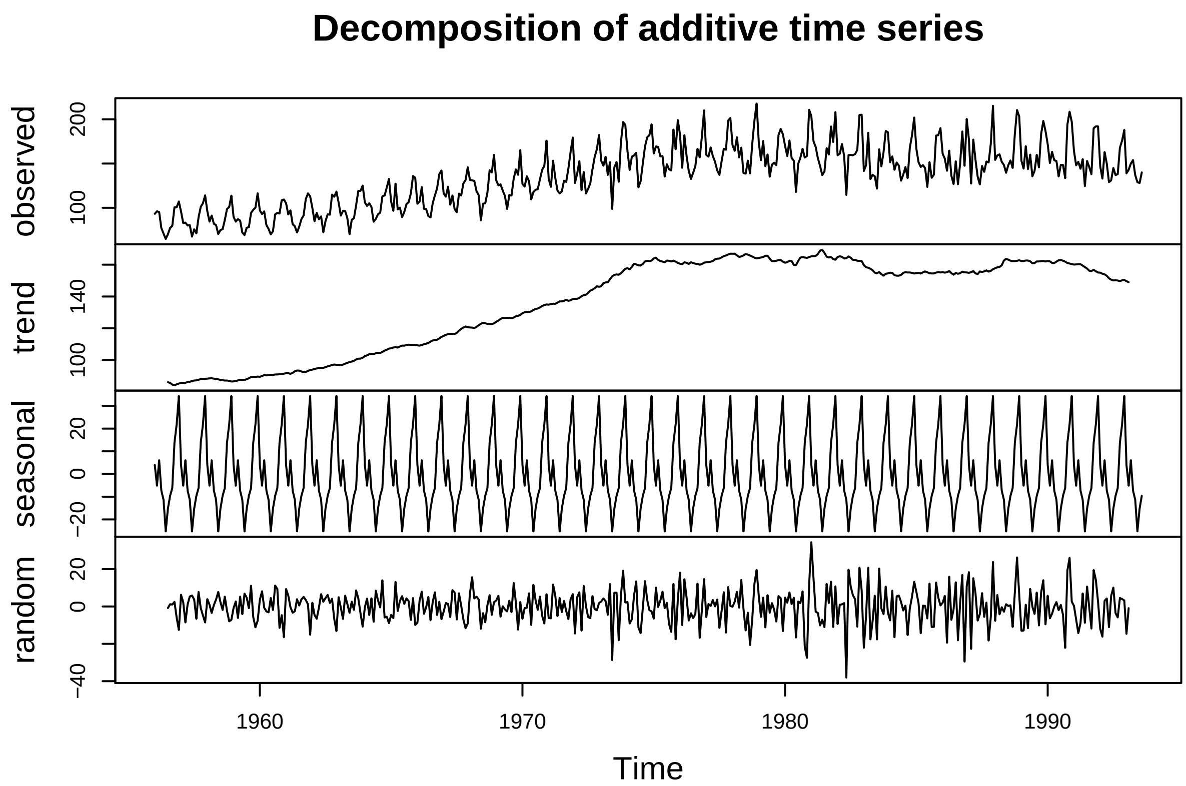



## Define helper functions

```
getModelString<-function(model) {
  modSpec<-model$arma
  modelString<-paste("SARIMA(", modSpec[1],",", modSpec[6], ",", modSpec[2],")(", modSpec[3], ",", modSpec[7],

  return(modelString)
}

plotResid<-function(model) {
  residuals<-ts(residuals(model), frequency=12, start=c(1956,1))
  modelString<-getModelString(model)
  par(mfrow=c(1,1))
  acf(residuals, main=paste("ACF of", modelString), lag.max=40, cex=.5)
  pacf(residuals, main=paste("PACF of", modelString), lag.max=40, cex=.5)
  par(mfrow=c(1,1))
}
```

## Decompsing the time series to see trends and patterns

```
decompbeer = decompose (beerTS, type="additive")
plot (decompbeer)
```




```r
#monthplot(beerTS, main="Decomposition of Series by Month")
```

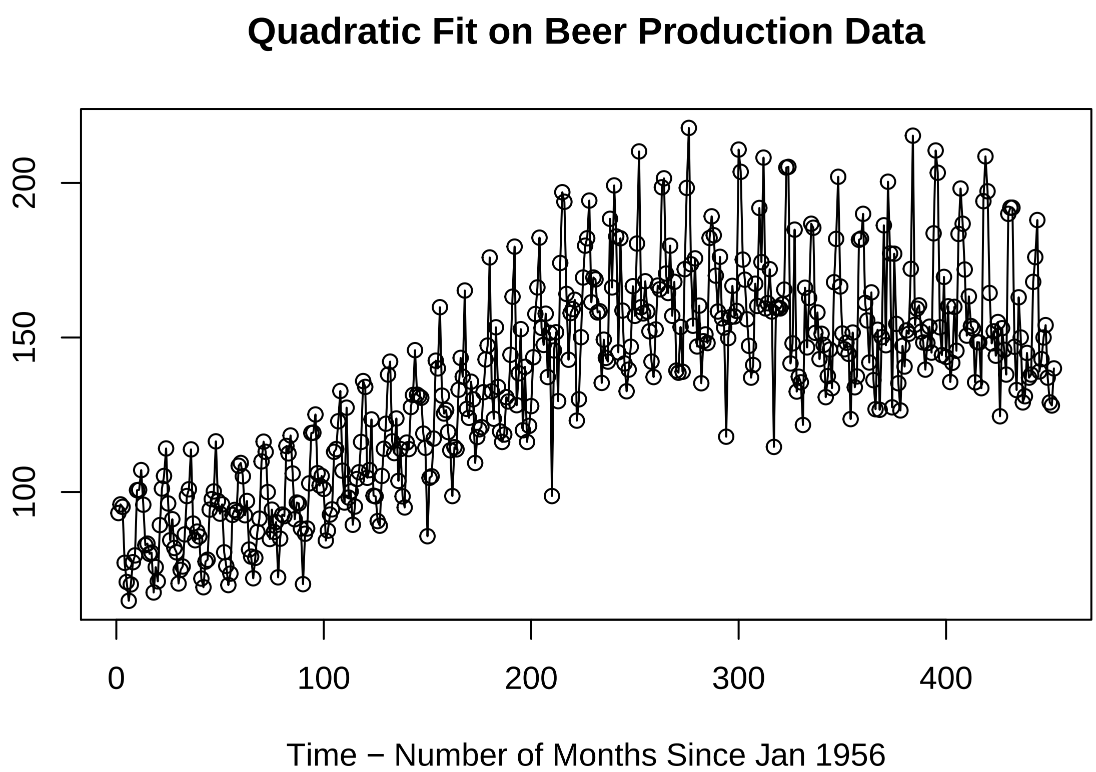
## Try to figure out deterministic trend

```r
t<-1:length(beerTS)
t2<-t^2
t3<-t^3
t4<-t^4
t5<-t^5

quadFit<-lm(beerTS~t+t2)
summary(quadFit)
```

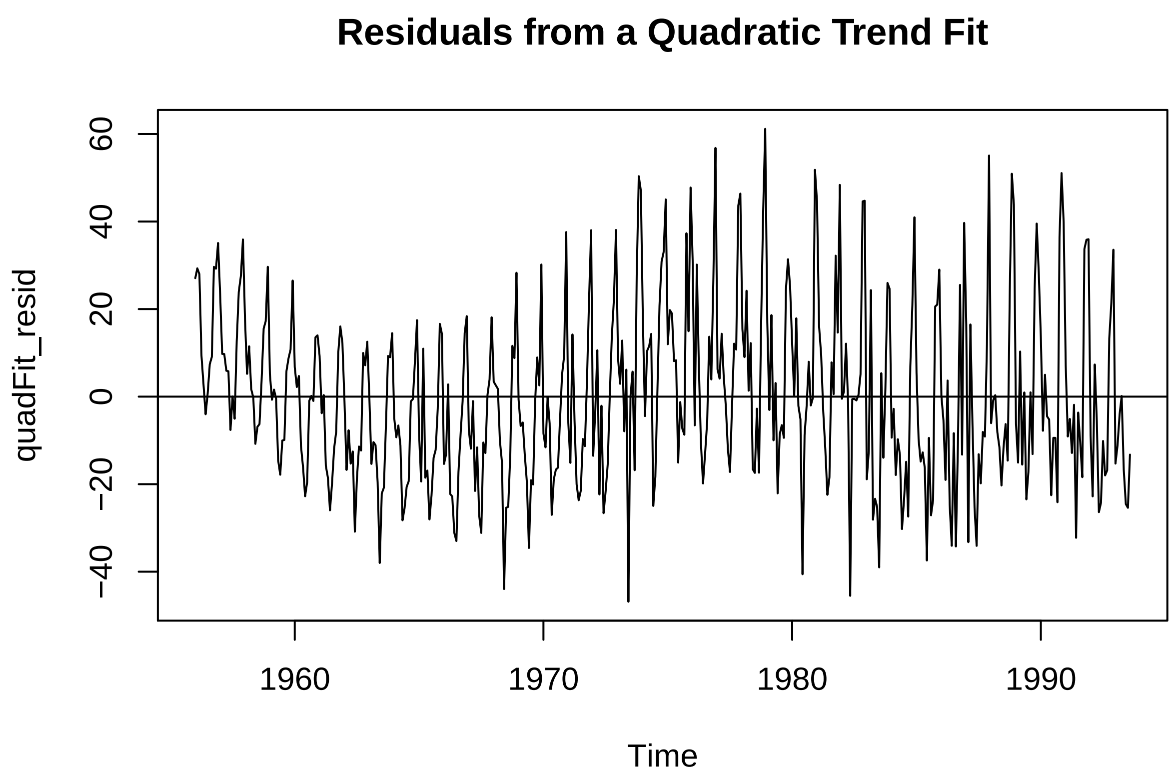
```
##
## Call:
## lm(formula = beerTS ~ t + t2)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -46.861 -14.133  -1.991  11.937  61.174
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  6.560e+01  2.828e+00   23.20   <2e-16 ***
## t            5.429e-01  2.883e-02   18.83   <2e-16 ***
## t2          -7.721e-04  6.163e-05  -12.53   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 19.95 on 449 degrees of freedom
## Multiple R-squared:  0.6616, Adjusted R-squared:  0.6601
## F-statistic:   439 on 2 and 449 DF,  p-value: < 2.2e-16
```

```
#### plot the data and the fitted quadratic trend function
plot(x=1:length(beerTS),y=beerTS,type='o',ylab="",xlab="Time - Number of Months Since Jan 1956",main="Quadrati
curve(expr = coef(quadFit)[1]+coef(quadFit)[2]*x+coef(quadFit)[3]*x^2+coef(quadFit)[4]*x^3,lty=1,add = TRUE, c
```



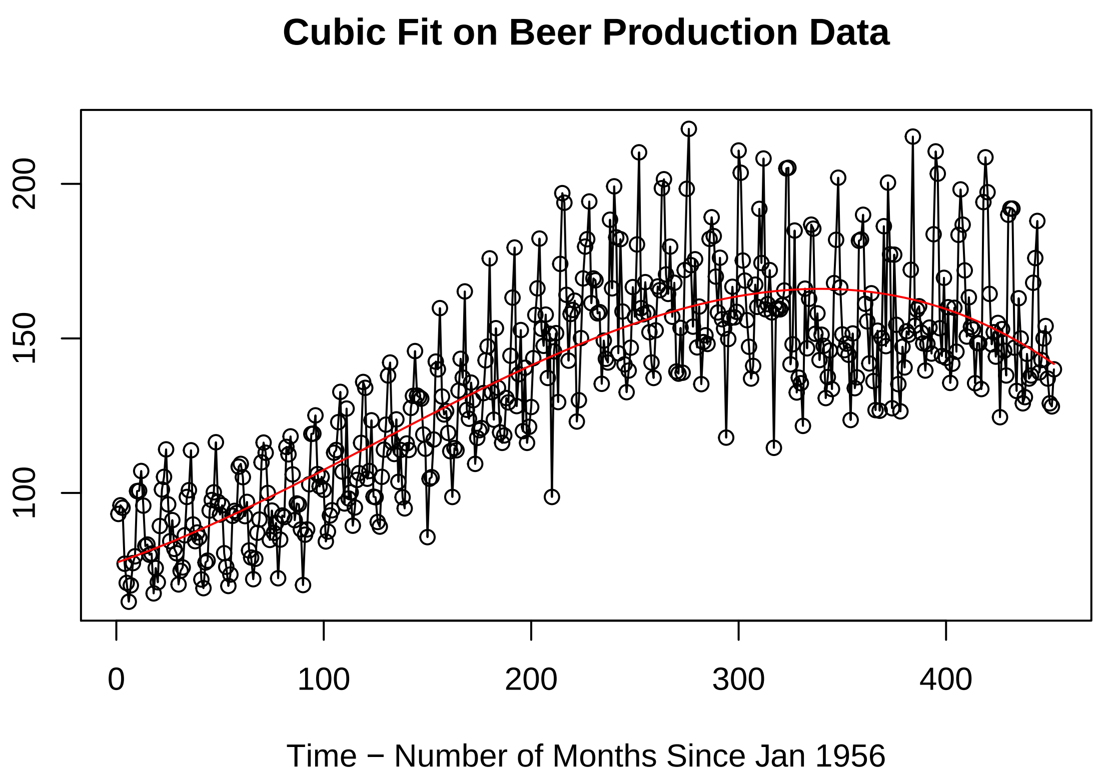

```
quadFit_resid<-ts(residuals(quadFit),frequency=12, start=c(1956,1))
plot(quadFit_resid, main="Residuals from a Quadratic Trend Fit")
abline(h=0)
```



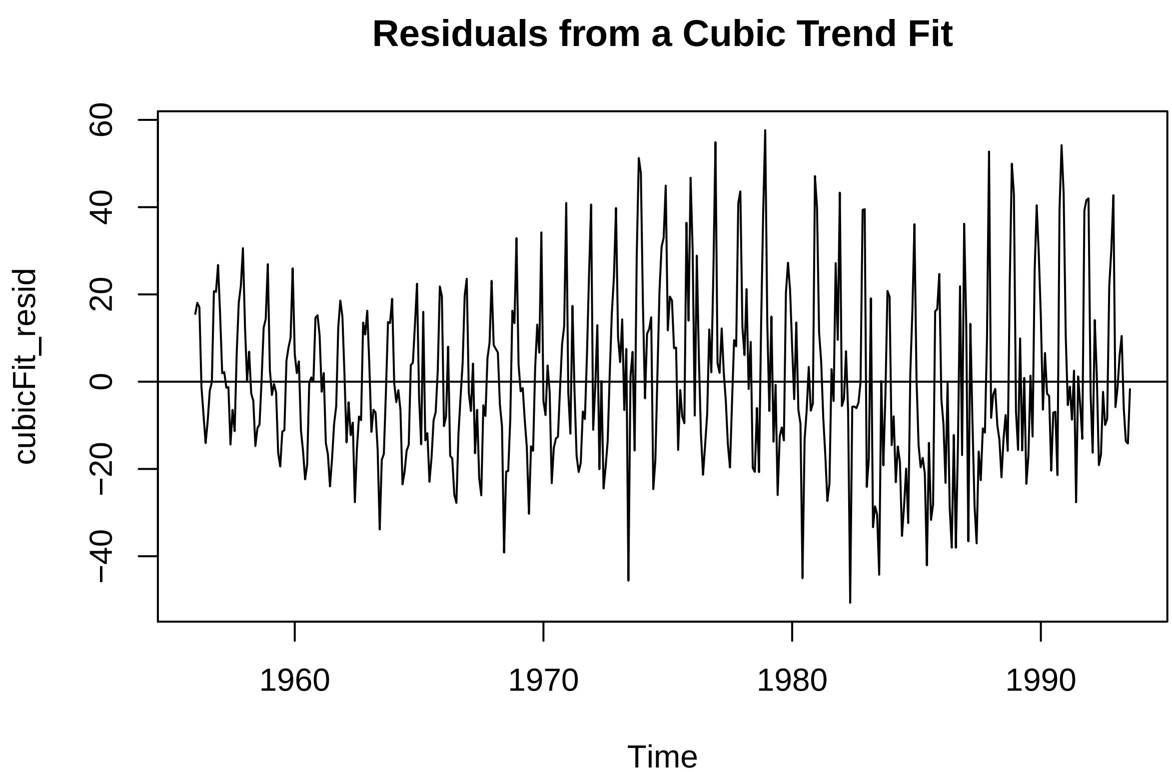

```
cubicFit<-lm(beerTS~t+t2+t3)
summary(cubicFit)
```

```
##
## Call:
## lm(formula = beerTS ~ t + t2 + t3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -50.660 -13.783  -2.601  12.434  57.639
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.745e+01  3.695e+00  20.963  < 2e-16 ***
## t            2.307e-01  7.056e-02   3.270  0.00116 **
## t2           9.490e-04  3.617e-04   2.624  0.00900 **
## t3          -2.533e-06  5.249e-07  -4.826 1.92e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 19.47 on 448 degrees of freedom
## Multiple R-squared:  0.6784, Adjusted R-squared:  0.6762
## F-statistic:   315 on 3 and 448 DF,  p-value: < 2.2e-16
```

```
#### plot the data and the fitted quadratic trend function
plot(x=1:length(beerTS),y=beerTS,type='o',ylab="",xlab="Time - Number of Months Since Jan 1956",main="Cubic Fi
curve(expr = coef(cubicFit)[1]+coef(cubicFit)[2]*x+coef(cubicFit)[3]*x^2+coef(cubicFit)[4]*x^3,lty=1,add = TRU
```



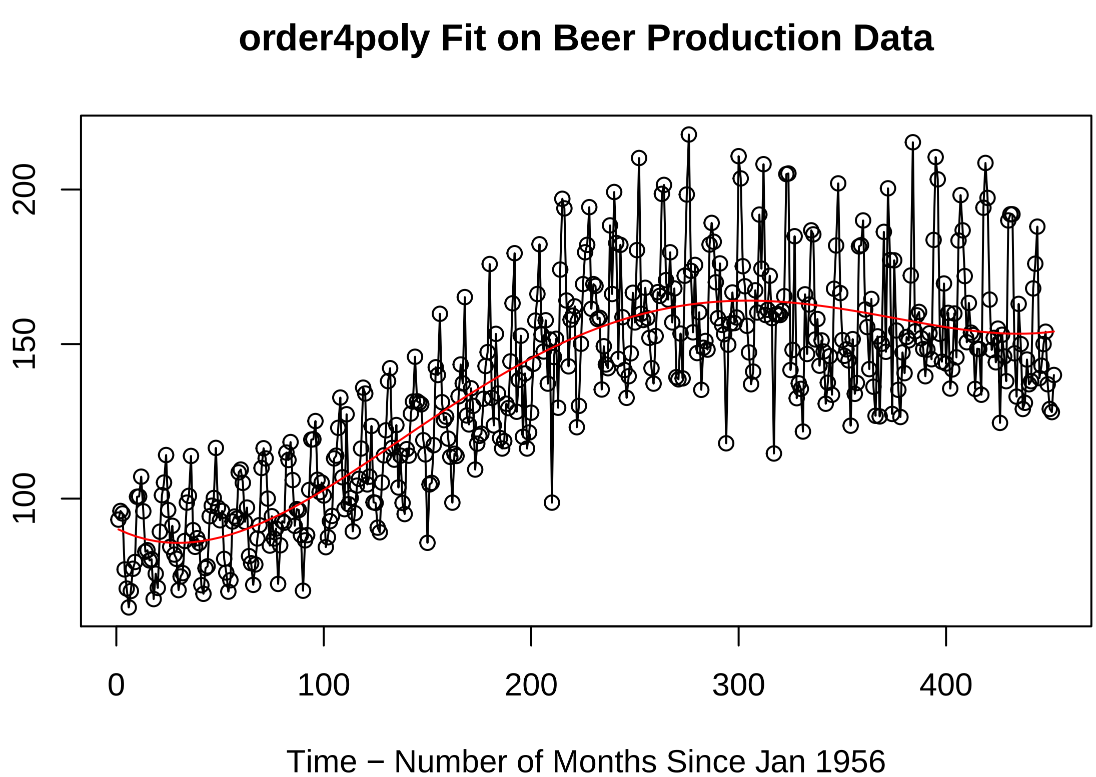

```
cubicFit_resid<-ts(residuals(cubicFit),frequency=12, start=c(1956,1))
plot(cubicFit_resid, main="Residuals from a Cubic Trend Fit")
abline(h=0)
```



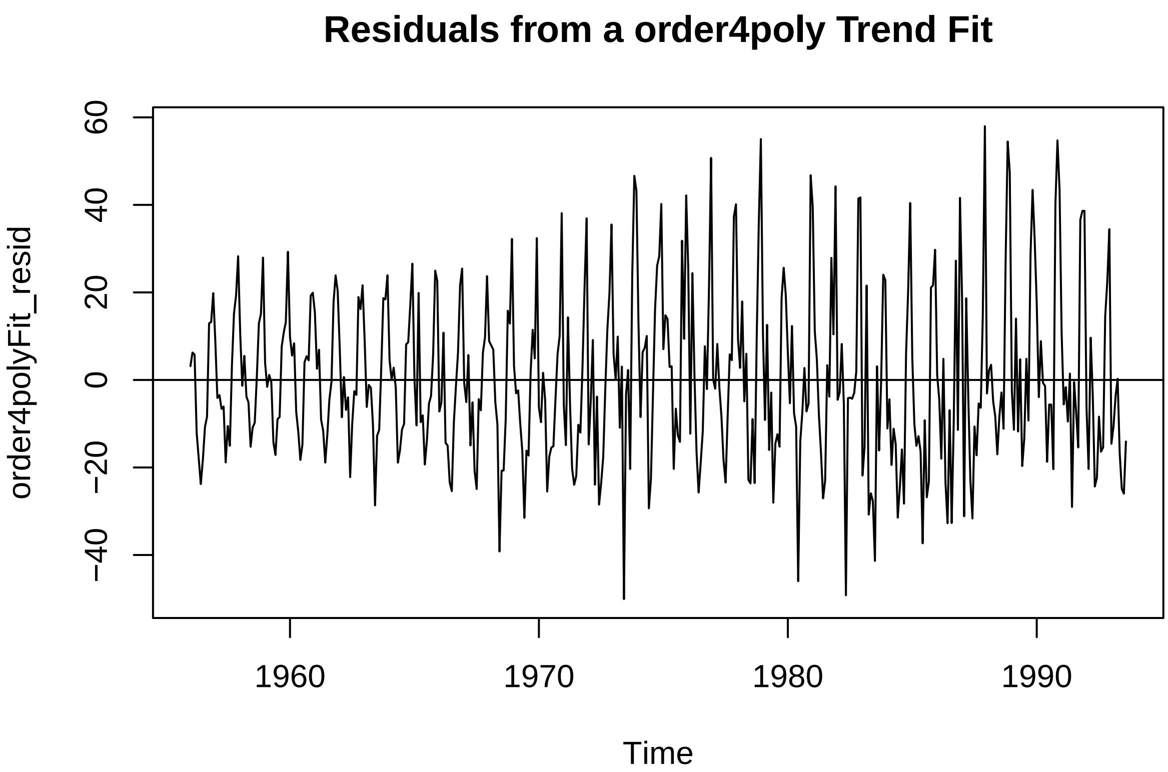
```r
order4polyFit<-lm(beerTS~t+t2+t3+t4)
summary(order4polyFit)
```

```
##
## Call:
## lm(formula = beerTS ~ t + t2 + t3 + t4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -50.079 -12.721  -3.199  10.135  57.983
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  9.037e+01  4.536e+00  19.924  < 2e-16 ***
## t           -3.341e-01  1.384e-01  -2.414   0.0162 *
## t2           6.545e-03  1.241e-03   5.276 2.07e-07 ***
## t3          -2.173e-05  4.113e-06  -5.285 1.97e-07 ***
## t4           2.119e-08  4.504e-09   4.706 3.38e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 19.03 on 447 degrees of freedom
## Multiple R-squared:  0.6935, Adjusted R-squared:  0.6908
## F-statistic: 252.9 on 4 and 447 DF,  p-value: < 2.2e-16
```

```r
#### plot the data and the fitted 4th order polynomial trend function
plot(x=1:length(beerTS),y=beerTS,type='o',ylab="",xlab="Time - Number of Months Since Jan 1956",main="order4po
curve(expr = coef(order4polyFit)[1]+coef(order4polyFit)[2]*x+coef(order4polyFit)[3]*x^2+coef(order4polyFit)[4]
```



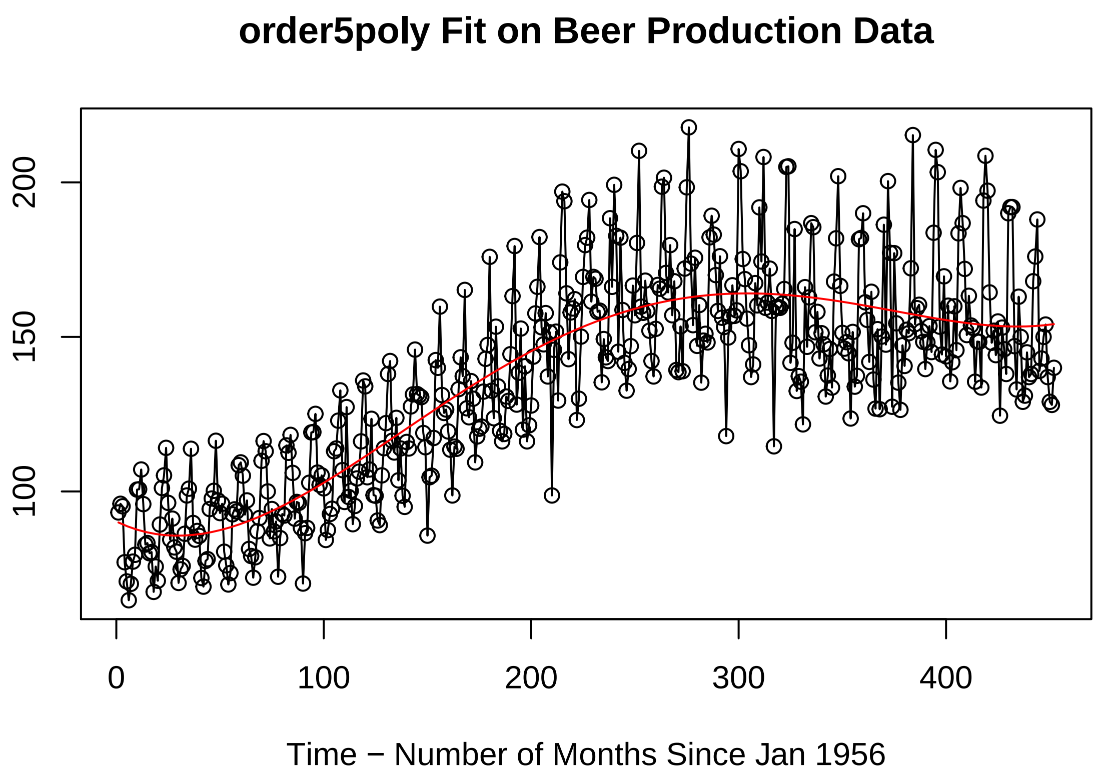
```r
order4polyFit_resid<-ts(residuals(order4polyFit),frequency=12, start=c(1956,1))
plot(order4polyFit_resid, main="Residuals from a order4poly Trend Fit")
abline(h=0)
```



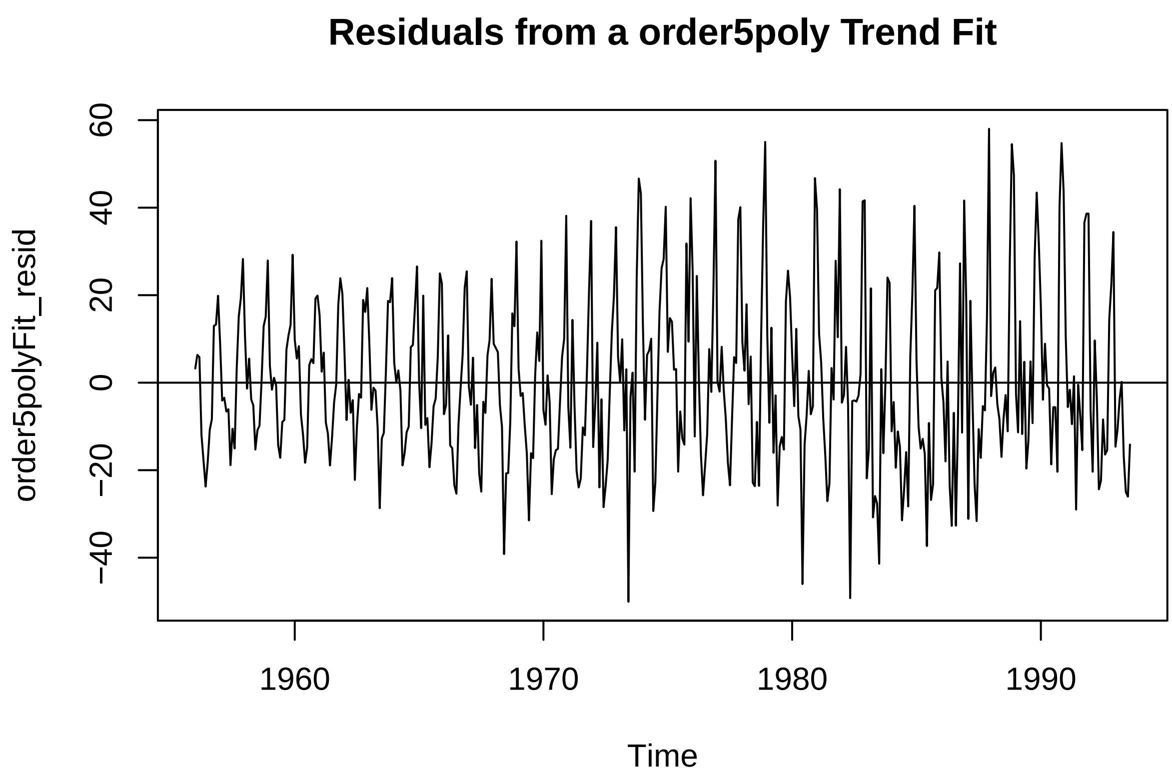

```r
order5polyFit<-lm(beerTS~t+t2+t3+t4+t5)
summary(order5polyFit)
```

```
##
## Call:
## lm(formula = beerTS ~ t + t2 + t3 + t4 + t5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -50.069 -12.729  -3.179  10.132  58.012
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  9.029e+01  5.483e+00  16.469   <2e-16 ***
## t           -3.288e-01  2.436e-01  -1.350   0.1778
## t2           6.463e-03  3.323e-03   1.945   0.0524 .
## t3          -2.126e-05  1.858e-05  -1.144   0.2532
## t4           2.000e-08  4.519e-08   0.443   0.6582
## t5           1.049e-12  3.970e-11   0.026   0.9789
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 19.05 on 446 degrees of freedom
## Multiple R-squared:  0.6935, Adjusted R-squared:  0.6901
## F-statistic: 201.9 on 5 and 446 DF,  p-value: < 2.2e-16
```

```
#### plot the data and the fitted 5th order polynomial trend function
plot(x=1:length(beerTS),y=beerTS,type='o',ylab="",xlab="Time - Number of Months Since Jan 1956",main="order5po
curve(expr = coef(order5polyFit)[1]+coef(order5polyFit)[2]*x+coef(order5polyFit)[3]*x^2+coef(order5polyFit)[4]
```




```
order5polyFit_resid<-ts(residuals(order5polyFit),frequency=12, start=c(1956,1))
plot(order5polyFit_resid, main="Residuals from a order5poly Trend Fit")
abline(h=0)
```



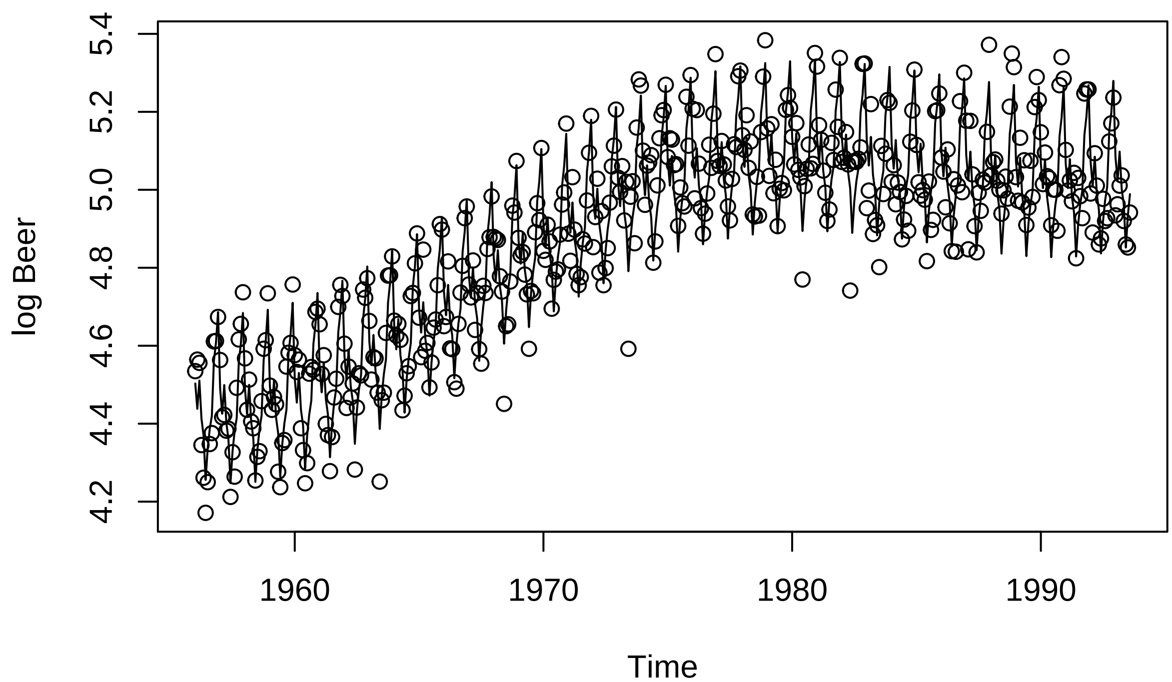

## Fit deterministic cosine trend model

```
startDate<-round(start(beer_forecast)[1]+start(beer_forecast)[2]/12,2)
endDate<-round(end(beer_forecast)[1]+end(beer_forecast)[2]/12,2)
numToFor<-length(beer_forecast)

allBeerData<-ts(c(beerTS, beer_forecast), start=c(1956, 1), frequency=12)

tnew<-1:length(allBeerData)
t2new<-tnew^2
t3new<-tnew^3
t4new<-tnew^4

har.=harmonic(logBeer,5)
modelHR=lm(logBeer~har.+t+t2+t3+t4)
summary(modelHR)
```

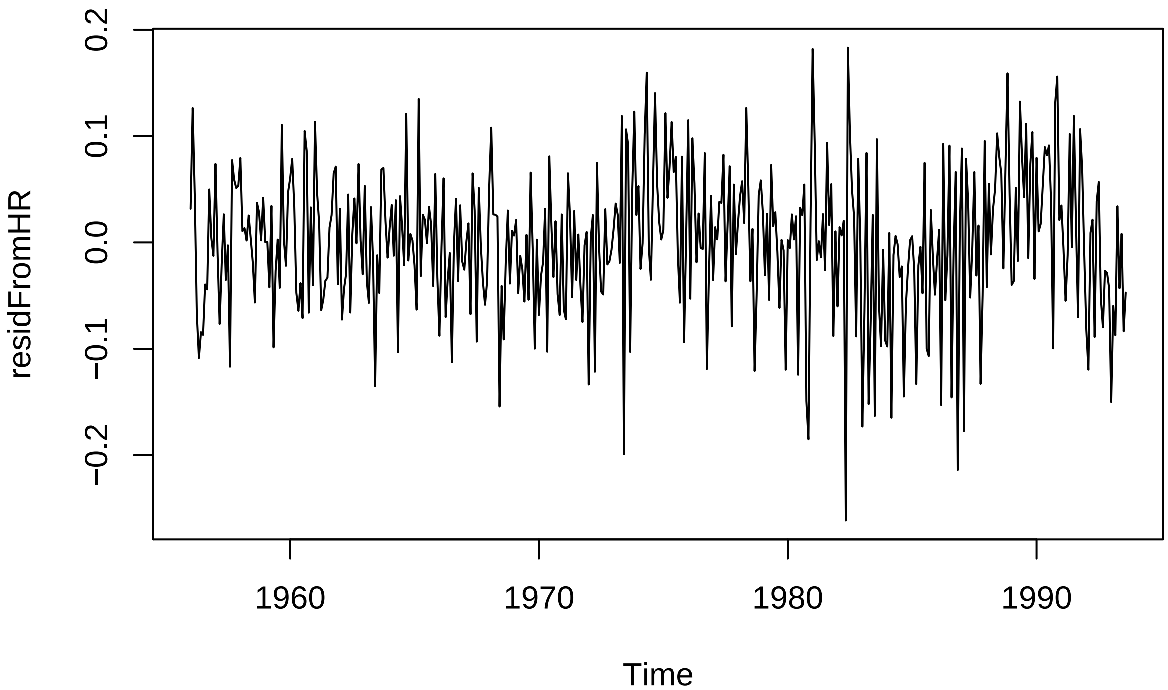
```
##
## Call:
## lm(formula = logBeer ~ har. + t + t2 + t3 + t4)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.261463 -0.039931  0.002551  0.043469  0.183185
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)       4.467e+00  1.642e-02 272.071  < 2e-16 ***
## har.cos(2*pi*t)   1.228e-01  4.572e-03  26.854  < 2e-16 ***
```

```
## har.cos(4*pi*t)  -3.543e-02  4.577e-03  -7.742 6.87e-14 ***
## har.cos(6*pi*t)  -2.830e-02  4.579e-03  -6.180 1.47e-09 ***
## har.cos(8*pi*t)  -5.185e-03  4.576e-03  -1.133 0.257829
## har.cos(10*pi*t) -1.557e-02  4.571e-03  -3.406 0.000720 ***
## har.sin(2*pi*t)  -8.192e-02  4.589e-03 -17.850  < 2e-16 ***
## har.sin(4*pi*t)  -2.568e-02  4.581e-03  -5.605 3.70e-08 ***
## har.sin(6*pi*t)  -3.967e-02  4.579e-03  -8.663  < 2e-16 ***
## har.sin(8*pi*t)  -1.067e-02  4.581e-03  -2.328 0.020366 *
## har.sin(10*pi*t) -3.546e-02  4.586e-03  -7.733 7.30e-14 ***
## t                -1.797e-03  5.009e-04  -3.587 0.000372 ***
## t2                4.927e-05  4.490e-06  10.973  < 2e-16 ***
## t3               -1.745e-07  1.488e-08 -11.724  < 2e-16 ***
## t4                1.785e-10  1.630e-11  10.952  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06882 on 437 degrees of freedom
## Multiple R-squared:  0.9365, Adjusted R-squared:  0.9345
## F-statistic: 460.5 on 14 and 437 DF,  p-value: < 2.2e-16
```

```
plot(ts(fitted(modelHR),freq=12,start=c(1956,1)),ylab='log Beer',type='l',ylim=range(c(fitted(modelHR),logBeer
points(logBeer)
```




```
residFromHR<-ts(residuals(modelHR), frequency=12, start=c(1956,1))
plot(residFromHR)
```




```r
chosenMod<-modelHR
library(TSA)

har.=harmonic(log(beer_forecast),5)
newRegData<-data.frame(t=tnew, t2=t2new, t3=t3new, t4=t4new)
newRegData<-newRegData[(nrow(newRegData)-numToFor+1):nrow(newRegData),]
newRegData<-data.frame(har., newRegData)
colnames(newRegData)<-c(colnames(har.),"t","t2","t3","t4")
```

## Diagnostics on Cosine Trend

```r
adf.test(residFromHR)
```

```
## Warning in adf.test(residFromHR): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  residFromHR
## Dickey-Fuller = -5.3975, Lag order = 7, p-value = 0.01
## alternative hypothesis: stationary
```

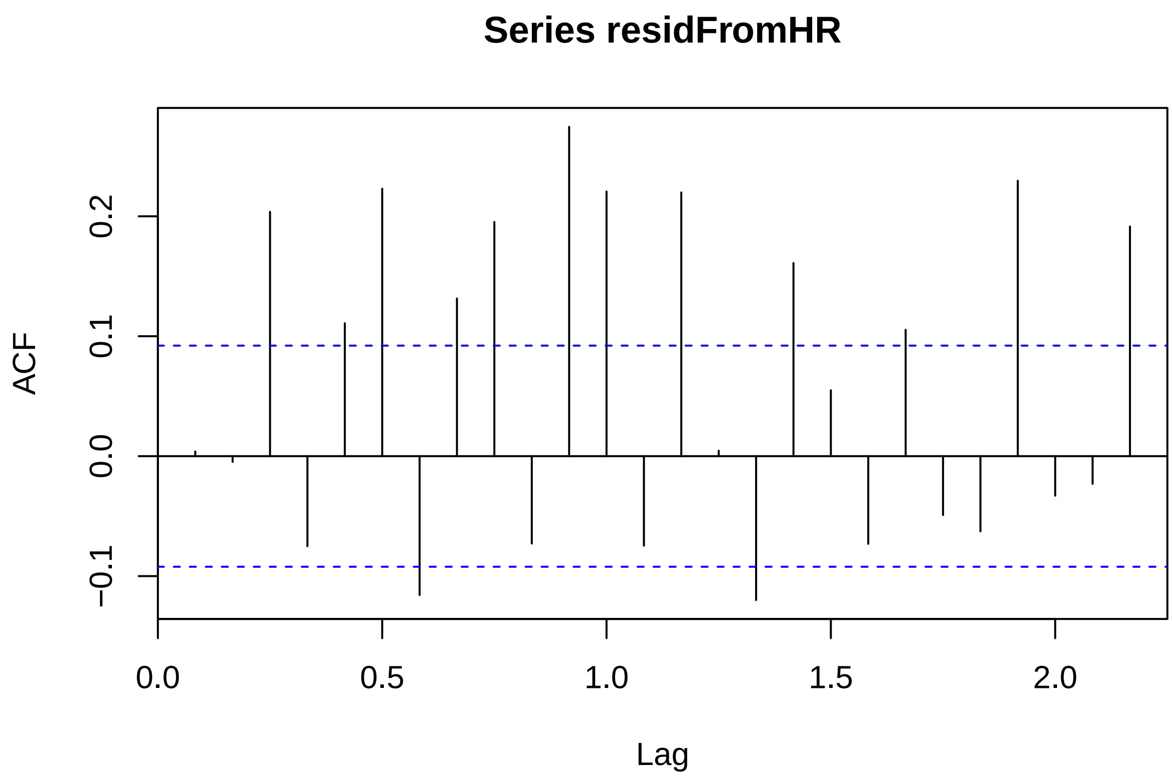
```r
pp.test(residFromHR)
```

```
## Warning in pp.test(residFromHR): p-value smaller than printed p-value
```

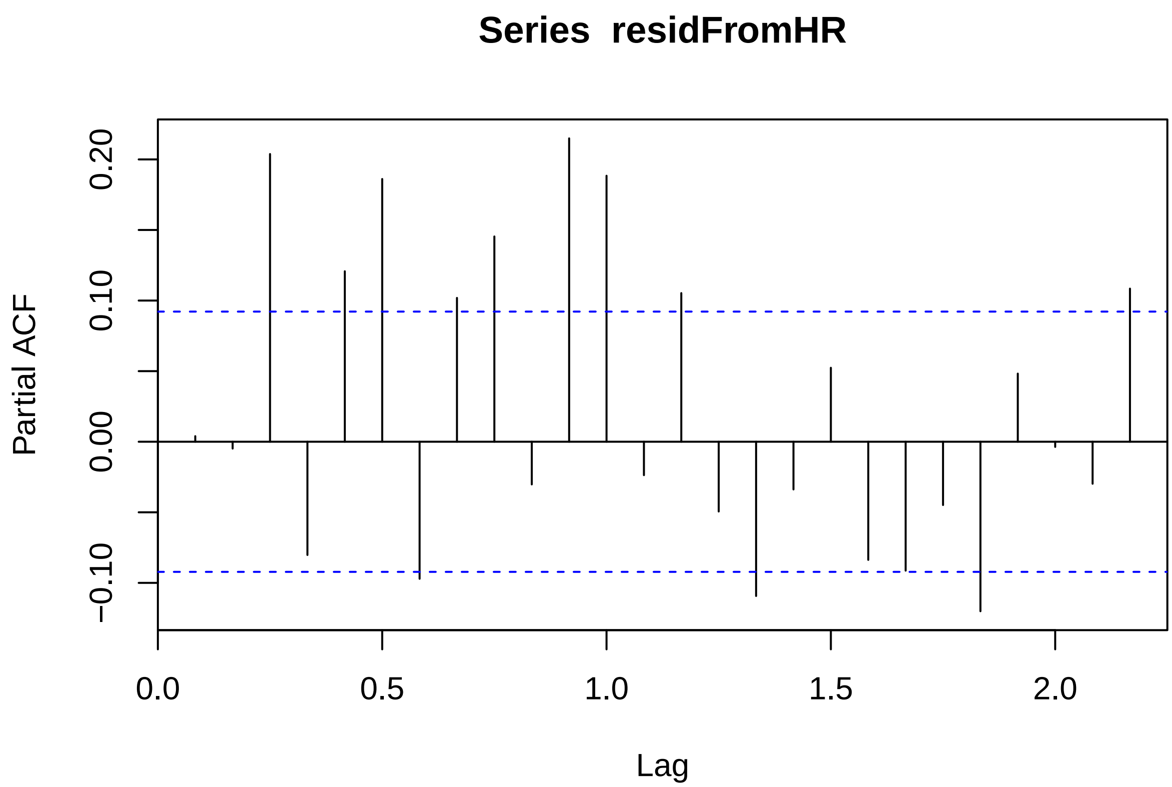
```
##
```

```
##  Phillips-Perron Unit Root Test
##
## data:  residFromHR
## Dickey-Fuller Z(alpha) = -490.03, Truncation lag parameter = 5,
## p-value = 0.01
## alternative hypothesis: stationary
```

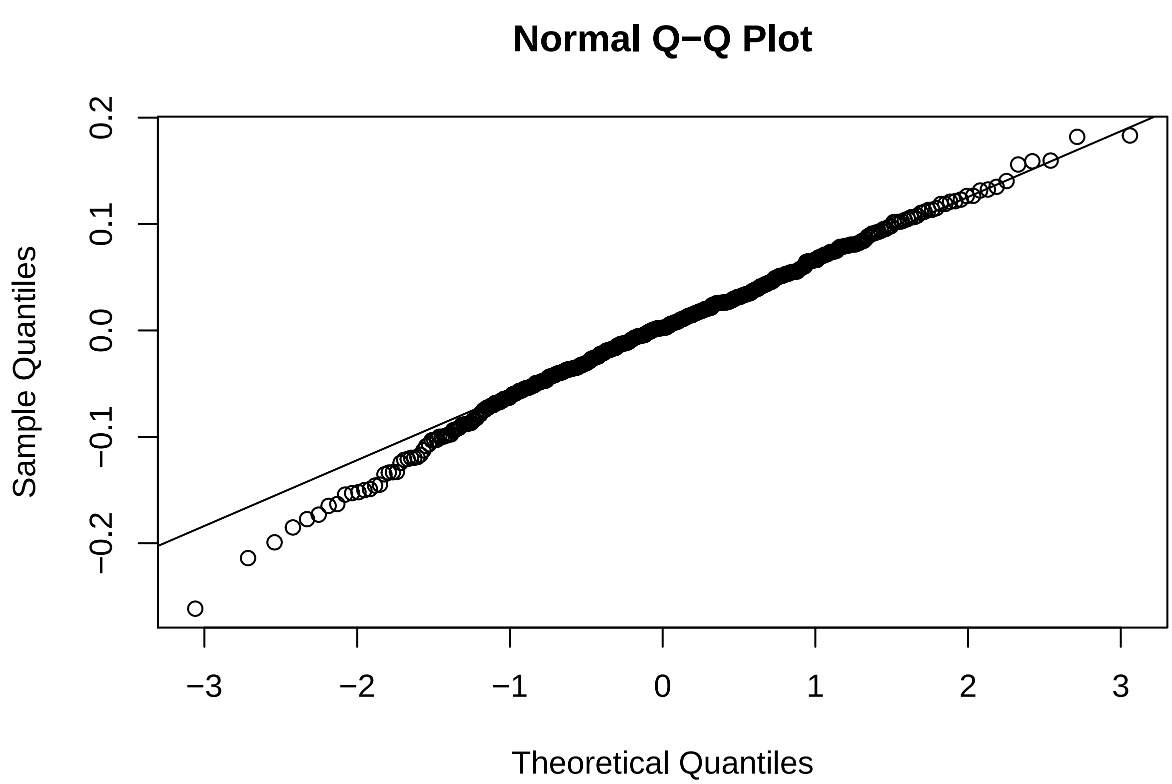
```r
acf(residFromHR)
```




```r
pacf(residFromHR)
```

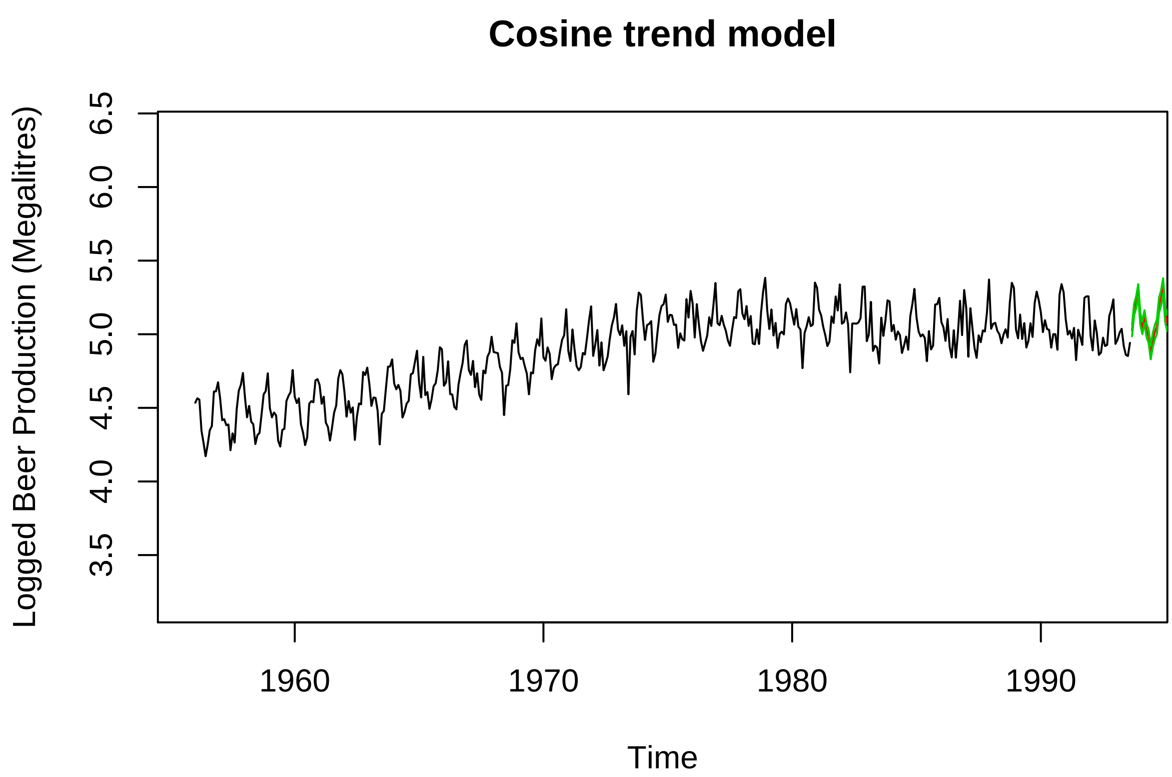



```r
qqnorm(residFromHR)
qqline(residFromHR)
```

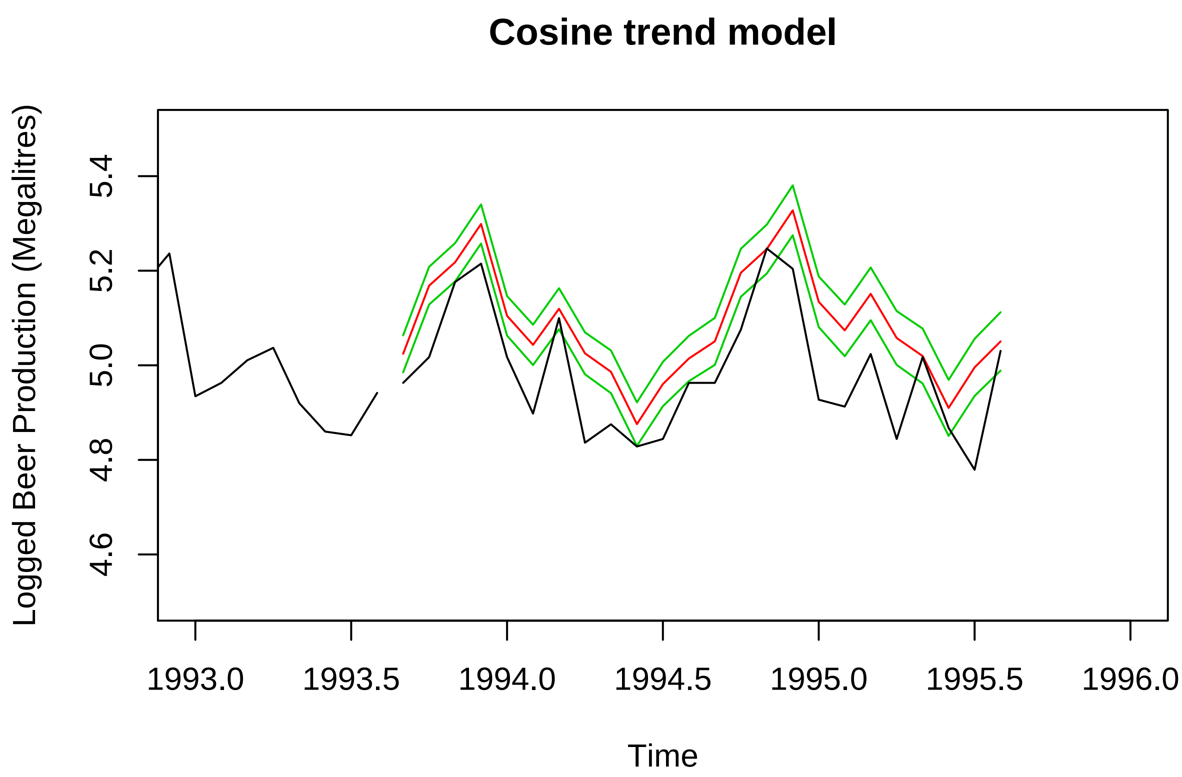


## Forecast based on cosine trend model

```
modelString<-"Cosine trend model"
predictions<-predict(chosenMod,newdata =newRegData,se.fit = T)
pred<-ts(predictions$fit,start = c(1993,9),frequency = 12)
uci<-ts(pred+2*predictions$se.fit,start = c(1993,9),frequency = 12)
lci<-ts(pred-2*predictions$se.fit,start = c(1993,9),frequency = 12)
ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,ylim=c(ymin,ymax),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
```




```
ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,xlim=c(1993, 1996), ylim=c(4.5,5.5),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
lines(log(beer_forecast), col="black")
```



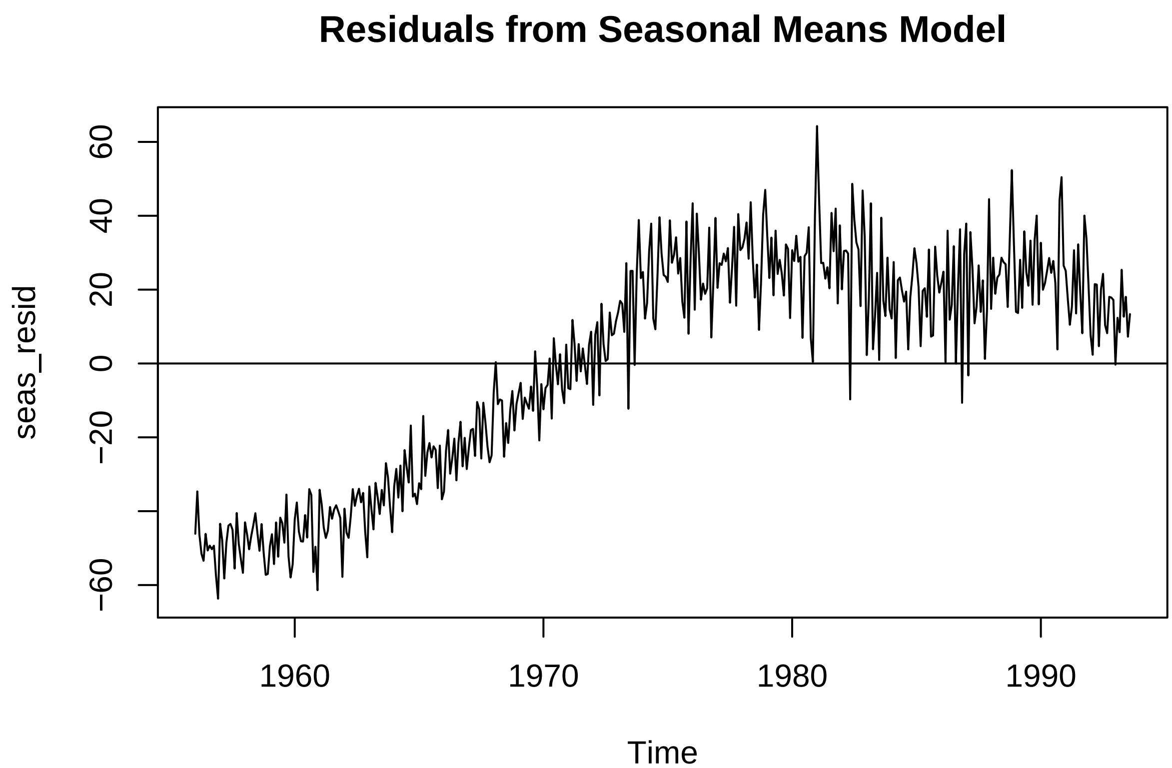

## Seasonal means model with ARIMA

```
logBeer<-log(beerTS)
t<-1:length(logBeer)
t2<-t^2
t3<-t^3
t4<-t^4
month<-season(logBeer)

seasMod<-lm(beerTS~month)
summary(seasMod)
```

```
##
## Call:
## lm(formula = beerTS ~ month)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -63.70 -27.90    8.20   24.91   64.28
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)      139.316      4.957  28.106  < 2e-16 ***
## monthFebruary     -8.674      7.010  -1.237  0.21662
## monthMarch         2.203      7.010   0.314  0.75350
## monthApril       -10.674      7.010  -1.523  0.12856
## monthMay         -14.989      7.010  -2.138  0.03304 *
## monthJune        -28.361      7.010  -4.046 6.16e-05 ***
## monthJuly        -18.571      7.010  -2.649  0.00836 **
```

```
## monthAugust     -12.687      7.010  -1.810  0.07100 .
## monthSeptember   -9.516      7.057  -1.348  0.17822
## monthOctober     10.641      7.057   1.508  0.13231
## monthNovember    18.830      7.057   2.668  0.00791 **
## monthDecember    31.479      7.057   4.461 1.04e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 30.56 on 440 degrees of freedom
## Multiple R-squared:  0.2224, Adjusted R-squared:  0.2029
## F-statistic: 11.44 on 11 and 440 DF,  p-value: < 2.2e-16
```

```r
seas_resid<-ts(residuals(seasMod),frequency=12, start=c(1956,1))
plot(seas_resid, main="Residuals from Seasonal Means Model")
abline(h=0)
```

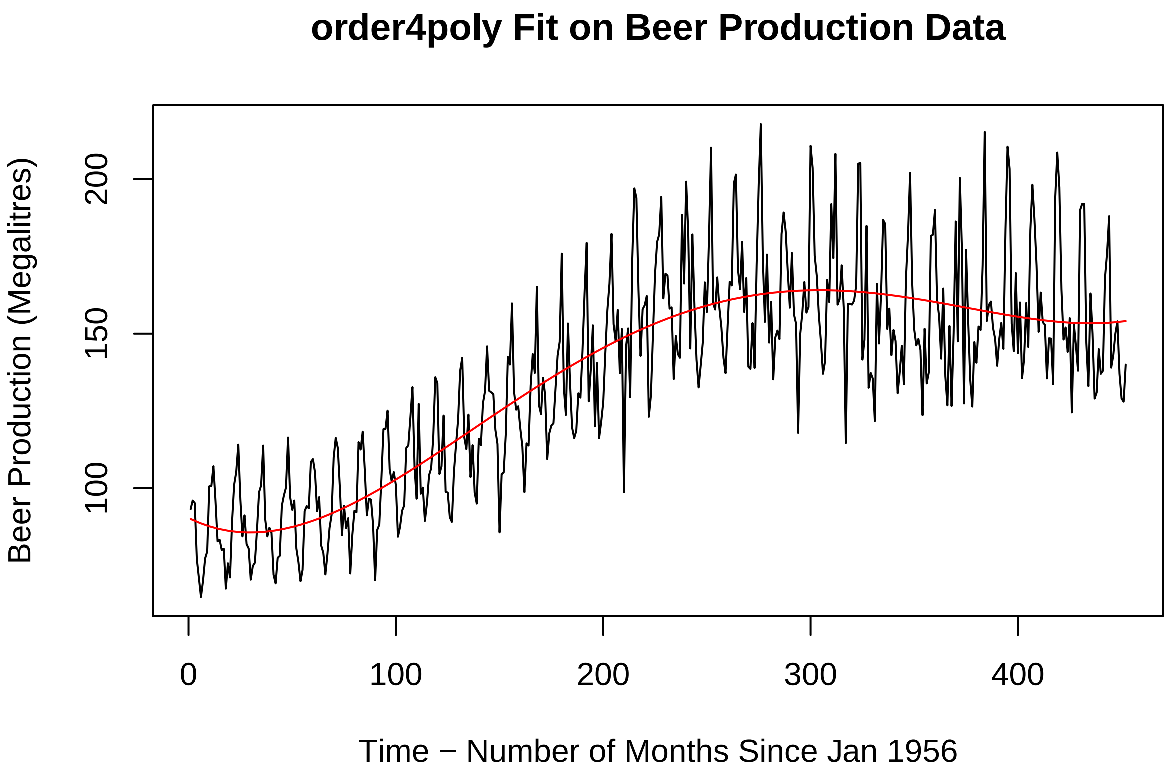



```r
order4polyFit<-lm(beerTS~t+t2+t3+t4)
summary(order4polyFit)
```

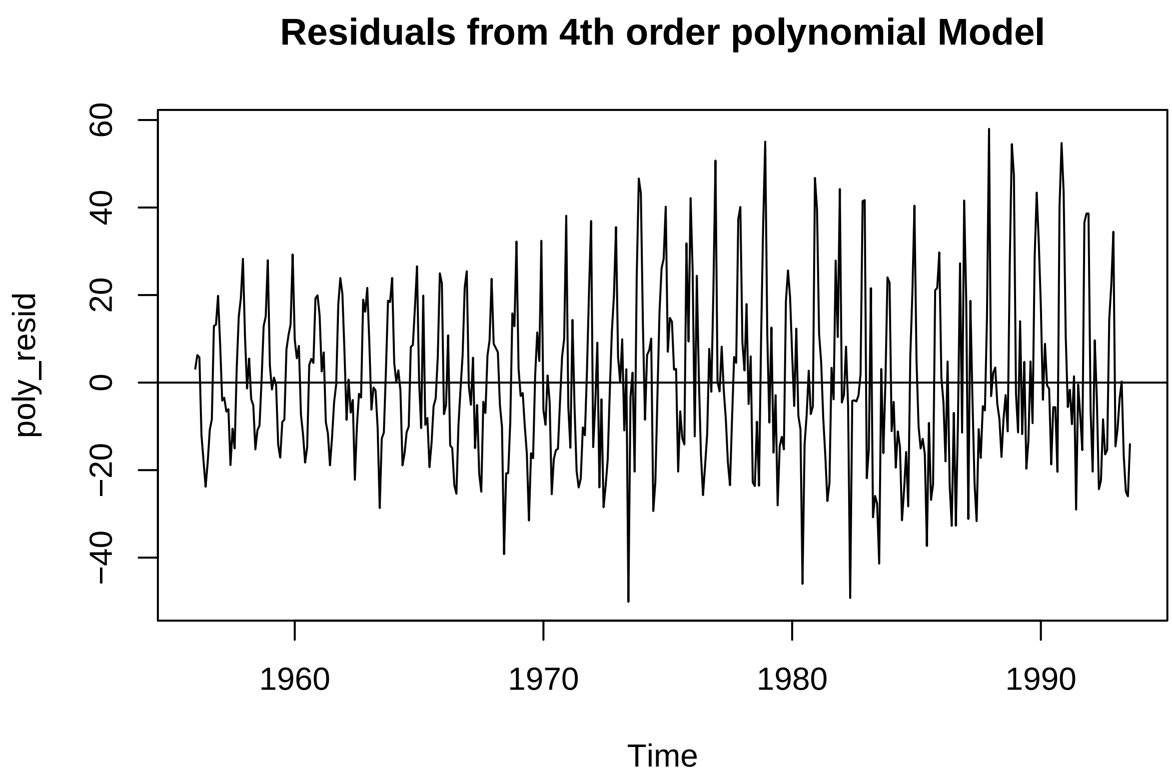
```
##
## Call:
## lm(formula = beerTS ~ t + t2 + t3 + t4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -50.079 -12.721  -3.199  10.135  57.983
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  9.037e+01  4.536e+00  19.924  < 2e-16 ***
## t           -3.341e-01  1.384e-01  -2.414   0.0162 *
```

```
## t2           6.545e-03  1.241e-03   5.276 2.07e-07 ***
## t3          -2.173e-05  4.113e-06  -5.285 1.97e-07 ***
## t4           2.119e-08  4.504e-09   4.706 3.38e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 19.03 on 447 degrees of freedom
## Multiple R-squared:  0.6935, Adjusted R-squared:  0.6908
## F-statistic: 252.9 on 4 and 447 DF,  p-value: < 2.2e-16
```

```
#### plot the data and the fitted 4th order polynomial trend function
plot(x=1:length(beerTS),y=beerTS,type='l',ylab="Beer Production (Megalitres)",xlab="Time - Number of Months Si
curve(expr = coef(order4polyFit)[1]+coef(order4polyFit)[2]*x+coef(order4polyFit)[3]*x^2+coef(order4polyFit)[4]
```




```
poly_resid<-ts(residuals(order4polyFit),frequency=12, start=c(1956,1))
plot(poly_resid, main="Residuals from 4th order polynomial Model")
abline(h=0)
```

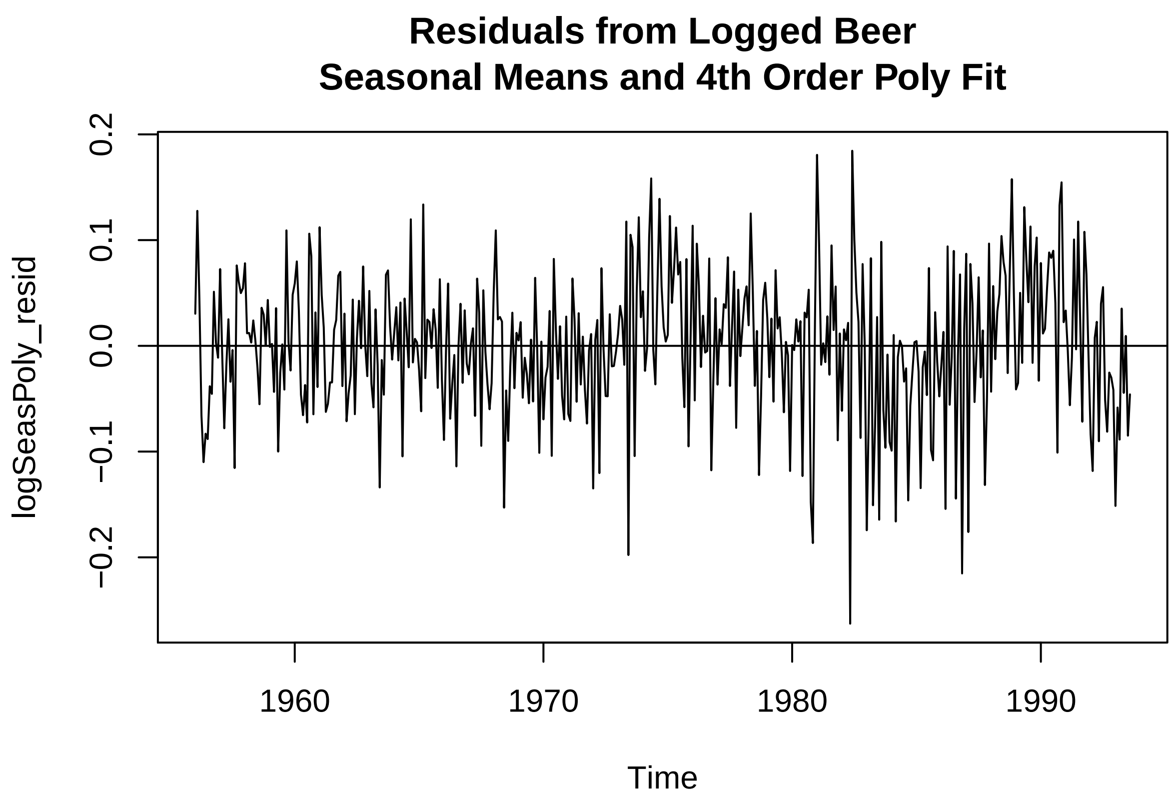



```r
logSeasPoly<-lm(logBeer~t+t2+t3+t4+month)
summary(logSeasPoly)
```

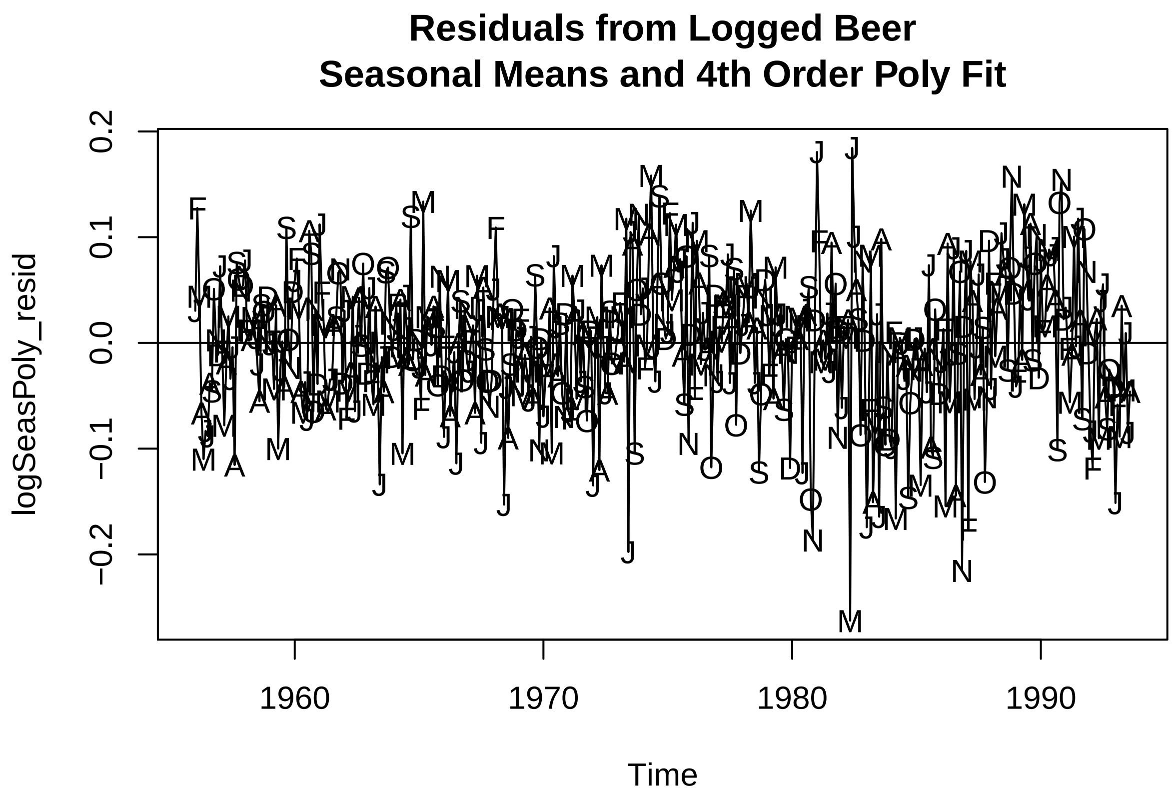
```
##
## Call:
## lm(formula = logBeer ~ t + t2 + t3 + t4 + month)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.262750 -0.039816  0.003297  0.043475  0.184483
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     4.506e+00  1.945e-02 231.675  < 2e-16 ***
## t              -1.796e-03  5.014e-04  -3.583 0.000378 ***
## t2              4.926e-05  4.494e-06  10.962  < 2e-16 ***
## t3             -1.745e-07  1.490e-08 -11.713  < 2e-16 ***
## t4              1.785e-10  1.631e-11  10.941  < 2e-16 ***
## monthFebruary  -6.602e-02  1.580e-02  -4.178 3.56e-05 ***
## monthMarch      1.069e-02  1.580e-02   0.676 0.499268
## monthApril     -8.834e-02  1.581e-02  -5.590 4.02e-08 ***
## monthMay       -1.271e-01  1.581e-02  -8.042 8.39e-15 ***
## monthJune      -2.427e-01  1.581e-02 -15.354  < 2e-16 ***
## monthJuly      -1.578e-01  1.581e-02  -9.984  < 2e-16 ***
## monthAugust    -1.089e-01  1.581e-02  -6.890 1.96e-11 ***
## monthSeptember -7.261e-02  1.591e-02  -4.563 6.57e-06 ***
## monthOctober    6.706e-02  1.591e-02   4.213 3.06e-05 ***
## monthNovember   1.172e-01  1.592e-02   7.363 9.03e-13 ***
## monthDecember   1.936e-01  1.592e-02  12.164  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.06889 on 436 degrees of freedom
## Multiple R-squared:  0.9365, Adjusted R-squared:  0.9344
## F-statistic:   429 on 15 and 436 DF,  p-value: < 2.2e-16
```

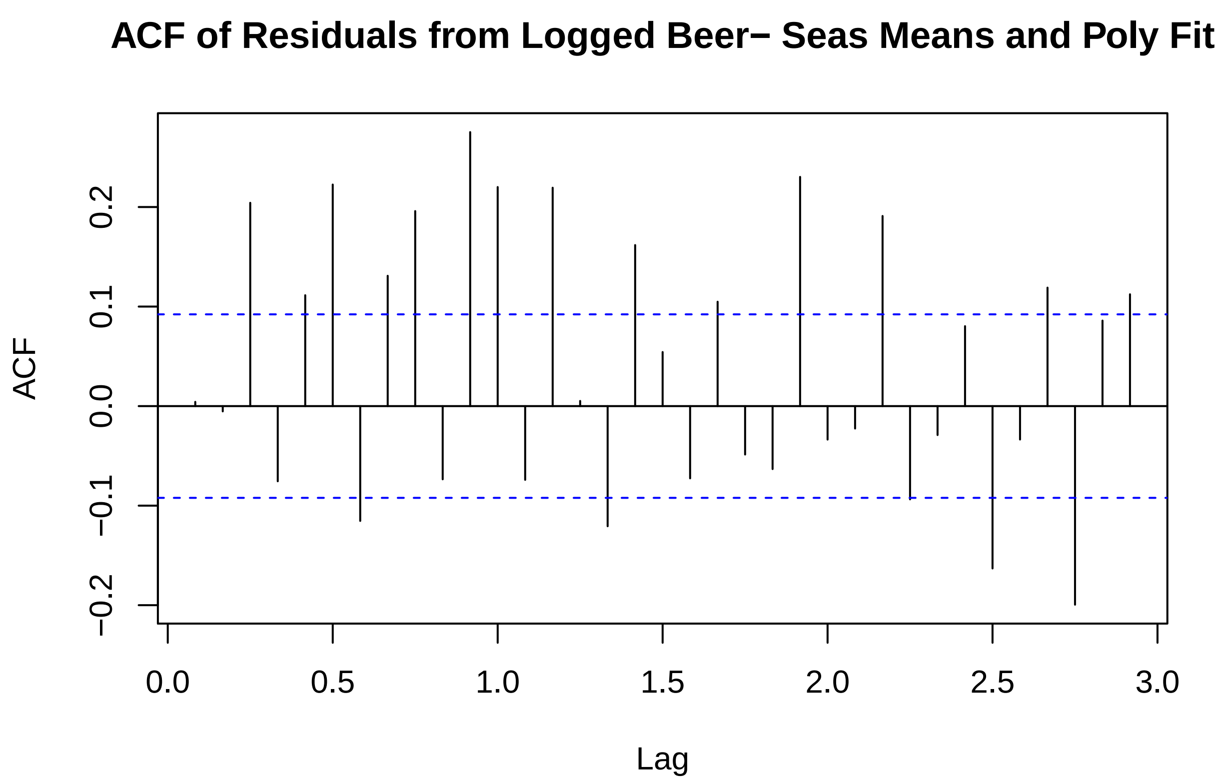
```
logSeasPoly_resid<-ts(residuals(logSeasPoly),frequency=12, start=c(1956,1))
plot(logSeasPoly_resid, main="Residuals from Logged Beer\nSeasonal Means and 4th Order Poly Fit")
abline(h=0)
```



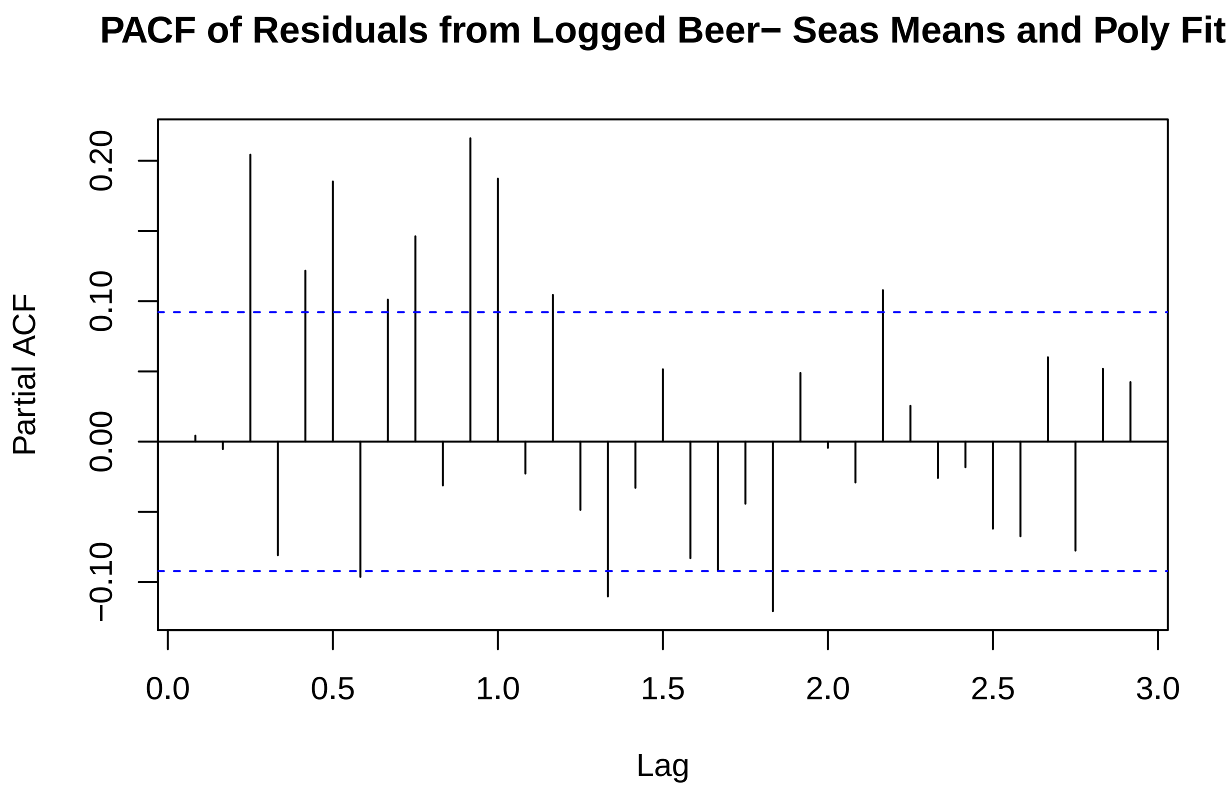

```
plot(logSeasPoly_resid, main="Residuals from Logged Beer\nSeasonal Means and 4th Order Poly Fit", type="l")
points(y=logSeasPoly_resid, x=time(logSeasPoly_resid), pch=as.vector(season(logSeasPoly_resid)))
abline(h=0)
```




```r
acf(logSeasPoly_resid, main="ACF of Residuals from Logged Beer- Seas Means and Poly Fit", lag=35)
```



```r
pacf(logSeasPoly_resid,main="PACF of Residuals from Logged Beer- Seas Means and Poly Fit", lag=35)
```




```r
adf.test(logSeasPoly_resid)
```

```
## Warning in adf.test(logSeasPoly_resid): p-value smaller than printed p-
## value

##
##  Augmented Dickey-Fuller Test
##
## data:  logSeasPoly_resid
## Dickey-Fuller = -5.3999, Lag order = 7, p-value = 0.01
## alternative hypothesis: stationary
```

```r
pp.test(logSeasPoly_resid)
```

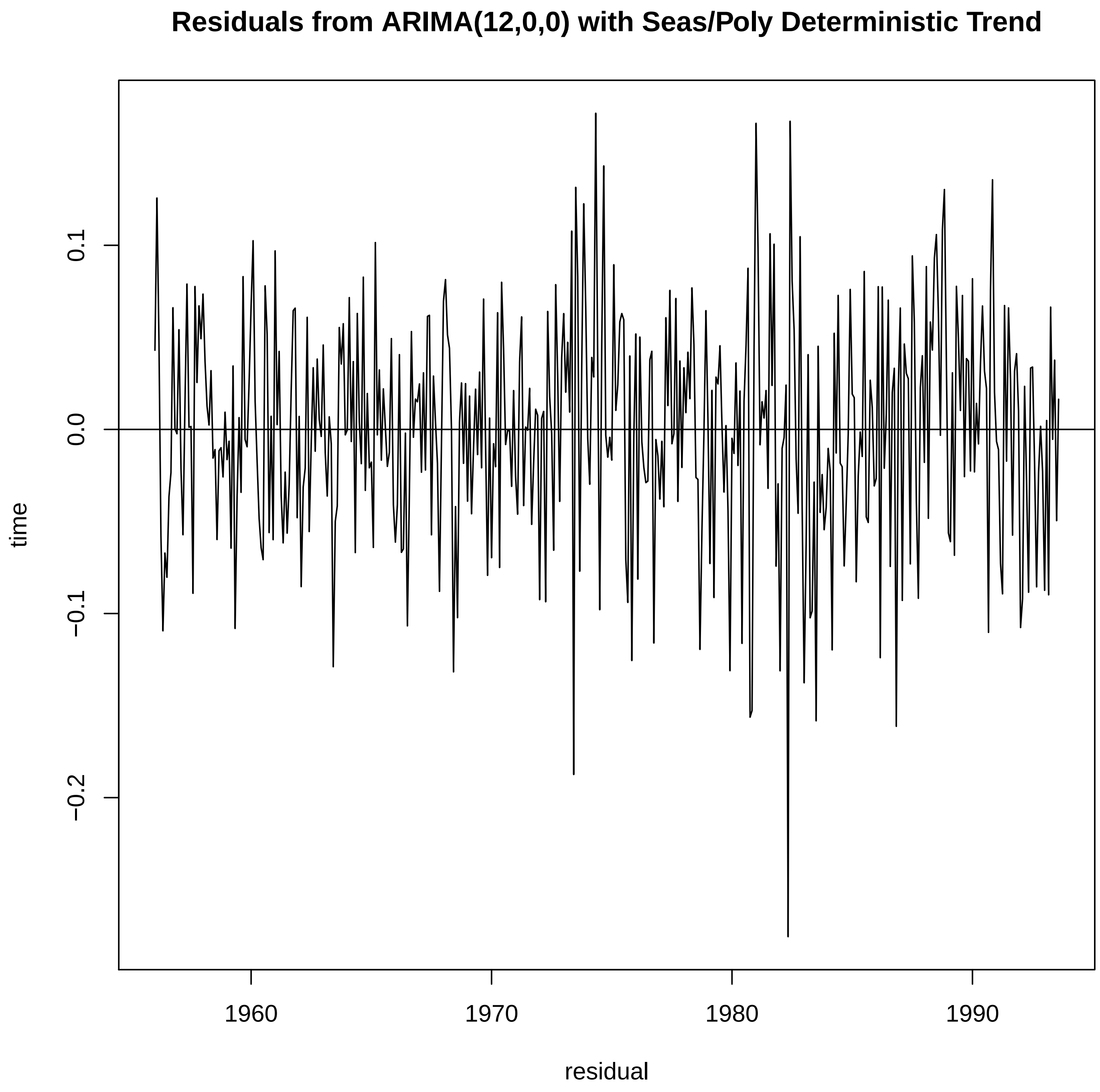
```
## Warning in pp.test(logSeasPoly_resid): p-value smaller than printed p-value

##
##  Phillips-Perron Unit Root Test
##
## data:  logSeasPoly_resid
## Dickey-Fuller Z(alpha) = -489.81, Truncation lag parameter = 5,
## p-value = 0.01
## alternative hypothesis: stationary
```

## Try an AR 12 model with the seasonal means and polynomial

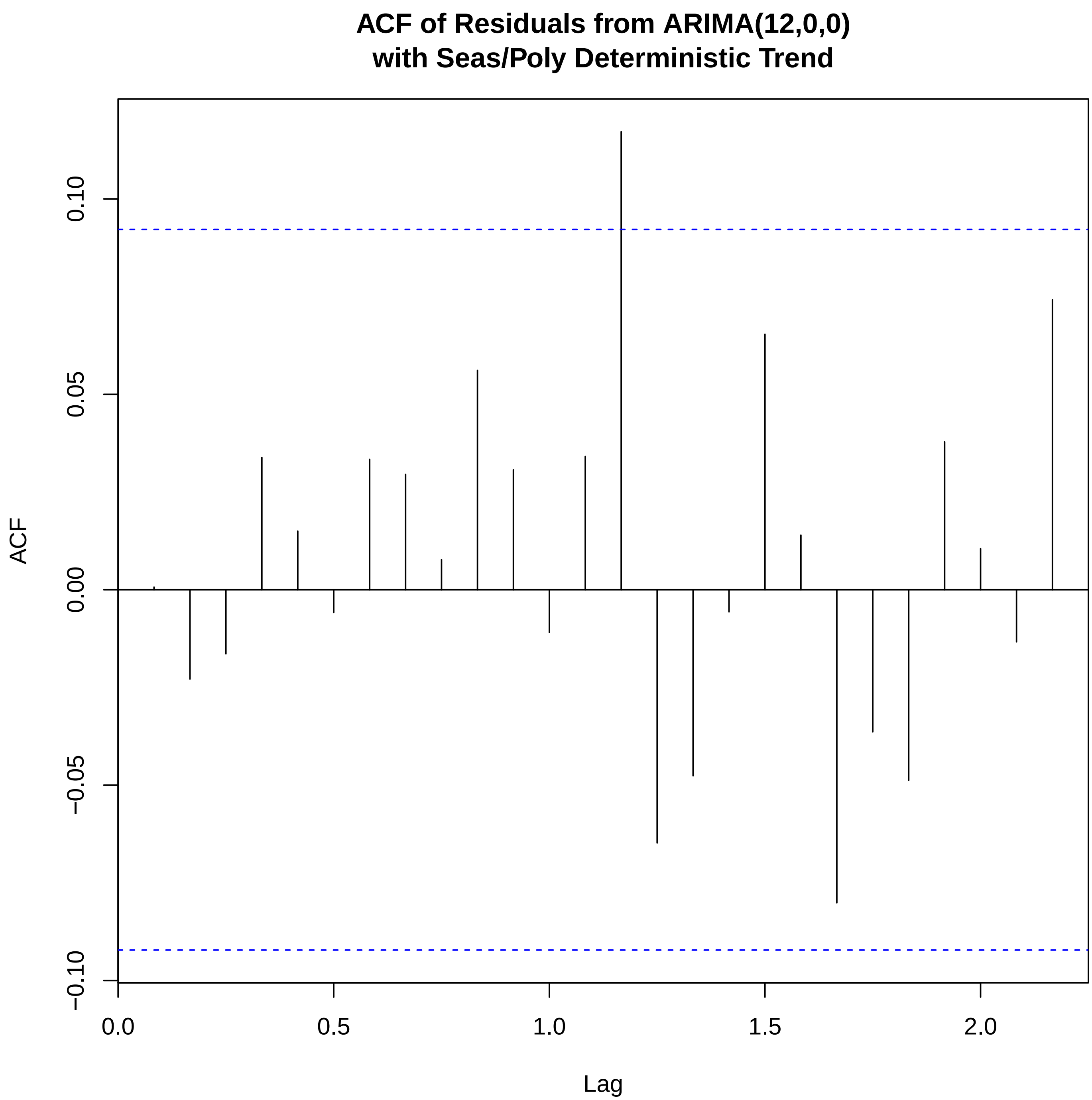
```r
#Set up external regressors and dummy vars
library(forecast)
monthDummies<-seasonaldummy(logBeer)
externReg<-data.frame(t, t2, t3, t4, monthDummies)

ar12_poly<-arima(logBeer, order=c(12,0,0), xreg=externReg)
ar12_poly
```

```
##
## Call:
## arima(x = logBeer, order = c(12, 0, 0), xreg = externReg)
##
## Coefficients:
##          ar1      ar2     ar3      ar4     ar5     ar6      ar7     ar8
##      -0.0185  -0.0373  0.0592  -0.0600  0.0852  0.1086  -0.0873  0.0867
## s.e.   0.0460   0.0449  0.0449   0.0441  0.0443  0.0442   0.0443  0.0438
##         ar9     ar10    ar11    ar12  intercept        t      t2  t3  t4
##      0.1421  -0.0077  0.2301  0.2099     4.6792  -0.0009  0e+00   0   0
## s.e.  0.0440   0.0440  0.0440  0.0453     0.0781   0.0014  2e-04   0   0
##          Jan      Feb      Mar      Apr      May      Jun      Jul
##      -0.1923  -0.2566  -0.1788  -0.2787  -0.3181  -0.4344  -0.3506
## s.e.   0.0154   0.0170   0.0156   0.0165   0.0167   0.0156   0.0167
##          Aug      Sep      Oct      Nov
##      -0.3012  -0.2658  -0.1259  -0.0756
## s.e.   0.0165   0.0157   0.0171   0.0155
##
## sigma^2 estimated as 0.003593:  log likelihood = 629.73,  aic = -1203.47
```

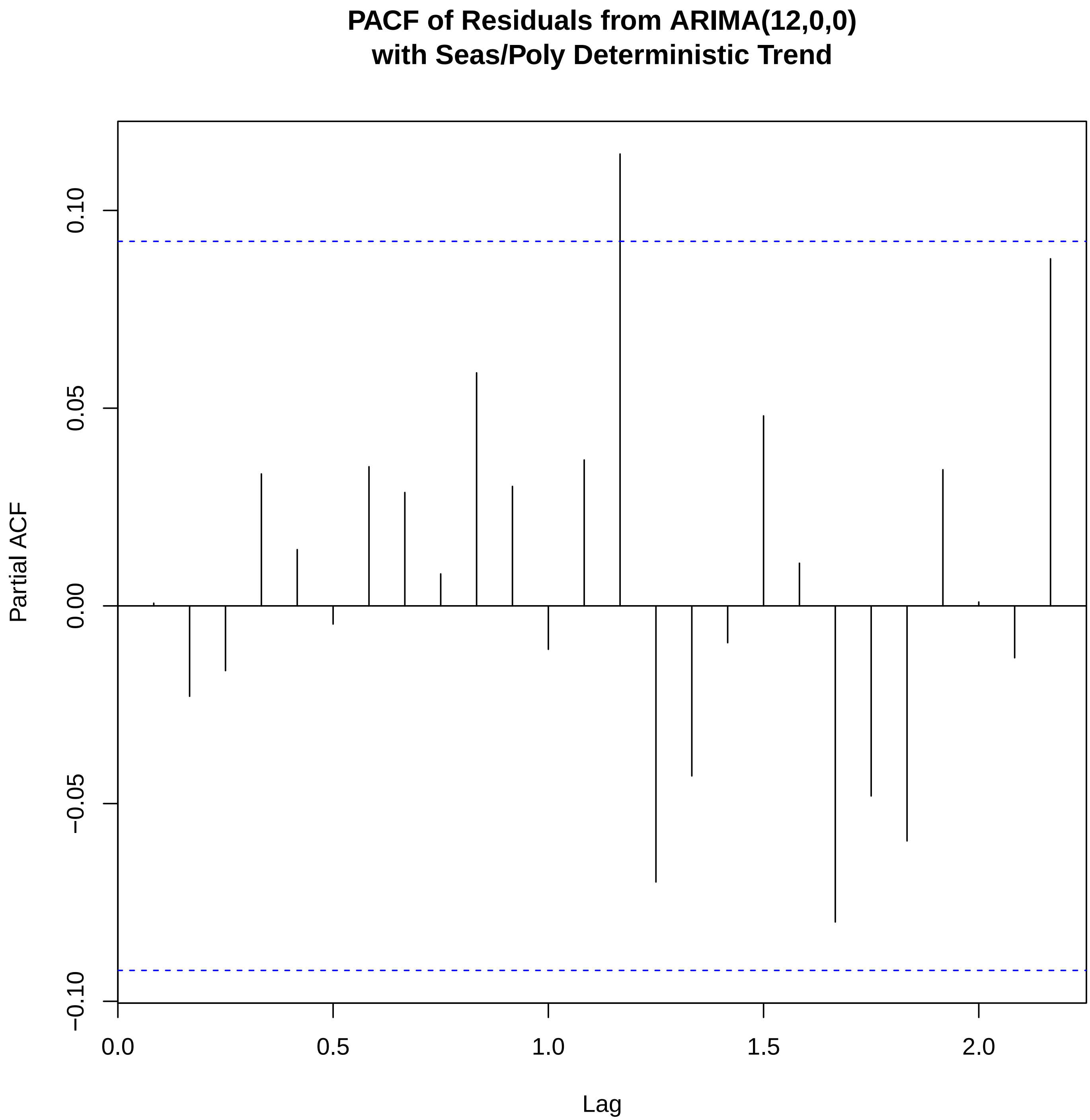
```r
ar12_poly_resid<-ts(resid(ar12_poly), start=c(1956, 1), frequency=12)
plot(ar12_poly_resid, xlab="residual", ylab="time",main="Residuals from ARIMA(12,0,0) with Seas/Poly Determini
abline(h=0)
```




```
acf(ar12_poly_resid,main="ACF of Residuals from ARIMA(12,0,0)\nwith Seas/Poly Deterministic Trend")
```

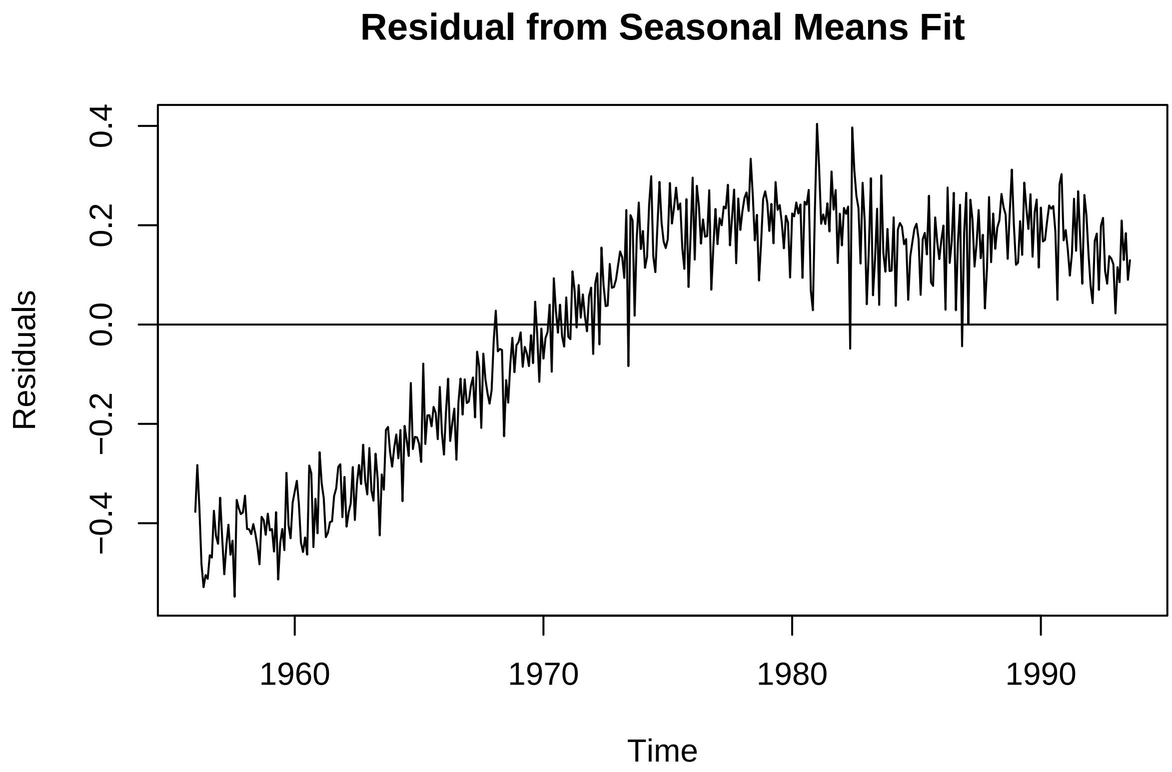



```
pacf(ar12_poly_resid,main="PACF of Residuals from ARIMA(12,0,0)\nwith Seas/Poly Deterministic Trend",mar=c(4,2
```




## Build models based on the seasonal means only

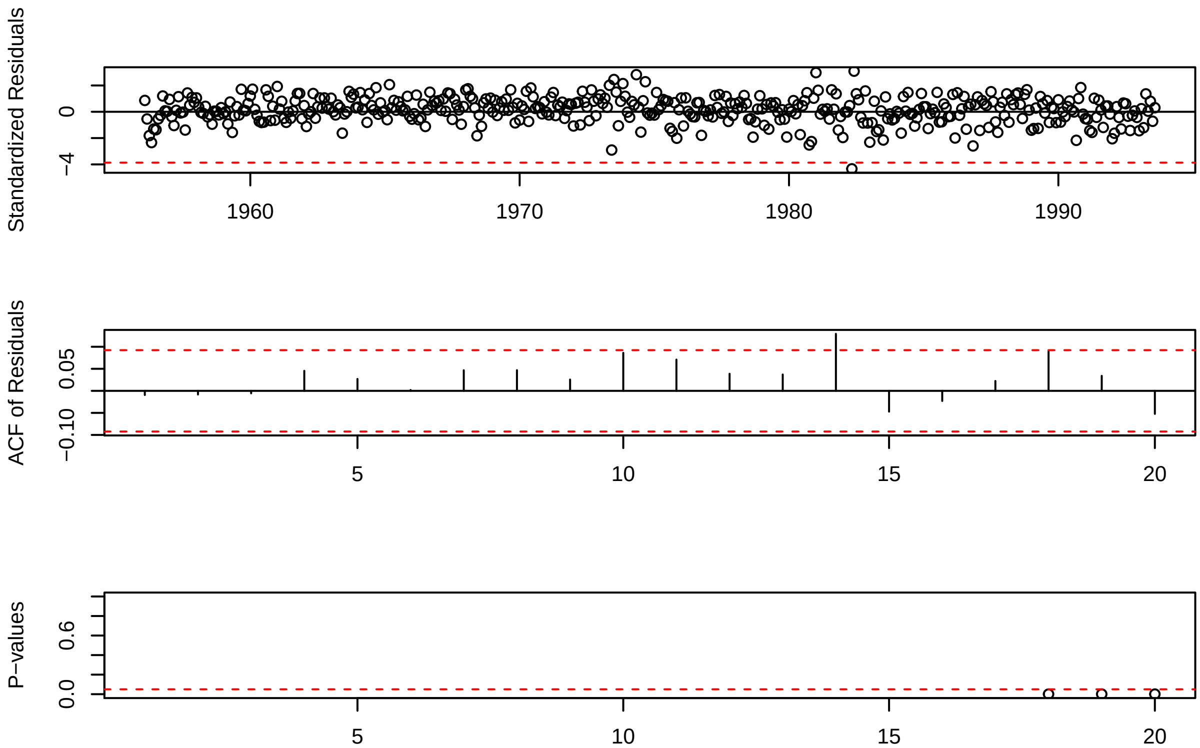
```
seasMeansMod<-lm(logBeer~season(logBeer))
plot(ts(residuals(seasMeansMod), start=c(1956,1),frequency=12), ylab="Residuals", main="Residual from Seasonal
abline(h=0)
```



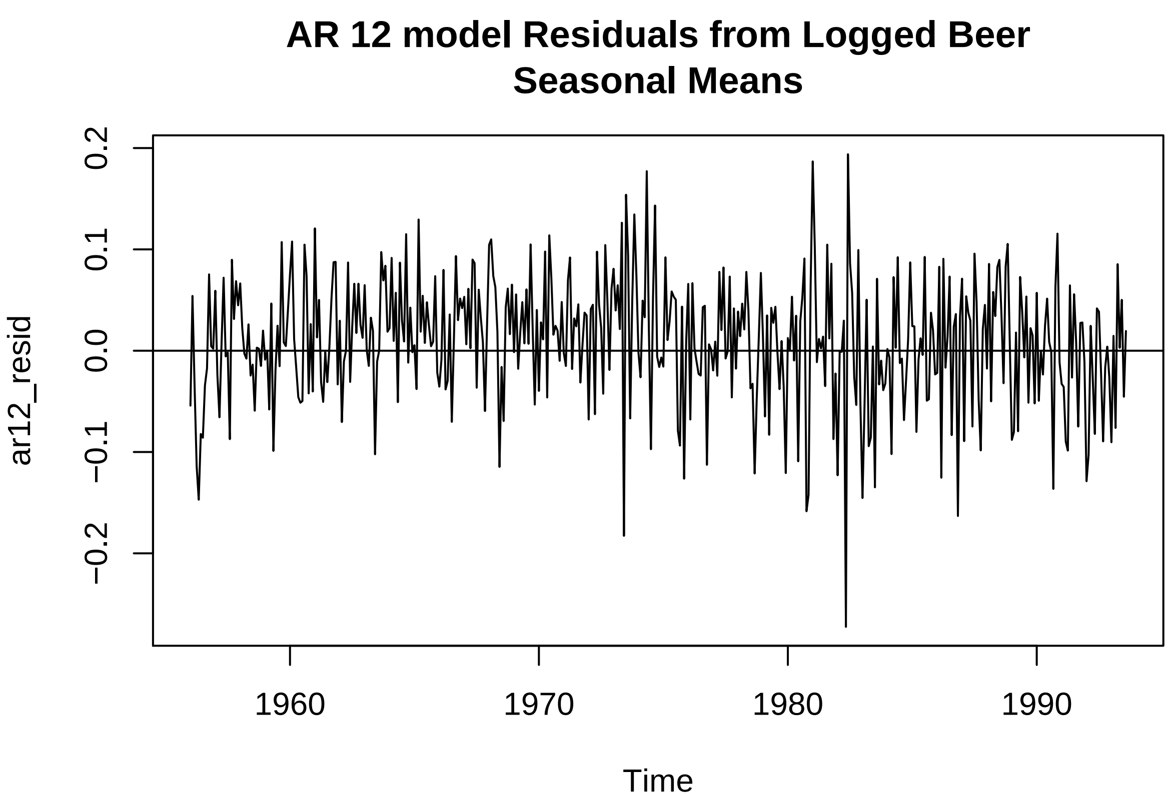

```r
ar12<-arima(logBeer, order=c(12,0,0), xreg=monthDummies)
ar12
```

```
##
## Call:
## arima(x = logBeer, order = c(12, 0, 0), xreg = monthDummies)
##
## Coefficients:
##          ar1     ar2     ar3      ar4     ar5     ar6      ar7     ar8
##       0.0631  0.0283  0.1255  -0.0127  0.1286  0.1447  -0.0733  0.0983
## s.e.  0.0464  0.0458  0.0458   0.0457  0.0458  0.0460   0.0461  0.0459
##          ar9     ar10    ar11    ar12  intercept      Jan      Feb
##       0.1446  -0.0278  0.2102  0.1670     4.9720  -0.1925  -0.2574
## s.e.  0.0461   0.0461  0.0461  0.0471     0.2644   0.0152   0.0169
##           Mar      Apr      May      Jun      Jul      Aug      Sep
##       -0.1798  -0.2797  -0.3188  -0.4349  -0.3507  -0.3012  -0.2657
## s.e.   0.0154   0.0165   0.0167   0.0153   0.0167   0.0165   0.0155
##          Oct      Nov
##       -0.126  -0.0757
## s.e.   0.017   0.0153
##
## sigma^2 estimated as 0.003946:  log likelihood = 606.68,  aic = -1165.36
```

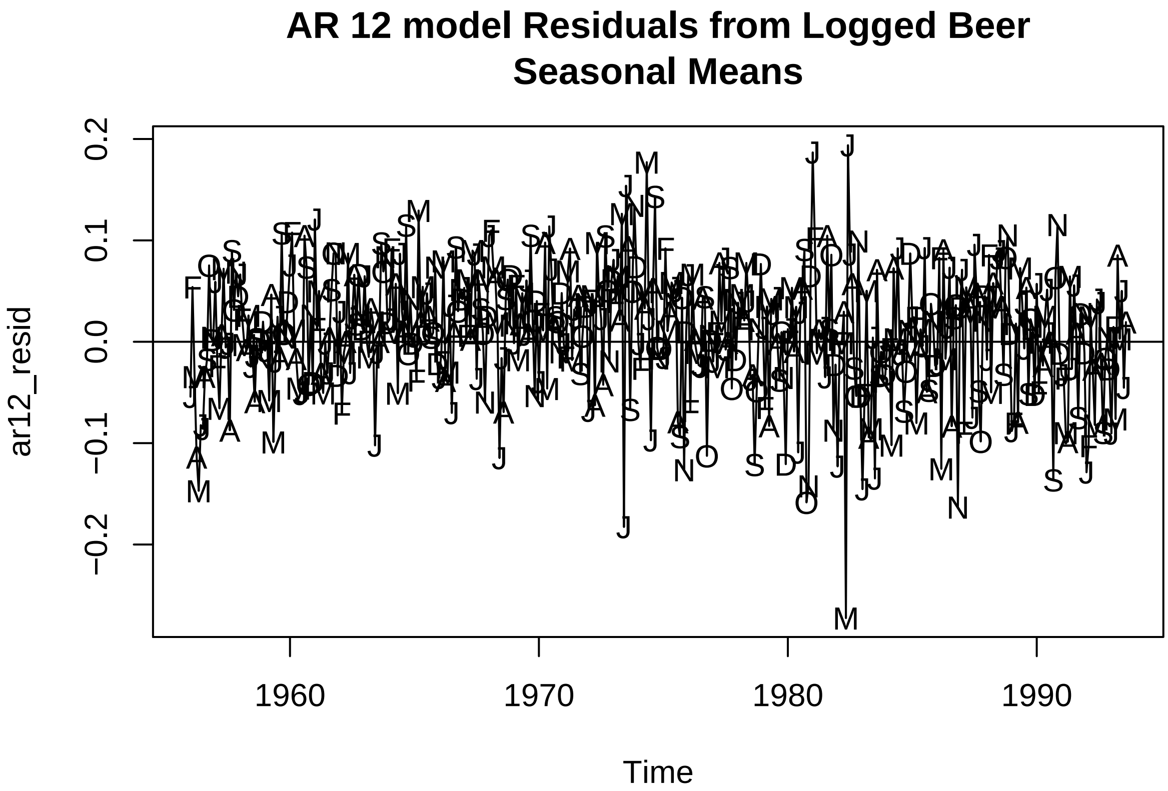
```r
tsdiag(ar12, gof.lag=20)
```



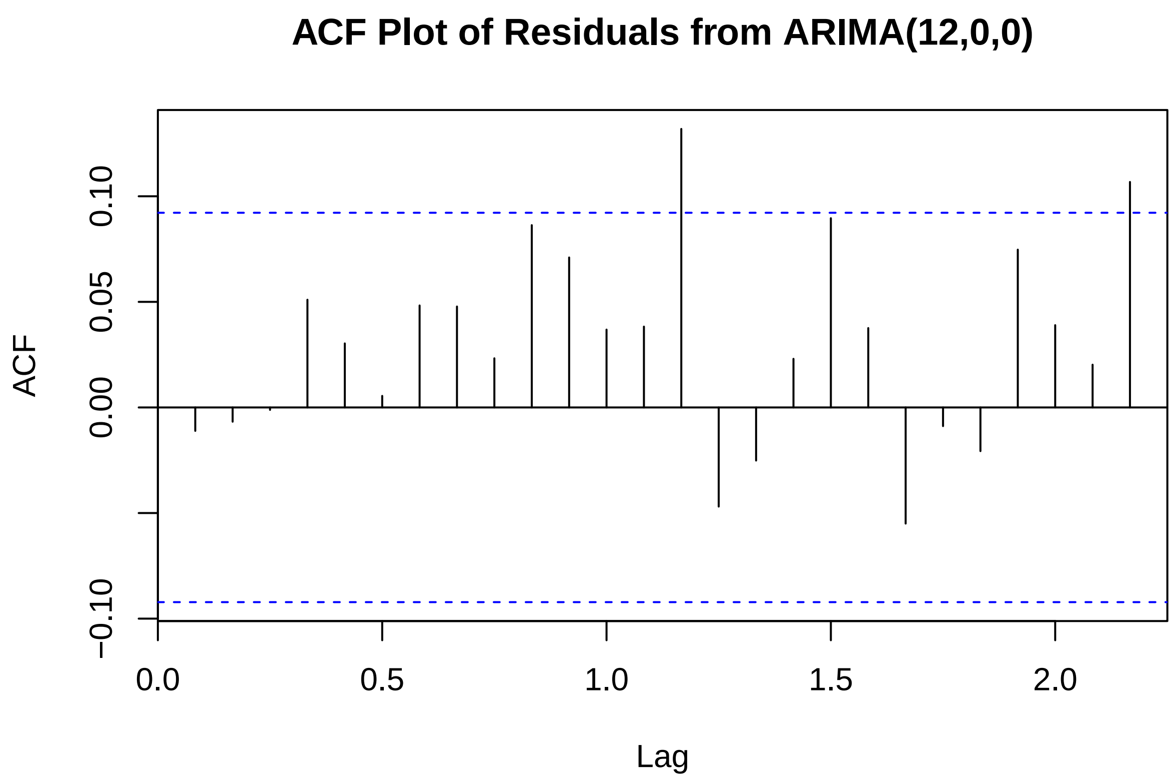

```r
#residuals
ar12_resid<-ts(residuals(ar12), frequency=12, start=c(1956,1))
plot(ar12_resid, main="AR 12 model Residuals from Logged Beer\nSeasonal Means")
abline(h=0)
```



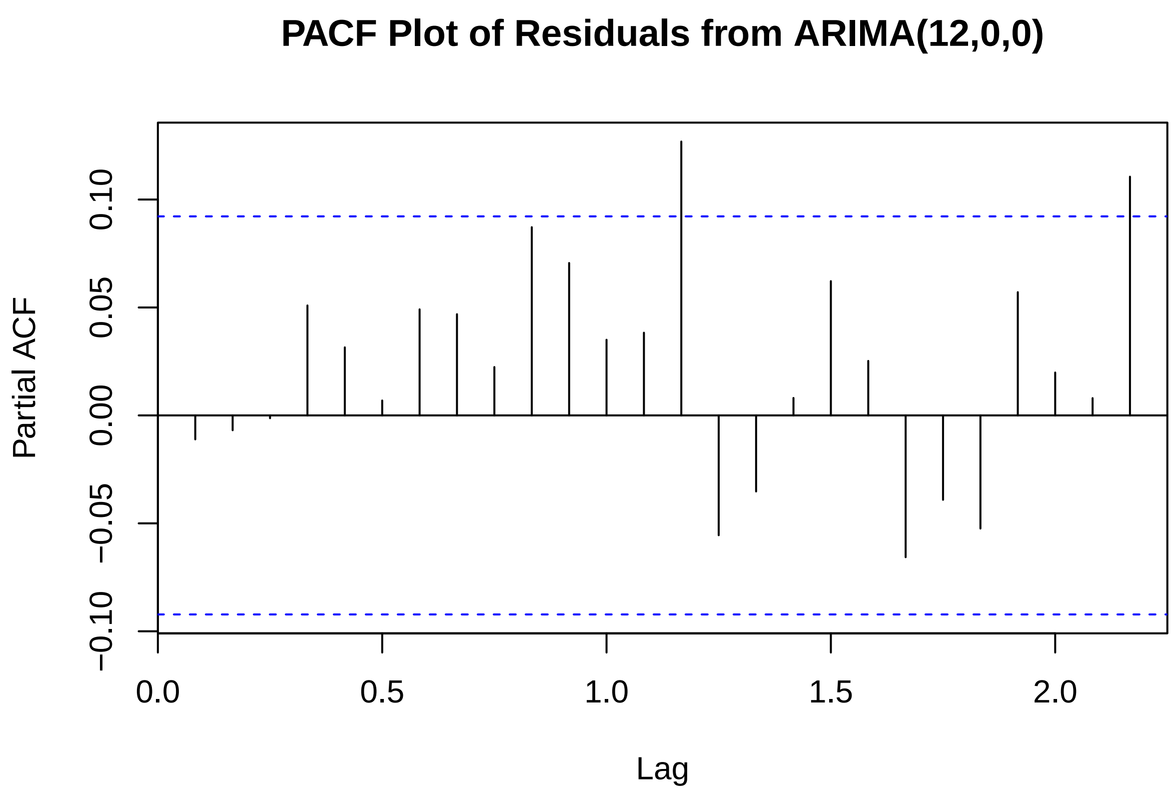
```r
plot(ar12_resid, main="AR 12 model Residuals from Logged Beer\nSeasonal Means", type="l")
points(y=ar12_resid, x=time(ar12_resid), pch=as.vector(season(ar12_resid)))
abline(h=0)
```




```r
acf(ar12_resid, main="ACF Plot of Residuals from ARIMA(12,0,0)")
```



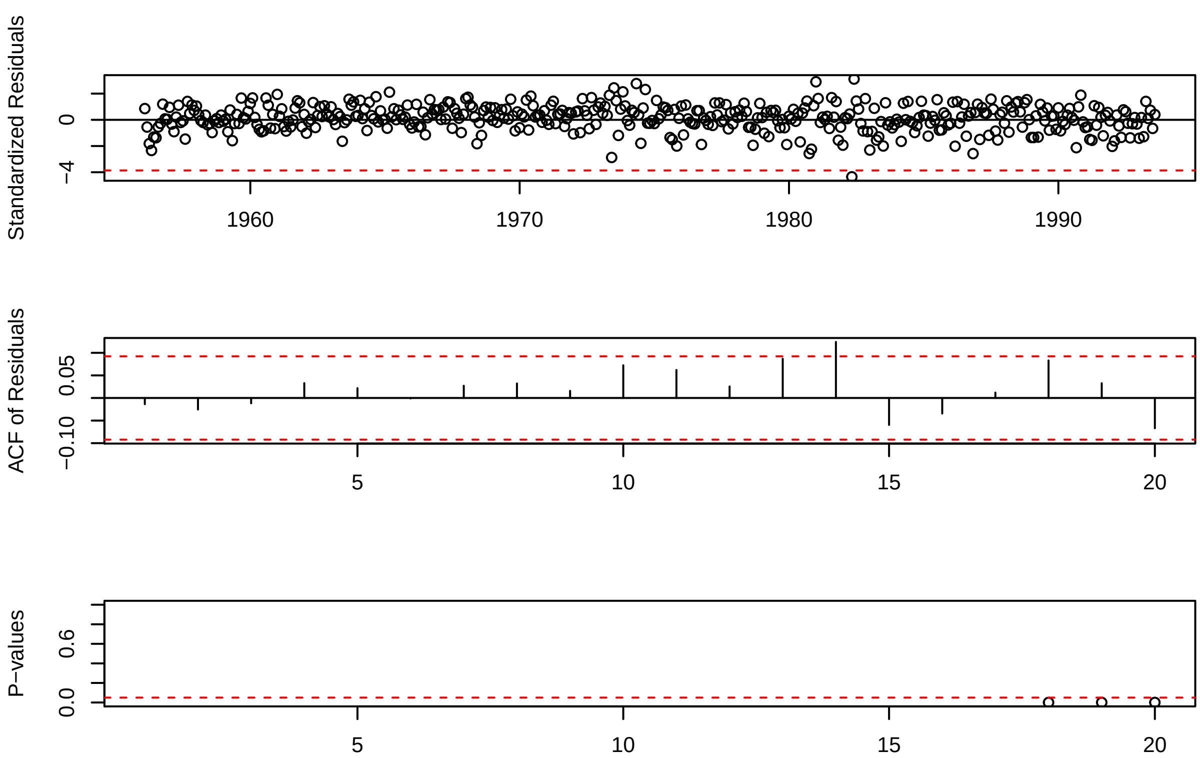

```r
pacf(ar12_resid, main="PACF Plot of Residuals from ARIMA(12,0,0)")
```



```r
ar13<-arima(logBeer, order=c(13,0,0), xreg=monthDummies)
ar13
```

```
##
## Call:
## arima(x = logBeer, order = c(13, 0, 0), xreg = monthDummies)
##
## Coefficients:
##          ar1     ar2     ar3      ar4     ar5     ar6      ar7     ar8
##       0.0731  0.0406  0.1232  -0.0038  0.1344  0.1406  -0.0638  0.1074
## s.e.  0.0470  0.0467  0.0458   0.0461  0.0459  0.0460   0.0466  0.0464
##          ar9     ar10    ar11    ar12     ar13  intercept      Jan
##       0.1442  -0.0190  0.2112  0.1696  -0.0614     4.9746  -0.1925
## s.e.  0.0460   0.0465  0.0460  0.0470   0.0477     0.2625   0.0152
##           Feb      Mar      Apr      May      Jun      Jul      Aug
##       -0.2571  -0.1795  -0.2793  -0.3185  -0.4344  -0.3504  -0.3009
## s.e.   0.0164   0.0152   0.0159   0.0162   0.0152   0.0162   0.0159
##           Sep      Oct      Nov
##       -0.2656  -0.1258  -0.0755
## s.e.   0.0153   0.0165   0.0153
##
## sigma^2 estimated as 0.003931:  log likelihood = 607.51,  aic = -1165.02
```

```r
tsdiag(ar13, gof.lag=20)
```

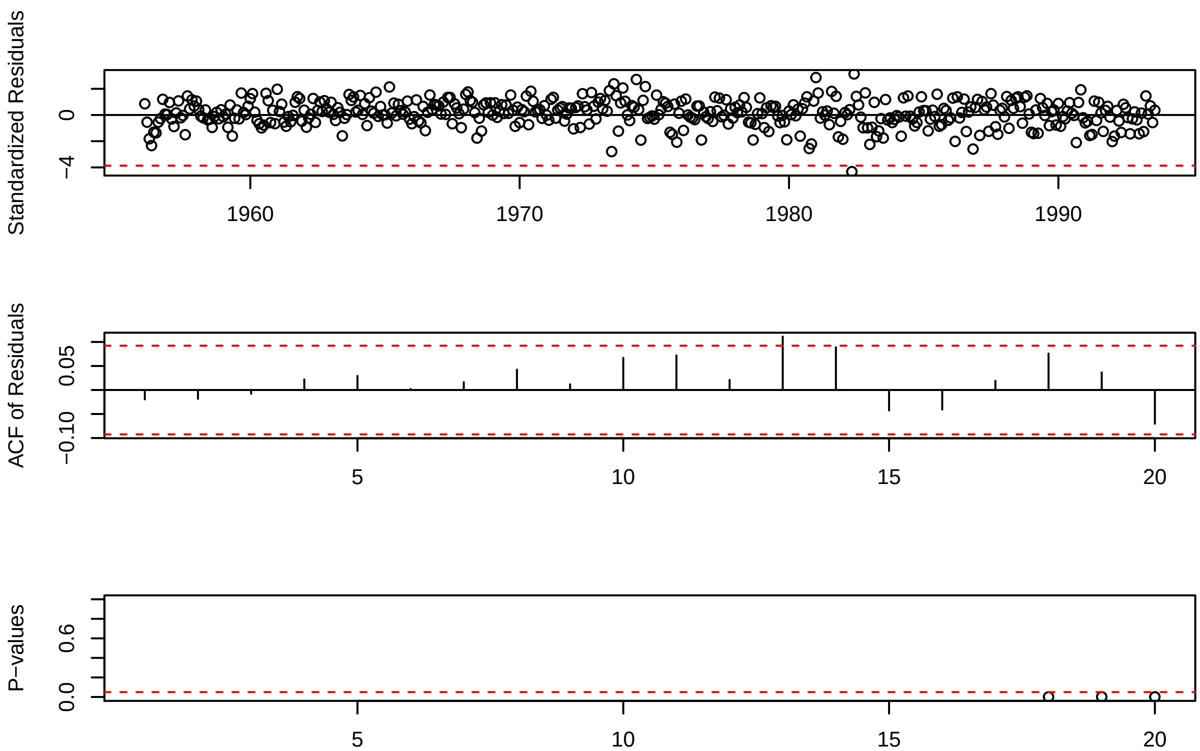



```r
ar12ma1<-arima(logBeer, order=c(12,0,1), xreg=monthDummies)
ar12ma1
```

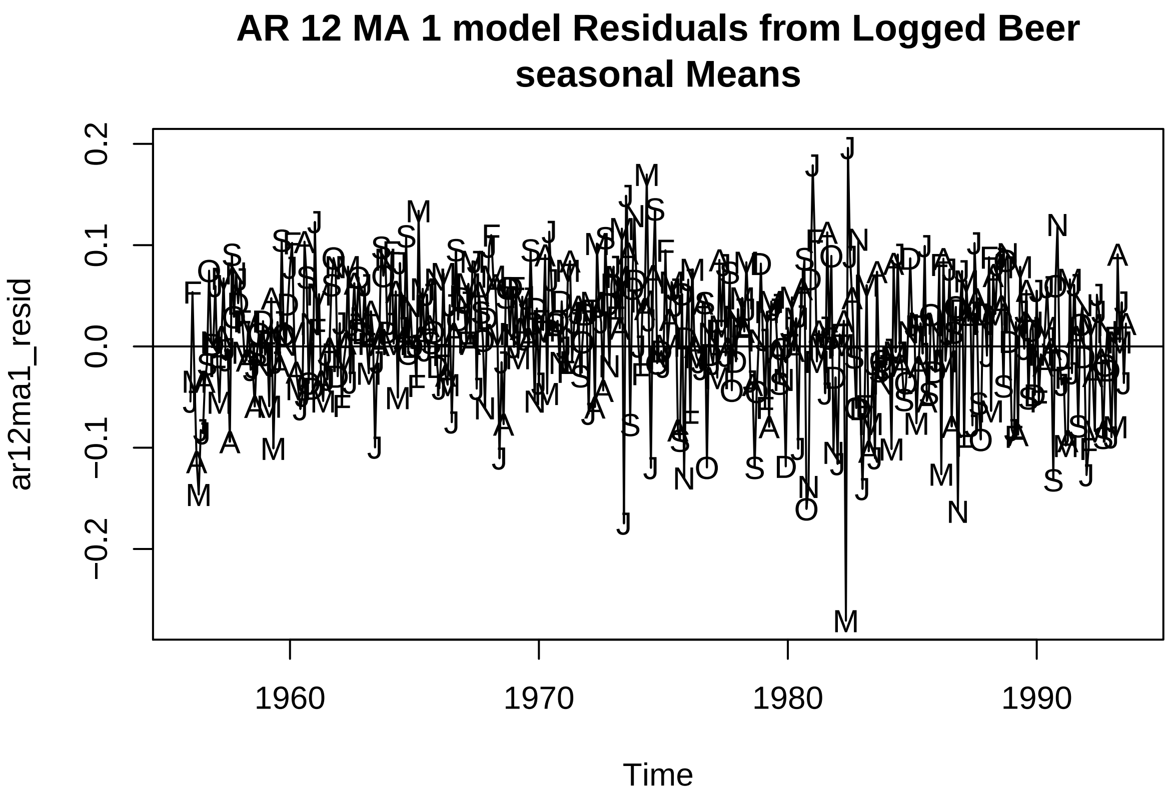
```
##
## Call:
```

```
## arima(x = logBeer, order = c(12, 0, 1), xreg = monthDummies)
##
## Coefficients:
##           ar1     ar2     ar3     ar4     ar5    ar6     ar7     ar8
##       -0.4282  0.0770  0.1375  0.0634  0.1301  0.205  0.0136  0.0737
## s.e.   0.1845  0.0522  0.0501  0.0576  0.0494  0.056  0.0609  0.0504
##          ar9    ar10    ar11    ar12     ma1  intercept      Jan      Feb
##       0.1947  0.0575  0.1979  0.2726  0.5101     4.9738  -0.1927  -0.2573
## s.e.  0.0542  0.0593  0.0499  0.0503  0.1902     0.2632   0.0151   0.0160
##           Mar      Apr      May      Jun      Jul      Aug      Sep
##       -0.1799  -0.2794  -0.3189  -0.4344  -0.3507  -0.3009  -0.2659
## s.e.   0.0152   0.0157   0.0160   0.0150   0.0160   0.0157   0.0153
##           Oct      Nov
##       -0.1260  -0.0757
## s.e.   0.0161   0.0152
##
## sigma^2 estimated as 0.003916:  log likelihood = 608.36,  aic = -1166.72
```

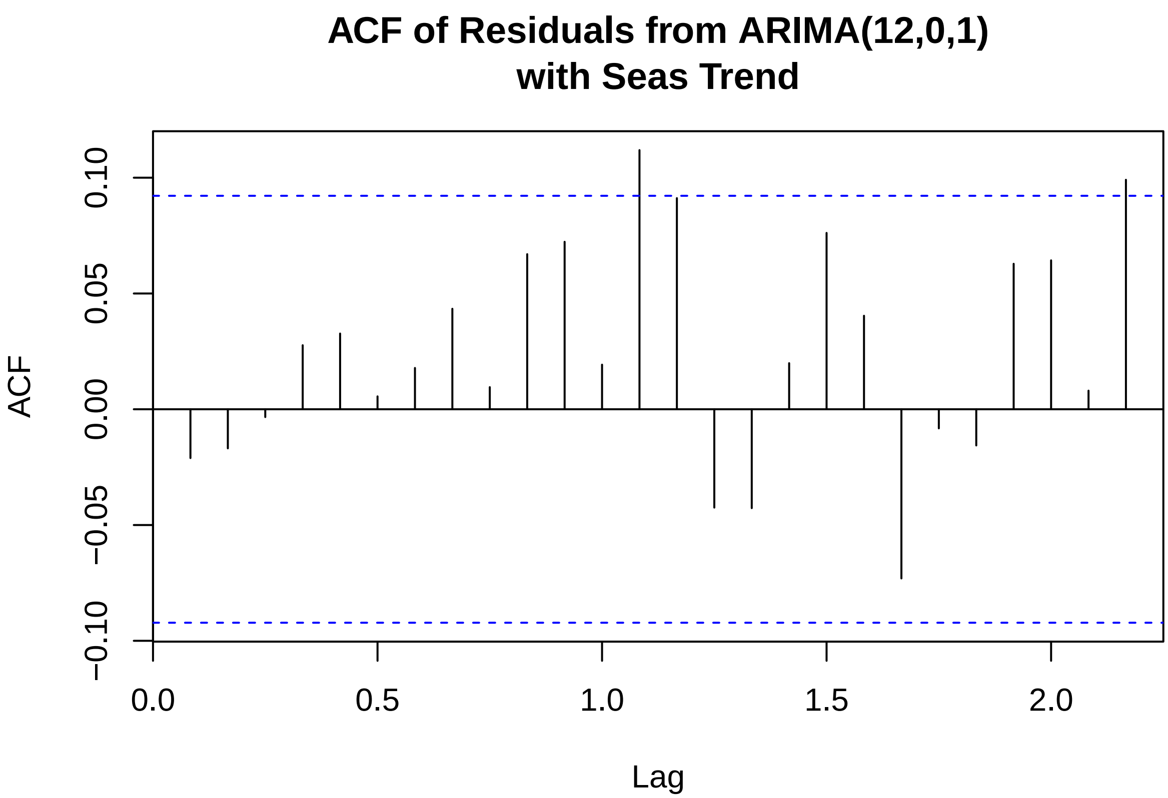
```
tsdiag(ar12ma1, gof.lag=20)
```



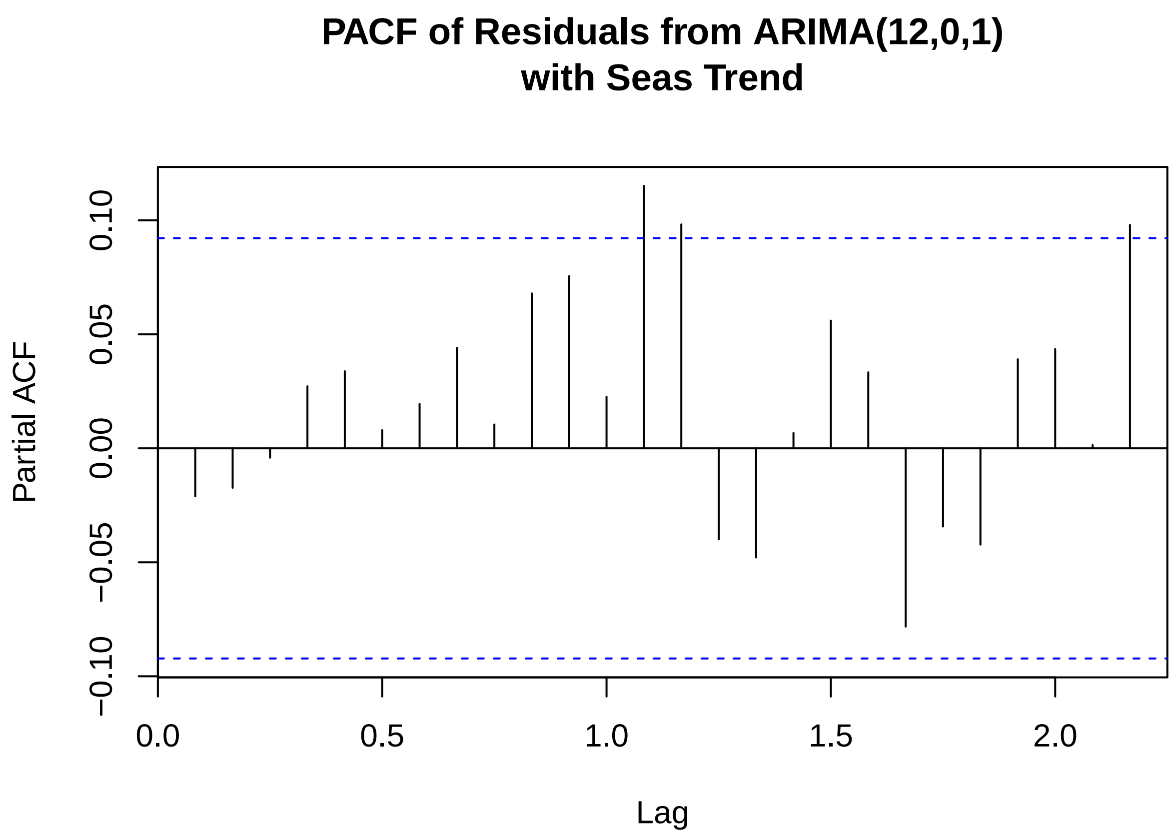

```
ar12ma1_resid<-ts(residuals(ar12ma1), frequency=12, start=c(1956,1))
plot(ar12ma1_resid, main="AR 12 MA 1 model Residuals from Logged Beer\nseasonal Means", type="l")
points(y=ar12ma1_resid, x=time(ar12ma1_resid), pch=as.vector(season(ar12ma1_resid)))
abline(h=0)
```




```
acf(ar12ma1_resid,main="ACF of Residuals from ARIMA(12,0,1)\nwith Seas Trend")
```



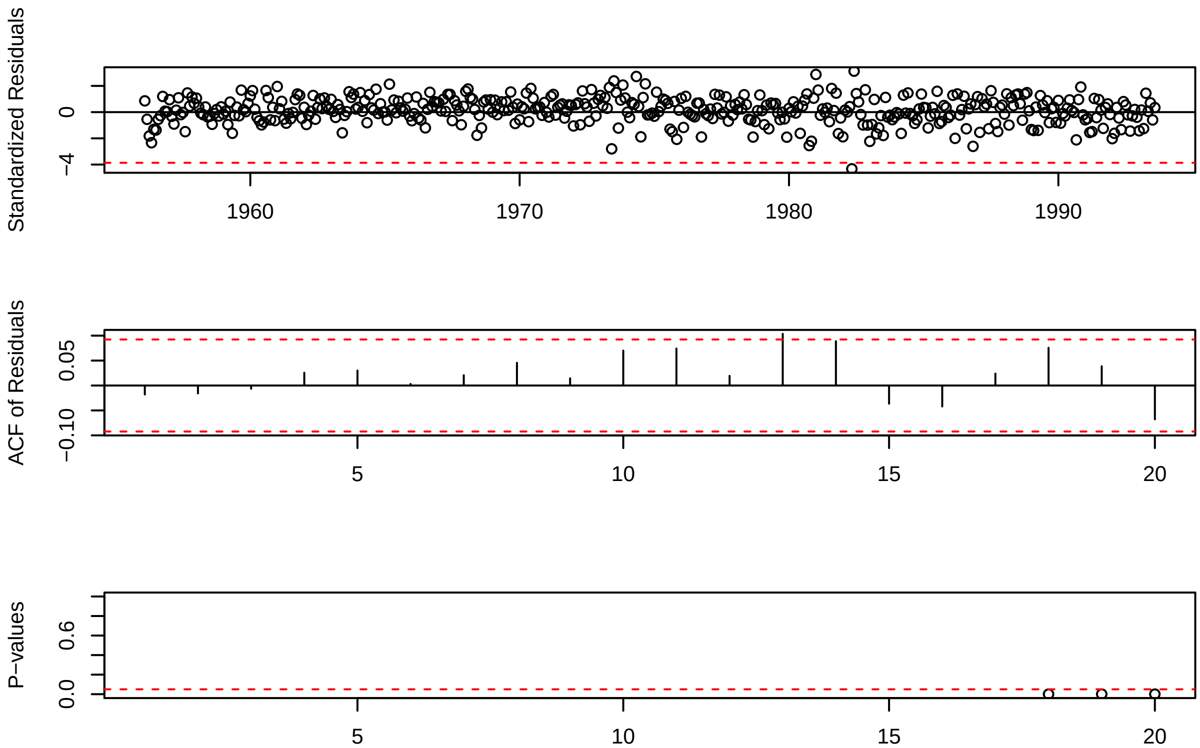
```r
pacf(ar12ma1_resid,main="PACF of Residuals from ARIMA(12,0,1)\nwith Seas Trend",mar=c(5,2,2,0.8), oma=c(1,1,1,
```




```r
ar13ma1<-arima(logBeer, order=c(13,0,1), xreg=monthDummies)
ar13ma1
```

```
##
## Call:
## arima(x = logBeer, order = c(13, 0, 1), xreg = monthDummies)
##
## Coefficients:
##           ar1     ar2     ar3     ar4     ar5     ar6     ar7     ar8
##       -0.5046  0.0793  0.1393  0.0704  0.1281  0.2144  0.0217  0.0664
## s.e.   0.2870  0.0532  0.0517  0.0608  0.0512  0.0633  0.0647  0.0565
##          ar9    ar10    ar11    ar12    ar13     ma1  intercept      Jan
##       0.2012  0.0663  0.1953  0.2919  0.0248  0.5841     4.9734  -0.1927
## s.e.  0.0581  0.0642  0.0520  0.0780  0.0804  0.2826     0.2635   0.0152
##           Feb      Mar      Apr      May      Jun      Jul      Aug
##       -0.2573  -0.1799  -0.2794  -0.3190  -0.4345  -0.3507  -0.3009
## s.e.   0.0161   0.0153   0.0158   0.0162   0.0151   0.0162   0.0158
##           Sep      Oct      Nov
##       -0.2660  -0.1260  -0.0757
## s.e.   0.0155   0.0162   0.0153
##
## sigma^2 estimated as 0.003915:  log likelihood = 608.41,  aic = -1164.82
```

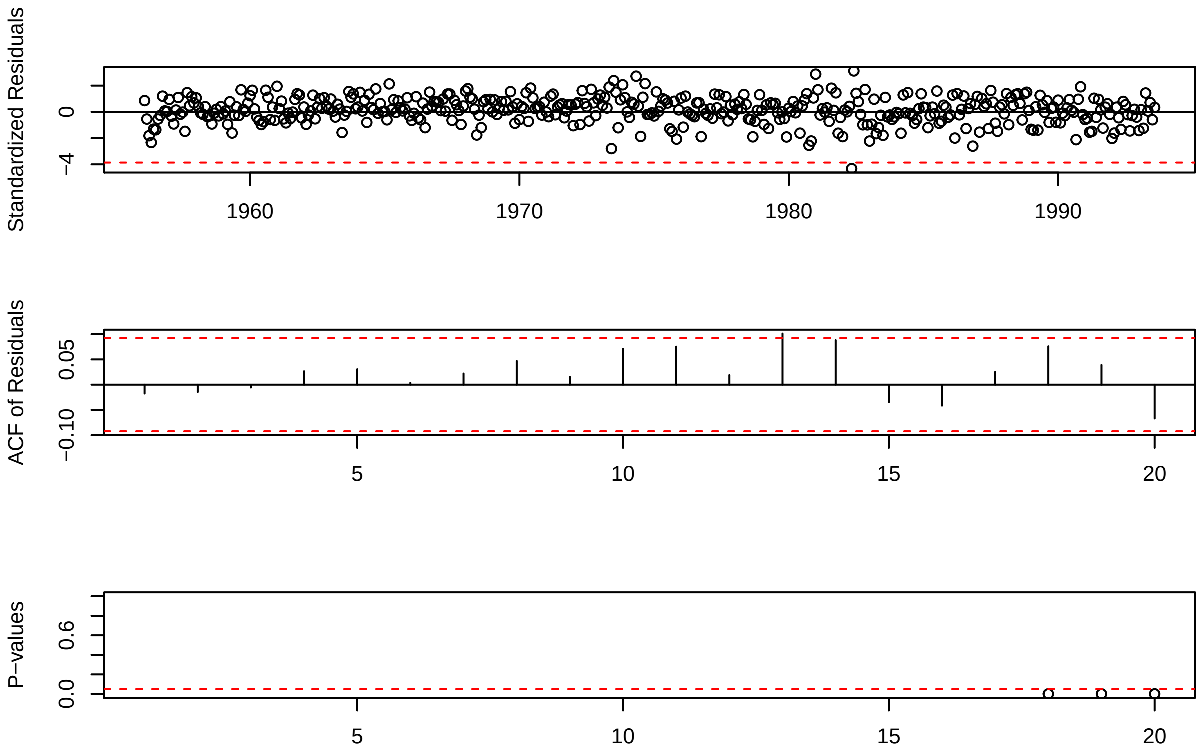
```r
tsdiag(ar13ma1, gof.lag=20)
```



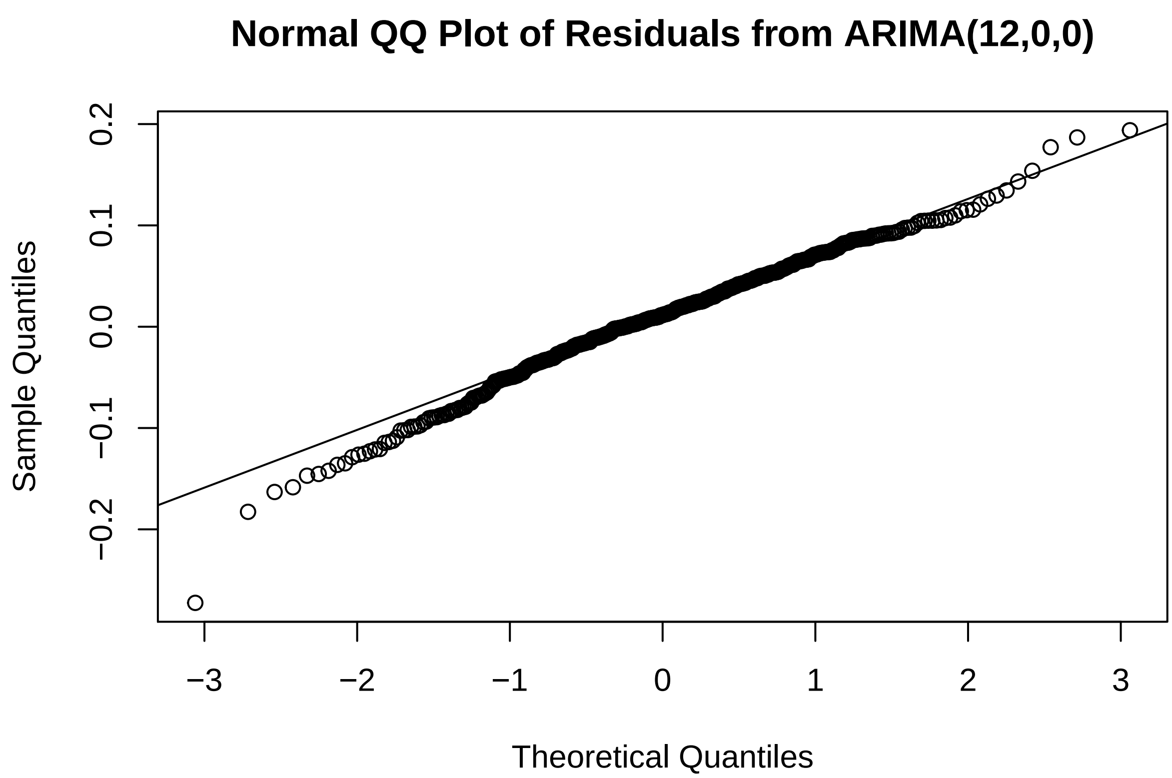

```r
ar12ma2<-arima(logBeer, order=c(12,0,2), xreg=monthDummies)
ar12ma2
```

```
##
## Call:
## arima(x = logBeer, order = c(12, 0, 2), xreg = monthDummies)
##
## Coefficients:
##           ar1     ar2     ar3     ar4     ar5     ar6    ar7     ar8
##       -0.4094  0.1303  0.1308  0.0563  0.1201  0.2020  0.000  0.0627
## s.e.   0.1777  0.1517  0.0528  0.0592  0.0559  0.0553  0.069  0.0581
##          ar9    ar10    ar11    ar12     ma1      ma2  intercept      Jan
##       0.1944  0.0460  0.1877  0.2742  0.4882  -0.0600     4.9731  -0.1928
## s.e.  0.0534  0.0652  0.0571  0.0496  0.1843   0.1602     0.2638   0.0152
##           Feb      Mar      Apr      May      Jun      Jul      Aug
##       -0.2573  -0.1800  -0.2795  -0.3190  -0.4345  -0.3508  -0.3009
## s.e.   0.0162   0.0154   0.0159   0.0162   0.0151   0.0162   0.0159
##           Sep      Oct      Nov
##       -0.2660  -0.1260  -0.0757
## s.e.   0.0155   0.0163   0.0153
##
## sigma^2 estimated as 0.003915:  log likelihood = 608.43,  aic = -1164.85
```

```r
tsdiag(ar12ma2, gof.lag=20)
```




```r
par(mfrow=c(1,1))

qqnorm(residuals(ar12), main="Normal QQ Plot of Residuals from ARIMA(12,0,0)")
qqline(ar12_resid)
```



```r
shapiro.test(ar12_resid)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  ar12_resid
## W = 0.98657, p-value = 0.000348
```

```r
LB.test(ar12, lag=35)
```

```
##
##  Box-Ljung test
##
## data:  residuals from  ar12
## X-squared = 49.126, df = 23, p-value = 0.001198
```

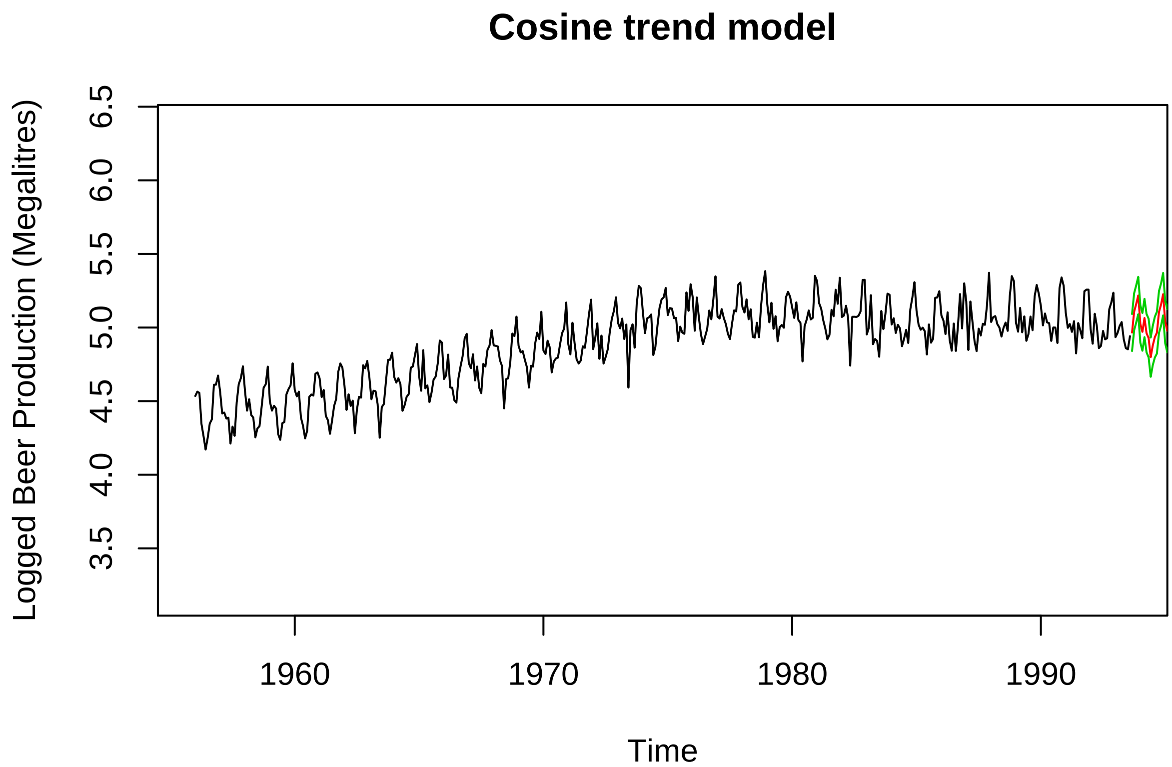
```r
pacf_acf<-data.frame(acfVal=acf(ar12_resid, plot=FALSE)$acf, pacfVal=pacf(ar12_resid, plot=FALSE)$acf)
#print(pacf_acf)
```

## Make the forecasts- set up external regressor data frame

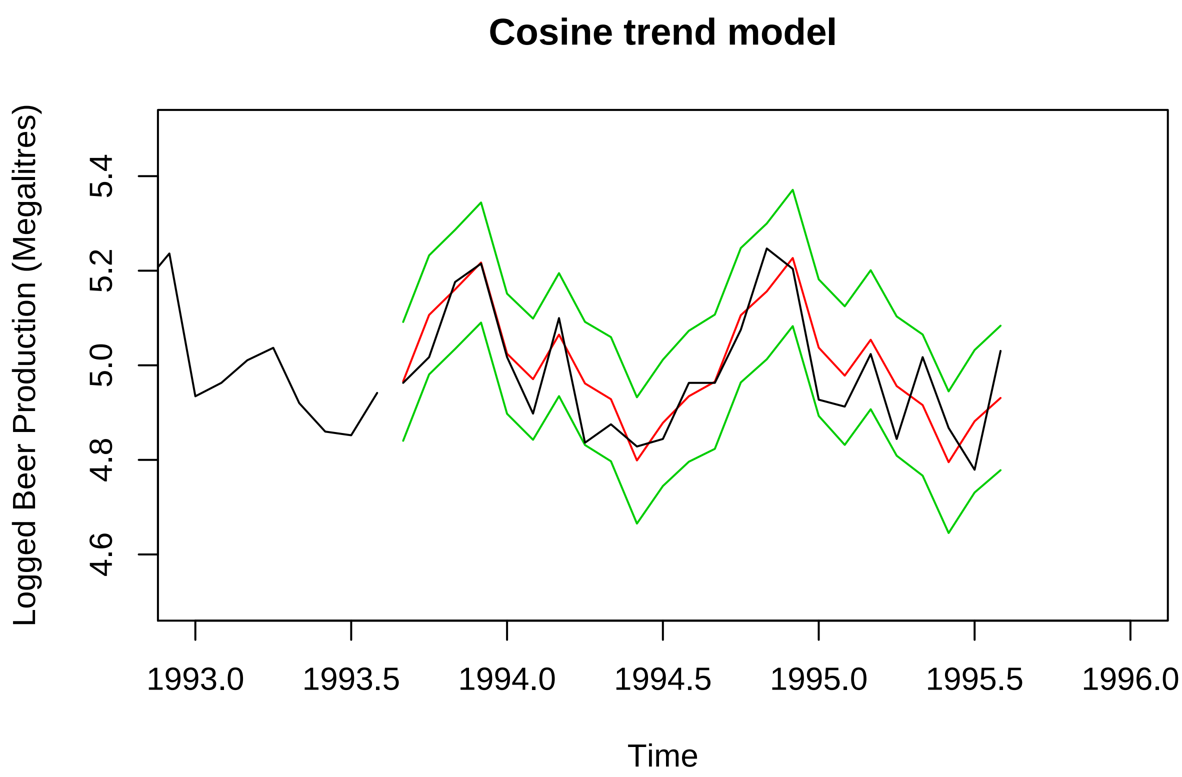
```r
newMonthDummy<-seasonaldummy(beer_forecast)
```

## Plot the model forecasts

```r
chosenMod<-ar12
predictions<-predict(chosenMod, n.ahead=24,newxreg=newMonthDummy)
pred<-predictions$pred
uci<-pred+2*predictions$se
lci<-pred-2*predictions$se

sumSqErrSeasMean<-sum((log(beer_forecast)-pred)^2)

ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,ylim=c(ymin,ymax),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
```




```
ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,xlim=c(1993, 1996), ylim=c(4.5,5.5),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
lines(log(beer_forecast), col="black")
```



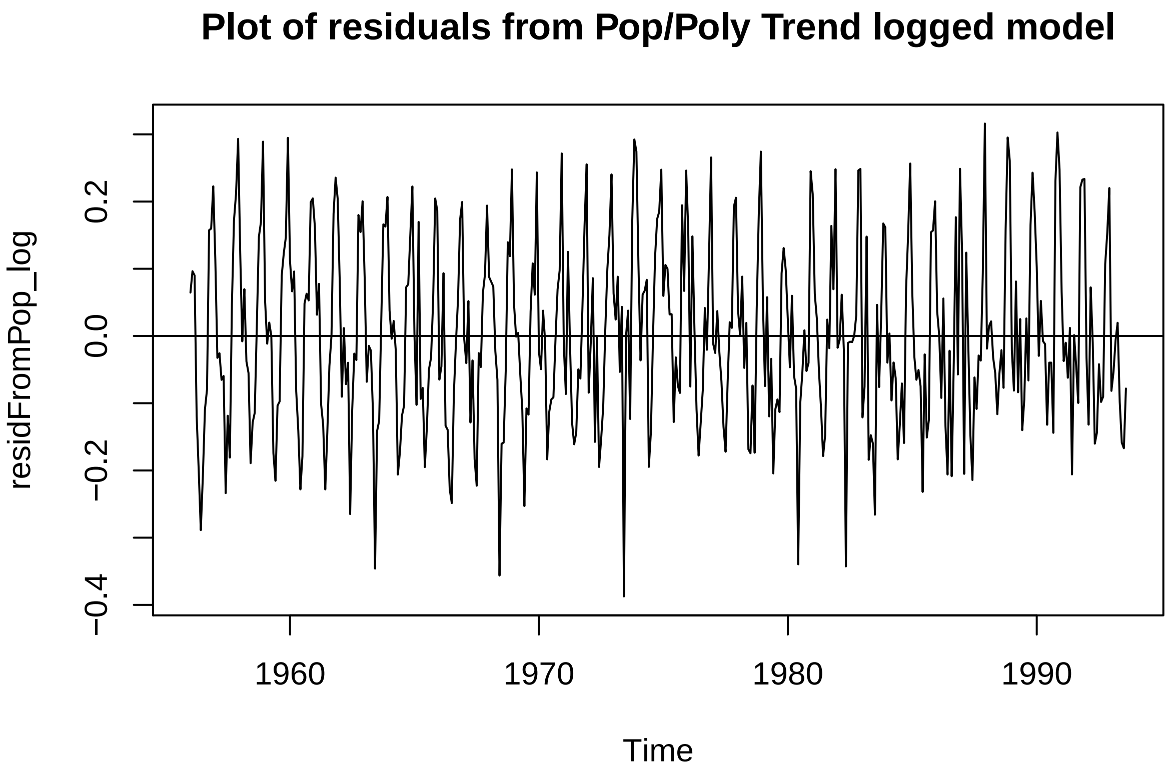

## SARIMA model with population data

```
logBeer<-log(beerPopMonth$beer)
lag6_10_14<-beerPopMonth$lag6_10_14
t<-1:length(beerTS)
t2<-t^2
t3<-t^3
t4<-t^4
externalReg<-data.frame(lag6_10_14, t, t2, t3, t4)
monthlyPopModel_log<-lm(logBeer ~ lag6_10_14+t+t2+t3+t4)
monthlyPopOnly_log<-lm(logBeer ~ lag6_10_14)
summary(monthlyPopModel_log)
```

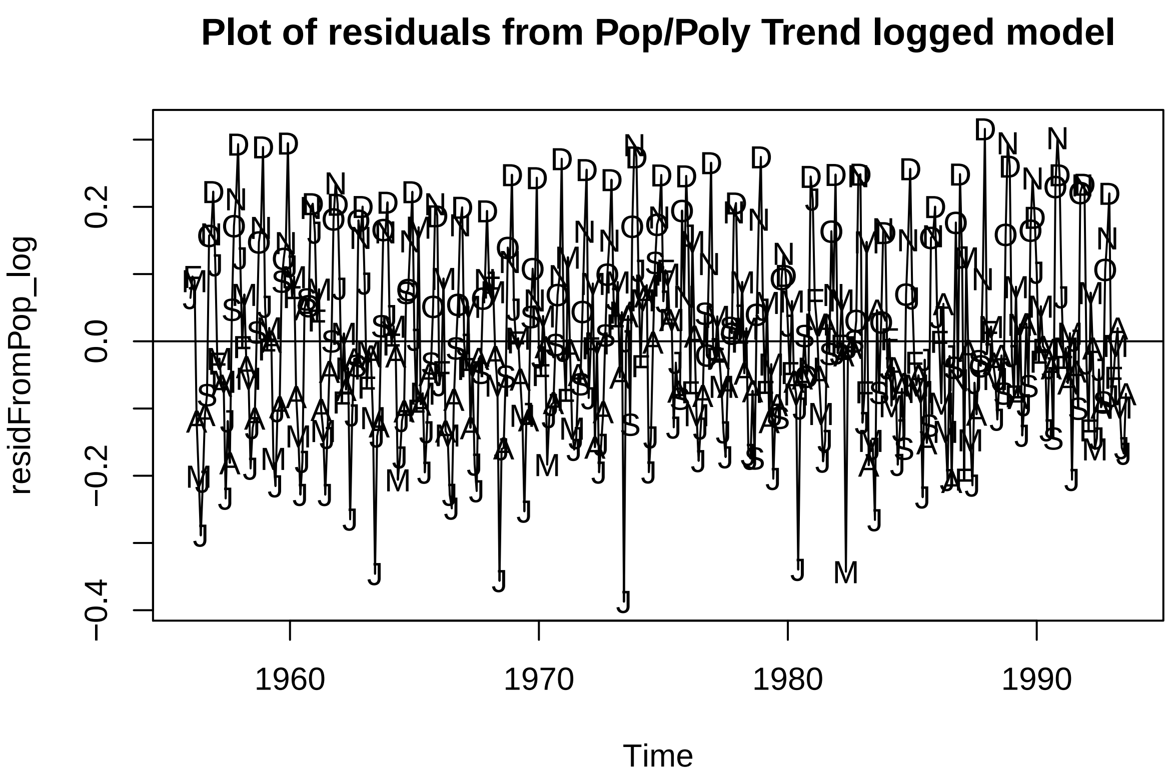
```
##
## Call:
## lm(formula = logBeer ~ lag6_10_14 + t + t2 + t3 + t4)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.38742 -0.09499 -0.01169  0.08863  0.31604
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.233e+00  1.167e-01  36.286  < 2e-16 ***
## lag6_10_14   4.122e-07  2.091e-07   1.971   0.0493 *
## t           -3.114e-03  1.322e-03  -2.356   0.0189 *
## t2           4.855e-05  8.989e-06   5.401 1.08e-07 ***
## t3          -1.647e-07  2.938e-08  -5.604 3.67e-08 ***
## t4           1.668e-10  3.217e-11   5.185 3.28e-07 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1357 on 446 degrees of freedom
## Multiple R-squared:  0.748,  Adjusted R-squared:  0.7452
## F-statistic: 264.8 on 5 and 446 DF,  p-value: < 2.2e-16
```

```r
residFromPop_log<-ts(residuals(monthlyPopModel_log), frequency=12, start=c(1956,1))
plot(residFromPop_log, main="Plot of residuals from Pop/Poly Trend logged model")
abline(h=0)
```




```r
plot(residFromPop_log, type="l", main="Plot of residuals from Pop/Poly Trend logged model")
points(y=residFromPop_log, x=time(residFromPop_log), pch=as.vector(season(residFromPop_log)))
abline(h=0)
```




```r
adf.test(residFromPop_log)
```

```
## Warning in adf.test(residFromPop_log): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  residFromPop_log
## Dickey-Fuller = -14.166, Lag order = 7, p-value = 0.01
## alternative hypothesis: stationary
```

```r
pp.test(residFromPop_log)
```

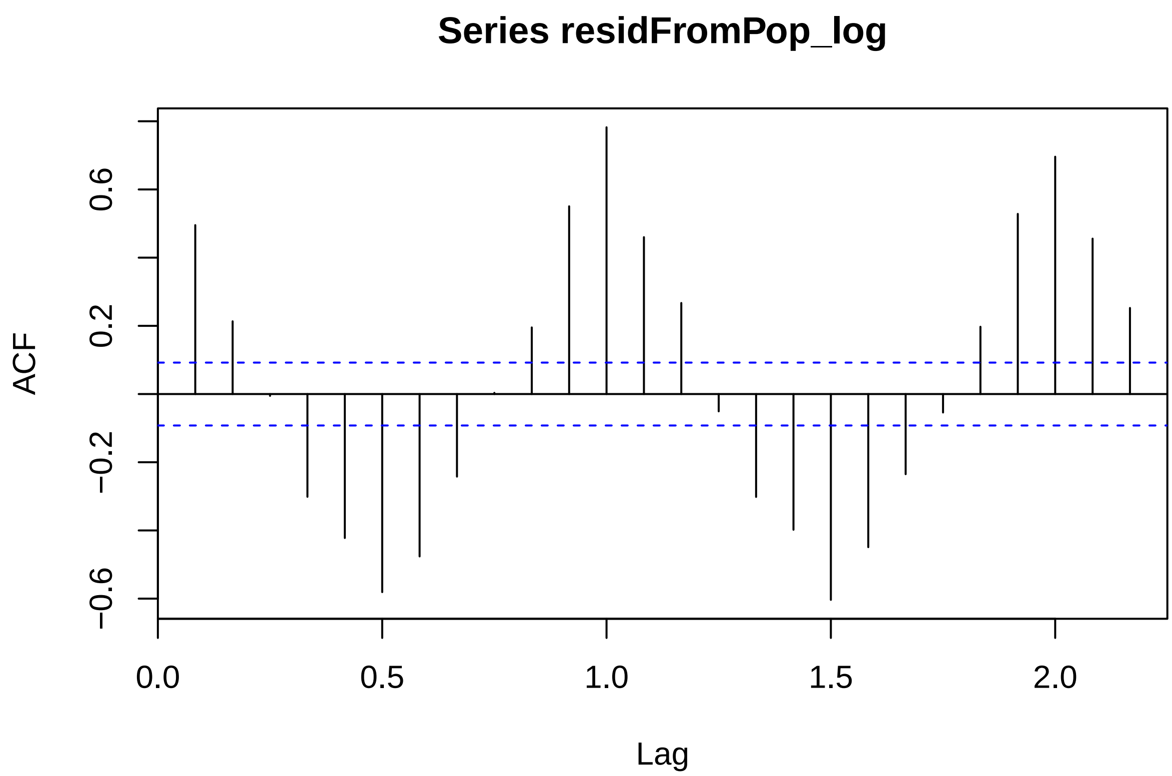
```
## Warning in pp.test(residFromPop_log): p-value smaller than printed p-value
```

```
##
##  Phillips-Perron Unit Root Test
##
## data:  residFromPop_log
## Dickey-Fuller Z(alpha) = -217.82, Truncation lag parameter = 5,
## p-value = 0.01
## alternative hypothesis: stationary
```

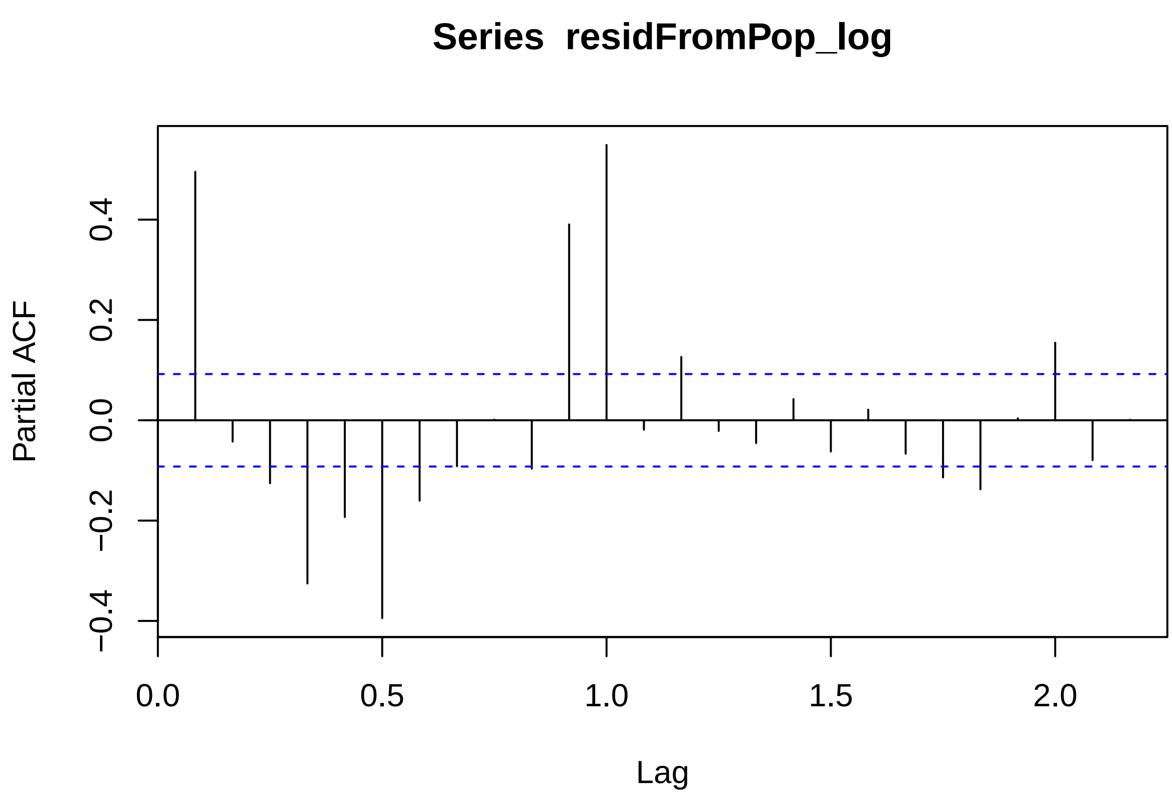
```r
nsdiffs(residFromPop_log, m=frequency(residFromPop_log), test=c("ocsb","ch"), max.D=1)
```

```
## [1] 0
```

```r
acf(residFromPop_log)
```




```r
pacf(residFromPop_log)
```

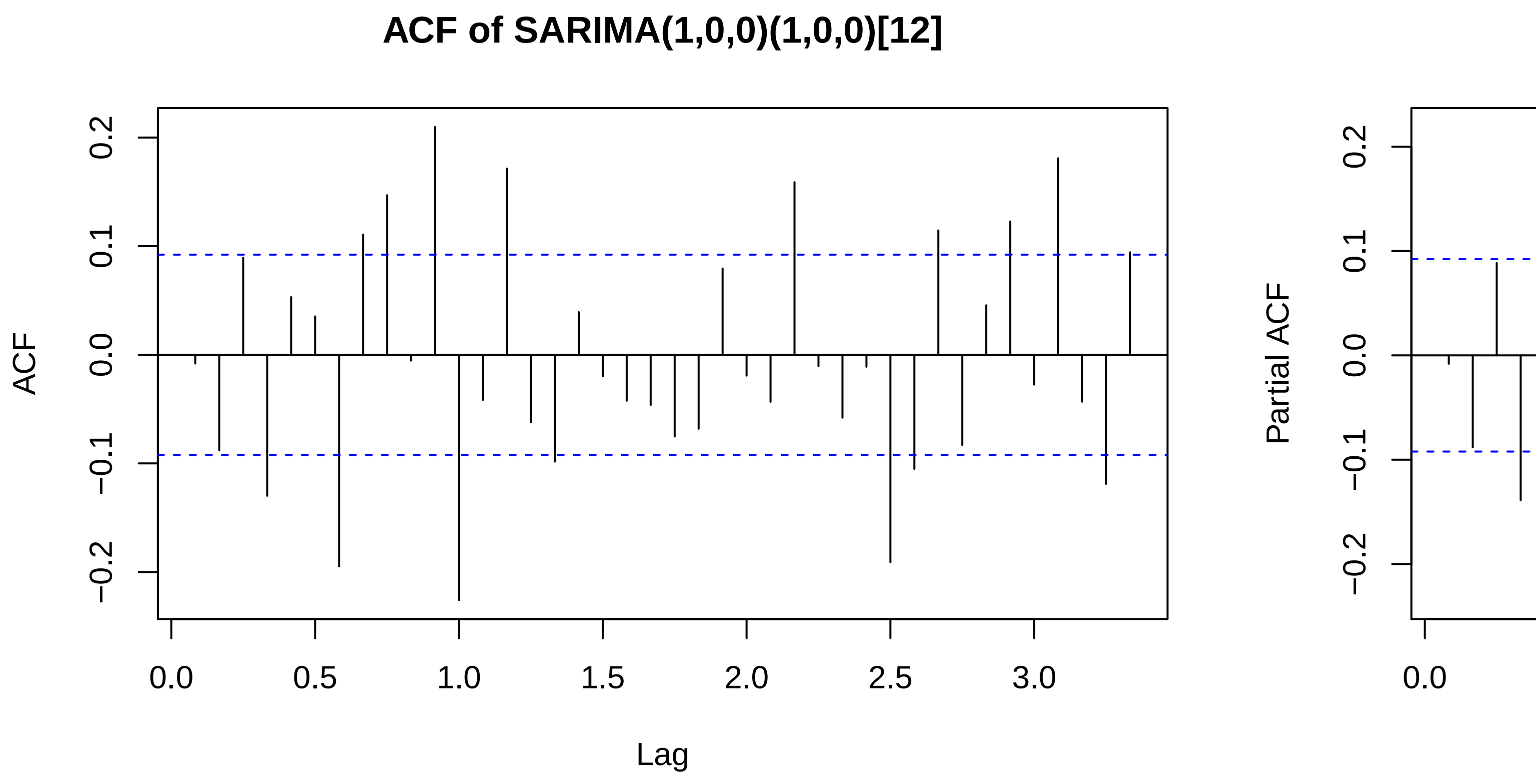


```r
eacf(residFromPop_log)
```

```
## AR/MA
##   0 1 2 3 4 5 6 7 8 9 10 11 12 13
## 0 x x o x x x x x o x x  x  x  x
## 1 o x o x o x x x o o x  x  o  x
## 2 x o x x o x o o o o o  x  o  x
## 3 x o x o x x o o o x o  x  x  x
## 4 x x x o x x o o o o o  x  x  x
## 5 x x x x x o o o o o o  x  x  x
## 6 x o x x x o o o o x o  x  x  o
## 7 x x o o x x o o o o o  x  x  o
```

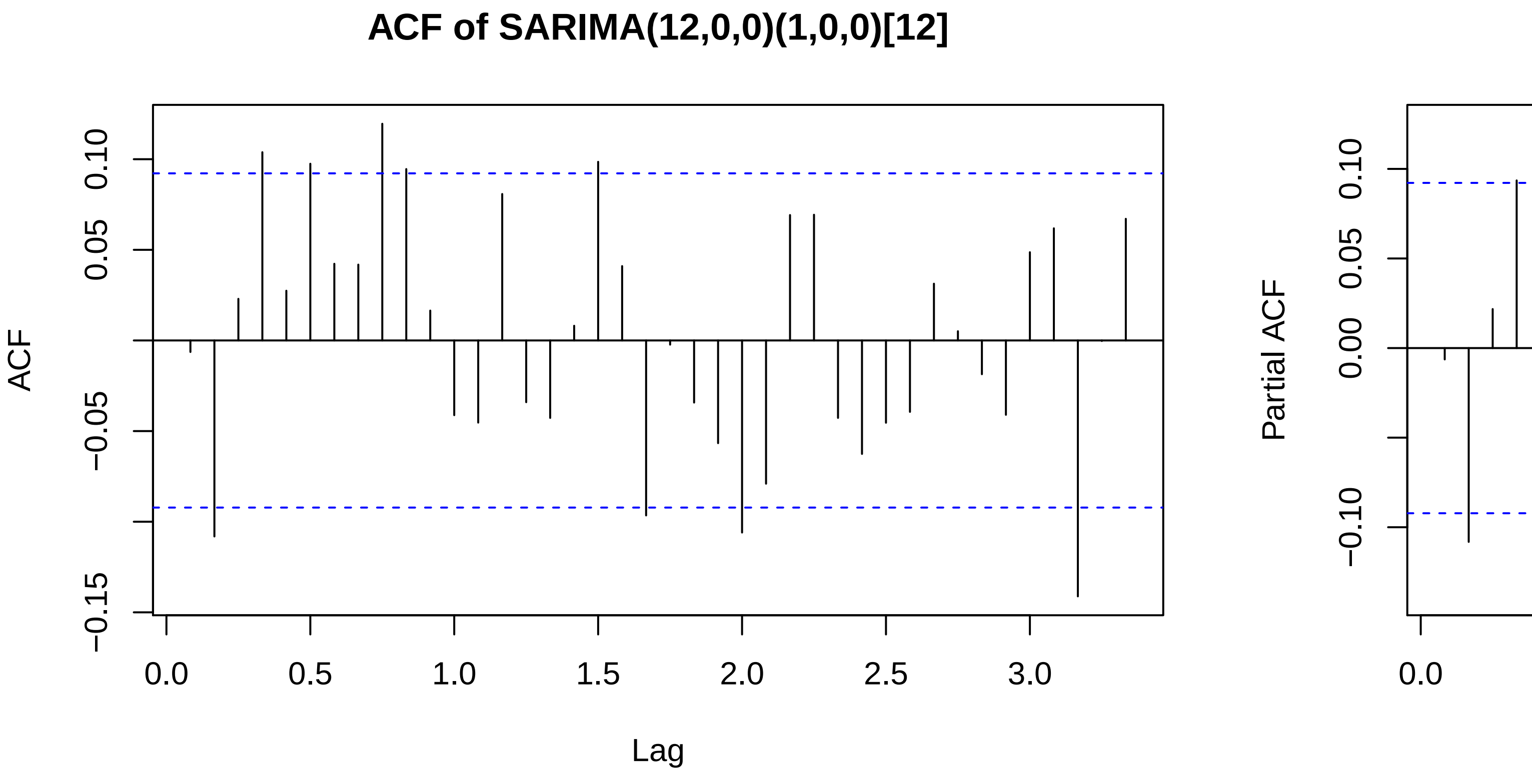
## Build initial model

```r
popModel1<-arima(residFromPop_log, order=c(1,0,0), seasonal=list(order=c(1,0,0), period=12))
plotResid(popModel1)
```

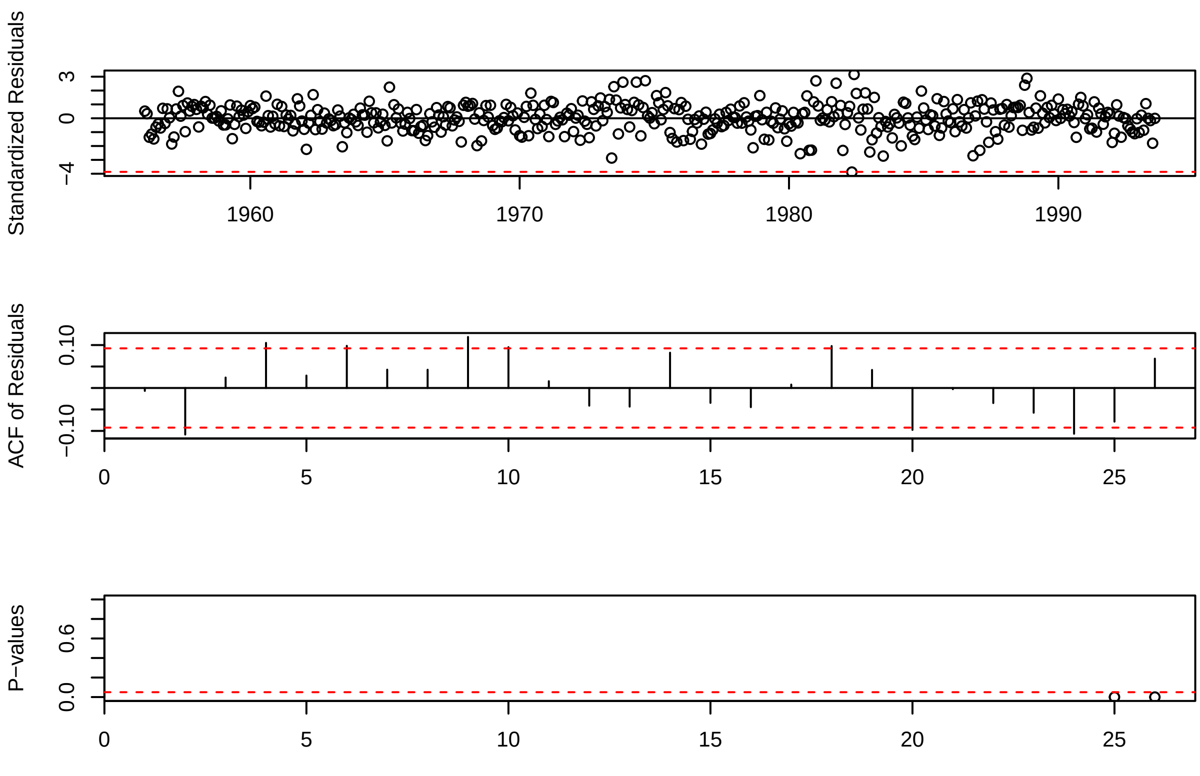



## Try p=12 and q=12

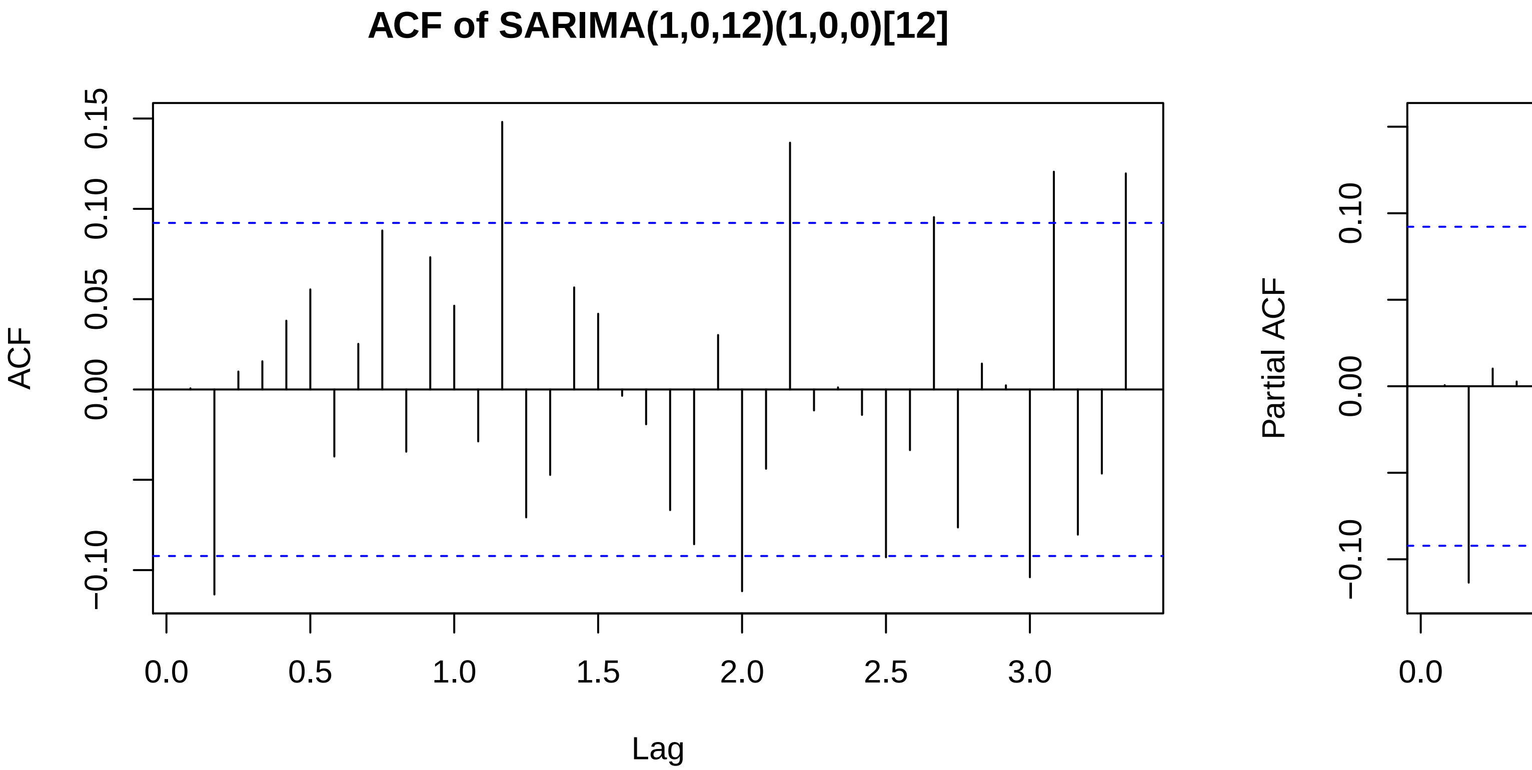
```r
popModel2<-arima(residFromPop_log, order=c(12,0,0), seasonal=list(order=c(1,0,0), period=12))
plotResid(popModel2)
```



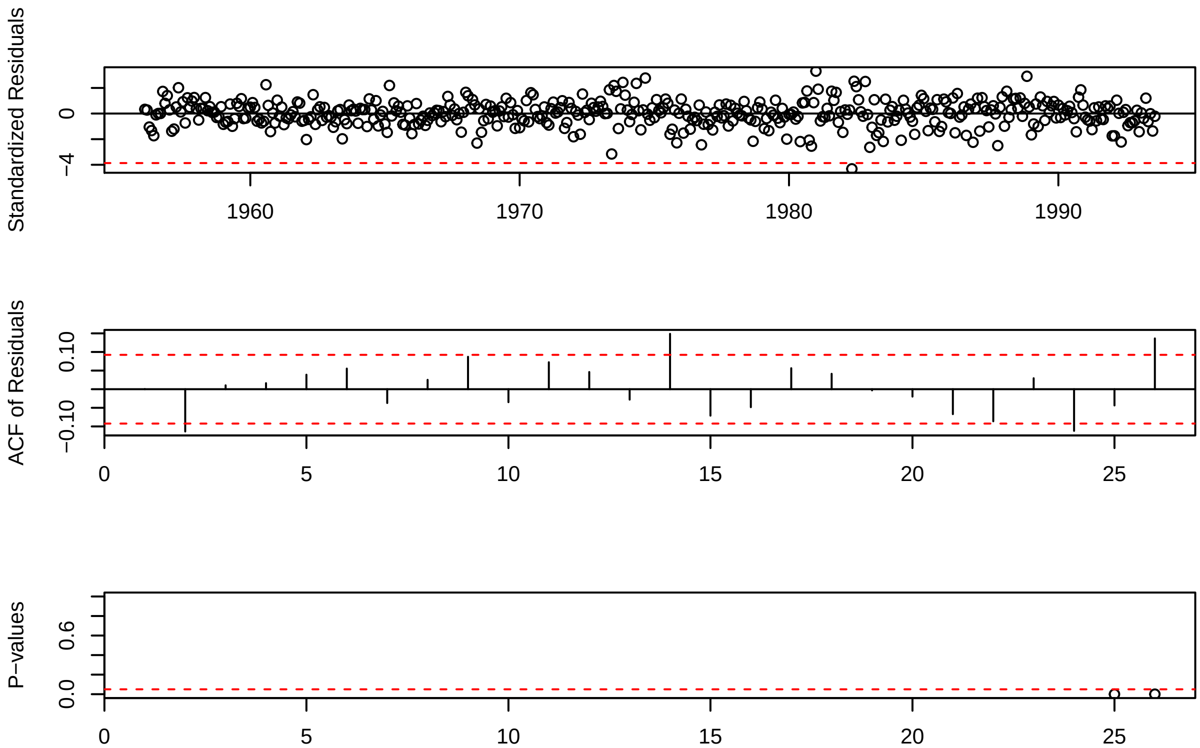

```r
tsdiag(popModel2)
```



```r
popModel3<-arima(residFromPop_log, order=c(1,0,12), seasonal=list(order=c(1,0,0), period=12))
plotResid(popModel3)
```




```r
tsdiag(popModel3)
```




## Try overfitting the SARIMA(12,0,0)(1,0,0)[12]

```
#popModel4<-arima(residFromPop_log, order=c(13,0,0), seasonal=list(order=c(1,0,0), period=12))
#Produces error

popModel5<-arima(residFromPop_log, order=c(12,0,1), seasonal=list(order=c(1,0,0), period=12))
popModel5
```

```
##
## Call:
## arima(x = residFromPop_log, order = c(12, 0, 1), seasonal = list(order = c(1,
##     0, 0), period = 12))
##
## Coefficients:
##          ar1     ar2     ar3      ar4     ar5      ar6      ar7     ar8
##       0.0083  0.0269  0.0119  -0.1320  0.1293  -0.1074  -0.0709  0.0316
## s.e.  0.0493  0.0327  0.0295   0.0291  0.0311   0.0307   0.0336  0.0299
##          ar9     ar10    ar11    ar12      ma1     sar1  intercept
##       0.0174  -0.1302  0.2063  0.7417  -0.0301  -0.3180    -0.0008
## s.e.  0.0296   0.0292  0.0318  0.0405   0.0825   0.0528     0.0082
##
## sigma^2 estimated as 0.00456:  log likelihood = 571,  aic = -1112
```

```
popModel6<-arima(residFromPop_log, order=c(12,0,0), seasonal=list(order=c(2,0,0), period=12))
popModel6
```

```
##
## Call:
```

```
## arima(x = residFromPop_log, order = c(12, 0, 0), seasonal = list(order = c(2,
##     0, 0), period = 12))
##
## Coefficients:
##           ar1      ar2     ar3      ar4     ar5     ar6      ar7     ar8
##       -0.0548  -0.1008  0.0923  -0.0492  0.0658  0.0729  -0.0987  0.0549
## s.e.   0.0500   0.0483  0.0465   0.0460  0.0473  0.0515   0.0506  0.0481
##          ar9     ar10    ar11     ar12    sar1    sar2  intercept
##       0.2046  -0.0134  0.2072  -0.0683  0.5945  0.3155    -0.0092
## s.e.  0.0470   0.0490  0.0491   0.0707  0.0723  0.0650     0.0401
##
## sigma^2 estimated as 0.004827:  log likelihood = 554.21,  aic = -1078.41
```

```
popModel7<-arima(residFromPop_log, order=c(12,0,0), seasonal=list(order=c(1,0,1), period=12))
popModel7
```

```
##
## Call:
## arima(x = residFromPop_log, order = c(12, 0, 0), seasonal = list(order = c(1,
##     0, 1), period = 12))
##
## Coefficients:
##           ar1     ar2      ar3      ar4     ar5      ar6      ar7     ar8
##       -0.0127  0.0180  -0.0031  -0.0785  0.0743  -0.0670  -0.0219  0.0234
## s.e.   0.0197  0.0219   0.0183   0.0284  0.0339   0.0244   0.0232  0.0226
##           ar9     ar10    ar11    ar12    sar1     sma1  intercept
##       -0.0127  -0.0726  0.0907  0.9079  0.1563  -0.7465     0.0008
## s.e.   0.0183   0.0273  0.0418  0.0390  0.0779   0.1105     0.0056
##
## sigma^2 estimated as 0.004344:  log likelihood = 580.28,  aic = -1130.57
```

# Overfit model 7 (SARIMA(12,0,0)(1,0,1)[12])

```
popModel8<-arima(residFromPop_log, order=c(13,0,0), seasonal=list(order=c(1,0,1), period=12))
popModel8
```

```
##
## Call:
## arima(x = residFromPop_log, order = c(13, 0, 0), seasonal = list(order = c(1,
##     0, 1), period = 12))
##
## Coefficients:
```

```
## Warning in sqrt(diag(x$var.coef)): NaNs produced
```

```
##           ar1    ar2     ar3      ar4     ar5      ar6      ar7     ar8
##       -0.0600  0.016  0.0068  -0.0947  0.0988  -0.0754  -0.0276  0.0322
## s.e.   0.0056    NaN  0.0037      NaN  0.0047      NaN   0.0033     NaN
##           ar9     ar10    ar11    ar12    ar13    sar1     sma1  intercept
##       -0.0027  -0.0964  0.1196  0.8842  0.0480  0.0909  -0.6295    -0.0015
## s.e.   0.0040   0.0013  0.0071     NaN  0.0038     NaN   0.0345     0.0076
##
## sigma^2 estimated as 0.004419:  log likelihood = 577.49,  aic = -1122.98
```

```r
popModel9<-arima(residFromPop_log, order=c(12,0,1), seasonal=list(order=c(1,0,1), period=12))
popModel9
```

```
##
## Call:
## arima(x = residFromPop_log, order = c(12, 0, 1), seasonal = list(order = c(1,
##     0, 1), period = 12))
##
## Coefficients:
##           ar1     ar2     ar3      ar4     ar5      ar6      ar7     ar8
##       -0.0005  0.0087  0.0001  -0.0702  0.0667  -0.0649  -0.0088  0.0146
## s.e.   0.0208  0.0219  0.0179   0.0292  0.0380   0.0268   0.0226  0.0234
##           ar9     ar10    ar11    ar12      ma1    sar1     sma1
##       -0.0089  -0.0649  0.0790  0.9158  -0.0730  0.1851  -0.7909
## s.e.   0.0180   0.0279  0.0451  0.0412   0.0561  0.0748   0.1079
##       intercept
##          0.0009
## s.e.     0.0051
##
## sigma^2 estimated as 0.004323:  log likelihood = 581.08,  aic = -1130.15
```

```r
popModel10<-arima(residFromPop_log, order=c(12,0,0), seasonal=list(order=c(2,0,1), period=12))
popModel10
```

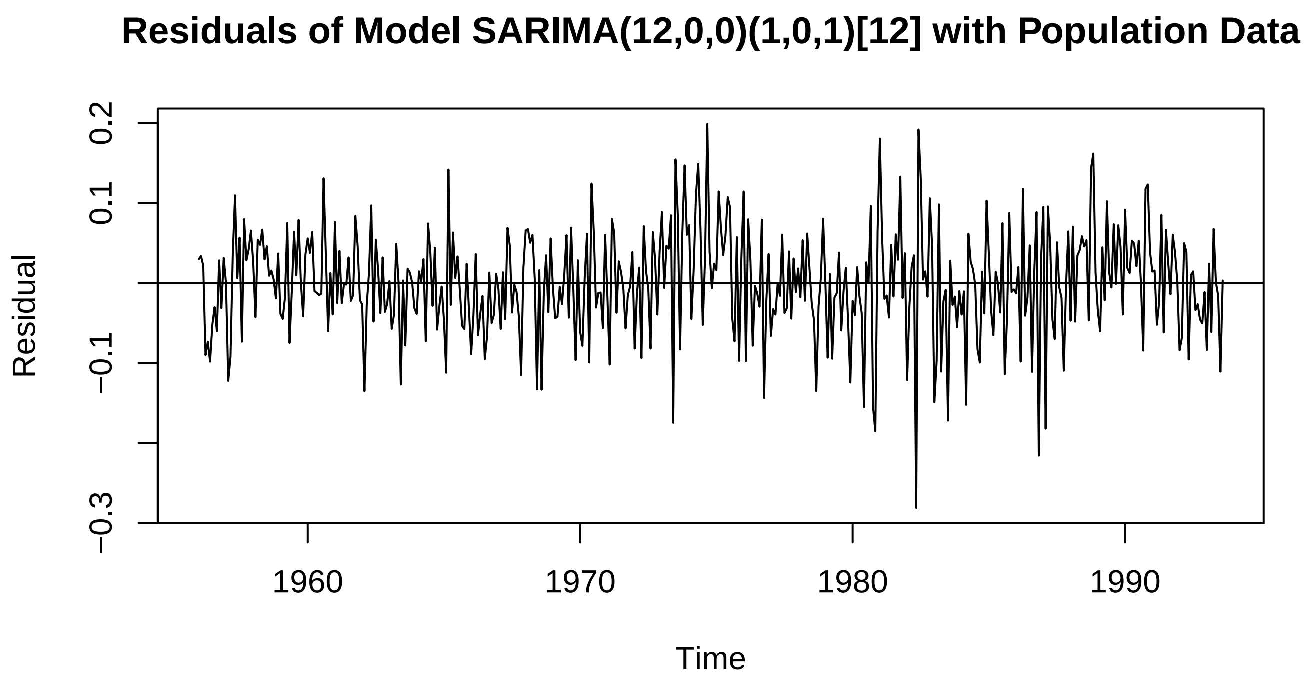
```
##
## Call:
## arima(x = residFromPop_log, order = c(12, 0, 0), seasonal = list(order = c(2,
##     0, 1), period = 12))
##
## Coefficients:
##           ar1      ar2     ar3      ar4     ar5     ar6      ar7     ar8
##       -0.0246  -0.0221  0.0663  -0.0715  0.0796  0.0831  -0.1084  0.0583
## s.e.   0.0482   0.0505  0.0453   0.0447  0.0451  0.0482   0.0472  0.0457
##          ar9     ar10    ar11    ar12    sar1    sar2     sma1  intercept
##       0.1370  -0.0217  0.2249  0.2416  0.9178  0.0803  -0.9069    -0.0014
## s.e.  0.0492   0.0478  0.0462  0.1065  0.1056  0.1054   0.0335     0.0711
##
## sigma^2 estimated as 0.003779:  log likelihood = 602.36,  aic = -1172.72
```

```r
popModel11<-arima(residFromPop_log, order=c(12,0,0), seasonal=list(order=c(1,0,2), period=12))
popModel11
```

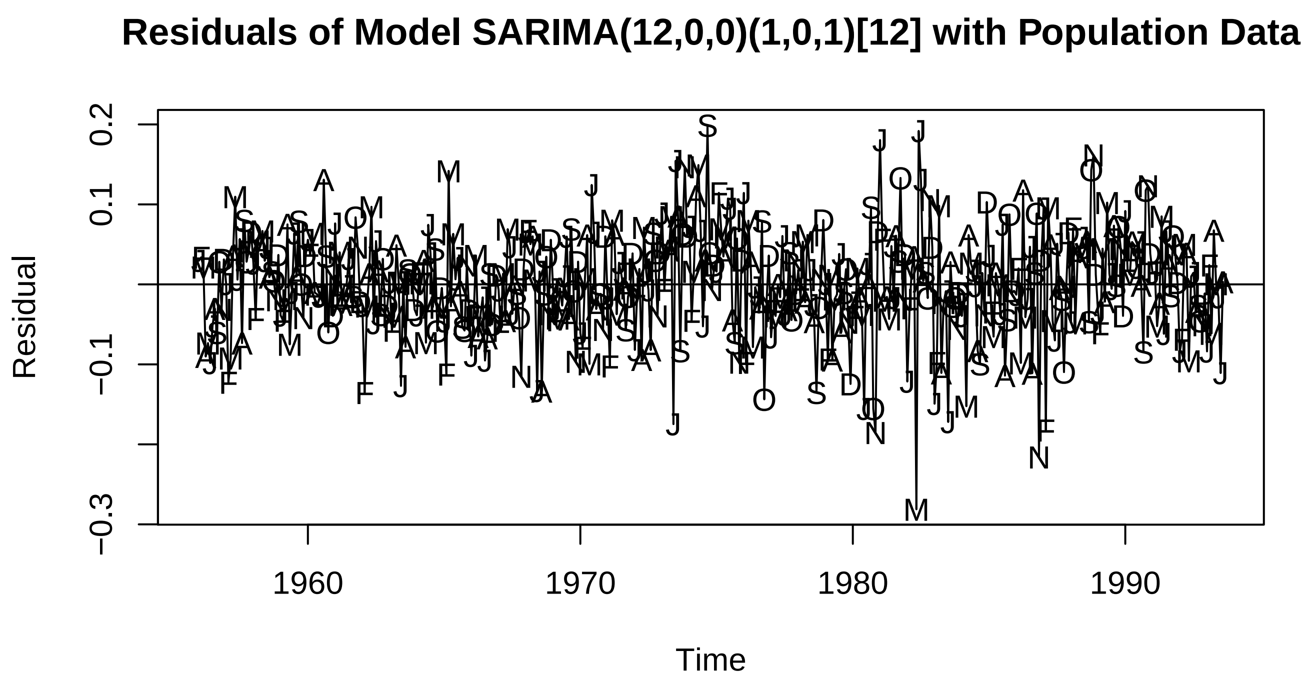
```
##
## Call:
## arima(x = residFromPop_log, order = c(12, 0, 0), seasonal = list(order = c(1,
##     0, 2), period = 12))
##
## Coefficients:
##           ar1     ar2      ar3      ar4     ar5      ar6      ar7     ar8
##       -0.0124  0.0179  -0.0020  -0.0773  0.0729  -0.0658  -0.0217  0.0232
## s.e.   0.0196  0.0227   0.0183   0.0296  0.0363   0.0253   0.0236  0.0236
##           ar9     ar10    ar11    ar12     sar1      sma1     sma2
##       -0.0118  -0.0710  0.0892  0.9091  -0.0100  -0.5788  -0.1180
## s.e.   0.0183   0.0283  0.0448  0.0413   0.3515   0.3665   0.2292
##       intercept
##          0.0010
## s.e.     0.0057
##
## sigma^2 estimated as 0.004342:  log likelihood = 580.41,  aic = -1128.83
```

### Run diagnostics on model 7

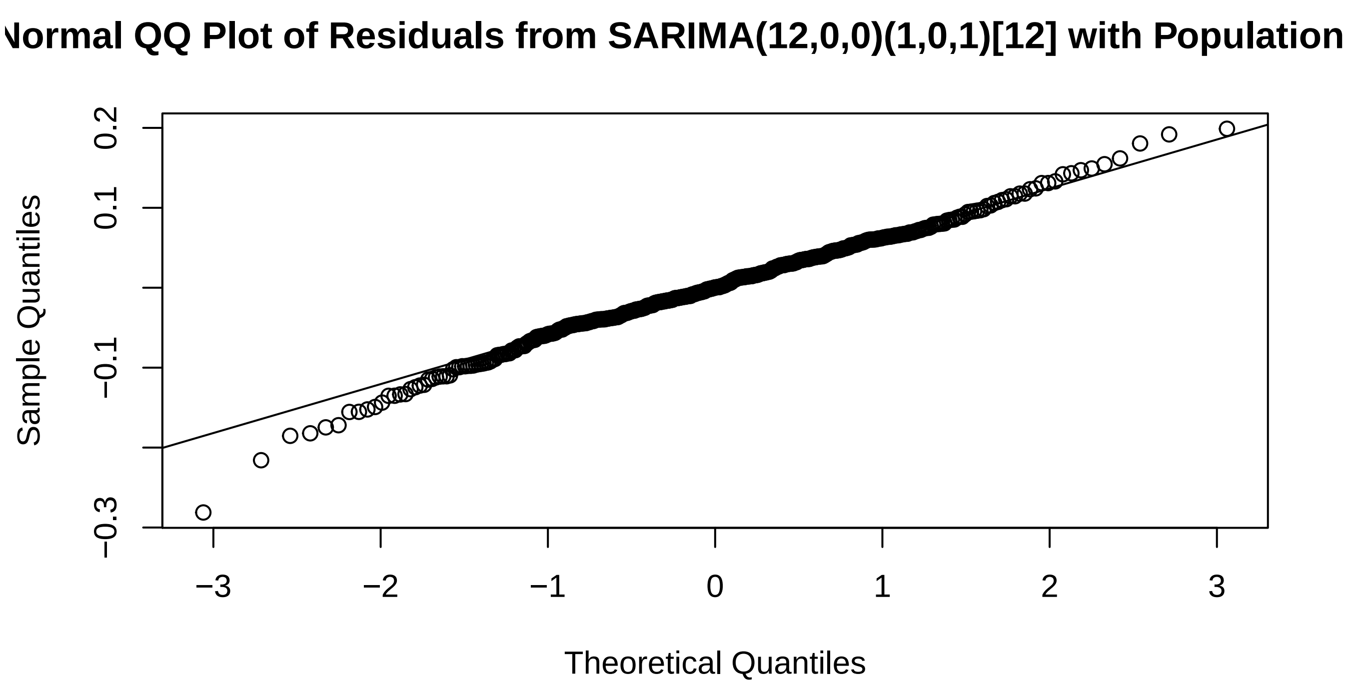
```
chosenMod<-popModel7
modelString<-paste(getModelString(chosenMod), "with Population Data")

par(mfrow=c(1,1))
plot(residuals(chosenMod), main=paste("Residuals of Model", modelString), ylab="Residual")
abline(h=0)
```




```
par(mfrow=c(1,1))
plot(residuals(chosenMod), main=paste("Residuals of Model", modelString), ylab="Residual", type="l")
points(y=residuals(chosenMod), x=time(residuals(chosenMod)), pch=as.vector(season(residuals(chosenMod))))
abline(h=0)
```




```
par(mfrow=c(1,1))
qqnorm(residuals(chosenMod), main=paste("Normal QQ Plot of Residuals from", modelString))
qqline(residuals(chosenMod))
```

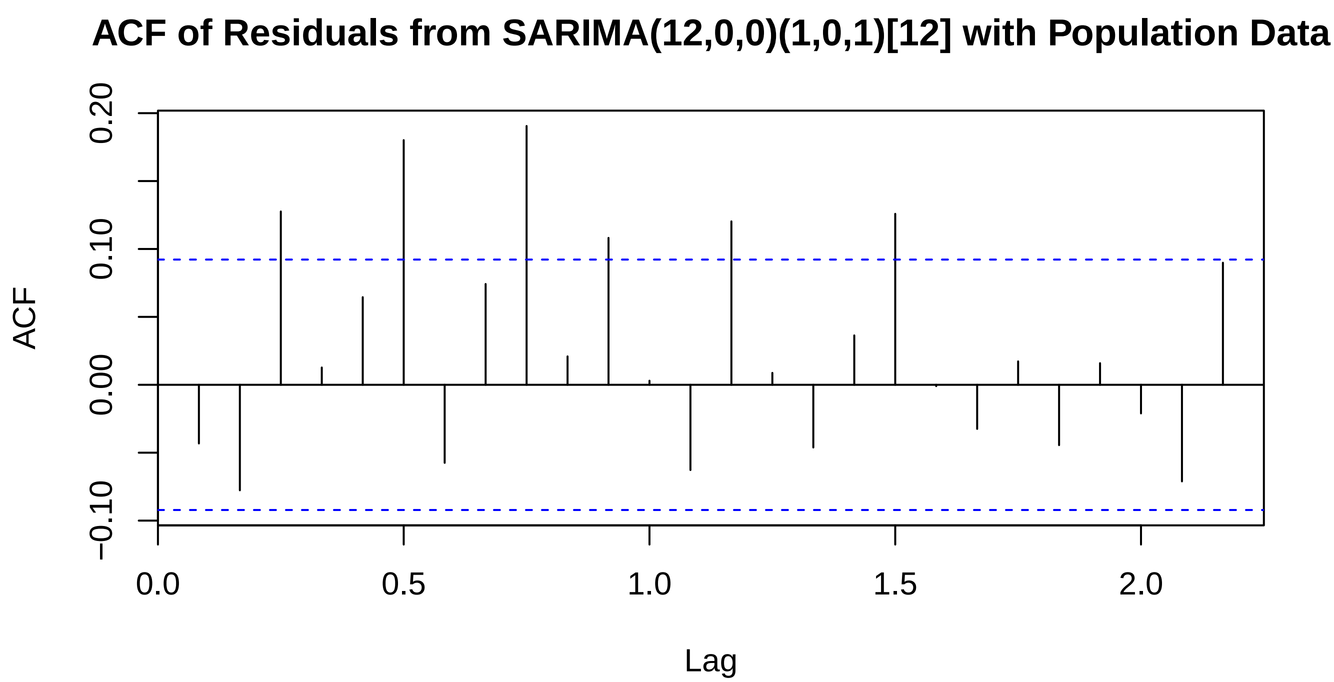



```
shapiro.test(residuals(chosenMod))
```

```
##
##  Shapiro-Wilk normality test
##
```

```
## data:  residuals(chosenMod)
## W = 0.9911, p-value = 0.008028
```

```r
par(mfrow=c(1,1))
acf(residuals(chosenMod), main=paste("ACF of Residuals from", modelString))
```




```r
LB.test(chosenMod, lag=35)
```

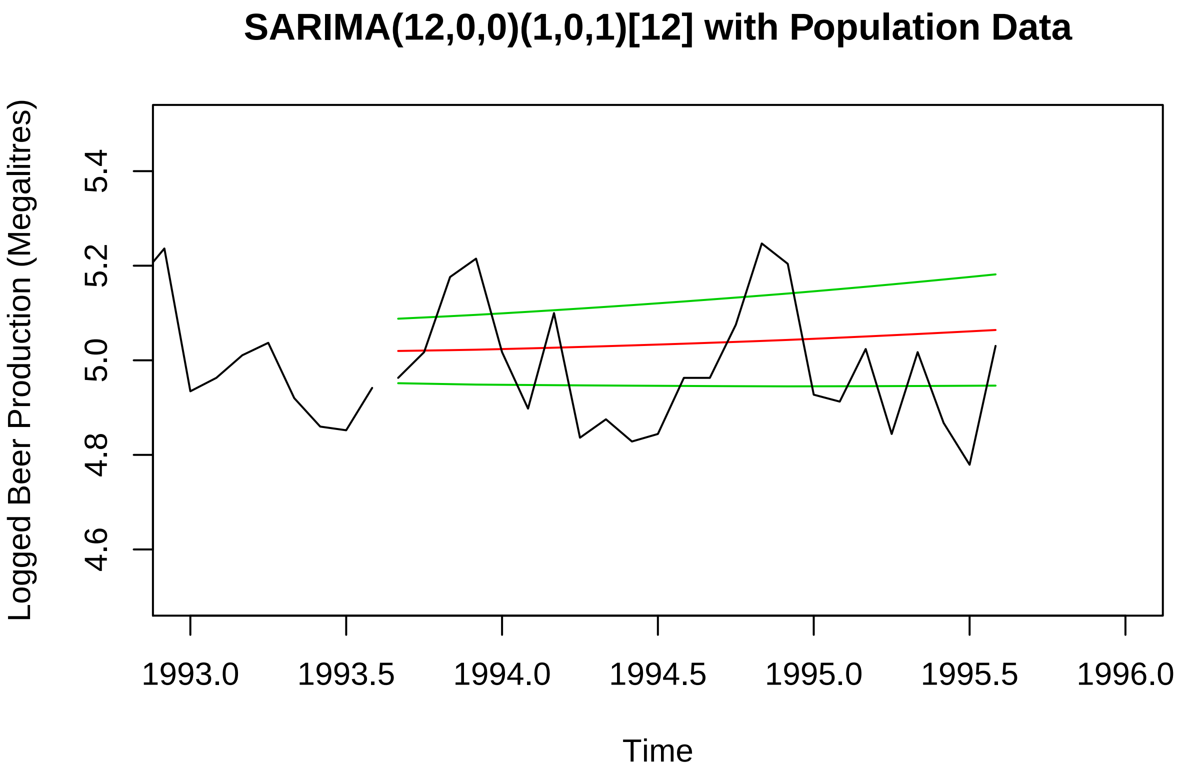
```
##
##  Box-Ljung test
##
## data:  residuals from  chosenMod
## X-squared = 87.347, df = 21, p-value = 4.611e-10
```

```r
runs(residuals(chosenMod))
```

```
## $pvalue
## [1] 0.963
##
## $observed.runs
## [1] 227
##
## $expected.runs
## [1] 226.9956
##
## $n1
## [1] 225
##
## $n2
## [1] 227
##
## $k
## [1] 0
```

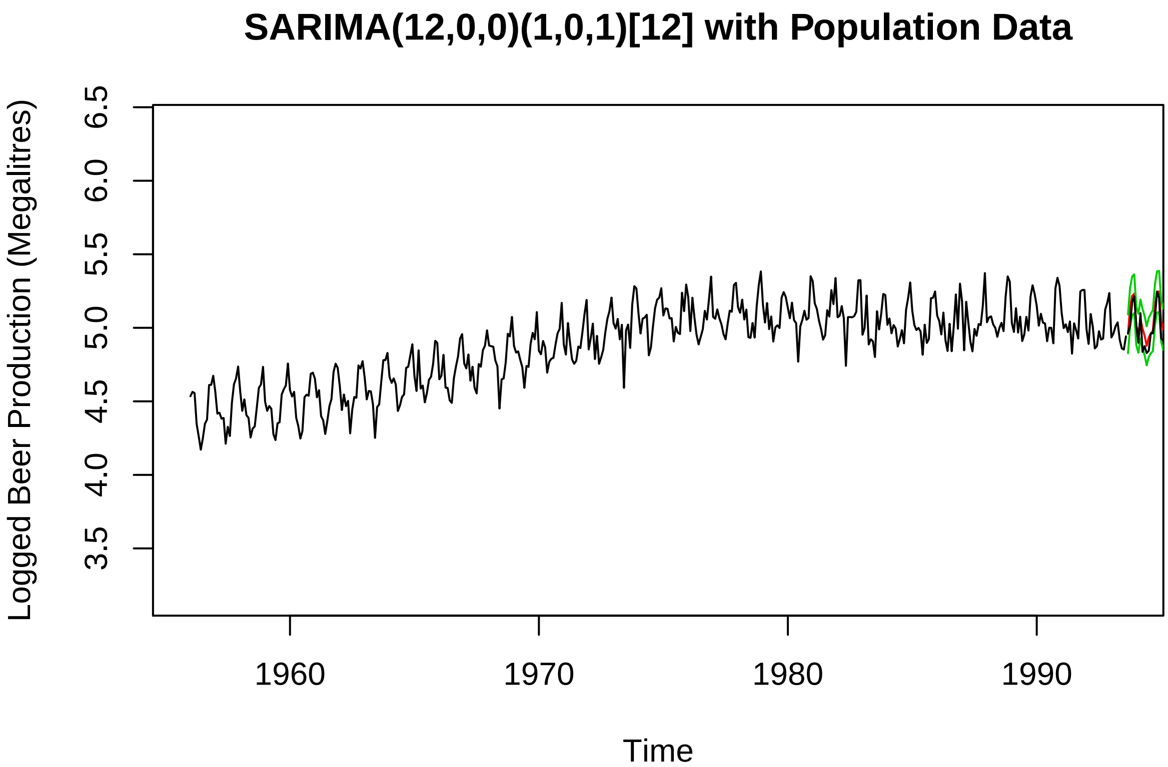
## Set up for forecast of population model

```r
startDate<-round(start(beer_forecast)[1]+start(beer_forecast)[2]/12,2)
endDate<-round(end(beer_forecast)[1]+end(beer_forecast)[2]/12,2)
numToFor<-length(beer_forecast)

allBeerData<-ts(c(beerTS, beer_forecast), start=c(1956, 1), frequency=12)

#Pull data for population
lag6_10_14new<-subset(monthlyLag6Long, as.numeric(rownames(monthlyLag6Long))>=startDate)
lag6_10_14new<-subset(lag6_10_14new, as.numeric(rownames(lag6_10_14new))<=endDate)

tnew<-1:length(allBeerData)
t2new<-tnew^2
t3new<-tnew^3
t4new<-tnew^4

newRegData<-data.frame(t=tnew, t2=t2new, t3=t3new, t4=t4new)
newRegData<-newRegData[(nrow(newRegData)-numToFor+1):nrow(newRegData),]
newRegData<-data.frame(lag6_10_14=lag6_10_14new, newRegData)
colnames(newRegData)<-c("lag6_10_14", colnames(newRegData)[2:5])

predFromPop<-predict(monthlyPopModel_log, newdata=newRegData, se.fit=TRUE)
uci_lm<-ts(predFromPop$fit+2*predFromPop$se.fit, start=c(1993, 9), frequency = 12)
lci_lm<-ts(predFromPop$fit-2*predFromPop$se.fit, start=c(1993, 9), frequency = 12)

ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,xlim=c(1993, 1996), ylim=c(4.5,5.5),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(ts(predFromPop$fit, start=c(1993, 9), frequency = 12),col=2)
lines(uci_lm,col=3)
lines(lci_lm,col=3)
lines(log(beer_forecast), col="black")
```

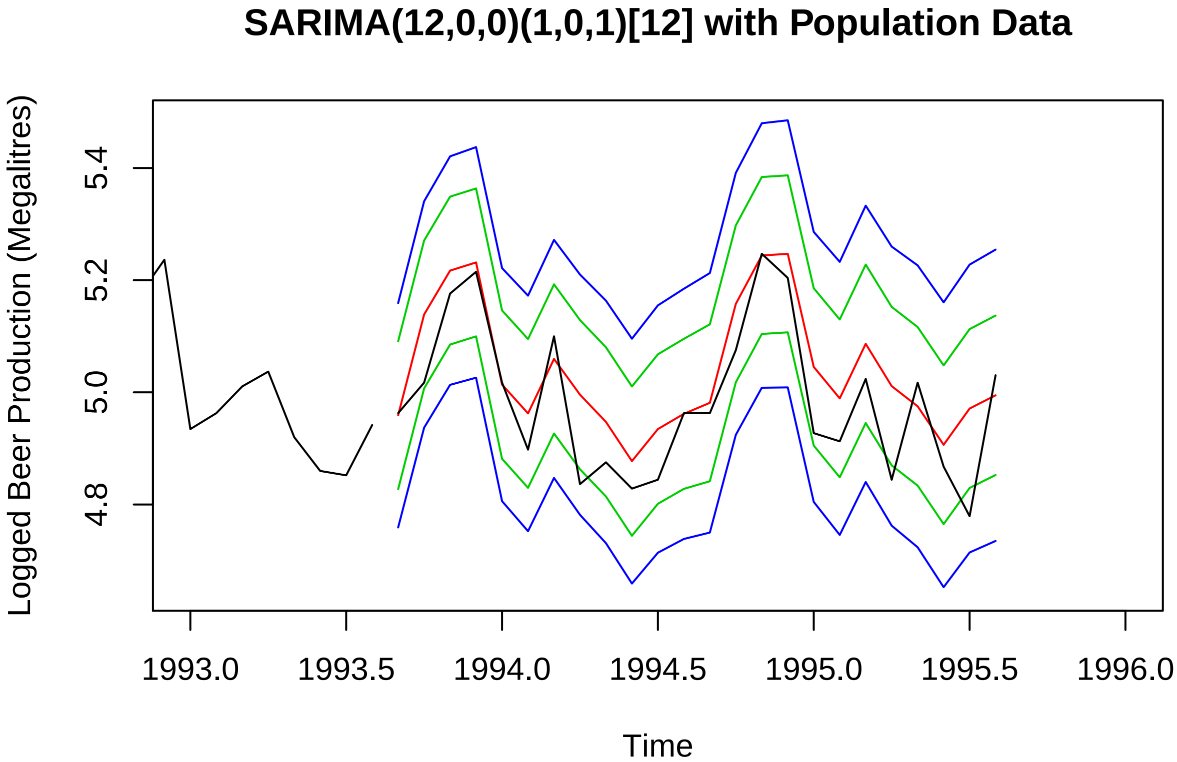



## Plot the model forecasts

```
predictions<-predict(chosenMod, n.ahead=24)

pred_raw<-(predictions$pred+predFromPop$fit)
pred<-predictions$pred+predFromPop$fit
uci<-pred_raw+2*predictions$se
lci<-pred_raw-2*predictions$se
uci_lm<-pred_raw+2*(predictions$se+predFromPop$se.fit)
lci_lm<-pred_raw-2*(predictions$se+predFromPop$se.fit)

sumSqErrSARIMA<-sum((log(beer_forecast)-pred)^2)

ymin=min(c(as.vector(lci),logBeer))-1
ymax=max(c(as.vector(uci),logBeer))+1
plot(logBeer,ylim=c(ymin,ymax),main=modelString, ylab='Logged Beer Production (Megalitres)')
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
lines(log(beer_forecast), col="black")
```




```r
ymin=min(c(as.vector(lci),log(beer_forecast)))-0.1
ymax=max(c(as.vector(uci),log(beer_forecast)))+0.1
plot(logBeer,xlim=c(1993, 1996), ylim=c(ymin,ymax),main=modelString, ylab='Logged Beer Production (Megalitres)
lines(pred,col=2)
lines(uci,col=3)
lines(lci,col=3)
lines(uci_lm,col="blue")
lines(lci_lm,col="blue")
lines(log(beer_forecast), col="black")
```



SARIMA(12,0,0)(1,0,1)[12] with Population Data
Logged Beer Production (Megalitres)
4.8
5.0
5.2
5.4
1993.0
1993.5
1994.0
1994.5
1995.0
1995.5
1996.0
Time