VAR_Model_Clem_v1

Steps for VAR Modeling -

1. Seasonally adjust the data
2. Individual ARIMA models, both time series needs to be I(1) process. Interpret ACF, PACF, Residuals - White noise plots?
3. ADF and KPSS test -> Not stationary.
4. Johanessen test for cointegration.
5. VAR Model - Train / test prediction error

Read seasonally adjusted data for modeling

```
library(tseries)
library(xlsx)
```

```
## Loading required package: rJava
## Loading required package: xlsxjars
```

```
library(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
## This is forecast 5.9
```

```
setwd("/Users/kevalshah/Keval_Backup/University/UChicago/Capstone/Data/Data Clean up/Clean data to be used f
or Analysis")

options(java.parameters = "-Xmx1000m")

clem_data_social <- read.xlsx("clem_social_seasonally_adjusted_v1_average_weekly.xlsx", sheetName = "Seasona
lly Adjusted data")


# subset the data to have include observations that have both sales and social media data

clem_data_social_ts <- clem_data_social[1:260,]
head(clem_data_social_ts)
```

```
##   Analysis_Date clemBlogSeasonallyAdjusted clemFacebookSeasonallyAdjusted
## 1    2010-01-03                   581.6909                     -74.357581
## 2    2010-01-10                   942.6203                    -140.438351
## 3    2010-01-17                   505.8102                    -158.056139
## 4    2010-01-24                   527.6058                     -45.693158
## 5    2010-01-31                   569.3438                     -14.529697
## 6    2010-02-07                   629.9015                       4.919822
##   clemTwitterSeasonallyAdjusted clemCommentsSeasonallyAdjusted
## 1                    -1464.1786                      -3.356490
## 2                    -2532.8262                      -2.658894
## 3                    -1907.9080                     -12.057933
## 4                    -1636.2469                     -21.456971
## 5                    -1177.8623                      -2.800721
## 6                     -524.3407                      -5.286298
##   clemReviewsSeasonallyAdjusted clemForumsSeasonallyAdjusted
## 1                    -22.712518                   -148.30772
## 2                     -5.244249                   -297.93560
## 3                      2.087482                   -196.14474
## 4                     -2.549538                   -106.06060
## 5                      5.231712                     96.99228
## 6                      4.123539                    256.67978
##   Total.social.media
## 1         -1131.2220
## 2         -2036.4831
## 3         -1766.2691
## 4         -1284.4013
## 5          -523.6249
## 6           365.9977
```

```
# Read seasonally adjusted Clementine sales volume data

clem_data_sales <- read.xlsx("clem_social_seasonally_adjusted_v1_average_weekly.xlsx", sheetName = "Clem Sal
es Volume")

myvars = c("Date", "salestszSeasonallyAdjusted")

clem_data_sales_ts <- clem_data_sales[myvars]
head(clem_data_sales_ts)
```

```
##         Date salestszSeasonallyAdjusted
## 1 2010-01-09                  2077991.2
## 2 2010-01-16                  1320663.6
## 3 2010-01-23                  1909651.8
## 4 2010-01-30                   689723.6
## 5 2010-02-06                  1220800.4
## 6 2010-02-13                   979856.2
```

ARIMA Model

```
# Function
  fun.illustrate.2=function(data,nperiod,p,d,q,P,D,Q) {

    error.holdout = rep(0,nperiod)
    r.sq.error.holdout = rep(0, nperiod)


    for(i in 1:nperiod) {

      # Keeping the first week as hold out for i[1] and then increment until 52nd value
      # 52nd value = 52 week = 1 year i.e last year as hold out.
      cutoff = length(data) - i
      #cutoff = cutoff - i

      #yvec.train=as.vector(data)[1:cutoff]
        if(cutoff >= nperiod) {
        yvec.train=as.vector(data)[1:cutoff]
        #break;
        yvec.hold=as.vector(data)[(cutoff+1):length(data)]
        #yvec.hold

        y=ts(yvec.train, start=2010, frequency=52)
        pred=predict(arima(y, order = c(p,d,q), seasonal = list(order = c(P,D,Q))),n.ahead=(length(data)-cut
off))
        # Predicted - Actual? or Actual - predicted.
        error.holdout[i]=mean((pred$pred-yvec.hold)^2)
        if(length(pred$pred) > 1) {r.sq.error.holdout[i] = (cor(pred$pred,yvec.hold))^2}
        #residuals.holdout[i] = yvec.hold - pred$pred
      }

    }
    # Ignore R Square of the i = 1 when holdout is last week.
    #return(list(error.holdout=error.holdout, Average = (error.holdout)^(1/length(error.holdout))))

    return(list(error.holdout=error.holdout, Average = mean(error.holdout), R.Squared = r.sq.error.holdout,
length(pred$pred), length(yvec.hold)))

    #predict(arima(y, order = c(p,d,q), seasonal = list(order = c(P,D,Q))),n.ahead=12)$pred
    #predict(arima(y, order = c(p,d,q), seasonal = list(order = c(P,D,Q))),n.ahead=12)$pred)^2

  }
```

ARIMA for Clementine Social Media Mentions

```
# Clementines Social Media Mentions

f1<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,0,0,0,0,0)
f2<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,0,1,0,0,0)
f3<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,0,2,0,0,0)
f4<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,1,1,0,0,0)
f5<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,1,2,0,0,0)
f6<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,1,0,0,0,0)
f7<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,2,0,0,0,0)
f8<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,2,1,0,0,0)
f9<- fun.illustrate.2(clem_data_social$Total.social.media,52, 2,2,2,0,0,0)

f10<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,0,0,0,0,0)
f11<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,0,1,0,0,0)
f12<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,0,2,0,0,0)
f13<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,1,1,0,0,0)
f14<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,1,2,0,0,0)
f15<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,1,0,0,0,0)
f16<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,2,0,0,0,0)
f17<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,2,1,0,0,0)
f18<-fun.illustrate.2(clem_data_social$Total.social.media,52, 1,2,2,0,0,0)
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f19<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,0,0,0,0,0)
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f20<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,0,1,0,0,0)
f21<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,0,2,0,0,0)
f22<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,1,0,0,0,0)
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f23<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,1,1,0,0,0)
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```
f24<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,1,2,0,0,0)
f25<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,2,0,0,0,0)
f26<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,2,1,0,0,0)
f27<-fun.illustrate.2(clem_data_social$Total.social.media,52, 0,2,2,0,0,0)

# Concatenate
total.social_media <- c(f1$Average, f2$Average, f3$Average, f4$Average, f5$Average, f6$Average, f7$Average,
f8$Average,f9$Average, f10$Average, f11$Average, f12$Average, f13$Average, f14$Average, f15$Average, f16$Ave
rage, f17$Average, f18$Average, f19$Average, f20$Average, f21$Average, f22$Average, f23$Average, f24$Averag
e, f25$Average, f26$Average, f27$Average)

# Minimum
summary(total.social_media)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 5.122e+06 5.631e+06 6.400e+06 7.654e+07 7.189e+06 1.134e+09
```

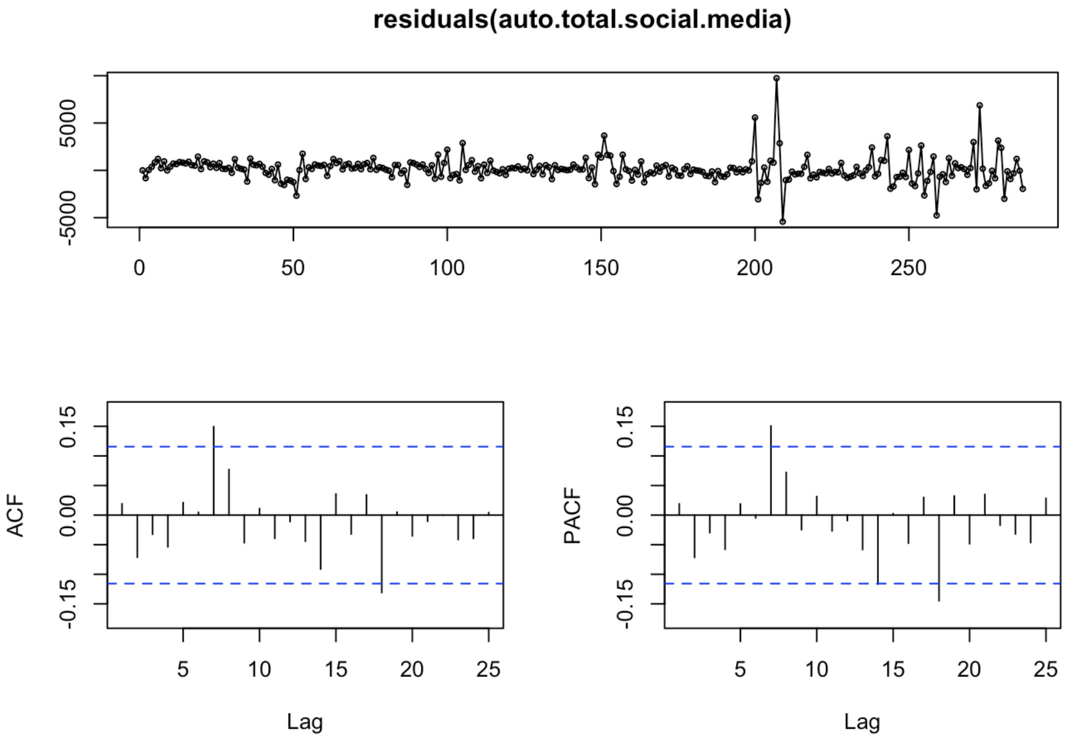
```
which.min(total.social_media)
```

```
## [1] 13
```

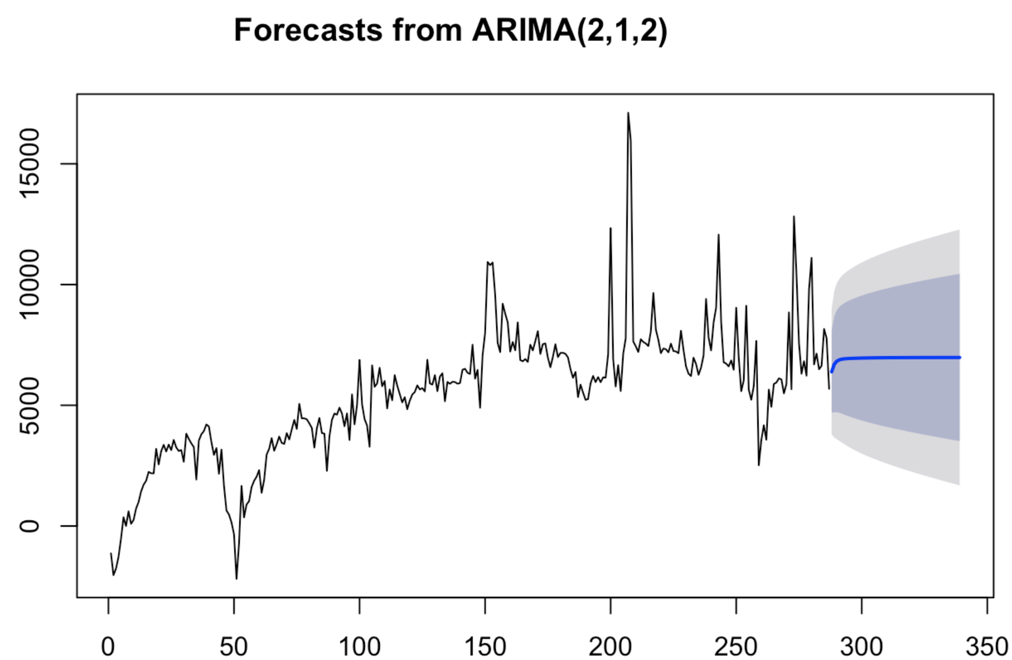
```
# Auto ARIMA (2,1,2)
auto.total.social.media <- auto.arima(clem_data_social$Total.social.media)
auto.total.social.media
```

```
## Series: clem_data_social$Total.social.media
## ARIMA(2,1,2)
##
## Coefficients:
##          ar1      ar2      ma1     ma2
##       1.3254  -0.3817  -1.7204  0.7322
## s.e.  0.1317   0.0966   0.1138  0.1051
##
## sigma^2 estimated as 1737494:  log likelihood=-2460.74
## AIC=4931.47   AICc=4931.69   BIC=4949.75
```

```
tsdisplay(residuals(auto.total.social.media))
```



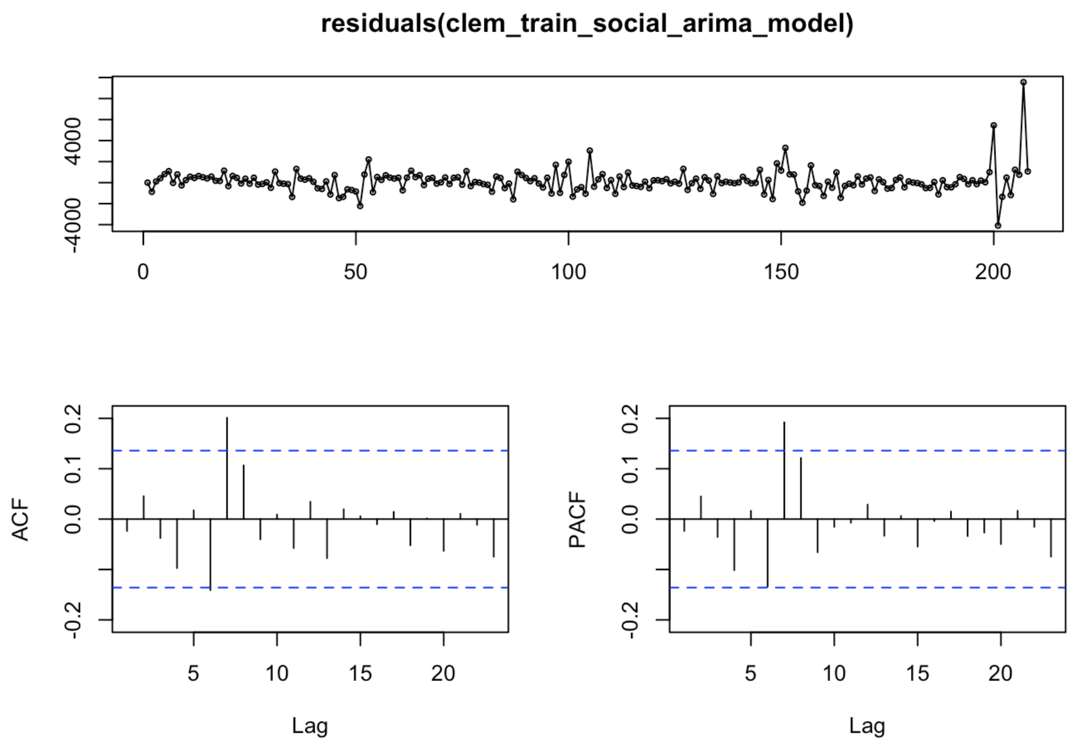

```
# Forecast Auto ARIMA
auto.total.social.media.forecast <- forecast(auto.total.social.media, h=52)
plot(auto.total.social.media.forecast)
```



```
# Train and Test Split
clem_train_social_data_arima <- clem_data_social_ts[1:208,8]
head(clem_train_social_data_arima)
```

```
## [1] -1131.2220 -2036.4831 -1766.2691 -1284.4013  -523.6249   365.9977
```

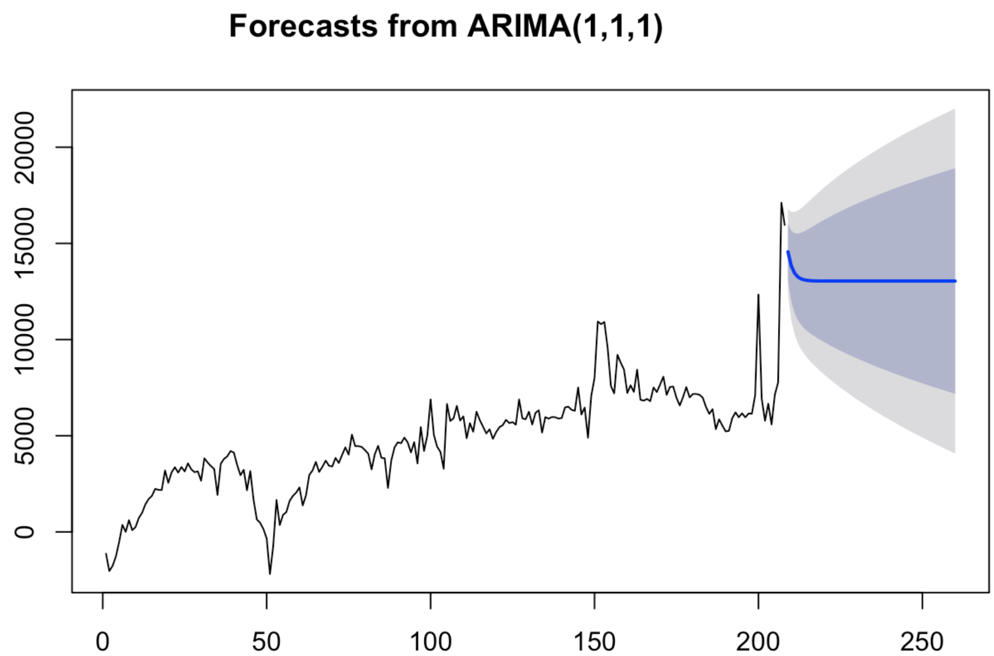
```
# Choosing Model 13 - ARIMA(1,1,1,0,0,0)
clem_train_social_arima_model <- Arima(clem_train_social_data_arima, order=c(1,1,1))
tsdisplay(residuals(clem_train_social_arima_model))
```




```
# Forecasting
forecast.clem.social.arima <- forecast(clem_train_social_arima_model, h=52)
forecast.clem.social.arima$mean
```

```
## Time Series:
## Start = 209
## End = 260
## Frequency = 1
##  [1] 14564.48 13837.09 13457.46 13259.34 13155.94 13101.97 13073.81
##  [8] 13059.11 13051.44 13047.43 13045.34 13044.25 13043.68 13043.39
## [15] 13043.23 13043.15 13043.11 13043.09 13043.07 13043.07 13043.07
## [22] 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06
## [29] 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06
## [36] 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06
## [43] 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06 13043.06
## [50] 13043.06 13043.06 13043.06
```

```
# Plot
plot(forecast(object=forecast.clem.social.arima,h="52"))
```



ARIMA for Clementine Sales Volume

```
# Clementines Sales Volume

f1<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,0,0,0,0,0)
f2<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,0,1,0,0,0)
f3<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,0,2,0,0,0)
```

```
## Warning in arima(y, order = c(p, d, q), seasonal = list(order = c(P, D, :
## possible convergence problem: optim gave code = 1
```

```
## Warning in arima(y, order = c(p, d, q), seasonal = list(order = c(P, D, :
## possible convergence problem: optim gave code = 1
```

```
f4<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,1,1,0,0,0)
```

```
## Warning in log(s2): NaNs produced
```

```
f5<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,1,2,0,0,0)
```

```
## Warning in arima(y, order = c(p, d, q), seasonal = list(order = c(P, D, :
## possible convergence problem: optim gave code = 1
```

```
## Warning in arima(y, order = c(p, d, q), seasonal = list(order = c(P, D, :
## possible convergence problem: optim gave code = 1
```

```
## Warning in arima(y, order = c(p, d, q), seasonal = list(order = c(P, D, :
## possible convergence problem: optim gave code = 1
```

```
f6<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,1,0,0,0,0)
f7<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,2,0,0,0,0)
f8<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,2,1,0,0,0)
f9<- fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 2,2,2,0,0,0)
```

```
## Warning in log(s2): NaNs produced
```

```
f10<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,0,0,0,0,0)
f11<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,0,1,0,0,0)
f12<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,0,2,0,0,0)
f13<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,1,1,0,0,0)
f14<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,1,2,0,0,0)
f15<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,1,0,0,0,0)
f16<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,2,0,0,0,0)
f17<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,2,1,0,0,0)
f18<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 1,2,2,0,0,0)

f19<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,0,0,0,0,0)
```

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## Warning in cor(pred$pred, yvec.hold): the standard deviation is zero
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```

```
f20<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,0,1,0,0,0)
f21<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,0,2,0,0,0)
f22<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,1,0,0,0,0)
```

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```
f23<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,1,1,0,0,0)
```

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## Warning in cor(pred$pred, yvec.hold): the standard deviation is zero
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```

```
f24<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,1,2,0,0,0)
f25<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,2,0,0,0,0)
f26<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,2,1,0,0,0)
f27<-fun.illustrate.2(clem_data_sales_ts$salestszSeasonallyAdjusted,52, 0,2,2,0,0,0)

# Concatenate
total.sales.volume <- c(f1$Average, f2$Average, f3$Average, f4$Average, f5$Average, f6$Average, f7$Average,
f8$Average,f9$Average, f10$Average, f11$Average, f12$Average, f13$Average, f14$Average, f15$Average, f16$Ave
rage, f17$Average, f18$Average, f19$Average, f20$Average, f21$Average, f22$Average, f23$Average, f24$Averag
e, f25$Average, f26$Average, f27$Average)

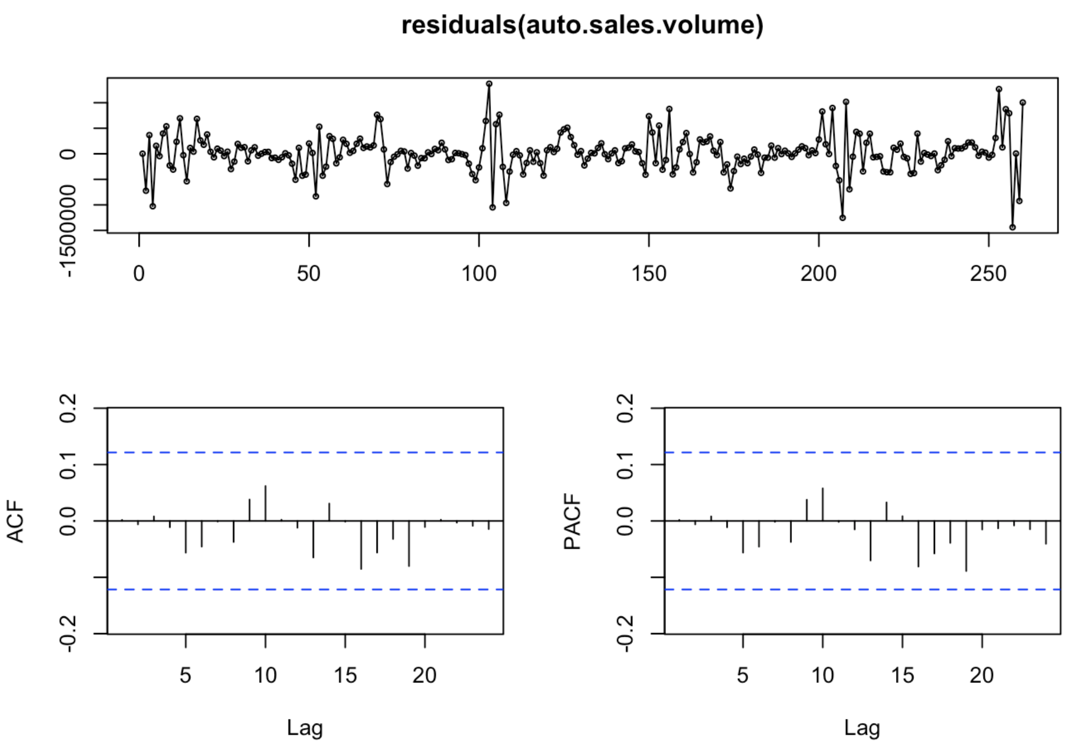
# Minimum
summary(total.sales.volume)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 1.343e+12 1.404e+12 1.411e+12 5.285e+12 1.873e+12 7.704e+13
```

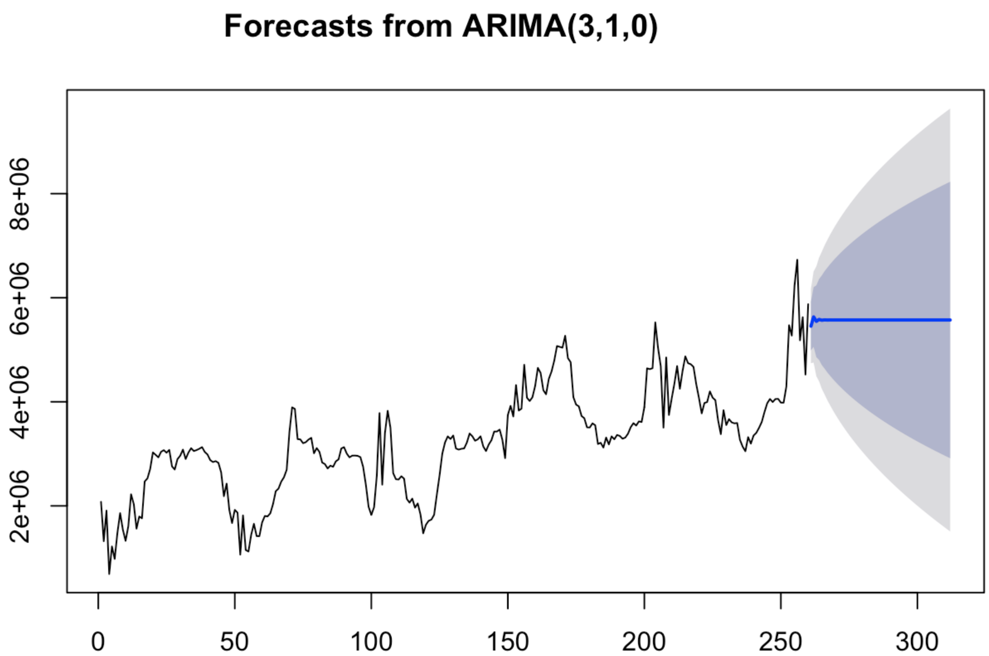
```
which.min(total.sales.volume)
```

```
## [1] 17
```

```
# Auto ARIMA (3,1,0)
auto.sales.volume <- auto.arima(clem_data_sales_ts$salestszSeasonallyAdjusted)
tsdisplay(residuals(auto.sales.volume))
```



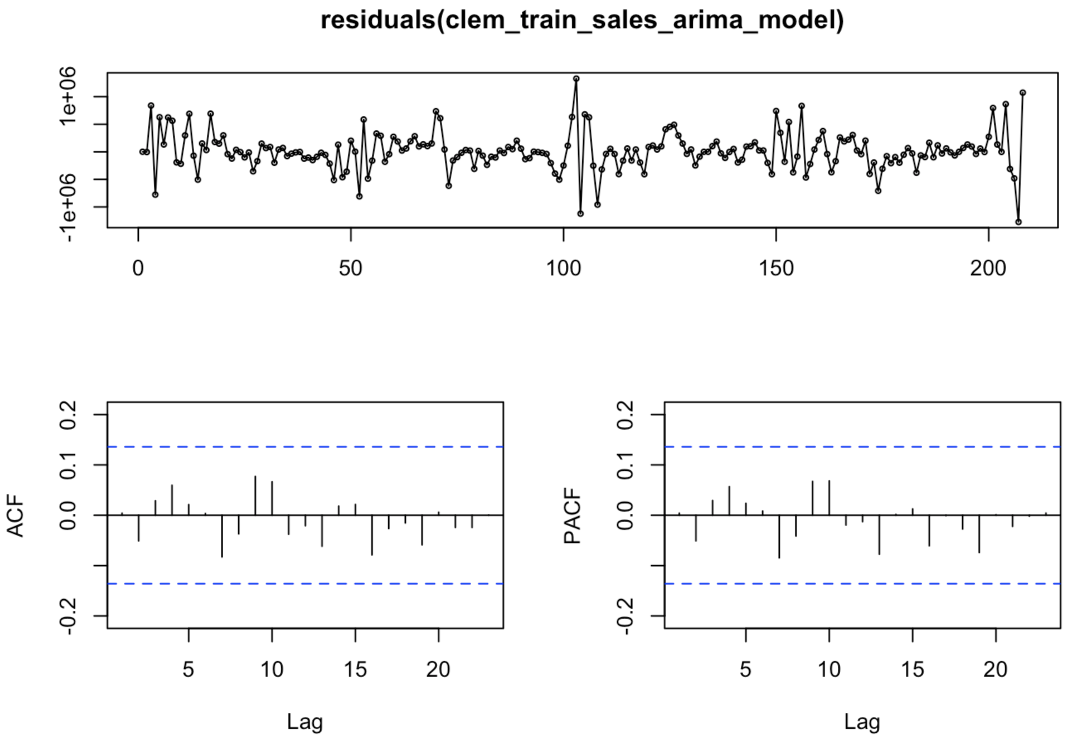

```
# Forecast Auto ARIMA
auto.sales.volume.forecast <- forecast(auto.sales.volume, h=52)
plot(auto.sales.volume.forecast)
```




```
# Train and Test Split
clem_train_sales_data_arima <- clem_data_sales_ts[1:208,2]
head(clem_train_sales_data_arima)
```

```
## [1] 2077991.2 1320663.6 1909651.8  689723.6 1220800.4  979856.2
```

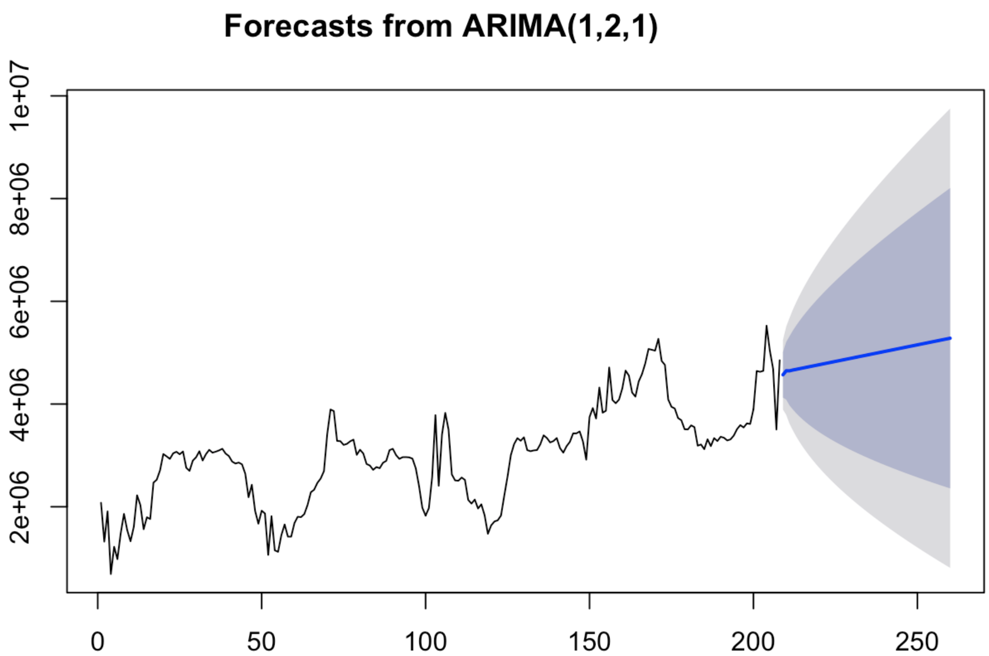
```
# Choosing Model 17 - ARIMA(1,2,1,0,0,0)
clem_train_sales_arima_model <- Arima(clem_train_sales_data_arima, order=c(1,2,1))
tsdisplay(residuals(clem_train_sales_arima_model))
```




```
# Forecasting
forecast.clem.sales.arima <- forecast(clem_train_sales_arima_model, h=52)
forecast.clem.sales.arima$mean
```

```
## Time Series:
## Start = 209
## End = 260
## Frequency = 1
##  [1] 4569266 4647909 4646237 4662379 4674570 4687638 4700511 4713427
##  [9] 4726333 4739242 4752150 4765058 4777966 4790874 4803783 4816691
## [17] 4829599 4842507 4855415 4868324 4881232 4894140 4907048 4919956
## [25] 4932865 4945773 4958681 4971589 4984497 4997406 5010314 5023222
## [33] 5036130 5049038 5061947 5074855 5087763 5100671 5113579 5126488
## [41] 5139396 5152304 5165212 5178121 5191029 5203937 5216845 5229753
## [49] 5242662 5255570 5268478 5281386
```

```
# Plot
plot(forecast(object=forecast.clem.sales.arima,h="52"))
```



Both time series, clementine sales volume and social media are of I(1) OR > 1 process, therefore the series is not stationary and has a trend and drift, and is not showing a tendency to return back to mean.

Step 1: Check if the series is stationary.

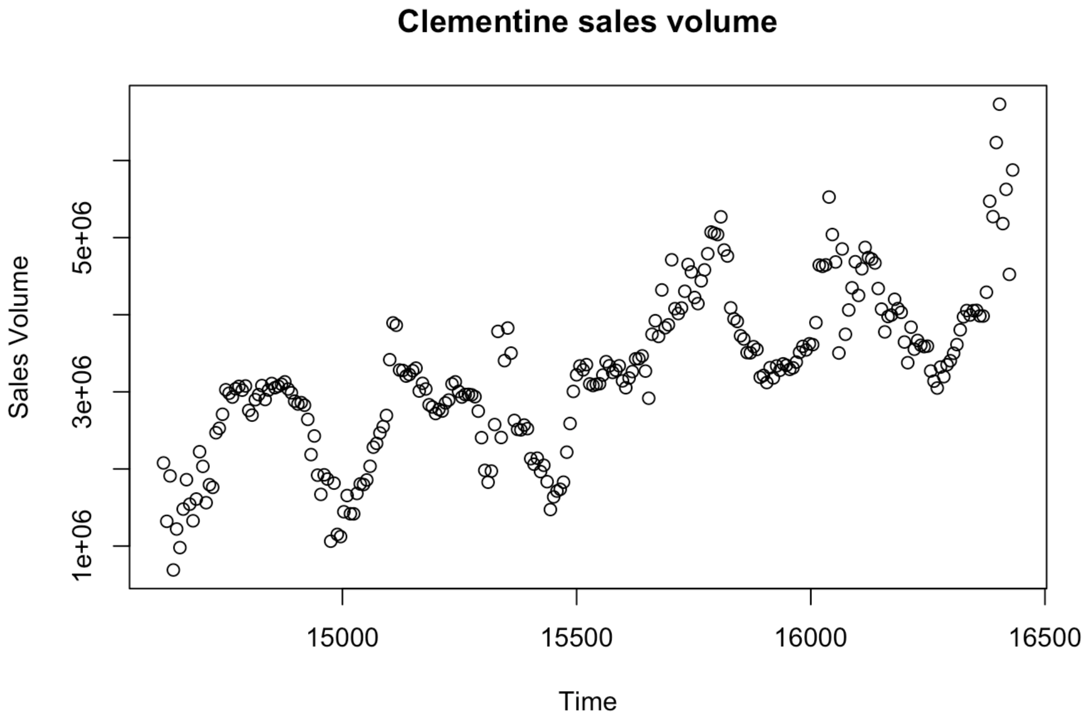
```
sales.volume <- clem_data_sales_ts$salestszSeasonallyAdjusted
#d.sales.volume <- diff(sales.volume)
week <- clem_data_sales_ts$Date


# Descriptive statistics and plotting the data
summary(sales.volume)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  689700 2639000 3219000 3229000 3865000 6730000
```

```
#summary(d.sales.volume)

plot.ts(week, sales.volume, main = "Clementine sales volume", xlab = "Time", ylab = "Sales Volume")
```




```
#Based on the sales volume time series, there appears to be a linear trend.

#Therefore, for stationarity test we include a trend element in augmented dickey fuller test.

#Augmented Dickey Fuller test for stationarity




# Sales Volume
# Null hypothesis H0: Non - Stationary

#library(urca)
#summary(ur.df(y=sales.volume, lags = 52, type = "trend"))

adf.test(sales.volume, alternative = "stationary")
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  sales.volume
## Dickey-Fuller = -3.2802, Lag order = 6, p-value = 0.07494
## alternative hypothesis: stationary
```

```
# KPSS test
# Null hypothesis: Series is stationary around a constant mean
# Alternative: Series is non stationary

kpss.test(sales.volume, null = "Trend")
```

```
## Warning in kpss.test(sales.volume, null = "Trend"): p-value greater than
## printed p-value
```

```
##
##  KPSS Test for Trend Stationarity
##
## data:  sales.volume
## KPSS Trend = 0.1167, Truncation lag parameter = 3, p-value = 0.1
```

ADF Test: With the p-value of 0.07, greater than significance level of 0.05 suggests that we fail reject the null hypothesis that the series is not stationary and unit root. In other words, we have no evidence that the series is stationary.

KPSS Test: At significance level of 5% or p-value > 0.05, we reject the ‘Trend’ null hypothesis that the series is stationary with a linear trend. In other words, we have no evidence that the series is stationary.

:::::::::::::::::::::: SOCIAL MEDIA MENTIONS :::::::::::::::::::::::::::

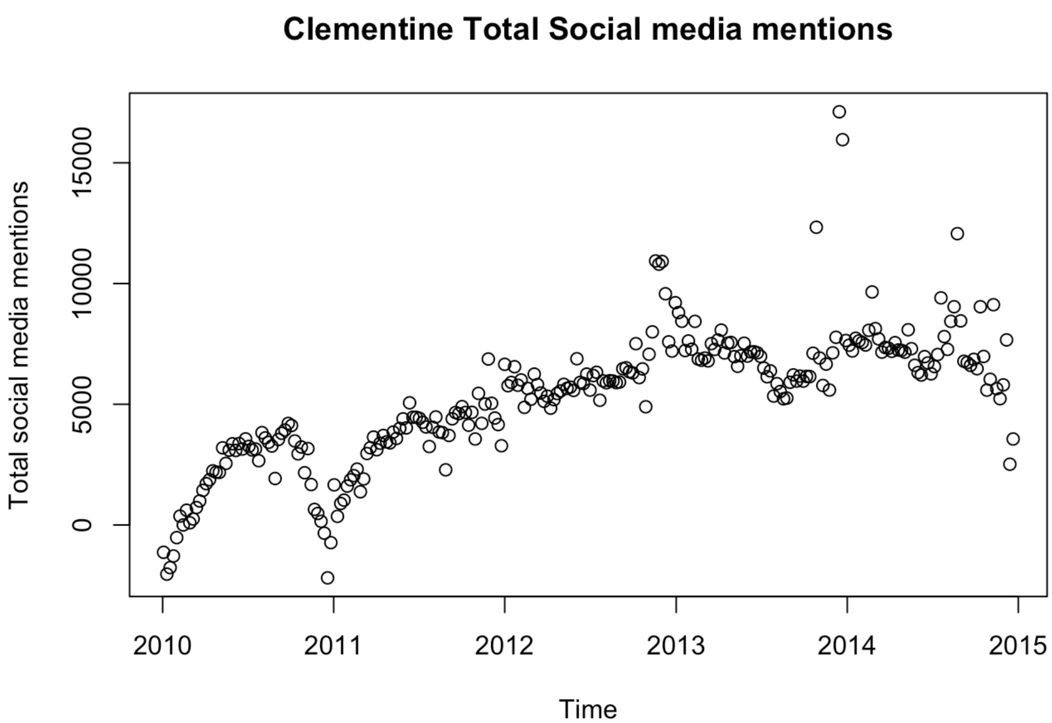
```
clem_total_social_media <- clem_data_social_ts$Total.social.media

#d.clem_blogs <- diff(clem_blogs)
week <- clem_data_social_ts$Analysis_Date


# Descriptive statistics and plotting the data
summary(clem_total_social_media)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   -2191    3556    5772    5276    7020   17110
```

```
plot(week, clem_total_social_media, main = "Clementine Total Social media mentions", xlab = "Time", ylab =
"Total social media mentions")
```




```
# Augmented Dickey Fuller test for stationarity
adf.test(clem_total_social_media, alternative = "stationary")
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  clem_total_social_media
## Dickey-Fuller = -2.3232, Lag order = 6, p-value = 0.4398
## alternative hypothesis: stationary
```

```
# KPSS test
# Null hypothesis: Series is stationary.
# Alternative: Series is non stationary

kpss.test(clem_total_social_media, null = "Level")
```

```
## Warning in kpss.test(clem_total_social_media, null = "Level"): p-value
## smaller than printed p-value
```

```
##
##  KPSS Test for Level Stationarity
##
## data:  clem_total_social_media
## KPSS Level = 4.7557, Truncation lag parameter = 3, p-value = 0.01
```

```
# Low p-value suggests that the series is Non - Stationary. We reject the null hypothesis of stationarity.
```

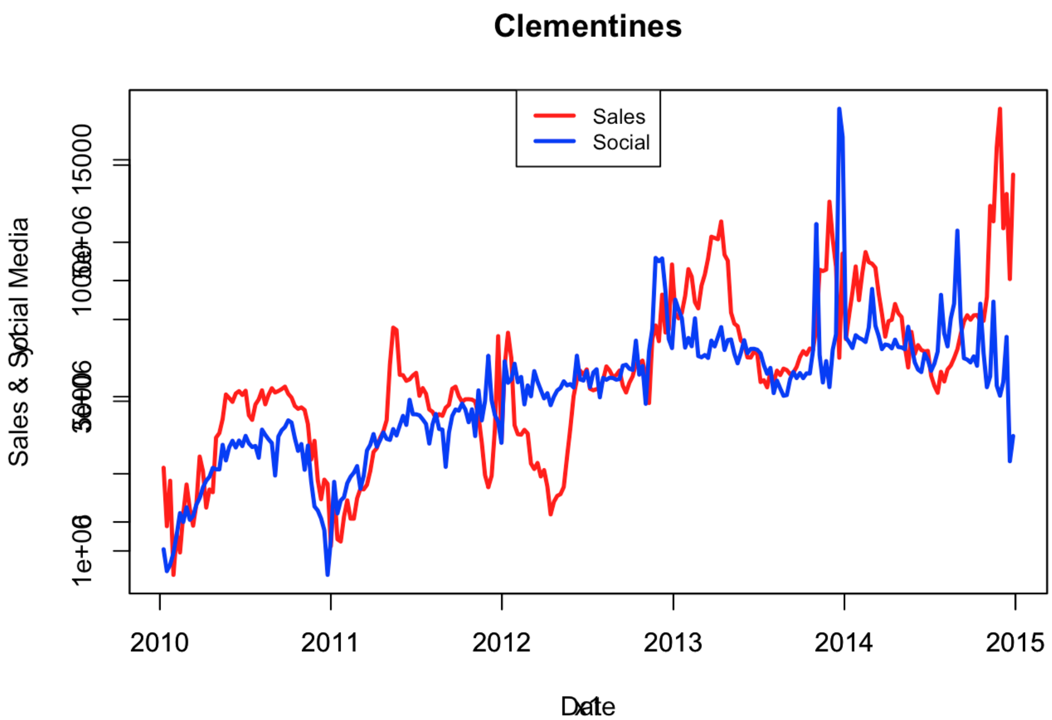
Small p-value of 0.01, less than significance level of 0.05 suggests that we reject the null hypothesis that the series is stationary.

Now that we have established both series are not stationary and has a trend or drift component, and are of I(1) or > process, we perform Johansen test for cointegration.

```
# Plot Sales and Sum Social Media Mentions

x1 <- clem_data_sales_ts$Date
y1 <- sales.volume
y2 <- clem_total_social_media

plot( x1, y1, type="l", col="red", main = "Clementines", xlab = "Date", lwd = "2.5")
par(new=TRUE)
plot( x1, y2, type="l", col="blue", ylab = "Sales & Social Media", lwd = "2.5")
legend("top", legend=c("Sales", "Social"), col=c("red", "blue"), lwd = 2.5, cex=0.8)
```




```r
library("urca")

co.test.matrix <- cbind(sales.volume, clem_total_social_media)

CoIntegrationTest =ca.jo(co.test.matrix,type="trace",K=4,ecdet="none", spec="longrun")
summary(CoIntegrationTest)
```

```
##
## ######################
## # Johansen-Procedure #
## ######################
##
## Test type: trace statistic , with linear trend
##
## Eigenvalues (lambda):
## [1] 0.05653831 0.03226990
##
## Values of teststatistic and critical values of test:
##
##           test 10pct  5pct  1pct
## r <= 1 |  8.4  6.50  8.18 11.65
## r = 0  | 23.3 15.66 17.95 23.52
##
## Eigenvectors, normalised to first column:
## (These are the cointegration relations)
##
##                            sales.volume.l4 clem_total_social_media.l4
## sales.volume.l4                     1.0000                     1.0000
## clem_total_social_media.l4       -432.5455                   149.9026
##
## Weights W:
## (This is the loading matrix)
##
##                           sales.volume.l4 clem_total_social_media.l4
## sales.volume.d              -0.0965732245              -0.0292266540
## clem_total_social_media.d    0.0002522272              -0.0001353827
```

With lag of k=4, we see that our test statistic (r <= 1) of 8.4 is higher than at least one of # the critical values at 10% confidence level 6.50, we can assume there is cointegration of r time series.

http://denizstij.blogspot.com/2013/11/cointegration-tests-adf-and-johansen.html (http://denizstij.blogspot.com/2013/11/cointegration-tests-adf-and-johansen.html)

Running VAR model for Multivariate time series.

Multivariate time series analysis is used when one wants to model and explain the interactions and comovements among a group of time series variables

- http://faculty.washington.edu/ezivot/econ584/notes/multivariatetimeseries.pdf (http://faculty.washington.edu/ezivot/econ584/notes/multivariatetimeseries.pdf)

Granger Causality One of the main uses of VAR models is forecasting.

The following intuitive notion of a variable’s forecasting ability is due to Granger (1969).

• If a variable, or group of variables, y1 (social media mentions) is found to be helpful for predicting another variable (sales volume), or group of variables, y2 then y1 is said to Granger-cause y2; otherwise it is said to fail to Granger-cause y2.

VAR Model Building and Evaluation steps:

1. Split Raw Clem sales and social data into train and validation (1 year).
2. Based on the # of observation split the ARIMA values into train and validation (1 year).
3. Run the VAR model on training set and forecast sales, social and measure the prediction accuracy by comparing the validation set.
4. Make plots of sales, social and arima (benchmark)
5. Run the model on validation set.
6. Make plots of sales, social and arima (benchmark)
7. Calculate the difference / lift / between sales arima forecasts and sales forecasts from var model.

```
library(vars)
```

```
## Loading required package: MASS
## Loading required package: strucchange
## Loading required package: sandwich
## Loading required package: lmtest
```

```
library(astsa)
```

```
##
## Attaching package: 'astsa'
##
## The following object is masked from 'package:forecast':
##
##     gas
```

```
# Read Clementine Google Trends data in for exogenous variable in VAR model
setwd("/Users/kevalshah/Keval_Backup/University/UChicago/Capstone/Data/Data Clean up/Clean data to be used f
or Analysis")
clem_google_trends <- read.csv("Clem_Google_Trends_Searches.csv")

# Plot sales, social media and google trends

x1 <- clem_data_sales_ts$Date
y1 <- clem_data_sales_ts$salestszSeasonallyAdjusted
y2 <- clem_data_social_ts$Total.social.media
y3 <- clem_google_trends$clementine.Searches

#plot( x1, y1, type="l", col="red", main = "Clementines Sales, Social #Media and Google Trends", xlab = "Dat
e", lwd = "2.5")
#par(new=TRUE)
#plot( x1, y2, type="l", col="blue", ylab = "Social", lwd = "2.5")
#par(new=TRUE)
#plot( x1, y3, type="l", col="orange", ylab = "Social & GT", lwd = "2.5")
#legend("top", legend=c("Sales", "Social"), col=c("red", "blue"), lwd = #2.5, cex=0.8)


# Run VAR Model on Training set

length(clem_data_social_ts$Total.social.media)
```

```
## [1] 260
```

```
length(clem_data_sales_ts$salestszSeasonallyAdjusted)
```

```
## [1] 260
```

```
length(clem_data_sales_ts$Date)
```

```
## [1] 260
```

```
length(clem_google_trends$clementine.Searches)
```

```
## [1] 260
```

```
Train_clem_sales <- clem_data_sales_ts[1:208,2]
Train_clem_week <- clem_data_sales_ts[1:208,1]
Train_clem_social <- clem_data_social_ts[1:208,8]
Train_clem_google_trends <- clem_google_trends[1:208,3]

# Endogenous variables
Train_VAR_clem <- cbind(Train_clem_sales, Train_clem_social)

#VAR Select
VARselect(Train_VAR_clem, lag.max = 10, type = "both", exogen = cbind(x3 =Train_clem_google_trends))
```

```
## $selection
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      9      1      1      9
##
## $criteria
##                   1            2            3            4            5
## AIC(n) 3.942164e+01 3.941067e+01 3.944051e+01 3.944992e+01 3.947104e+01
## HQ(n)  3.948886e+01 3.950478e+01 3.956151e+01 3.959780e+01 3.964581e+01
## SC(n)  3.958771e+01 3.964317e+01 3.973945e+01 3.981528e+01 3.990283e+01
## FPE(n) 1.320110e+17 1.305756e+17 1.345400e+17 1.358253e+17 1.387452e+17
##                   6            7            8            9           10
## AIC(n) 3.949217e+01 3.941717e+01 3.939753e+01 3.937395e+01 3.940232e+01
## HQ(n)  3.969384e+01 3.964572e+01 3.965297e+01 3.965628e+01 3.971153e+01
## SC(n)  3.999039e+01 3.998182e+01 4.002861e+01 4.007146e+01 4.016626e+01
## FPE(n) 1.417376e+17 1.315308e+17 1.290163e+17 1.260623e+17 1.297549e+17
```

```
Train_VAR_model_clem <- VAR(Train_VAR_clem, p=2, type="both", exogen = cbind(x3 =Train_clem_google_trends))
summary(Train_VAR_model_clem)
```

```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: Train_clem_sales, Train_clem_social
## Deterministic variables: both
## Sample size: 206
## Log Likelihood: -4632.721
## Roots of the characteristic polynomial:
## 0.939 0.655 0.1561 0.1561
## Call:
## VAR(y = Train_VAR_clem, p = 2, type = "both", exogen = cbind(x3 = Train_clem_google_trends))
##
##
## Estimation results for equation Train_clem_sales:
## =================================================
## Train_clem_sales = Train_clem_sales.l1 + Train_clem_social.l1 + Train_clem_sales.l2 + Train_clem_social.l
2 + const + trend + x3
##
##                        Estimate Std. Error t value Pr(>|t|)
## Train_clem_sales.l1   7.146e-01  7.059e-02  10.123  < 2e-16 ***
## Train_clem_social.l1  6.661e+01  2.102e+01   3.169  0.00177 **
## Train_clem_sales.l2   1.345e-01  6.992e-02   1.924  0.05582 .
## Train_clem_social.l2 -1.277e+01  2.371e+01  -0.539  0.59072
## const                 2.486e+05  8.975e+04   2.770  0.00614 **
## trend                -3.291e+02  7.294e+02  -0.451  0.65236
## x3                   -7.640e+01  1.197e+03  -0.064  0.94919
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 327500 on 199 degrees of freedom
## Multiple R-Squared: 0.8824,  Adjusted R-squared: 0.8789
## F-statistic: 248.9 on 6 and 199 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation Train_clem_social:
## ==================================================
## Train_clem_social = Train_clem_sales.l1 + Train_clem_social.l1 + Train_clem_sales.l2 + Train_clem_social.
l2 + const + trend + x3
##
##                        Estimate Std. Error t value Pr(>|t|)
## Train_clem_sales.l1  -3.122e-04  2.340e-04  -1.334  0.18362
## Train_clem_social.l1  6.745e-01  6.968e-02   9.680  < 2e-16 ***
## Train_clem_sales.l2   5.885e-04  2.318e-04   2.539  0.01187 *
## Train_clem_social.l2  5.552e-02  7.860e-02   0.706  0.48075
## const                -3.760e+02  2.975e+02  -1.264  0.20778
## trend                 7.356e+00  2.418e+00   3.042  0.00267 **
## x3                    4.643e+00  3.969e+00   1.170  0.24351
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 1086 on 199 degrees of freedom
## Multiple R-Squared: 0.8437,  Adjusted R-squared: 0.839
## F-statistic:   179 on 6 and 199 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##                   Train_clem_sales Train_clem_social
## Train_clem_sales         1.073e+11         -29461429
## Train_clem_social       -2.946e+07           1178445
##
## Correlation matrix of residuals:
##                   Train_clem_sales Train_clem_social
```

```
## Train_clem_sales           1.00000          -0.08287
## Train_clem_social         -0.08287           1.00000
```

The adjusted R-Squared of 87% for equation predicting sales as dependent variable and endogenous variables of social media and sales with lag order of 2 and exogenous variable of google trends with constant and trend deterministic variable indicates a good fit. On the other hand, the inverse, of predicting social media with sales as predictors has Adj. R-Squared of 67%.

Now, we fit our training model on our validation set and check the prediction error / accuracy.

```
# Run VAR Model on Validation / Test Set

Test_clem_sales <- clem_data_sales_ts[209:260,2]
Test_clem_week <- clem_data_sales_ts[209:260,1]
Test_clem_social <- clem_data_social_ts[209:260,8]
Test_clem_google_trends <- clem_google_trends[209:260,3]

length(Test_clem_sales)
```

```
## [1] 52
```

```
length(Test_clem_week)
```

```
## [1] 52
```

```
length(Test_clem_social)
```

```
## [1] 52
```

```
length(Test_clem_google_trends)
```

```
## [1] 52
```

```
# Endogenous variables
#Test_VAR_clem <- cbind(Test_clem_sales, Test_clem_social)

#VAR Select
#VARselect(Test_VAR_clem, lag.max = 10, type = "both", exogen = cbind(x3 =Test_clem_google_trends))

#Test_VAR_model_clem <- VAR(Test_VAR_clem, p=7, type="both", exogen = cbind(x3 =Test_clem_google_trends))
#summary(Test_VAR_model_clem)
```

```
# Clementine prediction

var_train_forecasts <- predict(Train_VAR_model_clem, n.ahead = 52, ci = 0.95, dumvar = cbind(x3 =Test_clem_g
oogle_trends))

summary(var_train_forecasts)
```

```
##          Length Class  Mode
## fcst       2    -none- list
## endog    416    -none- numeric
## model     10    varest list
## exo.fcst  52    -none- numeric
```

```
head(var_train_forecasts)
```

```
## $fcst
## $fcst$Train_clem_sales
##          fcst   lower   upper        CI
##  [1,] 4957466 4315589 5599342  641876.5
##  [2,] 5083290 4288474 5878107  794816.4
##  [3,] 5165505 4265563 6065447  899942.0
##  [4,] 5205713 4224459 6186968  981254.1
##  [5,] 5223492 4176771 6270214 1046721.8
##  [6,] 5227128 4126110 6328145 1101017.5
##  [7,] 5220000 4073232 6366767 1146767.6
##  [8,] 5208112 4022412 6393812 1185700.2
##  [9,] 5192129 3973075 6411183 1219054.1
## [10,] 5174838 3927070 6422606 1247767.8
## [11,] 5155159 3882580 6427738 1272579.0
## [12,] 5135517 3841435 6429598 1294082.0
## [13,] 5116309 3803546 6429072 1312763.1
## [14,] 5096950 3767924 6425976 1329025.7
## [15,] 5078296 3735088 6421503 1343207.4
## [16,] 5063851 3708259 6419444 1355592.4
## [17,] 5050097 3683675 6416519 1366421.9
## [18,] 5038051 3662149 6413953 1375901.6
## [19,] 5025050 3640843 6409258 1384207.5
## [20,] 5014255 3622765 6405746 1391490.7
## [21,] 5004746 3606864 6402628 1397881.6
## [22,] 4997014 3593521 6400507 1403493.0
## [23,] 4986625 3578202 6395047 1408422.6
## [24,] 4977389 3564634 6390145 1412755.1
## [25,] 4968331 3551767 6384896 1416564.5
## [26,] 4959147 3539232 6379062 1419915.1
## [27,] 4949552 3526689 6372415 1422863.0
## [28,] 4942551 3517093 6368008 1425457.4
## [29,] 4935123 3507382 6362864 1427741.1
## [30,] 4929426 3499674 6359178 1429751.9
## [31,] 4925912 3494390 6357435 1431522.5
## [32,] 4921139 3488057 6354221 1433082.0
## [33,] 4919630 3485174 6354085 1434455.8
## [34,] 4916202 3480536 6351868 1435666.0
## [35,] 4914955 3478223 6351688 1436732.3
## [36,] 4912323 3474651 6349995 1437671.9
## [37,] 4912048 3473548 6350548 1438499.9
## [38,] 4911231 3472001 6350460 1439229.7
## [39,] 4920050 3480177 6359923 1439872.8
## [40,] 4926456 3486016 6366896 1440439.7
## [41,] 4934930 3493991 6375870 1440939.4
## [42,] 4942126 3500746 6383506 1441379.8
## [43,] 4948544 3506776 6390312 1441768.1
## [44,] 4955207 3513096 6397317 1442110.3
## [45,] 4962805 3520393 6405217 1442412.1
## [46,] 4971847 3529169 6414525 1442678.1
## [47,] 4987158 3544245 6430070 1442912.6
## [48,] 5007802 3564683 6450922 1443119.4
## [49,] 5026665 3583364 6469967 1443301.7
## [50,] 5047449 3603987 6490912 1443462.4
## [51,] 5069068 3625464 6512672 1443604.2
## [52,] 5091584 3647855 6535313 1443729.1
##
## $fcst$Train_clem_social
##           fcst     lower    upper       CI
##  [1,] 13783.91 11656.250 15911.58 2127.663
##  [2,] 13026.47 10443.024 15609.91 2583.445
##  [3,] 12350.29  9566.001 15134.57 2784.287
##  [4,] 11893.97  8991.194 14796.74 2902.774
##  [5,] 11587.19  8606.328 14568.05 2980.861
##  [6,] 11352.55  8314.280 14390.81 3038.267
##  [7,] 11198.58  8115.022 14282.14 3083.557
```

```
##  [8,] 11074.85  7953.967 14195.74 3120.887
##  [9,] 10985.08  7832.630 14137.54 3152.454
## [10,] 10895.16  7715.613 14074.70 3179.545
## [11,] 10832.87  7629.872 14035.87 3202.998
## [12,] 10784.55  7561.139 14007.95 3223.407
## [13,] 10736.47  7495.246 13977.70 3241.226
## [14,] 10707.80  7450.982 13964.62 3256.819
## [15,] 10725.03  7454.548 13995.52 3270.484
## [16,] 10718.28  7435.804 14000.75 3282.474
## [17,] 10710.92  7417.921 14003.93 3293.002
## [18,] 10680.88  7378.627 13983.13 3302.254
## [19,] 10681.80  7371.415 13992.19 3310.387
## [20,] 10685.08  7367.541 14002.62 3317.540
## [21,] 10685.78  7361.942 14009.61 3323.834
## [22,] 10639.33  7309.953 13968.70 3329.374
## [23,] 10621.50  7287.246 13955.75 3334.250
## [24,] 10603.65  7265.110 13942.20 3338.544
## [25,] 10580.83  7238.500 13923.15 3342.326
## [26,] 10559.90  7214.244 13905.56 3345.657
## [27,] 10572.63  7224.036 13921.22 3348.591
## [28,] 10566.42  7215.247 13917.60 3351.176
## [29,] 10580.77  7227.315 13934.22 3353.454
## [30,] 10604.94  7249.479 13960.40 3355.461
## [31,] 10598.95  7241.716 13956.18 3357.230
## [32,] 10629.20  7270.413 13987.99 3358.789
## [33,] 10618.91  7258.748 13979.07 3360.163
## [34,] 10637.24  7275.865 13998.61 3361.375
## [35,] 10633.35  7270.911 13995.80 3362.442
## [36,] 10665.33  7301.951 14028.72 3363.384
## [37,] 10698.78  7334.563 14062.99 3364.213
## [38,] 10835.78  7470.840 14200.73 3364.945
## [39,] 10872.50  7506.910 14238.09 3365.589
## [40,] 10918.28  7552.119 14284.44 3366.158
## [41,] 10933.88  7567.221 14300.54 3366.659
## [42,] 10946.14  7579.038 14313.24 3367.101
## [43,] 10974.66  7607.165 14342.15 3367.491
## [44,] 11022.73  7654.894 14390.56 3367.834
## [45,] 11098.29  7730.151 14466.42 3368.137
## [46,] 11244.39  7875.991 14612.80 3368.404
## [47,] 11393.28  8024.644 14761.92 3368.639
## [48,] 11463.29  8094.439 14832.13 3368.847
## [49,] 11551.90  8182.872 14920.93 3369.030
## [50,] 11638.46  8269.268 15007.65 3369.191
## [51,] 11718.37  8349.037 15087.70 3369.334
## [52,] 11766.70  8397.238 15136.16 3369.459
##
##
## $endog
##         Train_clem_sales Train_clem_social
##    [1,]        2077991.2     -1131.2220137
##    [2,]        1320663.6     -2036.4830714
##    [3,]        1909651.8     -1766.2691291
##    [4,]         689723.6     -1284.4013406
##    [5,]        1220800.4      -523.6248983
##    [6,]         979856.2       365.9976979
##    [7,]        1479185.4         0.3558709
##    [8,]        1860749.0       611.2741402
##    [9,]        1542671.6        90.0217363
##   [10,]        1327480.1       248.4544286
##   [11,]        1609361.3       721.6827940
##   [12,]        2222929.9       992.8246209
##   [13,]        2033281.7      1432.3174094
##   [14,]        1562119.6      1711.1755825
##   [15,]        1795808.3      1873.9496209
##   [16,]        1760854.6      2241.0385632
```

```
## [17,]        2469287.5      2183.4568325
## [18,]        2527210.0      2178.9496209
## [19,]        2709033.8      3195.3198132
## [20,]        3027068.1      2551.1202940
## [21,]        2981474.2      3097.3005825
## [22,]        2931852.3      3363.2573132
## [23,]        3039766.0      3085.2693325
## [24,]        3070881.7      3372.0938517
## [25,]        3021445.2      3143.9015440
## [26,]        3076130.2      3565.0361594
## [27,]        2758538.9      3255.1856786
## [28,]        2698152.9      3105.3760632
## [29,]        2898349.3      3147.4260632
## [30,]        2963534.5      2660.4491402
## [31,]        3081420.0      3824.7356786
## [32,]        2900307.0      3607.7818325
## [33,]        3022943.2      3422.6626017
## [34,]        3108343.1      3268.9222171
## [35,]        3053562.0      1925.0106786
## [36,]        3072462.0      3541.6299094
## [37,]        3097452.3      3797.8914479
## [38,]        3129129.2      3931.5087556
## [39,]        3036085.4      4207.6068325
## [40,]        2987174.6      4119.8491402
## [41,]        2879341.9      3479.5395248
## [42,]        2841920.4      2945.5145248
## [43,]        2860287.6      3228.0587555
## [44,]        2826199.7      2162.7683709
## [45,]        2642833.1      3164.6414479
## [46,]        2185830.1      1674.1837555
## [47,]        2427464.4       644.1472171
## [48,]        1919336.4       475.3202940
## [49,]        1670006.9       152.5318325
## [50,]        1923753.6      -340.0412444
## [51,]        1868952.9     -2190.7181675
## [52,]        1062789.1      -731.7797060
## [53,]        1816196.4      1660.7779863
## [54,]        1151283.9       357.5169286
## [55,]        1122230.4       889.7308709
## [56,]        1444634.3      1028.5986594
## [57,]        1655096.4      1610.3751017
## [58,]        1418642.3      1871.9976979
## [59,]        1417775.8      2042.3558709
## [60,]        1681882.6      2314.2741402
## [61,]        1805371.3      1375.0217363
## [62,]        1797987.2      1905.4544286
## [63,]        1857040.8      2959.6827940
## [64,]        2034920.6      3196.8246209
## [65,]        2282016.0      3641.3174094
## [66,]        2331639.7      3116.1755825
## [67,]        2465413.2      3385.9496209
## [68,]        2549572.6      3707.0385632
## [69,]        2693755.2      3443.4568325
## [70,]        3416675.3      3398.9496209
## [71,]        3893915.3      3847.3198132
## [72,]        3863239.9      3583.1202940
## [73,]        3282693.9      3999.3005825
## [74,]        3277275.7      4394.2573132
## [75,]        3204178.0      4020.2693325
## [76,]        3224071.2      5059.0938517
## [77,]        3274183.2      4461.9015440
## [78,]        3307544.7      4460.0361594
## [79,]        3010483.5      4417.1856786
## [80,]        3110268.3      4250.3760632
## [81,]        3036715.1      4060.4260632
```

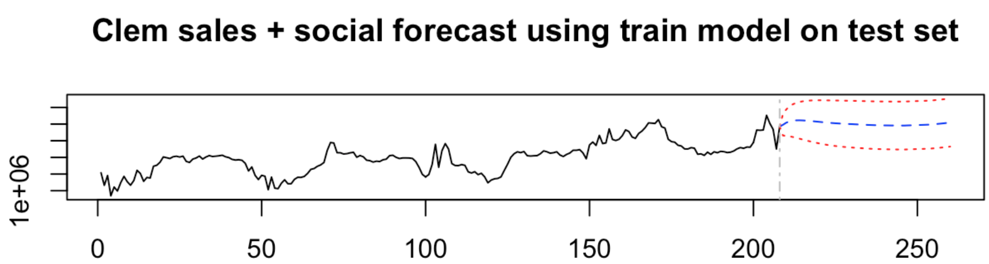
```
##  [82,]         2832657.0      3248.4491402
##  [83,]         2802963.4      4046.7356786
##  [84,]         2718567.4      4473.7818325
##  [85,]         2772830.2      3851.6626017
##  [86,]         2750812.7      3824.9222171
##  [87,]         2855598.4      2284.0106786
##  [88,]         2893680.6      3707.6299094
##  [89,]         3102093.2      4395.8914479
##  [90,]         3128923.4      4657.5087556
##  [91,]         3005128.3      4610.6068325
##  [92,]         2932257.0      4902.8491402
##  [93,]         2965397.8      4659.5395248
##  [94,]         2966578.1      4131.5145248
##  [95,]         2961161.5      4665.0587555
##  [96,]         2936383.4      3560.7683709
##  [97,]         2749571.7      5450.6414479
##  [98,]         2405608.3      4209.1837555
##  [99,]         1981605.4      5008.1472171
## [100,]         1827741.7      6874.3202940
## [101,]         1972377.4      5040.5318325
## [102,]         2575755.0      4428.9587556
## [103,]         3783529.3      4158.2818325
## [104,]         2407656.1      3281.2202940
## [105,]         3404523.8      6653.7779863
## [106,]         3827436.2      5766.5169286
## [107,]         3501785.9      5904.7308709
## [108,]         2629319.0      6553.5986594
## [109,]         2512624.7      5788.3751017
## [110,]         2506626.4      6005.9976979
## [111,]         2569186.5      4871.3558709
## [112,]         2522442.1      5654.2741402
## [113,]         2132970.4      5208.0217363
## [114,]         2061745.6      6248.4544286
## [115,]         2139889.8      5815.6827940
## [116,]         1965566.4      5466.8246209
## [117,]         2047397.1      5119.3174094
## [118,]         1834710.0      5334.1755825
## [119,]         1473312.3      4837.9496209
## [120,]         1637293.6      5191.0385632
## [121,]         1712948.7      5445.4568325
## [122,]         1736100.5      5549.9496209
## [123,]         1828442.3      5825.3198132
## [124,]         2217328.1      5656.1202940
## [125,]         2589052.4      5709.3005825
## [126,]         3005289.8      5573.2573132
## [127,]         3220444.8      6885.2693325
## [128,]         3335409.4      5905.0938517
## [129,]         3285071.4      5856.9015440
## [130,]         3352387.0      6249.0361594
## [131,]         3102707.3      5584.1856786
## [132,]         3081498.6      6188.3760632
## [133,]         3097255.0      6323.4260632
## [134,]         3104773.8      5165.4491402
## [135,]         3217716.8      5967.7356786
## [136,]         3391157.8      5889.7818325
## [137,]         3337973.0      5973.6626017
## [138,]         3251749.7      5961.9222171
## [139,]         3279336.1      5894.0106786
## [140,]         3337459.8      5919.6299094
## [141,]         3141980.4      6472.8914479
## [142,]         3053319.6      6511.5087555
## [143,]         3178707.0      6347.6068325
## [144,]         3262688.0      6295.8491402
## [145,]         3428266.8      7508.5395248
## [146,]         3428911.5      6103.5145248
```

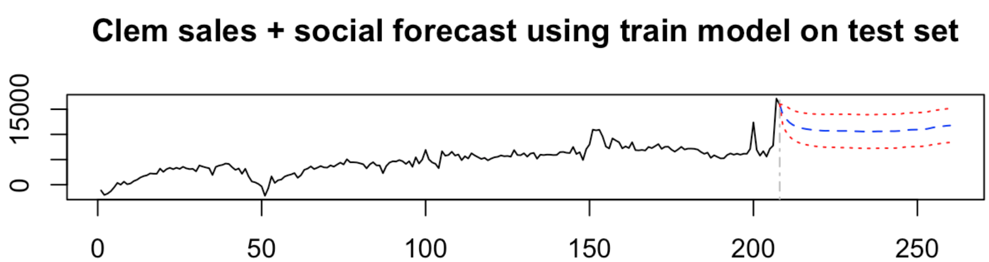
```
## [147,]        3466194.8      6464.0587555
## [148,]        3268942.3      4895.7683709
## [149,]        2916938.9      7071.6414479
## [150,]        3746737.1      7998.1837555
## [151,]        3922153.6     10936.1472171
## [152,]        3718288.6     10801.3202940
## [153,]        4321226.9     10913.5318325
## [154,]        3830955.8      9575.9587556
## [155,]        3868903.8      7584.2818325
## [156,]        4712227.8      7202.2202940
## [157,]        4078340.8      9206.7779863
## [158,]        4014880.9      8796.5169286
## [159,]        4087165.5      8436.7308709
## [160,]        4303987.9      7222.5986594
## [161,]        4651768.6      7620.3751017
## [162,]        4554273.3      7278.9976979
## [163,]        4223135.7      8432.3558709
## [164,]        4143781.8      6872.2741402
## [165,]        4439329.0      6822.0217363
## [166,]        4581554.0      6914.4544286
## [167,]        4790849.7      6794.6827940
## [168,]        5071836.4      7509.8246209
## [169,]        5056321.8      7271.3174094
## [170,]        5039456.1      7660.1755825
## [171,]        5269521.9      8070.9496209
## [172,]        4839400.7      7125.0385632
## [173,]        4761428.7      7533.4568325
## [174,]        4089047.1      7558.9496209
## [175,]        3946073.5      6970.3198132
## [176,]        3912808.2      6573.1202940
## [177,]        3727163.8      7007.3005825
## [178,]        3684843.5      7528.2573132
## [179,]        3508703.5      6994.2693325
## [180,]        3505929.6      7168.0938517
## [181,]        3585424.6      7172.9015440
## [182,]        3549844.9      7131.0361594
## [183,]        3188808.8      6982.1856786
## [184,]        3213007.1      6497.3760632
## [185,]        3120410.0      6138.4260632
## [186,]        3313654.9      6380.4491402
## [187,]        3180083.5      5339.7356786
## [188,]        3336044.6      5852.7818325
## [189,]        3279727.8      5526.6626017
## [190,]        3362907.8      5225.9222171
## [191,]        3343593.6      5256.0106786
## [192,]        3291203.4      5909.6299094
## [193,]        3311678.7      6214.8914479
## [194,]        3385868.4      5959.5087556
## [195,]        3511870.9      6165.6068325
## [196,]        3589654.9      5956.8491402
## [197,]        3543135.9      6154.5395248
## [198,]        3623337.3      6146.5145248
## [199,]        3612042.2      7113.0587555
## [200,]        3898106.6     12330.7683709
## [201,]        4643754.5      6915.6414479
## [202,]        4627300.3      5778.1837555
## [203,]        4645862.9      6663.1472171
## [204,]        5525928.9      5588.3202940
## [205,]        5039683.8      7129.5318325
## [206,]        4683987.3      7772.9587555
## [207,]        3503620.6     17114.2818325
## [208,]        4852728.4     15958.2202940
## 
## $model
## 
```

```
## VAR Estimation Results:
## =======================
##
## Estimated coefficients for equation Train_clem_sales:
## =====================================================
## Call:
## Train_clem_sales = Train_clem_sales.l1 + Train_clem_social.l1 + Train_clem_sales.l2 + Train_clem_social.l
2 + const + trend + x3
##
##  Train_clem_sales.l1 Train_clem_social.l1  Train_clem_sales.l2
##        7.146392e-01         6.661391e+01         1.344991e-01
## Train_clem_social.l2                const                trend
##       -1.277255e+01         2.485746e+05        -3.290917e+02
##                   x3
##       -7.639602e+01
##
##
## Estimated coefficients for equation Train_clem_social:
## ======================================================
## Call:
## Train_clem_social = Train_clem_sales.l1 + Train_clem_social.l1 + Train_clem_sales.l2 + Train_clem_social.
l2 + const + trend + x3
##
##  Train_clem_sales.l1 Train_clem_social.l1  Train_clem_sales.l2
##       -3.122388e-04         6.744784e-01         5.885164e-04
## Train_clem_social.l2                const                trend
##        5.552320e-02        -3.759710e+02         7.355501e+00
##                   x3
##        4.642846e+00
##
##
##
## $exo.fcst
##       x3
##  [1,] 78
##  [2,] 79
##  [3,] 63
##  [4,] 60
##  [5,] 59
##  [6,] 53
##  [7,] 54
##  [8,] 50
##  [9,] 49
## [10,] 43
## [11,] 43
## [12,] 42
## [13,] 39
## [14,] 40
## [15,] 48
## [16,] 44
## [17,] 43
## [18,] 37
## [19,] 41
## [20,] 41
## [21,] 40
## [22,] 29
## [23,] 31
## [24,] 29
## [25,] 26
## [26,] 24
## [27,] 29
## [28,] 25
## [29,] 28
## [30,] 30
## [31,] 24
```

```
## [32,] 30
## [33,] 22
## [34,] 26
## [35,] 21
## [36,] 27
## [37,] 28
## [38,] 51
## [39,] 37
## [40,] 39
## [41,] 33
## [42,] 31
## [43,] 33
## [44,] 37
## [45,] 44
## [46,] 62
## [47,] 70
## [48,] 60
## [49,] 65
## [50,] 67
## [51,] 68
## [52,] 63
```

```
plot(var_train_forecasts, type = "l", main = "Clem sales + social forecast using train model on test set")
```






```
# Check accuracy of our forecasts using train model on test data

# Clem sales volume forecast
accuracy(var_train_forecasts$fcst$Train_clem_sales[,1], Test_clem_sales)
```

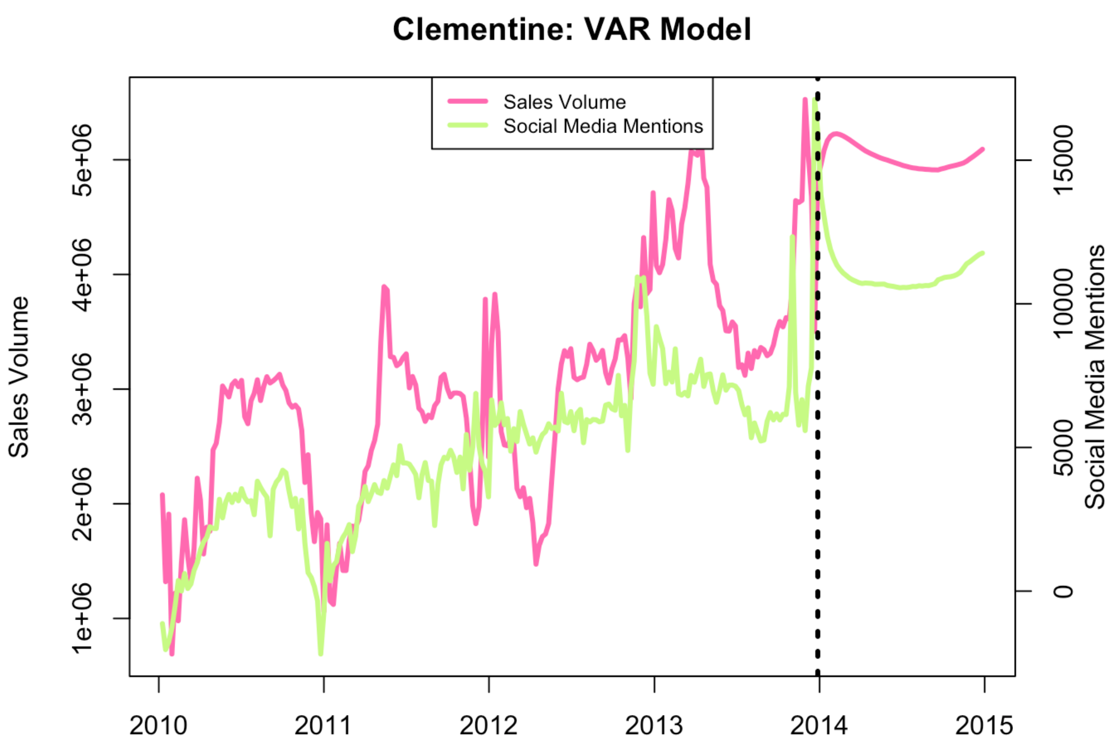
```
##                  ME    RMSE     MAE       MPE     MAPE
## Test set -850438.1 1135944 1054108 -23.93629 27.29017
```

```
# Clem social media forecast
accuracy(var_train_forecasts$fcst$Train_clem_social[,1], Test_clem_social)
```

```
##                  ME     RMSE      MAE       MPE     MAPE
## Test set -3820.709 4162.057 3875.811 -61.91988 62.37655
```

Plot Raw Sales and Social media with Forecasts

```
# Append raw + forecast
clem.sales.VAR.All <- append(Train_clem_sales, var_train_forecasts$fcst$Train_clem_sales[,1])
clem.social.VAR.All <- append(Train_clem_social, var_train_forecasts$fcst$Train_clem_social[,1])
clem.week.All <- append(Train_clem_week, Test_clem_week)

clem_df_total <- data.frame(clem.week.All, clem.sales.VAR.All, clem.social.VAR.All)


mar.default <- c(3,3,3,3) + 0.1
par(mar = mar.default + c(0, 1, 0, 0))
plot(clem_df_total[,1:2], type="l",
     ylab="Sales Volume", xlab="Time (Year)",
     lwd=3, main="Clementine: VAR Model", col="hotpink")
par(new=TRUE)
plot(clem_df_total[,3], type="l", col="darkolivegreen1", axes=FALSE,
     ylab="", xlab="", lwd=3)
axis(4)
mtext("Social Media Mentions", side=4, line=+2, adj=0.5)
abline(v=208, lty=3, lwd=3)
legend("top", legend=c("Sales Volume", "Social Media Mentions"),
       col=c("hotpink","darkolivegreen1"), lwd=3, cex=0.75)
```



Comparing sales prediction to ARIMA benchmark, make plots and calculate lift

```
# Calculate accuracy of arima sales forecast and VAR model sales forecast to actual sales values in
# test set
# Compare prediction error of each and calculate the lift obtained from prediction error.


# Difference in Predictions Clementines

All_Clem_Forecasts <- cbind.data.frame(Test_week = as.Date(Test_clem_week), AR=forecast.clem.sales.arima$mea
n, VAR=var_train_forecasts$fcst$Train_clem_sales[,1],
                   ACTUAL=Test_clem_sales)
head(All_Clem_Forecasts)
```

```
##    Test_week      AR     VAR  ACTUAL
## 1 2014-01-04 4569266 4957466 3746226
## 2 2014-01-11 4647909 5083290 4060837
## 3 2014-01-18 4646237 5165505 4348938
## 4 2014-01-25 4662379 5205713 4687070
## 5 2014-02-01 4674570 5223492 4250070
## 6 2014-02-08 4687638 5227128 4595462
```

```
# Calculate the RMSE. Predicted - Actual values.
AR.error <- forecast.clem.sales.arima$mean - Test_clem_sales
ar.clem.sales.rmse <- sqrt(mean(AR.error^2))
# Calculate MAE
ar.clem.sales.mae <- mean(abs(AR.error))


# Calculate the RMSE. Predicted - Actual values.
VAR.error <- var_train_forecasts$fcst$Train_clem_sales[,1] - Test_clem_sales
var.clem.sales.rmse <- sqrt(mean(VAR.error^2))
# Calculate MAE
var.clem.sales.mae <- mean(abs(VAR.error))


# Calculate Lift in prediction accuracy
paste(round((((ar.clem.sales.rmse - var.clem.sales.rmse)/ar.clem.sales.rmse))*100, digits = 2), "%", sep =
"")
```

```
## [1] "-4.96%"
```

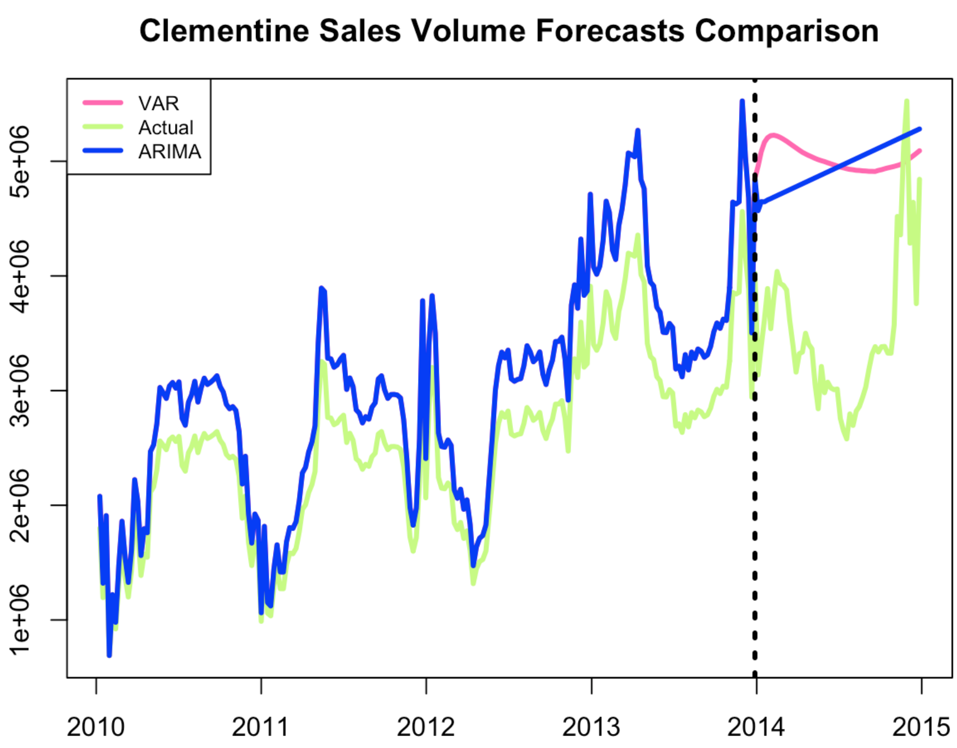
```
paste(round((((ar.clem.sales.mae - var.clem.sales.mae)/ar.clem.sales.mae))*100, digits = 2), "%", sep = "")
```

```
## [1] "-12.78%"
```

```
# Create a table to compare RMSE and MAE
accuracy_table <- matrix(c(1082234,790863.8,"26.92%",934652.2,672441,"28.05%"),ncol=3,byrow=TRUE)
colnames(accuracy_table) <- c("ARIMA","VAR", "Lift in Prediction accuracy")
rownames(accuracy_table) <- c("RMSE","MAE")
accuracy_table
```

```
##      ARIMA      VAR        Lift in Prediction accuracy
## RMSE "1082234"  "790863.8" "26.92%"
## MAE  "934652.2" "672441"   "28.05%"
```

```
# Append ARIMA sales data and forecasts
clem.sales.arima.All <- append(clem_train_sales_data_arima, forecast.clem.sales.arima$mean)

clem.sales.actual.All <- append(Train_clem_sales, Test_clem_sales)

# Create a dataframe w Raw sales data, VAR Forecasts, ARIMA Forecasts and
# Test data.

clem_df_total_final <- cbind.data.frame(clem.week.All, clem.sales.VAR.All, clem.sales.actual.All, clem.sale
s.arima.All)


mar.default <- c(3,3,3,3) + 0.1
par(mar = mar.default + c(0, 1, 0, 0))
plot(clem_df_total_final[,1:2], type="l",
     ylab="", xlab="Time (Year)",
     lwd=3, main="Clementine Sales Volume Forecasts Comparison", col="hotpink")
par(new=TRUE)
# Actual data train + test
plot(clem_df_total_final[,3], type="l", col="darkolivegreen1", axes=FALSE,
     ylab="", xlab="", lwd=3)
par(new=TRUE)
# ARIMA Forecast
plot(clem_df_total_final[,4], type="l", col="blue", axes=FALSE,
     ylab="", xlab="", lwd=3)

abline(v=208, lty=3, lwd=3)
legend("topleft", legend=c("VAR", "Actual", "ARIMA"),
       col=c("hotpink","darkolivegreen1","blue"), lwd=3, cex=0.75)
```



Based on the above plot we can see that VAR model which includes social media and lagged sales volume as endogenours predictors and google trends as exogenous variables does predict better than ARIMA model series predicting itself.

```
print(accuracy_table)
```

```
##      ARIMA      VAR        Lift in Prediction accuracy
## RMSE "1082234"  "790863.8" "26.92%"
## MAE  "934652.2" "672441"   "28.05%"
```

Based on Root mean squared error and Mean Absolute Error which calculates the prediction error (predicted - actual), from our train and test split, we see increased accuracy of more than 25% when using VAR models.