Analysis of stock market crash on Goldman Sachs stock price

Siddarth Viswanathan

Abstract.
Using 191 data points of closing stock market price from February 2002 to December 2015 I build a time series model which includes the intervention of the stock market crash during the 2007 Summer. The intervention is modeled as a pulse. Tests are performed to see the series requires differencing and residual analysis is performed on the fitted intervention time series model.

Introduction.
The financial crash of 2007-2008 was the largest financial catastrophe since the 1930s and is by now well-known to have been instigated by excessive risk-taking on the part of large banks. It is useful then to study how the crash impacted the closing stock price of a very prominent global investment bank, Goldman Sachs.

The data consists of 191 data points of monthly Goldman Sachs closing stock market price from February 2002 to December 2015 [1]. The crash is detailed to have occurred during August 2007 which is around the 100th point into the series.

Model Identification and Building.

Figure 1 shows a plot of the series of Goldman Sachs prices. Importantly note that the series does not reveal any changing variance so we do not require analysis using ARCH-GARCH framework. The McLeod-Li test for heteroscedascity confirms this and reveals there is not enough evidence to suggest heteroscedascity. Note the large drop around the middle of the series during 2007-2008.

Figure 2 shows the ACF and PACF plots of the series using data up to the intervention point at 2007-2008. These plots reveal that differencing is required due to the oscillating PACF and slowly decreasing ACF plot. Also the augmented Dickey-Fuller test reveals significant nonstationarity.

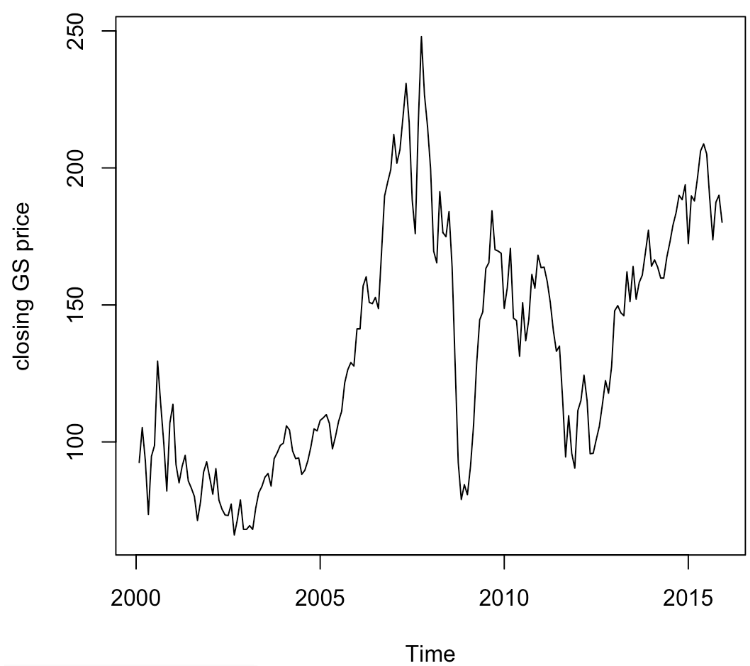

Figure 1: Plot of 191 monthly Goldman Sachs closing price data from 2000-2015.

After differencing the argument is that seasonality modeling is not required here since the intervention severely disrupted seasonality patterns which should not be considered to continue after the intervention. Therefore the model will utilize only one differencing term.

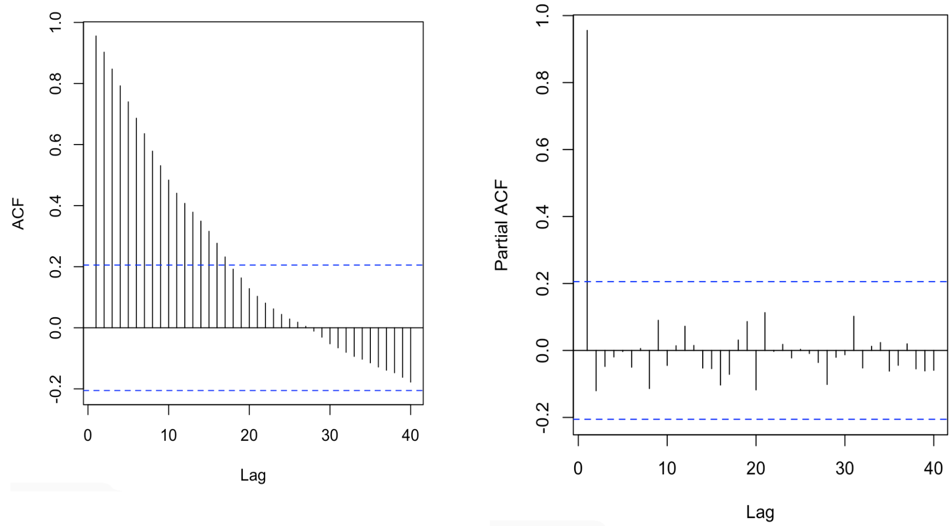

Figure 2 ACF and PACF plot of series until intervention revealing need for differencing.

Figure 3 shows the ACF and PACF plots for the differenced series for the time points up to the intervention. Figure 3 suggests a moving average component of 1 by the following reasoning:

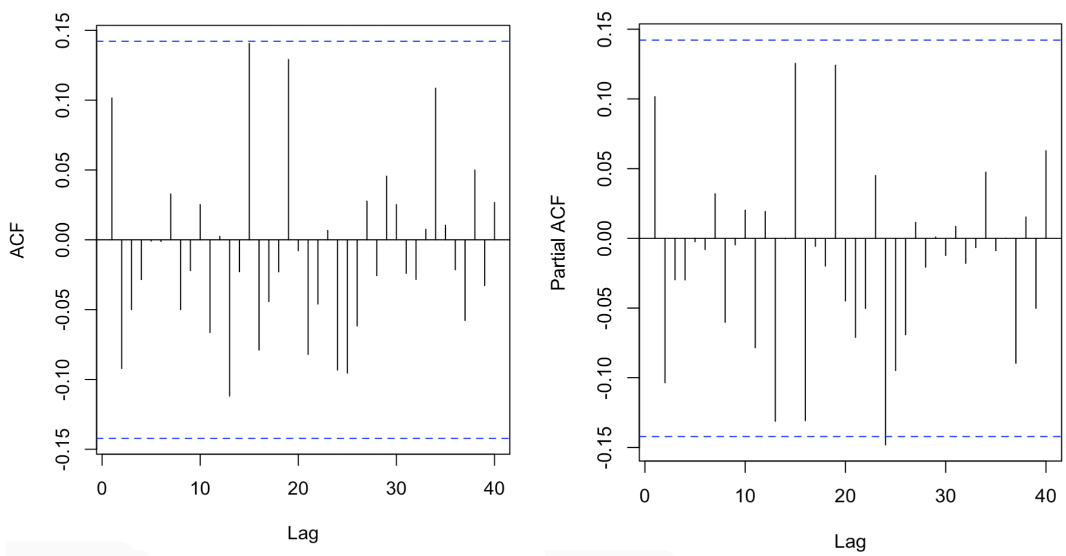

Figure 3 ACF and PACF plots of differenced series pre-intervention revealing some lower-lag MA component is appropriate.

the differenced ACF and PACF plots both do not show significant lags until very high lag counts and exhibit no seasonality so if we are to add any model terms we should add p=1 or q=1, but since the PACF plot generally is larger valued and tails off less slowly than the ACF plot we choose an MA(1) component to the model.

The model indicated by the pre-intervention datapoints is an ARIMA(0,1,1) model which can be augmented using intervention analysis with a pulse term at the time point at August 2007. The argument for using a pulse term is that there was a widespread recognition and spread of financial information around this pulse point of August 2007

[2]. Further the terminology of a “breaking bubble” suggests a key turning points of eents around the intervention time which will direct the financial trading activity governing the closing prices. Thus a pulse model at the time point around August 2007 is an appropriate intervention model.

We fit the following model using the R TSA package. And arimax function. The function contains a pulse around the 100^{th} term in the series (at the time point August 2007). Outlier tests reveal as expected no additive outliers and an innovative outliers near the intervention point. The transfer function includes a dummy variable at the time point of the intervention. The error term is assumed Gaussian which is common for financial time series data. The estimated variance from the model fitting is 146.1.

The model equation is given as $Zt = w_0 I_t + (1 - \theta B) / (1- \Theta B^2) a_t$ where I indicates the time point of the intervention.The estimated coefficients (with s.e.) are for the θ term .14 (.082), for the adjusted Θ term .95 (.025) and for the adjusted w_0 term -11.2 (36.2). The only significant coefficient is for the Θ term, we are unable to provide deeper reasoning why this should be the only significant term. For model comparison support for using intervention analysis with ARIMA(0,1,1) is given from the lower AIC than when using ARIMA(0,1,2), (1,1,1), (1,1,0) models. The AIC for (0,1,1) is 1492 while for the other models is 1493, 1494, 1493. All of these AIC scores are similar indicating that additional data from other related series may provide further information for better modeling approaches.

Figure 4 shows the residual plots for the model which are not problematic since significant lags only occur at very high points and do not show further seasonality to be adjusted for.

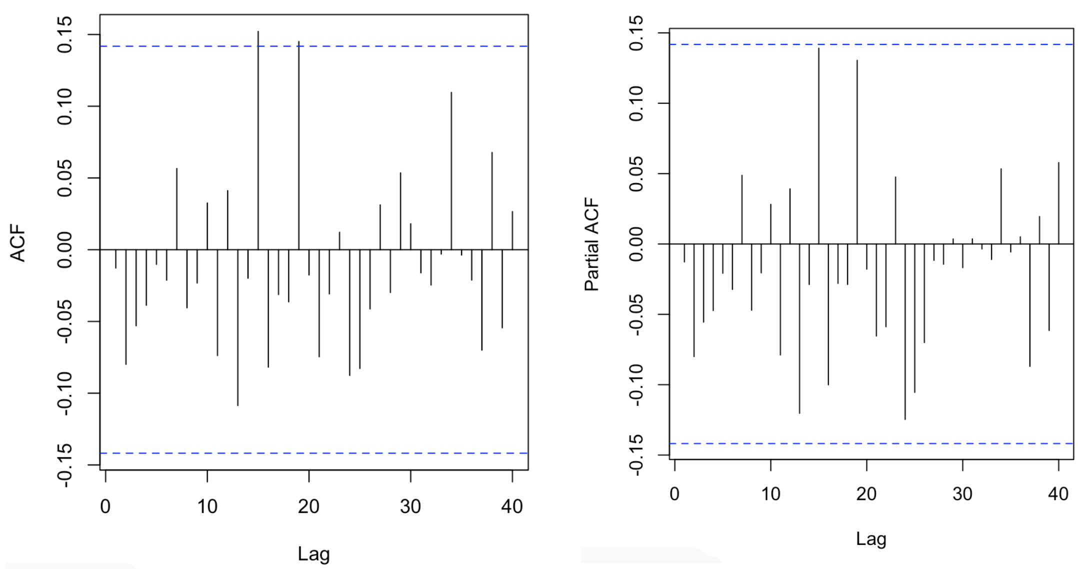

Figure 4 ACF and PACF plot of residuals for series fitted with intervention revealing adequate fit since no seasonality in the lags is revealed and all significant lags are few and are high-order.

Conclusion

For 15 years of monthly Goldman Sachs time series data from 2000-2105 we construct an intervention model to include the effect of the 2007-2008 financial crisis. We argued for the need to difference the series and also that no seasonality component is needed. We also tested for no heteroscedascity and therefore no need for using the ARCH-GARCH framework. We then fit an ARIMA(0,1,1) model with a pulse at the 100^{th} time point and observed nonproblematic residual ACF and PACF plots. We also ran outlier tests on these models and observed outliers at expected points when the series is more chaotic.

References

[1] Goldman Sachs (GS). Historical Data. *Yahoo! Finance*. Retrieved from https://finance.yahoo.com/quote/GS/history?period1=925776000&period2=1604448000&interval=1mo&filter=history&frequency=1mo&includeAdjustedClose=true.

[2] Amadeo, K., 2007 Financial Crisis, Explanation, Causes, and Timeline. The Balance (2020).

[3] Kung-Sik Chan and Brian Ripley (2020). TSA: Time Series Analysis. R package version 1.3. https://CRAN.R-project.org/package=TSA

Code

```
rm(list=ls())

library(tseries)
library(forecast)
library(ggplot2)
library(xts)
library(TSA)
library(aTSA)

# start
# load data GS price
dat <- read.csv('/Users/siddarthviswanathan/Desktop/GS.csv')

# feb 2000 to december 2015
# 10:100 (2007-08-01) for crash, 10:200 for whole
series <- ts(dat$Close[10:200] ,start=c(2000,2), frequency=12)
plot(series, ylab='closing GS price') # no noticeable periods of increased variation
# there is an intervention

series <- ts(dat$Close[10:100] ,start=c(2000,2), frequency=12)
plot(series)

plot(series, ylab="closing stock price",xlab='year')

acf_plot <- acf(series, lag.max=40)
acf_plot$lag <- acf_plot$lag*12
plot(acf_plot)

pacf_plot <- pacf(series, lag.max=40)
pacf_plot$lag <- pacf_plot$lag*12
```

```
plot(pacf_plot)

plot(decompose(series), xlab='')

adf.test(series) # nonstationary
McLeod.Li.test(y=series)

## differenced series
diff_1 <- diff(series, 1)

plot(diff_1, ylab="differenced closing stock price",xlab='')

acf_plot <- acf(diff_1, lag.max=40)
acf_plot$lag <- acf_plot$lag*12
plot(acf_plot)

pacf_plot <- pacf(diff_1, lag.max=40)
pacf_plot$lag <- pacf_plot$lag*12
plot(pacf_plot)

# so we have identified an ARIMA(0,1,1 model)
mod1 <- arima(series, order=c(0,1,1))
acf(mod1$residuals)
pacf(mod1$residuals) # residuals look good
Box.test(mod1$residuals)

detectIO(mod1)
detectAO(mod1)

arch.test(mod1)
# ## add intervention into model
mod2 <- arimax(series, order=c(0,1,1),
          xtransf=data.frame(I1 = (1*(seq(series) == 100))),
          transfer=list(c(1,0)))

acf_plot <- acf(mod2$residuals, lag.max=40)
acf_plot$lag <- acf_plot$lag*12
plot(acf_plot)

pacf_plot <- pacf(mod2$residuals, lag.max=40)
pacf_plot$lag <- pacf_plot$lag*12
plot(pacf_plot)

Box.test(mod2$residuals)
arch.test(mod2)

detectIO(mod2)
detectAO(mod2) # possible additive outlier at time point 7, interesting.
```

Data

From query for adjusted closing price for Goldman Sachs from 2000-2015 from:
https://finance.yahoo.com/quote/GS/history?period1=925776000&period2=1604448000&interval=1mo&filter=history&frequency=1mo&includeAdjustedClose=true.