Forecasting the Next Recession

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Motivation

The Need

We would like to forecast the next recession.

Definition

Two consecutive quarters of decline in GDP is considered a working definition of a recession.*

Proposed Solution

We will forecast the GDP for the next 2 quarters to see if the models can predict the next recession.

* https://www.investopedia.com/terms/r/recession.asp

Dataset

Response Variable

- Response Variable: % change in GDP (USA)
- Quarterly observations from 1971 to 2019
  - 195 observations

Exogenous Variables

- An additional 13 exogenous variables were also collected.
- Contained economic indicators related to the labor market, monitory policy, consumer related data, business environment, and several macro-economic factors

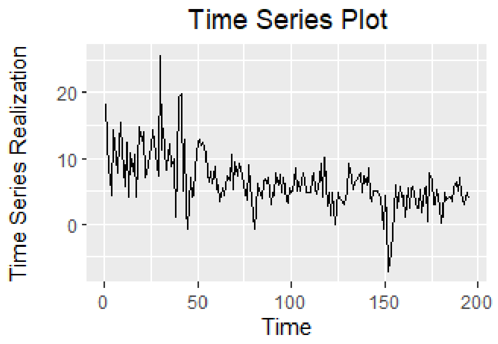
Data was collected from the Federal Reserve Bank of St. Louis Economic Data (FRED) https://fred.stlouisfed.org/

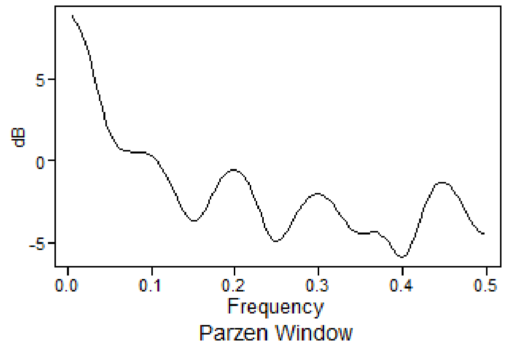
EDA: Checking Stationarity

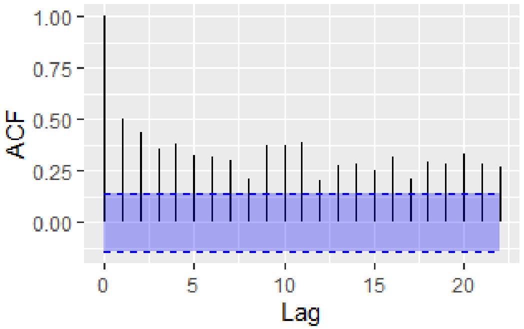
Condition 1: Mean does not depend on time

- Case for Non Stationarity
  - There appears to be a slight downward trend in the realization.
  - The spectral density shows a high peak at 0, which could be generated by a stationary or non-stationary process.
  - The ACF shows a hint of extended autocorrelations, which could indicate a non-stationary process.
  - Since the mean appears to change over time, this suggests a non-stationary process.

- Case for Stationarity
  - However, once could argue that looking at the second half of the data (beyond time point 100), there is no long term trend and that the GDP hovers around a mean value.
  - This makes sense since the US is a developed country and we would not expect the GDP to show very big fluctuations or trends.
  - So going forward this data could be generated through a stationary process also.



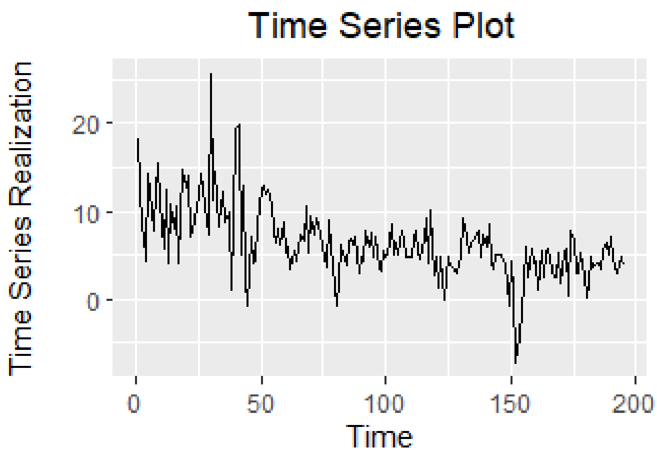




EDA: Checking Stationarity

Condition 2: Variance does not depend on time

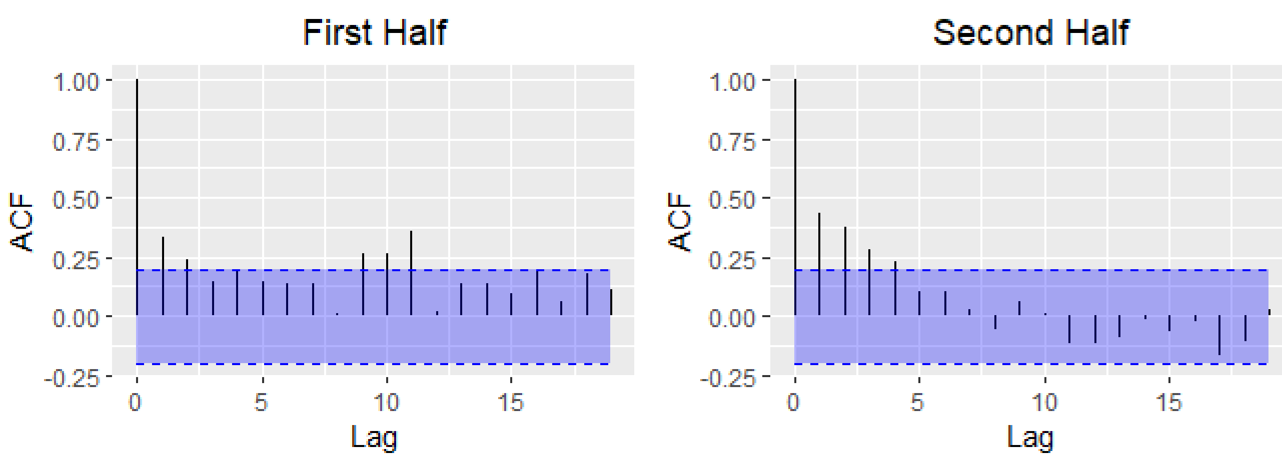
- Since only one realization is possible, it is difficult to assess the realization variance.
- However, there is more volatility in the first half (before 75) than in the second half.
- This may be an indication of non-constant variance, which would suggest a non-stationary process, but again difficult to say with just one realization.



EDA: Checking Stationarity

Condition 3: The correlation of X_{t_1} and X_{t_2} depends only on $t_2 - t_1$

- The ACFs of the first and second half exhibit different characteristics.
- A hint of seasonality in first half of the data though it is not appreciable
- More exponentially damped autocorrelations and no hints of seasonality in the second half of the data.
- This may suggest a non-stationary process, though the evidence is weak.



DataSc

EDA: Checking Stationarity

Conclusion

- Based on the analysis, there appears to be some evidence that the process is non-stationary.
- However, we expect that the change in GDP will eventually stabilize to a stationary process in the long run. If so, it may be possible to model this as a stationary process as well.
- **We will continue the analysis modeling the data using both an ARMA (stationary) model and an ARIMA (non stationary) model.**

ARMA: Model ID

- AIC and BIC both indicate that an ARMA(2,1) might be an appropriate model.
- The parameter estimation clears a lot of confusion about whether this is coming from a stationary or non stationary process. **Even when fitting a stationary ARMA model, we get an estimated root of 0.9917 in the factor table which is very close to 1 (non stationary model)**.

p	q	aic	bic
2	1	2.400740	2.467879
1	2	2.407727	2.474865
1	1	NA	2.477624
3	1	2.405507	2.489430
2	2	2.408653	2.492576
4	1	2.414109	NA

AR Factor Table

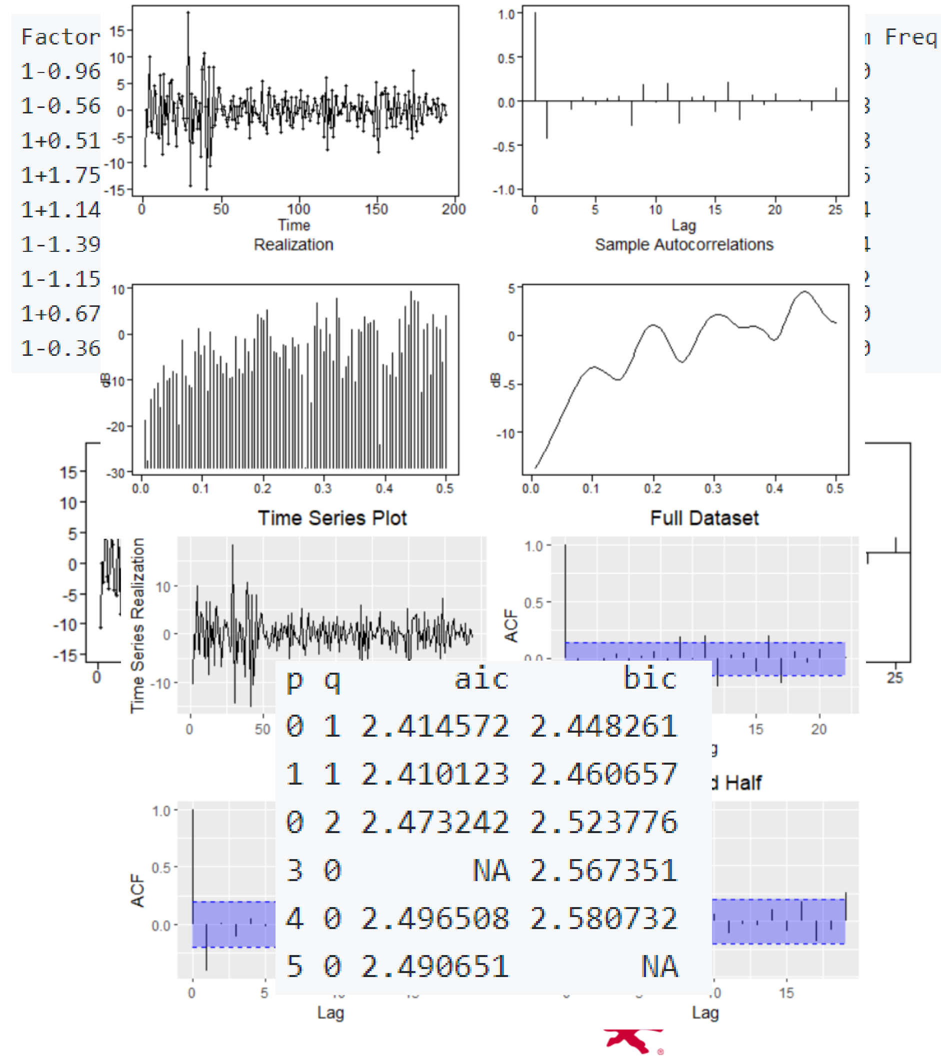
Factor	Roots	Abs Recip	System Freq
1-0.9917B	1.0084	0.9917	0.0000
1-0.2257B	4.4298	0.2257	0.0000

MA Factor Table

Factor	Roots	Abs Recip	System Freq
1-0.8881B	1.1261	0.8881	0.0000

ARIMA: Model ID

- The overfit tables show that 1-B may be a dominant factor in the model. The other factors don’t indicate any major seasonality
- We will proceed with including only a (1-B) term (i.e. d = 1).
- The differenced data seems stationary and seems to be indicative of an MA(1) process due to the appreciable dip at f = 0.
- AIC and BIC both confirm that an ARMA(0,1) model is appropriate for the differenced data.



p	q	aic	bic
0	1	2.414572	2.448261
1	1	2.410123	2.460657
0	2	2.473242	2.523776
3	0	NA	2.567351
4	0	2.496508	2.580732
5	0	2.490651	NA

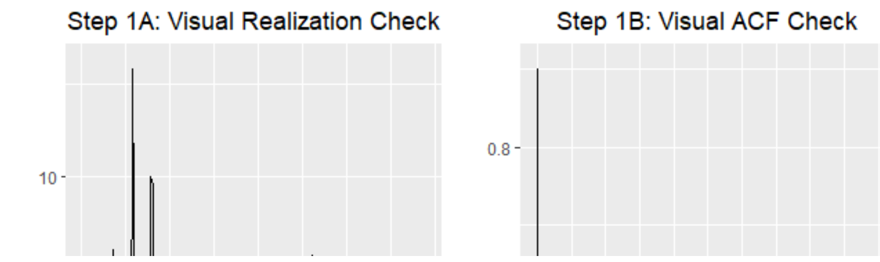
Model Comparison: White Noise Evaluation

- Evaluating the residuals for the ARMA(2,1) model, we see that they do not look like white noise.

- Evaluating the residuals for the ARIMA(0,1,1) model also do not indicate that the residuals are white noise

- The Ljung-Box test for white noise also rejects the null hypothesis for both models for K = 24 and K = 48.

- **Hence both these models may not be the best model since they are not capturing all the trend in the data.**

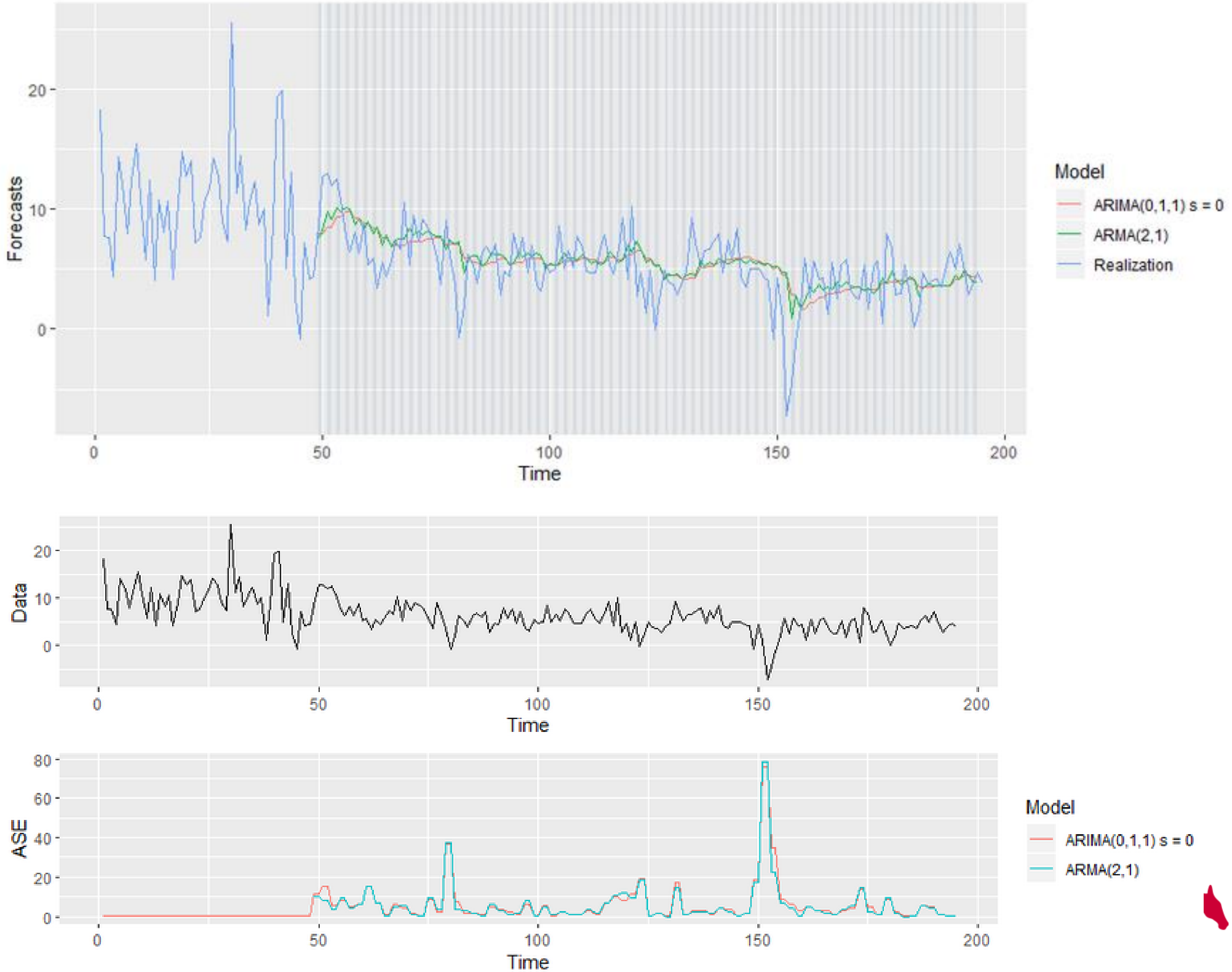


Ljung-Box Tests

Model	K	p-Value	Decision
ARMA(2,1)	24	0.00174	Reject
ARMA(2,1)	48	0.00219	Reject
ARIMA(0,1,1)	24	0.000491	Reject
ARIMA(0,1,1)	48	0.00150	Reject

ARIMA(0,1,1) White Noise Evaluation

Model Comparison: Forecasting



Fitting Higher Ordered Models

Stationary ARMA(13,1) Model

Factored Model

$$(1-0.9928\,B)(1-\ 0.604B+0.888B^2)(1+1.794B\ +0.878\,B^2)(1+0.539\,B +0.841B^2)(1-1.424\,B+0.807\,B^2)(1-1.662\,B+0.742\,B^2)(1+1.155\,B +0.720\,B^2)(X_t-6.39)=(1-0.882B)a_t\ \ with\ \ \hat{\sigma}_a^2=8.56$$

AR Factor Table

Factor	Roots	Abs Recip	System Freq
1-0.9928B	1.0073	0.9928	0.0000
1-0.6044B+0.8884B^2	0.3401+-1.0049i	0.9426	0.1981
1+1.7937B+0.8782B^2	-1.0213+-0.3094i	0.9371	0.4532
1+0.5388B+0.8414B^2	-0.3202+-1.0421i	0.9173	0.2974
1-1.4240B+0.8065B^2	0.8828+-0.6787i	0.8981	0.1043
1-1.6618B+0.7424B^2	1.1192+-0.3072i	0.8616	0.0426
1+1.1548B+0.7202B^2	-0.8017+-0.8636i	0.8487	0.3691

MA Factor Table

Factor	Roots	Abs Recip	System Freq
1-0.8822B	1.1336	0.8822	0.0000

Non Stationary ARIMA(11,1,0) Model

Factored Model

$$(1\ -0.6227B\ +0.8766B^2)(1+1.7743\,B+0.8617\,B^2)(1-1.5025\,B +0.8361\,B^2)(1\ +0.5210B+0.8091\,B^2)(1\ +1.0965B+0.6776\,B^2)(1 -0.6025B)(1-B)X_t=a_t\ \ with\ \ \hat{\sigma}_a^2=9.05$$

AR Factor Table

Factor	Roots	Abs Recip	System Freq
1-0.6227B+0.8766B^2	0.3552+-1.0073i	0.9363	0.1960
1+1.7743B+0.8617B^2	-1.0295+-0.3171i	0.9283	0.4524
1-1.5025B+0.8361B^2	0.8985+-0.6235i	0.9144	0.0966
1+0.5210B+0.8091B^2	-0.3220+-1.0641i	0.8995	0.2968
1+1.0965B+0.6776B^2	-0.8092+-0.9062i	0.8231	0.3660
1-0.6025B	1.6598	0.6025	0.0000

Model Comparison: White Noise Evaluation

- Evaluating the residuals for the ARMA(13,1) model, we see that they now look like white noise.
- Evaluating the residuals for the ARIMA(11,1,0) model also indicate that the residuals are white noise
- The Ljung-Box test for white noise also fails to reject the null hypothesis for both models for K = 24 and K = 48.
- **Hence both these models are appropriately capturing the trends in the data and whitening the residuals to the best of their abilities.**

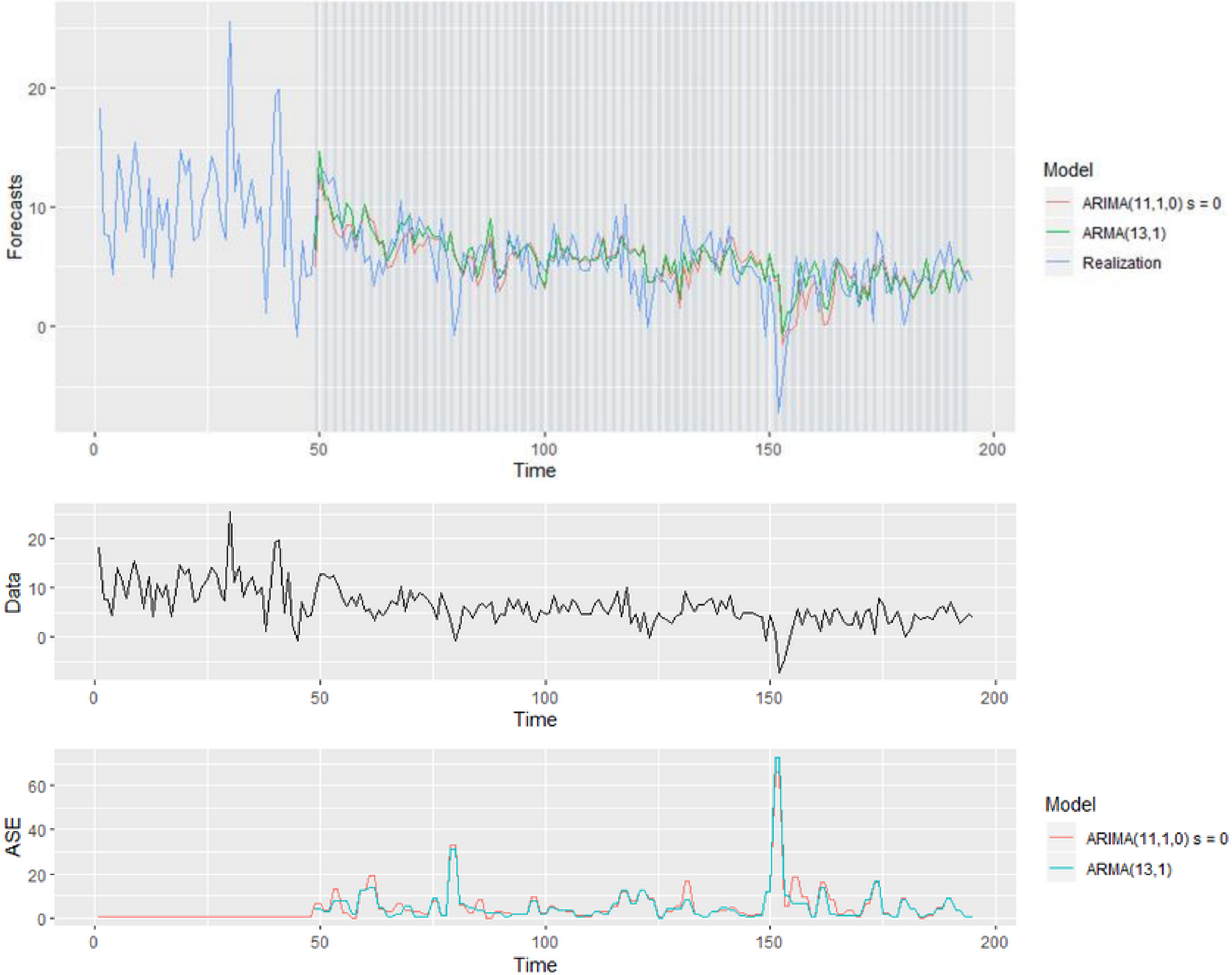
Ljung-Box Tests

Model	K	p-Value	Decision
ARMA(13,1)	24	0.236	FTR
ARMA(13,1)	48	0.789	FTR
ARIMA(11,1,0)	24	0.114	FTR
ARIMA(11,1,0)	48	0.625	FTR

Time Lag

ARIMA(11,1,0) White Noise Evaluation

Model Comparison: Forecasting



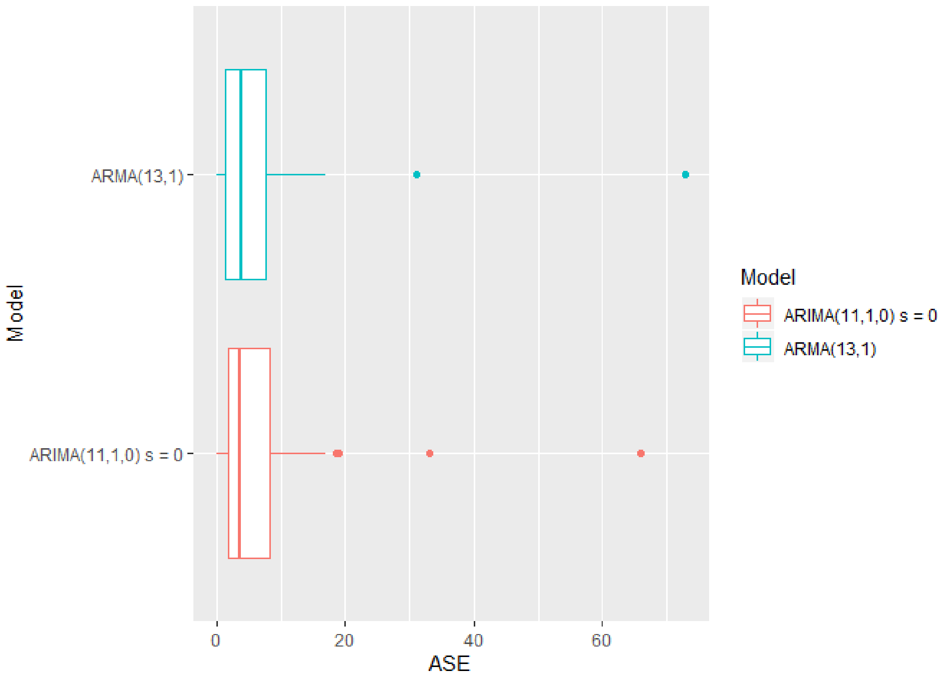
Model Comparison: Rolling ASE Values

There does not appear to evidence of difference between performance of the two models over 73 batches.

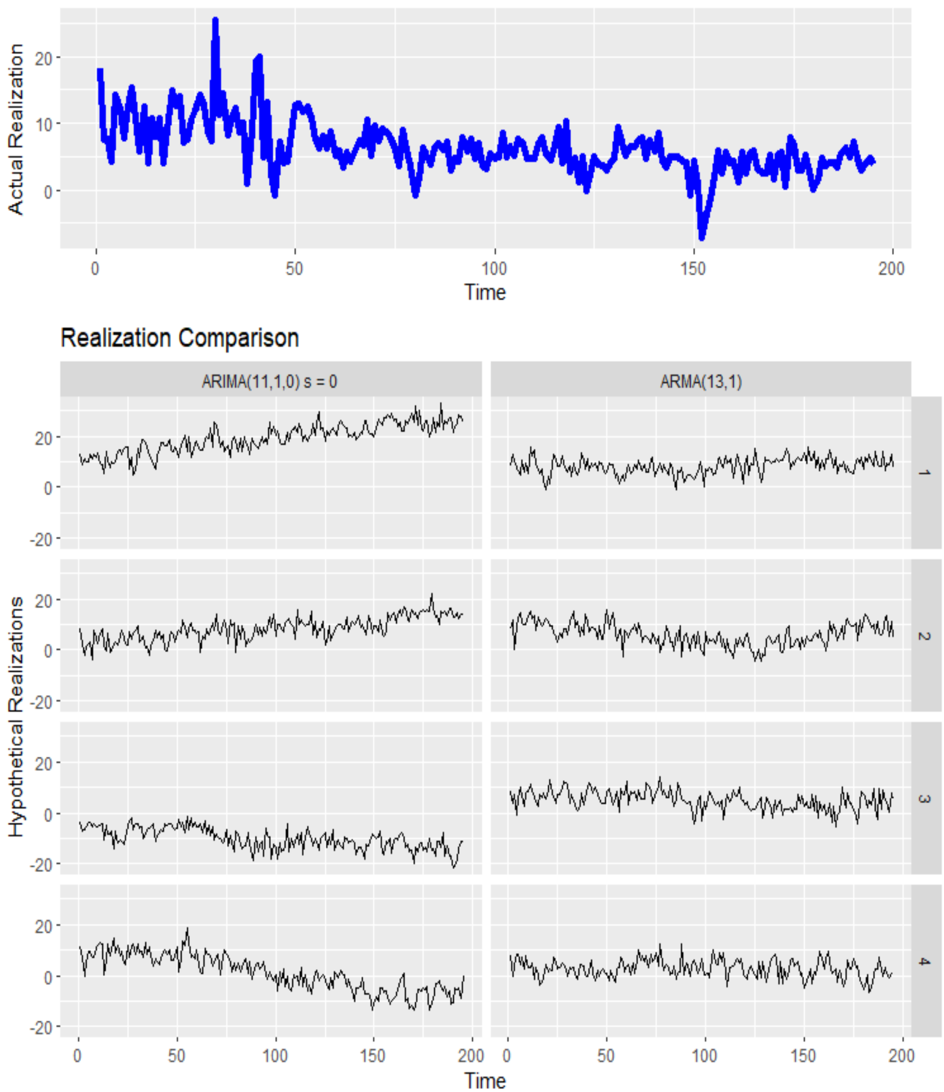
Test for difference in mean ASE
P-value: 0.685

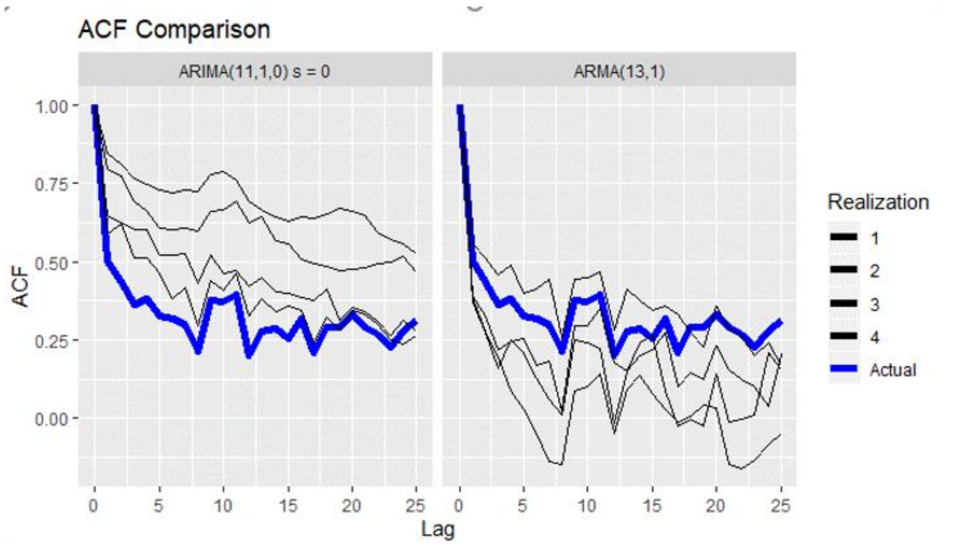
ASE Comparison

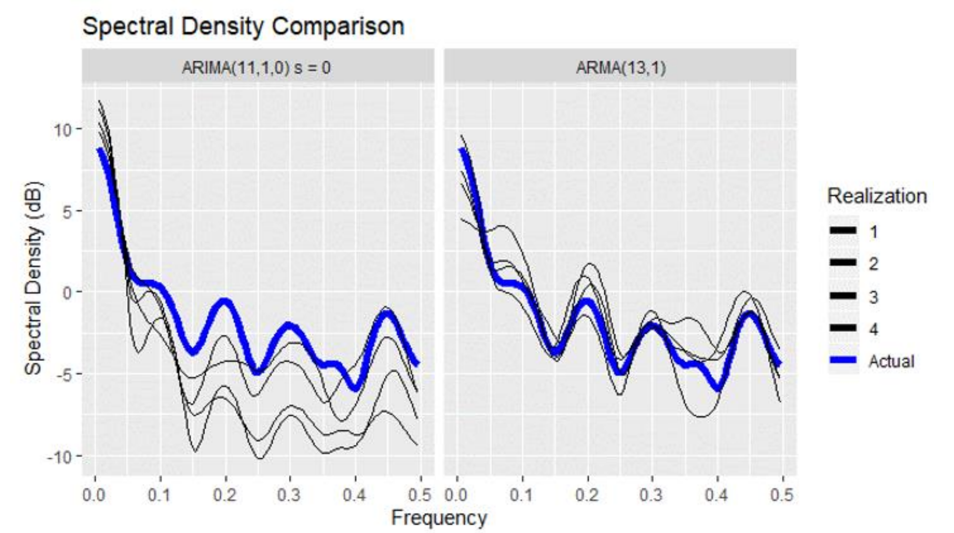
Model	Mean ASE	Median ASE	SD ASE
ARIMA(11,1,0)	6.40	3.55	9.12
ARMA(13,1)	5.77	3.73	9.42



Model Comparison: Realizations and Characteristics







Key Findings & Next Steps

Lower Ordered Models

- Not sufficient to capture the trend in the data.
- Residuals are not white noise.

Higher Ordered Models

- Generate residuals that are white noise.
- Forecasts are better than Lower Ordered Models.
- However, not good enough to capture sharp changes in GDP.

ARMA(13,1) vs. ARIMA(11,1,0)

- ARMA captures characteristics of the data better than ARIMA
- Mean ASE lower for ARMA although statistically not different.

Next Steps

- Modeling the GDP using univariate analysis is not easy.
- Add exogenous variables to improve modeling.

Reproducible Research: Code for the complete analysis is available on GitHub

Youtube Video: Link

References:

- Jim Chappelow, *Recession*, Investopedia. Accessed March 6, 2020. https://www.investopedia.com/terms/r/recession.asp
- U.S. Bureau of Economic Analysis, Gross Domestic Product [A191RP1Q027SBEA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/A191RP1Q027SBEA, March 6, 2020.
- U.S. Bureau of Labor Statistics, All Employees, Total Nonfarm [PAYEMS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/PAYEMS, March 6, 2020.
- Board of Governors of the Federal Reserve System (US), 10-Year Treasury Constant Maturity Rate [DGS10], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DGS10, March 6, 2020.
- Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate [FEDFUNDS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/FEDFUNDS, March 6, 2020.
- U.S. Bureau of Economic Analysis, Real Disposable Personal Income [A067RO1Q156NBEA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/A067RO1Q156NBEA, March 6, 2020.
- U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCNS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCNS, March 6, 2020.
- U.S. Bureau of Economic Analysis, Population [POPTHM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/POPTHM, March 6, 2020.
- U.S. Bureau of Economic Analysis, Corporate Profits After Tax (without IVA and CCAdj) [CP], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CP, March 6, 2020.
- Federal Reserve Bank of St. Louis, Spot Crude Oil Price: West Texas Intermediate (WTI) [WTISPLC], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WTISPLC, March 6, 2020.
- ICE Benchmark Administration Limited (IBA), Gold Fixing Price 10:30 A.M. (London time) in London Bullion Market, based in U.S. Dollars [GOLDAMGBD228NLBM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GOLDAMGBD228NLBM, March 6, 2020.
- Board of Governors of the Federal Reserve System (US), Japan / U.S. Foreign Exchange Rate [EXJPUS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/EXJPUS, March 6, 2020.
- Board of Governors of the Federal Reserve System (US), U.S. / U.K. Foreign Exchange Rate [EXUSUK], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/EXUSUK, March 6, 2020.