

The background is a dark blue gradient with various data visualization elements. On the left, there are green and blue bar charts. In the center, a red line graph trends upwards. On the right, there are glowing blue and red geometric shapes, possibly representing network structures or data clusters. Binary digits (0s and 1s) are scattered throughout the background, some in white and some in blue.

Assignment Advanced Time Series Analysis

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Outline

- I. Data definition.
- II. Univariate analysis.
- III. Forecasting models.
- IV. Multivariate analysis.
- V. Conclusions.

Data definition

- Unadjusted monthly stock price for Microsoft Corporation (MSFT) [Mar1986 – Nov2019] [1]. (main series to forecast).
 - For the multivariate analysis, the series is dimension to [Dec2002 – Oct2019], to match the other time series (in differences).
- 10-Year Breakeven Inflation Rate [Jan2003 – Oct2019] [2] (percentage).
 - Definition: “measure of expected inflation derived from 10-Year Treasury Constant Maturity Securities (BC_10YEARM) and 10-Year Treasury Inflation-Indexed Constant Maturity Securities (TC_10YEARM)” [2].
 - “The latest value implies what market participants expect inflation to be in the next 10 years, on average” [2].

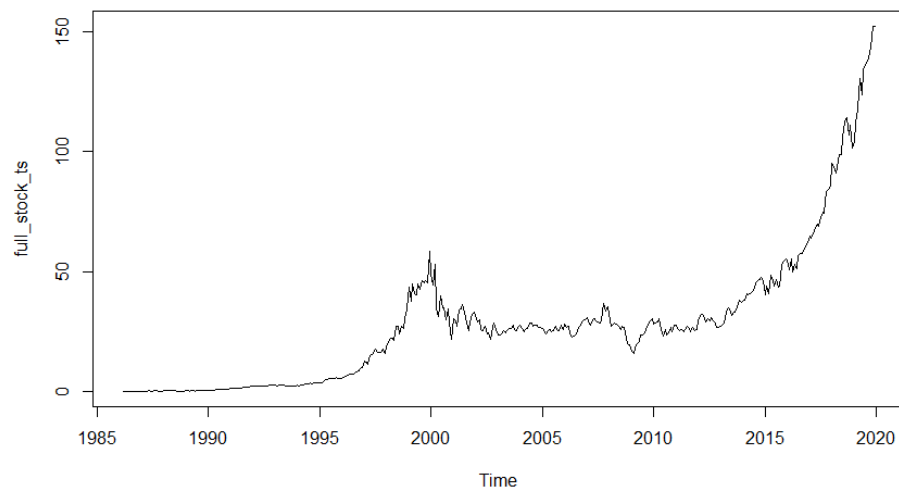
[1] Yahoo Finance (2019), Microsoft monthly stock price, retrieved

from <https://finance.yahoo.com/quote/MSFT/history?period1=511052400&period2=1574895600&interval=1mo&filter=history&frequency=1mo>.

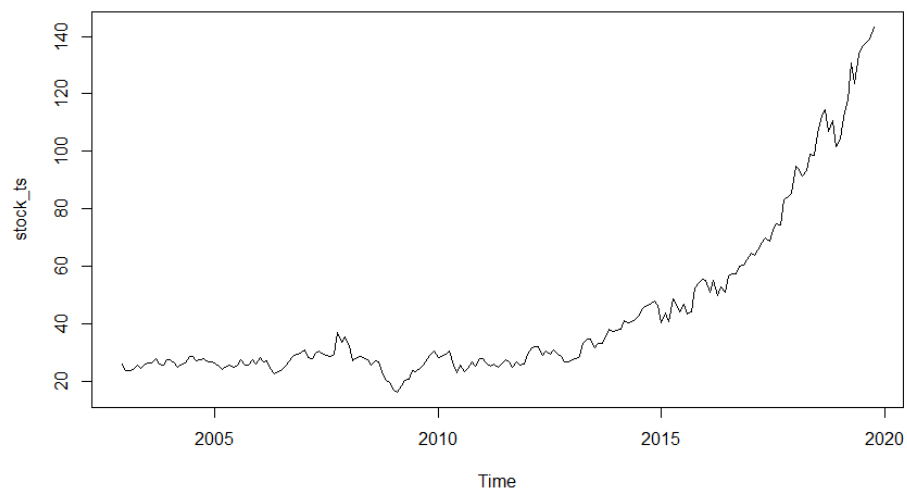
[2] Federal Reserve Bank of St. Louis (2019), 10-Year Breakeven Inflation Rate [T10YIEM], retrieved from <https://fred.stlouisfed.org/series/T10YIEM>.

Data plots

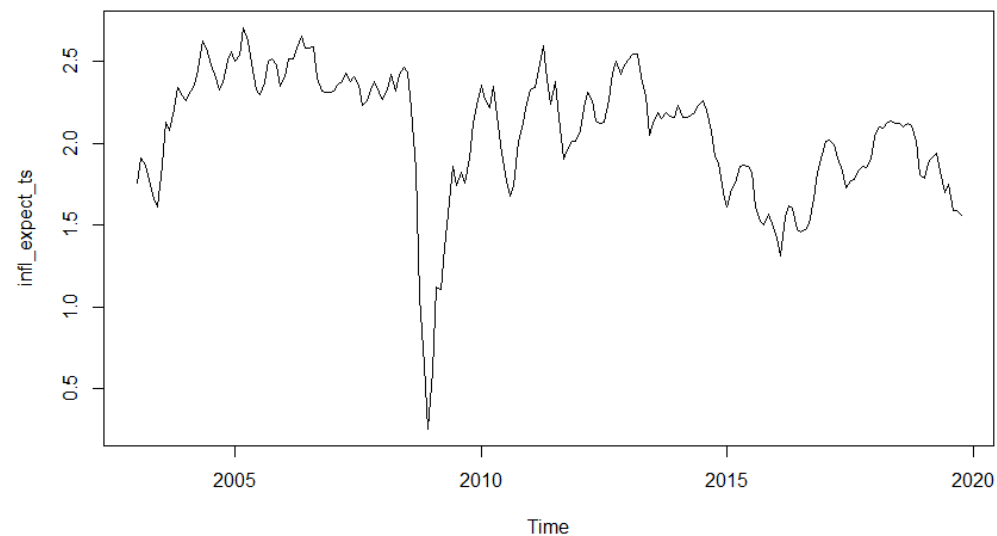
Microsoft closing monthly stock price (full)



Microsoft closing monthly stock price (short)

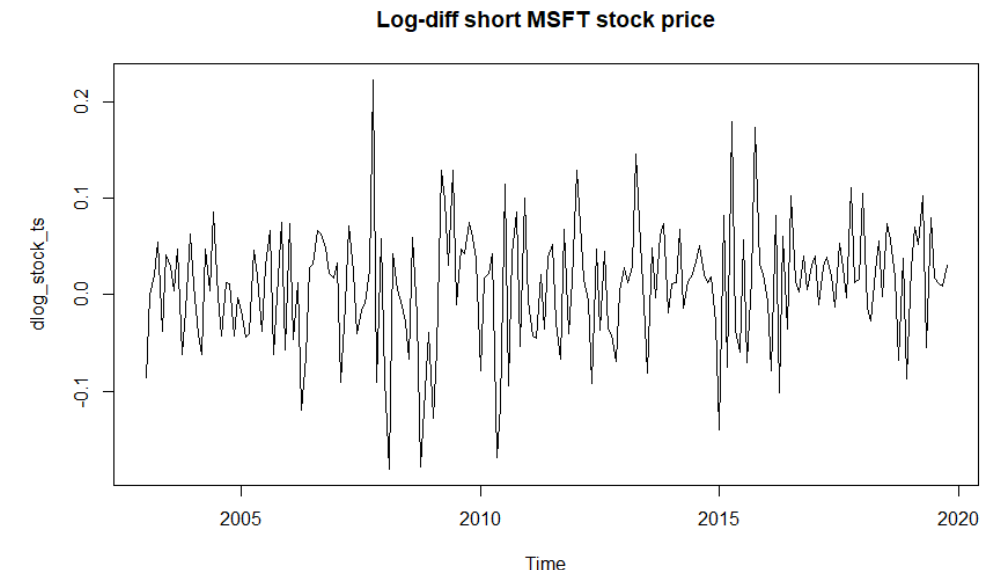
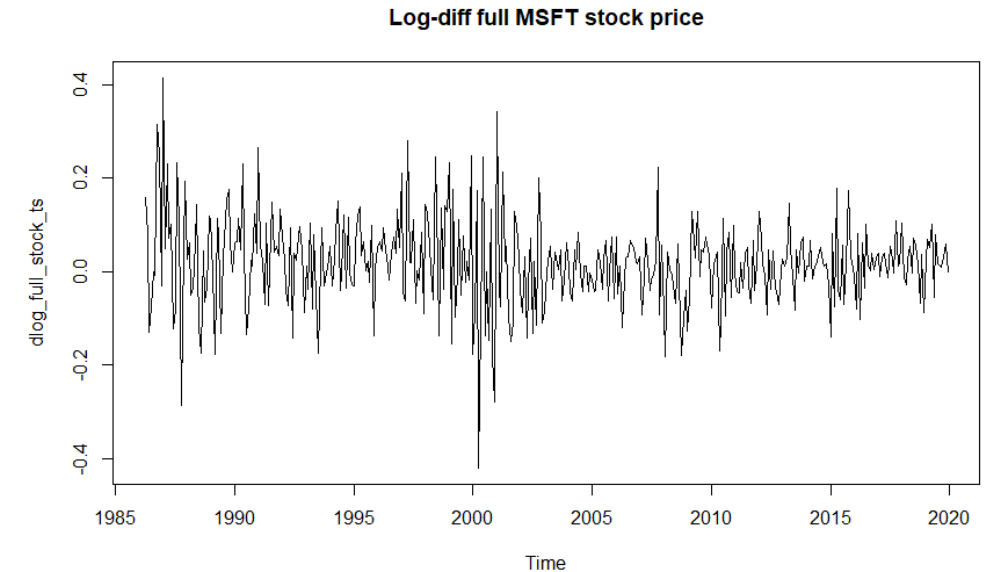


10-YR Breakeven inflation rate



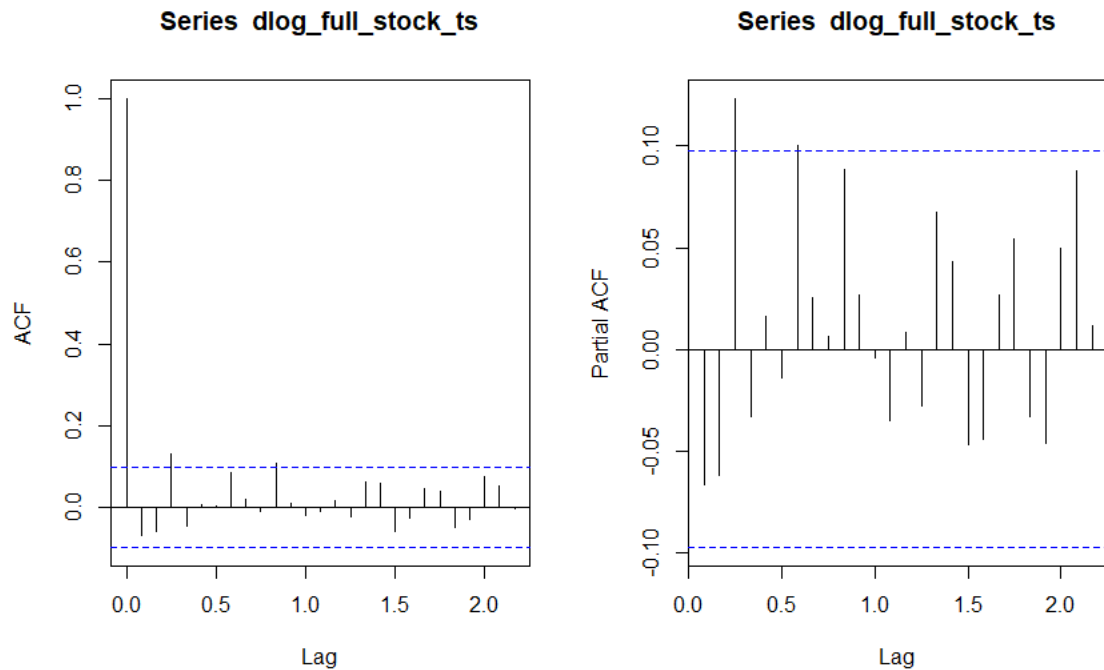
Stationarity and trend

- Both Full and Short MSFT stock price:
 - Stochastic trend.
 - Log-diff to get them stationary.
- 10-YR Breakeven Infl Rate is stationary.
 - ADF test: p-value= 0,003 (RH0 no unit root).

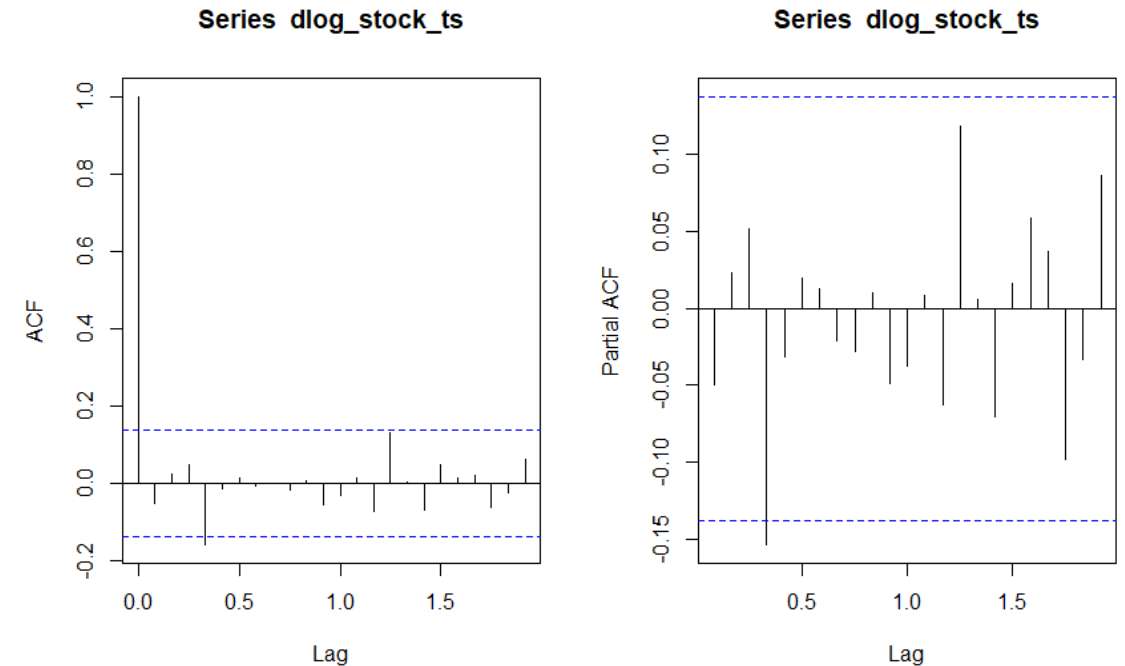


Correlogram and partial correlogram

Log-Diff Full MSFT stock price



Log-Diff Short MSFT stock price

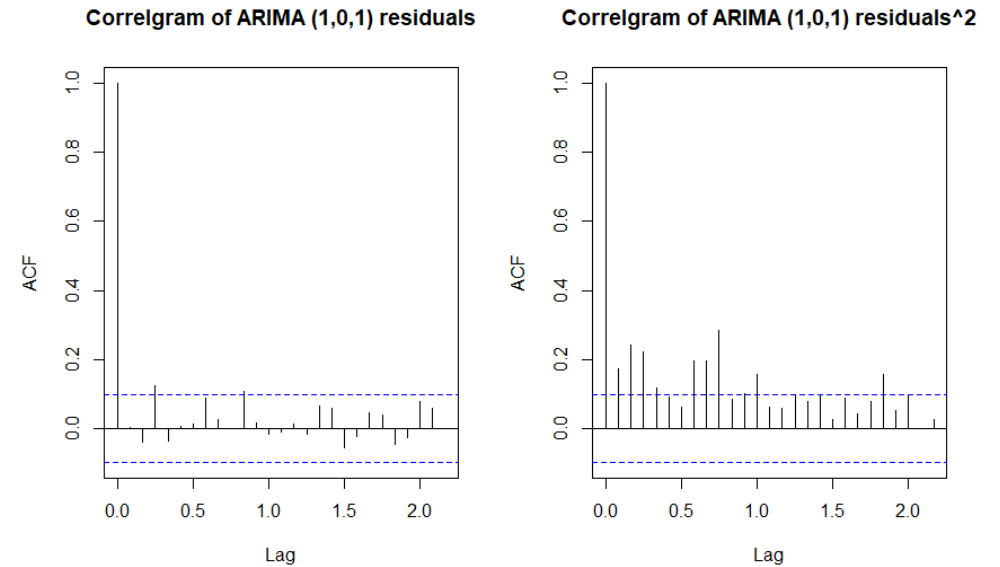


No visible seasonality, corroborated with a monthly linear regression (not significant).

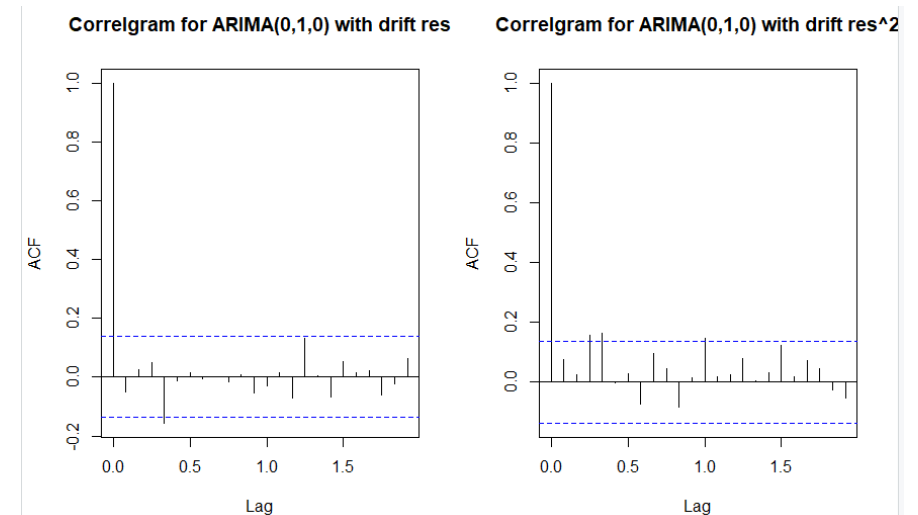
Heteroscedasticity

- The Log-Diff Full MSFT stock price ARMA models present conditional heteroscedasticity.
- The Log short MSFT stock price ARMA models present border line significance.
 - It might be due to having less data (shorter period of time).
 - Note that it can be modelled as an ARIMA(0,1,0) with drift (Log-diff being a white noise with drift).

Log-Diff Full MSFT stock price



Log Short MSFT stock price



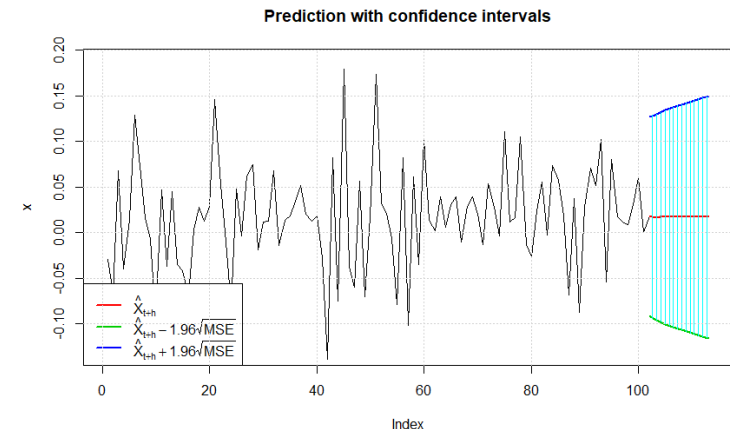
In-sample model analysis (Full MSFT stock price in log-differences)

Model	Highest order coefficient significant	Correlogram of the Std residuals	Correlogram of the Std residuals^2	Ljung-Box test for the standardized residuals	Ljung-Box test for the standardized residuals^2	BIC
ARMA (1,1) + GARCH (1,1)	No	Practically: OK Statistical: OK	Practically: OK Statistical: NOT	Fail to reject: OK	Fail to reject: OK	-1.9691
ARMA (1,1) + GARCH (2,2)	No	Practically: OK Statistical: OK	Practically: OK Statistical: Border line significance	Fail to reject: OK	Fail to reject: OK	-1.9446
ARMA (2,1) + GARCH (1,1)	No	Practically: OK Statistical: OK	Practically: OK Statistical: NOT	Fail to reject: OK	Fail to reject: OK	-1.9557
ARMA (1,2) + GARCH (1,1)	No	Practically: OK Statistical: Border line significance	Practically: OK Statistical: OK	Fail to reject: OK	Fail to reject: OK	-2.0089
AR (3) + GARCH (1,1)	Yes	Practically: OK Statistical: OK	Practically: OK Statistical: NOT	Fail to reject: OK	Fail to reject: OK	-1.9669
MA (3) + GARCH (1,1)	Yes	Practically: OK Statistical: OK	Practically: OK Statistical: NOT	Fail to reject: OK	Fail to reject: OK	-1.9649
ARMA (2,2) + GARCH (1,1)	Yes	Practically: OK Statistical: OK	Practically: OK Statistical: OK	Fail to reject: OK	Fail to reject: OK	-1.9522

Out-of-sample model analysis (Full MSFT stock price in log-differences)

Model	MAE (h = 1)
ARMA (1,1) + GARCH (1,1)	0.04193
ARMA (1,2) + GARCH (1,1)	0.04214
AR (3) + GARCH (1,1)	0.04282
MA (3) + GARCH (1,1)	0.04292

Diebold-Mariano test: Fail to reject H_0 : there is no significant difference.
ARMA (1,1) + GARCH (1,1) is chosen since it is simpler.



Multivariate analysis

- 10-YR Breakeven Inflation rate is $I(0)$.
 - Based on the US Dec2002 CPI of 180,9 (1982-84 = 100) the corresponding $I(1)$ series is calculated (to be able to perform the Engle-Granger test).
- ADL(3) is a valid model.
- H_0 of no Granger Causality is rejected (not very significant p-value 0,04).
 - 10-YR Breakeven inflation rate (lag 3) has an incremental power in predicting $d\log$ Short MSFT stock.
- Engle-Granger test: fail to reject H_0 (T-statistic -0.782) .
 - No evidence for cointegration (no cointegration).
 - No need for ECM nor VECM.
- Proposed VAR(2) is not a good approximation for Log-diff Short MSFT stock price.
 - Model $d\log_stock_ts = d\log_stock_ts.l1 + d\log_CPI_ts.l1 + d\log_stock_ts.l2 + d\log_CPI_ts.l2 + const$ is not significant.

Conclusions

- Based on the data, the best evaluated forecast model for the Log-Diff Full MSFT stock price series is the ARMA(1,1) + GARCH(1,1) with a MAE ($h = 1$) of 0,04193.
- The auto.arima function for the Log-Diff Full MSFT stock price series proposed a SARMA(2,1,3)(2,0,0). This model is rejected due to Heteroscedasticity, and there is no seasonality.
- The Short MSFT stock price dataset is very small (approx. 17 values per month), going into differences once makes it already white noise.
 - A lot of models will fit the data.
 - It can be modelled as a white noise with drift.
 - Border line Heteroscedasticity significance.
- The final result for the VAR(2) model was expected, since the Granger Causality was border line significant.