Time Series Analysis – Home Project #1

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Abstract

This paper describes the construction of the short-term forecasting model of cryptocurrencies' prices for the two popular cryptocurrencies - Bitcoin and Litecoin - using the time series analysis approach. We found that taking into account the last five years (from the beginning of 2015) both currencies were cointegrated. We used autoregressive integrated moving average (ARIMA) models and Vector Error Correlation Model (VECM). We tested the model by creating a short-term forecast (10 days). We found that the proposed VEC model performs better in forecasting both cryptocurrencies prices.

Introduction

The rapid development of digital currencies during the last decade is one of the most controversial and ambiguous innovations in the modern global economy. Significant fluctuations in the exchange rate of cryptocurrencies' prices and their high volatility, as well as the lack of legal regulation of their transactions in most countries, resulted in significant risks associated with investment into crypto assets. This has led to heated discussions about their place and role in the modern economy.

There are different approaches to study only the time series and make a prediction based on the processing and analysis of past observations. One of the most common models is the Box-Jenkins ARIMA time series models. The other is to create a Vector Error Correction Model (VECM) that is designed to estimate a potential long-run relationship.

The following study aims to create an ARIMA and VECM models in the R tool to use them to forecast prices of Bitcoin and Litecoin. In this study, the Johansen cointegration test and the Engle-Granger two-step analysis for cointegration are conducted to evaluate if there are any cointegrating pairs between Bitcoin. Additionally, we also test Granger causality. Both models we obtained using both visual methods, manual testing of models, and automatic function from R. The last goal is to analyze the performance of estimated models using appropriate statistics.

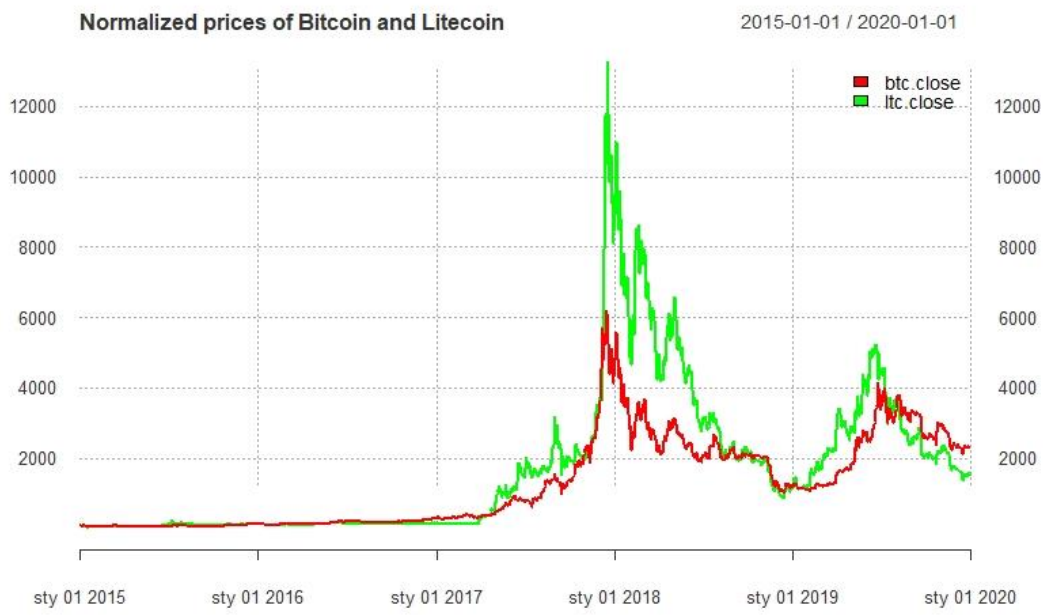
Data description

We uploaded the data from yahoo finance, which provides financial news, data, and commentary including stock quotes, press releases, financial reports, and original content including cryptocurrencies' prices. We collected prices for Bitcoin (BTC) and Litecoin (LTC) from the begging of 2015 till the end of 2019. Both time series contains around 1800 observations. The data are composed of four elements: open price, highest price, lowest price, close price, volume, and adjusted price. In this research, the closing price is chosen to represent the day price of the cryptocurrencies, because it very well reflects the activity on the currency for the whole day. Prices for both currencies appeared to be integrated with order one, tested by the D-F test.

Cointegration

As we can see in the following graph, the prices of both cryptocurrencies seem to have a long-term relationship:

Figure 1. Normalized prices of Bitcoin and Litecoin.



Source: Own calculations based on the data from yahoo finance.

We performed the Engle-Granger two-step procedure and Johansen cointegration test to prove that both cryptocurrencies are cointegrated. Both tests provided the same results. We can do it because both time series have to be integrated of the same order (it is first). Then we estimated the cointegrating vector by using OLS regression. The results of the cointegrating relationship are given by the formula:

*btc.close - 1090.8953 - 61.9403 * ltc.close*

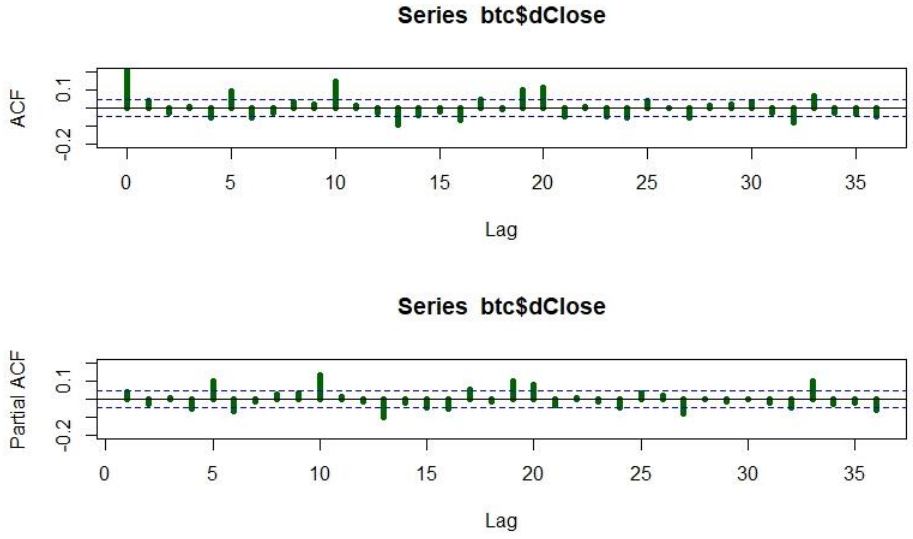
The second step of the Engle-Granger procedure proved that residuals are stationary - DF test showed that they are stationary with a confidence level of 95%. The model described that cointegration exists between both cryptocurrencies, describing a relationship between the prices. More specifically, the results show that if LTC price increases by 1, in the long-term, BTC price will increase by 61.9403. The short-run relationship, taken by the ECM model, shows that if in short-term LTC price increases by 1, the BTC price will increase by 71.05223. The adjustment is 98,335% of the unexpected error (increase in the gap) will be corrected in the next day, so any unexpected deviation should be corrected finally within around one day (1/98.335%) Granger causality test tells us that there seems to be bidirectional causality.

Results of the analysis

1. **ARIMA**

The first step is to find separately for them the most attractive univariate ARIMA models and produce forecasts for the reasonably out-of-sample period. We follow the Box-Jenkins approach. The first thing to this issue is making sure that the variables are stationary. For both cryptocurrencies the first difference of the close price is stationary. Then using plots of the autocorrelation (ACF) and partial autocorrelation (PACF) functions of the dependent time series we decided which autoregressive or moving average component should be used in the model. For Bitcoin ACF and PACF are presented in Figure 2:

Figure 2. ACF and PACF for Bitcoin close price.

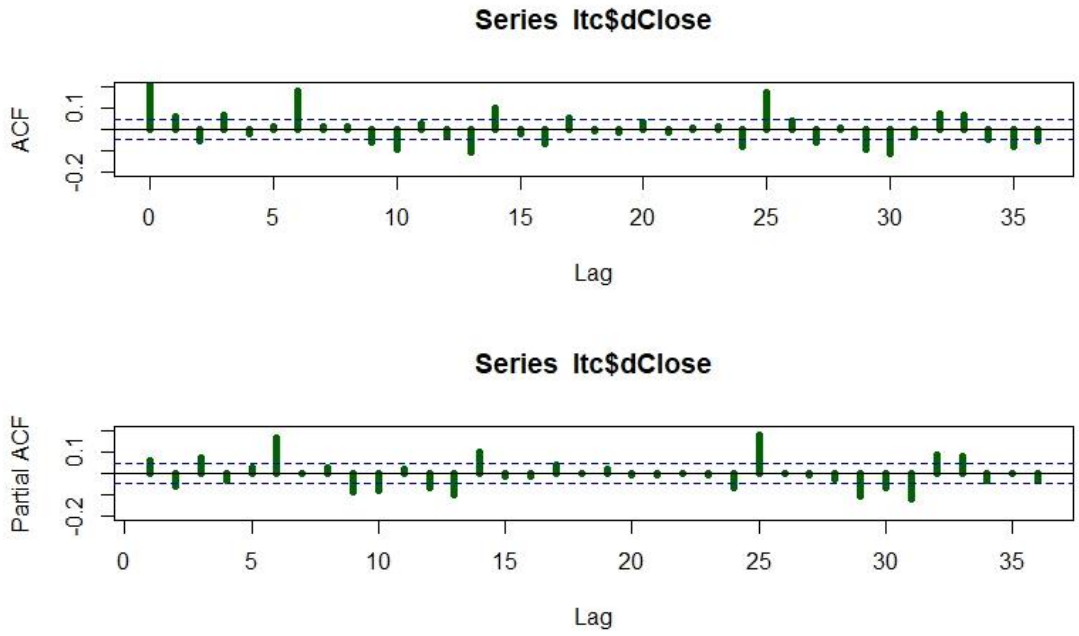


Source: Own calculations based on the data from yahoo finance.

ACF and PACF suggest that maybe Arima(1,1,1) could be a sensible model for Bitcoin However, PACF is not exponentially decreasing. Also Arima(5,1,5) or Arima(10,1,10) could fit. Then we started parameter estimation using computation algorithms to arrive at coefficients that best fit the selected ARIMA model. The most common methods use maximum likelihood estimation and select model basing on the lowest Akaike Information Criterion (AIC) and testing if the residuals should be independent of each other and constant in mean and variance over time by performing a Ljung–Box test. The best model for Bitcoin is Arima (10,1,10) without 3rd, 5th, and 7th autoregressive coefficients.

The same procedure has been applied to Litecoin prices. ACF and PACF are presented in Figure 3:

Figure 3. ACF and PACF for Litecoin close price.

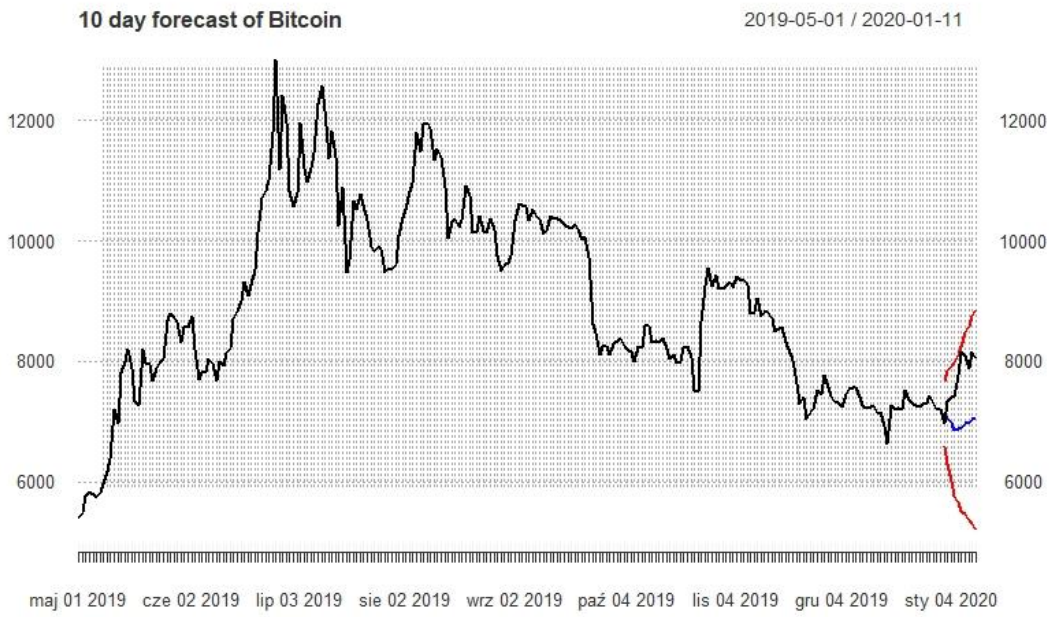


Source: Own calculations based on the data from yahoo finance.

In ACF 1st, 6th, 9th and 10th lags are significant and in PACF none of the lags is significant until 8th This suggests that the appropriate model for Litecoin could be ARIMA(1,1,1) or Arima(6,1,6) without 2,3, 4 and 5 lag, etc. Using auto.arima function it appeared that the best model is Arima(15,1,0). Again it was concluded basing on on the lowest Akaike Information Criterion (AIC) and testing if the residuals should be independent of each other and constant in mean and variance over time by performing a Ljung–Box test.

We forecast for 10 days. However VECM model is created for more long-run predicting, Arima isn't, so just to compare them we decided to choose such a period. Figure 4 and Figure 5 contain a prediction for 182 days for Bitcoin and Litecoin accordingly.

Figure 4. Arima(10,1,10) Forecast for Bitcoin



Source: Own calculations based on the data from yahoo finance.

Figure 5. Arima(15,1,0) Forecast for Litecoin

Source: Own calculations based on the data from yahoo finance.

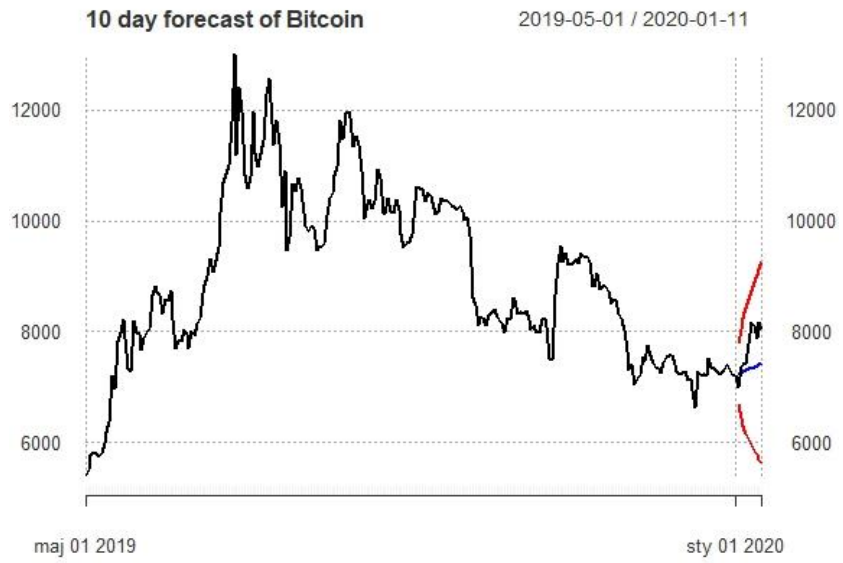
2. VECM

The error correction model is commonly used for data where the underlying variables exhibit cointegration. As far as we proved the cointegration between Bitcoin and Litecoin, the proper analysis was conducted. We followed Johansen's procedure. Using two alternative variants of the test (trace and eigen), we have obtained exactly one cointegrating relationship and our cointegration vector is:

$$\beta = (1.00000,-78.48916,-286.19006)$$

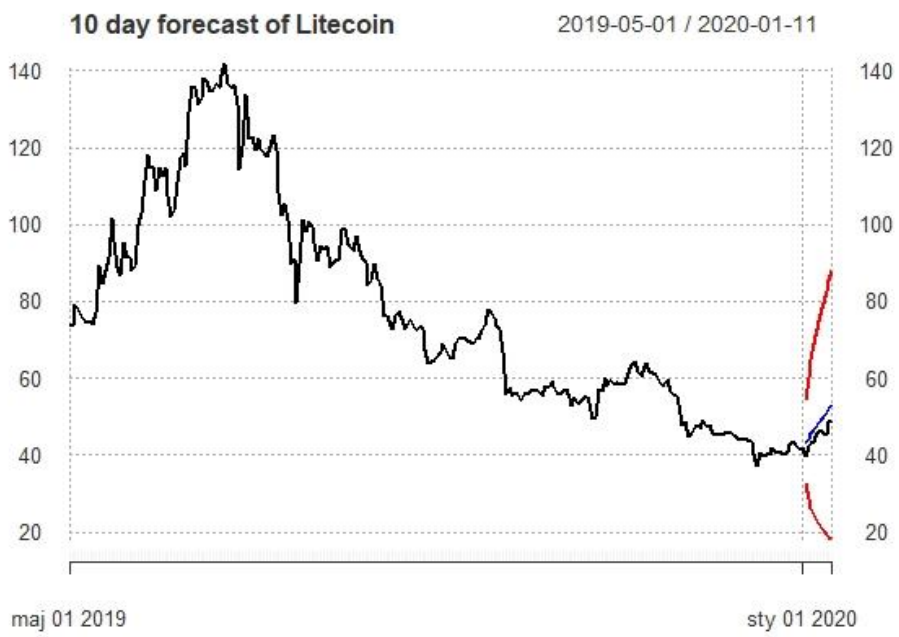
Unfortunately, the model demonstrates some problems regarding residuals - they are autocorrelated and do not the origin of normal distribution. To run the forecast we have reparametrized VEC into the VAR model and predicted 10-day-ahead forecasts for both BTC and LTC.

Figure 4. VECM Forecast for Bitcoin



Source: Own calculations based on the data from yahoo finance.

Figure 5. VECM Forecast for Litecoin



Source: Own calculations based on the data from yahoo finance.

From half of 2019, Litecoin lost more value than Bitcoin, and Litecoin´s model forecasts a larger upwards trend than in the case of Bitcoin, which is almost symmetrical. In Arima models for both cryptocurrencies upper and lower bounds where symmetrical.

Forecast comparison

Both presented model forecast prices accurately. There are not so many differences between them for Litecoin, but still, VEC is slightly better when we take into consideration MAE, MSE, MAPE, and AMAPE. There are higher differences in BTC. Here errors for the VEC model are almost half of these from the Arima model. Error measures are presented in Table 1:

Table 1. Error measures for both models.

Model	MAE	MSE	MAPE	AMAPE
Bitcoin – Arima	898.50	808356.43	0.11	0.06
Bitcoin - VEC	467.67	219042.95	0.06	0.03
Litecoin – Arima	3.38	11.51	0.07	0.04
Litecoin - VEC	3.27	10.73	0.07	0.03

Source: Own calculations based on the data from yahoo finance.