Academy of Economic Studies
Doctoral School of Finance and Banking - DOFIN

An economic analysis on bitcoin

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Motivation for choosing the topic

- Novelty character (faculty recommendation).
- The agresivity with which it appears in international transactions.
- Vastness of the topic.

- The possibility of performing research in an exciting and unexplored topic.

OBJECTIVES OF THE PAPER

- To understant what bitcoin is and how it's produced.
- To see if bitcoin is or not real money.
- To analyze the two exchange rate series: BTC/USD and BTC/EUR.
- Modelling an ARMA model and forecasting.
- Volatility analisys: ARCH, GARCH, EGARCH, TARCH.

Importance of the theme

- The long history of virtual currencies dating to 1982, when David Chaum first described a cryptographic system for untraceble payments.
- Understanding bitcoin, how it works, what it is and it's potential.
- Major international interest for this currency.

What is bitcoin?

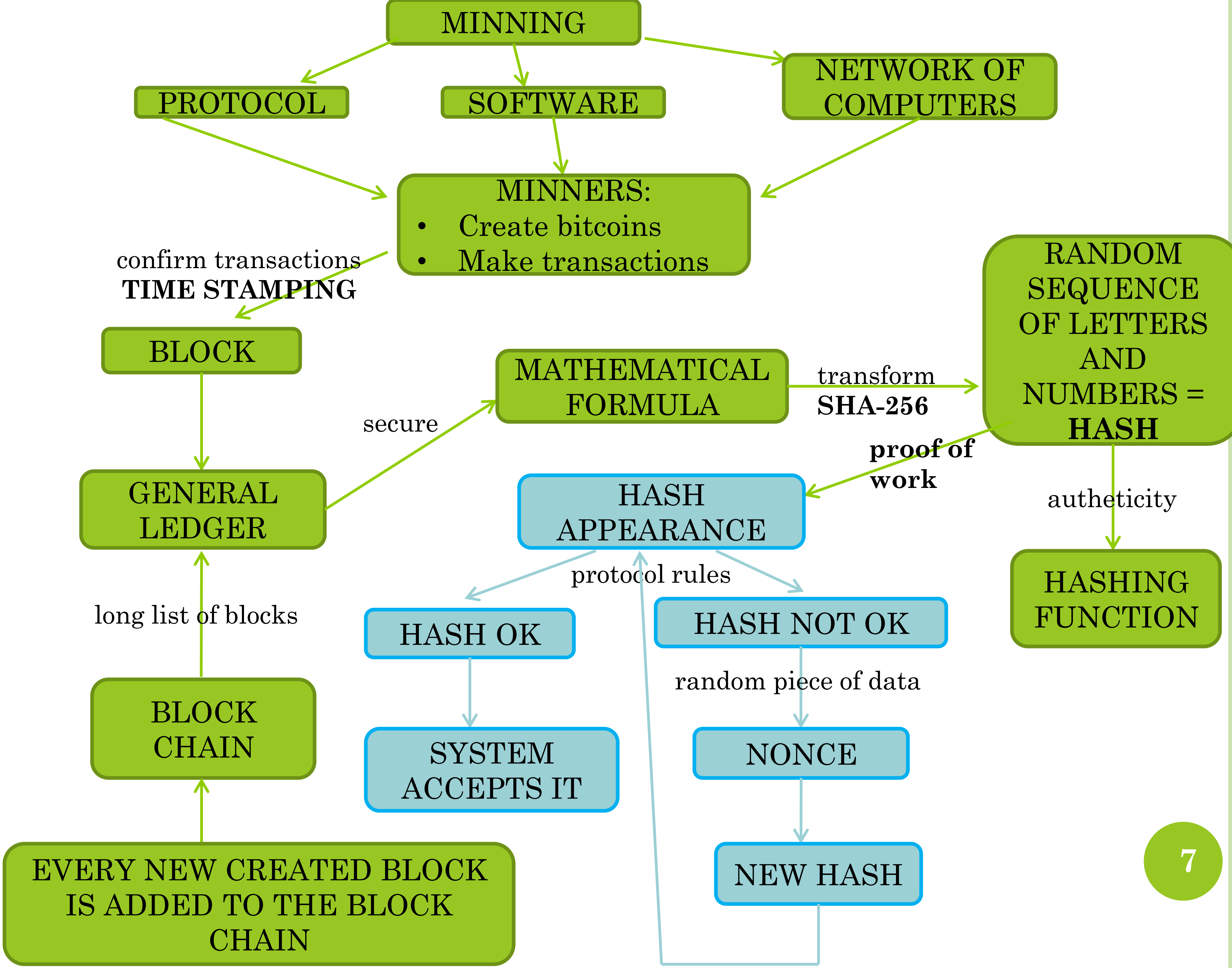
- The European Central Bank (ECB) defines virtual currency as „a type of unregulated, digital money, which is issued and usually controlled by it's developers, and used and accepted among the members of a specific virtual community"

- Bitcoin is the first cryptocurrency and it uses SHA-256 (a set of cryptographic hash functions designed by the U.S. National Security Agency) as it's ***proof-of-work*** scheme.

- The FBI says that bitcoin is a „*decentralized, peer-to-peer* (P2P) network-based *virtual currency* that provides a venue for individuals to generate, transfer, launder, and steal illicit funds with some anonymity."

How are bitcoins created

- Bitcoin are created throught a process called mining composed of three elements: protocol, software and network of computers.


MINNING
PROTOCOL
SOFTWARE
NETWORK OF COMPUTERS
MINNERS:
• Create bitcoins
• Make transactions
confirm transactions
TIME STAMPING
BLOCK
GENERAL LEDGER
secure
MATHEMATICAL FORMULA
transform
SHA-256
RANDOM SEQUENCE OF LETTERS AND NUMBERS = HASH
proof of work
autheticity
HASHING FUNCTION
HASH APPEARANCE
protocol rules
HASH OK
HASH NOT OK
SYSTEM ACCEPTS IT
random piece of data
NONCE
NEW HASH
long list of blocks
BLOCK CHAIN
EVERY NEW CREATED BLOCK IS ADDED TO THE BLOCK CHAIN

BITCOIN VS FIAT MONEY

SIMILARITIES

- no intrinsec value
- depends on peoples trust in the currency
- inconvertibility

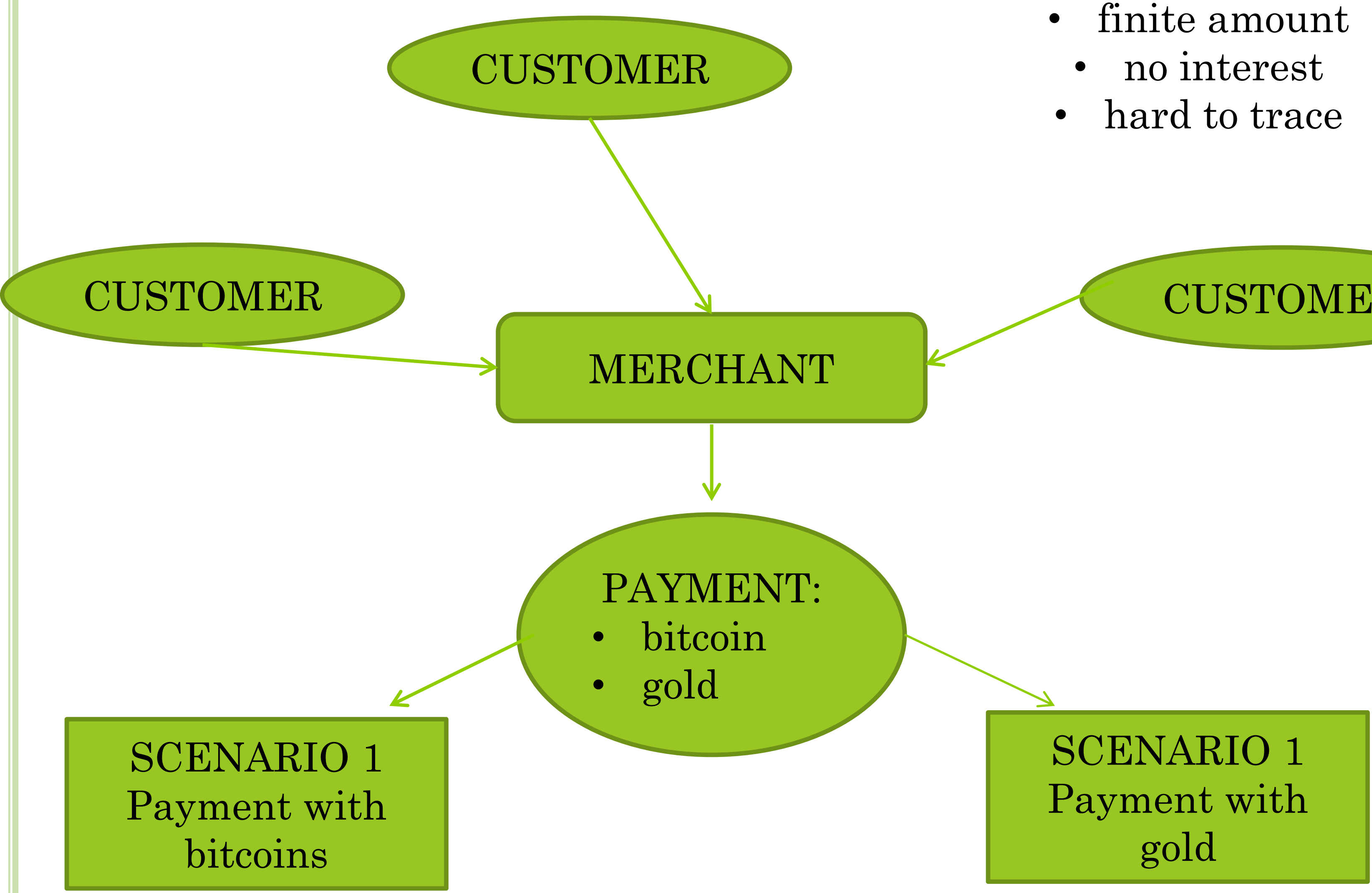
DIFFERENCES

- legal tender
- not backed by a commodity (gold or silver)

WHICH ONE IS BETTER - BITCOINS OR GOLD?

SIMILARITIES

- finite amount
- no interest
- hard to trace



Money functions

- According to the „Economics of Money, Banking and Financial Markets", Miskin, money have three functions:

- *Medium of Exchange* – money are used to pay for goods and services;

- *Unit of Account* – money are used to measure the value of different goods and services;

- *Store of Value* – „used to save purchasing power from the time income is received until the time it is spent."

Bitcoin – money or commodity?

The oppinions about bitcoin are divide throughout the world.

- ECB classifies it as a virtual currency scheme with bidirectional flow.
- Germany defined them as private money and financial instrument.
- Denmark doesn't consider bitcoin a currency nor asset.
- IRS stated that for tax purposes „virtual currency is treated as a property.- General tax principles applicable to property transactions apply to transactions using virtual currency. "
- Countries like Iceland and Vietman, made bitcoin illegal due to lack of laws applicable for virtual currency.

BITCOINS IN THE WORLD

BITBILLS

CASASCIUS BITCOIN POS

CASASCIUS BITCOIN COINS

BITCOIN ATM ROMANIA

BITCOIN OPTIONS

Expires	Option	Profit(%)	Units	Price(€)	Return(€)	
15.04.14	Bitcoin/USD 701.4 ↑	70 %	1	€ 50	€ 85	BUY »
	Will bitcoin price (as defined in the general terms) touch or go above 701.4 at 16:00 15.04.14					
15.04.14	Bitcoin/USD 651.3 ↑	50 %	1	€ 50	€ 75	BUY »
	Will bitcoin price (as defined in the general terms) touch or go above 651.3 at 16:00 15.04.14					
15.04.14	Bitcoin/USD 350.5 ↓	50 %	1	€ 50	€ 75	BUY »
	Will bitcoin price (as defined in the general terms) touch or go below 350.5 at 16:00 15.04.14					
15.04.14	Bitcoin/USD 301.10 ↓	70 %	1	€ 50	€ 85	BUY »
	Will bitcoin price (as defined in the general terms) touch or go below 301.10 at 16:00 15.04.14					
30.04.14	Bitcoin/USD 701.4 ↑	70 %	1	€ 50	€ 85	BUY »
	Will bitcoin price (as defined in the general terms) touch or go above 701.4 at 16:00 30.04.14					
30.04.14	Bitcoin/USD 651.3 ↑	50 %	1	€ 50	€ 75	BUY »
	Will bitcoin price (as defined in the general terms) touch or go above 651.3 at 16:00 30.04.14					
30.04.14	Bitcoin/USD 370.4 ↓	50 %	2	€ 100	€ 150	BUY »
	Will bitcoin price (as defined in the general terms) touch or go below 370.4 at 16:00 30.04.14					
30.04.14	Bitcoin/USD 301.10 ↓	70 %	2	€ 100	€ 170	BUY »
	Will bitcoin price (as defined in the general terms) touch or go below 301.10 at 16:00 30.04.14					
15.05.14	Bitcoin/USD 701.4 ↑	70 %	2	€ 100	€ 170	BUY »
	Will bitcoin price (as defined in the general terms) touch or go above 701.4 at 16:00 15.05.14					

COINKITE BITCOIN POS

BITCOIN WALLET

DATA CONSTRUCTION AND ANALYSIS

- The set of variables are the price of the following exchange rates: BTC/USD, BTC/EUR.

- The frame of the data spans from 19th July 2010 to 23th May 2014, which is almost 4 years of daily series data, counting 1405 observations, the computing of the data was done with Eviews 7, and the source for all data is http://www.oanda.com/currency/historical-rates/ .

- The two series BTC/USD and BTC/EUR were transformed to a logarithmical form and they can be found under the named l_btc_usd respectively l_btc_eur, using the generate option, after which I applied the first difference operator on both logarithmical forms obtaining a daily price variation named dl_btc_usd respectively dl_btc_eur.

- The commands are:
- l_btc_usd=log(btc_usd)
- l_btc_eur=log(btc_eur)
- dl_btc_usd= l_btc_usd-l_btc_usd(-1)
- dl_btc_eur= l_btc_eur-l_btc_eur(-1)

ABOUT STATISTICS

- ***Skewness*** is an indicator of asymetry and deviation from the normal distribution. This indicator can take three different values pozitive, zero or negative.

- The formula for skweness is:

$$S = \frac{1}{n} \times \frac{\sum_{i=1}^{n}(y_i - \bar{y})^3}{{\sigma^2}^{3/2}} \text{ and } \sigma^2 = \frac{1}{n} \times \sum_{i=1}^{n}(y_i - \bar{y})^2$$

- ***Kurtosis*** is an indicator which describes the distribution of the series around it's mean, it's a measure for the probability peakness and it's based on a scaled version of the fourth moment. This indicator can also take three values greater, equal or lower than 3.

- The formula for kurtosis is:

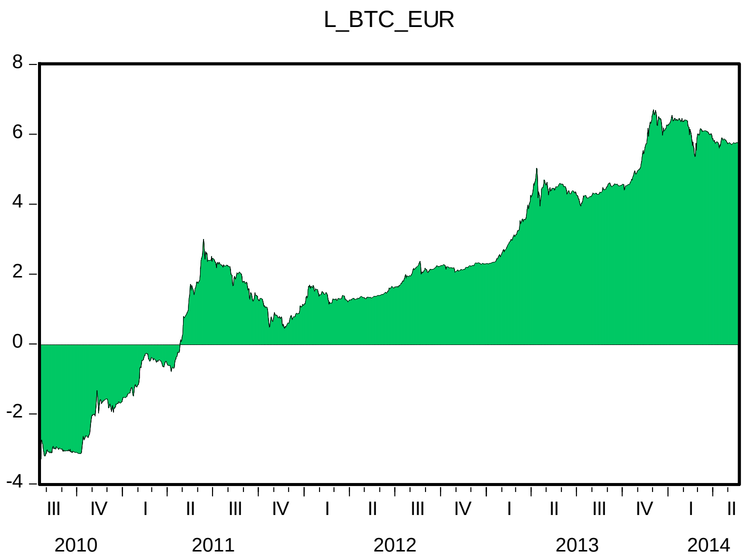
$$K = \frac{1}{n} \times \frac{\sum_{i=1}^{n}(y_i - \bar{y})^4}{{\sigma^2}^2}$$

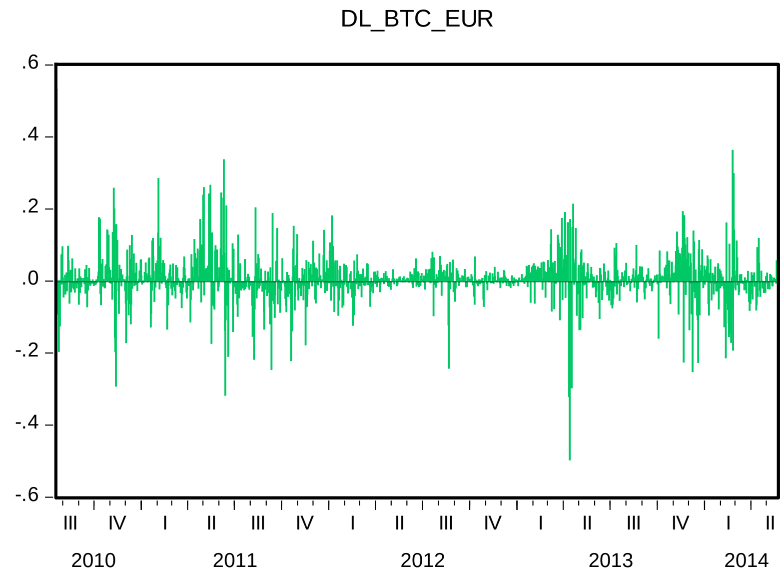
- ***Jarque-Bera*** (Charles Jarque and Anil Bera, 1979) is a test for goodness-of-fit, meaning that it shows whether the series have the skewness and kurtosis matching of a normal distribution.

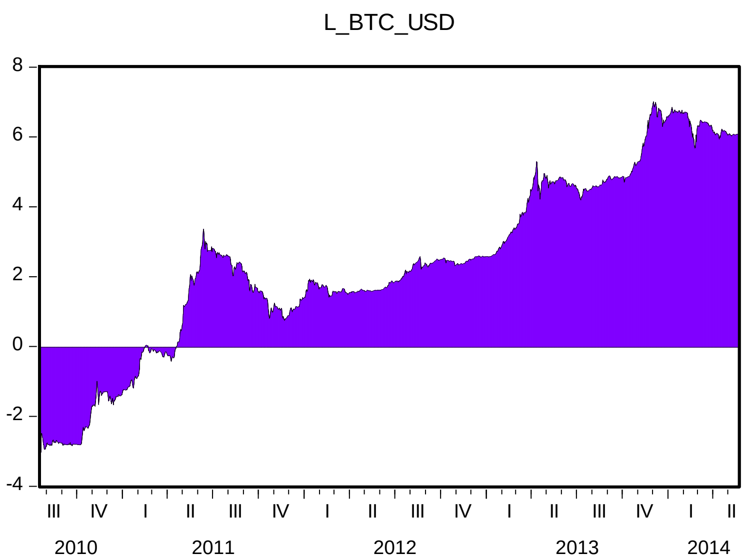
- The formula for Jarque-Bera test is:

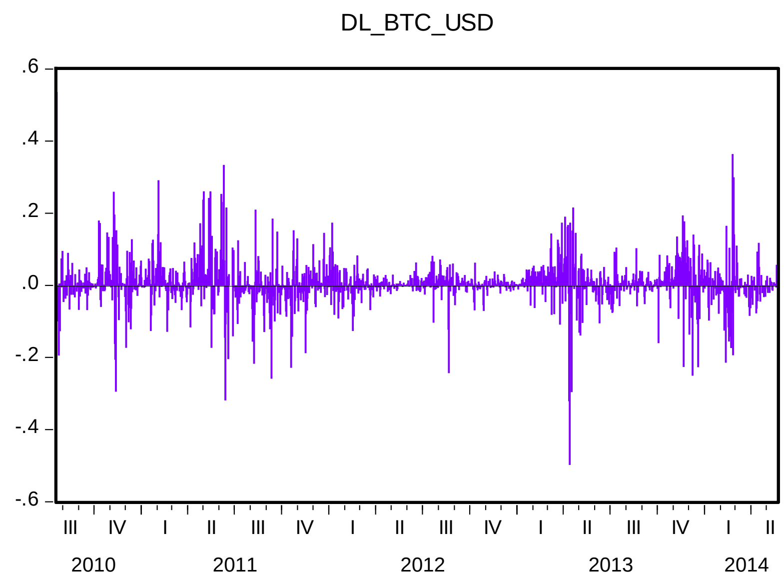
$$JB = \frac{n}{6} \times \left(S^2 + \frac{1}{4} (K-3)^2 \right)$$

Representation of L_BTC and DL_BTC









Unit root testing – Augmented Dickey Fuller

- Augmented Dickey Fuller (David Dickey and Wayne Arthur Fuller, 1981) is a unit root test for large and complicated time series. The ADF t-statistic is a negative number and the more negative it is compared to the critical values, the rejection of the null hypothesis „the series has a unit root" is stronger meaning that the series is stationary.

- The test for unit root was done in level, include in test equation: intercept (constant), lag lenght was on automatic selection Schawrz Info Critirion with maximum lags:23 for l_btc_usd and l_btc_eur series.

Unit root testing – Kwiatkowski-Phillips-Schmidt-Shin

- Kwiatkowski-Phillips-Schmidt-Shin (Denis Kwiatkowski, Peter Charles Bonest, Youngcheol Shin, Peter Schmidt; 1992) is used for testing the null hypothesis that a time series is stationarity. KPSS is often used to reinforce the results obtaind in the ADF test. The acceptance of the null hypothesis is based on the value of t – statistic being smaller than all the critical values

- The test for unit root was done in level, include in test equation: intercept (constant), spectral estimation method: default (Bartlett kernel), bandwidth : Newey – West Bandwidth for both series.

ADF TEST

ADF	t-Statistic	Probability	Critical values	
l_btc_usd	-1.101536	0.7172	1%	-3.434802
			5%	-2.863393
			10%	-2.567806
l_btc_eur	-1.09288	0.7206	1%	-3.434802
			5%	-2.863393
			10%	-2.567806

KPSS TEST

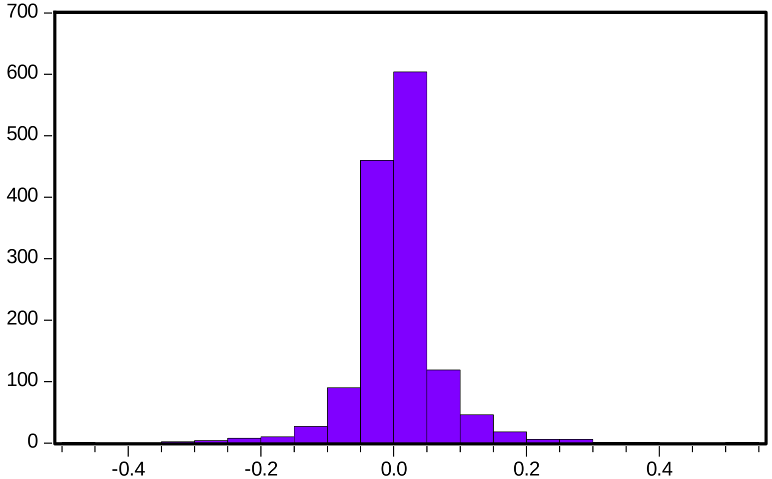
KPSS (level)	t-Statistic	Critical values	
l_btc_usd	4.00177	1%	0.739
		5%	0.463
		10%	0.347
l_btc_eur	4.032417	1%	0.739
		5%	0.463
		10%	0.347

UNIT ROOT TESTIN - ADF AND KPSS 1ST DIFFERENCE

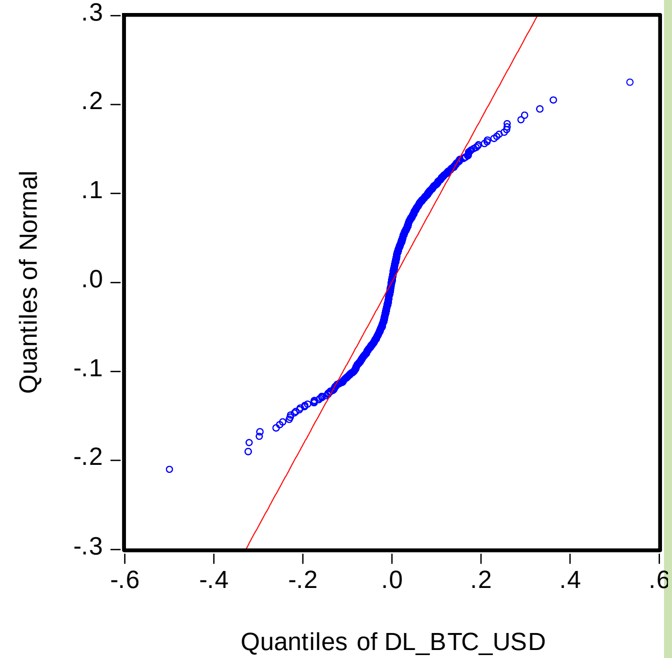
Unit root test	Series	t-Statistic	Probability	Critical values	
ADF	dl_btc_usd	-30.70504	0.0000	1%	-3.434802
				5%	-2.863393
				10%	-2.567806
	dl_btc_eur	-30.68699	0.0000	1%	-3.434802
				5%	-2.863393
				10%	-2.567806
KPSS	dl_btc_usd	0.161037	-	1%	0.739000
				5%	0.463000
				10%	0.347000
	dl_btc_eur	0.153664	-	1%	0.739000
				5%	0.463000
				10%	0.347000

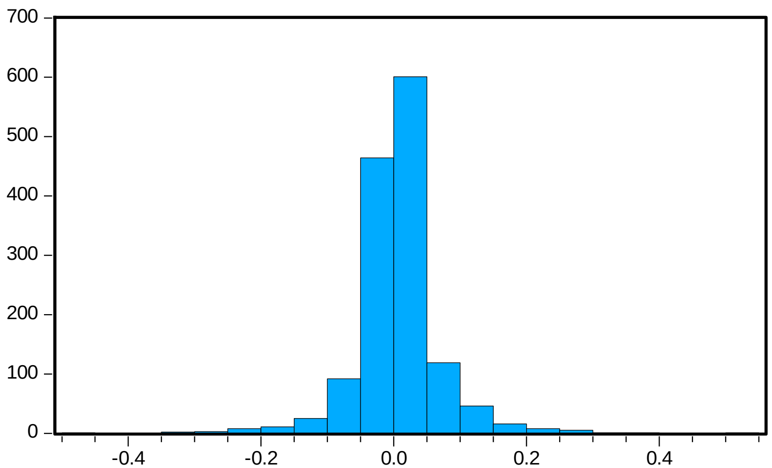
Series distribution

kernel density graph

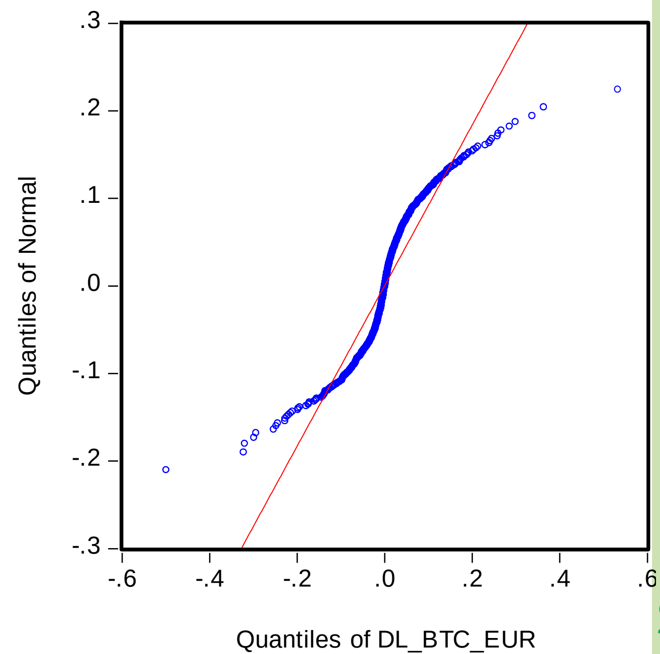


Series: DL_BTC_USD	
Sample 7/19/2010 5/23/2014	
Observations 1404	
Mean	0.006574
Median	0.003665
Maximum	0.535962
Minimum	-0.497501
Std. Dev.	0.064298
Skewness	0.123719
Kurtosis	13.90817
Jarque-Bera	6964.388
Probability	0.000000





Series: DL_BTC_EUR	
Sample 7/19/2010 5/23/2014	
Observations 1404	
Mean	0.006534
Median	0.003788
Maximum	0.533542
Minimum	-0.497720
Std. Dev.	0.064210
Skewness	0.130415
Kurtosis	13.87479
Jarque-Bera	6922.248
Probability	0.000000



ARMA - CORRELOGRAM

Table: UNTITLED Workfile: UNTITLED::Untitled\

View | Proc | Object | Print | Name | Edit+/- | CellFmt | Grid+/- | Title | Comments+/-

Correlogram of CORRELOGRAM_L_BTC_USD

Date: 05/25/14 Time: 01:20
Sample: 7/19/2010 5/23/2014
Included observations: 1405

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.997	0.997	1400.5	0.000
		2	0.995	0.033	2794.9	0.000
		3	0.992	0.002	4183.4	0.000
		4	0.990	-0.001	5566.0	0.000
		5	0.987	-0.009	6942.5	0.000
		6	0.985	-0.034	8312.5	0.000
		7	0.982	-0.016	9675.8	0.000
		8	0.979	-0.013	11032.	0.000
		9	0.976	0.001	12382.	0.000
		10	0.973	-0.001	13725.	0.000
		11	0.971	0.001	15061.	0.000
		12	0.968	-0.013	16390.	0.000
		13	0.965	-0.000	17713.	0.000
		14	0.962	0.001	19028.	0.000
		15	0.959	-0.015	20337.	0.000
		16	0.956	-0.001	21638.	0.000
		17	0.953	-0.005	22932.	0.000
		18	0.950	-0.007	24220.	0.000
		19	0.947	-0.005	25500.	0.000
		20	0.944	-0.003	26773.	0.000
		21	0.941	-0.005	28039.	0.000
		22	0.938	-0.015	29297.	0.000
		23	0.935	-0.006	30548.	0.000

Table: CORRELOGRAM_DL_BTC_USD Workfile: UNTITLED::Untitled\

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Correlogram of DL_BTC_USD

Date: 05/25/14 Time: 01:19
Sample: 7/19/2010 5/23/2014
Included observations: 1404

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.220	0.220	68.297	0.000
		2	-0.006	-0.058	68.355	0.000
		3	-0.067	-0.056	74.769	0.000
		4	0.025	0.055	75.621	0.000
		5	0.084	0.066	85.473	0.000
		6	0.101	0.068	99.761	0.000
		7	-0.037	-0.071	101.65	0.000
		8	-0.040	-0.005	103.88	0.000
		9	0.007	0.024	103.94	0.000
		10	0.053	0.031	107.95	0.000
		11	0.088	0.062	118.91	0.000
		12	0.061	0.035	124.26	0.000
		13	-0.010	-0.013	124.40	0.000
		14	0.067	0.086	130.75	0.000
		15	-0.012	-0.058	130.95	0.000
		16	0.028	0.029	132.04	0.000
		17	0.034	0.020	133.66	0.000
		18	-0.017	-0.037	134.05	0.000
		19	0.004	0.026	134.07	0.000
		20	0.034	0.018	135.68	0.000
		21	0.079	0.073	144.60	0.000
		22	0.046	0.004	147.61	0.000
		23	0.014	-0.002	147.88	0.000

Table: CORRELOGRAM_L_BTC_EUR Workfile: UNTITLED::Untitled\

View | Proc | Object | Print | Name | Edit+/- | CellFmt | Grid+/- | Title | Comments+/-

Correlogram of L_BTC_EUR

Date: 05/25/14 Time: 01:19
Sample: 7/19/2010 5/23/2014
Included observations: 1405

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.997	0.997	1400.5	0.000
		2	0.995	0.033	2795.1	0.000
		3	0.992	0.002	4183.8	0.000
		4	0.990	-0.000	5566.7	0.000
		5	0.987	-0.009	6943.5	0.000
		6	0.985	-0.034	8313.9	0.000
		7	0.982	-0.016	9677.7	0.000
		8	0.979	-0.013	11035.	0.000
		9	0.976	0.001	12385.	0.000
		10	0.974	-0.002	13729.	0.000
		11	0.971	0.001	15065.	0.000
		12	0.968	-0.014	16395.	0.000
		13	0.965	-0.000	17719.	0.000
		14	0.962	0.001	19035.	0.000
		15	0.960	-0.014	20344.	0.000
		16	0.957	-0.001	21647.	0.000
		17	0.954	-0.006	22942.	0.000
		18	0.951	-0.006	24230.	0.000
		19	0.948	-0.005	25511.	0.000
		20	0.945	-0.003	26786.	0.000
		21	0.942	-0.005	28053.	0.000
		22	0.939	-0.015	29312.	0.000
		23	0.936	-0.007	30565.	0.000

Table: CORRELOGRAM_DL_BTC_EUR Workfile: UNTITLED::Untitled\

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Correlogram of DL_BTC_EUR

Date: 05/25/14 Time: 01:19
Sample: 7/19/2010 5/23/2014
Included observations: 1404

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.221	0.221	68.540	0.000
		2	-0.003	-0.054	68.552	0.000
		3	-0.066	-0.056	74.729	0.000
		4	0.022	0.053	75.427	0.000
		5	0.082	0.066	84.889	0.000
		6	0.103	0.071	99.983	0.000
		7	-0.035	-0.072	101.74	0.000
		8	-0.038	-0.004	103.82	0.000
		9	0.008	0.026	103.91	0.000
		10	0.053	0.030	107.84	0.000
		11	0.090	0.065	119.42	0.000
		12	0.062	0.033	124.90	0.000
		13	-0.009	-0.012	125.01	0.000
		14	0.064	0.082	130.75	0.000
		15	-0.015	-0.060	131.08	0.000
		16	0.028	0.030	132.16	0.000
		17	0.032	0.017	133.65	0.000
		18	-0.017	-0.037	134.08	0.000
		19	0.001	0.023	134.08	0.000
		20	0.032	0.017	135.50	0.000
		21	0.079	0.074	144.45	0.000
		22	0.049	0.006	147.94	0.000
		23	0.015	-0.003	148.26	0.000

ARMA – Autoregressive moving average

- Autoregressive Moving Average model, ARMA for short, was first described by Peter Whittle in 1951. ARMA models are used to describe stationary time series and it represents time series that are generated by passing a white noise test (recursive filter) – AR(p), and also a non-recursive linear filter – MA(q), consecutively.
-
- The AR(p) model is describes by:

$$X_t = c + \sum_{i=1}^{p} \rho_i X_{t-i} + \varepsilon_t$$

- Where:
- ε_t – white noise process, with a zero mean and a constant variance if the series is normal distributed;
- c – constant;
- ρ_i – coefficients.

- MA(q) model represent the moving average of older q with white noise errors and is described by:

$$X_t = \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

- Where θ_i are the MA coefficients.

- Combining the two previous model we get ARMA(p,q) model and is described as follows:

$$X_t = \varepsilon_t + \sum_{i=1}^{p} \rho_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

ARMA ESTIMATION – MODEL SELECTION

- AIC (1973-1974) is a measure of the relative quality, of a statistical model for a given set of data, proides a mean for model selection; deals with a tradeoff between the goodness of fit of the model. Can't tell anything about a tests null hypothesis.

- SC (Gideon E Schwarz 1978), a criterion for model selection among a finite set of models. It is based on the likelihood function and it's closely related ro AIC.

- The basic information criteria are given by the following formulas:

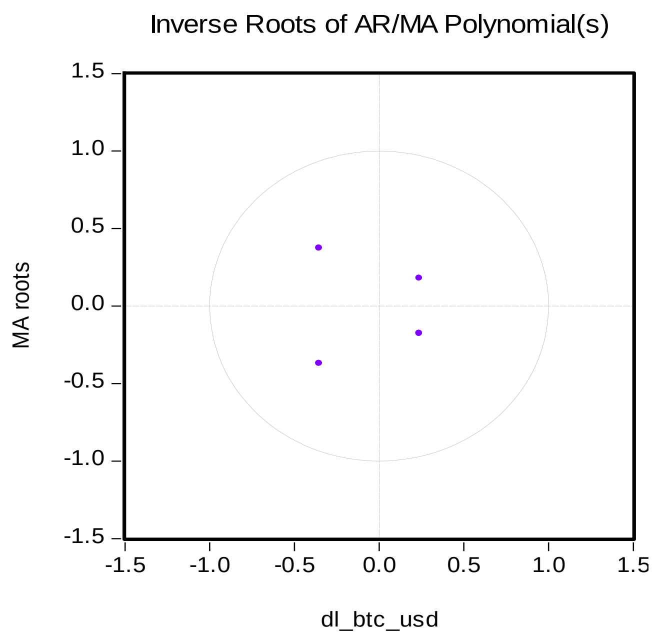
$$AIC = -2\frac{l}{T} + 2\frac{k}{T}$$

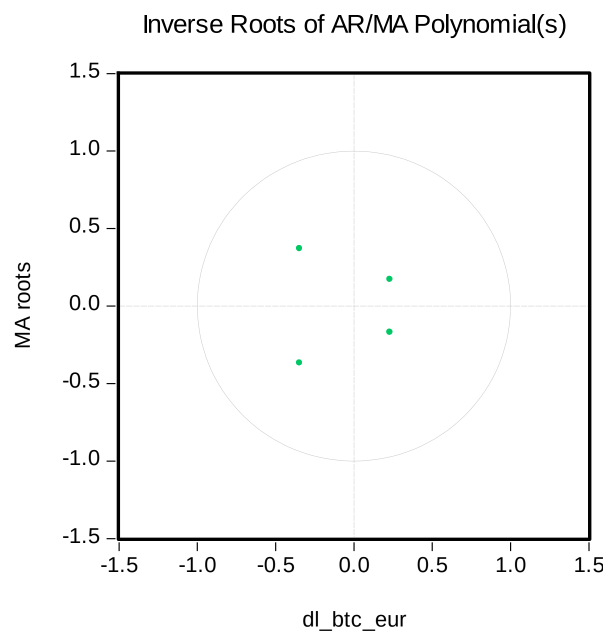
$$SC = -2\frac{l}{T} + \frac{k\ logT}{T}$$

- Where l – the value of the likelihood function with k parameters estimated using T observation and the criterions are baed on (-2) times the average log likelihood function, adjusted by a penalty function.

Moving Average estimation

- To estimate the MA(4) I generated a new eguation for each exchange rate that looks like:
- dl_btc_usd c dl_btc_usd(-1) ma(1) ma(2) ma(3) ma(4)
- dl_btc_eur c dl_btc_eur(-1) ma(1) ma(2) ma(3) ma(4)
- and it’s estimated with LS- Least Sequence Squared (NLD and ARMA) method
- Let’s take a look at the at the characteristic polynomial roots, graph and tabel representations.





Inverse Roots of AR/MA Polynomial(s)
Specification: DL_BTC_USD C DL_BTC_USD(-1)
MA(1) MA(2) MA(3) MA(4)
Date: 05/25/14 Time: 02:09
Sample: 7/19/2010 5/23/2014
Included observations: 1403

MA Root(s)	Modulus	Cycle
-0.351885 ± 0.372220i	0.512221	2.698825
0.237943 ± 0.178296i	0.297332	9.770665

No root lies outside the unit circle.
ARMA model is invertible.

Inverse Roots of AR/MA Polynomial(s)
Specification: DL_BTC_EUR C DL_BTC_EUR(-1)
MA(1) MA(2) MA(3) MA(4)
Date: 05/25/14 Time: 02:22
Sample: 7/19/2010 5/23/2014
Included observations: 1403

MA Root(s)	Modulus	Cycle
-0.344400 ± 0.368567i	0.504433	2.705575
0.231383 ± 0.170535i	0.287437	9.892523

No root lies outside the unit circle.
ARMA model is invertible.

Table: MA4_CORREL_DL_BTC_USD Workfile: UNTITLED::Untitled\

Correlogram of Residuals

Date: 05/25/14 Time: 02:10
Sample: 7/21/2010 5/23/2014
Included observations: 1403
Q-statistic probabilities adjusted for 4 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.001	0.001	0.0004	
		2	0.001	0.001	0.0024	
		3	-0.009	-0.009	0.1143	
		4	0.010	0.010	0.2533	
		5	0.057	0.057	4.8406	0.028
		6	0.118	0.119	24.619	0.000
		7	-0.059	-0.059	29.458	0.000
		8	-0.025	-0.026	30.368	0.000
		9	0.008	0.010	30.465	0.000
		10	0.029	0.023	31.656	0.000
		11	0.071	0.059	38.704	0.000
		12	0.055	0.049	42.915	0.000
		13	-0.038	-0.023	44.995	0.000
		14	0.095	0.099	57.805	0.000
		15	-0.039	-0.048	59.926	0.000
		16	0.023	0.008	60.664	0.000
		17	0.047	0.034	63.868	0.000
		18	-0.031	-0.035	65.269	0.000
		19	0.006	0.014	65.324	0.000
		20	0.025	0.006	66.180	0.000
		21	0.068	0.083	72.821	0.000
		22	0.023	0.012	73.589	0.000

Table: MA4_CORREL_DL_BTC_EUR Workfile: UNTITLED::Untitled\

Correlogram of Residuals

Date: 05/25/14 Time: 02:22
Sample: 7/21/2010 5/23/2014
Included observations: 1403
Q-statistic probabilities adjusted for 4 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.000	0.000	0.0003	
		2	0.001	0.001	0.0023	
		3	-0.009	-0.009	0.1105	
		4	0.010	0.010	0.2456	
		5	0.055	0.055	4.5135	0.034
		6	0.122	0.122	25.419	0.000
		7	-0.058	-0.058	30.165	0.000
		8	-0.025	-0.025	31.024	0.000
		9	0.010	0.012	31.168	0.000
		10	0.028	0.023	32.303	0.000
		11	0.073	0.062	39.823	0.000
		12	0.054	0.047	43.979	0.000
		13	-0.036	-0.021	45.854	0.000
		14	0.091	0.095	57.712	0.000
		15	-0.041	-0.050	60.048	0.000
		16	0.023	0.009	60.813	0.000
		17	0.046	0.032	63.767	0.000
		18	-0.031	-0.035	65.124	0.000
		19	0.004	0.012	65.144	0.000
		20	0.023	0.004	65.881	0.000
		21	0.068	0.083	72.469	0.000
		22	0.026	0.014	73.458	0.000

Autoregressive estimation

- To estimate the AR(1) I generated a new equation for each exchange rate, that looks like:
- dl_btc_usd c dl_btc_usd(-1)
- dl_btc_eur c dl_btc_eur(-1)
- and it's estimated whit LS- Least Sequence Squared (NLD and ARMA) method.
- AR coefficient is smaller than 1 which means that the equation is stable.

Dependent Variable: DL_BTC_USD
Method: Least Squares
Date: 05/25/14 Time: 07:35
Sample (adjusted): 7/21/2010 5/23/2014
Included observations: 1403 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.004753	0.001641	2.896699	0.0038
DL_BTC_USD(-1)	0.220356	0.025391	8.678376	0.0000

R-squared	0.051015	Mean dependent var	0.006197
Adjusted R-squared	0.050338	S.D. dependent var	0.062747
S.E. of regression	0.061147	Akaike info criterion	-2.749631
Sum squared resid	5.238361	Schwarz criterion	-2.742152
Log likelihood	1930.866	Hannan-Quinn criter.	-2.746836
F-statistic	75.31422	Durbin-Watson stat	1.945339
Prob(F-statistic)	0.000000		

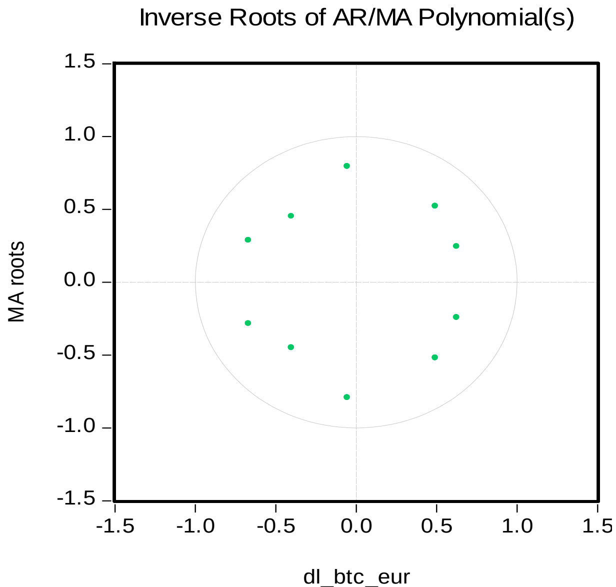
Dependent Variable: DL_BTC_EUR
Method: Least Squares
Date: 05/25/14 Time: 07:41
Sample (adjusted): 7/21/2010 5/23/2014
Included observations: 1403 after adjustments

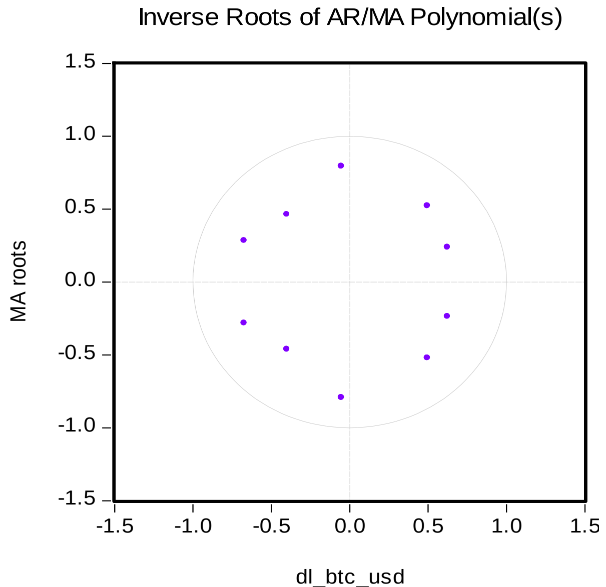
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.004722	0.001639	2.881223	0.0040
DL_BTC_EUR(-1)	0.220752	0.025393	8.693270	0.0000

R-squared	0.051181	Mean dependent var	0.006159
Adjusted R-squared	0.050504	S.D. dependent var	0.062671
S.E. of regression	0.061068	Akaike info criterion	-2.752228
Sum squared resid	5.224774	Schwarz criterion	-2.744750
Log likelihood	1932.688	Hannan-Quinn criter.	-2.749433
F-statistic	75.57294	Durbin-Watson stat	1.947826
Prob(F-statistic)	0.000000		

ARMA ESTIMATION

- To estimate ARMA, I generated a new eguation for each exchange rate that looks like:
- dl_btc_usd c dl_btc_usd(-1) ma(5) ma(6) ma(7) ma(8) ma(9) ma(10)
- dl_btc_eur c dl_btc_eur(-1) ma(5) ma(6) ma(7) ma(8) ma(9) ma(10)
- and the MA value starting at 5 is justified by the serial correlation that exists starting with the fifth lag. The equation is estimated whit LS- Least Sequence Squared (NLD and ARMA) method.
- The inverted roots are in the unit circle for both series and the modulus of the characteristic polynomial roots is smaller than 1, meaning that the ecuation is stable.





Inverse Roots of AR/MA Polynomial(s)

Specification: DL_BTC_USD C DL_BTC_USD(-1)
MA(5) MA(6) MA(7) MA(8) MA(9) MA(10)
Date: 05/25/14 Time: 08:30
Sample: 7/19/2010 5/23/2014
Included observations: 1403

MA Root(s)	Modulus	Cycle
-0.051429 ± 0.792755i	0.794421	3.841566
-0.672177 ± 0.282881i	0.729277	2.290418
0.497047 ± 0.522779i	0.721356	7.751041
0.625330 ± 0.237736i	0.668997	17.29469
-0.398771 ± 0.461824i	0.610164	2.752091

No root lies outside the unit circle.
ARMA model is invertible.

Inverse Roots of AR/MA Polynomial(s)

Specification: DL_BTC_EUR C DL_BTC_EUR(-1)
MA(5) MA(6) MA(7) MA(8) MA(9) MA(10)
Date: 05/25/14 Time: 08:45
Sample: 7/19/2010 5/23/2014
Included observations: 1403

MA Root(s)	Modulus	Cycle
-0.052625 ± 0.793801i	0.795544	3.838244
-0.666866 ± 0.285577i	0.725440	2.295661
0.493270 ± 0.520966i	0.717440	7.731258
0.627357 ± 0.243019i	0.672782	17.00131
-0.401136 ± 0.450714i	0.603368	2.734126

No root lies outside the unit circle.
ARMA model is invertible.

Correlogram ARMA(1, 10)

Table: ARMA110_CORRE_DL_BTC_USD Workfile: UNTITLED::Untitled\

Correlogram of Residuals

Date: 05/25/14 Time: 08:30
Sample: 7/21/2010 5/23/2014
Included observations: 1403
Q-statistic probabilities adjusted for 6 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.022	0.022	0.6873	
		2	-0.028	-0.029	1.7946	
		3	-0.064	-0.063	7.5976	
		4	0.042	0.044	10.092	
		5	-0.002	-0.007	10.096	
		6	-0.007	-0.008	10.161	
		7	-0.000	0.006	10.161	0.001
		8	-0.014	-0.017	10.436	0.005
		9	-0.000	0.000	10.436	0.015
		10	0.005	0.005	10.469	0.033
		11	0.058	0.056	15.275	0.009
		12	0.059	0.059	20.225	0.003
		13	-0.032	-0.031	21.655	0.003
		14	0.087	0.099	32.284	0.000
		15	-0.045	-0.049	35.126	0.000
		16	0.016	0.015	35.490	0.000
		17	0.027	0.041	36.522	0.000
		18	-0.029	-0.046	37.752	0.000
		19	0.007	0.021	37.829	0.000
		20	0.015	0.018	38.159	0.000
		21	0.074	0.065	45.922	0.000
		22	0.012	0.014	46.116	0.000

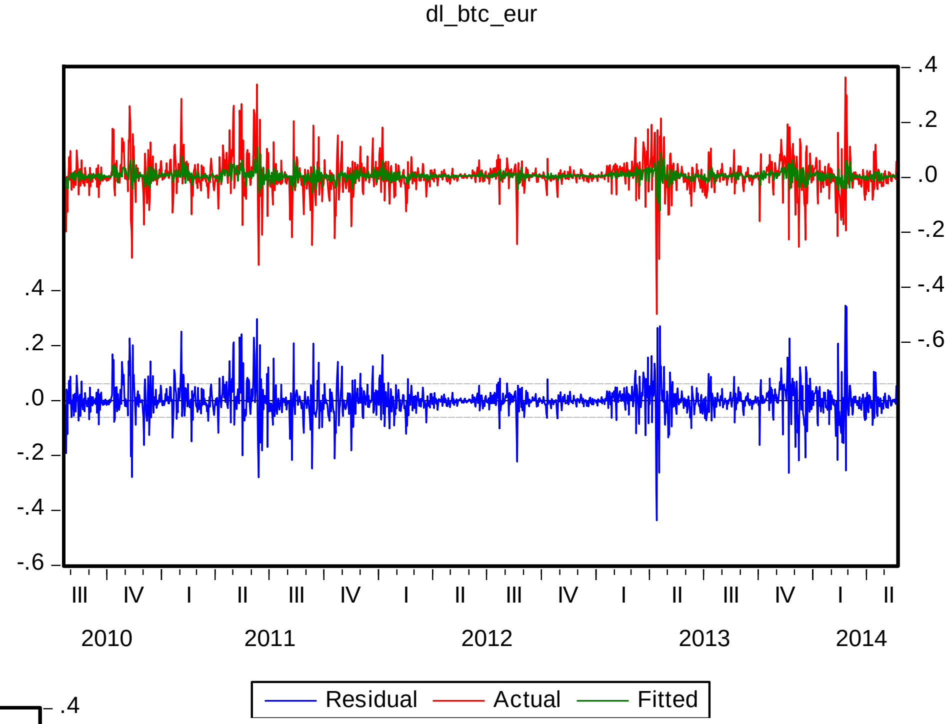
le: ARMA110_CORRE_DL_BTC_EUR Workfile: UNTITLED::Untitled\

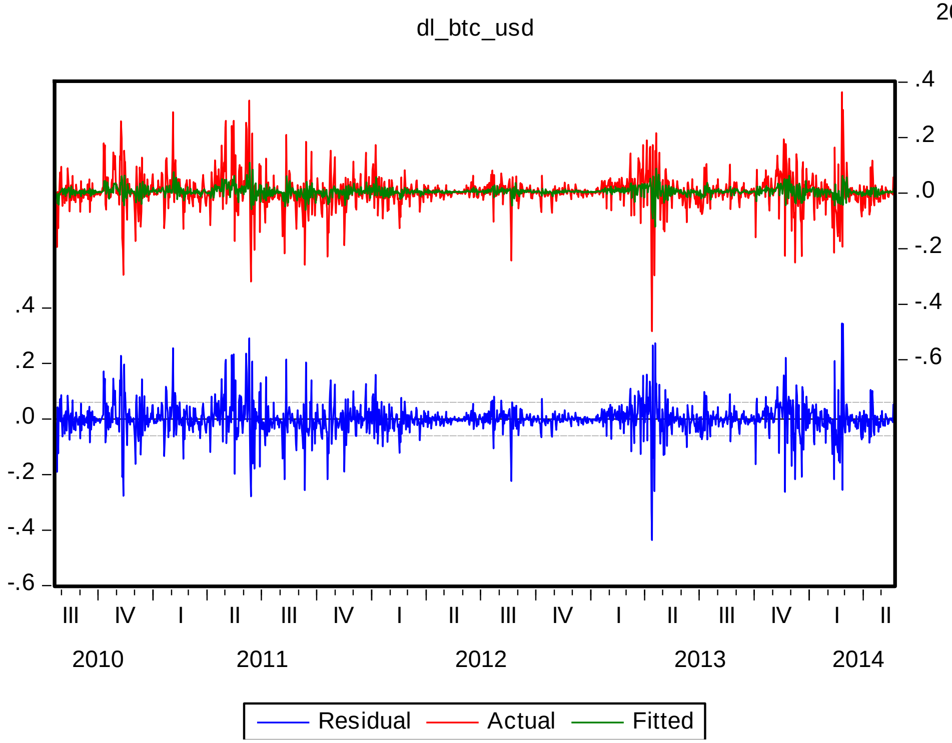
Correlogram of Residuals

Date: 05/25/14 Time: 08:45
Sample: 7/21/2010 5/23/2014
Included observations: 1403
Q-statistic probabilities adjusted for 6 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.021	0.021	0.6252	
		2	-0.025	-0.026	1.5097	
		3	-0.064	-0.063	7.2077	
		4	0.040	0.042	9.4155	
		5	-0.002	-0.007	9.4238	
		6	-0.007	-0.009	9.4891	
		7	-0.000	0.005	9.4891	0.002
		8	-0.014	-0.017	9.7737	0.008
		9	0.001	0.001	9.7743	0.021
		10	0.005	0.005	9.8034	0.044
		11	0.061	0.059	15.078	0.010
		12	0.059	0.058	20.016	0.003
		13	-0.030	-0.030	21.305	0.003
		14	0.084	0.096	31.299	0.000
		15	-0.047	-0.051	34.445	0.000
		16	0.016	0.015	34.819	0.000
		17	0.025	0.039	35.718	0.000
		18	-0.029	-0.045	36.914	0.000
		19	0.005	0.018	36.948	0.000
		20	0.013	0.016	37.206	0.001
		21	0.073	0.065	44.864	0.000
		22	0.014	0.016	45.158	0.000

RESIDUAL, ACTUAL, FILTERED DATA ARMA(1, 10)

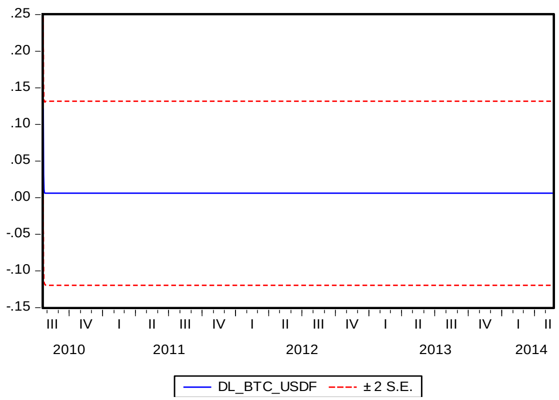




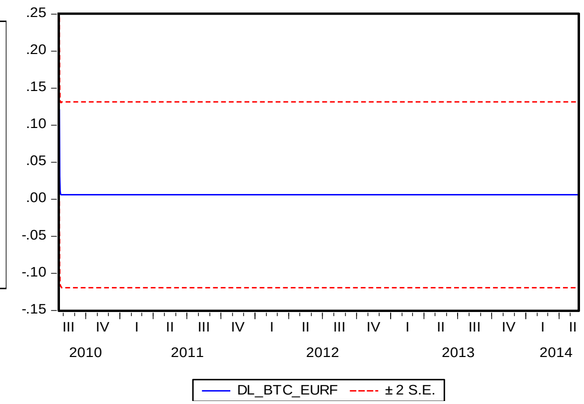
ARMA MODELS - COMPARISON

	MA(4)		AR(1)		ARMA(1,10)	
	dl_btc_usd	dl_btc_eur	dl_btc_usd	dl_btc_eur	dl_btc_usd	dl_btc_eur
Adjusted R-squared	0.058673	0.058137	0.050338	0.0504	**0.066713**	**0.06716**
Akaike info criterion	-2.755604	-2.757457	-2.749631	-2.752228	**-2.762763**	**-2.76581**
Schwarz criterion	-2.733168	-2.735021	**-2.742152**	**-2.74475**	-2.732848	-2.735766

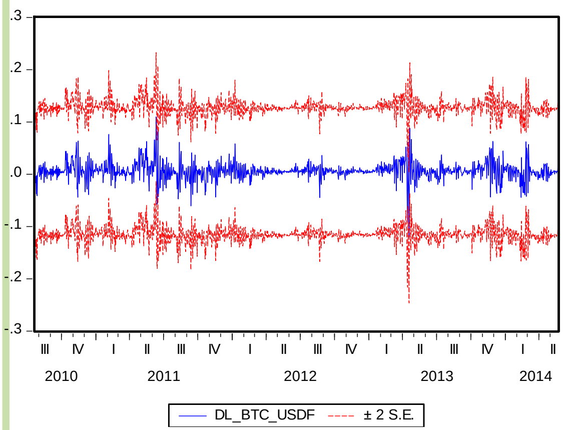
FORECAST ARMA(1,10)



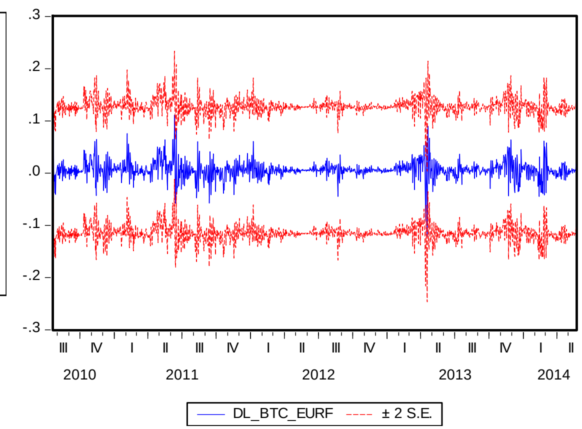
Forecast: DL_BTC_USDF	
Actual: DL_BTC_USD	
Forecast sample: 7/19/2010 5/23/2014	
Adjusted sample: 7/21/2010 5/23/2014	
Included observations: 1403	
Root Mean Squared Error	0.062848
Mean Absolute Error	0.037851
Mean Abs. Percent Error	195.9082
Theil Inequality Coefficient	0.897754
Bias Proportion	0.000000
Variance Proportion	0.898179
Covariance Proportion	0.101821



Forecast: DL_BTC_EURF	
Actual: DL_BTC_EUR	
Forecast sample: 7/19/2010 5/23/2014	
Adjusted sample: 7/21/2010 5/23/2014	
Included observations: 1403	
Root Mean Squared Error	0.062766
Mean Absolute Error	0.037945
Mean Abs. Percent Error	190.1320
Theil Inequality Coefficient	0.898045
Bias Proportion	0.000000
Variance Proportion	0.898338
Covariance Proportion	0.101662



Forecast: DL_BTC_USDF	
Actual: DL_BTC_USD	
Forecast sample: 7/19/2010 5/23/2014	
Adjusted sample: 7/21/2010 5/23/2014	
Included observations: 1403	
Root Mean Squared Error	0.060445
Mean Absolute Error	0.036774
Mean Abs. Percent Error	241.6502
Theil Inequality Coefficient	0.747047
Bias Proportion	0.000000
Variance Proportion	0.577921
Covariance Proportion	0.422079



Forecast: DL_BTC_EURF	
Actual: DL_BTC_EUR	
Forecast sample: 7/19/2010 5/23/2014	
Adjusted sample: 7/21/2010 5/23/2014	
Included observations: 1403	
Root Mean Squared Error	0.060357
Mean Absolute Error	0.036856
Mean Abs. Percent Error	222.6150
Theil Inequality Coefficient	0.746456
Bias Proportion	0.000000
Variance Proportion	0.576666
Covariance Proportion	0.423334

VOLATILITY ANALYSIS
ARCH

- ARCH (autoregressive conditional heterskedasticity, intoduced by Robert Fry Engle, 1982) models are used for modelling financial time series and assumes that the variance of the current error term or innovation (the difference between the observed value of a variable at time *i* and the optimal forecast of that value based on information available prior to time *i*) to be function of the actual size of the previous time periods error terms, often the variance is related to the squares of previous innovations.

- The error terms ε_t is composed of two stochastic terms z_t (white noise) and standard deviation σ_t .

$$\varepsilon_t = z_t \sigma_t$$

- The representation of ARCH(p) variance σ_t^2 is as followed:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \cdots + \alpha_q \epsilon_{t-q}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2$$

- Where: $\alpha_0 > 0$ and $\alpha_i > 0$, i > 0.

- The ARCH testing is done with the estimation method: ARCH and the orders are as follows: ARCH – 1, GARCH – 0 and Treshold - 0, error distribution – normal.

GARCH

- GARCH (generalized autoregressive conditional heteroskedasticity) is a generalized ARCH model introduced by Tim Petter Bollerslev in 1986.

- The representation of GARCH (p,q) variance is as follows:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \beta_i \sigma_{t-i}^2 \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2$$

- Where ω a constant.

- The GARCH testing is done with the estimation method: ARCH and the orders are as follows: ARCH – 1, GARCH – 1 and Treshold - 0, error distribution – normal.

EGARCH

- EGARCH model (exponential generalized autoregressive conditional heteroskedasticity) was introduced by Nelson in 1991 and is another form of GARCH.

- The representation of EGARCH variance is as follows:

- $log\ (\sigma_t^2) =$
$$\omega + \sum_{j=1}^{q} \beta_i \log\left(\sigma_{t-j}^2\right) + \sum_{i=1}^{p} \alpha_i \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\sigma_{t-k}}$$

- The GARCH testing for is done with the estimation method: EGARCH and the orders are as follows: ARCH – 1, GARCH – 1 and Asymmetric order – 0, error distribution – normal.

TARCH

- TARCH (Treshold autoregressive conditional heteroskedasticity) was introduced independently by Zakoian (1994) and Glosten.

- The generalized representantion of TARCH variance is as followed:

- $\sigma_t^2 = \omega + \sum_{j=1}^{q} \beta_i \sigma_{t-i}^2 \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + \sum_{k=1}^{r} \delta_k \, \varepsilon_{t-k}^2 \bar{I}_{t-k}$

- Where: $\bar{I}_{t-k}$ =1 if ε_t< 0 and zero otherwise.

- The GARCH testing for is done with the estimation method: EGARCH and the orders are as follows: ARCH – 1, GARCH – 1 and trashold – 1, error distribution – normal.

VOLATILITY MODELS - COMPARISON

	ARCH 1		GARCH 1_1		EGARCH 1_1		TARCH 1_1_1	
	dl_btc_usd	dl_btc_eur	dl_btc_usd	dl_btc_eur	dl_btc_usd	dl_btc_eur	dl_btc_usd	dl_btc_eur
Log likelihood	2120.676	2121.752	2309.084	2306.274	**2316.511**	**2313.593**	2309.173	2306.443
Akaike info criterion	-3.018057	-3.01959	-3.28505	-3.281017	**-3.2956**	**-3.290019**	-3.283722	-3.279834
Schwarz criterion	-3.010583	-3.012115	-3.273808	-3.269805	**-3.284389**	**-3.27507**	-3.268773	-3.264885

ARCH LM-TEST

Heteroskedasticity Test: ARCH		dl_btc_usd		
F-statistic	0.201248	Prob. F(1,1401)		0.6538
Obs*R-squared	0.201506	Prob. Chi-Square(1)		0.6535

Heteroskedasticity Test: ARCH		dl_btc_eur		
F-statistic	0.285457	Prob. F(1,1401)		0.5932
Obs*R-squared	0.285806	Prob. Chi-Square(1)		0.5929

CONCLUSION

- Comparison of any classic or gold coins can not be achieved in practice without involving state organizations, and this contradicts the fundamental principle of virtual currency, therefore not be under state control and be managed by specific rules (banking and financial system).
- The increase in the use of bitcoins and other similar virtual currencies might lead to a decrease in the use of real money, reducing the cash needed to conduct transactions.
- From the conducted research, besides that bitcoin can be currency financial assets, property, also appears the probability that bitcoin can be used as a real weapon to destroy and control the financial system.
- ARMA (1,10) is the best model to estimate the forecast, based on the values of adjuster R-squared, Akaike info criterion and Schwarz criterion.
- Altough I chose the best ARMA model, the forecast of bitcoin is very complicated and the result are not conclusive, because the series are very volatile and it's very difficult to estimate future outcome. The future of bitcoin relying only on it's developers and users.
- The volatility analysis has determined that the best model is EGARCH (1,1), and both series have an assymetrical distribution to the left, leptokurtic and normal distribution.
- Attempts of econometric application on the current series have proven that can be applied to a point, beyond which analysis parameters can not be common to Bitcoin and other currencies.
- In my opinion Bitcoin power should not be neglected, but rather should support users of this currency with respect to the risks and benefits of transactions made.

PROPOSAL

- The creation on an educational system by the developers, for users.
- Collect all the official statements of state organisation, financial institutions, states etc and centralize all the oppinions about bitcoin and see the frequency with which they appear.
- I commit to post this paper, to be public to all persons interested in this topic, to discuss and clarify what is Bitcoin ultimately.
- To try and understand the general trend of bitcoin and see what and how influences it.

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THANK YOU VERY MUCH FOR YOUR ATTENTION !

Q & A