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# COMPARATIVE ANALYSIS OF VOLATILITY OF CRYPTOCURRENCIES AND FIAT MONEY

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## Abstract

The object of the research is the leading national fiat currencies and transnational anonymous analogues of the currency. They have received the slang name of cryptocurrencies. The subject of the study is volatility. It is the most important financial indicator in the management of financial flows, as a measure of risk of using a financial instrument at a specified time interval. The subject of the research requires consideration of digital goods of limited emission, which are the product of energy conversion into information in the form of a program code on a tangible medium. The limited amount of the emission for these goods without the syndrome of “printing press” has served as a basis for the name “cryptocurrency” and “digital gold”. The issue of cryptocurrency is a reward in the competitive procedure of checking transactions in peer-to-peer networks that implement the technology of distributed registries, and it is essentially a by-product of their functioning. The significant feature of such a product is anonymity and cross-border. They give rise to fundamental legal issues. Cryptocurrency obtaining technology is available to general public and has become an innovative phenomenon. The latest financial phenomena need to be investigated, so it is necessary to conduct a multilateral scientific analysis, identification and comparison of cryptocurrency with the fiat currency. The article compares the volatility of different currencies such as fiat (US dollar, euro, Chinese yuan and Japanese yen) and the most popular cryptocurrencies (Bicoin, Litecoin, Ethereum and Monero) at the present time. The aim of the study is to obtain new estimates of cryptocurrency based on the use of tools such as GARCH model, simple historical volatility (SHV) and developed by the authoring tool, which is based on the Chaikin method.

**Keywords**

Cryptocurrency – Blockchain – Volatility assessment – Assessment methods – Fiat currency

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## Introduction

The domain name bitcoin.or was registered on 18 August 2008, and the document "Bitcoin P2P e-cash paper" was published on 31 October, it introduced the digital good, bitcoin (bit is a unit of measure for the amount of information, coin is a penny), it was called the virtual currency (cryptocurrency). [1]

Bitcoin[2] is a decentralized peer-to-peer digital virtual currency (*cryptocurrency*) system in which a blockchain is *a key innovation*. In fact, the blockchain is a specialized distributed database designed to handle time-ordered data, such as financial transactions[3].

Nick Szabo, the inventor of the idea of smart-contracts, considers "real financial instruments are already somewhat decentralized due to the human blockchain consisting of accountants, auditors, etc., checking each other's work"[4].

Since 2014, the theme of databases based on blockchains has become popular among banks and other financial institutions. Several prototypes and models have been announced using the technology of blockchains. In some cases, the Bitcoin Blockchain is used directly. Several examples are mentioned below:

• The Estonian LHV Bank is testing Cuber (Cryptographic Universal Blockchain Entered Receivables), a payment system based on the colored coins, organized on top of the Bitcoin Blockchain[5].

• Similarly, the stock exchange NASDAQ plans to use one of the Open Assets Protocol for coloring the bitcoins to provide a full cycle of securities management[6].

• The largest French bank BNP Paribas, according to some information, is exploring possible ways to integrate bitcoins into the currency reserves of the bank[7].

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[1]http://ru.bitcoinwiki.org/%D0%98%D1%81%D1%82%D0%BE%D1%80%D0%B8%D1%8F_Bitcoins – История Bitcoins

[2] Satoshi Nakamoto, Bitcoin: A peer-to-peer electronic cash system. 2008. Retrieved 05.12.2017 from: https://bitcoin.org/bitcoin.pdf

[3] Matt Levine, "Blockchain for banks probably can't hurt". Bloomberg View, (2015). Retrieved 05.12.2017 from: http://www.bloombergview.com/articles/2015-09-01/blockchain-for-banks-probablycan-t-hurt

[4] Ian Allison & Nick Szabo, "If banks want benefits of blockchains they must go permissionless". International Business Times, (2015). Retrieved 05.12.2017 from: http://www.ibtimes.co.uk/nick-szabo-if-banks-want-benefits-blockchains-they-mustgo-permissionless-1518874

[5] Leon Pick, "Estonia's LHV Bank Testing Colored Coins-Based 'Cuber'". Finance Magnates, (2015). Retrieved 05.12.2017 from: http://www.financemagnates.com/cryptocurrency/news/estonias-lhv-bank-testingcolored-coins-based-cuber/

[6] Nasdaq launches enterprise-wide blockchain technology initiative. 2015. Retrieved 05.12.2017 from:
http://www.nasdaqomx.com/newsroom/pressreleases/pressrelease?messageId=1361706&displayLanguage=en
VI. Nasdaq and Chain to partner on blockchain technology initiative. 2015. Retrieved 05.12.2017 from:
http://www.nasdaqomx.com/newsroom/pressreleases/pressrelease?messageId=1373282&displayLanguage=en

[7] Ian Allison, "The French bitcoin revolution: BNP Paribas testing crypto on its currency funds". International Business Times, (2015). Retrieved 05.12.2017 from: http://www.ibtimes.co.uk/french-bitcoin-revolution-bnp-paribas-plans-add-cryptoits-currency-funds-1512360

• The British Bank Barclays has launched a partnership with the bitcoin exchange Safello to explore possible applications of the blockchain technology in the financial sector[8].

• Goldman Sachs has published the report "Future of finance. Payment: redefining the way we pay in the next decade"[9]. Goldman Sachs has also taken part in the financing of $ 50 million for the Bitcoin startup Circle[10].

## The review of popular cryptocurrencies

The article considers the most popular cryptocurrencies, among the top five to assess their volatility.

*Bitcoin* (BTC) was historically the first cryptocurrency, the system was launched on 9 January 2009[11]. Its creator is allegedly Satoshi Nakamoto. In the Bitcoin system, all payments are public, and each user can see where and how many virtual coins are sent, but for real security, both the actual senders and recipients are encrypted. Bitcoin is often compared to gold in the financial world[12].

*Litecoin.* If bitcoin is called gold in the world of cryptocurrency, then Litecoin (Lightcoin) is called silver. Litecoin was launched on 7 October 2011 on the basis of bitcoin technology. The creator Charlie Lee proposed an alternative to BTC. In contrast to the original source, the transaction confirmation time is shortened in Litecoin. Thanks to the chain of blocks, the number of transactions, that the system can process, is significantly increased.

*Ethereum*. It is particularly popular as "Ether" in the Russian segment. It was developed by the Russian programmer Vitalik Buterin. For the first time the author expressed the idea of creating Ethereum in the Bitcoin Magazine in the late 2013, the presentation of the currency was successfully held in the same year. After this, the active fundraiser was performed in the specialized sites for the founders of start-ups.

*Monero.* Monero is in the top five in terms of capitalization. In contrast to the bitcoin, there is no restriction on emissions from users in this currency. The system was launched on 25 April 2014 with the goal of maximum anonymity for payments. The main feature of this cryptocurrency is the use of the CryptoNote protocol. The essence of the protocol states that all payments are mixed and merged, after that it is difficult to track them. Vulnerability can be identified as a deficiency in comparison with the bitcoin.

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[8] Grace Caffyn, "Barclays trials Bitcoin tech with pilot program". CoinDesk, (2015). Retrieved 05.12.2017 from: http://www.coindesk.com/barclays-trials-bitcoin-tech-with-pilot-program/

[9] Joon Ian Wong, "Goldman Sachs report says Bitcoin could shape 'future of finance'". CoinDesk, (2015). Retrieved 05.12.2017 from: http://www.coindesk.com/goldman-sachs-report-says-bitcoin-could-shape-future-offinance/

[10] Emily Spaven, "Circle raises $50 million with Goldman Sachs support". CoinDesk, (2015). Retrieved 05.12.2017 from: http://www.coindesk.com/circle-raises-50-million-with-goldman-sachs-support/

[11] S. Nakamoto, "Bitcoin v O. l. Released". The Mail Archive. 09.01.2009.

[12] A. Fork, Bitcoin. More than money (JSC: Tver regional printing house, 2014); N. Popper, Digital gold: Bitcoin and the inside story of the misfits (Moscow: LLC "I. Williams", 2016); Paul Vigna & Michael J. Casey, The Age of Cryptocurrency: How Bitcoin and digital money are challenging the global economic order (Moscow: Mann, Ivanov and Ferber, 2017) y S. Raval, Decentralized applications: Blockchain Technology in action. L. Kiselev & Yu. Sergienko (eds) (Saint Petersburg: Publishing house Piter, 2017).

The number of cryptocurrencies is now in the thousands, but in the overwhelming case, all of them are clones with some modifications and developments of the most popular systems, such as bitcoin and Litecoin.

Blockchain has a tremendous opportunity in the field of increasing the level of cybersecurity[13] and protecting financial networks from hacker attacks, because it uses the Proof-of-work (PoW), "the proof of work performance". The PoW mechanism prevents the problem of double-rate fraud in the network, suppressing the requirements of secondary payment and denying the success of the previous transaction. The "proof of work performance" mechanism solves the problem of securing for the secondary payment through the network miners, who can search for cryptographic evidence with the help of their equipment. The Proof-of-work mechanism depends on the consumption of electric and processing power, but this is the only known mechanism for preventing attacks, in which the hacker, as a rule, receives resources illegally.

## Methodology

The article presents some intermediate results of the initiative inter-University research work carried out at the Department of "Financial monitoring", National Research Nuclear University MEPhI (G. Krylov, L. Polyakov) and the Department of "Information security" of Financial University (I. Sheremet, G. Krylov, Yu. Beketnova) obtained on the basis of previous work performed[14] . As a scientific-methodological apparatus the tools of fundamental and technical analysis of the markets, cluster and factor analysis method, neural networks etc. have been used. Volatility has been tested on the basis of SHV model (Simple Historical Volatility), it is a model of simple historical volatility by calculation and method of simple (equally weighted) moving average, a model of autoregressive conditional heteroscedasticity, or abbreviated – ARCH (Autoregressive Conditional Heteroscedastic, the author is Robert Engle, 1982), GARCH model (Generalized Autoregressive Conditional Heteroscedasticity, the author is Tim Bollerslev, 1986), Chaikin Volatility model or oscillator (developed by trader Chaikin as an indicator for analyzing the moment of the Accumulation Distribution Line). Chaikin volatility (CHV) allows you to determine the difference between the maximum and the minimum rate in one time interval[15]. With the help of Chaikin method, it is possible to carry out a qualitative analysis for the changing ranges of maximums and minimums. But CHV fails to take into account the exchange rate breaks. It relates to disadvantages.

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[13] Yu. Beketnova; P. Kolesnikov & G. Krylov, Technology of a blockchain Analysis attacks, the protection strategy (Saarbrücken: LAP LAMBERT Academic Publishing, 2017).

[14] G. Krylov; V. Naumov & D. Sat, Neural networks in time series forecasting problems of Bitcoin exchange rate (Saarbrücken: LAP LAMBERT Academic Publishing, 2016); A. Kasatkin; G. Krylov; I. Kornev & D. Sat "Investigation of money laundering methods through cryptocurrency". Journal of Theoretical and Applied Information Technology, vol: 83 num 2 (20th January 2016): 244-254; G. Krylov & I. Loskutov, Is cryptocurrency a future without inflation or new AML/CFT issues? Proceedings of the international scientific-practical conference of the network Institute "Threats and risks to the world economy", November 1-3, 2016. Moscow; G. Krylov & D. Sat, Formation and adaptation of signs of deviant financial transactions in the problems of assessment of cryptocurrency transactions on the example of Bitcoin. Proceedings of the international scientific-practical conference of the network Institute "Threats and risks to the world economy", November 1-3, 2016. Moscow y A. Aydaralieva; G. Krylov; D. Mochalin & D. Sat, "Research and approbation of the method of cluster analysis using neural networks for the evaluation of BITCOIN'S transactions". Informatization and communication, num 3 (2017): 107-111.

[15] O. Demidov, Obzor mezhdunarodnogo regulirovanija kriptovaljuty.

The method allows to consider volatility increase on a short time interval (three- and ten- day), with the high probability of currency rate approaching to its minimum or maximum. When volatility falls over medium and long periods, it is assumed that the rate has reached its point (minimum/maximum).

This method allows generating signals based on the intersection of the zero line for high- and low- level charts of minimums for the cost rates, as well as high- and low- level charts of maximums for the indicator-oscillator, pointing the reversal of the directional rate up[16]/down[17].

The task of calculating the volatility of cryptocurrencies in comparison with the fiat currencies requires a systematic approach. Moving average method was been used to solve the problem. The initial data on the rate of cryptocurrencies were taken from the public sites[18] and transferred to the tabular data, the data on the rate of fiat currencies – dollar, euro, yuan were taken from the database of the Bank of Russia[19].

Volatility was calculated based on initial data for the period 2013-2017. When determining the volatility for the year on the basis of available daily data, a significant error is allowed, the standard deviation follows the “mean reversion” process (return to the average). In this case, volatility fluctuates around the average value in the long term (the minimum values increase and the maximum values decrease, trying to get closer to the average value). In this regard, the time interval of 10 trading days is taken to calculate volatility, the duration of the year – the number of trading days is taken to be 250 days (including weekends and holidays). Relative volatility is defined as the standard deviation of daily changes in the rate for 10 days, assigned to the average value of the rate during this period and divided by the square root of 10/250, equal to 0.2.

**The program implementation of methodology**

To implement automated calculations of the currency volatility, the software was developed in the programming language C ++ on the platform of Visual Studio 2017 regarding to Windows operating system.

It has been implemented in the software:

• SHV, GARCH (1.1) methods and Chaikin method, which are given above;
• graphical display of information on the tabular presentation implemented in the Math.net library, an example is shown in the Figure 1;
• uploading to excel and MySQL database;
• uploading data from excel and from the database, an example is shown in the Figures 2, 3;
• mathematical model, performed by means of C ++ library, Math.net.

[16] uptrend is the a Bullish divergence model
[17] downtrend is a Bearish divergence model
[18] For instance, retrieved 10.05.2017 from:http://www.eurasiangroup.org/ru/; Crypto Currency, retrieved 11.05.2017 from: http://www.cryptocurrencychart.com/
[19] Retrieved 12.05.2017 from: http://www.cbr.ru/-currency_base/dynamics.aspx/

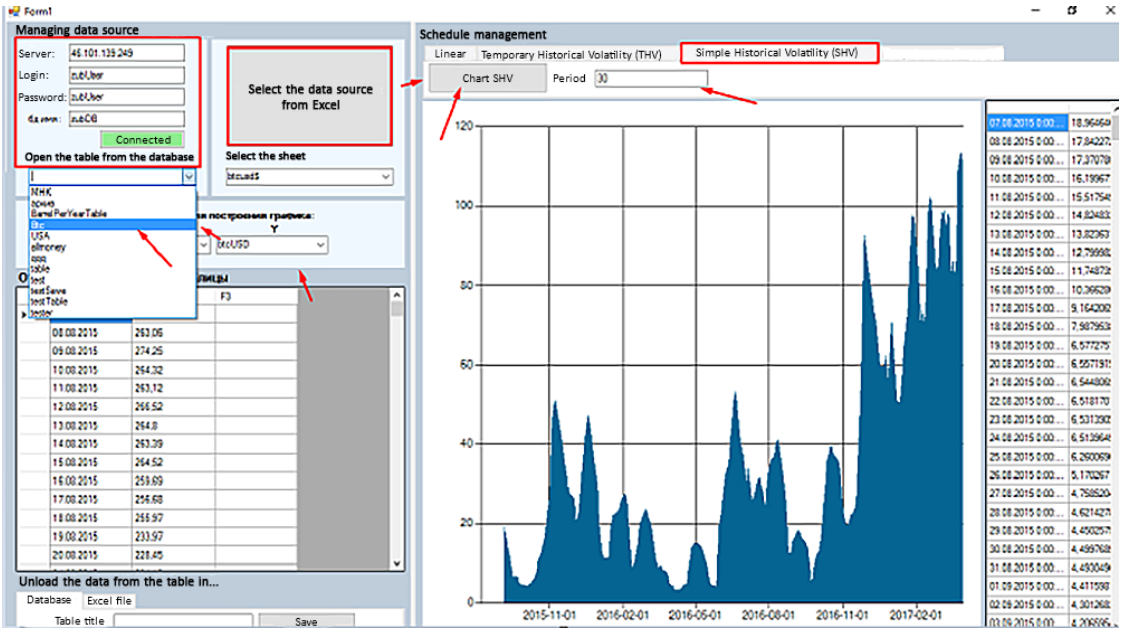


Fig. 1
Graphic representation of calculations.
The source is the screenshot of the program's screen

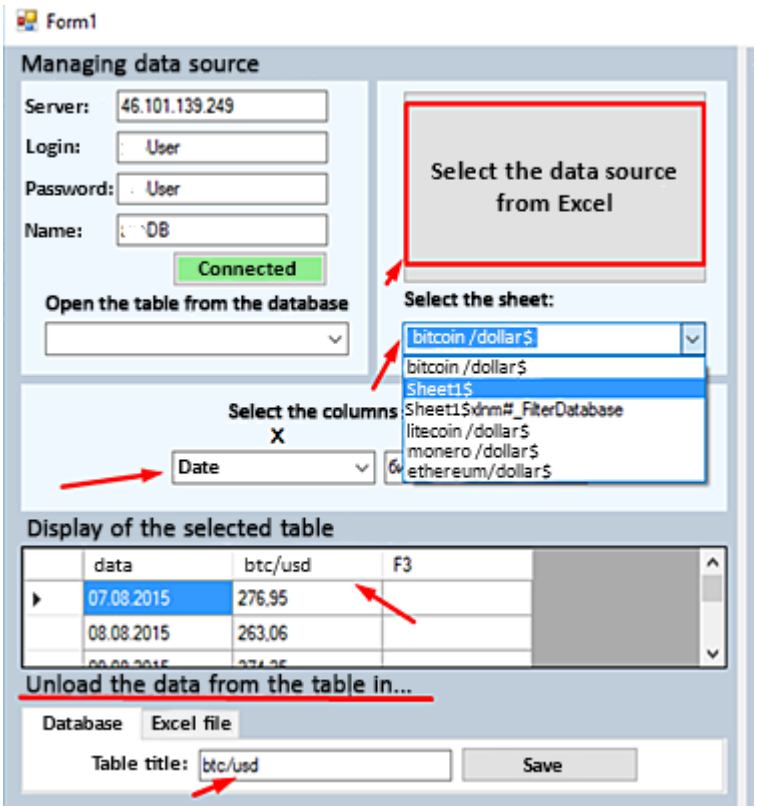


Fig. 2
The example of entering into the database
The source is the screenshot of the program's screen

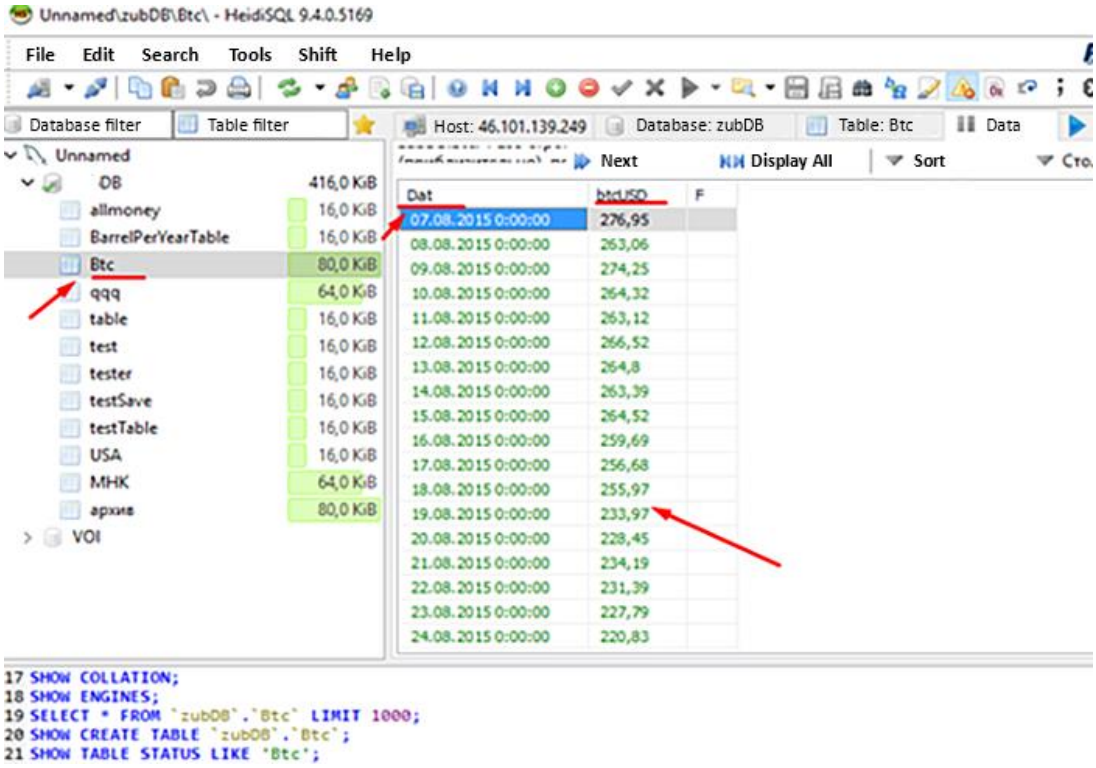


Fig. 3
The example of interface for the database.
The source is the screenshot of the program's screen

A database has been developed to automate the calculations and ease-of-use by the analysts. In the implemented database all the courses of the requested fiduciary (fiat) currencies and cryptocurrencies are stored and loaded. The ability to upload data, which can be used remotely over the Internet, has been implemented. The program uses a MySql database; it is deployed on Ubuntu operating system.

## Results

The calculation of the historical volatility of the US dollar for the period from January 2013 to March 2017 was based on the data on the change of dollar-ruble exchange rate. The historical volatility of other fiat currencies (euro, Japanese yen and Chinese yuan), as well as bitcoin, was calculated for the same period on the basis of data on the exchange rates of these currencies to the US dollar.

The volatility of such cryptocurrencies as Litecoin, Montero, Ethereum was calculated for the period from 2015 to March 2017.

The paper presents the calculations based on the method of simple historical volatility (Simple-Historical-Volatility, SHV). The figures 4-11 indicate the charts of changes in the exchange rates for the indicated periods, and the tables 1-7 – calculations results.

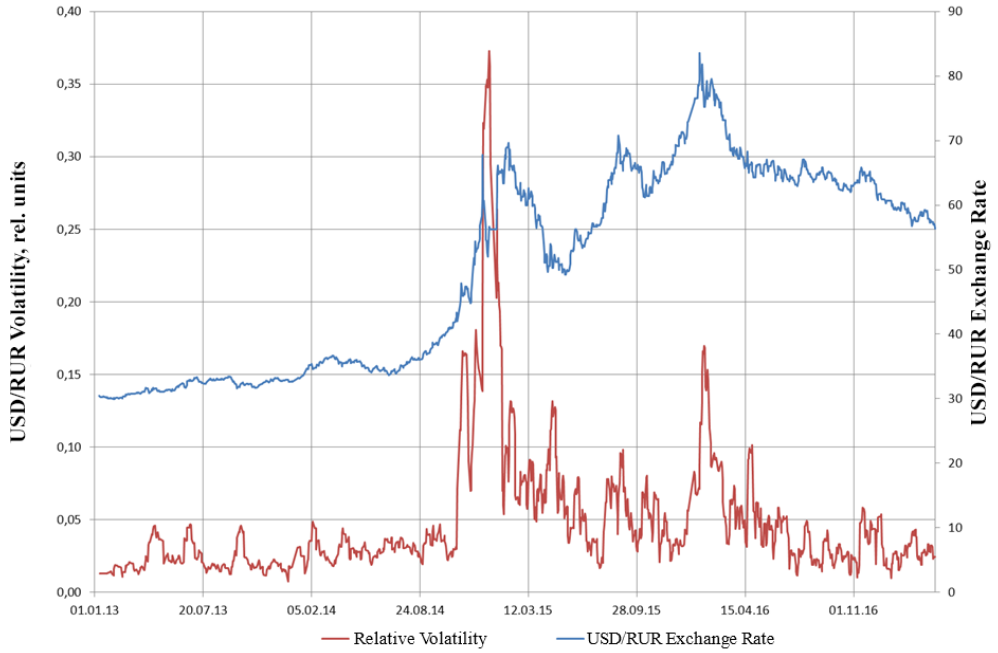


Fig. 4
Changes in the US dollar exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on http://www.cbr.ru/currency_base/dynamics.aspx for the relevant years (date of circulation: 10/05/2017)

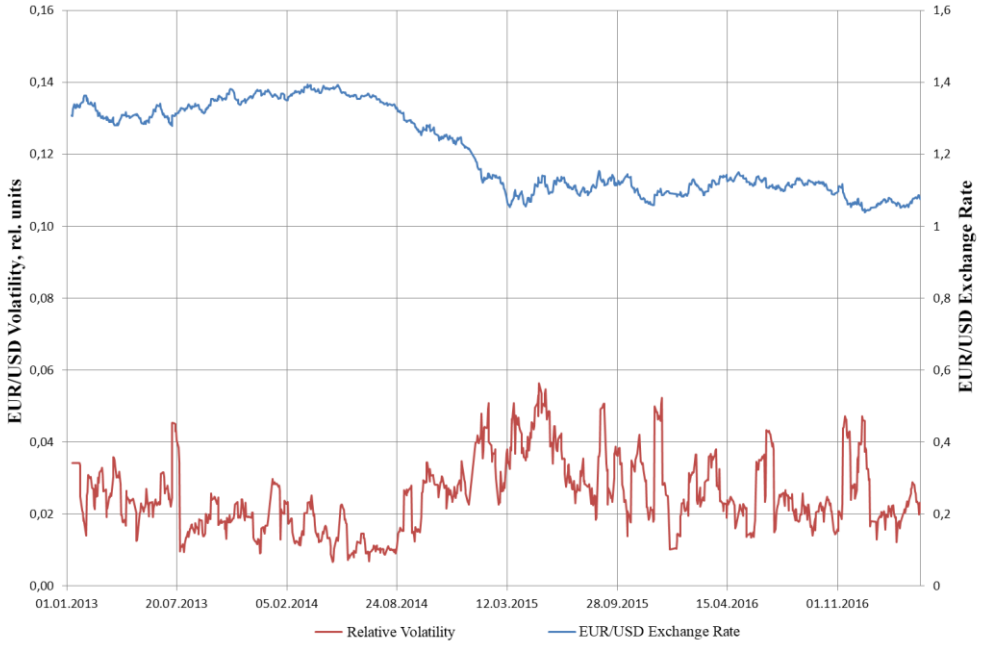


Fig. 5
Changes in euro exchange rate and its volatility in 2013-2017
The source is the author's visualized summary of the estimation results based on CBR base http://www.cbr.ru/ for the relevant years (date of circulation: 10/05/2017).

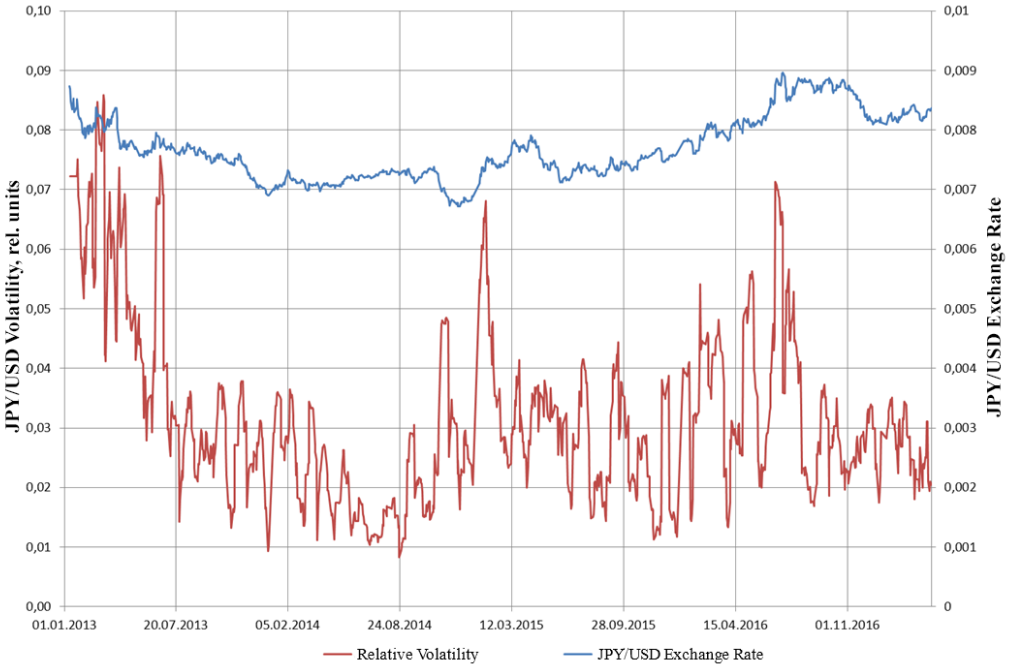


Fig. 6
Changes in yen exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on CBR base http://www.cbr.ru/ for the relevant years (date of circulation: 10/05/2017).

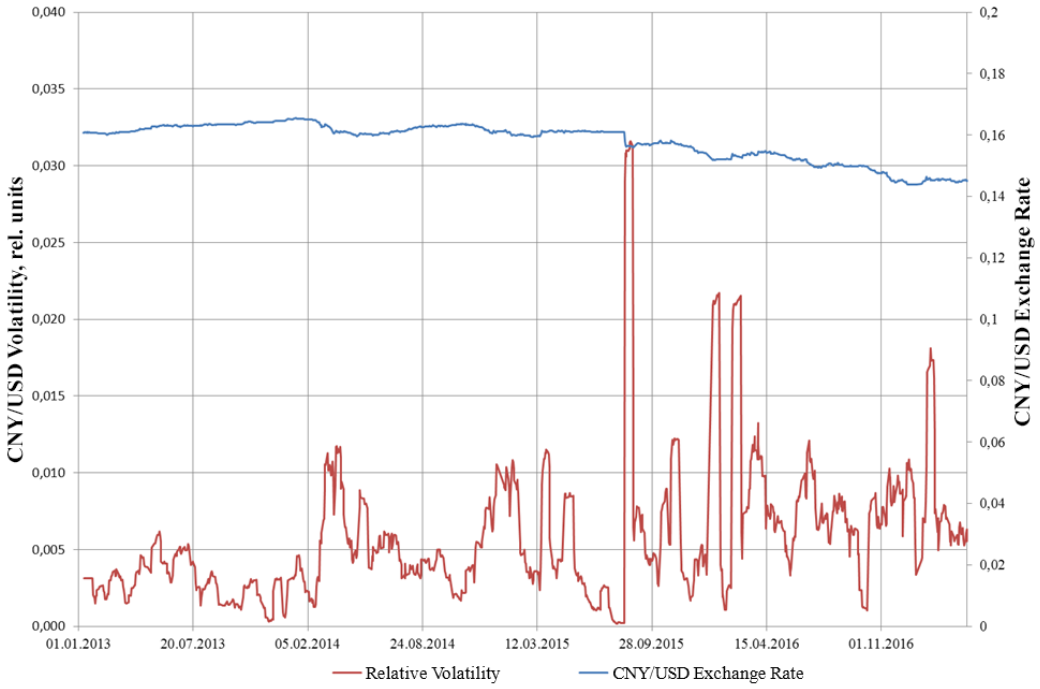


Fig. 7
Changes in yuan exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on CBR base http://www.cbr.ru/ for the relevant years.

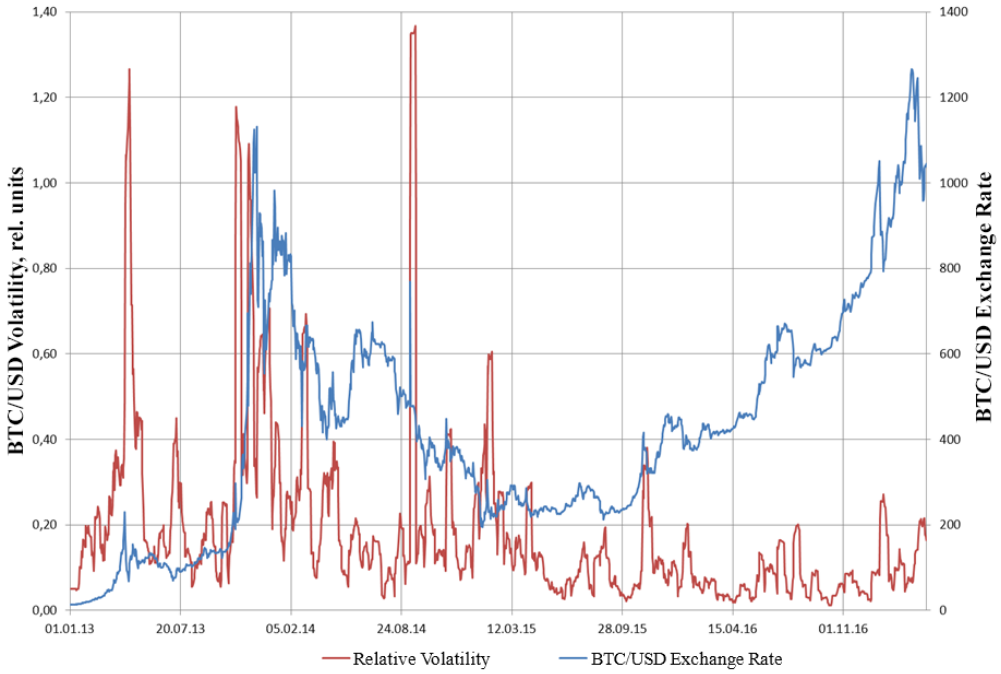


Fig. 8
Changes in bitcoin exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on http://time-forex.com/skripty/raschet-volatilnosti/ for the relevant years (date of circulation: 10/05/2017).

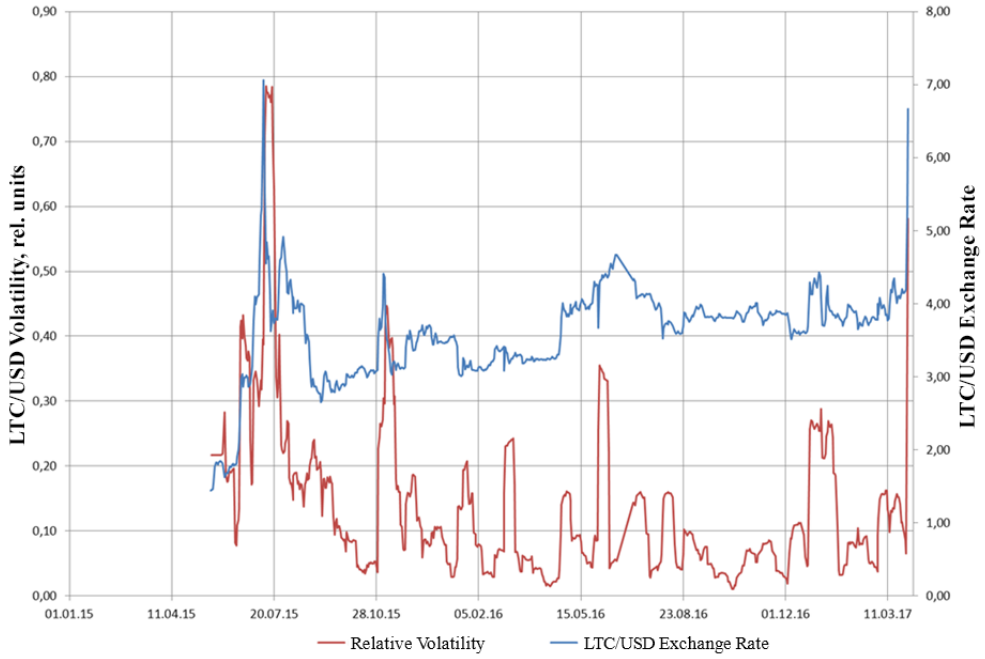


Fig. 9
Changes in Litecoin exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on http://time-forex.com/skripty/raschet-volatilnosti/ for the relevant years (date of circulation: 10/05/2017)

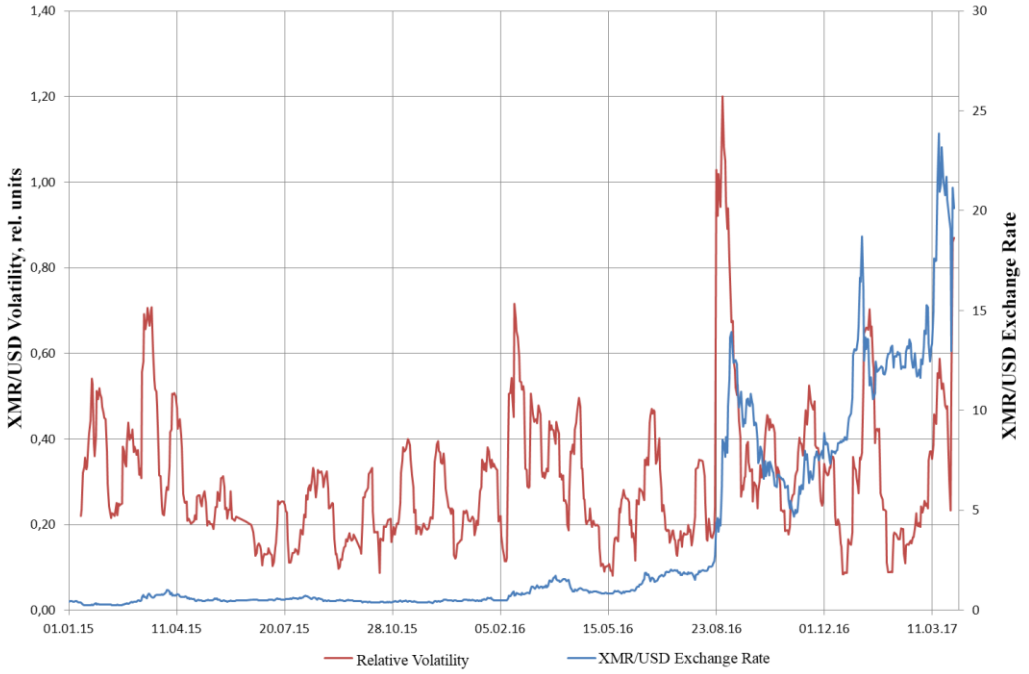


Fig. 10
Changes in Monero exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on http://time-forex.com/skripty/raschet-volatilnosti/ for the relevant years (date of circulation: 10/05/2017).

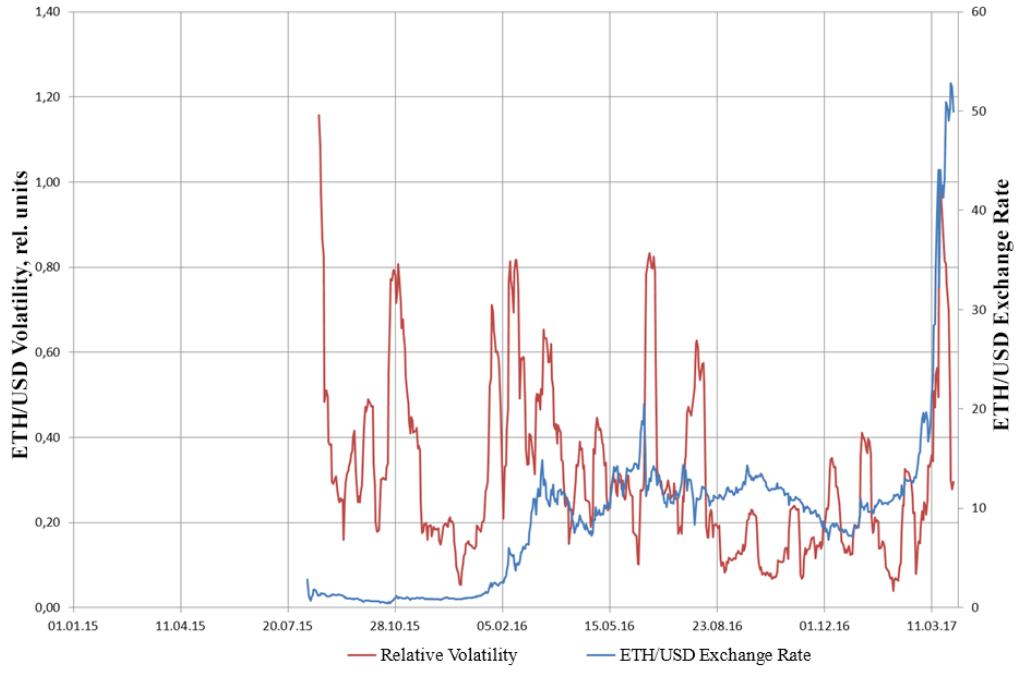


Fig. 11
Changes in Ethereum exchange rate and its volatility
The source is the author's visualized summary of the estimation results based on CBR base http://www.cbr.ru/ for the relevant years (date of circulation: 10/05/2017)

| | Monthly average exchange rate (rub.) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 30.22714 | 33.78435 | 61.87731 | 77.92361 | 59.95834 |
| February | 30.16307 | 35.24404 | 64.68331 | 77.32848 | 59.95834 |
| March | 30.80029 | 36.19857 | 60.25626 | 70.51013 | 58.10909 |
| April | 31.35021 | 35.66773 | 52.93358 | 66.69208 | |
| May | 31.30588 | 34.87483 | 50.5895 | 65.71244 | |
| June | 32.3068 | 34.44953 | 54.50856 | 65.31235 | |
| July | 32.74075 | 34.63541 | 57.07866 | 64.34227 | |
| August | 33.02487 | 36.09843 | 65.20406 | 64.92926 | |
| September | 32.60167 | 37.90178 | 66.77489 | 64.5889 | |
| October | 32.09923 | 40.79869 | 63.08707 | 62.68104 | |
| November | 32.694 | 46.21748 | 65.03369 | 64.36581 | |
| December | 32.8807 | 55.77044 | 69.6801 | 62.20063 | |
| Average volatility rate in a year, rel. units | 0.0218 | 0.0557 | 0.0653 | 0.0472 | 0.0269 |
| Max. volatility rate, rel. units | 0.0467 | 0.3728 | 0.2946 | 0.1698 | 0.0434 |

Table 1
Changes in US dollar exchange rate (USD/RUR) and its volatility in 2013-2017.
The source is the author's summary of the estimation results based on the data of http://www.cbr.ru/currency_base/dynamics.aspx for the relevant years (date of circulation: 10/05/2017).

| | Monthly average exchange rate of euro (USD) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 1.33244402 | 1.363323 | 1.157162 | 1.087744 | 1.065981 |
| February | 1.33865508 | 1.364895 | 1.136037 | 1.111463 | 1.065861 |
| March | 1.2966333 | 1.38211 | 1.08372 | 1.110224 | 1.068964 |
| April | 1.30080003 | 1.380527 | 1.077577 | 1.133809 | |
| May | 1.29505043 | 1.37319 | 1.115852 | 1.12945 | |
| June | 1.31849004 | 1.36035 | 1.122185 | 1.123752 | |

| | Monthly average exchange rate of euro (USD) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| July | 1.30772294 | 1.355861 | 1.101622 | 1.1066 | |
| August | 1.33140412 | 1.332487 | 1.112672 | 1.121082 | |
| September | 1.33403485 | 1.292405 | 1.123664 | 1.120923 | |
| October | 1.36296072 | 1.26853 | 1.123435 | 1.103886 | |
| November | 1.35048573 | 1.248137 | 1.074647 | 1.081376 | |
| December | 1.36948108 | 1.2328 | 1.086978 | 1.055026 | |
| Average volatility rate in a year, rel. units | 0.0225 | 0.0185 | 0.0351 | 0.0256 | 0.0208 |
| Max. volatility rate, rel. units | 0.0454 | 0.0347 | 0.0564 | 0.0473 | 0.0288 |

Table 2
Changes in euro exchange rate (EUR/USD) and its volatility in 2013-2017.
The source is the author's summary of the estimation results based on the data of http://www.cbr.ru/currency_base/dynamics.aspx for the relevant years (date of circulation: 12/05/2017).

| | Monthly average exchange rate of yuan (USD) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 0.160793 | 0.165282 | 0.160764 | 0.152109 | 0.145224 |
| February | 0.160446 | 0.164582 | 0.159944 | 0.152669 | 0.145462 |
| March | 0.160874 | 0.162067 | 0.160256 | 0.153571 | 0.145034 |
| April | 0.161613 | 0.160714 | 0.161241 | 0.154359 | |
| May | 0.16285 | 0.160287 | 0.161204 | 0.15305 | |
| June | 0.163007 | 0.160402 | 0.161137 | 0.151758 | |
| July | 0.163016 | 0.161276 | 0.161076 | 0.149783 | |
| August | 0.163352 | 0.162443 | 0.157982 | 0.150417 | |
| September | 0.163409 | 0.162901 | 0.156989 | 0.149853 | |
| October | 0.163805 | 0.16321 | 0.157479 | 0.148723 | |
| November | 0.16412 | 0.163223 | 0.156947 | 0.146219 | |
| December | 0.164593 | 0.16155 | 0.155038 | 0.144472 | |
| Average volatility rate | 0.00284 | 0.00504 | 0.00611 | 0.00829 | 0.00818 |

| | Monthly average exchange rate of yuan (USD) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| in a year, rel. units | | | | | |
| Max. volatility rate, rel. units | 0.00617 | 0.01175 | 0.03158 | 0.02172 | 0.01810 |

Table 3
Changes in yuan exchange rate (CNY/USD) and its volatility in 2013-2017.
The source is the author's summary of the estimation results based on the data of http://www.cbr.ru/currency_base/dynamics.aspx for the relevant years (date of circulation: 12/05/2017).

| | Monthly average exchange rate of yen (USD) | | | | |
|---|---|---|---|---|---|
| month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 0.00840 | 0.00706 | 0.00733 | 0.00778 | 0.00820 |
| February | 0.00804 | 0.00718 | 0.00743 | 0.00783 | 0.00829 |
| March | 0.00815 | 0.00708 | 0.00767 | 0.00798 | 0.00828 |
| April | 0.00787 | 0.00706 | 0.00776 | 0.00804 | |
| May | 0.00763 | 0.00716 | 0.00742 | 0.00811 | |
| June | 0.00777 | 0.00720 | 0.00720 | 0.00842 | |
| July | 0.00767 | 0.00726 | 0.00736 | 0.00869 | |
| August | 0.00768 | 0.00729 | 0.00729 | 0.00882 | |
| September | 0.00755 | 0.00722 | 0.00741 | 0.00875 | |
| October | 0.00751 | 0.00730 | 0.00742 | 0.00875 | |
| November | 0.00741 | 0.00689 | 0.00759 | 0.00857 | |
| December | 0.00706 | 0.00680 | 0.00755 | 0.00817 | |
| Average volatility rate in a year, rel. units | 0.0419 | 0.0220 | 0.0296 | 0.0335 | 0.0269 |
| Max. volatility rate, rel. units | 0.0858 | 0.0485 | 0.0682 | 0.0713 | 0.0351 |

Table 4
Changes in yen exchange rate (JPY/USD) and its volatility in 2013-2017.
The source is the author's summary of the estimation results based on the data of http://www.cbr.ru/currency_base/dynamics.aspx for the relevant years (date of circulation: 12/05/2017).

| | Monthly average rate of BTC (USD) | | | | |
|---|---|---|---|---|---|
| Month / year | 2013 | 2014 | 2015 | 2016 | 2017 |
| January | 13.36 | 770.52 | 345.43 | 429.07 | 1000.44 |
| February | 20.51 | 832.32 | 213.71 | 374.9 | 955.28 |
| March | 33.38 | 561.38 | 246.94 | 435.53 | 1193.72 |
| April | 93.25 | 474.18 | 245.14 | 416 | |
| May | 139 | 455.29 | 236.63 | 454.14 | |
| June | 128.83 | 645.88 | 229.76 | 530.56 | |
| July | 97.51 | 650.07 | 261.88 | 602.01 | |
| August | 106.23 | 591.96 | 281.24 | 625.94 | |
| September | 141 | 474.03 | 227.25 | 574.64 | |
| October | 143.28 | 388.59 | 236.73 | 609.76 | |
| November | 211.2 | 339.78 | 312.65 | 707.81 | |
| December | 1081.2 | 382.48 | 370.68 | 743.02 | |
| Average volatility rate in a year, rel. units | 0.308 | 0.230 | 0.141 | 0.069 | 0.133 |
| Max. volatility rate, rel. units | 1.266 | 1.367 | 0.606 | 0.203 | 0.272 |

Table 5
Changes in bitcoin exchange rate (BTC/USD) and its volatility in 2013-2017.
The source is the author's summary of the estimation results based on the data of http://time-forex.com/skripty/raschet-volatilnosti/ for the relevant years (date of circulation: 12/05/2017).

The data of cryptocurrencies Ethereum, Litecoin, Monero are available for the period since 2015. The volatility of these cryptocurrencies is calculated for 2015-2017 to the US dollar (table 6). On the basis of data obtained from the charts published on the website time-forex.com/skripty/raschet-volatilnosti.

| | Monthly average rate of cryptoportfolio (USD) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ethereum | | | Litecoin | | | Monero | | |
| Month / year | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 |
| January | | 1.498 | 10.19 | | 3.28 | 3.94 | 0.336 | 0.518 | 12.909 |
| February | | 4.505 | 12.39 | | 3.21 | 3.8 | 0.287 | 0.681 | 12.511 |
| March | | 11.156 | 34.09 | | 3.26 | 4.17 | 0.644 | 1.261 | 17.787 |
| April | | 8.996 | | | 3.38 | | 0.699 | 1.13 | |
| May | | 11.351 | | 1.71 | 4 | | 0.492 | 0.887 | |
| June | | 14.327 | | 2.38 | 4.31 | | 0.491 | 1.35 | |
| July | | 11.833 | | 4.52 | 4.1 | | 0.496 | 1.873 | |
| August | 1.3614 | 11.069 | | 3.69 | 3.72 | | 0.545 | 3.116 | |
| September | 0.9718 | 12.442 | | 2.88 | 3.82 | | 0.471 | 10.51 | |
| October | 0.6565 | 12.055 | | 3.1 | 3.85 | | 0.402 | 6.707 | |
| November | 0.9298 | 9.957 | | 3.4 | 3.86 | | 0.424 | 6.649 | |
| December | 0.8821 | 7.809 | | 3.54 | 3.78 | | 0.458 | 9.094 | |
| Average volatility rate in a year, rel. units | 0.363 | 0.3 | 0.309 | 0.209 | 0.089 | 0.143 | 0.273 | 0.326 | 0.338 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Max. volatility rate, rel. units | 1.158 | 0.833 | 1.00 | 0.785 | 0.355 | 0.622 | 0.708 | 1.20 | 0.87 |

Table 6
Changes in cryptocurrencies exchange rate and their volatility in 2015-2017.
The source is the author's summary of the estimation results based on the data of http://time-forex.com/skripty/raschet-volatilnosti/ for the relevant years (date of circulation: 10/05/2017).

As indicated in the calculation, cryptocurrency is characterized by more than just floating exchange rate regime; moreover, in turn it is set as a result of supply and demand in the foreign exchange market.

| Year | USD | EUR | CNY | JPN | BTC | ETH | XMR | LTC |
|---|---|---|---|---|---|---|---|---|
| 2013 | 0.0218 | 0.0225 | 0.0028 | 0.0419 | 0.308 | | | |
| 2014 | 0.0557 | 0.0185 | 0.005 | 0.022 | 0.23 | | | |
| 2015 | 0.0653 | 0.0351 | 0.0061 | 0.0296 | 0.141 | 0.363 | 0.273 | 0.209 |
| 2016 | 0.0472 | 0.0256 | 0.0083 | 0.0335 | 0.069 | 0.3 | 0.326 | 0.089 |
| 2017 | 0.0269 | 0.0208 | 0.0082 | 0.0269 | 0.133 | 0.309 | 0.338 | 0.143 |

Table 7
The comparison of annual volatility values of cryptocurrency and fiat currency
The source is the author's summary of the estimation results based on the data of http://www.cbr.ru/currency_base/dynamics.aspx and http://time-forex.com/skripty/raschet-volatilnosti/ (date of circulation: 12/05/2017).

Considering the calculations of volatility performed by SHV method which are given in the tables 1-7, it can be confidently declared that volatility of US dollar is about 6-7% in 2014 and 2015, it is below 5% in the remaining years of the period of study (the maximum value of the volatility reaches about 30-40%, it is caused by the sharp decline in the value of the ruble during this period).

The average volatility of Euro-Dollar pair does not exceed 4%, and the maximum is below 6%. The Yen-Dollar pair has an average volatility of less than 5%, while the maximum does not exceed 9%. The Yuan-Dollar pair has an average volatility less than 1% for the entire period under review, and the volatility values exceeded 2% only in August 2015 and January–February 2016.

Bitcoin had a volatility of more than 30% in 2013, it was 23% in 2014, then the volatility reached 14% in 2015 and a little less than 7% in 2016, it was 13% in 2017 (during the period of three months). The maximum volatility was achieved in 2013-2014, it comprised about 130-140%, and 60, 20 and 15% in 2015, 2016 and 2017 respectively.

Litecoin had more than 20% of volatility in 2015, 9% in 2016, about 14% in 2017 (for three months). The maximum values during the same periods were approximately 80, 35 and 60%.

Monero had a volatility of about 27% in 2015, 33% in 2016, and 33% in 2017 (for three months). The maximum in the same periods reached approximately 70, 120 and 85%.

Ethereum had a volatility of approximately 36% in 2015, 30% in 2016, about 31% in 2017 (for the period of three months). The maximum values reached about 118, 85 and 80%, respectively.

On the basis of the analysis it should be concluded that Monero and Ethereum have the greater volatility of cryptocurrencies in 2017 and dollar-ruble pair of the fiat currency. The volatility of fiat currencies is much lower than the volatility of the considered cryptocurrencies, despite the fact that the volatility of bitcoin decreases.

Yuan is at the forefront of fiat currencies, Euro claims the second position, yen and dollar divide the third place.

It should be taken into account that the high levels of trade in cryptocurrencies may not always indicate a further strong price movement. The price of cryptocurrencies, unlike the fiat currencies, reacts to world events, but there are certain situations in which events do not affect the price, it remains volatile according to technical analysis, or can serve as a factor of trading terminals impact[20].

Events include political instability, which affects the value of currency pairs, but volatility may change in the market. The change of volatility may depend on the involvement of major banks. There is an assumption that many major players in the markets are maneuvering to buy or sell large amounts in order to make a profit.

Considering these important factors and the impact of the events on the currency pairs and cryptocurrencies under consideration, it should be noted that the currency pairs lag behind the events, while cryptocurrency makes enormous jumps.

## Calculation of volatility of fiat currencies and cryptocurrencies modelled on GARCH (1.1)

Forecasting volatility of risky assets plays an important role in the construction and calculation of mathematical models for financial mathematics. Forecasting is used in the study of pricing options, currency rates and in the development of profitable strategies for placing various types of portfolios, including cryptocurrencies.

The most appropriate method to calculate the course of cryptocurrencies compared to the fiat currencies is the process of predicting the volatility using GARCH method (1.1); it allows analyzing of correlated and high-frequency data. The method is based on the assumption of autoregressive dependence. Figure 12 shows the example of Excel table used to calculate the volatility of US dollar in the period from 2013 to 2017. For other currencies (fiat and cryptocurrency), the principle of determining volatility is similar. Table 8, explaining the work in Excel with GARCH model, shows the calculation formulas[21].

[20] C. Vavrinec, An empirical analysis of Bitcoin's volatility based on a GARCH model (Skidmore College: New York, 2017).

[21] E. Istigecheva & A. Mitsel, "Models with autoregressive conditioned heteroscedasticity", Journal "Proceedings of Tomsk State University of Control Systems and Radioelectronics", num 5 (13) (2006): 15-21.

The same source data are used for calculations by the method of simple historical volatility (SHV) for all studied currencies in turn (euro, dollar, yuan, bitcoin, Litcoin, Monero, Ethereum). The data is entered into the created data table using GARCH model.

To begin with, it is necessary to give some explanations on the features of GARCH method (1.1). GARCH model involves calculating the value of the volatility computed in the previous steps. Since the market has memory, this memory must be taken into account. It seems natural to assume a linear dependence of the current volatility on the previous one (yesterday, the day before yesterday, etc.).

Then the formula for the square of volatility in GARCH model can be represented as:

$$\sigma_\tau(T,M) = \sqrt{\sigma^2_{\tau 0} + \sum_{j=1}^{T} \alpha_j r^2_{t-j} + \sum_{j=1}^{T} \beta_{\square} \delta^2_{t-i}} \qquad ((1),$$

where $\upsilon_i$ is the additional weighting factors. The use of formula (1) in this form to determine the current level of volatility is almost impossible due to the wide discretion in the rules for determining the weights and the lack of obvious economic sense in a large number of members of both amounts.

Therefore GARCH (1.1) has worked out, it is the simplest method of determining volatility by GARCH method, when only the first members remain from the sums:

$$\sigma_\tau(1,1) = \sqrt{\square + \alpha r^2_{t-1} + \beta \delta^2_{t-1}} \qquad ((2)$$

In this case, the choice is restricted to the condition of equality to one of their sum ($\omega+\alpha+\beta=1$).

All fields of the table are filled in accordance with the formulas.

The target function, “log-likelihood function” on the column, has been optimized to the maximum, for this purpose, it is necessary to change the cells of the variable, where ω, α, β are. Next, find the function “search for solution”.

Next we find the function “search for a solution”.

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **GARCH(1,1) Analysis** | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | **Unconditional variance** | 0,00679066 | | | | | | | | |
| 4 | **ω** | 0,00069590 | | **The data of USD / RUR exchange rate change for the period from January 2013 to March 2017** | | | | | | |
| 5 | **α** | 0,13716048 | | | | | | | | |
| 6 | **β** | 0,88298107 | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | Date | Exchange Rate | Residual | Squared residual | Lag squared residual | Conditional variance | Log-likelihood function | Conditional time-weighted square deviation | Unconditional square deviation without weighing | Relative Conditional Volatility |
| 9 | 10.01.2013 | 30,4215 | | | | | | | | |
| 10 | 11.01.2013 | 30,365 | -0,0565 | 0,0032 | | 0,0068 | | | | |
| 11 | 12.01.2013 | 30,2537 | -0,1113 | 0,0124 | 0,0032 | 0,0071 | 0,6841 | 0,0844 | 0,0824 | 0,002791 |
| 12 | 15.01.2013 | 30,2607 | 0,007 | 0,0000 | 0,0124 | 0,0087 | 1,4510 | 0,0932 | 0,0824 | 0,003081 |
| 13 | 16.01.2013 | 30,2556 | -0,0051 | 0,0000 | 0,0000 | 0,0084 | 1,4707 | 0,0915 | 0,0824 | 0,003025 |
| 14 | 17.01.2013 | 30,3399 | 0,0843 | 0,0071 | 0,0000 | 0,0081 | 1,0504 | 0,0900 | 0,0824 | 0,002966 |
| 15 | 18.01.2013 | 30,3431 | 0,0032 | 0,0000 | 0,0071 | 0,0088 | 1,4459 | 0,0939 | 0,0824 | 0,003095 |
| 16 | 19.01.2013 | 30,2065 | -0,1366 | 0,0187 | 0,0000 | 0,0085 | 0,3662 | 0,0921 | 0,0824 | 0,003049 |
| 17 | 22.01.2013 | 30,297 | 0,0905 | 0,0082 | 0,0187 | 0,0107 | 0,9666 | 0,1037 | 0,0824 | 0,003422 |
| 18 | 23.01.2013 | 30,195 | -0,102 | 0,0104 | 0,0082 | 0,0113 | 0,8622 | 0,1063 | 0,0824 | 0,003522 |
| 1303 | | | | | | LOG L | 8,2970 | | | |

Fig. 12
The fragment of Excel table to calculate the volatility of GARCH model.
The source is the author's result.

| № | Explanations for filling in and using Excel tables for calculating GARCH volatility | |
|---|---|---|
| 1 | The columns A and B, beginning with line 9, contain the data of the exchange rate over the entire period under consideration | |
| 2 | Column (A9:A1302) | The date of exchange rate determination (t) |
| 3 | Column (B9:B1302) | Currency exchange rate at the relevant date P(t) |
| 4 | Column (C10:C1302) | Rate change compared to the previous value – "Balance" Dt= P(t)-P(t-1) |
| 5 | Column (D10:D1302) | Squared residual (D(t)) $^2$ |
| 6 | Column (E11:E1302) | Lag squared residual – the value of the squared residual in the previous phase (D(t-1)) $^2$ |
| 7 | Cell B3 | The dispersion of change in the balance distribution over the entire observation period – Excel function of the variance (C 10:C 1302), it determines the variance of the sample |
| 8 | Column (F10:F1302) | Conditional variance $б^2$, determined in accordance with the formula: $\sigma_t^2 = \omega + \alpha\sigma_{t-1}^2 + \beta б_{t-1}^2$ |
| 9 | Column (G11:G1302) | The elements of log-likelihood function, determined in accordance with the formula: $Ln[(1/^2))*EXP(б_t^2/2D^2)]$ |
| 10 | Cell G1303 | The column totals (G10:G1302) – log-likelihood function – a target function that is optimized to the maximum with the help of the analysis package in Excel by changing the values of cells B4 :B6 (parameters of the formula in the 8$^{th}$ item of this table) |
| 11 | Cells B4, B5, B6 | If the cells with ω, α, β variables (the parameters of the formula in the 8$^{th}$ item of this table) are changed, the target function is optimized to the maximum |

| № | Explanations for filling in and using Excel tables for calculating GARCH volatility | |
|---|---|---|
| 12 | Column (H11:H1302) | The volatility of the exchange rate (the conditional standard deviation $б_t$ – i.e. the square root of the variance $б_t^2$ defined by the model GARCH (1.1) ) |
| 13 | Column (I11:I1302) | Unconditional standard deviation $б_t$ – i.e. the square root of the variance $б^2$, defined by $D_t$ over the entire observation period |
| 14 | Column (J11:J1302) | Relative conditional volatility (the current value of volatility related to the current value of the exchange rate) |

Table 8
Explanations for the Excel spreadsheet in figure 12 to deal with GARCH model.
The source is the author's result.

The results of the numerical analysis are presented in Figures 13-20 and in Tables 9, 10.

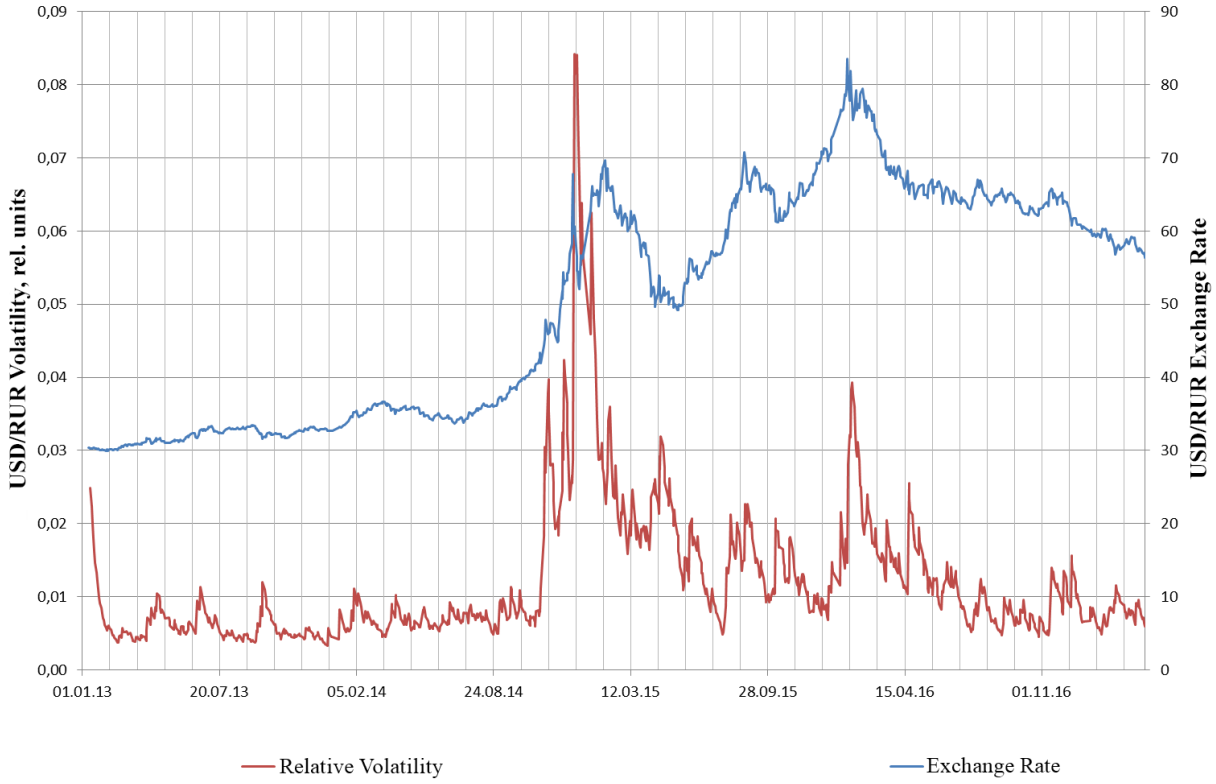


Fig. 13
Dollar/ruble exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result.

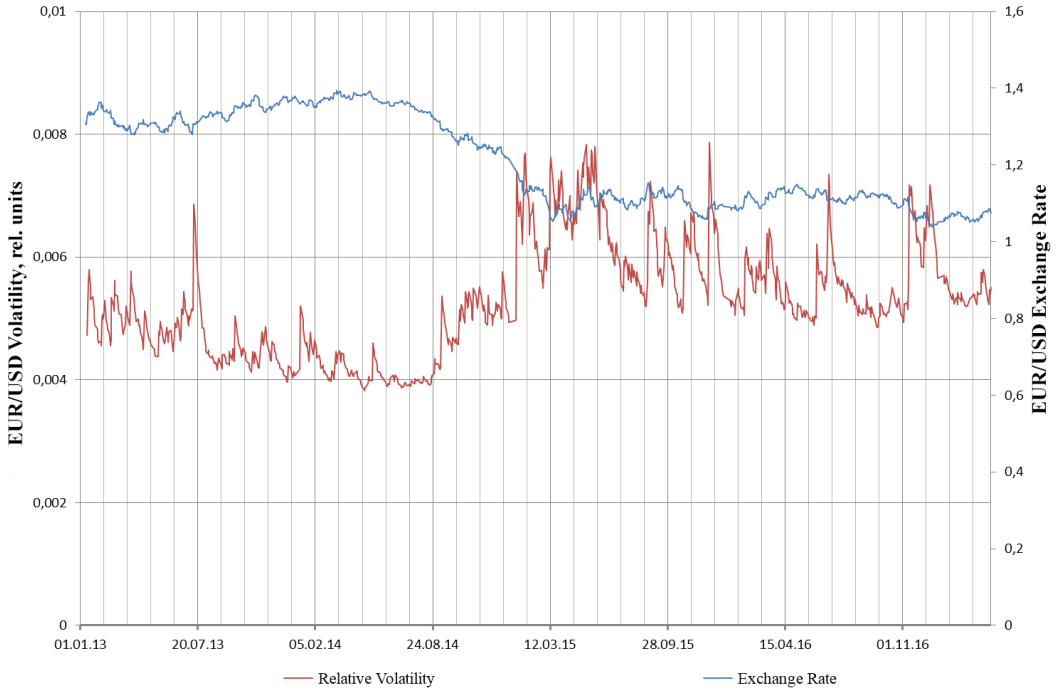


Fig. 14
Euro/dollar exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result.

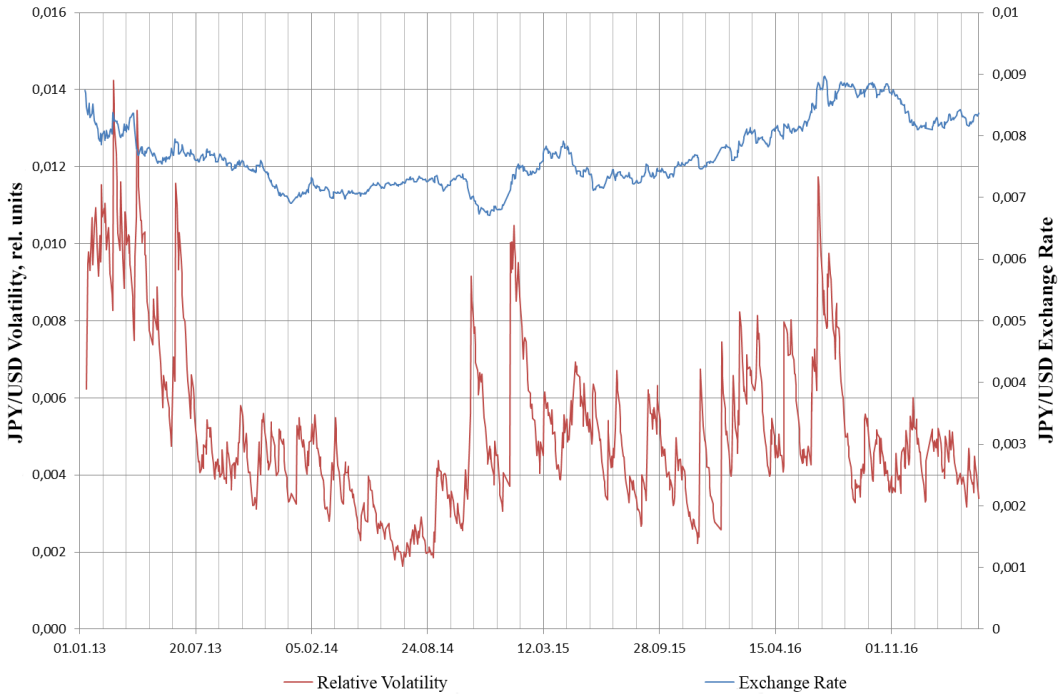


Fig. 15
Yen/dollar exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result.

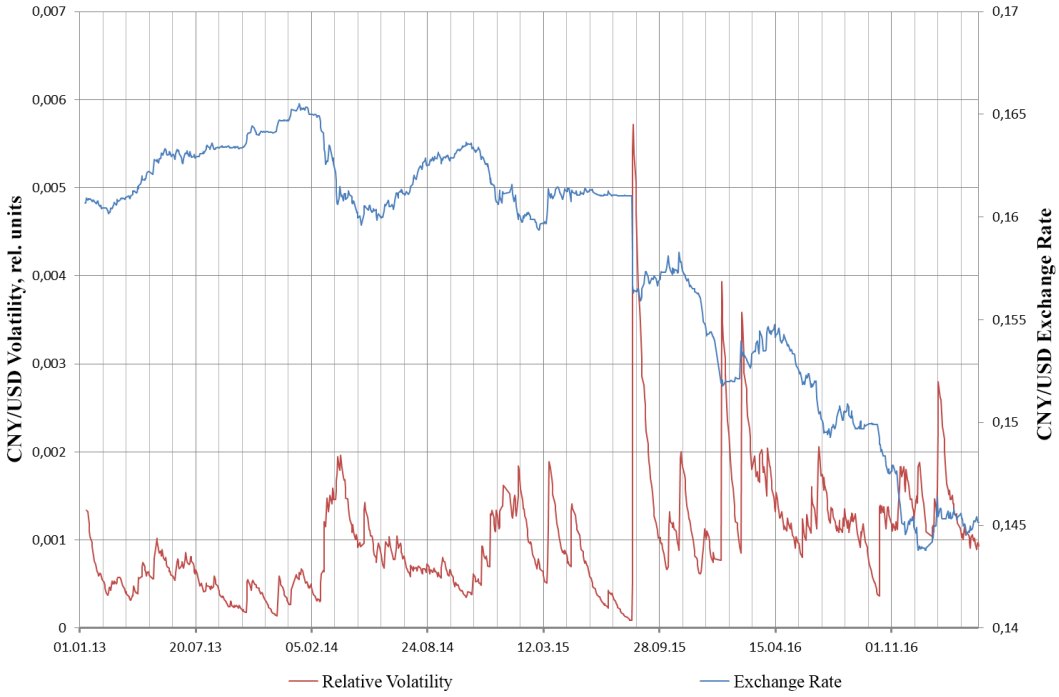


Fig. 16
Yuan/dollar exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result

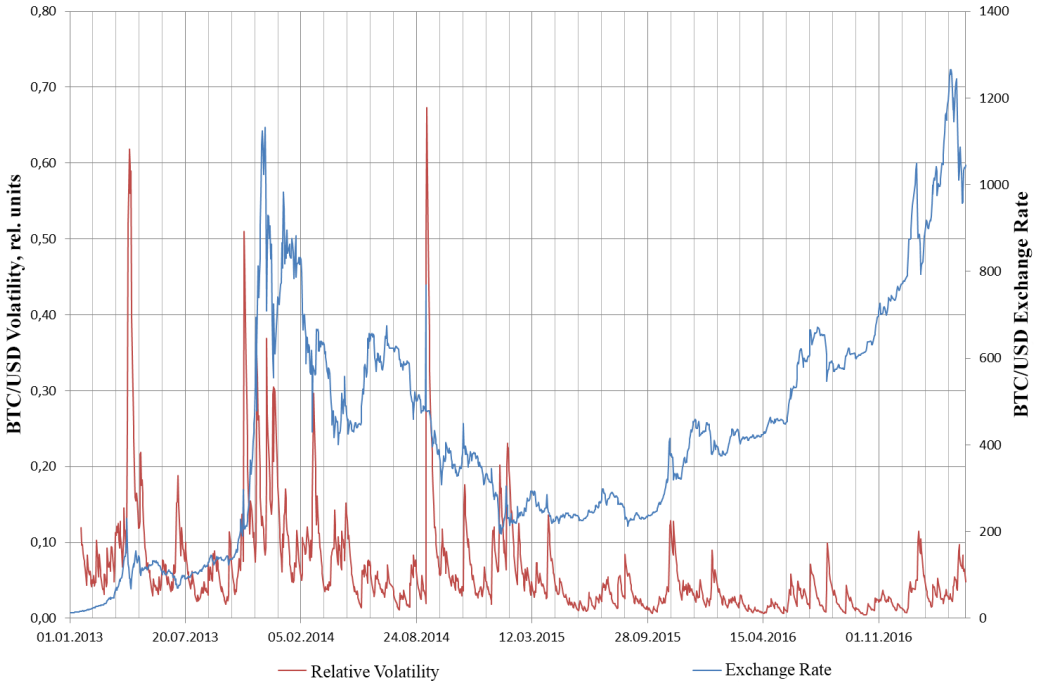


Fig. 17
Bitcoin/dollar exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result.

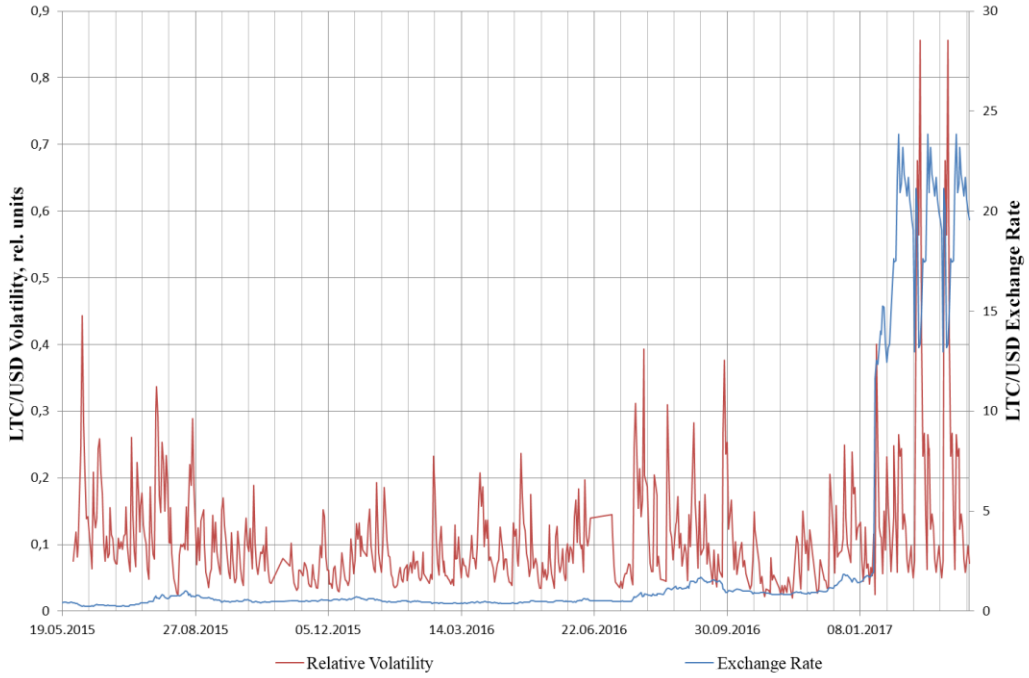


Fig. 18
Litecoin/dollar exchange rate and volatility of the period
from 2015 to 2017.
The source is visualization of calculations based on the author's result

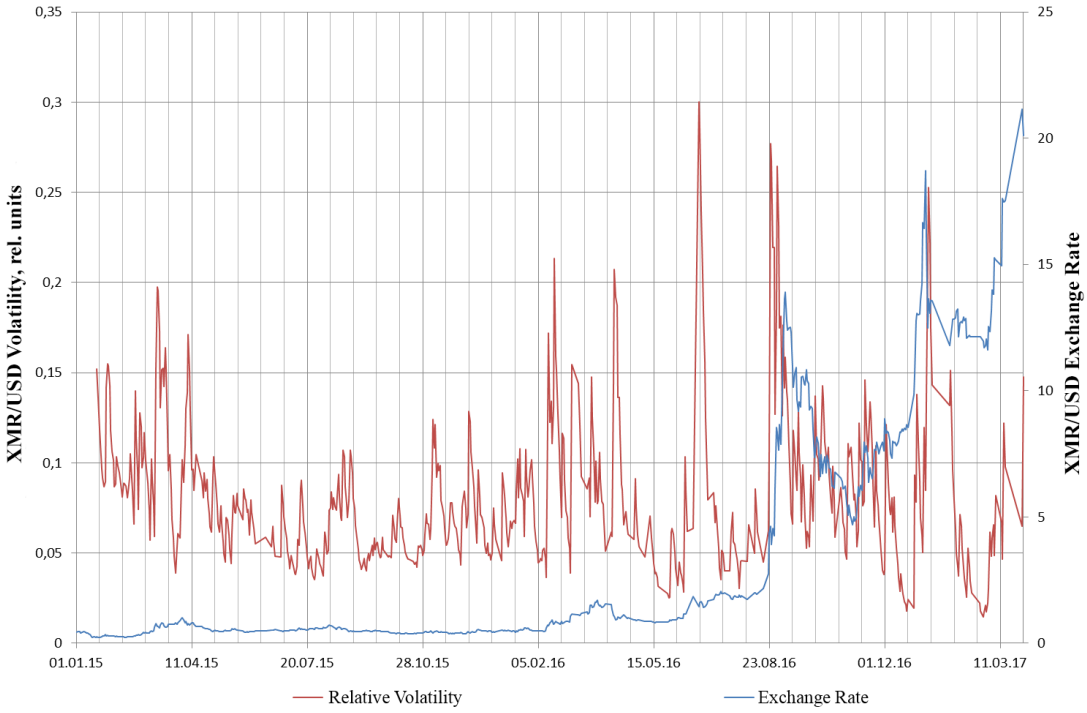


Fig. 19
Monero/dollar exchange rate and volatility of the period
from 2013 to 2017.
The source is visualization of calculations based on the author's result.

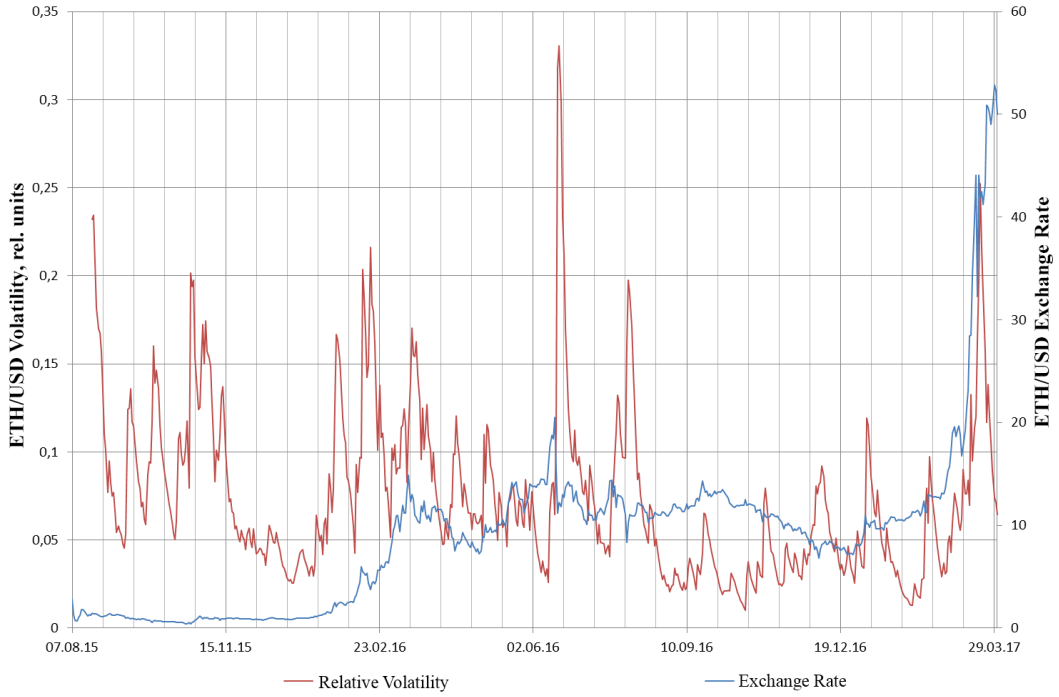


Fig. 20
Ethereum/dollar exchange rate and volatility of the period
from 2013 to 2017
The source is visualization of calculations based on the author's result.

Table 9 performs the results of calculating volatility of different currencies using GARCH (1.1) model.

| year | Currency | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | USD | EU | CNY | JPY | BTC | LTC | ETH | XMR |
| | Volatility | | | | | | | | |
| 2013 | avg. | 0.61% | 0.47% | 0.05% | 0.68% | 10.81% | | | |
| | max | 2.49% | 0.69% | 0.13% | 1.42% | 61.80% | | | |
| 2014 | avg. | 1.21% | 4.45% | 0.08% | 0.36% | 7.74% | | | |
| | max | 8.42% | 0.58% | 0.20% | 0.92% | 67.35% | | | |
| 2015 | avg. | 1.76% | 0.63% | 0.11% | 0.50% | 4.73% | 10.53% | 10.00% | 7.60% |
| | max | 6.25% | 0.79% | 0.57% | 1.05% | 23.07% | 44.32% | 42.08% | 19.73 % |
| 2016 | avg. | 1.24% | 0.56% | 0.14% | 0.55% | 2.31% | 9.25% | 7.21% | 8.82% |

| year | | Currency | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | USD | EU | CNY | JPY | BTC | LTC | ETH | XMR |
| | | Volatility | | | | | | | |
| | max | 3.93% | 0.73% | 0.39% | 1.17% | 9.35% | 39.27% | 33.25% | 30.02 % |
| 2017 | avg. | 0.77% | 0.54% | 0.14% | 0.43% | 4.64% | 18.39% | 6.69% | 7.54% |
| | max | 1.15% | 0.58% | 0.28% | 0.52% | 11.47% | 85.61% | 25.24% | 25.28 % |
| The entire period | avg. | 1.18% | 0.53% | 0.11% | 0.52% | 6.30% | 11.31% | 8.65% | 8.14% |
| | max | 8.42% | 0.79% | 0.57% | 1.42% | 67.35% | 85.61% | 42.08% | 30.02 % |

Table 9
The results of determining volatility of fiat and cryptocurrencies
based on the GARCH (1.1) model.
The source is the author's summary of the estimation results
based on GARCH (1.1.) model.

**Outcome volatility assessment based on GARCH (1.1)**

All cryptocurrencies, with the exception of bitcoin, have volatility that exceeds the volatility of fiat currencies, as it is shown in the table 9. Until 2016 the downward trend in the volatility of cryptocurrency was noted. There was a possibility that over time, the volatility of cryptocurrency, in particular bitcoin and Litecoin, would approach the volatility of fiat currencies. But 2017 showed a significant increase in the rate of cryptocurrency and the hope that cryptocurrency would be able to become a full-fledged financial currency was under great doubt.

**Comparative analysis of volatility calculation**

Table 10 performs the results of determining volatility using SHV method, GARCH model, and the author's program. It can be seen that the volatility of cryptocurrency, defined by each of the three methods, exceeds the volatility of fiat currencies. Even the fact that in the late 2014 or early 2015 there was a ruble exchange rate collapse due to the fall in oil prices, it did not lead to the fact that the volatility of the USD/RUR pair would be comparable to the volatility of cryptocurrencies. It is several times lower.

| Currency | Volatility values calculated by different methods, average/maximum | | | |
|---|---|---|---|---|
| | Simple Historical Volatility SHV | | GARCH model | |
| | Average value | Maximum value | Average value | Maximum value |
| Dollar | 4.9% | 37.3% | 1.18% | 8.42% |
| Euro | 2.6% | 5.6% | 0.53% | 0.79% |
| Yuan | 0.6% | 3.2% | 0.1% | 0.57% |
| Yen | 3.2% | 8.6% | 0.52% | 1.42% |
| Bitcoin | 18.6% | 137% | 6.30% | 67.35% |

| Currency | Volatility values calculated by different methods, average/maximum | | | |
|---|---|---|---|---|
| | Simple Historical Volatility SHV | | GARCH model | |
| | Average value | Maximum value | Average value | Maximum value |
| Litcoin | 14%1 | 78.5% | 11.31% | 85.59% |
| Ethereum | 31.6% | 115.8% | 8.65% | 42.08% |
| Monero | 30.5% | 120% | 8.14% | 40.02% |

Table 10
Comparison of calculated volatility values.
The source is the author's estimation results.

Volatility has been estimated on the basis of the available currency exchange rates and studied on three models. In this paper, a comparative analysis of the calculation for assessing the volatility is carried out in three ways: GARCH model, Simple Historical Volatility (SHV) and the developed algorithm of the author's program (Chaikin method has been chosen as a criterion). GARCH model allows you to calculate the moving average using lag and the difference in the rate of the previous day. The moving average of 10 tore sessions is used for determining volatility in SHV method. The results of calculations of SHV and GARCH (1.1) model are fully consistent with one another in the growth rate of fiat and cryptocurrencies, but with a small difference. SHV increases the percentage of volatility, while GARCH model provides more accurate information on the effective and even calculation. The calculation of GARCH model using a distributed lag of squares (see the 8$^{th}$ item in the table 8) for the exchange rate data based on the previous day gives a more accurate result. The developed algorithm of the author's program has brought the calculated data closer to the calculation of GARCH model. The implemented method of the forecast volatility assessment based on GARCH model gives an almost equal variant of calculations for the growth of the crypto and fiat currencies volatility in combination with the author's program for the model parameters estimation by the maximum likelihood estimation.

## Conclusion

The statistical characteristics of volatility for cryptocurrencies and fiat money are investigated. The cryptocurrencies selected and considered in this paper have quite a dynamic character. Cryptocurrencies from the cryptoportfolio manage to stand out from more than thousand cryptocurrencies currently existing. For the first time the comparative results of the leading fiat currencies (US dollar, Euro, Chinese yuan and Japanese yen) and their volatility and the most popular today so-called cryptocurrencies (Bitcoin, Litecoin, Ethereum and Monero) have been obtained. Volatility assessment based on different methods shows that cryptocurrencies are inferior to the fiat currencies so far, the comparative analysis and the calculations of volatility confirm it. The volatility assessment shows that "cryptocurrency", in particular, bitcoin has the volatility that is significantly higher than the volatility of fiat currency, the recognition of it as a monetary tool is premature, not only due to the lack of regulatory legal acts of recognition that a certain cryptocurrency and fiat money are equitable, but it is also based on the breaches of essential requirements for the currency properties, such as low levels of volatility. This conclusion is consistent with the position of the Bank of Russia; it considers cryptocurrency as a digital asset and property in trade, but not a currency, although according to other criteria[22].

[22] The draft law № 419059-7 "On digital financial assets". Retrieved 10.04.2018 from: http://www.garant.ru/news/1186382/#ixzz5BzOwFfbW

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