

ИННОВАЦИИ И ЦИФРОВАЯ ЭКОНОМИКА

JEL: G1; G15; G17

Cryptocurrency as an Investment Instrument in a Modern Financial Market

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For citation: Saksonova, S., Kuzmina-Merlino, I. (2019) Cryptocurrency as an Investment Instrument in a Modern Financial Market. *St Petersburg University Journal of Economic Studies*, vol. 35, issue 2, pp. 269–282. <https://doi.org/10.21638/spbu05.2019.205>

This paper considers the development of attractive strategies featuring cryptocurrency assets, considering their costs and potential risks. The object of analysis in this paper is cryptocurrency as an investment instrument. The main hypothesis of the research is that modern portfolio theory can be applied to cryptocurrency investments to design an investment portfolio with appropriate risk and profitability characteristics. The authors of the paper: (i) place cryptocurrencies in the context of modern financial market and financial technology development; (ii) develop assessment criteria for determining attractiveness of individual cryptocurrencies; and (iii) develop recommendations for creating an optimal cryptocurrency investment portfolio. In order to test the hypothesis, the authors performed calculations and used such methods of scientific research as the collection and processing historical values for cryptocurrency rates from July 2017 to January 2018, as well as data analysis for correlation, covariance, and return on investment. It is shown that a cryptocurrency investment portfolio should be created considering investor objectives and should obey a logical relationship between risk and profitability. Therefore, cryptocurrencies should not be correlated; an investment portfolio should be sufficiently diversified to minimize risk; cryptocurrencies should be liquid, that is freely exchangeable to a fiat currency on an appropriate exchange (e.g. dollars, euros). Investors should also consider regular rebalancing of the portfolio, which could help increase its profitability.

Keywords: cryptocurrencies, financial market, investment portfolio.

Introduction: Cryptocurrencies in Context of Financial Market Development

This paper evaluates cryptocurrencies as an investment instrument. Cryptocurrencies are a recent phenomenon. The paper outlining the proposal for the first cryptocur-

rency, Bitcoin, was published online in 2008. It argued: "A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution" [Nakamoto, 2008, p. 1]. The notion of avoiding financial institutions was placed at the heart of cryptocurrency development. This is a significant departure from the gradually increasing role of financial intermediaries (banks and other credit institutions) as specific economic agents, which has been rising since the 17th century [Kuznetsova, Permiakova, 2002].

A report by the European Central Bank placed Bitcoin in the context of a larger phenomenon: virtual currency schemes that are classified in three types: (i) closed schemes (for use in online gaming); (ii) schemes that have a unidirectional flow with a conversion rate for purchasing virtual currency, which is mostly used for virtual goods and services; and, finally, (iii) currency schemes with bidirectional flows, where a virtual currency acts like any other convertible currency [European Central Bank, 2012]. This paper considers this last type of cryptocurrency.

The definition of cryptocurrencies has not been settled among legislators, financial market regulators, and participants, as well as other stakeholders. The idea of cryptocurrency can be most clearly traced by outlining its distinguishing characteristics and discussing its advantages and disadvantages. Khidzev [Khidzev, 2014] identifies three distinct legal features of cryptocurrencies¹. First, cryptocurrencies are decentralized, in the sense that there is no possibility of central control over levels of emissions². Second, cryptocurrency users can generally hide their involvement in transactions³. Third, cryptocurrencies do not have any guarantees. This is contrast to fiat money, which, although no longer commonly backed by gold, still usually has the backing of a government requirement that it be legal tender and accepted for economic transactions in a given country, especially as payment of taxes. All cryptocurrencies considered in this paper possess these features, making these characteristics part of an appropriate definition for our purposes.

Among the advantages of cryptocurrencies is the possibility of innovative payment solutions featuring lower costs, global reach, payer anonymity, and speed of settlement. On the other hand, there are several disadvantages for users, i.e. lack of transparency, clarity, and continuity; high dependency on IT and networks; anonymity of actors involved; and high volatility [European Central Bank, 2015]. In addition, users face risks associated with anonymity of the payee, high volatility of the cryptocurrency exchange rates, and the risk of fraud due to the lack of transparency. Currently, there is no technical possibility to eliminate these risks, therefore, supervisory authorities in many countries have concerns about possible illegal operations, Ponzi schemes, and tax evasion.

Another important aspect of the definition of cryptocurrencies is its reliance on blockchain technology. Broadly speaking, blockchain is a system of interconnected data blocks, copies of which are stored in a decentralized manner by each participant of the information exchange. Each new block in a blockchain contains a link to the previous one, as well as all transactions that were confirmed after the previous block was created [Tap-

¹ Following the majority of economic and legal literature, we abstract from the technical details of the cryptocurrencies and focus on their economic and legal characteristics.

² Not all cryptocurrencies are decentralized, but most are.

³ Most cryptocurrencies are pseudonymous, which means that although transactions are associated with names, they need not be real names. A few cryptocurrencies are anonymous, which means that transaction participants in principle cannot be identified.

scott, Tapscott, 2017]. Unlike existing systems of money transfers, in which a transaction passes through several intermediaries (depending on the currency, the country of transfer, etc.), thereby increasing transaction costs, the blockchain allows excluding intermediaries, reducing commission costs, while guaranteeing reliability and safety. The introduction of this technology in the financial sector will significantly affect market participants. The ability to exclude intermediaries provided by the blockchain allows eliminating a variety of third parties such as brokers, depositary services, and dealers. In other words, areas of application for blockchain technology are not limited to cryptocurrencies (all cryptocurrencies rely on blockchains, but not everything that relies on a blockchain is a cryptocurrency). In fact, blockchain can be used by various elements of the financial industry (e.g. for remittances, online payments) as well as non-financial applications and the next generation of Internet interaction systems: smart contracts, public services, Internet of Things, etc. [Zheng et al., 2018]. Thus blockchain could be classified on the spectrum of fintech — financial innovations, as belonging to infrastructure and support services (see [Saksonova, Kuzmina-Merlino, 2017] for an overview of areas of fintech application)

Cryptocurrencies are only the most recent innovation in a long series of financial market developments that were generally aimed at accumulating, concentrating, and redistributing financial resources and risk. One example of previous innovations was the derivatives market, which enabled insurance against risks in adverse changes in prices [Ivanov, 2014]. Gradually an increasing amount of transactions in financial markets involved a time element and was devoted to financial as opposed to the real sector [Bulatov, 2005]. Thus, for example, the notional volume of derivatives contracts can exceed the volume of the underlying asset. Another trend that characterized financial market development at the time of the emergence of cryptocurrencies is increased integration and interdependence of financial markets. The modern credit market is a good example, as it is characterized by heterogeneity and is represented by a variety of participants, forms of transactions, and ways of their execution, a variety of institutions regulated by different bodies, and is the largest segment of the financial market [Frolova, Kardamonova, 2013]. This interdependence and integration are now widely considered to be one reason why the 2008 global financial crisis had such severe and wide-ranging consequences. The emergence of cryptocurrencies can be seen partly as a reaction to the growth in the role and impact of financial intermediaries, with cryptocurrency creators hoping to create an alternative to the reliance on traditional banking, which was widely seen as having failed society in the aftermath of the global financial crisis.

Interestingly, along with the trend of increasing interdependence, financial market development could also be characterized by a seemingly opposite trend of *disintermediation*. The stock market is a good example of this trend. The elimination of a huge number of intermediate links significantly reduced the cost of services. Commissions, spreads, and other brokerage fees have become several times smaller, and as a result there are more investors on the stock exchanges. Improvements of trade conditions have led to popularity of electronic exchange trading, an increase in liquidity, and the flowering of investment activity. Another example of disintermediation is the development of robo-advisors, a financial service for wealth management that provides automatically generated investment solutions on-line, based on algorithmic processing of information. The consultant robot evaluates information about the consumer of services to determine risk proneness and to analyse the investment objectives. After processing customer data and available informa-

tion from the stock market, the robo-advisors suggest ways to form an optimal investment portfolio. Thus, the development of robo-advisors obviates the needs for previously expensive third-party intermediaries (financial advisors), which reduces development costs and eliminates the risk of subjectivity (the significant potential for conflict of interest in financial advice industry is well-known) in the investment assessment.

To summarize, cryptocurrencies rely on blockchain technology and have a number of distinguishing characteristics (decentralization, use of pseudonyms, lack of government intervention) that give rise to advantages as well as disadvantages. Cryptocurrencies are only the most recent of a long chain of financial market innovations. On the one hand, they epitomise growing interconnectedness between different financial market participants by enabling different parties to join their platform and participate in the blockchain. On the other hand, cryptocurrencies were created with the intention to lower the power of intermediaries (financial institutions).

The remainder of this paper is structured as follows: Section 1 shows why cryptocurrencies can be considered an investment instrument, reviews literature on cryptocurrencies as investment instruments, and previous attempts to apply portfolio theory to cryptocurrencies. Section 2 outlines the application of modern portfolio theory to cryptocurrencies. Section 3 summarizes data on popular cryptocurrencies for the period from July 2017 to January 2018. This particular period was chosen because there were significant changes in exchange rate dynamics of different cryptocurrencies in the second half of the summer of 2017. In addition, data on certain cryptocurrencies was not available prior to this period. It is important to emphasize, however, that the principles outlined in this paper are meant to be general and applicable regardless of the period considered. The cryptocurrencies chosen for the analysis were considered based on their statistical characteristics (price trend and correlation with other cryptocurrencies). This section illustrates the creation of portfolios with the minimum risk and maximum yield, which can be recommended to a potential investor. This paper concludes with some recommendations for formulating crypto-currency investment portfolios.

1. Cryptocurrencies as Investment Instruments

Before considering cryptocurrencies as investment instruments, it is useful to consider what differentiates cryptocurrencies from traditional money. The definition of money has itself long been a controversial subject in economic literature. Most conventional economic theories tracing back *inter alia* to Marx postulate that money has to satisfy a few functions.

First, money must be able to act as medium of exchange. For cryptocurrencies to act as medium of exchange, developers first needed to solve the problem of eliminating the possibility of double spending (spending a single digital token more than once) without intermediaries. This was solved by blockchain technology featuring different forms of consensus protocols (proof of work, proof of stake, proof of service, proof of burn, proof of space, byzantine fault tolerance, etc.) — a way for all participants to agree on the validity of certain data. Mathematical algorithms behind blockchains ensure that information on transactions can be trusted by all protocol participants without the presence of a centralized intermediary (e.g. a bank in a traditional situation).

Second, money must be able to act as a measure of value. In principle cryptocurrencies can satisfy this condition. Third, cryptocurrency must act as a store of value. This function is most relevant to the use of cryptocurrency as an investment instrument. The value of cryptocurrencies, measured in terms of *fiat* currency, which is still the more common measure of value, fluctuates widely. This makes cryptocurrencies more like investment assets than money itself.

The main economic indicators applied to cryptocurrencies are exchange rate and capitalization. Capitalization is the market value of assets in circulation. From this, the capitalization of cryptocurrencies is calculated as the number of issued crypto signs of one currency multiplied by the current rate of the same currency. The total capitalization of all cryptocurrencies as of early 2019 was around 120 bln doll. USA⁴. By comparison the capitalization of just the US stock market has been fluctuating recently around 30 trln doll. USA or around 250 times the total capitalization of all cryptocurrencies. Bond markets are still larger (around 40 trln doll. USA in the US). The largest financial market in the world is foreign currency (forex) trading, which processes trillions of dollars in transactions per day. Thus, by all standards cryptocurrencies, despite their considerable price volatility and media attention, are still a tiny part of the overall financial market. Nevertheless, they can represent an attractive niche for investors, in part because of their lower correlation to other financial instruments and key macroeconomic events (e.g. decisions of central banks, profit announcements of major corporations, macroeconomic data releases, etc.).

Recent literature on the use of cryptocurrencies as investment instruments has typically focused the most popular representative, Bitcoin, which in early 2019 accounted for around 50 % of total cryptocurrency capitalization, and arrived at a diverse set of conclusions. On the one hand, the Bitcoin market has been declared to be highly speculative [Baek, Elbeck, 2015]. A similar conclusion was reached by Yermack, who argued that Bitcoin's daily exchange rates exhibit virtually zero correlation with widely used currencies and with gold, making Bitcoin useless for risk management and exceedingly difficult for its owners to hedge the fluctuations in Bitcoin exchange rate [Yermack, 2013].

A few years later the sentiment had changed. Dyhrberg argued that Bitcoin possessed some of the same hedging abilities as gold and could be included in a variety of tools available to market analysts to hedge market specific risk [Dyhrberg, 2016]. Trimborn and co-authors also argued that including cryptocurrencies can improve the risk-return trade-off of the portfolio [Trimborn, Li, Hardle, 2018]. Baur, Hong and Lee also found that Bitcoin was uncorrelated with traditional asset classes such as stocks, bonds, and commodities and is mainly used as a speculative investment and not as an alternative currency and medium of exchange [Baur, Hong, Lee, 2018]. This finding illustrates an interesting tension between the two functions of money (store of value and medium of exchange) that has perhaps been an obstacle to greater popularity of cryptocurrencies. The more attractive they are for speculative purposes (store of value), the less likely it will be that people will use them for daily transactions.

The formation of a profitable investment portfolio including cryptocurrencies is a relatively new task for financial market participants. Previous attempts to analyse this topic include Andrianto and Diputra, who analysed three cryptocurrencies together with stocks, commodities, and foreign currencies [Andrianto, Diputra 2017]. They also found

⁴ See e.g. <https://coinmarketcap.com> for the most recent information (accessed: 17.07.2018).

that cryptocurrencies can increase the effectiveness of an investment portfolio in part by lowering portfolio variance. On the other hand, Bouri and co-authors found that Bitcoin is a poor hedge and is suitable for diversification purposes only, although they also noted that Bitcoin's hedging and safe haven properties vary with different time horizons [Bouri et al., 2017].

In contrast to literature discussed above, this paper focuses on investment portfolios comprised exclusively of cryptocurrencies. An investment analysis of multiple cryptocurrencies has been conducted by [Chen et al., 2018], who constructed an investment index of 30 cryptocurrencies. Brauneis and Mestel [Brauneis, Mestel, 2019] related the risk and return of different mean-variance portfolio strategies to single cryptocurrency investments and two benchmarks, the naively diversified portfolio and the index constructed by [Chen et al., 2018] finding that portfolios feature lower risk than single cryptocurrencies and that in terms of the Sharpe ratio and certainty equivalent returns, the 1/N (naive portfolio) outperforms single cryptocurrencies and more than 75 % of mean-variance optimal portfolios. Gandal and Halaburda considered whether Bitcoin can be a beneficiary of network effects. In theory, if enough users were attracted to just one cryptocurrency, it would eventually eliminate all its competitors, in which case selecting an investment portfolio of cryptocurrencies would be rendered moot [Gandal, Halaburda, 2014]. This, however, does not seem to have been the case, as the number of competitors to Bitcoin has proliferated.

The volatility of cryptocurrencies highlighted earlier has naturally raised questions about bubbles in cryptocurrency markets. Corbet, Lucey and Yarovaya concluded that cryptocurrencies exhibit periods of clear bubble behaviour [Corbet, Lucey, Yarovaya, 2018]. A similar conclusion was reached earlier by [Chen, Fry, 2015]. In this, however, cryptocurrencies are no different from other financial and non-financial assets.

Another challenge in considering the attractiveness of cryptocurrencies as an investment instrument is whether the market is efficient. Urquhart found that the Bitcoin market is inefficient over the entire sample period, although it may be in the process of moving towards an efficient market [Urquhart, 2016]. Bartos, on the other hand, found that Bitcoin is an efficient market at least in a sense that the price of Bitcoin immediately reflects publicly available information [Bartos, 2015]. Some degree of market inefficiency, however, is to be expected with such a new market and does not necessarily make cryptocurrencies a less attractive investment instrument compared to other financial instruments, which feature their own market inefficiencies.

Overall, therefore, cryptocurrencies can certainly be considered a legitimate, and possibly attractive investment instrument. In this paper, the authors determine the optimal cryptocurrency investment portfolios calibrated both for maximum profit as well as minimum risk.

2. The Application of Portfolio Theory to Cryptocurrencies

In this section, the authors consider a model of modern portfolio theory, which is a mathematical formulation of risk diversification in investing aimed at selecting a group of investment assets that collectively have a lower risk than any individual asset. Intuitively, this becomes possible, as the value of various assets often changes in opposite directions. As a rule, any investment portfolio makes a compromise between risk and profitability,

with a high expected return on assets generally possibly with a high degree of risk. Portfolio theory makes the choice between these two considerations in an optimal manner.

The foundations of modern portfolio theory have been formulated in a seminal contribution by [Markowitz, 1952]. This is also a particularly attractive framework for our purposes, because as shown by e.g. [Kroll, Levy, Markovitz, 1984; Levy, Markovitz, 1979], portfolio optimization using mean-variance criteria is almost equivalent to the expected utility maximization under non-normality of returns, which is likely to be the case with cryptocurrencies.

An investment portfolio is the aggregate of securities and other assets gathered together to achieve certain goals and managed as a whole. Any asset can be a part of the investment portfolio from gold and real estate, to shares and options. The process of formation and management of the investment portfolio involves the implementation of the following stages: setting goals and selecting an adequate type of portfolio, analysing investment objects, forming an investment portfolio, selecting and implementing a portfolio management strategy, and evaluating the effectiveness of decisions taken.

When formulating the investment portfolio, one should adhere to the basic principles of increasing profitability and minimizing risks. First, the investment portfolio should comply with previously determined goals and investment strategies. According to the goals of investment (and the trade-off between profitability and risk), the following types of portfolios can be distinguished:

- Growth portfolios formed from assets that ensure the achievement of high growth rates of invested capital and are characterized by significant risk. Most cryptocurrencies are likely to belong to growth portfolios since they are risky assets with significant potential for appreciation.
- Yield portfolios formed from assets that ensure a high return on invested capital. Note that at the moment most cryptocurrencies do not pay interest, hence the only way to be compensated for the risk or time value of holding a cryptocurrency is to exchange it for fiat currency. This may change in the future, if central banks get more involved in designing cryptocurrencies to use them in implementing unconventional monetary policy measures.
- Balanced portfolios that ensure the achievement of a given level of profitability at a certain acceptable level of risk.
- Liquid portfolios, providing, the ability to quickly sell investment assets, if needed, but typically featuring lower profitability.
- Conservative portfolios, formed from low-risk and reliable assets, etc. For obvious reasons, cryptocurrencies are unlikely to be included in conservative portfolios.

Second, the investment portfolio should be sufficiently diversified, and therefore not depend on one or two economic factors. In order to make profits in the investment process and not lose money, the investor has to invest his or her money in different assets. The main purpose of diversification is not only obtaining an adequate and stable return, but also reducing the risk of catastrophic loss of capital. As already alluded to in Section 1, investors, in the first instance seek to diversify by different classes of assets (e.g. shares, bonds, cryptocurrencies, commodities, financial derivatives, etc.). Within the asset class one can also diversify, by e.g. different regions and countries, or different sectors of the economy within a country.

The question arises as to whether cryptocurrencies alone can ensure enough diversification. Koutmos [Koutmos, 2018] shows that there is a growing interdependence among cryptocurrencies and, by extension, a higher degree of contagion risk, with Bitcoin being the dominant contributor of return and volatility spillovers among major cryptocurrencies. In principle, this could limit the scope for portfolio diversification if investors stick to cryptocurrencies alone. On the other hand, if there is strong competition between cryptocurrencies, there could be a negative correlation in their exchange rates, as people shift money from one cryptocurrency to another. In all likelihood, a cryptocurrency investment portfolio should be a part of a broader investment strategy for investors. In that case the relevant question is whether a combination of cryptocurrencies can improve upon a single currency and the answer to that is a definite yes, even if correlations are high, at least until one cryptocurrency achieves sufficient dominance of the market.

Thus, the main purpose of portfolio investment is to obtain from a set of investment assets such characteristics that are unattainable when investing funds in a single asset. The goal of creating an investment portfolio is to achieve the most optimal combination of risk and return. The risk is reduced most often when the assets that are included in the portfolio are sufficiently uncorrelated. That is, diversification should lead to the fact that with a strong fall in the value of an individual asset the total value of the portfolio will not be greatly reduced. To some extent portfolio diversification can also protect investors against idiosyncratic risks of individual cryptocurrencies, for example, a hack of some sort, a bankruptcy of a major exchange, etc.

To choose the best portfolio from many possible alternatives, it is necessary to make two significant decisions. First, a set of effective portfolios needs to be identified. Second, the best portfolio must be chosen from the effective set. In order to choose the best portfolio, the following steps are needed:

- building a trend for the analysis of the prospects of cryptocurrencies;
- correlation analysis;
- optimization of the asset portfolio;
- portfolio rebalancing.

These stages will help to make the investment portfolio the most optimized in the risk/return ratio.

3. Assessing the Cryptocurrencies for the Inclusion in the Portfolio

The universe of cryptocurrencies available for investment is large. In this paper, we will focus on the cryptocurrencies from the Top 30, for which data were available from the CryptoCompare website [CryptoCompare, 2018]. Specifically, we include Bitcoin (BTC), BitcoinCash (BCH), Ethereum (ETH), Ethereum Classic (ETC), Ripple (XRP), Litecoin (LTC), Tron (TRX), VeChain (VEN), Icon (ICX), Dash (DASH), IOTA (IOT), Neo (NEO), Monero (HMR), Stellar Lumens (XLM), Cardano (ADA), Lisk (LSK), OmiseGo (OMG), ZCash (ZEC), Cindicator (CND), Walton (WTC), BitcoinGold (BTG) and Verge (XVG).

Not all cryptocurrencies can be converted to dollars, and the less popular ones can only be converted to Bitcoins. Since a reasonable degree of liquidity is a highly desirable feature of any investment portfolio, only cryptocurrencies with instant online conversion to US dollars were chosen for the analysis. Such currencies from the Top 30 as EOS, Bn-

bCoin, VibeCoin, Po.et are not converted to the US dollar, so these cryptocurrencies are not included in the portfolio.

We first assess the attractiveness of the cryptocurrency under consideration based on its price trend — an element of the technical analysis apparatus used to detect trends in price changes on various types of exchanges. A trend is the direction of the price movement of the cryptocurrency in question. Trends can be ascending, descending, and lateral, when there is no pronounced price movement, and the trend line is moving in a corridor.

The cryptocurrency market is characterized by high nonlinearity; therefore the authors chose a polynomial trend line. Polynomial approximation is used to describe quantities that alternately increase and decrease. It is useful, for example, for analysing a large set of data on an unstable value. The degree of the polynomial is determined by the number of extrema (maxima and minima) of the curve. The polynomial of the second degree can describe only one maximum or minimum. The polynomial of the third degree has one or two extrema. The polynomial of the fourth degree can have no more than three extrema.

One also has to note the in-sample accuracy of the approximation. This can be measured by a simple R-squared coefficient. After the initial analysis of the cryptocurrencies from the list provided above, high-volatility and downtrend cryptocurrencies were excluded, specifically Zcash, Verge, Tron, BitcoinGold, Walton, Monero, and Cardano. The remaining 15 cryptocurrencies could be analysed using correlation analysis.

Table 1 shows that in principle, the correlation between different cryptocurrencies is rather high. However, this is likely to be a spurious correlation caused by the presence of common trends (e.g. the tendency of all cryptocurrencies to appreciate in sync). In order to get a clearer picture, one can remove the polynomial trend from the cryptocurrency exchange rate and repeat the correlation analysis. These results are summarised in Table 2.

Table 1. Cryptocurrency correlations

	BTC	BCH	CND	DASH	ETC	ETH	IOT	LSK	LTC	NEO	OMG	VEN	XLM	XMR	XRP
BTC	1.00														
BCH	0.87	1.00													
CND	0.51	0.61	1.00												
DASH	0.92	0.97	0.65	1.00											
ETC	0.87	0.90	0.61	0.92	1.00										
ETH	0.78	0.86	0.80	0.87	0.89	1.00									
IOT	0.93	0.87	0.55	0.92	0.89	0.81	1.00								
LSK	0.73	0.87	0.85	0.87	0.82	0.95	0.77	1.00							
LTC	0.90	0.89	0.61	0.94	0.89	0.85	0.92	0.82	1.00						
NEO	0.64	0.75	0.77	0.74	0.76	0.94	0.68	0.87	0.71	1.00					
OMG	0.68	0.79	0.86	0.82	0.76	0.90	0.73	0.91	0.78	0.88	1.00				
VBN	0.60	0.70	0.84	0.70	0.74	0.94	0.64	0.89	0.67	0.93	0.83	1.00			
XLM	0.72	0.78	0.84	0.80	0.81	0.94	0.76	0.91	0.78	0.89	0.85	0.94	1.00		
XMR	0.91	0.95	0.72	0.98	0.93	0.92	0.93	0.91	0.94	0.81	0.87	0.78	0.86	1.00	
XRP	0.67	0.77	0.85	0.79	0.74	0.89	0.71	0.91	0.76	0.82	0.85	0.88	0.96	0.82	1.00

Note: Authors' calculations based on the data from [CryptoCompare, 2018].

Table 2. Detrended cryptocurrency correlations

	BTC	BCH	CND	DASH	ETC	ETH	IOT	LSK	LTC	NEO	OMG	VEN	XLM	XMR	XRP
BTC	1.00														
BCH	0.52	1.00													
CND	-0.04	0.26	1.00												
DASH	0.69	0.89	0.35	1.00											
ETC	0.68	0.76	0.32	0.83	1.00										
ETH	0.32	0.60	0.68	0.64	0.74	1.00									
IOT	0.86	0.67	0.20	0.81	0.76	0.55	1.00								
LSK	0.16	0.64	0.76	0.65	0.58	0.86	0.45	1.00							
LTC	0.74	0.72	0.31	0.87	0.75	0.64	0.81	0.57	100						
NEO	0.04	0.39	0.62	0.37	0.50	0.87	0.31	0.73	0.37	1.00					
OMG	0.12	0.50	0.77	0.56	0.50	0.79	0.41	0.81	0.52	0.75	1.00				
VBN	0.04	0.36	0.74	0.35	0.50	0.90	0.30	0.81	0.36	0.87	0.67	1.00			
XLM	0.29	0.49	0.73	0.55	0.61	0.88	0.50	0.81	0.52	0.77	0.70	0.88	1.00		
XMR	0.65	0.81	0.51	0.92	0.86	0.80	0.84	0.77	0.87	0.56	0.70	0.56	0.69	1.00	
XRP	0.23	0.53	0.76	0.57	0.49	0.80	0.43	0.84	0.53	0.67	0.71	0.79	0.94	0.66	1.00

Note: authors' calculations based on the data from [CryptoCompare, 2018].

Based on the results in Table 2, we can exclude currencies that exhibit a high correlation with others even after removing the trend. We set the threshold for “high” correlation at 0.8 to ensure that enough cryptocurrencies remain for portfolio construction. On this basis, we choose the following cryptocurrencies for the investment portfolio: Bitcoin (BTC), BitcoinCash (BCH), Cindicator (CND), EthereumClassic (ETC), Ethereum (ETH), Litecoin (LTC), Neo (NEO), OmiseGo (OMG) and Ripple (XRP).

To create a balanced portfolio, this paper uses the Markowitz model, which is an approach based on the analysis of expected mean values and variations of random variables. In addition, the risk/yield indicators are calculated for each asset in the portfolio. As a criterion for a possible deviation of profitability, the condition of an economic recovery or recession is usually taken. The expected portfolio risk is the standard deviation of the possible yields.

To calculate yields and risk, it is necessary to set the time horizon of the portfolio. Since cryptocurrencies have high volatility, it is better to make the portfolio for a short period of time, for example, three weeks. One can thus calculate the mean yield and the standard deviation for the cryptocurrency in a series of three-week periods covering the time horizon of the paper. The results are summarized in Table 3 and (averaged over three-week periods) in Figure 1 [Saksonova, Kuzmina-Merlino, 2018].

One can now calculate the overall standard deviation of portfolio returns (recall that in Markowitz model the optimal set of weights is the one that minimizes portfolio return variance, which is used as a proxy for risk). Total portfolio variance is given by:

$$\sigma_p = \sqrt{\sum_{i=1}^n (w_i^2 \cdot \sigma_i^2) + 2 \sum_{i=1}^{n-1} \sum_{j=i+1}^n (w_i \cdot w_j \cdot \rho_{ij} \cdot \sigma_i \cdot \sigma_j)}, \quad (1)$$

Table 3. Yields of select cryptocurrencies, %

Date	BTC	BCH	CND	ETC	ETH	LTC	NEO	OMG	XRP
14.08.2017	56.62	0.00	0.00	-12.24	29.91	1.84	0.00	364.86	-15.71
04.09.2017	-1.40	106.62	0.00	35.83	18.82	73.75	-36.47	56.10	38.99
25.09.2017	-7.84	-30.94	-43.00	-45.72	-19.82	-39.90	-36.22	-19.93	-23.71
16.10.2017	46.44	-25.44	-17.77	14.89	19.10	38.06	41.83	-7.21	50.94
06.11.2017	20.84	99.24	-61.62	9.53	-11.99	-16.74	-5.17	-21.43	-24.70
27.11.2017	39.85	174.68	62.12	65.27	58.82	57.86	44.04	34.77	22.43
18.12.2017	94.92	6.32	125.08	57.13	52.56	270.73	76.18	84.14	191.12
08.01.2018	-21.06	38.47	352.38	4.23	55.73	-15.02	50.16	56.43	290.56

Note: authors' calculations based on the data from [CryptoCompare, 2018].

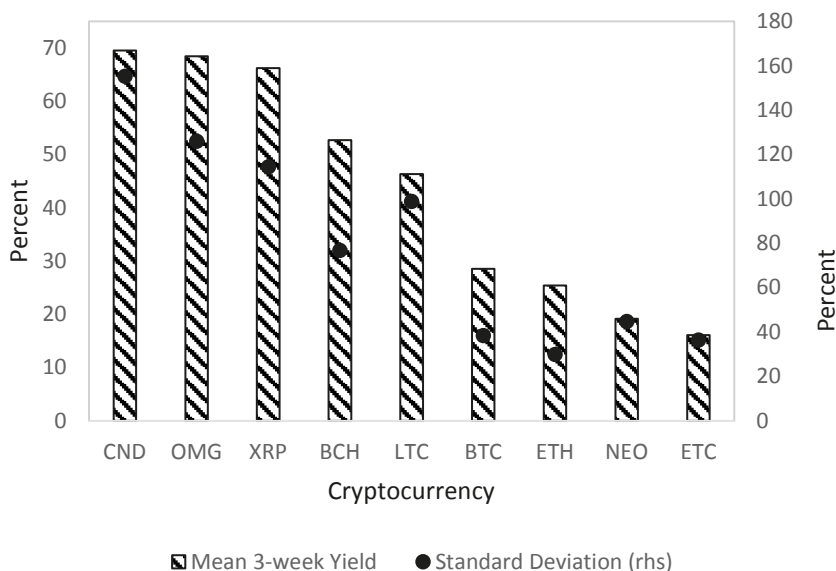


Fig. 1. Mean 3-week yield and standard deviation (July 2017 — January 2018), %
 Note: authors' calculations based on the data from [CryptoCompare, 2018].

where σ_p is the standard deviation of portfolio returns, w_i is the weight of the i -th financial instrument, ρ_{ij} is the correlation coefficient of yields of the i -th and j -th financial instrument, and σ_j is the standard deviation of the yield of the i -th financial instrument. One can then use equation (1) to solve numerically for weights w_i such that the standard deviation of portfolio return is minimized, or the weighted average return maximized. The corresponding solutions are shown in Figure 2.

Thus, an investment portfolio targeting maximum profit (standard deviation of returns of 34%) is largely focused on two currencies: OmiseGo accounting for 39% of the portfolio, and BitcoinCash accounting for 20% of the portfolio.

The investment portfolio with minimum risks (with expected yield of above 30%) is largely focused on BitcoinCash, which accounts for 60% of the portfolio.

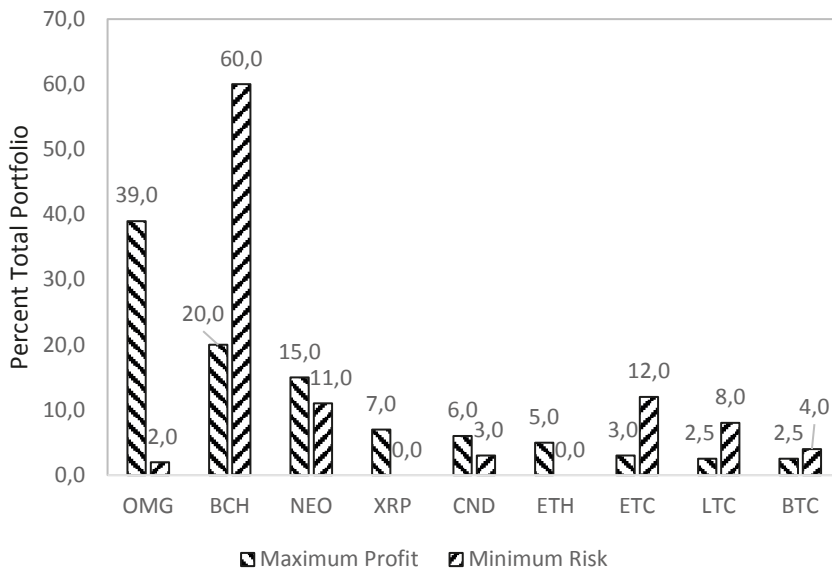


Fig. 2. Portfolio allocations for maximum profit and minimum risk (% total portfolio)
 Note: authors' calculations based on the data from [CryptoCompare, 2018].

Conclusions and Recommendations

Cryptocurrencies emerged as a result of dramatic innovations in finance. Over the past several years, interest in cryptocurrencies has increased significantly, and they can now be considered a legitimate investment instrument. However, due to the high volatility of their returns, cryptocurrency investment portfolios likely should be monitored in real time and constantly adjusted.

In the short term, investing in cryptocurrencies yields can achieve substantial returns, in combination with substantial risk. These risks can be minimized if a prospective investor follows a few recommendations. First, there should be enough portfolio diversification. Second, cryptocurrencies comprising the portfolio should be liquid, that is, convertible to a fiat currency. Third, to the extent possible, uncorrelated cryptocurrencies should be included. Portfolio weights can then be determined by the application of the standard Markowitz model, taking into account the risk/yield ratio.

This paper provided an illustrative demonstration of such an approach. It could easily be extended to more sophisticated applications by combining cryptocurrencies with other financial assets. Cryptocurrencies remain a rapidly evolving market. In the long-run their potential as an investment instrument will likely depend on regulatory developments, as well as market dynamics and whether there will be enough users for a variety of cryptocurrencies.

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**Криптовалюта как инвестиционный инструмент
на современном финансовом рынке**

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Для цитирования: Saksonova, S., Kuzmina-Merlino, I. (2019) Cryptocurrency as an Investment Instrument in a Modern Financial Market. *Вестник Санкт-Петербургского университета. Экономика*. Т. 35. Вып. 2. С. 269–282. <https://doi.org/10.21638/spbu05.2019.205> (In English)

В статье рассматривается разработка рекомендаций привлекательных инвестиционных стратегий, которые включают криптовалютные активы с учетом затрат и возможных рисков. Предмет анализа — криптовалюты как инвестиционный инструмент. Главная гипотеза исследования состоит в том, что современная портфельная теория может быть применена к криптовалютным инструментам для разработки инвестиционного портфеля с подходящим уровнем риска и доходности. Авторы статьи (1) рассматривают криптовалюты в контексте современного финансового рынка; (2) разрабатывают критерии оценки для определения привлекательности отдельных криптовалют и (3) предлагают рекомендации по формированию оптимального инвестиционного портфеля из криптовалют. Для подтверждения гипотезы были проведены расчеты и использованы такие методы научного исследования, как сбор и обработка исторических значений по курсам криптовалют с июля 2017 г. по январь 2018 г., а также осуществлено исследование данных на корреляцию, ковариацию, коэффициент возврата инвестиций. Показано, что инвестиционный портфель криптовалют необходимо формировать с учетом целей инвестора, с тем чтобы он соответствовал логической взаимосвязи между риском и прибылью. Следовательно, криптовалюты не должны коррелировать; инвестиционный портфель должен быть достаточно диверсифицированным, чтобы свести к минимуму риск; криптовалюты должны иметь ликвидность, т. е. свободно обмениваться, например, на доллары и евро. Инвесторам также следует рассмотреть возможность регулярной ребалансировки портфеля, что может помочь повысить его прибыльность.

Ключевые слова: криптовалюты, финансовый рынок, инвестиционный портфель.

Статья поступила в редакцию 08.10.2018
Статья рекомендована в печать 14.02.2019

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