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Optimal Cryptocurrency and BIST 30 Portfolios with the Perspective of Markowitz Portfolio Theory

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Abstract We apply the Markowitz mean-variance framework to assess risk-return benefits of cryptocurrency-portfolios. Using daily data of the three major cryptocurrencies for the time span 1/1/2019 to 27/04/2021, we relate risk and return of different mean-variance portfolio strategies to Bitcoin, Etherium, Ripple and BIST 30 benchmark. We find that combining cryptocurrencies crowds out BIST 30 index to maximize return and Sharpe ratio while cryptocurrencies are crowded out if the optimization problem is changed to a risk minimization problem rather than a return maximization problem. Furthermore, according to rolling-window approach shift from Bitcoin to Etherium is important.

Keywords: *cryptocurrencies, portfolio optimization, markowitz*

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1. Introduction

Crypto Currencies such as Bitcoin, Ethereum, Tether, Dodge, etc. are in close watch of investors, financial and government organizations, central banks, policymakers, economists, entrepreneurs, and the public, all around the World. Due to the high level of liquidation as a result of monetary easing and small yields from invested assets, the relevancy to the speculative assets increased over the years. Nowadays, the main discussion occurs specific to Bitcoin, if it can have accepted as a kind of payment tool (currency) or can be treated as a speculative financial asset, because of its high level of exchange rate volatility [1]. The economists canalize their attention to Bitcoin as it has the potential of turning the conventional monetary and payment system upside down [2]. Since the high level of volatility and even daily fluctuations keep away the accountability of Bitcoin, the common view is to consider Bitcoin as an asset [3]. The European Central Bank stated Bitcoin should be considered a high-risk asset [4,5]. The return and volatility of cryptocurrencies are more interested and examined research areas for the economics and finance literature [6,7]. The only thing we are sure of about these cryptocurrencies is that, even if they are considered as a tool for transaction systems or a high-risk asset, they are already in the financial system and the portfolio of some investors.

Bitcoin has been created by Nakamoto [8] and since then, many other cryptocurrencies have been created and introduced to the financial system. No doubt, Bitcoin is the most known and remarkable among thousands of others [9]. The philosophy of Bitcoin triggers its demand. The enthusiasm of freedom, invisibility, and singularity besides the willingness to pay low transaction costs are the key drivers of the use of Bitcoin. The possibility of avoiding currency controls and tax evasion programs may also be the other reasons for the favor of Bitcoin for large mass [10]. As of March 14, 2021, the market capitalization, and Circulation Supply of Bitcoin and the top 20 sub-coins are taken from Coin Market Cap (https://coinmarketcap.com/).

Table 1. The Top 20 Cryptocurrencies Market Cap and Circulating Supply [11]

Rank	Name	Market Cap	Price	Circulating Supply
1	Bitcoin	$1,135,462,788,823	$60,871.71	18.653.375 BTC
2	Ethereum	$217,910,014,372	$1,894.17	115.042.485 ETH
3	Binance Coin	$41,762,966,662	$270.25	154.532.785 BNB
4	Tether	$38,225,238,147	$1.00	38.243.573.409 USDT
5	Cardano	$34,429,771,777	$1.08	31.948.309.441 ADA
6	Polkadot	$34,318,064,876	$37.30	920.170.663 DOT

Rank	Name	Market Cap	Price	Circulating Supply
7	Ripple	$20,630,198,168	$0.45	45.404.028.640 XRP
8	Uniswap	$17,064,129,870	$32.71	521.718.319 UNI
9	Litecoin	$14,720,523,157	$220.87	66.648.577 LTC
10	Chainlink	$12,053,805,809	$29.19	413.009.556 LINK
11	Bitcoin Cash	$10,939,612,292	$585.66	18.679.244 BCH
12	USD Coin	$9,251,405,280	$1	9.251.713.289 USDC
13	Stellar	$9,013,338,531	$0.40	22.609.025.956 XLM
14	Wrapped Coin	$8,121,352,755	$60,745.22	133.695 WBTC
15	Dogecoin	$7,887,572,678	$0.06	128.743.201.388 DOGE
16	Theta	$7,452,701,110	$7.45	1.000.000.000 THETA
17	Terra	$6,015,093,559	$14.86	404.816.523 LUNA
18	Aave	$4,926,431,008	$396.12	12.436.683 AAVE
19	Crypto.com Coin	$4,642,370,081	$0.19	24.143.835.615 CRO
20	VeChain	$4,284,849,192	$0.07	64.315.576.989 VET

1.1. Can Bitcoin Be Considered as Gold?

Gold has always been a safe haven for investors as it is stable when fluctuations or risks occur either in financial markets or in politics. But the limited production and the supply of Bitcoin by non-governmental organizations make both similar. Gold is well known for its hedging capabilities against stocks.

An asset can be considered as a safe-haven only if the evidence of predictability from a stock index to that asset in the low quantiles of both the stock and the asset returns [12]. Some researchers consider Bitcoin as an asset and analyze the relationship between gold and bitcoin [12-17]. Reference [13] analyze the hedging capabilities of Bitcoin, and compare to gold. The data include daily observations for 5 years of the dollar-euro and dollar-sterling exchange rates as of 1769 observations from the Financial Times Stock Exchange Index (FTSE). The bitcoin price data is accumulated with the same observation methodology. Reference [15] examine the volatility behavior of cryptocurrencies, compare to stock indices and commodities. As the result of their study, they conclude that Bitcoin cannot be named as the Gold. Even though some dynamics of the behavior of Bitcoin may be like Gold and Silver, but from a viewpoint of portfolio structure, Bitcoin is far to be safe-haven and replace Gold. Reference [14] replace Gold with Bitcoin in an investment portfolio. They use Modern Portfolio Theory to argue the possible effects of this replacement. Their findings show that to substitute Gold for Bitcoin in a portfolio is possible but attain a high-risk adjusted return.

Return profile of Bitcoin and Gold also validate the literature view in Figure 1. Bitcoin/Gold price increase exponentially after December 2020 (left hand-side of the figure) and the return variance of bitcoin and is gold is not comparable since Bitcoin is too volatile to compare with gold in terms of volatility.

Reference [16] studies the classification of Bitcoin as a currency, a commodity, or an investment asset. He concludes that the ability of Bitcoin can be considered as an alternative product for investment assets. But, as the others conclude, the risk premium is significantly high. Reference [17] estimate the unconventional contribution of Bitcoin within portfolios of various asset classes and asses the return of the portfolio to consider the transaction costs. They conclude that considerable benefits can be obtained when Bitcoin is included in the investment portfolio. They dissociate from other studies, asserting that Bitcoin, because of its low correlation with other assets, may decrease the total risk of the investment portfolio.

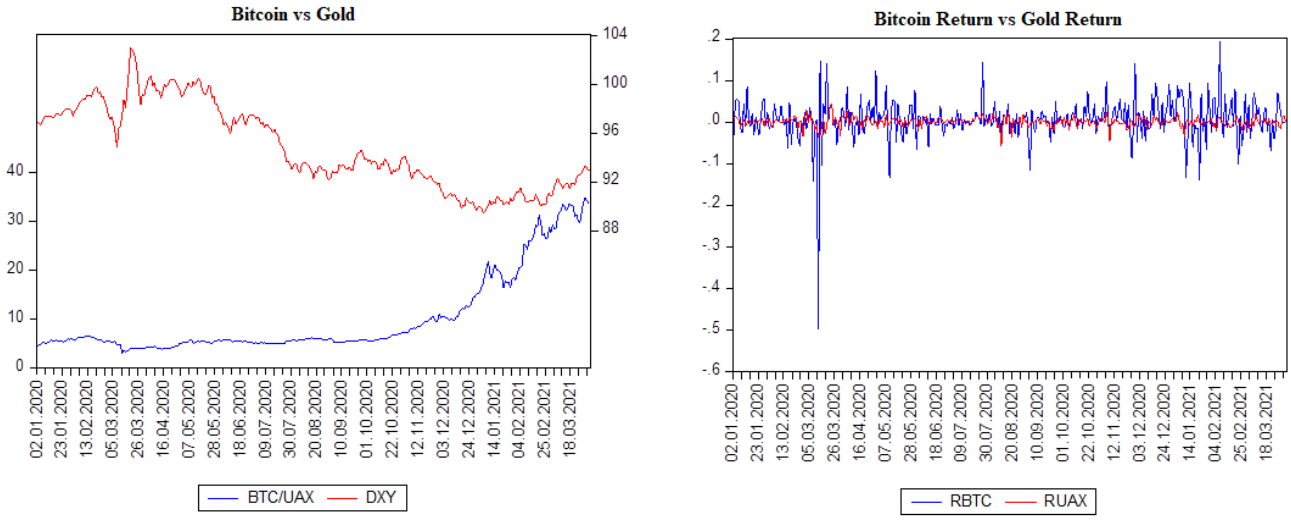

Figure 1. Bitcoin (blue line) vs Gold Return Profile (red line)

1.2. Bitcoin and Other Cryptocurrencies' Appearance in a Portfolio Investment

Many studies examine the contribution of Bitcoin as an asset to investment portfolios. But [18] discover that a significant number of studies focus on the role of cryptocurrencies as an alternative investment and source of diversification. Reference [19] for the first time examine intraday price behaviors of Cryptocurrencies. Reference [20] analyze the powerful effects of structural breaks (SB) on the storage of information over an extended period of Bitcoin and Ethereum price returns. Reference [21] study the significant aspects to affect prices of most well-known cryptocurrencies from 2010 through 2018 using weekly data. Reference [22] explore the stream and unique features of the price behavior of Bitcoin, Ethereum, and Ripple using Rescaled Range and Wavelet Analysis. Reference [23] analyze the high-tide/low-tide relationship between common cryptocurrencies such as Bitcoin and Ethereum. Reference [24] determine the existence of upside collective-movement in the return series of 12 cryptocurrencies and reach a remarkable upside movement activity on all occasions. Reference [25] study and estimate the risk of the portfolio by comparing the performance of cryptocurrencies. They use Markowitz diversification and the advanced Black– Litterman model to estimate errors in a cryptocurrency-based portfolio. Reference [26] shows that the investment outcome can be improved due to the portfolio diversification over different cryptocurrencies.

In this paper, we analyze the return of the portfolio in which major cryptocurrencies Bitcoin, Etherium, and Ripple take part as a subsidiary and risk spreading of the model portfolios by the diversification. The mean-variance portfolio optimization modeling [27] is the primary structure of our study. Markowitz is known as the "Father of the Modern Portfolio Theory" but as he mentioned [28], Roy also proposed making choices based on the mean and variance of the portfolio as a whole [29]. The main differences between both analyses can be concluded as follow: a. Markowitz's analysis necessitate nonnegative investments but Roy's Analysis tolerate the invested amount in any security to be positive or negative b. Markowitz set free the investors to make a choice any portfolio from the efficient edge, but Roy suggests the choice of a specific portfolio [27]. Markowitz states that there exist three very important circumstances that differ Portfolio Theory from the theory of the company and the theory of the consumer. 1. The Portfolio Theory tends to focus on investors 2. Economic agents try to make their decisions in an uncertain environment, and the Portfolio Theory tends these economic agents 3. The Portfolio Theory can be used by a large group of investors, just by computer aid and database [30]. Markowitz sees the portfolio as a mathematical problem. Markowitz's portfolio theory depends on an investor how he or she is risk-averse [31].

Markowitz's Theory is then considerably developed by Markowitz's fellow William Sharpe, who is known for The Capital Asset Pricing Model work on the theory of financial asset price formation [32]. Multiple numbers of studies in different countries all around the World are done based on Markowitz's Portfolio Theory since it is developed. But a few consider the cryptocurrencies in Markowit's Theory [33,34,35]. Our study is based on the benefit of risk diversification in Turkey's Stock Exchange (Borsa Istanbul) by including major cryptocurrencies into the Portfolio. Reference [36] pursue to examine an experimental valuation of the benefits of portfolio diversification in Malaysia's stock market.

2. Data and Methodology

We use daily market data, covering a period of 3 years from 1/1/2019 to 27/04/2021, freely available from www.investing.com. The data set includes Borsa Istanbul 30 Index (BIST 30), Bitcoin (BTC), Etherium (ETH) and Ripple (XRP). We divided the data set in to three different period to analyze the changing performance of cryptocurrencies since after December 2020 they increased tremendously compared to BIST 30 Index. So, the time periods for all portfolios are 01.02.2019-27.04.2021, 01.12.2020-27.04.2021 and 01.03.2021-27.04.2021 which will also enable us to observe Etherium's and Ripple's increasing market share and Bitcoin's decreasing dominance.

Table 2 exhibits the descriptive statistics for the returns. The mean values are close to zero for all the returns however cryptocurrencies are still more clustered compared to BIST 30. The statistics of each return differ from each other, but in common the skewness of each return is not equal to zero and neither is the kurtosis, indicating that each return has typical characteristics of leptokurtosis and fat-tail. It is well known that leptokurtosis and fat-tail are the typical characteristics of financial time series. The J-B statistic of each return is significant from zero, which means none of the returns obeys the normal distribution. Further, the stationarity of the variables has been examined using the Augmented Dickey-Fuller (ADF) unit root test. The null hypothesis of the unit root is strongly rejected for all return series.

Table 2. Descriptive Statistics

	RBIST 30	RBTC	RETH	RXRP
Mean	0.000461	0.004611	0.005227	0.001928
Median	0.001059	0.002962	0.001874	0.000360
Maximum	0.057398	0.193756	0.349153	0.622844
Minimum	-0.10476	-0.480904	-0.592454	-0.541017
Std. Dev.	0.015714	0.047707	0.062084	0.072093
Skewness	-1.034327	-1.768792	-1.387508	0.721273
Kurtosis	9.062669	23.37351	21.04962	22.84683
Jarque-Bera	983.1369	10244.45	7989.849	9486.966
Probability	0.00000	0.00000	0.00000	0.00000
ADF Tests (Level)	-23.18	-26.44	-16.38	-23.09

Notes: Between parenthesis: p-values. The number of observations for first period is 575 JB are the empirical statistics for Jarque Bera tests for normality based on skewness and kurtosis ADF Tests refer to Augemented Dickey Fuller test for the presence of unit root for long differences (returns).

In Figure 2 we can see the price walk of BIST 30 Index, Bitcoin, Etherium and Ripple. After December 2020 cryptocurrencies we chose for our portfolio rose very steeply which has driven us to construct six different

portfolios in three different time zones. This rolling window approach will enable us to understand the changing performance of cryptocurrencies among themselves as well. As a result, we will see that high volatile nature of these crypto-assets requires more frequent re-optimizations for portfolio managers to catch the ultimate optimal portfolio reflecting the recent dynamics of crypto markets.

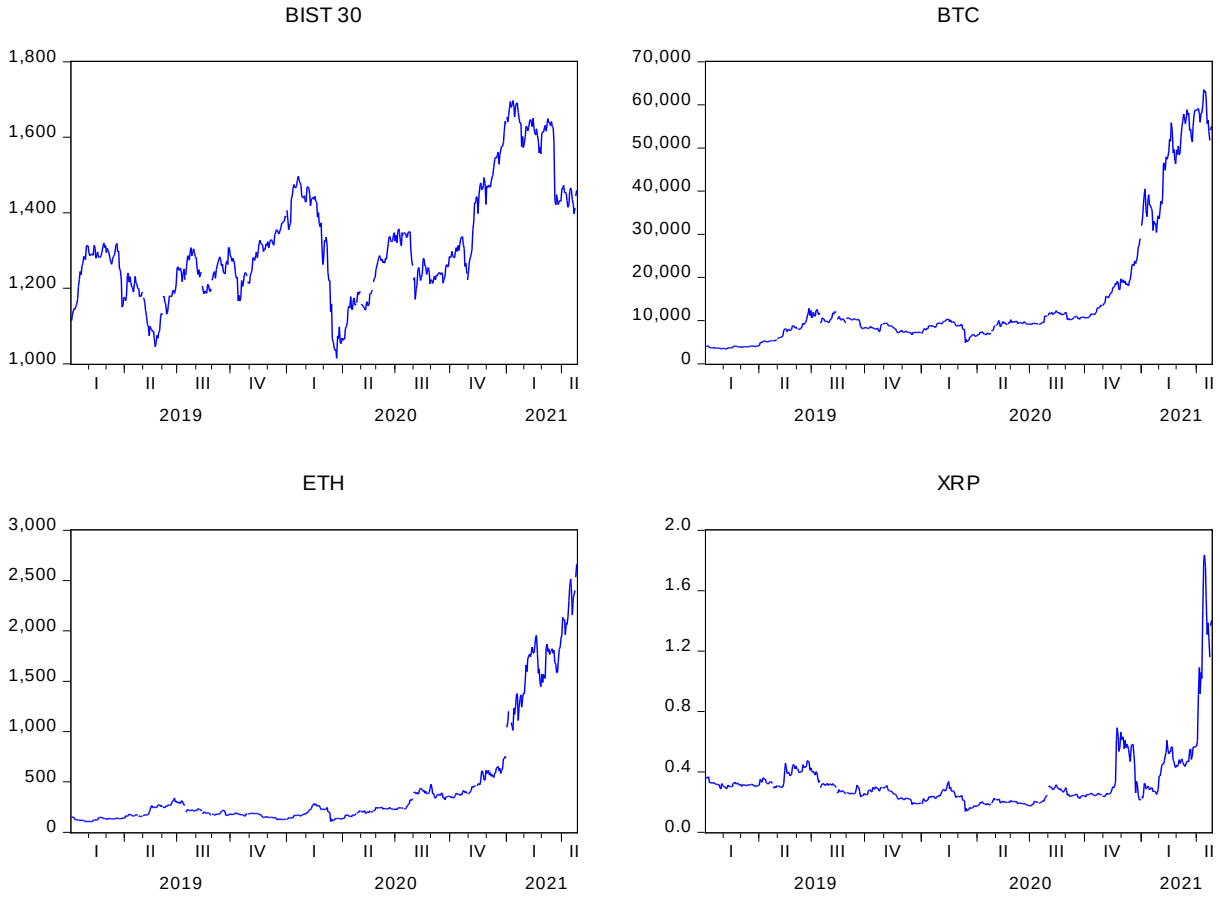

Figure 2. Daily Price Graphs of BIST 30, Bitcoin, Etherium and Ripple

In our attempt to address and quantify portfolio effects in the crypto-asset universe we rely on the traditional mean variance portfolio selection framework as proposed by Markowitz [27].

As a starting point for mean-variance optimization, we calculate daily log-returns r_{it} for CC i at time t, derived from close prices *P* according to

$$R_{it} = \ln(P_t) - \ln(P_{t-1}) \quad (1)$$

Markowitz portfolio theory enables us to analyze how good a given portfolio is based on only the means and the variance of the returns of the assets contained in the portfolio which requires an investor is supposed to be risk averse. In this context let us consider a portfolio with n different assets where asset number i will give the return R_i where mean, and variance will be represented with μ_i *and* σ_i^2. The covariance between R_i and R_j . Finally x_i will represent the portion of the value of the portfolio invested in asset *i*. If R is the return of the whole portfolio:

$$\mu = E[R] = \sum_{i=1}^{n} \mu_i x_i \quad (2)$$

$$\sigma^2 = Var[R] = \sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{i,j} x_i x_j \quad (3)$$

$$\sum_{i=1}^{n} x_i = 1 \quad (4)$$

For different choices of $x_1, ..., x_n$ the investor will get different combinations of μ and σ^2 . However, since short sales is not allowed in Markowitz framework, we need one more condition which is:

$$x_i \geq 0, i = 1, 2, ..., n \quad (5)$$

Condition (4) states that only long positions are allowed.

3. Results and Discussion

Since an investor wants a high profit and a small risk, he/she wants to maximize μ and minimize σ2 and therefore he/she should choose a portfolio which gives a (σ2, μ) combination in the efficient set. We settled three major objective function as;

- Maximizing Sharpe Ratio
- Maximizing portfolio annual return
- Minimizing portfolio annual volatility (standard deviation)

Furthermore, we settled various constraints for maximization objectives since the high returns of cryptocurrencies crowd-out the BIST 30 index in the

portfolios without any weight constraints while we also included constraints for minimization problem as well to avoid crowding out the cryptocurrencies. In this context for three major cases, we composed 18 different portfolios for three different time periods with various constraints.

Table 3- Panel A represents the results for a set of portfolios without any extra constraints with an objective function to maximize Sharpe ratios of the portfolios. Since compared to BIST 30 Index, the return of cryptocurrencies is 9.6x, 1.1x and 0.4x time more for Bitcoin, Etherium and Ripple respectively without any constraint, fund managers do not include any portion of BIST 30 to the portfolios in any three periods to maximize Sharpe ratio.

However, the portion of Bitcoin, Etherium and Ripple vary due to the sub periods as in 2021 Etherium and Ripple gain power against Bitcoin. Between 01.02.2019 and 27.04.2021 the optimal weights are calculated as 0% BIST 30, 81% Bitcoin, 19% Etherium and 0% Ripple for Sharpe ratio maximization while between 01.03.2021 and 27.04.2021 these weights change to 0% BIST 30, 0% Bitcoin, 74% Etherium and 26% Ripple. Yet adding another constraint such as telling the fund manager that the costumer wants to include at least 30% of BIST 30 in his/her portfolio than the weights for Sharpe maximization becomes 30% BIST 30, 56% Bitcoin, 14% Etherium and 0% Ripple between 01.02.2019 and 27.04.2021; 30% BIST 30, 0% Bitcoin, 48% Etherium and 22% Ripple between 01.03.2021 and 27.04.2021. Fund manager puts money no more than the minimum requirement to BIST 30 which is also consistent with previous findings. (Panel B).

Table 4-Panel A represents the results for a set of portfolios without any extra constraints with an objective function to maximize only return of the portfolios. Between 01.02.2019 and 27.04.2021 the optimal weights are calculated as 0% BIST 30, 0% Bitcoin, 100% Etherium and 0% Ripple for return maximization while between 01.03.2021 and 27.04.2021 these weights change to 0% BIST 30, 0% Bitcoin, 0% Etherium and 100% Ripple.

Yet again adding another constraint such as telling the fund manager that the costumer wants to include at least 30% of BIST 30 in his/her portfolio than the weights for return maximization becomes 30% BIST 30, 0% Bitcoin, 70% Etherium and 0% Ripple between 01.02.2019 and 27.04.2021 and 30% BIST 30, 0% Bitcoin, 40% Etherium and 70% Ripple between 01.03.2021 and 27.04.2021. Fund manager puts money no more than the minimum requirement to BIST 30 which is also consistent with previous findings (Panel B).

Table 3. Case 1 Portfolio Set and Outputs

Case 1

Panel A: Objective: Maximize Sharpe ratio, Constraint: No constraint

01.02.2019-27.04.2021			01.12.2020-27.04.2021			01.03.2021-27.04.2021		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	0%		**RBIST30**	0%		**RBIST30**	0%	
RBTC	81%		**RBTC**	41%		**RBTC**	0%	
RETH	19%		**RETH**	59%		**RETH**	74%	
RXRP	0%		**RXRP**	0%		**RXRP**	26%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.46%	169%	Return	1.32%	481%	Return	1.86%	678%
Variance	0.24%		Variance	0.34%		Variance	0.33%	
Std. Dev	4.90%	94%	Std. Dev	5.80%	111%	Std. Dev	5.78%	110%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	1.60		Sharpe Ratio	4.17		Sharpe Ratio	5.97	

Panel B: Objective: Maximize Sharpe ratio, Constraint: Minimum %30 share for BIST 30

01.02.2019-27.04.2021			01.12.2020-27.04.2021			01.03.2021-27.04.2021		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	30%		**RBIST30**	30%		**RBIST30**	30%	
RBTC	56%		**RBTC**	25%		**RBTC**	0%	
RETH	14%		**RETH**	45%		**RETH**	48%	
RXRP	0%		**RXRP**	0%		**RXRP**	22%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.34%	123%	Return	0.95%	348%	Return	1.31%	477%
Variance	0.12%		Variance	0.19%		Variance	0.19%	
Std. Dev	3.53%	67%	Std. Dev	4.33%	83%	Std. Dev	4.34%	83%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	1.55		Sharpe Ratio	3.98		Sharpe Ratio	5.52	

Table 4. Case 2 Portfolio Set and Outputs

Case 2

Panel A: Objective: maximize return, Constraint: No constraint									
01.02.2019-27.04.2021			**01.12.2020-27.04.2021**			**01.03.2021-27.04.2021**		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	0%		**RBIST30**	0%		**RBIST30**	0%	
RBTC	0%		**RBTC**	0%		**RBTC**	0%	
RETH	100%		**RETH**	100%		**RETH**	0%	
RXRP	0%		**RXRP**	0%		**RXRP**	100%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.51%	188%	Return	1.55%	565%	Return	2.89%	1056%
Variance	0.39%		Variance	0.51%		Variance	1.41%	
Std. Dev	6.21%	119%	Std. Dev	7.11%	136%	Std. Dev	11.87%	227%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	1.42		Sharpe Ratio	4.02		Sharpe Ratio	4.58	
Panel B: Objective: maximize return, Constraint: Minimum %30 share for BIST 30								
01.02.2019-27.04.2021			**01.12.2020-27.04.2021**			**01.03.2021-27.04.2021**		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	30%		**RBIST30**	30%		**RBIST30**	30%	
RBTC	0%		**RBTC**	0%		**RBTC**	0%	
RETH	70%		**RETH**	70%		**RETH**	0%	
RXRP	0%		**RXRP**	0%		**RXRP**	70%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.37%	137%	Return	1.09%	398%	Return	1.98%	722%
Variance	0.20%		Variance	0.26%		Variance	0.68%	
Std. Dev	4.43%	85%	Std. Dev	5.11%	98%	Std. Dev	8.25%	158%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	1.39		Sharpe Ratio	3.88		Sharpe Ratio	4.46	

Table 5-Panel A represents the results for a set of portfolios without any extra constraints with an objective function to minimizing risk of the portfolios. Between 01.02.2019 and 27.04.2021 the optimal weights are calculated as 93% BIST 30, 4% Bitcoin, 0% Etherium and 3% Ripple for return maximization while between 01.03.2021 and 27.04.2021 these weights change to 94% BIST 30, 0% Bitcoin, 2% Etherium and 5% Ripple.

Yet again adding another constraint such as telling the fund manager that the costumer wants to include at least 10% of all three crypto currencies in his/her portfolio than the weights for return maximization becomes 70% BIST 30, 10% Bitcoin, 10% Etherium and 10% Ripple between 01.02.2019 and 27.04.2021 which is the same for 01.03.2021 and 27.04.2021. Fund manager puts money no more than the minimum requirement to all three crypto currencies (Panel B). Consequently, without any specific constraint we can conclude that for either maximization or minimization problems.

Markowitz model has a tendency totally crowds out whether cryptocurrency or BIST 30 index based on the objective function. Figure 3 exhibits the efficient frontier of possible portfolios without any constraints with the perspective of Markowitz Portfolio Theory. Since the investor is supposed to be risk averse the frontier depends on the targeted revenues with an objection function of risk minimization and no asset weight constraints.

Figure 3 represents the period between 01.02.2019 and 27.04.2021 and Case 3 Panel A situation without minimum requirement cryptocurrency. In Figure 4 we can observe that as the targeted revenue increase the portion of the cryptocurrency included to the portfolio also increases. In this case although the investor is defined as a risk-averse profile if you want to increase your target revenue with a portfolio composed of BIST 30, Bitcoin, Etherium and Ripple you must increase their share in the portfolio.

Of course, these portions will be adjusted and most probably there will be a shift between Bitcoin, Etherium and Ripple based on our preliminary results in Table 3, Table 4 and Table 5. We did not perform this exercise since the result is obvious.

Table 5. Case 3 Portfolio Set and Outputs

Case 3

Panel A: Objective: minimize volatility, Constraint: No constraint								
01.02.2019-27.04.2021			**01.12.2020-27.04.2021**			**01.03.2021-27.04.2021**		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	93%		**RBIST30**	98%		**RBIST30**	94%	
RBTC	4%		**RBTC**	0%		**RBTC**	2%	
RETH	0%		**RETH**	0%		**RETH**	0%	
RXRP	3%		**RXRP**	2%		**RXRP**	5%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.07%	25%	Return	0.04%	15%	Return	-0.01%	-2%
Variance	0.02%		Variance	0.02%		Variance	0.04%	
Std. Dev	1.53%	29%	Std. Dev	1.57%	30%	Std. Dev	1.97%	38%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	0.19		Sharpe Ratio	-0.13		Sharpe Ratio	-0.57	
Panel B: Objective: minimize volatility, Constraint: Minimum %10 share for BTC, %10 share for ETH, %10 share for XRP								
01.02.2019-27.04.2021			**01.12.2020-27.04.2021**			**01.03.2021-27.04.2021**		
Portfolio Weights			**Portfolio Weights**			**Portfolio Weights**		
RBIST30	70%		**RBIST30**	70%		**RBIST30**	70%	
RBTC	10%		**RBTC**	10%		**RBTC**	10%	
RETH	10%		**RETH**	10%		**RETH**	10%	
RXRP	10%		**RXRP**	10%		**RXRP**	10%	
	100%			100%			100%	
	Daily	**Annualized**		**Daily**	**Annualized**		**Daily**	**Annualized**
Return	0.15%	56%	Return	0.34%	125%	Return	0.37%	135%
Variance	0.04%		Variance	0.05%		Variance	0.05%	
Std. Dev	2.02%	39%	Std. Dev	2.31%	44%	Std. Dev	2.33%	44%
Risk-free rate	19%		Risk-free rate	19%		Risk-free rate	19%	
Sharpe Ratio	0.94		Sharpe Ratio	2.40		Sharpe Ratio	2.62	

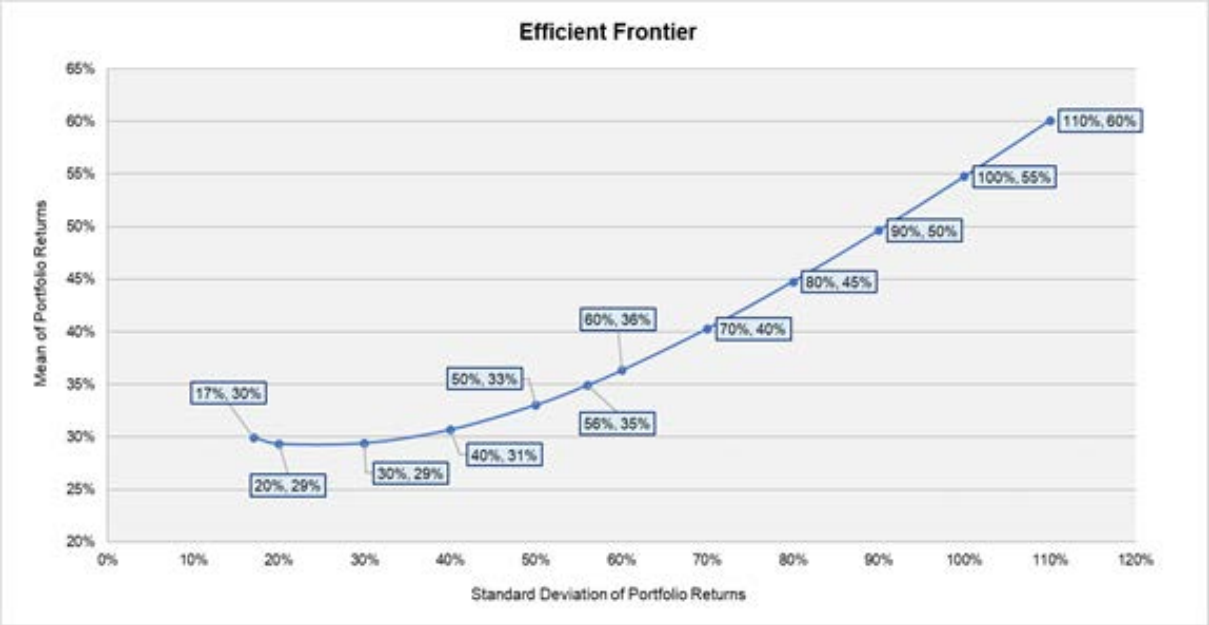

Figure 3. Efficient Frontier

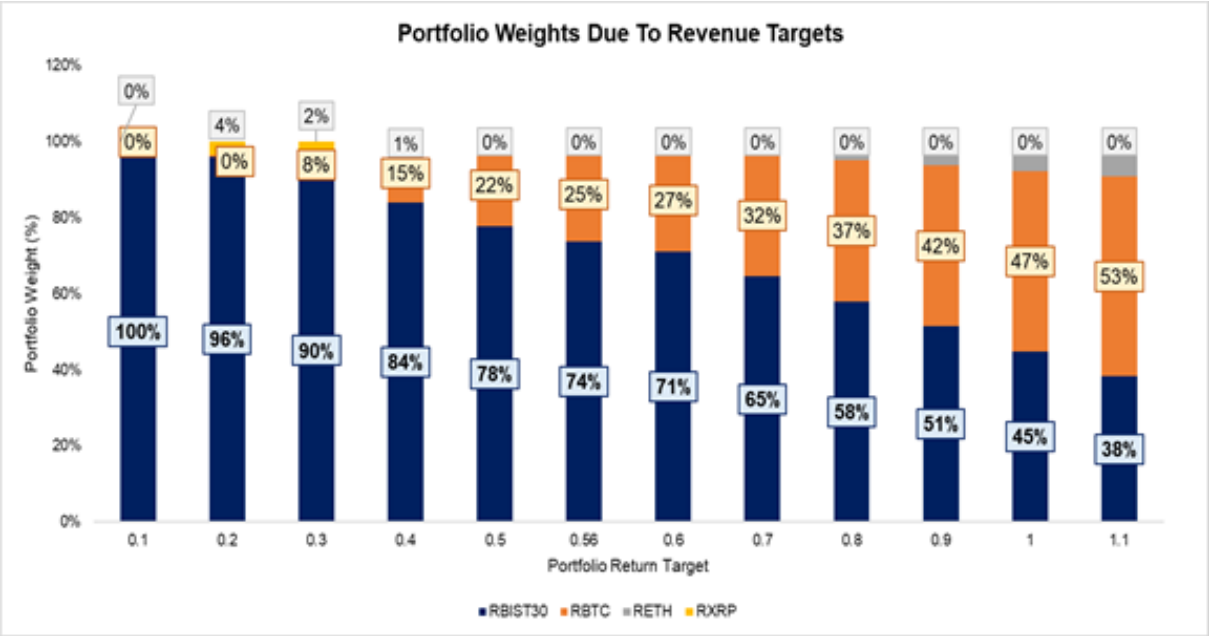

Figure 4. Portfolio Asset Breakdowns for Targeted Revenues

4. Conclusion

In this study we provide a pioneer study to understand the effects of diversified cryptocurrency investments to Turkish financial markets in a traditional Markowitz mean-variance framework. Although Markowitz model has limitations, we find this exercise useful to understand different characteristics of cryptocurrency assets and exchange indices. One weakness of Markowitz model is that the variance of a portfolio is not a complete measure of the risk taken by the investor. The model does not tell an investor which portfolio he/she can afford to buy if he/she is willing to take a certain high-level risk.

As a result, without any specific constraint for maximization or minimization problems Markowitz model totally crowds out whether cryptocurrency or BIST 30 index based on the objective function. In context, applying different constraints of mean-variance investments, our study identifies wide range of diversified portfolios to derive risk-adjusted outperformance. Our next attempt will cover alternative approaches to portfolio optimization for further research.

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