DECENTRALIZED FINANCIAL MARKETS: ASSESSING THE IMPACT OF CRYPTOCURRENCY INCLUSION ON PORTFOLIO PERFORMANCE

How does the inclusion of cryptocurrency impact the risk-adjusted returns of a multi-asset portfolio comprised of oil, gold, stocks, and real estate?

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1. Abstract

This research constructs ten optimal portfolios, where one is comprised of only oil (USO), gold (GLD), stock index (S&P500) and real estate index (VNQ). The remaining nine portfolios include all the abovementioned assets plus a cryptocurrency. A sample of the most traded cryptocurrencies examined in this study include Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), Solana (SOL), Binance (BNB), Dogecoin (DOGE), Cardano (ADA), Tron (TRX), and Avalanche (AVAX). The Sharpe ratio is used to assess the risk-adjusted performance before and after a cryptocurrency is added to the traditional portfolio. The aim is to find out which of the ten optimal portfolios produce the highest Sharpe ratio. In addition, the study also looks at risk exposure minimization to find out which of the ten optimal portfolios produce the lowest standard deviation. The latter approach is aimed at investors who only care about minimizing their portfolio's risk exposure, whereas the former approach is aimed at investors who want to optimize the portfolio's risk-adjusted returns.

Key words: cryptocurrency*, portfolio, Sharpe ratio, risk-adjusted returns, optimization

*cryptocurrency and crypto asset are used interchangeably.

AUTHOR'S DECLARATION

I, the undersigned, Mahmoud Al Hamdan, candidate for the BA degree in Culture, Politics and Society declare herewith that the present thesis titled "Decentralized Financial Markets: Assessing The Impact Of Cryptocurrency Inclusion On Portfolio Performance" is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

Vienna, 21 May 2025

Mahmoud Al Hamdan

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2. Background

Following the outbreak of the COVID-19 virus in late 2019, global economic activity was severely debilitated with unprecedented losses across all sectors. Consequently, financial markets across the world found themselves in a steep decline that persisted for months. On the other hand, the story picture looked considerably different for crypto assets that achieved remarkable gains that nobody had anticipated.

One of the key takeaways for investors during the pandemic was the rising correlation among traditional assets, making them more susceptible to economic cycles. As a result, constructing a portfolio with higher risk-adjusted returns has become increasingly challenging (Wuthisatian, 2022). Today, many retail and institutional investors are optimistic about cryptocurrency's capability to address the diversification challenges of their portfolio.

2.1 Purpose

The aim of this comparative research is to examine the effect of nine cryptocurrencies on the performance of a mixed portfolio comprised of traditional assets. More specifically, the objective is to deduce **A)** if an investment portfolio is better off having cryptocurrency and **B)** if so, which of those nine cryptocurrencies should it be included in the portfolio?

2.2 Analytical approach

The unit of measurement employed in this research is the Sharpe ratio, developed in 1966 by the renowned American economist William Sharpe. The Microsoft Excel function 'Solver' is used to construct all the portfolios presented, by using the minimization tool for the portfolio's standard

deviation (for those who only care about risk exposure) and the maximization tool (for those who only care about better risk-adjusted returns).

2.3 Key findings

In general, the inclusion of cryptocurrency leads to a higher Sharpe ratio of an optimally constructed portfolio. Meanwhile there is a wide variation in their risk exposure and Sharpe ratios of portfolios with cryptocurrency. It turns out that Bitcoin is not the best optimal choice to include in a portfolio, despite having the highest market capitalization. Instead, Ethereum has proved to have the best risk-adjusted returns compared to the other eight cryptocurrencies; investors can expect higher returns per unit of risk when adding Ethereum to their portfolio. Binance has the worst risk-adjusted returns, primarily due to the extreme volatility compared to others.

2.4 Literature review

While the literature on cryptocurrency's role in portfolio optimization is still emerging, scholars often agree that it can enhance the performance of a well-diversified portfolio. Meanwhile, some findings have diverging views on whether or not adding cryptocurrency enhances the Sharpe ratio. For example:

Brière et al. (2015) was one of the primary publications to test cryptocurrency's impact on portfolio optimization, where it measures the effect of adding Bitcoin investment to a portfolio of traditional assets (bonds and stocks) as well as alternative assets (commodities and real estate). The study concludes that a slight allocation to Bitcoin "may dramatically improve the risk-return trade-off of well-diversified portfolios." The research only assesses Bitcoin's weekly returns from 2010 to 2013, well before cryptocurrencies had entered the mainstream market. Hence, this study is

considered outdated and fails to capture the current landscape of cryptocurrency investment, given the rapid increase in crypto asset variations today.

A recent study by Abdelmalek (2024) finds that cryptocurrency diversification benefits occur more during crash periods than stable periods. For example, it discovered that ‘‘the efficient frontier during COVID-19 pandemic dominates the one before COVID-19 pandemic, giving the investor a better risk-return trade-off.’’ (Abdelmalek, 2024). This comparative study complements previous studies highlighting the hedging benefits of crypto inclusion into traditional portfolios. Furthermore, the study accounts for the diversification benefits when investing in multiple cryptocurrencies simultaneously, for instance adding two or more crypto assets into the portfolio.

In contrast to the majority, Wuthisatian (2022) finds that including cryptocurrencies in a portfolio does not result in superior risk-adjusted performance. ‘‘Rather, including cryptocurrency in a portfolio increases risk as well as the return.’’ (Wuthisatian, 2022). Furthermore, it argues that there is a positive correlation between cryptocurrency and stock indices S&P 500, FTSE 100 and Nikkei 225. The author finds that the Sharpe ratio decreases whenever any cryptocurrency is added to the portfolio. This is contrary to much of academic literature but remains consistent with the studies of Eisl et al. (2015) and Urquhart (2016) that also claim cryptocurrencies decrease the Sharpe ratio. The findings display a discrepancy against the widely accepted belief that cryptocurrencies are uncorrelated with market indices.

3. Introduction

Naïve portfolio: the standard advice is generally to construct a diversified portfolio of stocks and bonds, with typically more stocks early on and more bonds when nearing retirement (Fraser, 2016). A day-to-day investor holds the naïve 60/40 portfolio comprised of stocks and bonds, respectively. This disproportionate allocation is designed to generate high returns through stocks while minimizing volatility through bonds (Fraser, 2016). During recessions, stocks have an inverse relationship with bonds; meaning that when the stock market crashes, the value of bonds tends to increase (Filis, 2010). The dilemma is, however, when bond yields are also low during recessions, they would neither generate reward nor act as a hedge. Since the foundation of Modern Portfolio Theory (MPT) by Markowitz in 1952, traditional assets have been the standard products for portfolio construction (Baker, et. al. 2023). The theory suggests that investors should maximize their expected returns on securities and reduce their exposure to risk by investing in multiple asset classes (Letho, et al. 2022). A published study "*The Effect of Cryptocurrency on Investment Portfolio Effectiveness"* by Andrianto and Diputra (2017) finds that crypto allocation improves the risk adjusted returns of mixed portfolios and can even outperform the S&P 500 and Dow Jones indices. The begging question becomes what optimal proportion of crypto (and of which kind) should an investor allocate in their investment portfolio? This is precisely the focus of this research.

3.1 The Rise of Cryptocurrency

Despite the lack of a universal definition of what cryptocurrency actually is, financial scholars have defined cryptocurrency as a digital currency that relies heavily on cryptographic network and blockchain technology to conduct non-reversable transactions between two parties, ensuring that no counterfeiting or double spending occurs (Baker, et. al. 2023). Designed as a means of decentralized payment, cryptocurrency was never thought to become an investment-grade asset

(Nakamoto, 2008). Nonetheless, owners consider it a new investment class because it presents weak correlations with other asset classes such as equities, bonds, currencies, and commodities (Abdelmalek, 2024) and enables investors to compensate for losses during economic downturns. Ccryptocurrencies have piqued interest not only among speculators and investors but also financial institutions and surprisingly some governments, mainly due to their extreme volatility, can deliver higher returns than those of the traditional assets (Aljinović, et al. 2022).

In January 2024, the U.S. Securities and Exchange Commission (SEC) authorized the sale of Bitcoin-backed exchange traded funds (ETFs), a momentous decision that enables "mainstream investors to buy and sell Bitcoin as easily as stocks and mutual funds" (Huang & Kiernan, 2024). The following month, SEC also approved Ethereum ETFs to be listed on U.S. exchanges. Top investment firms like BlackRock and Fidelity raced to be among the first to offer Bitcoin ETFs, and some firms, such as Franklin Tempelton, begun nudging their customers to add Bitcoin to their naïve stock-bond portfolios (Greifeld, 2024).

According to CoinMarketCap figures, cryptocurrency reached an all-time high market capitalization of $3.46 trillion in December 2024. Nowadays, there are hundreds of crypto assets, some with limited supply, while others can be mined infinitely. This research focuses on the top nine cryptocurrencies based on their market cap. A sample of nine is considered sufficient to examine the impact of multiple crypto assets on a traditional portfolio, including Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), Solana (SOL), Binance (BNB), Dogecoin (DOGE), Cardano (ADA), Tron (TRX), and Avalanche (AVAX). Since BTC and ETH proved to be the highlight of this research, some background information is essential:

Bitcoin, the world's first and best-known cryptocurrency, was introduced during the 2008 market crash by a mysterious individual (or group) using the pseudonym Satoshi Nakamoto (Swammy, et

al. 2018). The underlying intentions were simple and clear; **(A)** to revolutionize the global financial structure by eliminating third party intermediaries, and **(B)** to institutionalize Bitcoin as a legal tender. Just like fiat money, since Bitcoin is a medium of exchange, a store of value, and unit of account, it is considered real money (Swammy, et al. 2018). Some economists may disagree, on the grounds that cryptocurrencies do not behave like fiat money. Bitcoin for example has a much greater volatility than all fiat currencies combined (Kim, 2020). This is probably the case because owners treat it as an investment asset and not as a currency, or to put it simply "*At the end of the day things are just what people think they are. If people treat Bitcoin as an investment and not a currency, well guess what, that is what it becomes"* (Goldman, 2024).

Unlike most cryptocurrencies, Bitcoin functions on its own blockchain with a limited supply of 21 million tokens and a market capitalization of $1.91 trillion at the time of writing, according to CoinMarketCap database. While Bitcoin holds no intrinsic value, proponents argue that it can preserve value due to its unique halving cycle. Meanwhile, speculative investors have called it an asset bubble as the daytime price fluctuates four times as much as gold (Liu, et al. 2020).

Conceived in 2015, Ethereum constitutes the second most traded crypto asset that also operates on a separate decentralized platform known as Ether, which enables users to create decentralized applications and smart contracts (Nadarajah, et al. 2021). Start-up companies are gradually using smart contracts for crowdfunding, where the firm defines the supply of tokens and issues an initial coin offering (ICO) using the Ethereum platform. Unlike Bitcoin, Ethereum has only reached a market cap worth $0.4 trillion, nevertheless its token supply is unlimited.

To address the aim of this research, the following two questions are set to guide the author answer the central research question:

RQ1: Does the inclusion of one cryptocurrency enhance the Sharpe ratio of a well-diversified portfolio?

RQ2: Does the simultaneous inclusion of more than one cryptocurrency enhance the Sharpe ratio further?

Both questions stem from the central research question and allow for a narrow analysis of how the (ex)inclusion of cryptocurrency influence the portfolio's Sharpe ratio, allowing for prior and subsequent comparison. RQ2 seeks whether there is evidential support that portfolios holding multiple cryptocurrencies achieve higher Sharpe ratios than those with only a single cryptocurrency.

4. Methodology

This quantitative research applies the Excel Solver tool to construct an optimal portfolio comprised of exclusively oil (USO), gold (GLD), stock index (S&P500) and real estate index (VNQ). This intentional selection consists of traditional and alternative assets that would realistically be included in a well-diversified investment portfolio. Nine other portfolios are constructed each adding one of the nine cryptocurrencies to regenerate a new optimal portfolio. This methodology allows to spot the portfolio with the best risk-adjusted returns, which can be identified through the highest Sharpe ratio. Similarly, the Solver tool is used to regenerate another set of portfolios where the risk (standard deviation) of the portfolio is minimized. The latter technique considers investors who are risk averse and only care about **a)** whether (or not) cryptocurrency leads to lower risk exposure in the first place and if so **b)** which cryptocurrency they should include so that their overall portfolio risk is optimally minimized.

4.1 Data procurement

The research derives closing daily historical prices from the CEU's financial database Refinitiv for all the assets between January 2020 – December 2024. It is important to note that for some cryptocurrencies, historical data was non-existent in 2020, as those crypto assets arrived later on the market. The so-called risk-free rate is derived from short term U.S. government bonds, considered a reliable inference since the U.S. Government has never defaulted on its debt and is unlikely to do so in the future (Reinhart & Rogoff, 2009). The risk-free rate is necessary to calculate the risk premium for the Sharpe ratio. Moreover, for reliability measures, all the raw data was verified with Yahoo Finance to avoid misinformation.

4.2 Hypothesis

H_1: An optimal portfolio having cryptocurrency leads to a higher risk and higher Sharpe ratio. The portfolio that includes the least volatile cryptocurrency BTC is expected to have the best risk-adjusted returns.

H_2: All nine cryptocurrencies lead to lower the overall risk exposure, when added to the traditional portfolio. The portfolio containing BTC is expected to yield the lowest standard deviation.

5. Data analysis

Descriptive statistics are computed for all the assets, providing a quantitative overview of the relationship between different assets. Such numerical measurements are later required for the following computations:

The rate of return is simply the percentage change in the value of an investment over a time period. It uses the daily historical prices to capture the gains and losses an investor generates, using the following formula:

$$R = \frac{V_f - V_i}{V_i}$$

where R is the arithmetic return on the investment. V_f is the final value of an investment at a given day f , V_i is initial value $i - 1$. The answer is then converted into percentage by multiplying $R\ x\ 100\%$. A positive R indicates profits, while a negative R indicates losses.

The expected returns are also computed by taking the arithmetic average of past daily returns, using the following formula:

$$A = \frac{1}{n} \sum_{i=1}^{n} a_i$$

where A is the expected return on an asset, n is the number of values, and a_i the data set of daily past returns.

The sample standard deviation measures the dispersion of an asset's returns away from the mean and is used to quantify risk exposure, using the following formula:

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{n - 1}}$$

A low standard deviation signifies a low volatility where asset returns are clustered close to the mean, which translates into low risk and vice versa.

The Pearson's correlation coefficient conveys the statistical relationship between two or more assets. It is computed using the following formula for a sample:

$$r = \frac{\sum(x_i - \bar{x})^2 (y_i - \bar{y})^2}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

where r is the correlation between two asset returns, x_i the values of asset returns x, y_i the values of asset returns y, $\bar{x}$ and $\bar{y}$ are their respective return means. While r can vary between -1 and 1, MPT states that a low r is always desirable to mitigate the portfolio's risk.

The cornerstone metric in MPT is the Sharpe ratio, which is a key measurement used to answer the research question of this thesis. It quantifies the expected returns per unit of risk, using the following formula:

$$S = \frac{(R_p - R_f)}{\sigma_p}$$

where S, is the Sharpe ratio, R_p is the expected return of an asset, R_f is the risk-free rate which equals the average yield on U.S. government bond; and σ_p is the standard deviation of the respective portfolio. The Sharpe ratio is the perfect measurement because it indicates how much excess return an investor receives above the risk-free rate for every extra unit of risk. Hence, the higher a portfolio's Sharpe ratio the better risk-adjusted returns an investor is expected to receive.

The study configures all optimal portfolios both with and without cryptocurrency inclusive of USO, GLD, S&P 500, and VNQ throughout the ten trials. To figure the standard deviation of a risky

portfolio, the following formula applies (for more details see the Excel file contained in the appendix):

$$Portfolio's\ stdev = \sqrt{w_x^2\sigma_x^2 + w_y^2w_y^2 + \cdots + 2w_xw_y\sigma_x\sigma_y\rho + \cdots}$$

where w^2 is the squared weight of the respective asset, σ^2 is variance of the respective asset, and ρ is the correlation coefficient of two assets. This computation is replicated for all the assets within the portfolio. The optimal portfolio is calculated using the Excel's built-in Slover function to maximize the Sharpe ratio by changing the proportion of asset allocation in the respective portfolio.

6. Findings

6.1 Descriptive statistics

Before diving into the results for cryptocurrency inclusive portfolios – the primary focus of this research – we need to first understand the relationships between USO, GLD, S&P 500, and VNQ. This will clarify their risk-return profiles and identify any inefficient assets in this traditional portfolio.

Table 1

	R_f	USO	GLD	S&P500	VNQ
E(r)	0.00989%	1.078%	4.803%	14.933%	1.868%
Stdev	0	2.7736	0.9799	5.4519	1.6123

The data in *Table 1* shows that higher risk does not inevitably lead to higher expected returns as is often believed, with the exception R_f because U.S. Government bonds are considered risk-free by investors. Nonetheless, both assets USO and VNQ are clearly inefficient because GLD dominates them by generating higher expected returns with significantly lower risk. This implies that for risk-loving investors, the S&P 500 would seem most attractive, while for risk-averse investors GLD has the least amount of risk as well as the highest Sharpe ratio (0.04892).

Table 2

Correlation	*% Return USO*	*% Return GLD*	*% Return S&P 500*	*% Return VNQ*
% Return USO	1			
% Return GLD	0.121814222	1		
% Return S&P 500	0.083465274	0.04651303	1	
% Return VNQ	0.226431055	0.179903998	0.177983254	1

Although a negative correlation between assets is desirable as it allows investors to ‘‘spread their eggs in different baskets’’, according to MPT such investment strategy maximizes the

diversification effect by minimizing the impact of simultaneous losses during financial crises. All four assets (commodities, stocks, real estate) share a weak positive correlation shown in *Table 2* above, oil and real estate being the highest correlation (0.226431055) and gold and stocks being the least correlated (0.04651303).

Table 3

	BTC	ETH	XRP	SOL	BNB	DOGE	ADA	TRX	AVAX
E(r)	20.322%	28.348%	28.639%	19.571%	138.575%	15.091%	68.809%	28.311%	36.717%
Stdev	3.4059	4.4226	5.6265	5.4876	49.2401	4.9432	19.7627	5.5426	6.5063
SR	0.0596	0.0641	0.0509	0.0356	0.0281	0.0305	0.0348	0.0511	0.0564

Moving forward to the primary focus of this study, it is evident not only that ETH generates the best risk-adjusted returns but also that BNB has the worst risk-adjusted returns. ETH has less risk than all the remaining eight cryptos, apart from BTC, making it the most attractive investment option for investors driven by risk-adjusted returns specifically, followed by BTC (0,0596) and AVAX (0.0564) as the second and third best performing crypto assets respectively.

On the opposite extreme, BNB is only suitable for a small fraction of investors with a strong appetite for risk as the price of BNB fluctuates by $+/-$ 49.2401% from the expected return on a daily basis. Both XRP and TRX are very similar in their expected returns and risk, despite having a weak positive correlation of only 0.014913777 (see table x below). BTC dominates both SOL and DOGE as it has higher expected returns and lower risk, making SOL and DOGE fall below the efficient frontier. Meanwhile, those investors today who remain sceptical about cryptocurrency investment and are anxious to minimize their risk exposure, may be tempted to invest in BTC ($+/-$ 3.4059) with the least volatility. However, they must note that BTC does not in fact have the best risk-adjusted returns and instead would be better off investing in ETH.

Table 4

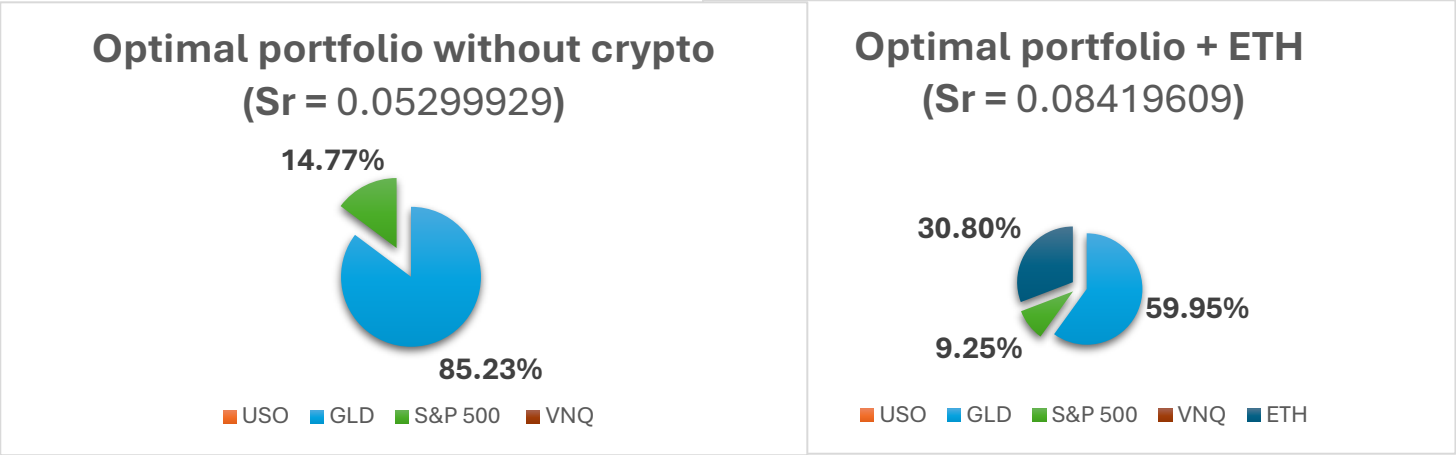
Correlation	% returen BTC	% retrurn ETH	% return XRP	% return SOL	% return BNB	% return DOGE	% return ADA	% return TRX	% return AVAX
% returen BTC	1								
% retrurn ETH	0.818853881	1							
% return XRP	0.547989624	0.571307214	1						
% return SOL	-0.005314131	-0.030891378	-0.024862155	1					
% return BNB	0.004767303	-0.00544291	-0.013644091	0.003605256	1				
% return DOGE	0.601273812	0.580333798	0.444328741	-0.029480592	-0.01760744	1			
% return ADA	0.003961715	0.000495365	0.005327576	-0.011210232	0.001091037	0.071492772	1		
% return TRX	-0.019162663	-0.034229721	0.014913777	0.028883164	0.001059926	0.036455851	0.729507841	1	
% return AVAX	0.069872803	0.059882102	0.057505215	-0.009643059	0.109526563	0.027111626	0.093574183	0.127971764	1
% return USO	-0.010344582	-0.013234402	-0.00869757	0.002803322	-0.045163377	-0.007444018	-0.024148038	-0.052667169	-0.063928522
% return GLD	-0.066684377	-0.056258405	-0.02596116	0.028508569	0.001768872	-0.065626159	0.047929126	0.047297678	0.010868149
% return S&P 500	0.000210178	-0.010931547	-0.011482276	0.015126638	-0.023840272	0.036770339	-0.001819325	0.003604643	0.012572159
% return VNQ	-0.019144444	0.005437872	-0.011798264	-0.017014758	-0.094242573	-0.001682004	-0.02298587	-0.005789381	-0.055711147

As demonstrated by *Table 4* above, both ETH and BTC display a strong positive correlation of 0.81885, the strongest correlation found in this entire research, followed by ADA and TRX with a semi strong positive correlation of 0.72950. Similarly, DOGE shares a moderate positive correlation of 0.60127, 0.58033, and 0.44432 with BTC, ETH, and XRP, respectively. This is unusual since all the remaining crypto assets display either a weak negative correlation or none, setting DOGE apart from the remaining six crypto assets. Meanwhile, correlation does not necessarily equal causation, as it could be due to a spurious circumstance, which fall outside the focus of this research.

6.2 Optimization of the Sharpe Ratio

The next important step is to find the ten different optimal portfolios and their respective Sharpe ratios, one without any crypto (comprised of USO, GLD, S&P 500, VNQ) and the remaining nine optimal portfolios include a different cryptocurrency in each trial. To avoid confusion, only the main findings are included (for full overview, check the Excel sheet link).

Figure 1



It is clear that adding crypto into the portfolio is beneficial regardless of which of the nine cryptocurrencies is added since they all lead to an increased risk-adjusted retruns. However, a portfolio that consists of only USO, GLD, S&P 500 and VNQ could never reach a higher Sharpe ratio of more than 0.05299929 when allocating 14.77% to stocks and 85.23% to gold. Any change in the percentage allocations between stocks and gold will lead to a decrease in the portfolio's Sharpe ratio (and standard deviation). USO and VNQ are considered ineffiecient assets, hence their 0% allocation due to high-risk low-returns characteristics shown in *Table 1*. Although eliminating them from the the portfolio would not have an immediate impact on the portfolio, investors should diversify their investments, by spreading their eggs across different baskets, especially alternative assets such as commodities and real estate that can offset losses during market turmoil.

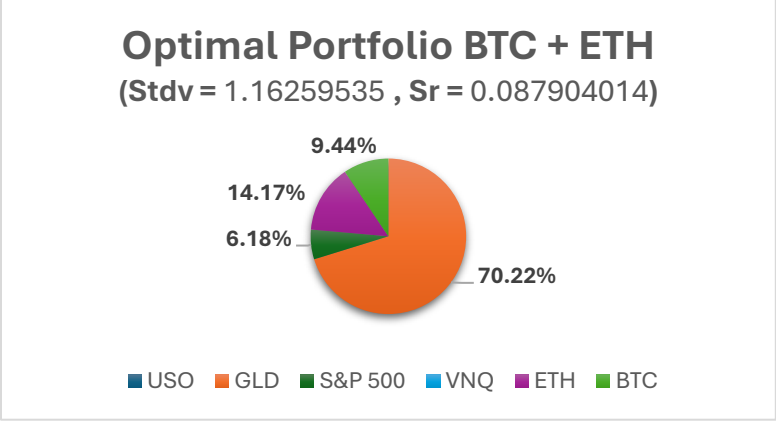
In the portfolio construction it is found that ETH leads to the highest Sharpe ratio compared to the remaining eight cryptocurrencies. Investors can expect ETH to generate better risk-adjusted returns after rebalancing their portfolio with 9.25% to stocks, 30.80% to ETH, and 59.95% to gold. This composition results in a Sharpe ratio of 0.08419609, which is an 58.86% improvement in the

portfolio that did not contain crypto. The Sharpe ratio begins to decrease as soon as the the optimal asset allocation are altered. This is because when returns (y-axis) and Sharpe ratio (x-axis) are plotted on a graph, a bell-shaped curve is expected with an upward slope at the start, a constant slope of zero at the optimal point, followed by a downward slope. The goal of a rational invetor is to reach the constant slope as this is where the Sharpe ratio is highest.

Since BNB had the lowest Sharpe ratio shown in *table 3*, one would expect the optimal portfolio contatining BNB to produce the lowest Sharpe ratio. Suprisingly, the portfolio with BNB included, had the second lowest Sharpe ratio of 0.058750555 (see appendix), when allocating 14.89% to stocks, 83.05% to gold and a small proportion of 2.07% to BNB, due to its extreme volatility. However, the optimal portfolio containg TRX produced the lowest Sharpe ratio of 0.054299907 when allocating 14.51% to stocks, 83.14% to gold and 2.34% to TRX. Overall, despite TRX being the least effective crypto it managed to improve the risk-adjusted returns of the portfolio containing no crypto at all, by 2.45%.

Now suppose an investor is interested in adding a combination of two cryptocurrencies into their optimal portfolio, which mix of two cryptocurrencies should they choose and would this result in a higher or lower Sharpe ratio than only when adding ETH?

Figure 2

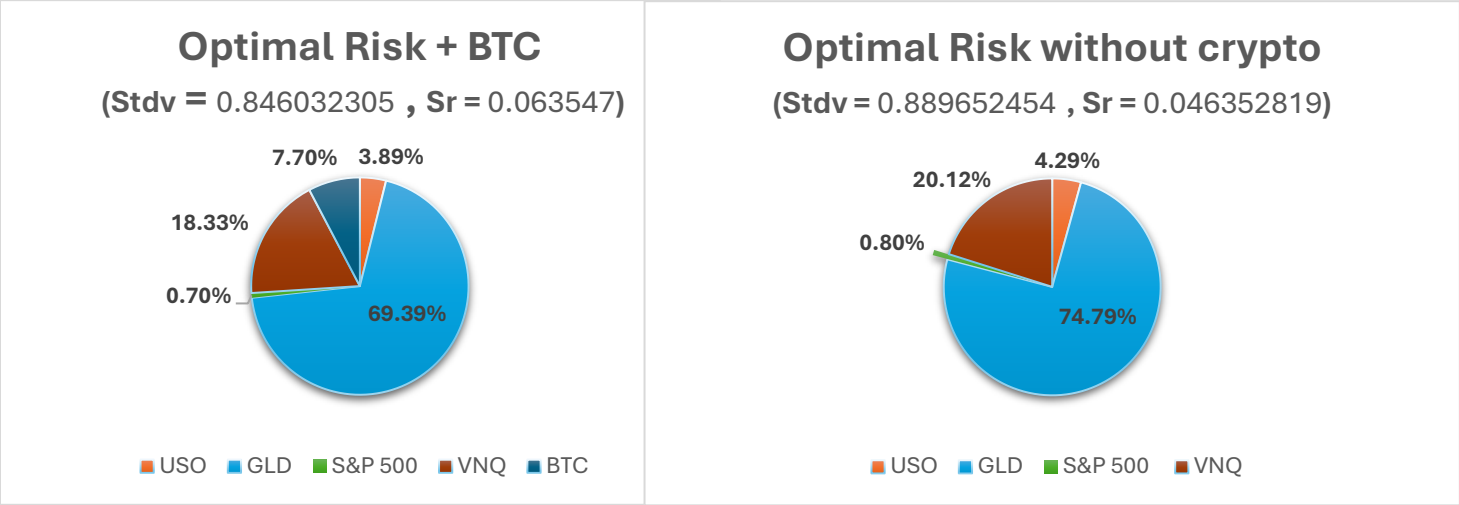


When maximizing the Sharpe ratio of an optimal portfolio containing two different cryptocurrencies, it is discovered that a combination of any two cryptocurrencies results in a higher Sharpe ratio than when only one crypto (ETH) is added individually to the portfolio. However, the inclusion of BTC and ETH simultaneously will yield the highest Sharpe ratio of 0.087904014, which is an 8.25% improvement than when a portfolio included either BTC or ETH. This optimization is achieved when allocating 70.22% to gold, 6.18% to stocks, 14.17% to ETH, and 9.44% to BTC, an alteration in the weights will automatically trigger the Sharpe ratio to decrease. The same weight allocations minimized the portfolio's risk from 1.347999226 to 1.16259519 which is 13.75% reduction in the portfolio's risk compared to the inclusion of either BTC or ETH. Most notably, the portfolio's risk-adjusted returns improved by 65.86% against a portfolio that did not have any cryptocurrency included in the first place. While this pattern continues when optimizing the Sharpe ratio – more crypto leads to higher Sharpe ratios – at some point the portfolio's risk becomes inefficient after the addition of any third crypto as risk starts to increase rather than decrease. This is clearly not suitable for risk-averse investors who prioritize their risk minimization over securing higher expected returns.

6.3 Minimization of Portfolio's Standard Deviation

Since cryptocurrencies are considered highly risky and most investors only care about minimizing the portfolio's risk when choosing to invest in a cryptocurrency, the question is which of the nine cryptocurrencies can reduce the portfolio's risk the most, if at all?

Figure 3

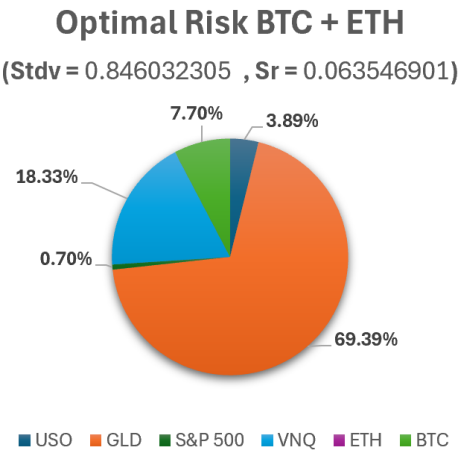


Using the Solver function to minimize all the portfolio's standard deviations (risk exposure), it is found that all nine crypto assets lead to a risk reduction once included in the portfolio, even the most risky ones like ADA, TRX, and BNB! It comes as no suprise that the portfolio containing BTC produces the lowest risk of 0.846032305 when allocating 18.33% to real estate, 0.70% to stocks, 7.70% to Bitcoin, 3.89% to oil, and the remainder 69.39% to gold. This is because BTC's returns are clustered close from the mean, making it the least volatile cryptocurrency (Stdv 3.4059) as shown in *Table 3.* The portfolio containing BTC accounts for 4.90% risk reduction and an increase of 37.09% in the Sharpe ratio compared to the portfolio containing no cryptocurrency at all. While the portfolios containing ADA, TRX and BNB account for almost 0% improvement in both risk reduction and Sharpe ratio, hence a rational investor would be better off excluding them from their investment portfolio. In all the ten portfolio formations for optimal risk, GLD is always dominant in allocation, followed by VNQ due to their low volatility. However, BTC is more dominant than USO, while ETH, XRP, SOL, DOGE, and AVAX are more dominant than stocks (shown in the appendix). This implies the largest allocation is always given to assets having the lowest standard deviation, i.e. GLD. What is interesting is that in the optimization portfolios shown

previously, USO and VNQ lie below the efficient frontier and therefore were never allocated any weights. However, due to their low volatility, they were allocated optimal weights when minimizing the portfolio's risk exposure (standard deviation) illustrated in *Figures 3* and *4*.

Moreover, one would expect adding more crypto leads to lower risk, since the risk of the portfolio containing no crypto decreased after adding BTC from 0.889652454 to 0.846032305 shown in *Figure 3* above. When minimizing a portfolio's risk, the addition of a second crypto does not lead to a decrease in the portfolio's Sharpe ratio, in fact it has zero effect as both the standard deviation and Sharpe ratio remain constant at 0.846032305 and 0.063547 respectively, after adding ETH on top of BTC for example:

Figure 4



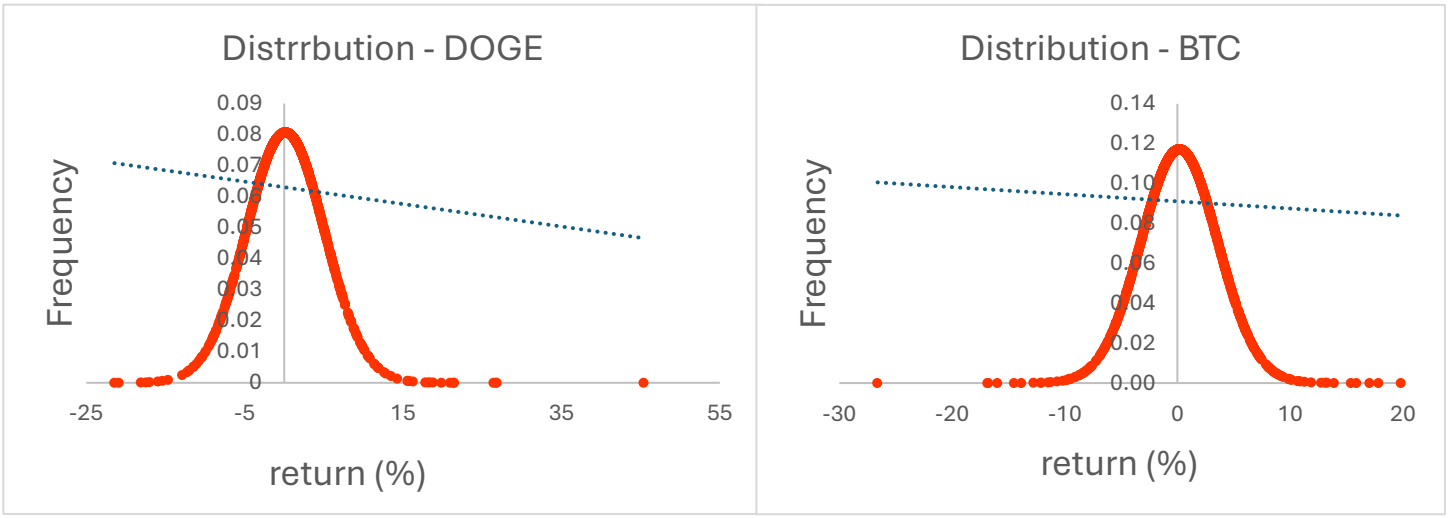
This implies that an additional second crypto does not lead to an improvement in the portfolio's risk minimization – since BTC has the lowest risk it will always be allocated the optimal crypto weight – while the remaining eight cryptos will be allocated 0% weight as they all carry more risk than BTC.

6.4 Data Distribution

Risk management is a crucial aspect once it comes to cryptocurrencies, hence analysing the returns distributions of the nine crypto assets is key to obtaining an impression of their long-term volatility. Generally, investors dislike left-skewed distributions but are attracted to right-skewed distributions especially ones that display 'fat tails'. The x-axis represents the returns of the respective crypto asset from 01/Jan/2020 until 01/Dec/2024, while the y-axis represents the frequency of values that occur within the dataset.

Not surprising, all the crypto assets exhibit asymmetrical bell curves with the exception of BTC and SOL being left-skewed, while the remaining seven are right-skewed showing a juxtaposition in the dispersion of their returns. The most interesting case is between BTC and DOGE, as illustrated below in figures.

Figure 5



Despite having the slowest standard deviation of 3.4059, BTC has a longer tail on the negative side of the curve than on the positive side raising concerns for all risk-averse investors as it implies on average there were more losses than gains. Although the probability is extremely small (less

than 0.01%), investing in BTC could lead to a drastic loss of nearly 30% and a gain of just 20% as shown in the left and right tails of the curve. The majority of BTC returns, however, are clustered close to the mean, making the returns look more stable than the other eight cryptocurrencies. Another important observation is that the frequency of BTC is significantly larger than all the rest of the cryptocurrencies represented by the tall peak in the middle, which means that the range of values occurs very often within the dataset of BTC returns.

On the contrary, DOGE with just a slightly higher standard deviation (4.9432) than BTC, exhibits a positively skewed distribution. Though the probability of making 45% gain is negligible, where the right-tail of the curve implies that this gain had in fact already occurred according to our dataset for DOGE historical returns. This implies that DOGE has on average experienced more gains than losses as compared to BTC (and SOL). Furthermore, the frequency of DOGE returns is low and therefore the curve's peak is also lower which implies that DOGE returns are more unpredictable than BTC and that the dispersion of data from the mean is wider than that of BTC.

The logical question to ask is: do those distribution curves suggest that investing in DOGE in the long term is more profitable than BTC? The answer is not necessarily, because the negative tail of BTC and positive tail of DOGE are being dragged by the last points on the tails which are clearly far away from the rest of the points, hence those two points must be outliers. Additionally, it is equally likely that the same percentage gain could also occur on the negative side of the curve and lead to a loss, such a scenario is not displayed on the distribution curve simply because it has never happened in the dataset returns of DOGE.

All the distributions plotted exhibit a negative trendline with varying slopes. This implies that the data does not display a perfectly normal distribution; the most plausible argument is due to the noise observed in the data series. The crypto asset with the shallowest gradient is BTC as the daily

prices deviate by only $+/-3.4059$ on average, while the cryptocurrencies with the steepest gradients include BNB and ADA as having the highest volatility and therefore their dataset cannot reflect a normal distribution curve. One of the reasons is their extreme outliers that surprisingly lie far from the positive tail of the distribution and may seem attractive to investors at first glance. Those outliers, however, have a probability of almost zero and with the same likelihood the outliers may equally appear on the negative tail of the distribution and incur catastrophic losses.

7. Results and limitations

Contrary to the findings of this study, ETH might not be on everyone's investment of choice. The truth is that ETH proved itself to be the best option for risk-adjusted returns compared to the other eight cryptocurrencies, while BTC ranked second on the list. This is surprising because **a)** ETH's market cap of $\$\ 413\ billion$ is significantly lower that that of BTC $\$\ 2.1\ trillion$, **b)** the majority of investors prefer to invest in BTC as reflected by its market cap, despite it having less risk-adjusted returns than ETH. One explanation to this behaviour could be because of BTC having a limited supply that is about to deplete, and investors are experiencing the fear of missing out (FOMO) effect. Another explanation could be that risk-averse investors are only attracted to BTC's low risk exposure, making BTC an ideal diversifier when minimizing the overall portfolio risk. In reality though, not every investor thinks the same way, because of personal convictions and asymmetrical information that shape their views on markets. ETH has more excess returns per unit of risk, therefore it is unwise to exclude it from an investment portfolio.

The cryptocurrency that should be avoided is clearly BNB because it has the lowest Sharpe ratio when compared to the others and an extreme volatility that is unsuitable for almost all investors. Although very few investors may have a high tolerance for risk and find BNB attractive to maximize their expected returns at the expense of extreme volatility, with an equal probability of leading to catastrophic losses.

The unintended result that is most fascinating is that the addition of an *extra* cryptocurrency into the portfolio can lower the optimal risk even further than when only one cryptocurrency was added at the beginning. Moreover, the addition of two cryptocurrencies simultaneously also leads to an increase of the Sharpe ratio, meaning an investor receives even better risk-adjusted returns when including both ETH and BTC simultaneously, rather than just BTC or ETH alone. This result will

surprise investors who were unsure whether to only commit to BTC for yielding minimum portfolio risk or ETH for yielding the best Sharpe ratio. Their simultaneous addition leads to both the lowest portfolio risk and best risk-adjusted returns noted in the entire study. Any different combination of the remaining seven crypto is not optimal. It was not anticipated that the combination of BTC and ETH would become the highlight of this thesis. Since the two cryptos had a positive correlation of 0.818853881 they were able to achieve a lower risk when added into the portfolio at once, contrary to MPT that claims assets should be negatively correlated in order to minimize a portfolio's risk exposure.

Some of the nine cryptocurrencies – TRX and XRP for example – can have very similar expected returns and risk despite having a low correlation. This is a case of spurious correlations, meaning that their similar expected returns and risk profiles could stem from underlying macroeconomic influence, rather than a direct causal relationship between the two cryptocurrencies. Moreover, while commodities (GLD , USO) and real estate (VNQ) were not the central focus, it is intriguing to find that oil and real estate were ignored completely in the risk optimization experiments throughout the ten trials, since both assets are dominated by GLD which generates higher expected returns for lower risk than USO and VNQ.

The debate on whether BTC is a bubble or not, remains a subjective question among investors and researchers (Swammy, et al. 2018). Recent price records signal that the asset has surpassed its intrinsic value, while others believe it is a hedge against inflation due to its unique characteristics such as the 'halving' cycle and capped supply. However, behavioural finance research suggests that irrational investors driven by FOMO, disproportionately favour BTC over any other cryptocurrency. Consequently, this creates a self-reinforcing mechanism feedback loop that overestimate the asset's value (Podhorsky, 2024).

7.1 Limitations

The results found in this study are not indicative of any future risks or expected returns, as financial markets are constantly reacting to new information and past data is not to be equated with future data. Notwithstanding, it is important to acknowledge the weakness of using the Sharpe ratio as a quantitative measurement for portfolio's performance before and after the inclusion of cryptocurrency; firstly, the Sharpe ratio only considers asset risks and return while ignoring liabilities. Secondly, it does not distinguish between upside and downside volatility. Thirdly, it assumes that investment returns are normally distributed with a bell-shaped curve (Schellinger 2020), which is not the case for all the nine cryptocurrencies. Unlike BTC, ETH and XRP, some of the cryptocurrencies were launched less than four years ago, making it impossible to include their historical returns starting in 2020 or even 2021 in the cases of SOL and DOGE. In addition, the study excludes stable cryptocurrencies that are pegged by the U.S. Dollar and just looks at the largest nine cryptocurrencies. Pegged cryptocurrencies like Tether (USDT) and USD Coin (USDC) are as riskless as the American dollar and reduce the overall portfolio risk accordingly (Wang, et al. 2020). Similarly, the basic portfolio was only comprised of oil, gold, equities, and real estate are not the only asset types found in a typical portfolio. Nonethless, it is important to acknowledge that some of those limitations were a direct result of limited word space and availability of data sources. Furthermore, the government bonds were only used to calculate the risk-free rate and were not included in any of the ten portfolios which is unrealistic since most investors include counter-cyclical assets such as government bonds to counteract market fluctuations (Andritzky and International Monetary Fund, 2012). Lastly, the research lacks primary qualitative sources such as interviews and surveys that could convey people's beliefs and understanding and experience with

cryptocurrency investment. Such sources open space for comparison between the results of this empirical study and the real world.

8. Recommendations for Future Research

Firstly, the time frame should be extended to at least six years and only include monthly rather than daily prices to reduce trading noise such as rumours and news events that would otherwise deliver incorrect conclusions. For example, this could simplify the statistical analysis, making it easier to identify the different behaviours of cryptocurrencies and their optimization. In addition, it is more useful to employ the Sortino ratio rather than only the Sharpe ratio, because the former accounts for downside risk while the latter for total risk. In reality, investors only care about the downside risk which makes Sortino ratio a better measurement for risk, by using the standard deviation of negative returns only (the red cells in Excel). The portfolio should similarly include assets that are held by an everyday investor, for example corporate and government bonds as well as international stocks. Geographical diversification plays a crucial role in risk management and is often neglected as investors tend to be biased in their portfolio formation as I learned from behavioural finance session of *Trading Portfolio Theory* course that the majority of investors trust their country's assets more than foreign ones, mainly driven by personal conviction and overconfidence. Finally, one could include twenty crypto assets for instance and attempt to add more than two assets per portfolio to find out which input combination yields the optimal output when crypto assets are added simultaneously. This would allow for variation in the portfolio and potentially reduce overall risk or simply discover new crypto assets that outperform ETH in achieving a high Sharpe ratio when added to a portfolio.

9. Conclusion

In conclusion, although cryptocurrencies were engineered to replace fiat money, people have been treating them as digital assets rather than a currency. They have enabled portfolio managers, retail, and institutional investors to minimize their risk by investing into crypto assets. While the study has found that all nine crypto assets improve the Sharpe ratio, some cryptos were evidently more effective than others. Most notably, adding both BTC and ETH to the portfolio consisting of oil, real estate, stocks, and gold will generate the highest Sharpe ratio. In fact, the risk decreased by -13.75% when adding both ETH and BTC than when adding either ETH or BTC individually. Furthermore, investors should be aware that the portfolio that has ETH has a significantly higher Sharpe ratio than that with BTC. The study has found that ETH leads to 58.86% improvement of the Sharpe ratio, compared to BTC with only 53.21% when added to the portfolio. The crypto asset that should be avoided is BNB because the Sharpe ratio is extremely low and has the highest volatility $+/- 49.2401\ \%$. The assets displayed a wide variation in their data distribution with some being somewhat normal such as BTC and ETH whereas others like BNB and ADA demonstrate clear anomality in their returns signified by the steep downward gradient. It is evident that the higher the cryptocurrency's standard deviation the steeper its gradient becomes in the distribution curve. It can be assumed that BTC has the most consistent returns among cryptocurrencies, especially after the year 2022, but surprisingly it does not produce the highest Sharpe ratio in the study which is unusual for a cryptocurrency since risk is closely associated with returns.

10. Reflection and Academic Relevance

Having completed the graduate course *Trading and Portfolio Theory*, I was confident to write a thesis on decentralized financial markets. This study has been an eye-opening experience in expanding my understanding of MPT and the impact of crypto on portfolio optimization. More importantly, this research has been valuable preparation for my master's studies in Economics by improving my know-how skills of using Excel to analyze and visualize real world data. Personally, I have never invested in cryptocurrency and am unlikely to do so in the future because of my personal conviction that cryptocurrency is a mysterious asset and is not protected under any deposit insurance scheme in case of fraudulence or loss of access credentials.

In addition, the research topic is highly relevant to my academic major Political, Legal and Governmental Studies (PLGS), since governments have not yet agreed on a universal legal definition of cryptocurrencies. Some governments view them as financial instruments, while others do not view them as such. How a government defines cryptocurrency i.e. an asset, currency, or security has an explicit impact on investor behavior and therefore portfolio performance. In some countries – like China – have implemented a total ban on cryptocurrency, while in Western countries cryptocurrency is still subject to regulation, and in countries like Russia, Iran, and Venezuela cryptocurrency seems an alternative to bypass U.S. sanctions and reduce reliance on the American dollar.

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12. Appendix

All data analysed is accessible here: Thesis_Data_Excel.xlsx.