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Optimal Shares of NFT, DeFi and Bitcoin on Czech, Hungarian, and Polish Equity Markets

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Abstract

The purpose of the paper is to present the results of the research on the potential inclusion of different types of crypto assets, such as Bitcoin, NFTs (Non-Fungible Tokens), and DeFi (Decentralised Finance), within optimal portfolios to help reduce variance or increase returns compared to equity investments. The analysis includes comparisons of different crypto assets and countries, specifically the Czech Republic, Hungary, and Poland.

The author constructs optimal equity-crypto portfolios in the Markowitz environment for the period from 16 February 2021 to 8 January 2024, which was adjusted to NFT data availability from this date. Calculations are conducted under two scenarios: minimizing portfolio variance and maximizing returns.

The research demonstrates that Bitcoin, NFTs and DeFi can be part of a well-diversified equity portfolio, primarily due to their low correlation with equity markets in the Czech Republic, Hungary and Poland.

The paper is important for investors seeking diversification possibilities. Although diversification has been increasingly difficult recently due to increasing correlation coefficients between assets, new asset classes, such as crypto assets, have been created, offering new potential for portfolio creation. The conclusions drawn may also be vital for policymakers who should consider them when formulating regulations concerning systematic risk.

The paper contributes value in four aspects. 1) The paper demonstrates that including NFTs, DeFi and Bitcoin in a stock portfolio creates diversification benefits for most portfolios. This is partially due to their slightly higher returns but mostly because of the lower risk that results from the low correlation of crypto assets with traditional markets. 2) Optimal shares of crypto assets differ depending on the equity and the crypto involved. 3) The paper considers Czech, Hungarian, and Polish markets while existing papers concentrate mostly on the American market. 4) The paper shows that there are minimal connections between the Czech, Hungarian, and Polish equity markets and crypto assets.

Keywords: NFT, DeFi, Bitcoin, optimization, diversification, Czech Republic, Poland, Hungary

JEL: C1, F3, G1

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Introduction

There are numerous papers devoted to portfolio diversification through different optimization methods. Most authors concentrate on the United States (e.g., Ma et al. 2020; Aliu, Bajra, and Preniqi 2022, p. 452; Osman et al. 2023; Youssef et al. 2023; Houda et al. 2024), Eurozone countries (e.g., Poljašević and Grujić 2022) Gulf and BRICs markets (Bejaoui et al. 2023) the Indian market (e.g., Aggarwal, Santosh, and Bedi 2018) and Middle East markets (e.g., Kumaran 2022). They often neglect Poland, the Czech Republic, and Hungary. Therefore, this paper addresses these countries for portfolio construction with crypto assets.

Recent events such as the COVID-19 pandemic, the Russia–Ukraine war, and rising energy costs have increased connections between markets and made it more difficult to hedge against risk (Aharon and Demir 2022; Maitra et al. 2022; Kumar et al. 2023; Ugolini, Reboredo, and Mensi 2023). Consequently, there is a greater demand for assets that can help create diversified portfolios. Baur, Hong, and Lee (2018) highlighted Bitcoin's low correlation with traditional markets and noted its popularity as a financial instrument often applied as a speculative asset rather than as a means of exchange. This raises the question of whether it can be part of a well-diversified portfolio. Polat (2023) noticed that both NFTs (Non-Fungible Tokens) and DeFi (Decentralised Finance) have totally different risk-return parameters than traditional assets, which suggests that these assets could be used in the optimization of traditional portfolios.

The purpose of the paper is to present the results of research on the potential inclusion of different types of crypto assets, such as Bitcoin, NFTs, and DeFi, within optimal portfolios to reduce variance or increase returns compared to equity investments. The author investigates whether these crypto assets can behave as portfolio diversifiers, specifically assessing their ability to increase returns or decrease risk in a stock portfolio. The hypothesis posits that these crypto assets can be used as part of well-diversified portfolios both as risk reducers and return intensifiers. Additionally, the research reveals minimal connections between Czech, Hungarian and Polish equity markets and crypto assets. The conclusions align with Damianov and Elsayed (2020), who showed that while including cryptos in equity portfolios is beneficial, it should be done cautiously. However, the conclusions contrast with Osman et al. (2023), who argued that Markowitz investors should not use equity when they can invest in cryptos.

Literature review

Many papers highlight the high risks connected with crypto assets. Kajtazi and Moro (2019) noted that while Bitcoin can improve portfolio results thanks to increased returns, it does not contribute to risk reduction. They also note its speculative nature. Aliu et al. (2020) further underscore the high risk of cryptocurrencies compared to equities. Corbet, Lucey, and Yarovaya (2018) demonstrated that Bitcoin exhibits bubble-like behavior. Smales (2022) points out that both higher returns and higher risk attract investors to the cryptocurrency market.

Some researchers argue that cryptocurrencies, NFTs and DeFis can be used to construct optimally diversified portfolios. Ma et al. (2020) performed stock portfolio optimization using stocks from five companies from the American market within the Markowitz framework and five cryptocurrencies. They concluded that crypto assets reduce risk and increase returns for the portfolio. Aliu et al. (2020) showed equity diversification benefits for some developed European countries. Khaki et al. (2023) used the mean-variance optimization technique as well as higher central moments to show that cryptocurrencies may give some risk diversification advantages for traditional assets.

Aliu, Bajra, and Preniqi (2022) suggested constructing stock-crypto portfolios in the US market to achieve a better return than for stocks and a lower risk than for crypto, operating within Markowitz's theory. Ko et al. (2022) showed that NFTs offer a stock portfolio diversification within a Markowitz context. Houda et al. (2024) used a DCC-GARCH model to assess the potential of applying NFTs in American stock portfolios for diversification benefits. They concluded that it is worth considering NFTs in stock portfolios to gain diversification advantages. Sharma, Rawat, and Kaur (2022) indicated that cryptocurrencies can minimize investment risk in stocks due to negative correlations between these markets. This paper finds low correlations between stock markets and crypto assets, and some are negative. This suggests that cryptocurrencies can be employed in portfolio diversification as risk minimizers.

Ali, Umar, and Gubareva (2024) asserted that investors may use NFTs to diversify American stock portfolios. This paper extends this analysis to include DeFi and Bitcoin across different equity markets. Aharon and Demir (2022) noted that NFTs are independent of equities, suggesting that they may serve as effective optimizing assets. Youssef et al. (2023) showed that adding cryptocurrencies helps improve portfolio parameters, especially for investors who are not risk averse; however, their research was for American equity only. This paper demonstrates that for equities from the Czech Republic, Hungary, and Poland, the same rule applies.

Poljašević and Grujić (2022) showed that the Markowitz model has many virtues, allowing for the creation of optimal portfolios based on historical returns using equity from eurozone countries and Bitcoin. Aggarwal, Santosh, and Bedi (2018) showed that Bitcoin can be used to optimize portfolios in the Indian equity market, while Kumaran (2022) showed that cryptocurrencies can be used as portfolio diversifiers and give a higher return for Middle Eastern stock markets. Damianov and Elsayed (2020) showed that although Bitcoin's correlation with traditional assets (global industry sectors) is close to zero, its higher returns are accompanied by high volatility. They suggest that the optimal share of Bitcoin in a minimum variance portfolio is only 1% only, and conclude that the real share of Bitcoin in a portfolio depends on the investor's views on the future of crypto assets.

The literature frequently mentions low or no correlation between crypto and equity markets. For example, Baur, Hong, and Lee (2018) showed that Bitcoin is uncorrelated with stocks, even during periods of financial turmoil. Lee, Guo, and Wang (2018) highlight the low correlation of cryptocurrencies with the S&P 500 index, while Borri (2019) also confirmed the low correlation of cryptocurrencies with traditional markets.

Bejaoui et al. (2023) established that there are some connections between Gulf and BRICS stock markets and cryptocurrencies, including NFTs and DeFi. They also found similar but weak connections for Poland, the Czech Republic and Hungary regarding crypto assets. However, their study did not construct diversified portfolios as this paper does.

Other studies indicate that the correlation tends to rise during specific market situations. For example, Yousaf, Jareño, and Tolentino (2023) showed that the connectedness between DeFi assets and the American equity market increased during the COVID-19 pandemic. Similarly, Xia, Li, and Fu (2022) pointed out that NFTs are more linked to traditional assets during extreme market conditions.

Methodology

This paper constructs optimal equity-crypto asset portfolios within the Markowitz framework. Each index (PX – the index of major stocks from the Prague Stock Exchange, BUX – the index of blue chip stocks from the Budapest Stock Exchange and WIG20 – the index of 20 biggest companies from the Warsaw Stock Exchange) – see Chart 1) is diversified with each crypto asset (Bitcoin, NFT Index, DeFi Pulse Index – see Charts 2, 3, and 4). Optimization employs both variance minimization and return maximization. The results do not change even when short selling is not permitted; however, this restriction does not apply to NFTs or DeFis.

The research period spans from 16 February 2021 to 8 January 2024, which aligns with the availability of NFT data. Daily data are used, with NFT and Bitcoin data extracted from www.coinmarketcap.com, DeFi Pulse data from www.coincodex.com, and stock quotations from www.stooq.com. The WIG20 index was downloaded in USDs, while the PX and BUX indices were downloaded in local currencies and recalculated into USDs using currency rates from www.stooq.com.

Before the optimization procedure, logarithmic returns and descriptive statistics were calculated. All calculations were conducted in American dollars, so the conclusions show the American perspective. Including the currency rate risk may alter these findings.

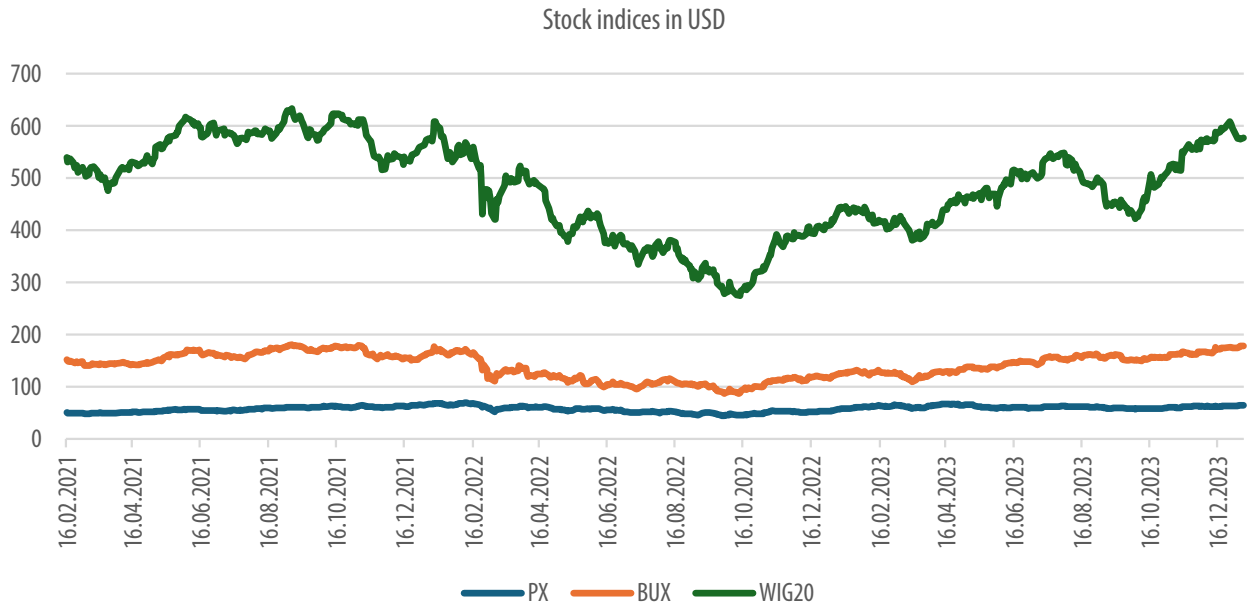

Chart 1. PX, BUX, and WIG20 daily quotations in USD from 16 February 2021 to 8 January 2024

Source: author's own analysis based on data from Stooq n.d.

Chart 2. Bitcoin daily quotations from 16 February 2021 to 8 January 2024

Source: author's own analysis based on data from CoinMarketCap n.d.

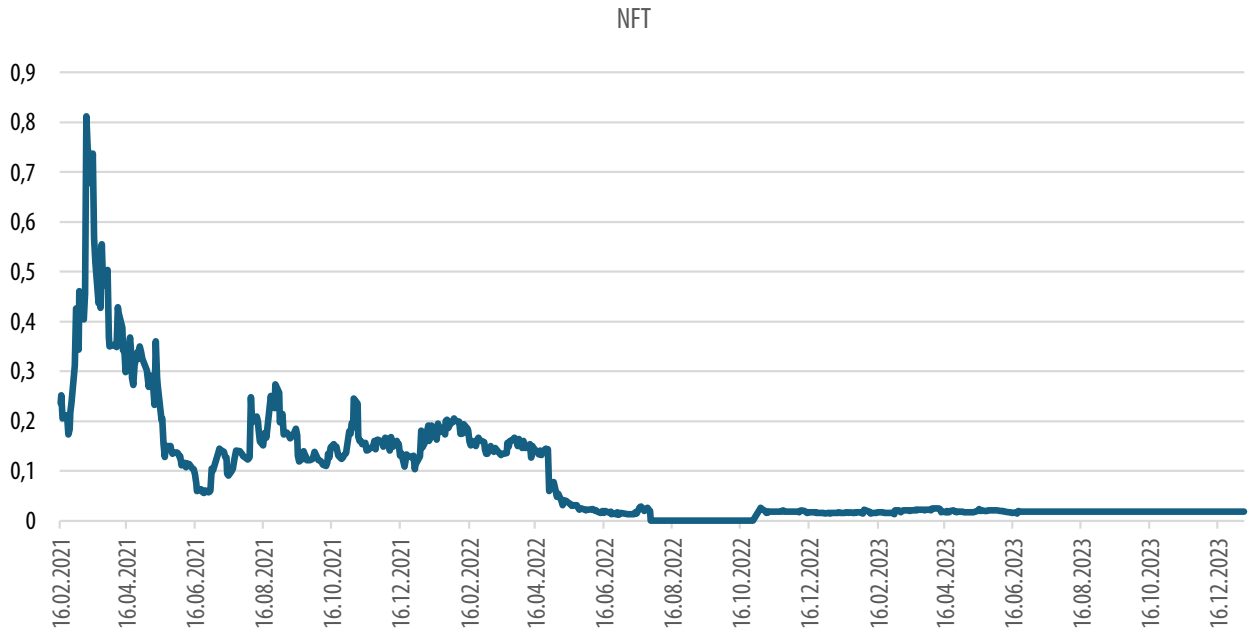

Chart 3. NFT Index daily quotations from 16 February 2021 to 8 January 2024

Source: author's own analysis based on the data from CoinMarketCap n.d.

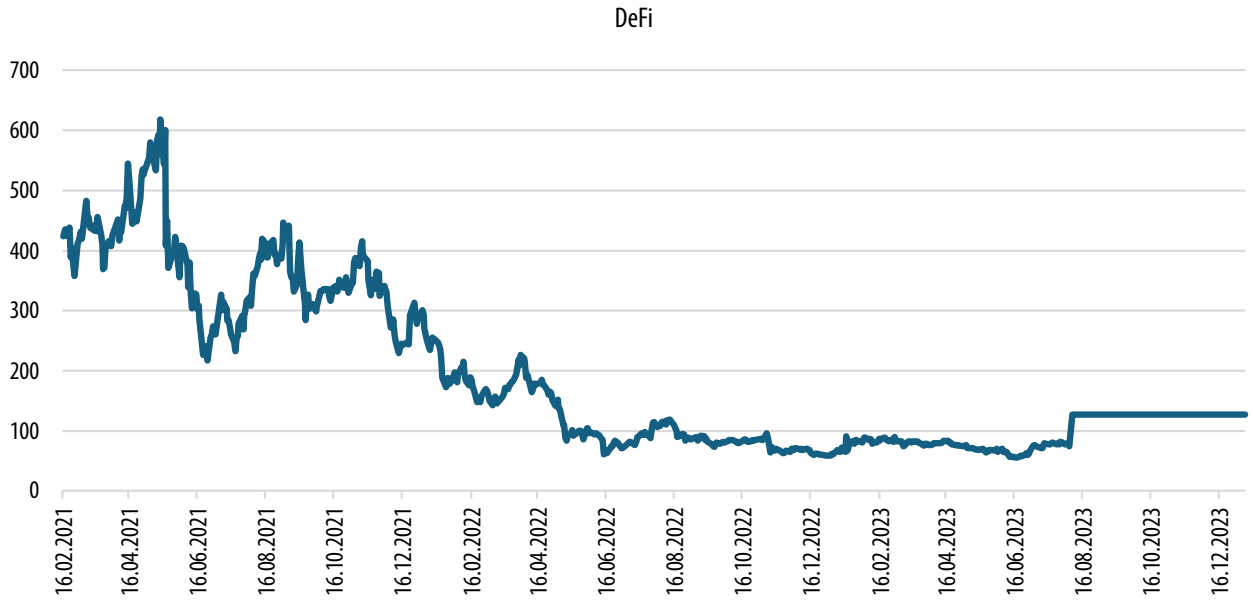

Chart 4. DeFi Pulse Index daily quotations from 16 February 2021 to 8 January 2024

Source: author's own analysis based on data from CoinCodex n.d.

Following Aliu et al. (2020), Ma et al. (2020), and Osman et al. (2023), the well-known Markowitz theory (Markowitz 1952) is applied for optimization. This theory serves as the foundation for the classical theory of finance. It assumes that investors are risk-averse, meaning that at a given risk level, they will choose higher returns, while at a specific level of return, they will choose lower risk.

Logarithmic returns are calculated with the following formula:

$$R_t = \ln(q_t) - ln(q_{t-1}), \tag{1}$$

where:
q_t – asset quotations at time t,
q_{t-1} – asset quotations at time t – 1.

Pearson correlation coefficients (ρ) are calculated, and the significance of these coefficients is tested by setting the following null hypothesis:

$H_0 : \rho = 0$ – the correlation coefficient is not statistically significant.

Against the alternate hypothesis:

$H_1 : \rho \neq 0$ – the correlation coefficient is statistically significant.

The test statistic is:

$$t = \frac{\rho\sqrt{n-2}}{\sqrt{1-\rho^2}}, \tag{2}$$

where:
n – sample size,
n – 2 – degrees of freedom.

The applied significance level is set at 5%.

Two optimization procedures follow the following rules:

1. The purpose is to minimize variance under the following assumptions:
   - $s_1 + s_2 = 1$, where s_1 and s_2 are optimal shares of equity and crypto assets, respectively;
   - $R_p \geq R_{\text{avindex}}$, where R_p represents portfolio return, and R_{avindex} denotes the average return index during the examined period.
2. The purpose is to maximize returns under the following assumptions:
   - $s_1 + s_2 = 1$, where s_1 and s_2 are optimal shares of equity and crypto assets, respectively;
   - $V_p \leq V_{\text{avindex}}$, where V_p is the portfolio variance, and V_{avindex} is the average index variance during the examined period.

Optimization goals for both procedures are achieved by adjusting the portfolio shares of equity and crypto assets. The assumptions are structured to allow short selling to be mathematically treated as negative shares of assets in a portfolio. However, the results show that short selling is not recommended for constructing an optimal portfolio.

Portfolio variance is calculated as in the Markowitz theory (Markowitz 1952, p. 81):

$$V_p = s_1^2 v_1 + s_2^2 v_2 + 2 s_1 s_2 \sqrt{V_1} \sqrt{V_2} \rho_{12}, \tag{3}$$

where:
v_1 – average variance on equity during the examined period,
v_2 – average variance on crypto asset in the examined period,
ρ – correlation coefficient between assets used in the portfolio construction.

Portfolio returns are weighted averages on returns on the assets that comprise it:

$$R_p = s_1 R_1 + s_2 R_2, \tag{4}$$

where R_1 and R_2 are returns on equity and crypto assets, respectively.

Research results

Preliminary research

The first stage of the research involved calculating Pearson correlation coefficients for the examined assets. Their low values indicate potential opportunities for portfolio optimization (see Table 1). PX shows positive correlations that are low and close to zero correlations with Bitcoin (0.16), NFT (0.07) and DeFi (0.18), some of which are not significant. The correlations between Bitcoin and PX and between DeFi with PX are statistically significant (p = 0.00); however, the PX correlation with NFT is not. The correlation between BUX and Bitcoin is 0.11, which is significant a p = 0.00. The correlation coefficient between BUX and DeFi is also low (0.17) but significant at p = 0.00. BUX and NFT are weakly correlated (0.01) and not significant. The WIG20 has low correlation coefficients with Bitcoin (0.21) and DeFi (0.20), both of which are statistically significant at p = 0.00. WIG20 is insignificantly correlated with NFT, similar to PX and BUX.

These results suggest that all crypto assets can serve as diversifiers for Czech, Hungarian, and Polish equity markets. Consequently, these findings are applied in the portfolio optimization in the next part of the research. All correlations between stock indices are average and significant, so they would not serve as good diversifiers compared to cryptocurrencies.

Table 1. Correlation matrix for the examined assets

	DeFi	NFT	WIG20	BTC	BUX	PX
DeFi	1					
NFT	–0.06 (0.0897)	1				
WIG20	0.20 (0.0000)	–0.03 (0.8120)	1			
BTC	0.64 (0.0000)	–0.04 (0.5610)	0.21 (0.0000)	1		
BUX	0.17 (0.0000)	0.01 (0,9907)	0.59 (0.0000)	0.11 (0.0019)	1	
PX	0.18 (0.0000)	0.07 (0,6741)	0.57 (0.0000)	0.16 (0.0000)	0.62 (0.0000)	1

Source: author's own analysis.

Table 2 presents the main descriptive statistics relevant to this research. All means for stock indexes are negative (PX is –0.04, BUX is –0.02, and WIG20 is –0.01). The average returns for crypto assets are much higher: the mean for NFT is 0.36, for DeFi, it is 0.22, and for Bitcoin, it is 0.01. This suggests that they may succeed in return maximizing the equity-crypto portfolio. Simultaneously, variances for crypto assets are much higher than for stocks. However, considering low or non-existing correlations, they might be used to minimize portfolio variance. The highest variance is for NFT (3185.59), followed by DeFi (38.45) and Bitcoin (16.02). Variances in stock markets are as follows: 3.95 for WIG20, 3.73 for BUX, and 1.66 for PX.

Skewness and kurtosis are additionally provided, although they are not used by Markowitz. However, they also provide insights into risk characteristics. Higher kurtosis indicates more extreme values, understood as being far away from the standard normal distribution. NFT and DeFi have extremely high kurtosis levels (326.46 and 15.86, respectively), followed by BUX (0.85) and Bitcoin (7.32). Interestingly, variance-based risk assessment differs slightly from kurtosis-based assessments. In the former case, all crypto assets are riskier than equity; in the latter, Bitcoin is less risky than BUX.

Regarding skewness, which measures distribution asymmetry, negative values indicate undesirable fat tails on the left side. Both NFT and DeFi exhibit negative skewness. Surprisingly, Bitcoin has a positive asymmetry (0.54), which is even higher than for PX (0.33) and WIG20 (0.31) but lower than for BUX (0.92). In summary, skewness and kurtosis do not show as high risk for Bitcoin as variance does compared to equity.

Table 2. Descriptive statistics for the examined assets

	DeFi	NFT	WIG20	BTC	BUX	PX
Mean	0.22	0.36	–0.01	0.01	–0.02	–0.04
Standard deviation	6.20	56.44	1.99	4.00	1.93	1.29
Variance	38.45	3185.59	3.95	16.02	3.73	1.66
Skewness	–0.19	–0.73	0.31	0.54	0.92	0.33
Kurtosis	15.86	326.46	9.54	7.32	10.85	7.35

Source: author's own analysis.

Portfolio optimization with the minimum variance assumption

The next step of the research is conducting portfolio optimizations. Table 3 presents results for the assumption of minimum variance. Optimized Bitcoin shares in all equity portfolios are all lower than equity shares. It stands at 5.10% for the Czech Republic, 15.94% for Hungary, and 13.54% for Poland. Such shares allow for increased portfolio returns compared to portfolios consisting solely of equities, albeit sometimes only slightly.

The goal was to achieve a lower average daily portfolio variance than for single equity, which was achieved in all cases. Variance decreased in all cases: from 1.66 to 1.62 for PX, from 3.73 to 3.27 for BUX, and from 3.95 to 3.65 for WIG20. Although variances diminished, returns did not change significantly. When Bitcoin is included in the equity portfolio, PX rises from –0.04 to –0.03, so the average daily return is less negative. BUX also rose, from –0.023 to –0.018, while the WIG20 increased from –0.01 to 0.00.

For NFT, in the PX portfolio, the optimal share is equity only. Adding NFT to PX does not increase returns but significantly reduces variance from 3185.59 to 3.72. Analogically, adding NFT to BUX reduces variance to 3.73 and only slightly increases the portfolio return. The optimal share of NFT in the BUX portfolio is 0.1. The optimal NFT share in the WIG20 portfolio is 0.23. Including NFT in the WIG20 portfolio slightly increases the return from –0.01 to 0.00 and substantially decreases the variance from 3185.59 to 3.94.

Optimal shares of DeFi are 0.50% for PX, 8.70% for BUX, and 4.03% for WIG20. Portfolio optimization with crypto assets results in a slight increase in returns, from –0.04 (PX), –0.02 (BUX) and –0.01 (WIG20) to 0.00 in all examined cases. Variance does not change for PX, but it decreases for BUX from 3.73 to 3.41 and for WIG20 from 3.95 to 3.89.

To sum up, incorporating crypto assets into equity portfolios significantly reduces variance in most cases while slightly increasing returns.

Table 3. Equity and crypto asset portfolio optimization results for the minimum variance assumption

	Czech Republic	Hungary	Poland
Bitcoin			
Bitcoin share [%]	5.10	15.94	13.54
Equity share [%]	94.90	84.06	86.45
Bitcoin average daily historical return [%]	0.01	0.01	0.01
Equity average daily historical return [%]	–0.04	–0.023	–0.01
Assumed minimum diversified portfolio return for optimization process [%]	–0.04	–0.02	–0.01
Diversified portfolio average daily return [%]	–0.03	–0.018	0.00
Bitcoin average historical variance	16.02	16.02	16.02
Equity average historical variance	1.66	3.73	3.95
Diversified portfolio variance	1.62	3.27	3.65
NFT			
NFT share [%]	0	0.10	0.23
Equity share [%]	1	99.90	99.77
NFT average daily historical return [%]	0.36	0.36	0.36
Equity average daily historical return [%]	–0.04	–0.023	–0.01
Assumed minimum diversified portfolio return for optimization process [%]	–0.04	–0.023	–0.01
Diversified portfolio average daily return [%]	–0.04	–0.022	0.00
NFT average historical variance	3185.59	3185.59	3185.59
Equity average historical variance	1.66	3.728	3.95
Diversified portfolio variance	1.66	3.725	3.94
DeFi			
DeFi share [%]	0.50	8.70	4.03
Equity share [%]	99.50	91.30	95.97
DeFi average daily historical return [%]	0.22	0.22	0.22
Equity average daily historical return [%]	–0.04	–0.02	–0.01
Assumed minimum diversified portfolio return for optimization process [%]	–0.04	–0.02	–0.01
Diversified portfolio average daily return [%]	0.00	0.00	0.00
DeFi average historical variance	38.45	38.45	38.45
Equity average historical variance	1.66	3.73	3.95
Diversified portfolio variance	1.66	3.41	3.89

Source: author's own analysis.

Portfolio optimization with the maximum return assumption

The results of portfolio optimization for the assumption of maximum return are presented in Table 4. The goal of the optimization is to maximize return without increasing equity variance. The optimal shares of crypto assets are 1.88 for PX, 6.25 for BUX, and 7.04 for Poland. Including Bitcoin in the equity portfolio results in a slight increase in average daily returns: for PX, it rises from –0.0357 to –0.0349, for Hungary from –0.023 to –0.021, and for WIG20, from –0.0095 to –0.0084. Portfolio variances remain unchanged for those of the equity portfolios.

For NFT, only BUX can be optimized, with an optimal NFT share of 0.19%. This allocation allows the average daily return to increase slightly from –0.023 to –0.022, while variance remains at the same level as that of the 100% equity portfolio.

DeFi's optimal shares are as follows: 1.02% for PX, 17.40% for BUX, and 8.06% for WIG 20. Constructing crypto equity portfolios results in a slight increase in average daily return: PX rises from –0.04 to –0.03, BUX increases from –0.02 to 0.02, and WIG20 rises from –0.01 to 0.01. Variances remain the same.

In summary, adding crypto assets to equity portfolios to maximize returns allows for slight increases in most returns without any changes in variance values.

Table 4. Equity and crypto asset portfolio optimization results for the maximum return assumption

	Czech Republic	Hungary	Poland
Bitcoin			
Bitcoin share [%]	1.88	6.25	7.04
Equity share [%]	98.12	93.75	92.96
Bitcoin average daily historical return [%]	0.01	0.01	0.01
Equity average daily historical return [%]	–0.0357	–0.023	–0.0095
Assumed maximum diversified portfolio variance for optimization process [%]	1.66	3.73	3.95
Diversified portfolio average daily return [%]	–0.0349	–0.021	–0.0084
Bitcoin average historical variance	16.02	16.02	16.02
Equity average historical variance	1.66	3.73	3.95
Diversified portfolio variance	1.66	3.73	3.95
NFT			
NFT share [%]	0	0.19	0
Equity share [%]	1	99.81	1
NFT average daily historical return [%]	0.36	0.36	0.36
Equity average daily historical return [%]	–0.04	–0.023	–0.01

	Czech Republic	Hungary	Poland
Assumed maximum diversified portfolio variance for optimization process [%]	1.66	3.728	3.95
Diversified portfolio average daily return [%]	–0.04	–0.022	–0.01
NFT average historical variance	3185.59	3185.59	3185.59
Equity average historical variance	1.66	3.73	3.95
Diversified portfolio variance	1.66	3.73	3.95
DeFi			
DeFi share [%]	1.02	17.40	8.06
Equity share [%]	98.98	82.60	91.94
DeFi average daily historical return [%]	0.22	0.22	0.22
Equity average daily historical return [%]	–0.04	–0.02	–0.01
Assumed maximum diversified portfolio variance for optimization process [%]	1.657	3.73	3.95
Diversified portfolio average daily return [%]	–0.03	0.02	0.01
DeFi average historical variance	38.45	38.45	38.45
Equity average historical variance	1.66	3.73	3.95
Diversified portfolio variance	1.66	3.73	3.95

Source: author's own analysis.

In summary, incorporating crypto assets into a diversified portfolio can reduce variance or slightly increase average daily returns, although the latter change is small. Thus, crypto assets should be used for variance reduction thanks to their very low or no correlation with equity. This perspective aligns with Ma et al. (2020), who argue that crypto assets should be applied as risk-minimizing tools.

However, exceptions are observed for NFTs in the Czech Republic (for both minimum variance and maximum return portfolio) and in Poland (for the maximum return portfolio). In these cases, optimal portfolios consist of 100% equity. These findings contrast with Osman et al. (2023), who postulate that when investors consider cryptocurrencies in a Markowitz framework, they should not include equity when constructing an optimal portfolio.

Conclusions

The correlation between financial assets has significantly increased recently, particularly during crises. This trend makes portfolio diversification increasingly difficult, highlighting the need for investors to explore new strategies. The purpose of the research was to determine whether Bitcoin, NFT, and DeFi can be integrated into optimal crypto-equity portfolios to reduce variance or boost return compared to equity-only investments. The research compared results

for the three crypto assets in the Czech Republic, Hungary, and Poland. Calculations were conducted for both minimum portfolio variance and maximum return objectives.

The three crypto assets can be used as a part of well-diversified portfolios; however, their shares are generally small. Notable exceptions are NFTs in the Czech Republic for both minimum variance and maximum return portfolio, and NFTs in Poland for the maximum return portfolio. In these cases, the optimal portfolio is 100% equity. The paper also demonstrates that crypto assets should be used for variance reduction, thanks to their very low or no correlation with equity. The increase in portfolio return from diversification is relatively low.

These conclusions align with Aggarwal, Santosh, and Bedi (2018), Aharon and Demir (2022), and Ali, Umar, and Gubareva (2024), who stated that crypto assets can be used when constructing optimized portfolios. They are also in line with Damianov and Elsayed (2020), who suggest that it is beneficial to include cryptos in equity portfolios, but it should be done to a limited extent. The conclusions are also in accordance with Sharma, Rawat, and Kaur (2022), who stated that crypto assets should primarily be applied as risk-minimizing tools. These perspectives contrast with Osman et al. (2023), who argued that Markowitz investors should not use equity when they can invest in cryptocurrencies.

The results presented in the paper add value in several ways. First, they demonstrate that including NFT, DeFi and Bitcoin in stock portfolios in Poland, the Czech Republic, and Hungary creates diversification benefits for most portfolios, primarily by reducing risk since the increase in returns is relatively small. Second, optimal shares of crypto assets vary depending on which equity from which country is used. Third, there are notable differences in optimal shares between different countries' equities and different crypto assets. The paper additionally shows that there are minimal connections between the Czech, Hungarian, and Polish equity markets with crypto assets.

The paper is important for investors seeking diversification possibilities. Although such opportunities have decreased in recent years, new financial instruments, such as crypto assets, have emerged which may fill this gap. The conclusions may also be vital for policymakers who should consider these assets when developing regulations related to systematic risk.

Further research should focus on examining portfolio equities from other Eastern European countries, as this part of the world has not been fully examined yet. Additionally, other cryptocurrencies and crypto assets and different methodologies could be used.

A limitation of the study is that Markowitz's portfolio theory does not consider transaction costs and assumes that historical returns are repeated in the future. Furthermore, average daily returns and variances are calculated, while real profits may differ from average values and depend on the investment horizon.

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Optymalne udziały NFT, DeFi i Bitcoina w portfelach akcji na rynku czeskim, węgierskim i polskim

Celem artykułu jest prezentacja wyników badań, które weryfikują, czy różne rodzaje kryptoaktywów, takie jak Bitcoin, NFT i DeFi, mogą stanowić część optymalnego portfela pozwalającego na redukcję wariancji lub maksymalizację stopy zwrotu w porównaniu z inwestycjami wyłącznie w akcje. Porównano wyniki badań dla różnych kryptoaktywów oraz różnych krajów – Republiki Czeskiej, Węgier i Polski.
Skonstruowano optymalne portfele złożone z akcji i kryptoaktywów w środowisku Markowitza w okresie badawczym od 16 lutego 2021 do 8 stycznia 2024 roku, który rozpoczął się od momentu dostępności danych dotyczących NFT. Obliczenia przeprowadzono przy założeniu minimalizacji wariancji portfela oraz maksymalizacji stopy zwrotu.
Pokazano, że Bitcoin, NFT orz DeFi mogą stanowić elementy dobrze zdywersyfikowanego portfela akcji, szczególnie ze względu na ich niską korelację z rynkami akcji w Czechach, na Węgrzech i w Polsce.
Wnioski wynikające z artykułu są ważne dla inwestorów poszukujących możliwości dywersyfikacji kapitału. Chociaż dywersyfikacja portfela staje się ostatnio coraz trudniejsza z powodu rosnącej korelacji pomiędzy poszczególnymi rynkami, jednocześnie powstają nowe rodzaje aktywów, jak krypto, które – jak się okazuje – tworzą nowy potencjał dla kreacji zdywersyfikowanego portfela. Wnioski są także istotne dla organów ustawodawczych, które powinny je brać pod uwagę, tworząc prawo dotyczące ryzyka systemowego.
Zaprezentowane w artykule wyniki badań tworzą wartość dodaną dla dotychczasowych ustaleń zawartych w literaturze przedmiotu na cztery sposoby. Po pierwsze, pokazano, że włączenie do portfela NFT, DeFi i Bitcoina pozwala na odniesienie korzyści z dywersyfikacji w większości badanych przypadków. Uzyskuje się to dzięki nieco wyższym stopom zwrotu, ale przede wszystkim dzięki znacznie mniejszej wariancji w porównaniu do inwestowania w tzw. aktywa tradycyjne. Po drugie, dowiedziono, że optymalne udziały akcji i kryptoaktywów różnią się od siebie w zależności od tego, które kryptoaktywo zostało wzięte do portfela oraz który kraj podlega analizie. Po trzecie, artykuły naukowe koncentrują się na innych rynkach (głównie amerykańskim), natomiast w niniejszym opracowaniu skupiono się na rynku czeskim, węgierskim i polskim. Po czwarte, wykazano, że istnieją bardzo niewielkie powiązania pomiędzy rynkiem kryptoaktywów a badanymi rynkami akcji.

Słowa kluczowe: optymalizacja, dywersyfikacja, NFT, DeFi, Bitcoin, Polska, Czechy, Węgry