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Cointegration and Regression Analyses as Alternative Methods to Verify the Protective Properties of Inflation Hedge Investments

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Abstract

Aim: In the face of rising inflation, a variety of financial tools are increasingly important to protect capital from loss of value. This leads to questions about which investment to choose to protect capital from loss of value. The purpose of the work was to determine whether selected investment directions on the Polish capital market can protect capital against inflation-related loss of value.

Methodology: The study used a cointegration analysis using the Engle-Granger test and a regression analysis using the OLS method. The research covered the period from Q4 2008 to Q4 2022, using the bond TBSP index, Bitcoin and gold, the WIG index, the WIG Real Estate stock index and the NBP hedonic index of property prices in the seven largest cities in Poland. These investments were related to the HICP harmonised inflation index published by the European Statistical Office (EUROSTAT).

Findings: The analysis revealed different results depending on the survey methodology adopted. The co-integration analysis pointed to Bitcoin as an inflation hedging investment, whereas the regression analysis pointed to gold and residential property as inflation combined.

Implications: The study enables a better understanding of the complex dynamics involved in preserving purchasing power during periods of high inflation.

Originality/value: The study is an important contribution to filling the gaps in the Polish market in terms of analysis of capital protection options against inflation. Although the study focused only on the Polish market, this topic has not been addressed through a period of low inflation also in mature economies.

Keywords: investments, inflation hedging, portfolio, real estate, Poland

1. Introduction

In recent years the Polish economy has faced difficult times, resulting in economic problems and especially a sharp rise in inflation. The rise in prices is forcing investors to look for alternatives to poorly interest-bearing bank deposits and the topic of hedging capital against loss of its value is returning after a gap of some years. Investment in traditional assets such as bonds, cryptocurrencies, gold, shares, and real estate is a natural course of action. Although equity investments seem less obvious, they are based on real value and property, which makes them an important consideration. Among the current investment directions, it is necessary to mention Bitcoin. Cryptocurrencies, although relatively young, seem to have become a permanent fixture in investors' portfolios and play an important role as they are considered by some investors to be a substitute investment for gold. However, Bitcoin's responses to structural shocks show significant differences compared to the response of gold prices. This strongly contradicts the claim that Bitcoin is 'digital gold' (Choi & Shin, 2022). In the context of investment diversification, it should also be mentioned that the investor's objective is to maximise the rate of return at a given level of risk. A factor such as inflation makes this objective more difficult to achieve (Wang et al., 2011; Arnold & Auer, 2015; Yeap & Lean, 2017). In this context, research is important to show that the ability to protect capital through investment in the financial market depends on a number of factors and analysing the relationship between inflation and investment is difficult. Different research methods may lead to different results (Bond & Seiler, 1998; Arnold & Auer, 2015; Aye et al., 2016). Therefore, one can also consider what inflation is and how to measure it – Arnold and Auer (2015), among others, commented on this topic and defined inflation as the process of a continuous increase in the prices of raw materials, products, and services or, alternatively, a continuous decrease in the value of money by which the intuitive way to measure inflation is to use consumer price indices (CPI), which are based on real price increases. Summarising these considerations, the author reflected that it is worthwhile to attempt to analyse and answer the question of whether investments in the Polish capital market are able to protect capital from depreciation caused by inflation.

This article aims to determine whether selected investment directions on the Polish capital market are able to protect capital against inflation-related depreciation, and in the course of the research work a research hypothesis was established: investments in bonds, Bitcoin, gold, shares, and real estate are able to effectively protect the capital held against the negative impact of inflation.

The research was carried out on quarterly data from the fourth quarter of 2008 to the fourth quarter of 2022, including bond market indices, PLN-denominated Bitcoin and gold quotes, equity and property indices and inflation data. The study used cointegration analyses applying the Engle-Granger test and OLS regression analysis as a test of asset sensitivity to inflation. In addition, data distributions were tested and the Spearman correlation coefficient was calculated.

2. Literature Review

The subjects of inflation and capital preservation through investment appeared relatively late in the literature. In the 1970s, papers were published that are often cited by researchers as being the first and introducing the issue in the literature (Salisu et al., 2020). The analysis of the possibility of inflation hedging is usually based on the belief presented by Fisher (1930) that the expected nominal interest rate should move in line with expected inflation. On this basis, Lintner (1975) formulated the hypothesis that few issues are more important than the impact of inflation on financial markets and the investment process. Fama and Schwert (1977) came to similar conclusions, arguing that inflation hedging means matching returns on different asset classes with inflation. A similar definition of the inflation hedging function was formulated before them by Bodie (1976). Fama and Schwert analysed the US real estate market, showing that investments in US residential real estate protect capital against inflation. The researchers tested the relationship between property prices and expected and unexpec-

ted inflation, using quarterly and monthly data from 1953 to 1971. The research showed that investments in residential properties protect against expected inflation, but not against the unexpected part of it. Bird (1984) studied the usefulness of investments in the London commodity market as a hedge against inflation, comparing the commodity index with the price indices of physical and financial assets. The author examined returns, risk, and liquidity of investments, and the results indicated that commodities were classified as an average inflation hedging asset, with tin proving to be the most suitable commodity for inflation hedging. Stevenson and Murray (1999) conducted a study of the Irish market, based on data from 1985 to 1996 and used regression and cointegration analysis, and no relationship between the property market index and the CPI was found, either in the short or long term. In addition, it was shown that an increase in the prices of the property market can lead to an increase in inflation. Aye et al. (2016) investigated the properties of gold as a hedge against inflation using an interrupted Markov-switching cointegration model. The research was carried out on annual data from 1833 to 2013 in the US market. The authors found evidence that gold can act as an inflation fuse, but not all methods led to such conclusions, for example cointegration analysis using the Engle--Granger test did not provide such evidence, whilst Lee and Isa (2019) studied the Malaysian market, analysing stocks, bonds, and gold. Their study was conducted between 1980 and 2016, using the autoregressive distributed lag (ARDL) approach to analyse long-term correlations. The results indicated that stocks and bonds could protect against inflation, while real estate provided only partial protection. Salisu et al. (2020) conducted an analysis on the US market using monthly logarithmic returns from 2002 to 2011 and analysed three asset classes: real estate represented by an index of REIT funds, equities represented by the US S&P 500 index, and gold listed on the London Stock Exchange quoted in US dollars. They verified Fisher's (1930) hypothesis cited earlier. The analysis indicated that equities and real estate could be inflation hedging investments, while gold did not provide capital protection against inflation. It was also shown that the hedging relationship between assets and inflation varies over time. After 2010, there has been a trend in the literature to analyse another investment: Bitcoin. The study of Bitcoin as an inflation fuse seems quite obvious given that the cryptocurrency itself is regarded as an alternative investment that allows capital to escape the system. It is a tempting alternative to currencies or stocks in markets that are regulated and dependent on economic policy. The appearance of cryptocurrency in analyses is linked to its entry into circulation. Matkovskyy and Jalan (2021) studied the US, UK, Japanese, and Eurozone markets using the Quantile-on-Quantile Model and Bitcoin quotes in national currencies. Closing prices from the Kraken exchange between 1 January 2015 and 1 July 2019 were used for the analysis. The expected inflation was calculated using the ARMA (1.1) model. Unexpected inflation was calculated from the difference between actual and expected inflation. The results of this research suggest that, in an uptrend, bitcoin quoted in EUR, GBP, and JPY can provide a hedge against real (realised) inflation. Choi and Shin (2022) considered whether Bitcoin could replace gold in the realm of safe assets in times of increased investment risk. The research was inspired by the safety that gold generally provides investors. The authors used the Vector Autoregression Model (VAR). They noted that Bitcoin is a higher-risk investment than gold, reacting negatively to market shocks caused by financial factors, although they hedge against inflation shocks and shocks related to political uncertainty. The authors found this to be consistent with the idea of Bitcoin as an independent cryptocurrency, also noting that the cryptocurrency was more susceptible to large price fluctuations, meaning that it cannot be considered a safe investment, unlike gold. The research was carried out on weekly data in the US market between 21 July 2010 and 31 December 2020 – a research period was determined by the available Bitcoin quotes. Phochanachan et al. (2022) analysed Bitcoin, gold, oil, and equities in terms of investors' hedging against inflation. They considered dollar-quoted asset quotes and inflation rates for selected countries: Ukraine, Russia, Singapore, Kenya, United States, India, South Africa, Nigeria, Columbia and Vietnam. Inflation was measured by the Consumption Price Index (CPI). The study period covered January 2010 to March 2021 reported by International Financial Statistics (IFS), and used a Markov switching vector. The authors drew a number of conclusions, which can be summarised by saying that all assets were 'inflation hat', at least this was true for short periods of time. In the long term, inflation hedging was not as effective.

Similar studies were also carried out in Poland. Trojanek (2007) analysed the relationship of residential property prices in Poznań between 1996 and 2004, examining their links with expected and unexpected inflation; the study showed that real estate was effective in protecting capital from inflation. Fiszeder and Rowinski (2012) focused on the impact of macroeconomic factors on the equity market in Poland, taking into account the CPI inflation rate. The study was conducted between 2000 and 2010 and found a long-term relationship between the stock market index and the level of inflation, suggesting a lack of protection of the capital value against inflation in equity investments. Kasprzak--Czelej (2015) studied gold and CPI quotations in the Polish market. Statistical tests, such as the Kwiatkowski, Phillips, Schmidt, and Shin unit root test (KPSS test) and the Engle-Granger test, showed no relationship between gold prices and the CPI, suggesting that gold does not protect capital against loss of value due to inflation. Wolski (2022) analysed the equity, bond, gold, and residential property markets in Poland using cointegration analysis with the Engle-Granger test. The author cross--referenced quarterly listing data for individual assets with the CPI inflation index and took the interval from the first quarter of 2009 to the last quarter of 2021 as the research period. Wolski's study failed to show that the analysed indices and prices were related to the level of inflation, although it demonstrated the existence of a positive correlation between returns on stocks, bonds, and gold and the CPI inflation index. Melnychenko et al. (2022) used panel data conducted a regression analysis where the change in the price per square metre of residential property was a function of, among other things, changes in the level of inflation. They analysed quarterly residential property price returns in eight of Poland's largest cities in the period from 2009 to 2021. The research showed that in seven of the eight largest cities, property prices were positively related to the inflation rate. Wolski (2023) conducted a cointegration analysis using the Engle-Granger test. The study was carried out between the first quarter of 2009 and the fourth quarter of 2021, analysing the correlations between hedonic indices calculated by the National Bank of Poland for six, seven and ten selected cities in Poland and inflation rates – actual and forecast – published by Statistics Poland and the National Bank of Poland. The study did not succeed in demonstrating that property prices were related to the level of inflation in the period under review.

The presented literature review does not exhaust the topic of investment research in the context of inflationary processes. The author presented only those works considered to be the most important or representative of a given period or type of investment. Another factor motivating this rather than other selections of sources was the desire to show the multiplicity of methods and their sources in inflation hat research. It is worth mentioning here that, after years of low inflation, the topic has returned to the field of academic interest, and it is to be expected that research in this direction will continue, bringing more and more new publications.

3. Methodology

Inflation, which distorts the economic calculus, is of concern to investors looking for effective ways to protect the value of their capital holdings for a good reason. However, the question remains as to which investment directions are able to effectively constitute an inflation hedge. Therefore, the objective of this article was to determine whether selected investment directions in the Polish capital market are able to protect capital against loss of value associated with inflation. To achieve the objective, a research hypothesis was formulated: investments in bonds, Bitcoin, gold, shares, and real estate are able to effectively protect the capital held against the negative impact of inflation. The achievement of the objective and the verification of the hypothesis was carried out using the research methods described in the following sections.

3.1. Data

The research used data available for the Polish capital market. All stock market data: quotations of the sovereign bond market index (TBSPIndex), quotations of Bitcoin in PLN (BTC), quotations of gold in PLN (XAU), the broad stock exchange index from Warsaw Stock Exchange (WIG), and the sector stock exchange index for companies from the real estate sector (WIGN) were obtained from the Stooq database. The hedonic index quotes for the secondary residential property market (RealEst7) were obtained from the database created by the National Bank of Poland (NBP), while data on the inflation level in the form of the harmonised consumer price index (HICP) were obtained from the European Statistical Office EUROSTAT. The hedonic index of residential property prices covered the prices of the seven largest Polish cities (Gdańsk, Gdynia, Łódź, Kraków, Poznań, Warsaw, Wrocław). All data had a quarterly frequency for the period from Q4 2008 to Q4 2022. The duration of the research period was determined by the identified business cycle. A time was chosen in which equity market prices started to rise again after the crisis and the collapse of the financial markets in 2007. Furthermore, the hedonic index of residential property prices has been calculated since 2006, while Bitcoin quotes have been available since 2010. This limitation is due to the timing of the introduction of this cryptocurrency into public trading. Therefore, the research period for Bitcoin included fewer observations – from Q3 2010 to Q4 2022. The data were selected to examine the long-term relationship between subsequent investment and the HICP inflation measure. From an investor's point of view, the long-term relationship seems most appropriate in the context of examining the possibility of capital preservation against loss of value. The graphs of all listings are shown in Figure 1.

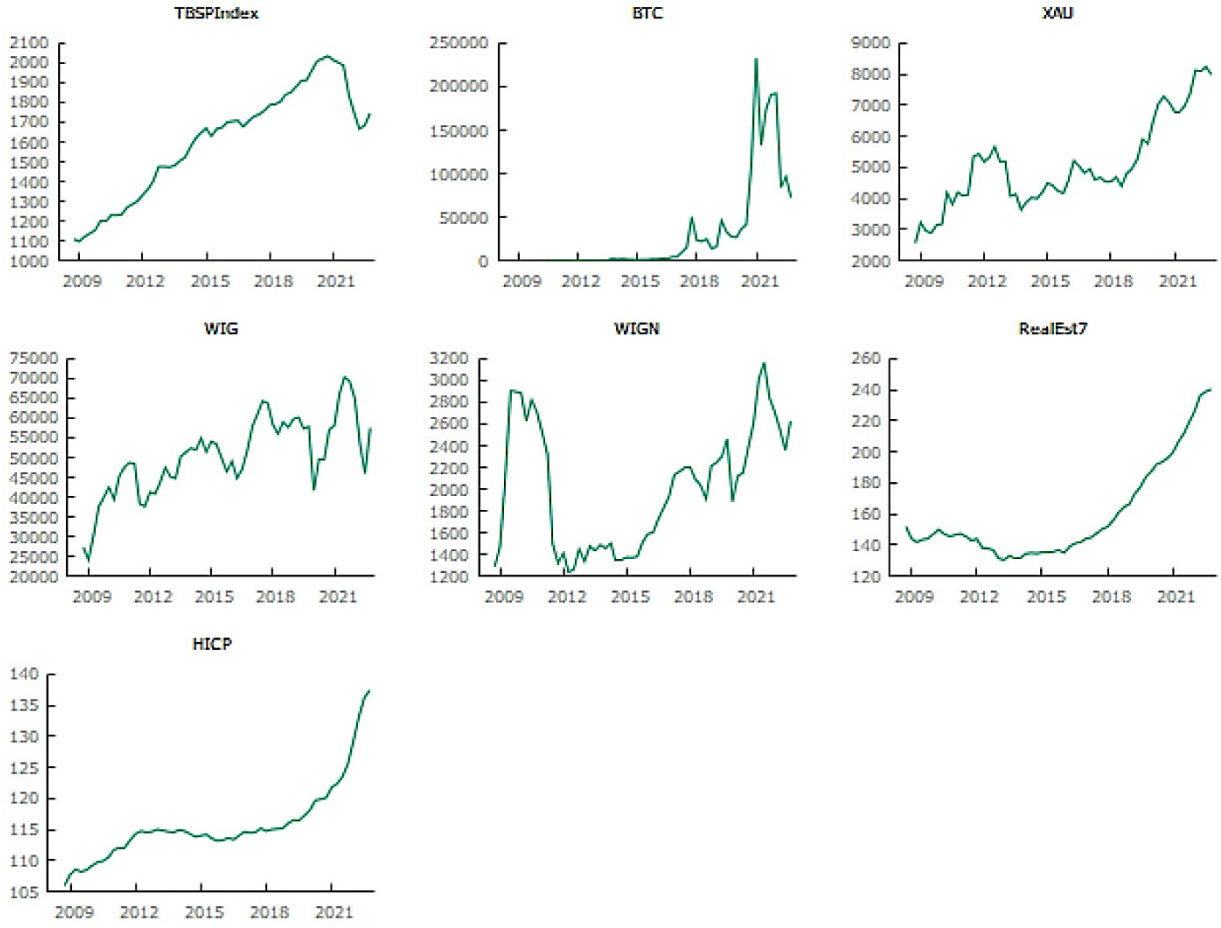

Fig. 1. Quotes of individual assets, indices and inflation index from Q4 2008 to Q4 2022.

Source: own work.

The choice of the analysed assets was determined by the author's conviction that these are popular investment destinations for capital owners. While the quotations of gold, Bitcoin, or a bond index and a broad stock market index do not raise any doubts, the choice of specific indices for the real estate market requires some explanation. For the measurement of property prices, the author decided to use a hedonic index instead of average prices, considering that it better reflects the actual state of the market. Hedonic indices take into account price changes in relation to qualitative changes, which makes it possible to measure 'pure' price change, independent of qualitative differences (cf. Widłak, 2010; Foryś, 2016; Trojanek, 2018). In addition to the hedonic index of prices of residential properties, the WIG Real Estate (WIGN) index was chosen for the study. The author recognised that not every investor has the opportunity to invest directly in real estate. This is beyond the characteristics of real estate, such as the high sensitivity to changes in the environment and in the local real estate market due to fixity in place, low liquidity, and high capital intensity (cf. Kucharska-Stasiak, 2009; Hoesli & MacGregor, 2000). Hence, some investors may opt for indirect investments, the simplest of which are investments in real estate companies represented by the WIG Real Estate sector index.

3.2. Methods

As the literature review shows, different research methods can produce different results (Bond & Seiler 1998; Arnold & Auer, 2015; Aye et al., 2016). Whether a method can correctly identify the protective properties of an investment depends, for example, on the research period chosen. As stated by Fogler (1984), this type of analysis is not straightforward, and many econometric methods are unable to capture the relevant relationships. An example is real estate investments, which, especially in the short run, may not provide adequate protection against inflation.

To effectively identify inflation hedge investments, three research methods were used. First, an analysis of the distributions of percentage returns was carried out. The author selected four tests to examine the normality of the distribution, which are frequently employed in this kind of research, namely: Doornik-Hansen, Shapiro-Wilk W, Lilliefors, and Jarque-Bera. The author did not opt for a single test because, as the literature suggests, these tests can vary in their results depending on factors such as the shape of the data distribution, hence the use of multiple tests may allow for a more thorough analysis (Lee et al., 2016). On this basis, Spearman's correlation analysis (Spearman, 1987) was chosen to check whether the time series of returns were related at all. However, correlation analysis did not give very precise answers if only by the very nature of the indicator being closed in a range of values between -1 and 1, therefore in the next step a cointegration analysis was performed. Such an analysis is mainly used to find links between time series of quotations over a long period. For the cointegration analysis, the Engle-Granger test was applied (Engle & Granger 1987). Finally, following the work of Salisu et al. (2020) and Phochanachan et al. (2022), a linear regression analysis with ordinary least squares (OLS) parameter estimation was performed. Percentage returns were used for this analysis. Using regression analysis and correlation analysis, statistical relationships between subsequent variables and inflation were examined, the HICP inflation rate was taken each time as the explanatory variable. In the case of cointegration analysis, long-term relationships between the same data sets were examined. No other explanatory variables except inflation were used in the models.

The correlation analysis was performed following an approach consistent with the classical Markowitz portfolio theory. According to it, maximising the return on a portfolio while keeping risk at a certain level is mainly achieved through portfolio diversification (Markowitz, 1952; Sharpe, 1967; Steinbach, 2001). If indices, Bitcoin and the price of gold are not correlated with the HICP, then it can be presumed that the investor will manage to mitigate the risk associated with the occurrence of inflation. This does not mean that investors will protect their capital from loss of value, but will diversify their returns in relation to the level of inflation. Following this approach, a normality test of the distributions was performed and then Spearman correlations were counted (Spearman, 1987).

In the next stage of the study, a cointegration analysis was conducted. This is consistent with the belief that the cointegration of index values and asset prices with inflation implies an association of returns with the inflation rate. Furthermore, according to Fisher's (1930) theory, the expected rate of return consists of the actual rate of return and the expected level of inflation, so the relationship between the inflation rate and stock prices should be positive (Salisu et al., 2020). A cointegration analysis was carried out using the Engle-Granger test (Engle & Granger, 1987), whilst the cointegration tests were performed in pairs, where invariably one of the issues was the HICP inflation index. According to the test methodology, the unit root test was conducted first for the following variables. A model with a constant of the form was tested: $(1-L)y = b_0 + (a-1) * y(-1) + \ldots + e$. A lag of four quarters was used in the model. The time series of the levels of subsequent variables were expected to be nonstationary, thus the null hypothesis of a unit root was not rejected. In the next step, the unit root was tested for the residual process (uhat) using a model without a constant: $(1-L)y = (a-1) * y(-1) + \ldots + e$, also with four delays. This time the residual process (uhat) from the co-integrating equation was expected to be the process for which the null hypothesis of a unit root is rejected. A similar methodological approach was used by, for example, Stevenson and Murray (1999), Lee (2013). Cointegration analysis was performed on quotations from consecutive data.

In the last step, model testing was carried out using linear regression estimated with the ordinarily least squares (OLS) model. This is consistent with the methodology of Fama and Schwert (1977), but also, sometimes in modified forms, applied by other researchers e.g., Le Long et al. (2013), Ghazali et al. (2015), Phochanachan et al. (2022). The study used a model of the form: $Ry = b_0 + b_1 * \Delta HICP + e$, where Ry is the quarterly return on subsequent assets and indices, $* \Delta HCPI$ is the inflation rate as measured by the harmonised consumer price index, *e* is the random component. The directional coefficient of a function, also called slope, allowed to answer the question of what is the growth of the dependent variable per unit growth of the independent variable. In this context, this measure can also be called a sensitivity measure. Inflation hedging is partial if $b_1 \in (0,1)$. If $b_1 = 1$, then one can speak of perfect inflation hedging, and if $b_1 > 1$, then inflation hedging is ahead of inflationary processes. A coefficient of $b_1 = 0$ means that the investment is independent of inflationary processes, and $b_1 < 0$, i.e. negative, means that investment returns fall when the level of inflation rises, a phenomenon that is highly undesirable from an investor's point of view (e.g. Arnold & Auer, 2015; Phochanachan et al., 2022). The methodology adopted in this article has also been criticised, pointing out that the nature of inflation means that linear models are not accurate and do not fully reflect the inflation hat properties of subsequent investments (Phochanachan et al., 2022). However, experience shows that linear models find a lot of use in finance and are accepted by investors, hence for measuring the sensitivity of investments to inflation they may not be ideal but are sufficient, just as the CAPM, which uses beta in an analogous way, is widely accepted.

Some authors argue that correlation analysis, as a static analysis, does not reflect, especially in the long term, the relationship between time series. Therefore, cointegration analysis is preferable, in particular in the context of studying the inflation hedging properties of real estate investments, see Stevenson and Murray (1999). In light of these concerns, but also based on the analysis of previous research, the use of both regression analysis and cointegration analysis seems justified.

All three research approaches implemented the thesis of the already cited Fisher (1930), according to which nominal investment returns are expected to adjust to changes in the price level, i.e. inflation.

4. Results

In the first step, the author examined distributions for the given data in order to decide which method to use to test the correlation between successive investments and inflation. The results are presented in Table 1.

Table 1. Test for normality of the percentage rate of return following variables

Veriable / Test	TBSPIndex (*p* value)	BTC (*p*-value)	XAU (*p*-value)	**WIG (*p*-value)**	WIGN (*p*-value)	RealEst7 (*p*-value)	HICP (*p*-value)
Doornik-Hansen	16.72 (0)***	454.24 (0)***	8.42 (0.01)**	**4.07 (0.13)**	26.67 (0)***	6.23 (0.04)**	29.21 (0)***
Shapiro-Wilk W	0.88 (0)***	0.42 (0)***	0.93 (0)***	**0.97 (0.15)**	0.91 (0)***	0.95 (0.03)**	0.86 (0)***
Lilliefors	0.16 (0)***	0.3 (0)***	0.12 (0.03)**	**0.09 (0.23)**	0.1 (0.13)	0.11 (0.08)*	0.15 (0)***
Jarque-Bera	58.03 (0)***	1873.52 (0)***	16.33 (0)***	**2.17 (0.34)**	26.04 (0)***	8.22 (0.02)**	41.17 (0)***

*** Significant at 0.01 (2-tailed significance).
** Significant at 0.05 (2-tailed significance).
* Significant at 0.1 (2-tailed significance).

Source: own work.

For tests of normality, in all four tests the null hypothesis of a normal distribution of the time series observations of percentage returns was set against the alternative hypothesis of no normal distribution. The null hypothesis of a normal distribution was not rejected for the WIG and WIGN indices in the Lillefors test. For the TBSPIndex bond price index, Bitcoin, gold and inflation, the hypothesis of a normal distribution was rejected in each test. For the WIGN real estate stock index, the null hypothesis of a normal distribution was rejected in the Doornik-Hansen, Shapiro-Wolf and Jarque-Bera tests. On the other hand, in the case of the RealEst7 hedonic index, the alternative hypothesis of the absence of a normal distribution was accepted, but at the very liberal level of 0.1 in the Lilliefors test, while in all other tests the alternative hypothesis was accepted at the significance level of 0.05. The results of these tests can be interpreted in such a way that only for the WIG index it was shown that the distribution of the time series of percentage returns can be said to be a normal distribution of the data. Therefore, the appropriate method had to be chosen for the correlation analysis and a Spearman correlation analysis for which a normal distribution is not necessary, and was carried out in the next step.

Thus, it was shown that the calculation of Spearman correlations was valid. The results of the study are presented in Table 2.

Table 2. Spearman's correlation coefficient calculated percentage of return with HICP as benchmark, N = 57 except BTC, where N = 49

Variable / Coefficient	TBSPIndex	**BTC**	**XAU**	WIG	WIGN	**RealEst7**
Spearman's correlation coefficient	-0.33**	**0.08**	**0.14**	-0.02	-0.05	**0.24**

** Significant at 0.05 (2-tailed significance).

Source: own study.

The table only presents correlations between the time series of percentage returns on subsequent investments and percentage changes in the level of inflation on a quarterly basis. The remaining data were not relevant for this study. The results of the correlation analysis indicated three investments positively correlated with the level of inflation, namely Bitcoin, gold, and the RealEst7 residential property price hedonic index. However, correlation is a measure that, while showing a dependency, does not explain the nature of the relationship in any way. Therefore, it was not sufficient in itself to verify the research hypothesis set out in this article.

In the next step, a cointegration analysis was performed using the Engle-Granger test with the ADF test with free expression. According to the methodology of this test, co-integration occurs if, for each process used, the null hypothesis of a unit root is not rejected and the residual process (uhat) from the co-integrating equation is not integrated, that is, the null hypothesis of a unit root is rejected. The test results are shown in Table 3.

Table 3. Augmented Dickey-Fuller test, testing down from 10 lags, AIC criterion, unit root null hypothesis: *a* = 1, model: (1 – L)*y* = *b*0 + (*a* – 1)**y*(–1) + e, including 4 lags of (*1* – L)*variable, sample size = 52, except BTC and HICP_45, where sample size = 45, test with constant

Variable	TBSPIndex	**BTC**	XAU	WIG	WIGN	RealEst7	HICP_52	HICP_45
Estimated value of (a – 1):	-0.03	**-0.26**	-0.03	-0.18	-0.09	0.02	0.04	0.09
Test statistic tau_c(1):	-1.80	**-2.65**	-0.52	-2.05	-1.47	0.64	1.40	1.72
(Asymptotic *p*-value)	(0.38)	**(0.08)**	(0.89)	(0.27)	(0.55)	(0.99)	(1.00)	(1.00)
1st-order autocorrelation coeff, for *e*:	0.01	**0.06**	0.03	-0.03	0.02	-0.03	-0.01	-0.03
Lagged differences: *F*(4.46)=	4.58 (0.00)	**x**	0.61 (0.66)	0.95 (0.44)	1.00 (0.42)	1.95 (0.12)	4.25 (0.01)	x
Lagged differences: *F*(4.39)= (*p*-value)	x	**2.36 (0.07)**	x	x	x	x	x	2.14 (0.09)
Augmented Dickey-Fuller test for uhat variable/HICP including 4 lags of (1 – L)uhat								
Estimated value of (*a* – 1):	-0.05	**-0.72**	-0.28	-0.30	-0.15	-0.07	x	x
Test statistic tau_*c*(1):	-1.58	**-4.65**	-2.37	-2.53	-2.28	-2.13	x	x
(Asymptotic *p*-value)	(0.73)	**(0.00)*** **	(0.34)	(0.27)	(0.38)	(0.46)	x	x
1st-order autocorrelation coeff, for *e*:	0.02	**0.04**	0.00	-0.02	0.02	-0.04	x	x
Lagged differences: *F*(4,46)=	9.79 (0.00)	**x**	0.78 (0.54)	1.87 (0.54)	1.50 (0.22)	5.36 (0.00)	x	x
Lagged differences: *F*(4,39)= (*p*-value)	x	**4.62 (0.00)*** **	x	x	x	x	x	x

There is evidence for a cointegrating relationship if: (a) The unit-root hypothesis is not rejected for the individual variables, and (b) the unit-root hypothesis is rejected for the residuals (uhat) from the cointegrating regression.
*** Significant at 0.01 (2-tailed significance).
** Significant at 0.05 (2-tailed significance).

Source: own study.

The analysis showed that the Bitcoin listings were integrated with the HICP inflation indicator. In contrast to the other analyses performed in the study, cointegration tests were performed on the quotations. The result obtained is partly in line with the correlation analysis performed earlier, in which a weak positive correlation was found between Bitcoin returns and changes in the level of inflation. In the first part of the configuration test, the unit-root hypothesis was not rejected for any of the variables. In testing the residual process, the unit-root hypothesis was rejected for the residuals (uhat) from the cointegrating regression Bitcoin and HICP_45. In the remaining cases, the null hypothesis was not rejected, which means that cointegration was not demonstrated for the remaining variables.

The final step was to perform the regression analysis. According to the assumptions outlined earlier, investments whose directional coefficient of regression function b_1 was greater than zero were considered protective against the negative impact of inflation on the value of capital. If $b_1 \in (0,1)$, one can speak of partial protection against inflation, whereas when $b_1 > 1$, then inflationary processes were overtaken by investment. The results are presented in Table 4.

Table 4. Model: $Ry = b_0 + b_1 * \Delta HCPI + e$, OLS, using observations: N = 57 and for BTC: N = 49, where Ry is a percentage rate of the return of subsequent variable, and $\Delta HCPI$ is percentage change of HICP

Independent var. $\Delta HCPI$	TBSPIndex	BTC	**XAU**	WIG	WIGN	**RealEst7**
b_1	-1.57	-28.92	**1.81**	-2.36	-1.23	**0.53**
std. error	0.32	54.06	**1.68**	1.96	2.35	**0.34**
t-ratio (*p*-value)	-4.9 (0)***	-0.53 (0.6)	**1.08 (0.29)**	-1.2 (0.23)	-0.52 (0.6)	**1.55 (0.13)**
Constant						
b_0	0.02	1.03	**0.02**	0.02	0.02	**0.01**

std. Error	0	0.49	**0.01**	0.02	0.02	**0**
t-ratio (*p*-value)	5.76 (0)***	2.13 (0.04)**	**1.31 (0.19)**	1.44 (0.16)	0.89 (0.38)	**1.97 (0.05)****
R-squared	0.3	0.01	**0.02**	0.03	0	**0.04**
Adjusted *R*-squared	0.29	-0.02	**0**	0.01	-0.01	**0.02**
F(1, N – 2) (*p*-value)	24 (0)***	0.29 (0.6)	**1.16 (0.29)**	1.45 (0.23)	0.28 (0.6)	**2.41 (0.13)**
Log-likelihood	149.11	-120.95	**54.7**	45.94	35.59	**145.07**
Schwarz criterion	-290.13	249.68	**-101.31**	-83.8	-63.09	**-282.06**
S.E. of regression (e)	0.02	2.92	**0.09**	0.11	0.13	**0.02**
Akaike criterion	-294.22	245.89	**-105.4**	-87.89	-67.17	**-286.15**
Hannan-Quinn	-292.63	247.33	**-103.81**	-86.3	-65.59	**-284.56**
Durbin-Watson	1.38	2.04	**2.06**	1.74	1.44	**1.25**

*** Significant at 0.01 (2-tailed significance).
** Significant at 0.05 (2-tailed significance).

Source: own study.

The results of the study pointed to two investments as an effective hedge against inflation. The b_1 coefficient was greater than zero for the two investments. The investment in real estate provided a hedge, albeit an incomplete one with b_1 of 0.53. In contrast, gold investment outperformed the investment processes with b_1 coefficient of 1.81. All other investments had b_1 coefficients lower than zero, and this means that as inflation increases, these investments are lost, i.e. they do not meet the criteria for protection against inflationary processes.

5. Discussion and Conclusion

The correlation analysis allowed to conclude that all of the assets studied offer opportunities for diversification of risk against inflation. According to the classical Markowitz theory (Markowitz, 1952; Sharpe, 1967; Steinbach, 2001), all assets with correlations different from 1 provide such an opportunity. However, the fact that the TBSPIndex, WIG and WIGN were negatively correlated meant that an increase in inflation was associated with a decrease in the returns of these assets. Thus, this is not desirable behaviour for inflation hedging. The performance of three assets – Bitcoin, gold and real estate – was different. In this case, the correlation was positive. The weak point of the correlation analysis is that it was not possible to establish the exact nature of the relationship and that although the results raise some expectations, further analysis is necessary. In doing so, it is worth noting that, according to Fisher's (1930) hypothesis, the expected rate of return consists of the actual rate of return and the expected level of inflation, hence the relationship between the rate of inflation and share prices should be positive (Salisu et al., 2020), and the possibility of hedging against inflation requires the return on investment to be at least equal to the rate of inflation, something that correlation analysis is unable to demonstrate (e.g. Fang et. al., 2008; Obereiner & Kurzrock, 2012; Van Hoang et al., 2016; Taderera & Akinsomi, 2020).

The results of the cointegration analysis identified Bitcoin as cointegrated with the level of inflation, in line with studies by Matkovskyy and Jalan (2021), Choi and Shin (2022), and Phochanachan et al. (2022). For the other investments, no such relationship could be demonstrated. In turn, these results were close to those obtained with corresponding or similar methods on the Polish market by Fiszeder and Rowiński (2012), Kasprzak-Czelej (2015), and more recently Wolski (2022, 2023), as well as Stevenson and Murray (1999) on the Irish market. Leaving aside Bitcoin, which could not be studied before, the results achieved are in contradiction with other studies (e.g. Fama & Schwert 1977; Lee & Isa 2019; Choi & Shin, 2022). However, as noted by researchers, different research methods may yield different results (Bond & Seiler, 1998; Arnold & Auer, 2015; Aye et al., 2016). Therefore, further research was

conducted using regression analysis, which found that two investments were inflation hedge. Gold, which hedged capital ahead of inflation, and real estate, which followed inflation, but at a slower pace. In the Polish market, in terms of real estate, the results are consistent with Trojanek (2007) and Melnychenko et al. (2022). On the other hand, in the context of the global literature, similar results for gold were achieved by Aye et al. (2016), but these authors also pointed to investments in equities as a hedge against the impact of inflation. In Poland, no such relationship has been demonstrated so far. It is also important to note that some research referred to a different economic reality, which may lead to inaccuracies when trying to compare results.

Summarising the results, it should be assumed that the research hypothesis that "investments in bonds, Bitcoin, gold, shares, and real estate are able to effectively protect the capital held against the negative impact of inflation" was positively verified for half of the assets. Two research methods were chosen to verify the hypothesis, taking into account that the results of the work of other researchers show a variation of the results with the same data depending on the choice of research method. Noteworthy were the results of Spearman's correlation, which indicated three possible investments with the potential to protect capital from the impact of inflation. In further research, the correlation analysis pointed to Bitcoin, and the regression analysis to gold and real estate as inflation hedge assets. It should also be emphasised that although Bitcoin can be considered an inflation hedge, some researchers, including the author of this paper, consider it to be a dangerous investment, as suggestively captured in the title of their paper by Choi and Shin (2022): "Bitcoin: An inflation hedge but not a safe haven."

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Analizy kointegracji i regresji jako alternatywne metody weryfikacji właściwości ochronnych inwestycji zabezpieczających przed inflacją

Streszczenie

Cel: W obliczu rosnącej inflacji różnorodne narzędzia finansowe stają się coraz ważniejsze dla ochrony kapitału przed utratą wartości. Prowadzi to do pytań o to, jaką inwestycję wybrać, aby ochronić kapitał przed utratą wartości. Celem pracy było określenie, czy wybrane kierunki inwestycyjne na polskim rynku kapitałowym mogą chronić kapitał przed utratą wartości związaną z inflacją.

Metodyka: W badaniu wykorzystano analizę kointegracji z wykorzystaniem testu Engle'a-Grangera oraz analizę regresji z wykorzystaniem metody OLS. Badaniem objęto okres od IV kwartału 2008 r. do IV kwartału 2022 r., wykorzystując indeks obligacji TBSP, Bitcoina i złoto, indeks WIG, indeks akcji WIG Nieruchomości oraz hedoniczny indeks cen nieruchomości NBP w siedmiu największych miastach w Polsce. Inwestycje te zostały powiązane ze zharmonizowanym wskaźnikiem inflacji HICP publikowanym przez Europejski Urząd Statystyczny (EUROSTAT).

Wnioski: Analiza ujawniła różne wyniki w zależności od przyjętej metodologii badania. Analiza kointegracji wskazała na Bitcoina jako inwestycję zabezpieczającą przed inflacją, podczas gdy analiza regresji wskazała na złoto i nieruchomości mieszkalne jako inwestycje chroniące przed inflacją.

Implikacje: Badanie umożliwia lepsze zrozumienie złożonej dynamiki związanej z zachowaniem siły nabywczej w okresach wysokiej inflacji.

Oryginalność/wartość: Badanie stanowi istotny wkład w wypełnienie luk na polskim rynku w zakresie analizy możliwości ochrony kapitału przed inflacją. Chociaż badanie koncentrowało się wyłącznie na rynku polskim, temat ten nie był poruszany w okresie niskiej inflacji również w dojrzałych gospodarkach.

Słowa kluczowe: inwestycje, zabezpieczenie przed inflacją, portfel, nieruchomości, Polska