A Work Project, presented as part of the requirements for the Award of a Master's degree in Finance from the Nova School of Business and Economics.

An analysis of the inflation-hedging properties of four different asset classes

Pauline Tsambika Staubert

Work project carried out under the supervision of:

Giorgio Ottonello

16/12/2022

Abstract

Rising inflation rates threaten the purchasing power of investors' assets. Therefore, finding ways to hedge this economic risk would be favorable. This thesis investigates the inflation-hedging capabilities of four traditional asset classes with an analysis mainly based on the Fisher Hypothesis (1930). Its results show that the inflation hedging efficiency is heterogeneous across the considered assets. While REITs and the S&P 500 act as perverse inflation hedges in the short term, they show some hedging capability over a long period. Gold and the GSCI, however, are proven unsuitable to be declared as inflation hedges.

Keywords: inflation-hedging, financial markets, investing, traditional asset classes

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209) .

1 Introduction

Consumer prices in the U.S. are soaring due to inflation at the fastest rate in decades. According to the U.S. Bureau of Labor Statistics (2022a), a forty-year high of 6.6% year-over-year core inflation was measured in September 2022, following a rising price rally in the same year.This price surge started at the beginning of the pandemic when growing demand for consumer products clashed with disrupted supply chains and was strongly enhanced by the invasion of Russia in Ukraine, which specifically impacted energy and food prices. According to Bekaert and Wang (2010), "inflation risk is one of the most important economic risks, faced by consumers and investors alike". Long-term investors aim to retain the purchasing power of their assets while achieving real returns in line with their investment objectives. On the other side, short-term investors who want to sustain their liquidity are pushing to find efficient short-run hedges against inflation. While it is already possible to hedge inflation effectively with financial products, such as inflation-linked bonds and other derivatives, their limited availability and liquidity make them less attractive to investors. Therefore, most investors must remain reliant on the hedging properties of traditional, more accessible asset classes such as stocks or bonds to secure their portfolios. This, however, raises various questions. First, what does preliminary empirical evidence suggest? Which asset classes have the best inflation-hedging properties? Moreover, are they protected from inflation in the short and long run? Finally, can these assets hedge both the expected and the unexpected components of the rate of inflation? Within this paper, I will find answers to all those questions by investigating empirical findings and conducting statistical data analysis. This paper will start off by defining "inflation" and elaborating on its role throughout history. The literature review in the following section creates the theoretical foundation of the subject of "inflation hedging" and describes what prior research suggests about the inflation-hedging capabilities of the observed asset classes. The next section describes the data used and illustrates the methodology applied to conduct the analysis. The analysis results are critically discussed and evaluated in the penultimate section. The conclusion summarizes the most valuable findings and proposes ideas for further research. This thesis's main finding is that the asset classes' inflation hedging capabilities are highly heterogeneous and that none of the analyzed asset classes reliably hedge against short and long term inflation. According to the analysis, gold cannot live up to its name of being a reliable "safe haven" asset during times of heightened inflation. The GSCI is not suitable to be declared as an inflation hedge due to substantial volatility and low average returns. While REITs and the S&P 500 act as perverse inflation hedges in the short term, they show some hedging capability over a long period.

2 Inflation and the value of money over time

The Federal Reserve Bank System (Fed) defines inflation as "the general increase in the overall price level of goods and services in the economy" over time (2022). Federal Reserve policymakers constantly monitor changes in inflation by analyzing various price indices. One of the most widely used measures of inflation and deflation is the Consumer Price Index (CPI), which measures the change in prices paid by U.S. consumers on a monthly basis. Several studies use indices such as the production price index (PPI), wholesale price index (WPI), retail price index (RPI), or GDP deflators to estimate inflation. However, the various forms of the CPI have become the most widely used indicators of inflation. According to Fernando (2022), the CPI is calculated "as a weighted average of prices for a basket of goods and services representative of aggregate U.S. consumer spending" by the Bureau of Labor Statistics (BLS). To calculate the inflation rate from the CPI, the BLS takes the average weighted cost of a basket of goods in a given month and divides it by the same basket's cost of the previous month. When discussing inflation, the FED usually suggests core inflation based on a CPI that excludes food and energy from the basket. Although these items make up a large part of the budget for most households, they tend to be very volatile in price. The Fed generally targets a core inflation rate of 2% since this rate is said to be most consistent with the Federal Reserve's mission for the lowest unemployment and price stability (FED 2020). Once the inflation rate diverges much from this number, the Fed usually becomes active by contracting or expanding the money supply. There have been various aberrations from this target rate in U.S. history (Rouse, Zhang, and Tedeschi 2021). When World War 2 ended, prices jumped over 20% (07.1946 – 10.1948). Shortly after, when the Korean war began, inflation reached 10% (12.1950 - 12.1951). The 1960s and 70s are also referred to as the "Great Inflation" (Kramer 2022). During the so-called late 60s expansion, a booming economy and an increase in the overall price level caused inflation. This was followed by the most prolonged period of increased inflation evoked by two surges in oil prices during the time of the Iranian Revolution and the Iran–Iraq War (Rouse, Zhang, and Tedeschi 2021). During 1989-1991 rising oil prices repeatedly led to a short heightening of inflation when Iraq invaded Kuwait leading to the first Gulf War. Interestingly, during the Financial Crisis of 2008/2009, also referred to as "The Great Recession," the inflation rate rose above the 2% mark and fell drastically from September 2008 to January 2009. Those signs of deflation are commonly considered as far worse than rising inflation. Inflation rates during 2020, the first year of the Covid 19 pandemic, were referred to as the highest rates in decades following a long period of low inflation. Throughout 2022, inflation has been a significant concern in the U.S. and reached a forty-year high of 6.6% year-over-year core inflation in September 2022. When discussing inflation's influence on financial markets, one must emphasize that inflation is not necessarily considered "bad". In fact, inflation is often subdivided into "the good," "the bad," and "the ugly" (Kapurvalapil 2022). Moderate levels of inflation, or in other words, a slowly increasing price level, are generally needed to drive consumption. This level of inflation motivates customers and businesses to continue consumption instead of waiting for prices to lower. Therefore, the so-called “good inflation” is crucial for economic growth (Ross 2022). Souliac, Ahnert & Bauer (2022) refer to “bad inflation” once inflation starts acting as a destructive factor for the economy and demands a more expansive monetary policy. “Bad inflation” turns into “ugly inflation” when central banks start a significant intervention that sends markets into a downward spiral. In this scenario, central banks favor price stability over economic growth and raise interest rates even during times of an uncertain economic outlook. This is often considered the worst-case scenario for financial markets.

3 Inflation Hedging

3.1 Theoretical Foundation

An investment that serves as an inflation hedge should protect from the decreased purchasing power of a currency which decreases in value due to rising prices during an inflationary period over a specific time horizon (Chen, Catalano, and Rathbrun 2022). The hedging capabilities of an asset are defined by the extent to which it can be used to diminish the risk of an investor's real return caused by changes in the level of the prices. E.g., if a stock price increases from 100$ to 110$ within one year, its financial return in nominal terms will be 10%. However, to receive its real return, one must adjust for inflation. For example, if inflation over the same period is at 5%, the investors will end up with an effective return of 5%. The so-called “real return” can be defined as the annual percentage of profit earned on an investment, decreased by inflation. There are several ways to examine the hedging capabilities of a security. Bodie (1976) names two alternative definitions for inflation hedging. Firstly, he concludes that an inflation hedge must ensure that real returns cannot be not lower than zero. Secondly, he states that a securities real return must be independent of the rate of inflation to be identified as an inflation hedge (Bodie 1976). Bodie's second definition goes along with the definition used by Bekaert, Wang & Tille (2010), who state that for securities to be declared as efficient inflation hedges, "their nominal returns must at the very least be positively correlated with inflation". Therefore they suggest the real returns to be independent of the inflation rate. All of those assumptions are partially based on the famous Fisher (1930) hypothesis, commonly used to explain inflation hedging. The hypothesis describes a relationship between asset returns and inflation by expressing nominal returns as the sum of real returns and the inflation rate.

3.2 Empirical Findings by asset class

3.2.1 Equity

One would think equities must be an effective hedge against inflation since they are shares of ownership issued by publicly traded companies. They represent a claim to tangible property and real assets of companies. Therefore, when the overall price level in the economy increases, one would expect stock prices to rise as well due to the intrinsic pricing power of businesses that is reflected in the earnings, which are, in turn, reflected in the company's valuation. If the Fisher Hypothesis holds, which indicates a positive relationship between stock returns and rates of inflation, stocks should move directly with the inflation rate. Prior literature concludes that equities serve as a long-term hedge since average annualized returns beat average annualized inflation over an extended timeframe. However, there is no confirmed positive relationship between equities and inflation over short periods. Many argue that stock returns and inflation are negatively correlated during short periods of high inflation, which undermines the hedging potential of equities during short periods of high inflation. Various researchers, such as Lintner (1975) and Nelson (1976), found stock returns to be negatively correlated with expected, unexpected, and changes in unexpected inflation during the short run. Bodie (1976) not only confirms this belief in his paper, he even suggests that to use common stocks as a hedge against inflation effectively, one has to sell them short. Various reasons serve as an explanation for this finding. In his proxy hypothesis, Fama (1981) discusses that since the stock market always anticipates economic growth, this would mean that if periods with high inflation coincide with low economic growth, the relationship between stock returns would also be perceived as negative. Economic uncertainty also greatly harms the ability of companies to plan, grow, invest, and engage in long-term contracts. This, in turn, accelerates a decrease in future cash flow, which will undermine the company’s profitability. When returning to the first thought of equities representing a claim on real physical assets, intuitively, stock prices should increase when overall prices in the economy soar due to the intrinsic pricing power of businesses which is reflected in the earnings. However, while this might be true for a small number of companies with significant pricing power, most companies can only partially pass on the increased cost of raw materials or cannot do so at all. Those companies will have to deal with lower margins since cost rises while income does not simultaneously. Equities also react to changes in interest rates, which are one of the main tools of the Federal Reserve Bank to target and control inflation. The reason for this is the Taylor Rule, a simple equation that can be used to explain the decisions the Federal Reserve makes concerning its benchmark interest rate based on levels of inflation and economic growth. (Hayes, Kelly, and Clarine 2022) This is done to prevent the economy from overheating. A high inflation rate also has negative tax implications for companies with high Capital Expenditures. Attié and Roache (2009) state that “rising inflation causes firms to report spuriously high profits”, this can be explained by “certain characteristics of the tax code, such as historical cost depreciation of assets and methods of inventory valuation that can increase accounting earnings”. This increase in the firm’s effective tax burden leads to a reduction in real profits. All the reasons above support the assumption that equities might not be a good hedge against inflation, at least not during and around high inflationary times. When talking about equities as an asset class, one must emphasize that the overall market index represented by, e.g., the S&P 500, which may be volatile over the short term, still generated remarkably consistent returns when measured over decades. The average annualized return from 1928 through Dec. 31, 2021, was 11.82%, while from 1960 to 2021, the average inflation rate was 3.8% per year (WorldData 2022). Stock valuations may fluctuate with the day’s economic news, but market indices have significantly outperformed inflation across multiple business cycles. However, even though most investors hold stocks over a long period and therefore do not mind temporary losses, e.g., due to high inflation periods, one must also consider that historical timing matters and that not all investors have a long investment horizon. Therefore, when evaluating the hedging potential of equities, it is also important to focus on short-period hedging capabilities. Overall, the review of prior research leads to the assumption that equities have inferior short-period inflation hedging characteristics. In the long term, however, this asset class appears to be the most suitable for achieving the goal of an above-inflation return.

3.2.2 Gold

The precious metal gold has been owned by people as a store of value and acted as a medium of exchange for thousands of years (Solt and Swanson 1981, 454).To this day, it is being used as a reserve medium by central banks and valued by investors to serve as a diversification benefit. Gold has valuable characteristics such as being durable and relatively easy to transport; most importantly, it is universally accepted and easily authenticated. Those attributes make gold stand out when compared with other multifaceted commodities. According to Ghosh et al. (2001), one can divide the demand for gold into two categories. First, the "use demand" describes gold's various real-world use cases. Not only is gold being used, e.g., in the production of jewelry and coins, but it is also commonly utilized by many industries such as electronics, automotive, and medical technology. The commodity provides tangible value, and unlike fiat money, there is only a limited supply of it. The second category that Ghosh et al. (2001) use to further describe the demand for gold is the “asset demand”. Gold is known to be a popular investment opportunity for various stakeholders such as governments, fund managers as well as individuals. Gold has traditionally been associated with being a very secure asset class, which is especially popular among investors in times of market volatility and uncertainty. There are various reasons which support this assumption. Not only has gold historically shown a low or negative correlation to both stocks and bonds, suggesting that it can serve as a valuable tool for diversification. Gold also obtains a lot of its value from psychology since many investors hold the asset for its store of value function and through being perceived as "rare" due to its limited supply. Therefore, gold has often been described as a "safe haven"[1] during "black swan"[2] events that negatively impact financial markets. However, according to literature and prior research, gold has had a mixed track record serving as an inflation hedge during previous inflationary periods. According to Baker et al. (2022), Gold shows inconsistent return patterns and is extremely sensitive to short-term factors. Ghosh et al. (2001) found that even though the gold price tends to rise at the general rate of inflation over a longer period, it is also characterized by significant short-run volatility. Most literature on this topic confirms a lack of consistent return patterns and finds a disproportionate influence of short-term factors in determining the gold price. Wang et al. (2011) describe the inflation-hedging abilities of gold as not absolute and add that, in its case, the essential keys of inflation-hedging are time and market selection. In summary, according to prior research, gold shows feeble inflation-hedging abilities in the short run but offers at least a partial hedge against inflation during high inflation periods.

3.2.3 Commodities

When talking about commodities, one might initially think of the physical market, which is strongly characterized by local preferences and less standardization. In addition, high transportation and storage costs lead to temporary deviations from the law of one price. However, when mentioning commodities as an asset class, one usually talks about financial

[1] A "safe haven" asset describes a type of investment that is expected to retain or even increase its value during times of market instability. Investors include those assets into their portfolios to limit their exposure to losses in the event of market downturns (Chen and Scott 2021).

[2] Black swan events are unpredictable events that usually imply severe consequences. These kinds of events are negatively impacting financial markets and investments (The investopedia Team 2022).

instruments which offer exposure to commodities in terms of futures, with treasuries (government bonds) as an underlying asset. Most commodities are direct input factors to produce consumer goods and are, therefore, some of the main drivers of inflation rates. Consequently, since commodity futures represent a bet on commodity prices, they are directly linked to components of inflation. With commodity prices often playing a major role in surging inflation trends, one would assume a positive relationship between core inflation and commodities over the short term. Additionally, commodities are said to be uncorrelated with the stock as well as the bond market. Therefore, it would be valuable for investors to diversify by including commodities in their portfolios, especially during turbulent times. This, however, has not been the case according to prior literature. In contrast, commodities' performance has been unpredictable and highly volatile during periods of economic strain in the stock market. Armour (2021) describes that "…the S&P GSCI, a broad index comprising 24 commodities, increased 1.05% while the S&P 500 dropped 21.54%..." in October 1987 and therefore showed hedging potential, on the contrary, "…in 2008 the S&P GSCI dropped 46% while the S&P 500 dropped 37%". He concludes that "commodities may not diversify stock market returns when investors need it most" (Armour 2021). Kat and Oomen (2007) find that some commodities efficiently hedge against changes in purchasing power while others do not. Spierdijk and Umar (2013) establish a significant hedging ability from commodity futures indices, but they emphasize that the hedging capacity demonstrates substantial variation over time. Additionally, they describe that while it is possible to reduce the return variance of a portfolio by diversifying with commodity futures, one incurs a trade-off by diminishing the expected real portfolio return (Spierdijk and Umar 2013). In contrast to many other studies, Gorton & Rouwenhorst (2004) find that extending the observed period leads to higher correlations between commodity futures returns and inflation and a better statistical significance. Commodities are a very diverse asset class, and according to prior literature, some sub-sectors, such as oil and industrial metals, provide good inflation hedges (Baker et al. 2022). However, most studies examining the relationship between commodities and inflation used broad indices such as the S&P Goldman Sachs Commodity Index (GSCI) or the Thomson Reuters/Jefferies CRB index instead of focusing on the individual types of commodities. One can conclude that it is difficult to explain the relationship between commodity returns and inflation in a simple way. Commodities exhibit a rather contrasted behavior. While their correlation with inflation tends to be volatile but mostly positive in the short run, it is said to be primarily negative over the long run. However, according to prior literature, these results vary depending on the type of commodities.

3.2.4 REIT

REITs, or real estate investment trusts, are essentially closed-end investment companies. Those companies own real-estate related assets across a range of property sectors (Park, Mullineaux, and Chew 1990), including e.g., office buildings, apartments, hotels, resorts, warehouses, and mortgages or loans (Investor.gov n.d.). Most REITs are traded on major stock exchanges, allowing individuals to invest in large-scale, income-producing real estate. This enables investors to gain property exposure while keeping their investments liquid. Due to their comparatively low correlation with other asset classes, REITs are said to have the ability to provide diversification benefits within a portfolio. According to Amonhaemanon et al. (2013), Fama and Schwert found changes in inflation to be positively related to changes in the value of private residential real estate during the 1953-1970 period. They describe this with the key fact that investors anticipate a return higher than long-dated treasury bonds due to the liquidity risk associated with the investment in real estate. Several studies, e.g., by Bond & Seiler (1998), confirmed a positive relationship between property prices and inflation and therefore described real estate as a relatively good asset to hedge inflation. Park et al. (1990) found some evidence that REITs are at least partial hedges against anticipated inflation. However, they generally conclude that “REITs tend to behave similarly to equities in general terms of their hedging characteristics." (Park, Mullineaux, and Chew 1990). Various studies confirm that REITs tend to behave like other equities with respect to their inflation-hedging characteristics. As stated above, stock returns are said to be either unrelated or negatively related to inflation and, therefore, inconsistent with the Fisher hypothesis. This leads to the assumption that REITs have a negligible relationship with changes in inflation. However, the REIT market comprises a broad range of subsectors. It is up to further investigation to determine if some of those provide superior inflation-hedging capabilities than the diversified REIT index.

4 Data and Methodology

The main objective of this study is to analyze the inflation hedging potential of stocks, gold, commodities, and real estate investment trust in the U.S., respectively. The study mainly focuses on how those asset classes perform during atypical CPI movements.

4.1 Data

In this section, I will give a detailed overview of the data that has been used to perform my analyses. The analysis is solely based on U.S. data and broadly covers a timeframe from 1957-2022. Throughout the analysis, all asset class returns and CPI inflation are computed as the respective variables' percentage log differences. All calculations are based on year-on-year asset class log returns per month[3] on annual inflation; to put it in another way, I used the annual percentage change per month. For the U.S. inflation, I used the "Consumer Price Index for All Urban Consumers: All Items Less Food & Energy," which is also referred to as "core CPI". According to the FRED website (2022b), this index is "an aggregate of prices paid by urban consumers for a typical basket of goods, excluding food and energy". The index covers about

[3] Whenever I mention "asset class returns" or "returns" in the following analysis, I refer to the 12-month percentage change per month. The same applies for inflation, whenever "inflation" or the "inflation rate" is mentioned, I am talking about annual inflation per month.

88 percent of the U.S. population and uses the Laspeyres formula[4] to average the price changes across categories of items. The monthly data, covering the period 1957-2022 provided by the Bureau of Labor Statistics, is sourced from the FRED website and was accessed through a FRED API (U.S. Bureau of Labor Statistics 2022b). The inflation time series reflects the 12-months changes in the consumer price index and is abbreviated ΔCPI or π. Concerning the expected inflation, I utilized estimates from 1982-2022, provided by the Federal Reserve Bank of Cleveland, which I sourced from the FRED website (Federal Reserve Bank of Cleveland 2022). According to the FRED website (2022), the “estimates are calculated with a model that uses treasury yields, inflation data, inflation swaps, and survey-based measures of inflation expectations“. Regarding equity as one of the observed asset classes, I used the S&P 500, a market-capitalization-weighted index comprising the 500 largest publicly traded U.S. companies.I retrieved daily data from 1957-2022 from Yahoo Finance (2022a). The S&P Goldman Sachs Commodity Index (GSCI) is utilized to analyze commodities. The composite index is broadly diversified throughout the commodity sector and represents an unleveraged, long-term investment in commodity futures. Daily data from 1985-2022 was retrieved from yahoo finance (Yahoo Finance 2022b). The Wilshire US Real Estate Investment Trust Total Market Index, representing real estate investment trust (REIT), was sourced from the FRED website through an API (Wilshire Associates 2022). The daily data covers a period from 1985-2022. As for Gold, I utilized gold prices from the LBMA, which reflect the average monthly gold spot prices according to the afternoon fixing in London quoted in USD per ounce (LBMA 2022).

[4] The Laspeyres price index is a formula used to calculate the consumer price index. In other words, the index measures the price development of a basket of goods and services consumed in the base period. The formula to calculate the index is: $Laspreyes\ Index = \frac{\Sigma\ (Observation\ Price \times Base\ Quantity)}{\Sigma\ (Base\ Price \times Base\ Quantity)}$ (Kumar Srivastav 2022).

4.2 Methodology

To understand the inflation hedging potential of the observed asset classes in the long and short term, I conducted tests based on the entire estimation period, which depends on the length of the available data for the individual asset classes. Additionally, I identified unique periods of interesting CPI movements, which are defined by either abnormally high or low inflation rates (Table 1). To do so, I used empirical findings on historical inflation movements, which have been described in section 2. After conducting various tests on month-to-month CPI changes on month-to-month asset class returns, I received highly volatile results. To remove this unwanted noise in the data, I decided to base my analysis on 12-month changes per month. This was useful for finding long-term trends that were not disguised by occasional fluctuations. The data analysis part was executed in Python.

4.2.1 Descriptive statistics

I started with a brief statistical analysis to understand the main characteristics of the examined asset classes in comparison. I used 1987-2022 as my estimation period to best compare the asset classes since all datasets for the individual asset classes cover this period. Therefore, I plotted the index data of all asset classes against each other and conducted individual plots showing the development of the yearly log returns for each asset class. Additionally, some descriptive statistics concerning yearly and monthly log returns help to understand each asset class's behavior better.

4.2.2 Hedging potential against actual inflation

Subsequently, I focused my analysis on the individual asset classes by putting them in relation to inflation. Therefore, the following steps were conducted for all four asset classes:

Firstly, I calculated the Pearson correlation coefficient, a common scientific measure to estimate the degree of linear dependence between two variables. In other words, the coefficient measures the strength of the relationship between two variables. For the nominal return r_n and inflation π it calculates as:

$$\rho_{r_n,\pi} = \frac{cov(r_n, \pi)}{\sigma_{r_n}\sigma_{\pi}} \tag{1}$$

Coefficient values can range from minus one, suggesting a perfect negative relationship, to plus one, indicating a perfect positive correlation. A correlation coefficient of zero implies that there is no relationship between the respective variables. The correlation coefficient is a scaled version of the β-coefficient estimated in the Fisher equation. One can calculate an ordinary least squares estimator in the ex-post Fisher equation as:

$$\beta = \rho_{r_n,\pi} \frac{\sigma_{r_n}}{\sigma_{\pi}} \tag{2}$$

In the case of high volatility within asset returns relative to inflation volatility, the β adjusts $\rho_{r_n,\pi}$, upwards. The Pearson correlation coefficient is initially used to describe the relationship between the analyzed asset classes' log return and the abbreviated log CPI over the entire timeframe and later facilitated again when analyzing the identified periods of financial instability. In the following, I conducted an Ordinary Least Squares regression based on the Fisher (1930) equation. Irvin Fisher was the first to conclude a hypothetical relationship between asset returns and inflation. According to him, the ex-ante nominal return on an asset can be expressed by the sum of the ex-ante real return and the anticipated inflation rate for the same period. He, therefore, predicts a one-for-one ex-ante relationship between nominal returns and inflation:

$$E(r_n) = \alpha + \beta E(\pi) + \epsilon \tag{3}$$

In this case, $E(r_n)$ stands for the expected nominal rate of return of an asset, α is the constant real return and β describes the asset's correlation with the expected inflation rate $E(\pi)$. Unsystematic forecasting errors are being described by ϵ. Since the required measure of expected inflation is difficult to observe, it is common to use the ex-post version of the fisher equation when conducting a long-term analysis (2):

$$r_n = \alpha + \beta\pi + \epsilon \qquad (4)$$

This equation proposes a one-for-one relationship between realized nominal returns r_n and realized inflation π. This equation is commonly used to conduct empirical tests on the hedging potential of an asset, by regressing nominal asset returns on the rate of inflation. According to Fama & Schwert (1977), the examined asset can be described as a perverse hedge for $\beta < 0$, a partial hedge for $0 < \beta < 1$, and a perfect hedge for $\beta = 1$.

$$r_n = \alpha + \beta\pi_i + \epsilon \qquad (5)$$

$$\boldsymbol{H_0} = \beta(\pi_i) = 0$$

$$\boldsymbol{H_1} = \beta(\pi_i) \neq 0$$

The Null-Hypothesis suggests that there is no significant relationship between inflation, serving as the independent variable, and the respective nominal asset class return, serving as the dependent variable. A coefficient (β) of one indicates a perfect hedge as inflation is transferred one-for-one on the nominal return of the asset while its real return remains unchanged. Additionally, various plots help to illustrate those findings.

4.2.3 Hedging potential against expected and unexpected inflation

Finally, I facilitated a two-part model based on the Fisher extension by Fama and Schwert (1977). While Fisher (1930) only incorporates expected inflation in his original hypothesis, Fama & Schwert (1977) extend the framework by additionally accounting for unexpected inflation:

$$r_n = \alpha + \beta_1 E(\pi) + \beta_2(\pi - \left(E(\pi)\right)) + \epsilon \qquad (6)$$

In this case, $E(\pi)$ describes the expected rate of inflation, therefore, $(\pi - \left(E(\pi)\right)$ denotes the unexpected inflation rate. An asset is defined a hedge against expected inflation if β_1 = 1 and a hedge against unexpected inflation if β_2 = 1. In case of β_1 = β_2= 1, the asset serves as a complete hedge against both types of inflation. During the analysis, I computed the unexpected inflation by subtracting the expected inflation from the actual inflation: $\pi_u = \pi - \pi_e$ (7). In the next step I conducted a multivariate regression based on equation (6):

$$r_n = \alpha + \beta_1 \pi_e + \beta_2 \pi_u + \epsilon \tag{7}$$

$$\boldsymbol{H_0} = \beta_1(\pi_e) = \beta_2(\pi_u) = 0$$

$$\boldsymbol{H_1} = \beta_1(\pi_e) \neq \beta_2(\pi_u) \neq 0$$

This model serves to assess the abilities of the individual asset classes to hedge expected and unexpected inflation. The Pearson Correlation coefficient serves as an additional measure to evaluate this relationship.

5 Results and Discussion

5.1 Summary statistics

Table 2 presents statistics describing the yearly inflation rate from 1958 to 2022. Additionally, Figure 1 illustrates the development of the annual inflation rate over the entire estimation period. Small bars indicate the periods of atypical CPI movements that this analysis focuses on. The red line demonstrates the targeted inflation rate of 2%. The average yearly inflation rate is at 3.56% and, therefore, enormously exceeds the feds' goal of 2%. However, looking at Figure 1, one can immediately see that a couple of periods indicate excessive inflation rates, which are the main reason for the high yearly average. During period 1, the average annual inflation rate was at 5.9%, followed by an even higher average inflation rate of 7.95 % in period 2, with the maximum inflation rate measured at 12.8% in 1981. The rate was estimated at 4.77% in period 3 and 2.34% in period 4. During the great financial crisis in period 5, the inflation rate showed signs of deflation with a minimal value of 1.7%, and average inflation was measured at 1.75%. In period 6, average inflation was 2.6%. Inflation rates reached their maximum for the first time in 30 years during period 7 when average yearly inflation was measured at 6.05%. Table 10 gives an overview of the summary statistics of actual inflation broken down into expected and unexpected inflation according to equation (7). Additionally, Figure 18 illustrates the development of the different inflation rates. The results show that expected inflation is highly correlated with actual inflation ($\rho = 0.82$). Even though unexpected inflation averages at 0.106%, it cannot be underestimated, as unexpected inflation has reached a maximum value of 3.62% in January 2022 and has been noticeably high throughout the year 2022. In the following, a brief statistical analysis will help understand the main characteristics of the examined asset classes. For comparability purposes, a period of 1987-2022 was chosen to cover all asset classes in a standardized manner. Table 3 presents descriptive statistics of all asset classes' yearly log returns and descriptive statistics for the annual inflation rate for the period 1987-2022. Figure 2 gives an overview of the development of the four indices in comparison. Additionally, Figure 3 shows plots of the individual indices next to each other. When looking at Table 3 one can immediately summarize that both the S&P 500 as well as the REITs index produce the best average returns ($\mu_{S\&P\ 500} = 8.5\%, \mu_{REIT} = 8.9\%$)), while the REIT index is more volatile than the S&P 500 ($\sigma_{S\&P\ 500} = 15.9\%,\ \sigma_{REIT} = 20\%$)). During this timeframe, Gold shows the least volatility (σ_{Gold}13.8%), but also only produces a mean return of 4.8% per year. The GSCI shows the worst results throughout the analyzed period. The index strikes out with the highest return volatility (σ_{GSCI} =22.9%) together with the lowest average returns of 3.4%.

5.2 Hedging abilities of the individual asset classes

When assessing the hedging potential of all asset classes during seven pre-selected periods, the results for two of the considered periods[5] stand out since all assets behave similarly during those periods. Therefore, I will start by describing and discussing the results for these two periods.

[5] Later, I will refer to those two periods as "Outlier" periods. Those periods will not be part of the analysis of the individual asset classes, since the results that were obtained during those two periods are discussed in the following paragraph. Therefore, I will sometimes speak about five selected periods when discussing results below.

All relevant results for this section are summarized in Table 5 and illustrated in Figure 5. Firstly, during the observed Period 5, the financial crisis, inflation fell from about 2.4% to 1.7%, indicating deflationary behavior. During this period, all the observed asset classes were strongly positively correlated with inflation, suggesting a very negative inflation hedging potential throughout the asset classes. The Pearson correlation coefficient measuring the strength of the relationship between individual monthly asset classes' log returns and inflation during this period ranges from 0.85 (for Gold) to 0.95 (for GSCI). This finding goes along with highly negative annualized returns throughout the analyzed period; the lowest returns were achieved by REIT (-32.3%) and the S&P 500 (-24.8%). Commodities indicate a more minor but significant annualized loss of -16.1% during this period. The only asset class that provided hedging potential during this period was gold, which achieved a remarkable annualized return of 18.6%. Another period that requires further explanation is the period of heightened inflation during the covid-crisis – Period 6. Clarida, Duygan-Bump & Scotti write that "the COVID-19 pandemic and the mitigation efforts put in place to contain it delivered the most severe blow to the U.S. economy since the Great Depression" (2021). The government and the federal reserve bank took various measures, such as multiple relief bills and stimulus packages, to boost the economy, which also led to a rise in inflation. As a result, the annualized inflation of 3.39% during this period exceeds the 2% goal of the fed. However, in this case, the heightened inflation rate can still be counted as "good inflation" since no harmful measures were taken to lower the rate; instead, the fed deliberately took higher inflation into account. During this period, all observed asset classes produced annualized returns that beat their average annualized returns. During those two "outlier" periods, the individual asset classes showed very similar behavior, which can be explained by some of the factors named above; the following part will further describe the hedging potential of the individual asset classes during the other periods of heightened inflation.

5.2.1 Equity

The estimation period to assess the inflation-hedging abilities of the S&P 500 was from 1957-2022. The index multiplied by a factor of 85 over the observed period and produced a total annualized return of 7.12%. In comparison, the CPI only multiplied by a factor of 9.2, producing a total annualized inflation of 3.65%. Knowing this, one can already take away that over a long period, the S&P outperforms inflation and therefore fulfills the main criteria to be a long-term hedge. However, the Pearson correlation coefficient between yearly S&P 500 returns and the yearly inflation rate is estimated at -0.15, suggesting a negative relationship. This finding is confirmed by the very noisy scatterplot (Figure 7) and the simple regression analysis (Table 6). The regression returns an inflation coefficient of -0.99, which is statistically significant since the P-Value of 0.000 is below any common significance level (1%, 5%, 10%). This would mean a one percentage point increase in the annual U.S. inflation rate leading to a decrease of about one percentage point in S&P 500 returns. Therefore, the Null-Hypothesis, that there is no significant relationship between inflation and the S&P 500, cannot be rejected. However, the low R^2 of 0.023 indicates that the model's explanatory power is insignificantly low. In the following, the inflation hedging potential of the S&P 500 was tested during periods of atypical CPI movements. Overall, the inflation-hedging abilities of the S&P 500 appear to be strongly nonlinear. The S&P 500 shows either a strongly negative correlation (e.g., in period 1, ($\rho = -0.5$), period 3 ($\rho = -0.85$) and 4 ($\rho = -0.67$)) or a correlation close to zero (period 2 ($\rho = 0.06$), period 7 ($\rho = -0.09$)). This goes along with negative annualized real returns throughout 4/5 of the selected periods. Even though the S&P 500 produced a positive annualized return of 12 during the third period, when considering the strong negative correlation with inflation illustrated in Figures 7 and 8, one can conclude that the S&P 500 does not serve as an inflation hedge during this period. According to Table 11, the S&P 500 has a low positive correlation with expected inflation ($\pi_e = 0.09$), but they are also negatively related to unexpected inflation

(π_u=-0.24). The multivariate regression based on equation (8) cannot confirm those results since the results are insignificant, and the low R^2=0.06 describes a weak explanatory power of the model. Overall, those findings of the negative relationship between equity returns and inflation expectations are in line with the results from Linter (1975), Bodie (1976), and Fama and Schwert (1977). This contradicts the traditional view that stocks represent the ownership of physical assets and should therefore offer perfect hedging abilities against inflation.

5.2.2 Gold

The estimation period to assess the inflation-hedging abilities of Gold was from 1969-2022. The index multiplied by a factor of 37.4 over the observed period and therefore produced a total annualized return of 7.05%. In comparison, the CPI only multiplied by a factor of 6.2, producing a total annualized inflation of 3.65%. This result indicates some inflation-hedging capabilities of gold over the longer term. However, Table 2, which covers approximately the second half of the observation period, shows low mean ($\mu = 4.8\%$) and median (3.5%) returns. Over the entire estimation period, a low positive correlation of $\rho = 0.14$ between the yearly inflation rate and yearly gold returns (Table 4), indicates that gold might be a better inflation hedge than, e.g., equity (the S&P 500). This is confirmed by the OLS results between Gold and Inflation over the entire period (Table 7). The simple regression returns a ß-coefficient of 1.16, which is close to one. According to the Fisher Hypothesis, a ß-coefficient of 1 describes a perfect hedge. However, even though this coefficient is significant (P>|t|=0.001), the low R^2 of 0.018 indicates a low explanatory power of the model. This general finding is illustrated in the scatterplot in Figure 4, where one can obtain a slight positive relationship between Gold and Inflation but also much noise. When looking at the scatterplots in Figure 10 to assess the hedging abilities of Gold throughout the selected periods, one can see that it is not easy to conclude a recurrent pattern. This is confirmed by the Pearson correlation results between gold and Inflation, which vary between -0.16 to 0.38 (Table 5). Overall, the OLS regression results for the respective periods are insignificant (Table 7). Additionally, negative annualized returns during 4/5 of those periods of high inflation undermine the ability of gold to hedge inflation. When looking at the graphs in Figure 11 one can, however, make the interesting observation that gold returns do seem to move quite similarly to inflation during some of the observed periods. E.g., in period 2, the correlation coefficient was estimated as ρ=0.09, though when looking at Figure 11, one can see both graphs developing in a very similar way, however with a little time delay. This finding is confirmed by annualized returns of gold of 17.43% during this period of high inflation ($\pi_{(\text{Period 2})}$ =8.38%). This raises the question if the Pearson correlation coefficient is an adequate measure to estimate the hedging ability of an asset over a longer term. When including the results of the inflation hedging abilities of the individual asset classes with inflation broken down into expected and unexpected inflation (Table 11), one can make an interesting observation. From 1982 to 2022 gold was negatively correlated with all three types of inflation ($\pi = -0.38, \pi_e = -0.35,\ \pi_u = -0.13$). Those results show much volatility in the inflation-hedging abilities of gold and generally undermine its ability to serve as an inflation hedge. Overall, my findings confirm a lack of consistent return patterns, making it an unstable hedge throughout periods of rising inflation.

5.2.3 Commodities

The inflation-hedging abilities of the GSCI, representing the asset class "commodities", are analyzed over an estimation period from 1985-2022. Throughout this period, the GSCI produced an annualized return of 3.05% (Table 5), which is only marginally higher than the total annualized inflation over the same period (2.75%). This performance can be confirmed by a very low mean annual return per month of 3.4% from 1987 to 2022, which is also only marginally higher than the mean inflation rate of 2.7% throughout the respective period (Table 3). The fact that the real returns are close to zero over the observed period already suggests inferior hedging abilities of the GSCI. Annual returns per month and inflation have a small positive correlation of $\rho_{r_n,\pi}$=0.11 over the entire estimation period (Table 4). This cannot be confirmed by the OLS regression since the estimated results are not significant (Table 8). The GSCI shows no signs of hedging potential throughout the individual periods. On the contrary, the Pearson correlation coefficient is negative and ranges between -0.002 to -0.64, and returns are negative during periods 3, 4, and 7 (Table 5). In Table 8, the only OLS regression with significant results and a positive R^2(0.416) is the regression for period 4, which returns a strongly negative ß-coefficient of -77.78. When breaking down actual inflation into expected and unexpected inflation (Table 11), one can observe that the GSCI has a low positive correlation with expected inflation ($\pi_e = 0.197$) and a negative correlation with unexpected inflation ($\pi_u = -0.1$). Overall, one can see substantial variation over time σ=22.9% (Table 3) along with low average returns and even worse returns during high inflation periods. Not being able to assess the first three periods due to a lack of available data makes it difficult to conclude the hedging abilities of this asset class compared to the others. However, it is interesting to observe a negative correlation between the asset class and inflation in period 7. One would anticipate that commodities should be a suitable asset class to hedge inflation that is mainly driven by the rise in energy prices. This observation encourages to conduct further analyses that investigate the hedging abilities of individual commodities instead of using a broad index. According to this analysis, this index is an inferior hedge during long- and short-term.

5.2.4 REIT

The inflation-hedging abilities of REITs were assessed over the period from 1978-2022. The index multiplied by a factor of 94.1 over the observed period and therefore produced a total annualized return of 10.97%. In comparison, the CPI only multiplied by a factor of 3.3, producing a total annualized inflation of 3.41%. Those results indicate that REITs can hedge inflation over a long period. In addition, compared to all other analyzed asset classes, REITs have the strongest relationship with inflation, as described by the Pearson correlation coefficient

(Table 4), which is 0.27 for the yearly differences. This is confirmed by the OLS results between REIT and Inflation over the entire period (Table 9). The simple regression returns a ß-coefficient of 1.40, which is positive and close to one. However, even though this coefficient is significant (P>|t|=0.000), the low R^2 of 0.027 indicates a low explanatory power of the model. When looking at the Scatterplot "REIT vs. CPI" in Figure 4, one can observe much noise within the returns during low inflation periods (around 2% inflation). However, when looking at extreme inflation values above 8%, one can see that REIT returns are overall positive, and the slight positive correlation gets obvious. This finding can, however, not be confirmed when analyzing the individual periods of high inflation. During period 3 and period 7, when inflation was over 4.5%, ($\pi_{(\text{Period 3})}$=4.74% and $\pi_{(\text{Period 7})}$=4.6%, Table 5), REITs were negatively correlated with inflation ($\rho_{(\text{Period 3})}$=-0.82 and $\rho_{(\text{Period 7})}$=-0.06) and produced negative annualized returns. Even though REITs show some hedging potential during period 4, during which the Pearson correlation coefficient was measured at $\rho_{(\text{Period 4})}$=0.76, and REITs produced an annualized return of 20.9%, it is not possible to derive a consistent pattern in the behavior of REIT returns. One can obtain a similar behavior to Equities (S&P 500) concerning REITs' relationship with expected and unexpected inflation. According to Table 11, REITs have a low positive correlation with expected inflation ($\pi_e = 0.11$), but they are also negatively related to unexpected inflation (π_u=-0.19). This is confirmed by the multivariate regression based on equation (8), which returns a positive β_1=1.49 and a negative β_2=-4.61. Both coefficients are significant at the 5% level; however, the low R^2=0.046 undermines the model's explanatory power. Overall, one can conclude that comparable to the S&P 500; the analyzed broad REIT index provides some hedging capability against expected inflation; however, it acts as a perverse hedge against unexpected inflation. Although this analysis shows that a broad REIT Index does not function as an efficient inflation hedge, it is up to further investigation to determine if individual REITs have return characteristics that are positively related to inflation.

6 Summary and Conclusion

The results of this thesis show that inflation hedging tendencies of assets are heterogeneous across the considered assets. While equities have inferior short-period inflation hedging characteristics in the long term, this asset class seems to be the best to achieve an objective of return above inflation. Against the common perception of gold serving as a "safe haven" asset during "black swan" events, my findings confirm a lack of consistent return patterns and significant short-run volatility. Even though gold shows partial hedging abilities during periods of crisis, it cannot be declared a reliable asset class to hedge inflation. The GSCI, which is used to analyze the hedging capabilities of commodities, shows substantial variation over time, going along with low average returns, and its correlation with inflation tends to be volatile. With a total annualized return that is only marginally higher than the total annualized of inflation over the same period going along with a high standard deviation, this index proves to be an inferior hedge during long and short term. The analyzed broad REIT index provides some hedging capability against expected inflation; however, it acts as a perverse hedge against unexpected inflation. Generally, the performance of this index shows a lot of similarity with the S&P 500 over the observed period. Of the examined assets, no single one hedges inflation perfectly. However, the analysis shows that some assets show hedging abilities (e.g., REITs have the strongest positive correlation out of all the assessed asset classes). To investigate where exactly these inflation hedging attributes lie, one must dig deeper into the individual components of the analyzed indices. For future research, it, therefore, makes sense to focus on each asset class individually. E.g., concerning equities, one could analyze companies from different sectors or regions or identify companies with pricing power during high inflationary times. Additionally, it makes sense to extend this research and include other asset classes, such as Fixed Income. Overall, one can conclude that inflation hedging becomes easier for long investment horizons, and hedging inflation proves more difficult in practice than conventional wisdom suggests.

References

Amonhaemanon, Dalina, Marc Ceuster, Jan Annaert, and Hau Le Long. 2013. "The Inflation-Hedging Ability of Real Estate Evidence in Thailand: 1987-2011." *Procedia Economics and Finance* 5 (December): 40–49. https://doi.org/10.1016/S2212-5671(13)00007-5.

Armour, Bryan. 2021. "Commodities: Inflation Hedge or Fool's Gold?" *Morningstar*, December 14, 2021. https://www.morningstar.com/articles/1070971/commodities-inflation-hedge-or-fools-gold.

Attié, Alexander P., and Shaun K. Roache. 2009. "Inflation Hedging for Long-Term Investors." Working Paper. International Monetary Fund.

Baker, Alastair, Philip Chandler, Joseph McGratty, Lesley-Ann Morgan, Matthias Scheiber, Simon Stevenson, and Neil Walton. 2022. "Investment Perspectives - What Are the Inflation Beating Asset Classes?" Schroder. https://prod.schroders.com/en/sysglobalassets/staticfiles/schroders/sites/americas/canada/documents/investment-perspective-what-are-the-inflation-beating-asset-classes.pdf.

Bekaert, Geert, Xiaozheng Wang, and Cédric Tille. 2010. "Inflation Risk and the Inflation Risk Premium [with Discussion]." *Economic Policy* 25 (64): 755–806.

Bodie, Zvi. 1976. "Common Stocks as a Hedge Against Inflation." *The Journal of Finance* 31 (2): 459–70. https://doi.org/10.2307/2326617.

Bond, Michael, and Michael Seiler. 1998. "Real Estate Returns and Inflation: An Added Variable Approach." *Journal of Real Estate Research* 15 (3): 327–38. https://doi.org/10.1080/10835547.1998.12090932.

Chen, James, Thomas J. Catalano, and Daniel Rathbrun. 2022. "Inflation Hedge." Investopedia. April 1, 2022. https://www.investopedia.com/terms/i/inflation-hedge.asp.

Chen, James, and Gordon Scott. 2021. "Safe Haven: Definition and Examples in Investing." Investopedia. June 30, 2021. https://www.investopedia.com/terms/s/safe-haven.asp.

Clarida, Richard H., Burcu Duygan-Bump, and Chiara Scotti. 2021. "The COVID-19 Crisis and the Federal Reserve's Policy Response*." Finance and Economics Discussion Series 2021-035. Federal Reserve Board. https://www.federalreserve.gov/econres/feds/files/2021035pap.pdf.

Fama, Eugene F. 1981. "Stock Returns, Real Activity, Inflation, and Money." *The American Economic Review* 71 (4): 545–65.

Fama, Eugene F., and G.William Schwert. 1977. "Asset Returns and Inflation." *Journal of Financial Economics* 5 (2): 115–46. https://doi.org/10.1016/0304-405X(77)90014-9.

FED. 2020. "Why Does the Federal Reserve Aim for Inflation of 2 Percent over the Longer Run?" Board of Governors of the Federal Reserve System. August 27, 2020. https://www.federalreserve.gov/faqs/economy_14400.htm.

———. 2022. "What Is Inflation and How Does the Federal Reserve Evaluate Changes in the Rate of Inflation?" 2022. https://www.federalreserve.gov/faqs/economy_14419.htm#:~:text=Inflation%20is%20the%20increase%20in,and%20services%20in%20the%20economy.

Federal Reserve Bank of Cleveland. 2022. "1-Year Expected Inflation [EXPINF1YR]." FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXPINF1YR.

Fernando, Jason. 2022. "Consumer Price Index (CPI) Explained: What It Is and How It's Used." Investopedia. October 18, 2022. https://www.investopedia.com/terms/c/consumerpriceindex.asp.

Fisher, R. A. 1930. "Inverse Probability." *Mathematical Proceedings of the Cambridge Philosophical Society* 26 (4): 528–35. https://doi.org/10.1017/S0305004100016297.

Ghosh, Dipak, Eric Levin, Peter Macmillan, and Robert Wright. 2001. "'Gold as an Inflation Hedge?'" *Studies in Economics and Finance* 22 (January). https://doi.org/10.1108/eb043380.

Gorton, Gary, and K. Rouwenhorst. 2004. “Facts and Fantasies about Commodity Futures.” *Financial Analysts Journal* 62 (July). https://doi.org/10.2469/faj.v62.n2.4083.

Hayes, Adam, Robert C. Kelly, and Skylar Clarine. 2022. “Taylor Rule.” Investopedia. June 24, 2022. https://www.investopedia.com/terms/t/taylorsrule.asp.

Investor.gov. n.d. “Real Estate Investment Trusts (REITs).” Investor.Gov. Accessed November 11, 2022. https://www.investor.gov/introduction-investing/investing-basics/investment-products/real-estate-investment-trusts-reits.

Kapurvalapil, Sajit. 2022. “The Myth Of Stocks As An Inflation Hedge.” Seeking Alpha. April 18, 2022. https://seekingalpha.com/article/4501976-the-myth-of-stocks-as-an-inflation-hedge.

Kat, Harry M., and Roel C.A. Oomen. 2007. “What Every Investor Should Know About Commodities, Part I.” *Journal of Investment Management* 5 (1). https://ssrn.com/abstract=972165.

Kramer, Leslie. 2022. “How the Great Inflation of the 1970s Happened.” Investopedia. May 26, 2022. https://www.investopedia.com/articles/economics/09/1970s-great-inflation.asp.

Kumar Srivastav, Ashish. 2022. “What Is the Laspeyres Price Index?” WallStreetMojo. 2022. https://www.wallstreetmojo.com/laspeyres-index/.

LBMA. 2022. “LBMA Precious Metal Prices - Gold Price.” London Bullion Market. https://www.lbma.org.uk/prices-and-data/precious-metal-prices#/.

Lintner, John. 1975. “Inflation and Security Returns.” *The Journal of Finance* 30 (2): 259–80. https://doi.org/10.2307/2978713.

Nelson, Charles R. 1976. “Inflation and Rates of Return on Common Stocks.” *The Journal of Finance* 31 (2): 471–83. https://doi.org/10.2307/2326618.

Park, Jeong Yun, Donald J. Mullineaux, and It-Keong Chew. 1990. “Are REITs Inflation

Hedges?” *The Journal of Real Estate Finance and Economics* 3 (1): 91–103. https://doi.org/10.1007/BF00153708.

Ross, Sean. 2022. “When Is Inflation Good for the Economy?” Investopedia. January 6, 2022. https://www.investopedia.com/ask/answers/111414/how-can-inflation-be-good-economy.asp.

Rouse, Cecilia, Jeffery Zhang, and Ernie Tedeschi. 2021. “Historical Parallels to Today’s Inflationary Episode.” The White House. June 7, 2021. https://www.whitehouse.gov/cea/written-materials/2021/07/06/historical-parallels-to-todays-inflationary-episode/.

Solt, Michael E., and Paul J. Swanson. 1981. “On the Efficiency of the Markets for Gold and Silver.” *The Journal of Business* 54 (3): 454.

Souliac, Olivier, Lukas Ahnert, and Frederike Bauer. 2022. “Three Tales of Inflation: The Good, the Bad and the Ugly.” DWS. https://etf.dws.com/globalassets/_-shared/pdfs/miscellaneous/3.6376_factsheet_inflation_20220202_03.pdf?v=-1983075032.

Spierdijk, Laura, and Zaghum Umar. 2013. “Are Commodity Futures a Good Hedge Against Inflation?” 3 (April). https://doi.org/10.2139/ssrn.1730243.

The investopedia Team. 2022. “Black Swan in the Stock Market: What Is It, With Examples and History.” Investopedia. July 6, 2022. https://www.investopedia.com/terms/b/blackswan.asp.

U.S. Bureau of Labor Statistics. 2022a. “United States Core Inflation Rate.” Trading Economics. https://tradingeconomics.com/united-states/core-inflation-rate.

———. 2022b. “Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average [CPILFESL].” FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/CPILFESL.

Wang, Kuan-Min, Yuan-Ming Lee, and Thanh-Binh Nguyen Thi. 2011. “Time and Place Where Gold Acts as an Inflation Hedge: An Application of Long-Run and Short-Run Threshold Model.” *Economic Modelling* 28 (3): 806–19. https://doi.org/10.1016/j.econmod.2010.10.008.

Wilshire Associates. 2022. “Wilshire US Real Estate Investment Trust Total Market Index (Wilshire US REIT) [WILLREITIND].” FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/WILLREITIND.

WorldData. 2022. “Inflation Rates in the United States.” Worlddata.Info. 2022. https://www.worlddata.info/america/usa/inflation-rates.php#:~:text=During%20the%20observation%20period%20from,year%20inflation%20rate%20was%208.2%25.

Yahoo Finance. 2022a. “S&P 500 (^GSPC).” https://finance.yahoo.com/quote/%5EGSPC?p=%5EGSPC.

———. 2022b. “S&P-GSCI Commodity Index Future (GD=F).” https://finance.yahoo.com/quote/GD=F?p=GD=F&.tsrc=fin-srch.

Appendix

Tables

Table 1: Periods of interesting CPI movement

This table gives an overview of the identified periods of interesting CPI movements. The classification is based on empirical findings that are discussed and cited in chapter 2. Additionally Figure 1 illustrates the inflation movements throughout these seven periods.
* This crisis is still ongoing at the time of the creation of this thesis, however data for this thesis ends in November 2022

		Start Date	End Date
Period 1	*Late 1960s expansion*	March 1969	January 1971
Period 2	*1970s Oil shocks*	April 1973	October 1982
Period 3	*Iraq invading Kuwait*	April 1989	May 1991
Period 4	*Dotcom Bubble*	December 1999	December 2001
Period 5	*Financial Crisis*	December 2007	June 2009
Period 6	*Covid Crisis*	January 2020	December 2021
Period 7	*Russia invading Ukraine*	February 2022	November 2022*

Table 2: Summary statistics of Inflation (π)

This table reports the main summary statistics of inflation from 1957 to 2022.

Annual Δ per month (1957-2022)	π
mean	3.56 %
median	2.63 %
std	2.38 %
skew	1.56
kurt	2.18
min	0.6 %
max	12.76 %
annualized	3.65 %

Table 3: Summary statistics of all asset class returns (1987-2022)

This table reports summary statistics concerning all four asst classes and the inflation rate over the period of 1987 to 2022. This period was chosen since there is sufficient data to cover it, which leads to better comparability.

Annual Δ per month	π	S&P 500	Gold	REIT	GSCI
mean	2.7 %	8.5 %	4.8 %	8.9 %	3.4 %
median	2.3 %	10.9 %	3.5 %	10.8 %	2.7 %
std	1.1 %	15.9 %	13.8 %	20 %	22.9 %
skew	1.08	-1.242	0.219	-1.51	-0.315
kurt	0.676	2.647	-0.301	6.304	0.560
min	0.6 %	-59.6 %	-32.1 %	-99.9%	-70.4 %
max	6.4 %	48.7 %	47.1 %	77.4 %	67.9 %

Table 4: Correlation of each asset class with the inflation rate

This table consolidates the Pearson correlation coefficients based on Equation (1) between inflation the inflation rate and the individual asst class returns.

	S&P 500 (1957-2022)	Gold (1969-2022)	GSCI (1985-2022)	REIT (1978-2022)
$\rho_{r_n,\pi}$ (Yearly Δ)	-0.14	0.14	0.08	0.27
$\rho_{r_n,\pi}$ (Annual Δ per month)	-0.15	0.13	0.11	0.16

Table 5: Pearson correlation coefficient and annualized returns over 7 periods

This table consolidates summary statistics on the Pearson correlation coefficient between annual returns per month of the different asset classes and the inflation rate over the seven observed periods. Additionally, a total value is calculated for each asset class depending on their individual observation horizon.
* For REIT Period 2 was only covered from 1979 to 1982 therefore the results are not suitable for comparison purposes.

		Total	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
CPI (1957-2022)	μ_π	3.65%	5.78%	8.38 %	4.74%	2.57%	1.75%	3.4%	4.6%
S&P 500 (1957-2022)	$\rho_{r_n,\pi}$	-0.15	-0.5	0.06	-0.85	-0.673	0.9	0.64	-0.09
	μ_{r_n}	7.12%	-3.22%	0.9%	12.45%	-9.35%	-24.8%	18.19%	-28.93%
Gold (1969-2022)	$\rho_{r_n,\pi}$	0.14	-0.05	0.09	0.38	-0.16	0.85	-0.87	0.08
	μ_{r_n}	7.05%	-7.1%	17.43%	-3.36%	-1.2%	10.86%	6.99%	-9.97%
GSCI (1985-2022)	$\rho_{r_n,\pi}$	0.07	-	-	-0.002	-0.64	0.95	0.79	-0.38
	μ_{r_n}	3.05%	-	-	0.0%	-5.5%	-13.6%	9.32%	-4.0 %
REIT (1978-2022)	$\rho_{r_n,\pi}$	0.27	-	0.52*	-0.82	0.76	0.87	0.88	-0.06
	μ_{r_n}	10.97%	-	22.45%*	-1.3%	20,9%	-32.3%	10.4%	-30.6%

Table 6: Simple Regression - S&P 500 returns

This table shows the Ordinary Least Squares regression results between S&P 500 returns and inflation based on Equation (5). The t-statistics are given in parentheses and ***, **,** and *** describe the significance at the 10%, 5%, and 1% levels, respectively.

	Full period	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
mean	0.07	-0.09	0.00	0.11	-0.03	-0.26	0.19	-0.02
median	0.10	-0.09	0.02	0.13	-0.03	-0.16	0.18	-0.02
std	0.15	0.11	0.16	0.12	0.16	0.23	0.14	0.13
skew	-0.90	-0.04	-0.56	-0.49	-0.32	-0.17	-0.23	0.29
kurt	1.63	-0.52	0.42	-0.48	-1.28	-1.67	0.48	-1.10
min	-0.60	-0.30	-0.53	-0.11	-0.32	-0.60	-0.15	-0.19
max	0.49	0.10	0.29	0.31	0.18	0.06	0.49	0.19
No. Observations	777	23	115	26	25	19	24	9
R-squared	0.02	0.25	0.00	0.73	0.45	0.82	0.41	0.00
R-squared adj	0.02	0.22	0.00	0.72	0.43	0.81	0.38	-0.14
Constant	0.11***	1.15**	-0.03	1.23***	1.23***	-1.74***	0.02	-0.21
t-stat	(10.71)	(2.46)	(-0.58)	(8.74)	(4.23)	(-10.19)	(0.32)	(-0.17)
Coefficient	-0.99***	-21.10**	0.44	-23.56***	-50.73***	69.85***	6.71***	3.17
t-stat	(-4.3)	(-2.66)	(0.69)	(-8.0)	(-4.37)	(8.75)	(3.91)	(0.16)
NOTE:						*p < 0.1	**p < 0.05	***p < 0.01

Table 7: Simple Regression - Gold returns

This table shows the Ordinary Least Squares regression results between gold returns and inflation based on Equation (5). The t-statistics are given in parentheses and ***, **,** and *** describe the significance at the 10%, 5%, and 1% levels, respectively.

	Full period	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
mean	0.07	-0.06	0.18	-0.06	-0.01	0.16	0.13	0.01
median	0.05	-0.07	0.22	-0.04	-0.01	0.15	0.18	0.00
std	0.22	0.11	0.37	0.08	0.06	0.16	0.13	0.06
skew	0.86	0.13	0.04	-0.11	-0.25	0.02	-0.47	0.88
kurt	1.93	-1.61	-0.87	-0.73	-0.48	-1.73	-1.30	-0.10
min	-0.45	-0.21	-0.45	-0.21	-0.14	-0.06	-0.10	-0.07
max	1.09	0.13	1.09	0.08	0.09	0.39	0.29	0.13
No. Observations	643.00	22.00	115.00	26.00	25.00	19.00	24.00	9.00
R-squared	0.02	0.00	0.01	0.15	0.03	0.72	0.76	0.00
R-squared adj	0.02	-0.05	0.00	0.11	-0.02	0.70	0.75	-0.14
Constant	0.03	0.08	0.06	-0.40**	0.11	-0.80***	0.35***	-0.06
t-stat	(1.66)	(0.13)	(0.51)	(-2.35)	(0.68)	(-5.46)	(11.89)	(-0.10)
Coefficient	1.16**	-2.41	1.50	7.23*	-4.81	44.93***	-8.36***	1.14
t-stat	(3.39)	(-0.23)	(1.0)	(2.02)	(-0.78)	(6.59)	(-8.36)	(0.11)
NOTE:						*p < 0.1	**p < 0.05	***p < 0.01

Table 8: Simple Regression - GSCI returns

This table shows the Ordinary Least Squares regression results between GSCI returns and inflation based on Equation (5). The t-statistics are given in parentheses and ***, **,** and *** describe the significance at the 10%, 5%, and 1% levels, respectively.

	Full period	Period 3	Period 4	Period 5	Period 6	Period 7
mean	0.03	0.09	0.14	-0.02	0.10	0.31
median	0.02	0.08	0.24	0.22	0.03	0.36
std	0.23	0.09	0.26	0.48	0.37	0.12
skew	-0.28	0.68	-0.59	-0.32	-0.06	-0.94
kurt	0.58	0.01	-0.66	-1.85	-1.08	-0.12
min	-0.70	-0.03	-0.39	-0.70	-0.58	0.08
max	0.68	0.30	0.53	0.58	0.68	0.42
No. Observations	453.00	26.00	25.00	19.00	24.00	9.00
R-squared	0.01	0.00	0.42	0.91	0.64	0.14
R-squared adj	0.01	-0.04	0.39	0.90	0.62	0.02
Constant	-0.03	0.09	2.07***	-3.27***	-0.47***	1.44
t-stat	(-0.96)	(0.44)	(4.32)	(-12.83)	(-4.58)	(1.37)
Coefficient	2.10**	-0.06	-77.78***	153.34***	22.20***	-18.65
t-stat	(2.27)	(-0.02)	(-4.05)	(12.88)	(6.25)	(-1.08)
NOTE:				*p < 0.1	**p < 0.05	***p < 0.01

Table 9: Simple Regression – REIT

This table shows the Ordinary Least Squares regression results between REIT returns and inflation based on Equation (5). The t-statistics are given in parentheses and ***, **,** and *** describe the significance at the 10%, 5%, and 1% levels, respectively.

	Full period	Period 3	Period 4	Period 5	Period 6	Period 7
mean	0.11	-0.06	0.14	-0.41	0.08	0.05
median	0.12	-0.03	0.16	-0.25	0.04	0.02
std	0.20	0.14	0.10	0.32	0.23	0.18
skew	-1.47	-0.81	-0.46	-0.68	0.07	0.00
kurt	6.16	-0.54	-0.99	-1.14	-1.64	-1.57
min	-1.00	-0.34	-0.07	-1.00	-0.29	-0.21
max	0.77	0.10	0.28	-0.06	0.43	0.28
No. Observations	525.00	26.00	25.00	19.00	24.00	9.00
R-squared	0.03	0.68	0.58	0.76	0.78	0.00
R-squared adj	0.02	0.66	0.56	0.75	0.77	-0.14
Constant	0.06***	1.19***	-0.78***	-2.42***	-0.31***	0.29
t-stat	(4.18)	(6.71)	(-4.78)	(-8.74)	(-6.21)	(0.18)
Coefficient	1.40***	-26.14***	36.68***	94.58***	15.12***	-4.02
t-stat	(3.79)	(-7.08)	(5.64)	(7.33)	(8.76)	(-0.15)
NOTE:				*p < 0.1	**p < 0.05	***p < 0.01

Table 10: Summary statistics on actual (π), expected (π_e) & unexpected (π_u) inflation

This table shows the summary statistics on the actual inflation rate (π), the expected inflation rate (π_e) and the unexpected inflation rate (π_u) from 1982-2022. The unexpected inflation rate was calculated through equation (7).

(1982-2022)	**Actual Inflation (π)**	**Expected Inflation (π_e)**	**Unexpected Inflation (π_u)**
mean	2.899 %	2.793 %	0.106 %
median	2.407 %	2.685 %	0.149 %
std	0.014	0.012	0.008
max	8.847 %	6.432 %	3.623 %
min	0.601 %	-0.048 %	-2.149 %

Table 11: Pearson correlation coefficient between asset classes and actual (π), expected (π_e) & unexpected (π_u) inflation

This table shows the Pearson correlation coefficients between the individual asset classes annual returns per month and the actual inflation rate (π), the expected inflation rate (π_e) and the unexpected inflation rate (π_u) from 1982-2022.

$\rho_{r_n,\pi}$ (1982-2022)	**Actual Inflation (π)**	**Expected Inflation (π_e)**	**Unexpected Inflation (π_u)**
S&P 500	-0.06	0.09	-0.24
Gold	0.38	-0.35	-0.13
GSCI	0.106	0.197	-0.1
REIT	-0.016	0.109	-0.19

Table 12: Multivariate Regression with expected and unexpected inflation

This table shows the regression results of the multivariate regression based on equation (8). The estimation period was from 1982-2022. The t-statistics are given in parentheses and ***, **,** and *** describe the significance at the 10%, 5%, and 1% levels, respectively.

	Full Period	**Period 3**	**Period 4**	**Period 5**	**Period 6**	**Period 7**
S&P 500						
No. Observations	490	26	25	19	24	9
R-squared	0.06	0.92	0.68	0.83	0.56	0.12
R-squared adj	0.06	0.92	0.65	0.81	0.52	-0.18
Constant (α)	0.07***	1.74***	0.11	-1.43***	-0.05	0.27
t-stat	(3.71)	(17.38)	(0.30)	(-4.52)	(-0.98)	(0.20)
Expected Inflation Coefficient (β_1)	0.86	-35.72***	-9.43	56.31***	13.46***	-8.30
t-stat	(1.47)	(-16.06)	(-0.68)	(4.05)	(4.62)	(-0.34)
Unexpected Inflation Coefficient (β_2)	-4.67***	-22.53***	-31.45***	49.95**	2.39	-0.19
t-stat	(-5.26)	(-14.22)	(-3.05)	(2.69)	(1.089)	(-0.00)
Gold						
No. Observations	490	26	25	19	24	9
R-squared	0.06	0.92	0.68	0.83	0.56	0.12
R-squared adj	0.06	0.92	0.65	0.81	0.52	-0.18
Constant (α)	0.07***	1.74	0.11	-1.43*	-0.05***	0.27
t-stat	(10.25)	(-1.59)	(-0.45)	(-2.07)	(11.73)	(0.17)
Expected Inflation Coefficient (β_1)	0.86***	-35.72	-9.43	56.31**	13.46***	-8.30
t-stat	(-8.67)	(1.26)	(0.34)	(2.91)	(-6.01)	(-0.25)
Unexpected Inflation Coefficient (β_2)	-4.67***	-22.53*	-31.45	49.95*	2.39***	-0.19
t-stat	(-4.04)	(1.99)	(-0.16)	(1.88)	(-4.76)	(-0.01)
GSCI						
No. Observations	453	26	25	19	24	9
R-squared	0.04	0.56	0.65	0.91	0.74	0.15
R-squared adj	0.04	0.53	0.61	0.90	0.71	-0.14
Constant (α)	-0.08**	-0.56***	0.27	-2.94***	-0.61***	1.34
t-stat	(-2.56)	(-3.09)	(0.44)	(-6.11)	(-5.90)	(1.08)
Expected Inflation Coefficient (β_1)	4.22***	15.41***	-11.27	138.98***	36.36***	-16.21
t-stat	(3.97)	(3.83)	(-0.48)	(6.57)	(6.06)	(-0.73)
Unexpected Inflation Coefficient (β_2)	-2.13	-1.37	-46.73	132.23***	13.15***	-17.94
t-stat	(-1.49)	(2.87)	(-2.69)	(4.68)	(2.91)	(-0.95)
REIT						
No. Observations	490	26	25	19	24	9
R-squared	0.05	0.81	0.61	0.78	0.80	0.11
R-squared adj	0.04	0.79	0.57	0.75	0.78	-0.19
Constant (α)	0.06***	1.67***	-0.53*	-1.94***	-0.35***	0.94
t-stat	(2.81)	(9.12)	(-2.07)	(-3.78)	(-6.34)	(0.51)
Expected Inflation Coefficient (β_1)	1.50**	-37.69***	27.69**	74.12	19.33***	-19.50
t-stat	(2.05)	(-9.27)	(2.82)	(3.28)	(5.98)	(-0.58)
Unexpected Inflation Coefficient (β_2)	-4.61***	-25.16***	32.49***	64.50	12.42***	-8.56
t-stat	(-4.16)	(-8.68)	(4.44)	(2.14)	(5.10)	(-0.29)

Figures

Figure 1: Development of the inflation rate from 1957-2022

This figure illustrates the development of the annual inflation rate per month (π) from 1957-2022. The bars below indicate the periods of atypical inflation movements that the analysis in section 5.2 focusses on.

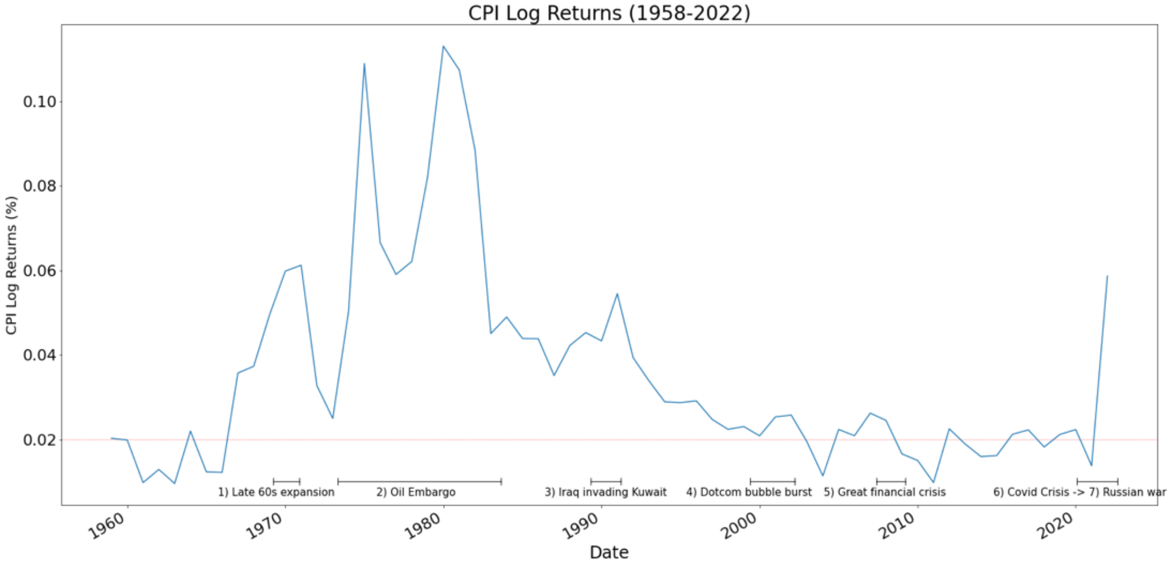


Figure 2: Development of all four asset classes in comparison (1987-2022)

The figure illustrates the development of the individual indices (CPI, S&P 500, Gold, REIT, GSCI) from 1987-2022.

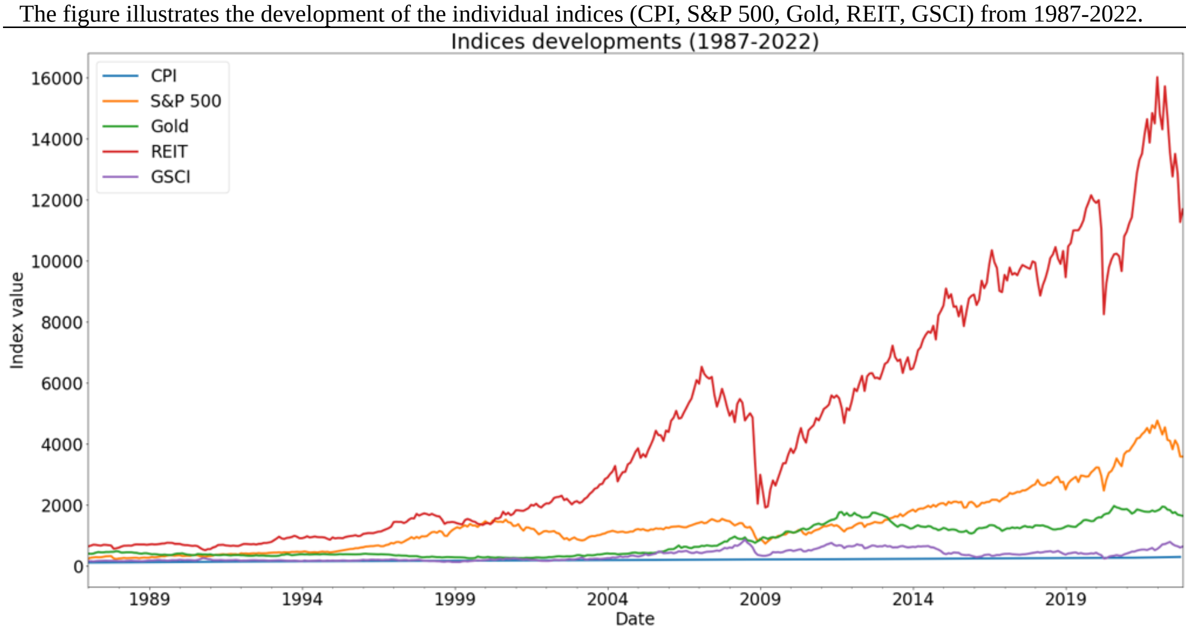


Figure 3: Development of the individual indices next to each other (1987-2022)

The four plots illustrate the development of the individual indices. The S&P 500 index was observed from 1957-2022, the Gold Index was observed from 1969-2022, the REIT Index was observed from 1979-2022 and the GSCI was observed from 1985-2022.

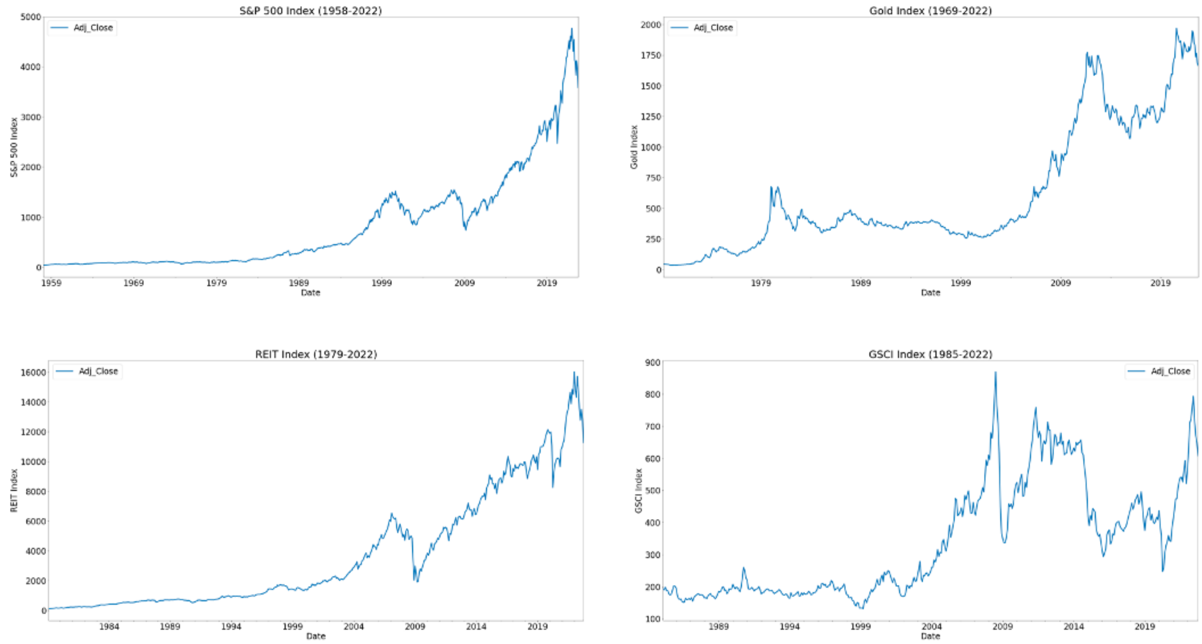


Figure 4: Scatterplots illustrating the relationship between all asset classes with inflation

The scatterplots illustrate the relationships of the individual asset class returns with the inflation rate. The S&P 500 index was observed from 1957-2022, the Gold Index was observed from 1969-2022, the REIT Index was observed from 1979-2022 and the GSCI was observed from 1985-2022.

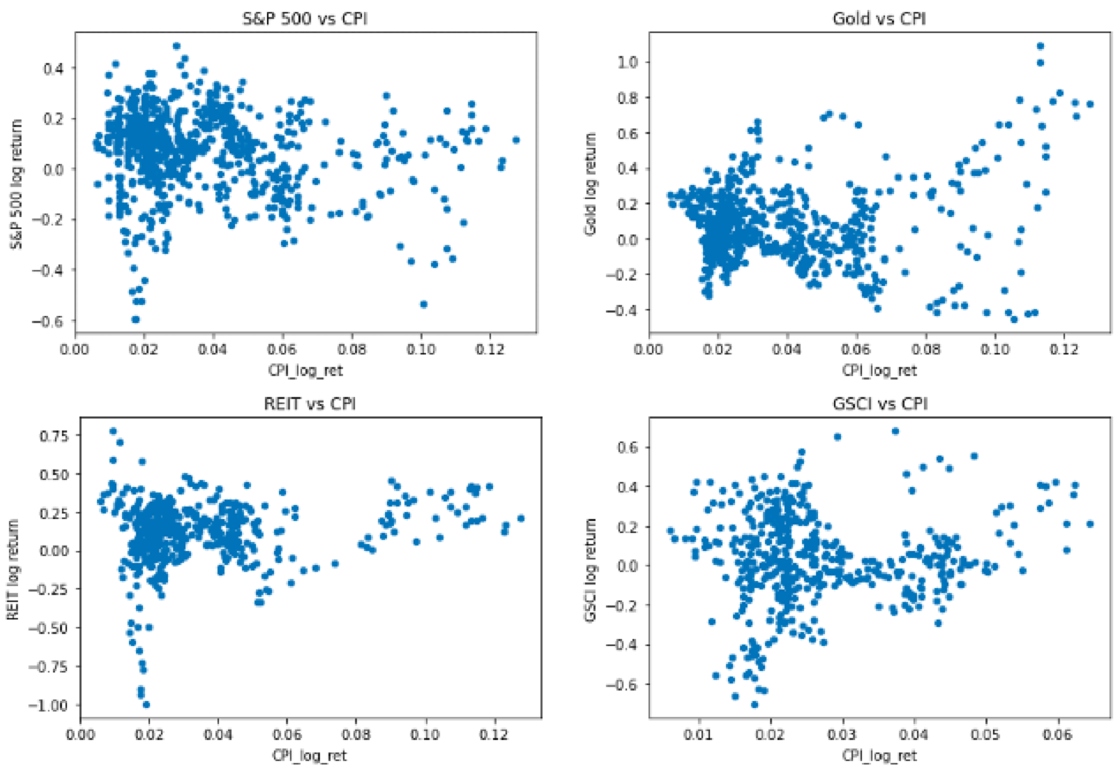


Figure 5: Bar plots illustrating the total annualized returns of all asset classes over 7 periods

The bar plots illustrate the total annualized returns (%) of the individual asset classes for each of the identified periods of unique inflation movements (Table 1).

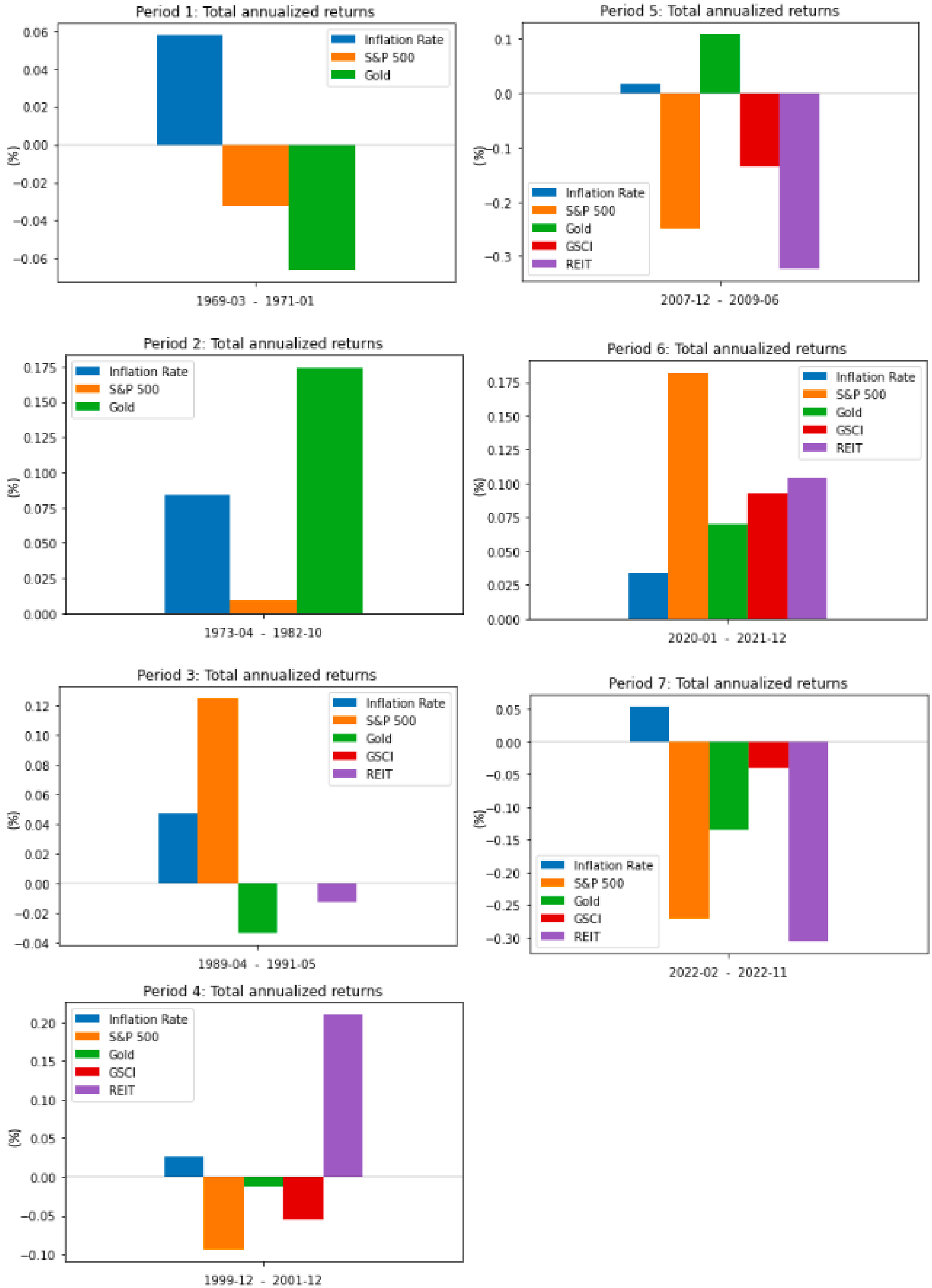


Figure 6: S&P 500 returns from 1957-2022

This figure illustrates the development of the annual S&P 500 returns per month from 1957-2022. The bars below indicate the periods of atypical inflation movements that the analysis in section 5.2 focusses on.

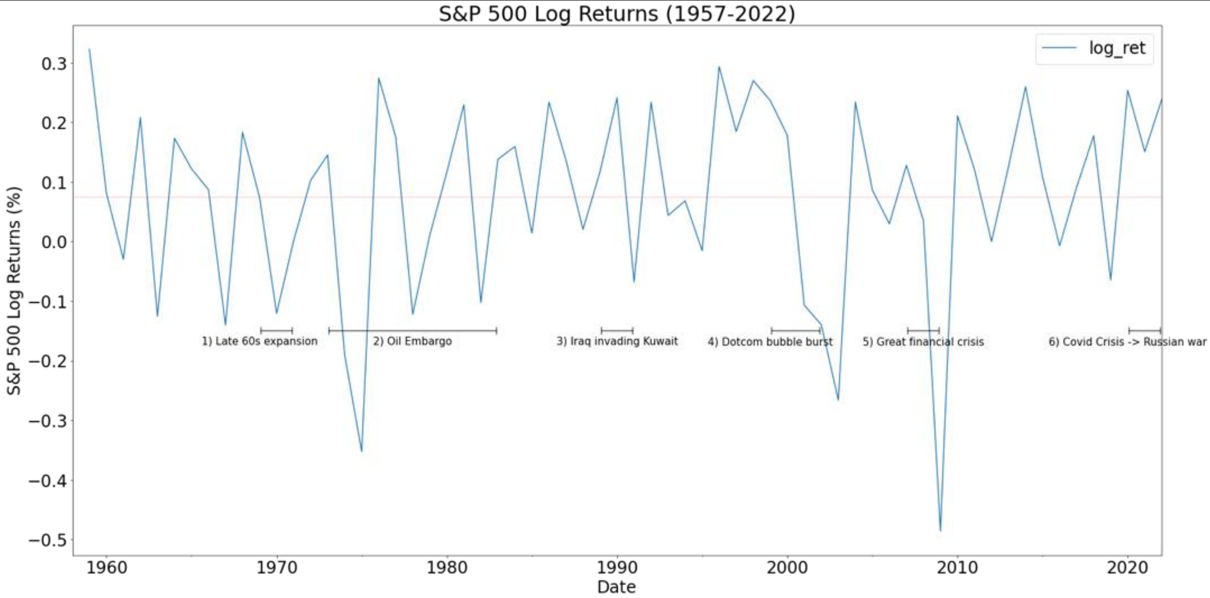


Figure 7: S&P 500 vs. Inflation (1)

The scatterplots illustrate the relationships of the annual S&P 500 returns per month with the inflation rate over the 7 periods of atypical CPI movements.

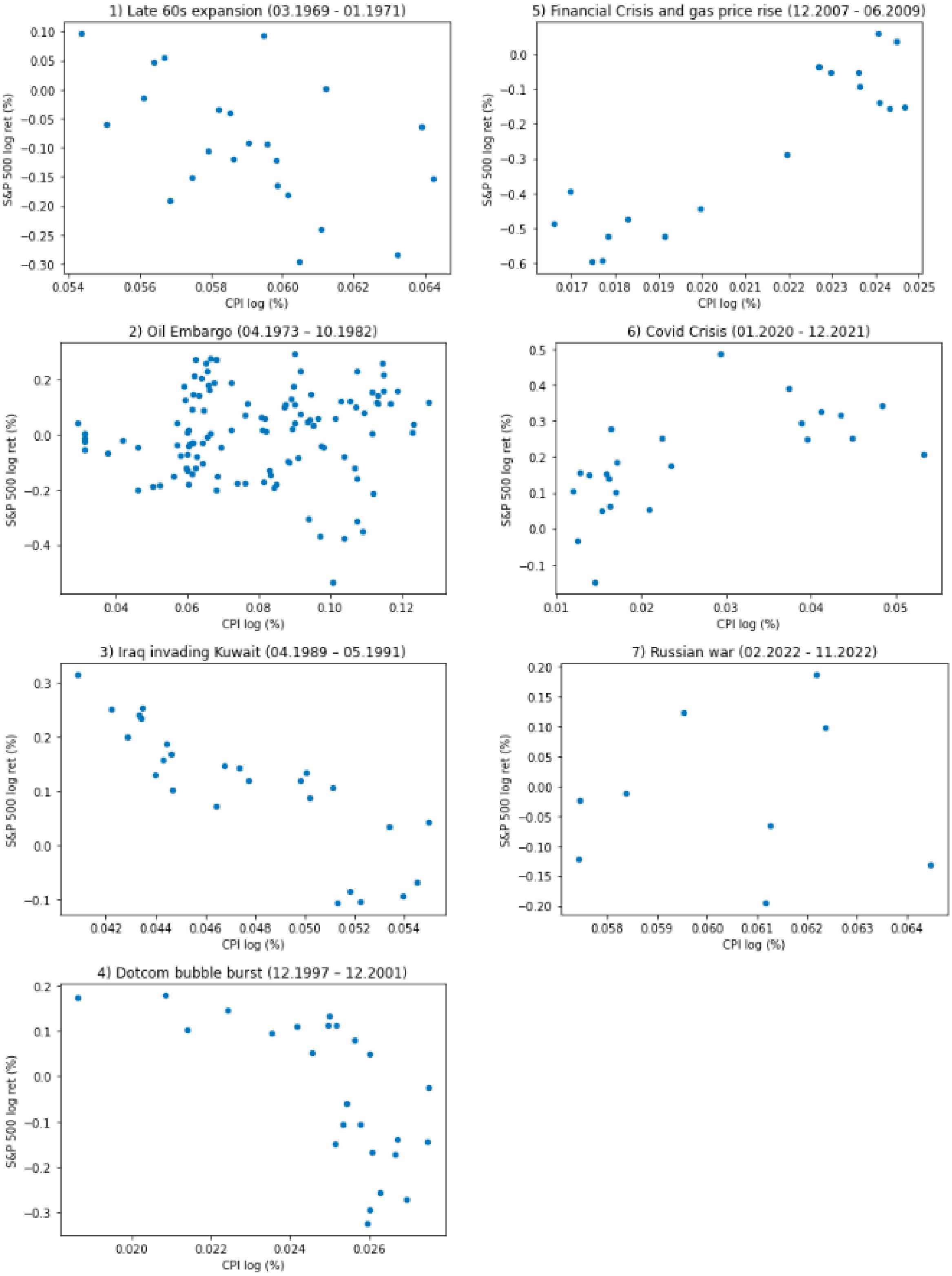


Figure 8: S&P 500 vs. Inflation (2)

The plots illustrate the relationships of the annual S&P 500 returns per month with the inflation rate over the 7 periods of atypical CPI movements.

Period 1

Period 5

Period 2

Period 6

Period 3

Period 7

Period 4

Figure 9: Gold returns 1969-2022

This figure illustrates the development of the annual gold returns per month from 1969-2022. The bars below indicate the periods of atypical inflation movements that the analysis in section 5.2 focusses on.

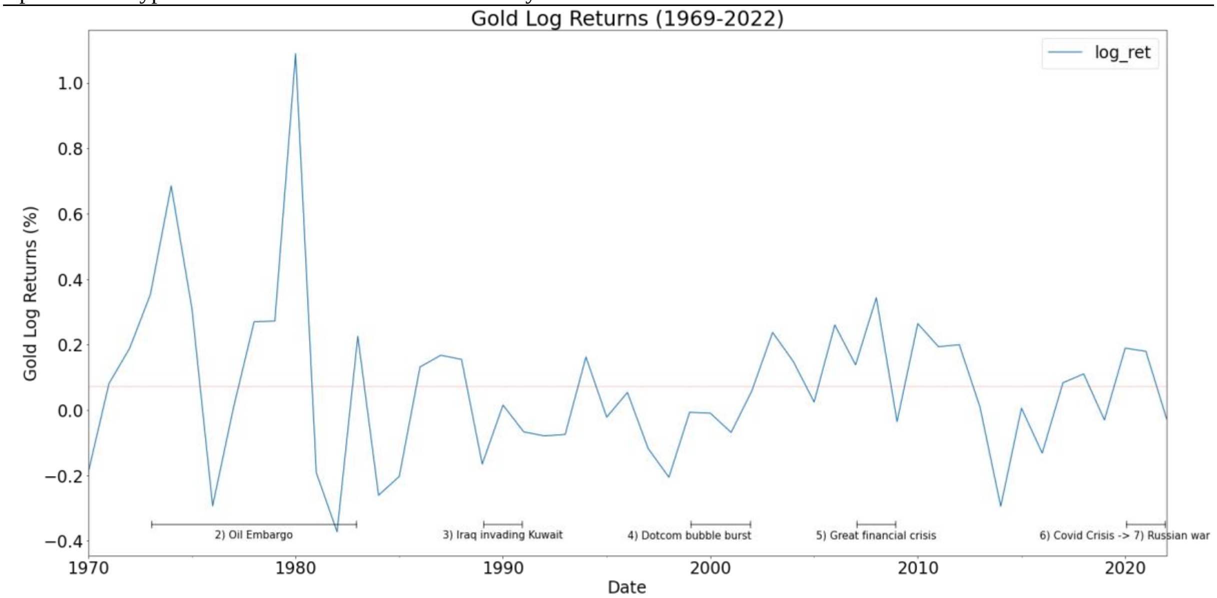


Figure 10: Gold vs. Inflation (1)

The scatterplots illustrate the relationships of the annual gold returns per month with the inflation rate over the 7 periods of atypical CPI movements.

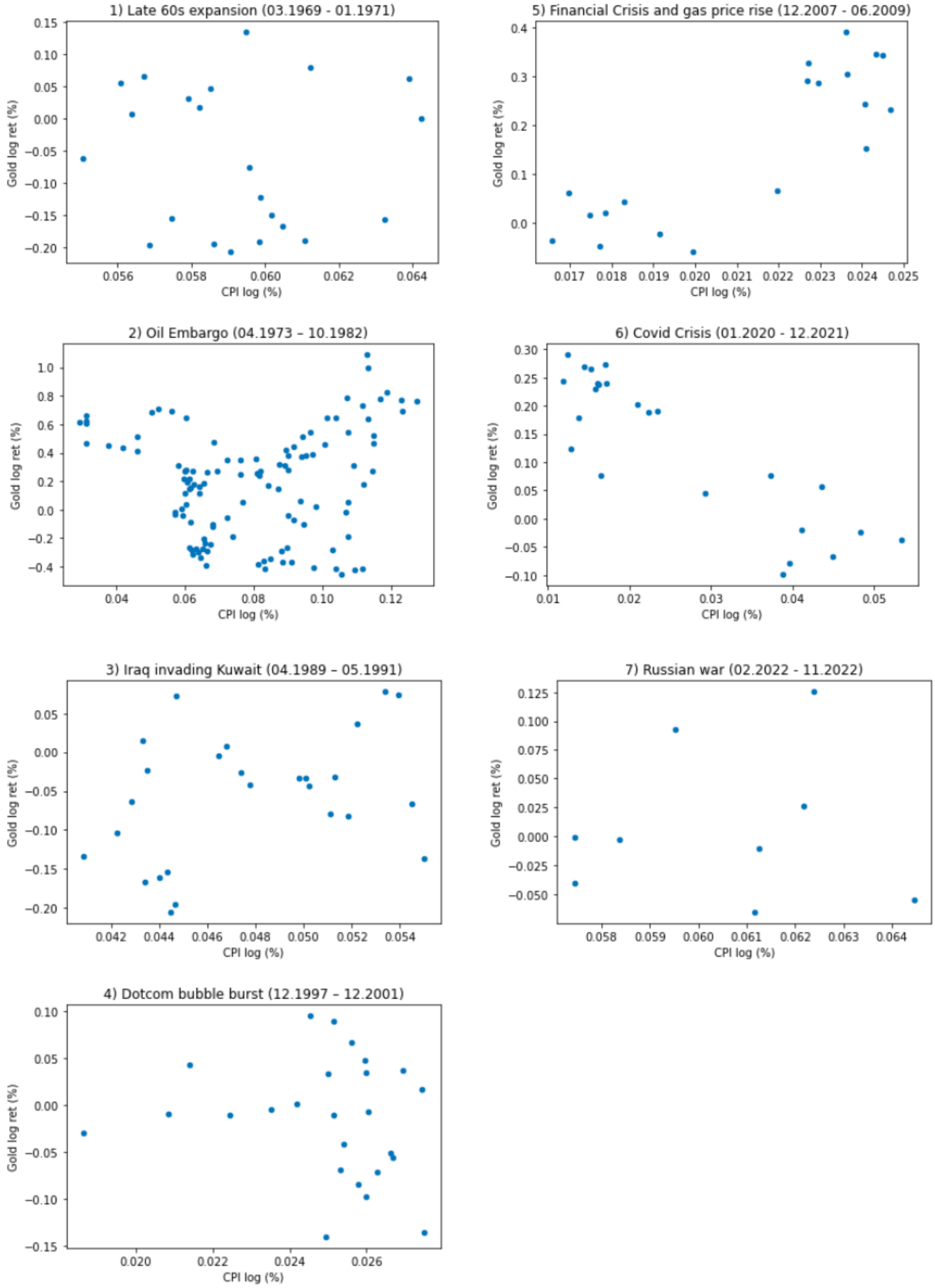
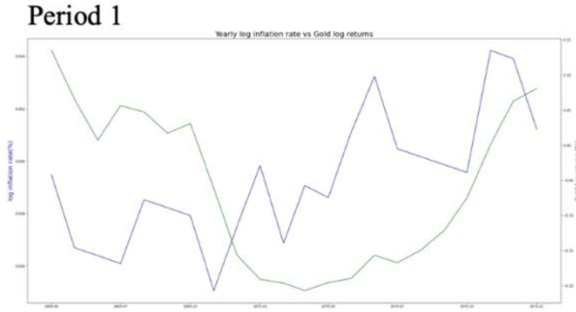


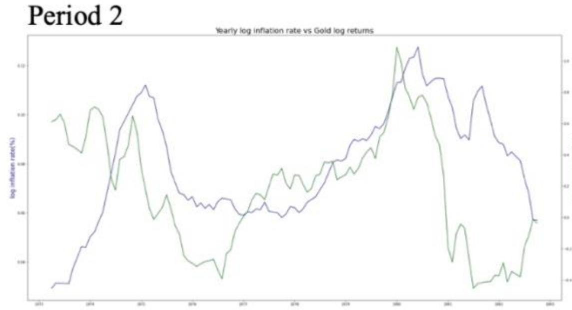
Figure 11: Gold vs. Inflation (2)

The plots illustrate the relationships of the annual gold returns per month with the inflation rate over the 7 periods of atypical CPI movements.

Period 1



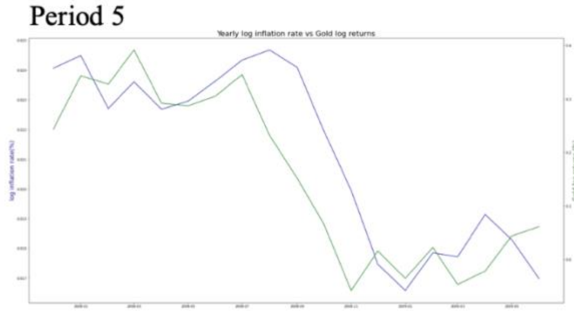
Period 2



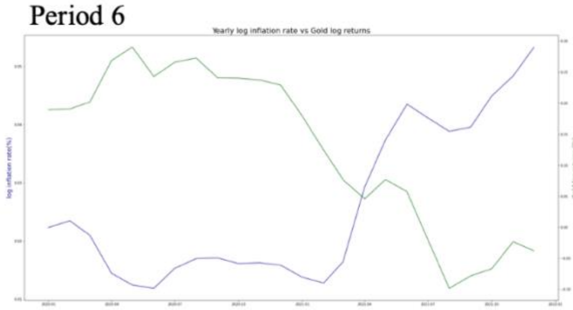
Period 3

Period 4

Period 5



Period 6



Period 7

Figure 12: GSCI returns from 1985-2022

This figure illustrates the development of the annual GSCI returns per month from 1985-2022. The bars below indicate the periods of atypical inflation movements that the analysis in section 5.2 focusses on.

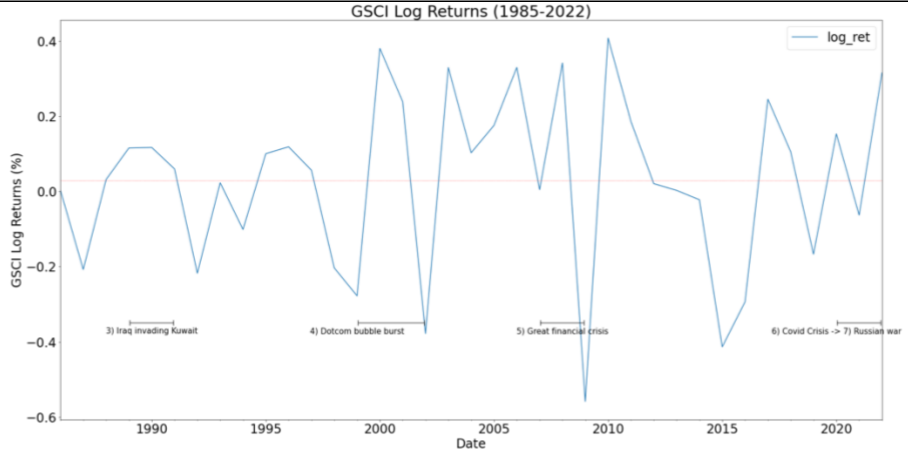


Figure 13: GSCI vs. Inflation (1)

The scatterplots illustrate the relationships of the annual GSCI returns per month with the inflation rate over the 7 periods of atypical CPI movements.

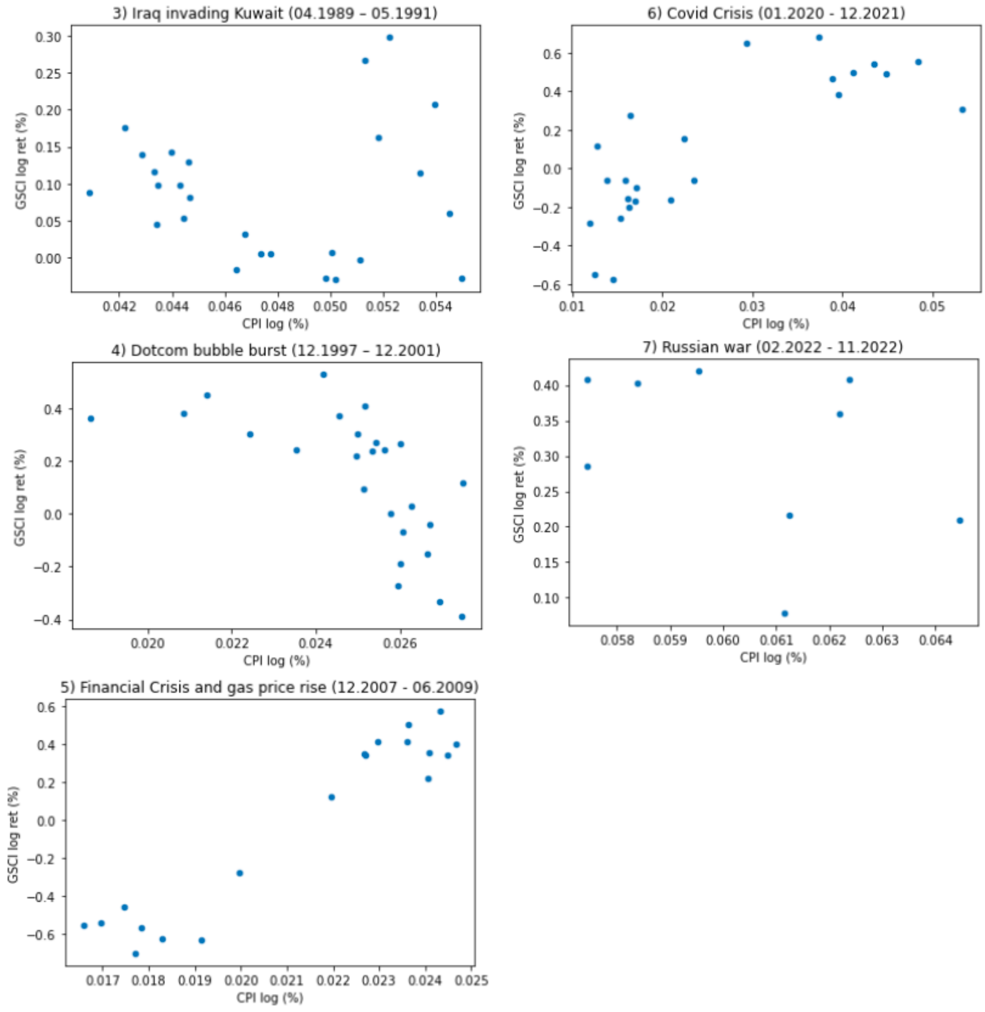


Figure 14: GSCI vs. Inflation (2)

The plots illustrate the relationships of the annual GSCI returns per month with the inflation rate over the 5 periods of atypical CPI movements.

Period 3

Period 6

Period 4

Period 7

Period 5

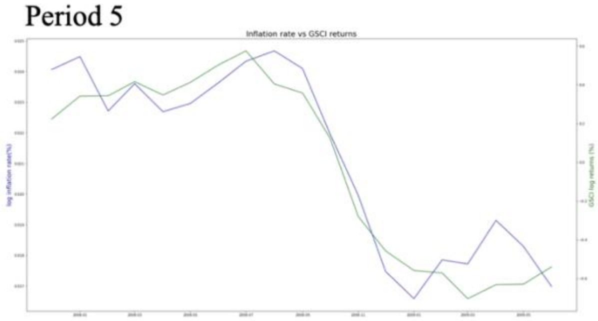


Figure 15: REIT returns from 1979-2022

This figure illustrates the development of the annual REIT returns per month from 1979-2022. The bars below indicate the periods of atypical inflation movements that the analysis in section 5.2 focusses on.

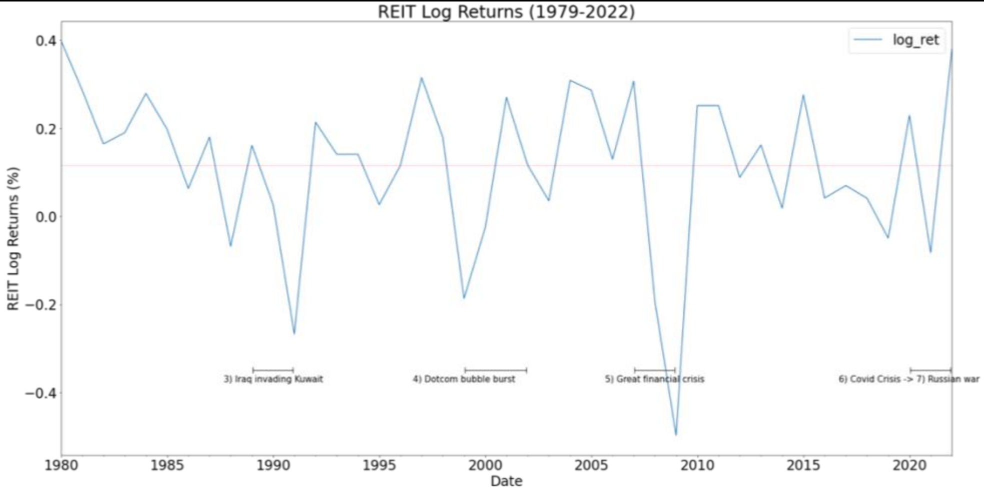


Figure 16: REIT vs. Inflation (1)

The scatterplots illustrate the relationships of the annual REIT returns per month with the inflation rate over 5 periods of atypical CPI movements.

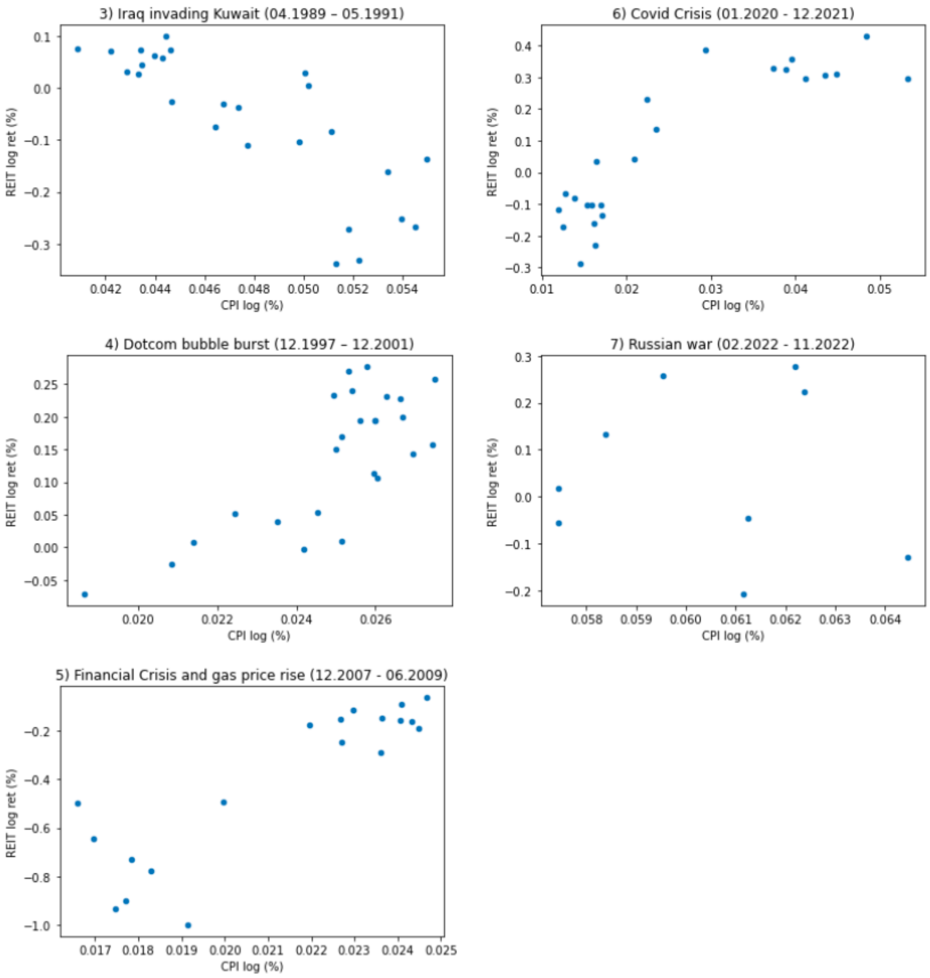


Figure 17: REIT vs. Inflation (2)

The plots illustrate the relationships of the annual REIT returns per month with the inflation rate over 5 periods of atypical CPI movements.

Period 3

Period 6

Period 4

Period 7

Period 5

Figure 18: Development of actual inflation, expected inflation, and unexpected inflation

The figure illustrated the development of actual inflation, as well as expected inflation and unexpected inflation from 1982-2022.