ERASMUS UNIVERSITEIT ROTTERDAM

-

# Mitigating Inflation Risk: An Empirical Analysis of Asset Class Diversification Strategies for Hedging Inflation

Thesis for Financial Economics


ABSTRACT

This paper examines the relationship between different asset classes and the inflation rate in the Eurozone. The dataset consists of 4 asset classes, namely stocks, bonds, commodities and real estate, with a total of 21 variables next to the inflation rate. The results show that the different asset classes behave differently as a response to inflation, where in general the 4 choses commodities and ILBs show a positive relation, real estate a negative relation and stocks an ambiguous relation depending on industry sector. The results of portfolio optimisation show that there is a significant cost of mitigating inflation risk in a portfolio.



Supervisor: Ricardo Barahona

By N.D. de Jong, 663900

Rotterdam, May 2023

TABLE OF CONTENTS

# 1. INTRODUCTION

Inflation is a persistent economic issue that affects many people around the world. The global inflation rate has risen to 8.75% in 2022, which is even higher than right before the Banking Crisis of 2008 (International Monetary Fund, 2023). Many people are negatively affected as the value of their investment and savings decrease, while the life around us continuously becomes more and more expensive. Despite central bank efforts to control inflation, it is impossible to know for sure whether inflation rates will return to their normal levels again or that likewise inflation surges will never take place again. For many businesses, but also individuals, hedging inflation risk has become a crucial part of their practices. This thesis is aimed at exploring a variety of strategies to hedge inflation. In this paper, I will have a specific look at the Eurozone inflation rate, consequently the strategies proposed in this paper are directed at addressing inflation risk of the Eurozone.

As mentioned, investors are troubled by inflation as it most likely decreases the value of their portfolios. The real value of capital and other financial assets have decreased massively in the beginning of 2022, as unease about the largest inflation in 40 years progressed. A variety of sources depict a variety of strategies to keep up with inflation and uphold your purchasing power, but there is no consensus on the one best strategy. Cussen (2022) advises to allocate your portfolio between bonds and stocks and to diversify internationally, but not all stocks are equally good inflation hedges. Moreover, gold is seen as a safe-haven commodity as it tends to fare well when interest rates go down and inflation rises (Royal, 2022).

In 1997, the first Treasury Inflation-Protected Securities (TIPS) were introduced (Treasury Direct, 2022). This is a type of security issued by the United States government that serves to protect investors against inflation risk. If inflation increases, the principal amount of these TIPS will adjust, which as a result will uphold their value. Intuitively, this would suggest it to be the perfect asset to mitigate inflation risk. However, several studies, including Bardong and Lehnert (2009), suggest these bonds are not entirely efficient. In addition, these TIPS serve as a hedge to US inflation and although correlated, do not always mitigate inflation in other global economies and also introduces exchange rates risk. In the Eurozone, an investor could buy inflation-linked obligations which are connected to countries in Europe, such as France, Germany and Italy (European Investors, 2022). However, there is no such TIPS that adjusts as accurately to the Eurozone inflation rate as it does to the inflation rate in the United States. Furthermore, the market for TIPS that is present in the Euro-area is substantially less developed and less liquid as compared to the United States. There are also a few measures to hedge inflation risk in developed countries. However, Bekaert and Wang (2023) claim it is generally more difficult to hedge inflation in developed markets than it is in emerging markets, emphasising the relevance for this thesis. Taking all this into consideration and addressing the gap between the best investment strategy and inflation, this paper is aimed at studying the impact of different (diversification) strategies relative to inflation risk in the Eurozone.

The research question of this paper will be as follows:

*How do different asset classes perform in mitigating inflation risk and what is the optimal allocation of each asset class in a portfolio to hedge against inflation in the Eurozone?*

The main results of this paper indicate that the studied variables react differently to the change of inflation and through portfolio optimisation I will construct a portfolio that mitigates the exposure to inflation. Analysis of both the normal optimal case and the optimal case while taking inflation into account show that there is indeed a cost to mitigating inflation.

This paper analyses the value of different asset classes, such as equities, fixed income, real estate, commodities and currencies over time relative to the inflation rate. It is aimed at finding an optimal investment strategy to mitigate this inflation risk. The remainder of the paper is structured as follows. In section 2, I will discuss relevant literature explaining the different asset classes and their relation to inflation. Moreover, I will discuss literature that includes investment strategies related to inflation risk. In section 3, I will describe the data collection and sources followed by the methodology in section 4 on which the results of this paper are based on. In section 5, I will present and interpret the results of my research, which are followed by a conclusion.

# 2. LITERATURE REVIEW

## 2.1. Inflation Risk

Inflation risk refers to the potential loss of purchasing power caused by a sustained increase in the general price level of goods and services over time (Halton, 2022). Inflation can induce this loss in value by undermining the performance of an investment. If assets do not increase by this same percentage, their value declines. The significance of inflation risk in the Eurozone is multifaceted. As a monetary union comprising multiple countries with varying economic conditions, the Eurozone experiences divergent inflation rates among its member states (Jones, 2016). This divergence in inflation rates can introduce imbalances and challenges for businesses and investors operating across the Eurozone. Different asset classes pose varying degrees of sensitivity to inflation, and understanding the performance of these asset classes in mitigating inflation risk is of great importance. To evaluate the effectiveness of different asset classes in mitigating inflation risk, it is essential to assess their historical performance and correlation with inflation. By examining past data and analysing the behaviour of various asset classes during several inflationary periods in the Eurozone, it becomes possible to identify which asset classes have the potential to preserve purchasing power in inflationary periods and also which perform best during periods of low inflation. The variable I will use throughout this paper to measure the performance of asset classes against inflation risk, is the Euro Area Inflation Rate or better known as Eurozone CPI, as retrieved from Bloomberg.

### 2.2. Asset Classes Performance in Inflationary Environments

To back up the first hypothesis stated in the last section of this chapter, I will conduct a research based on existing literature. This will help me form expectations on the outcome of the sign and magnitude of the performance of the asset classes, but will also help me decide on which asset classes I want to use in the regressions. This section is structured as follows: I will quickly describe each asset class followed by their performance in inflationary environments backed up by arguments from existing literature.

### 2.2.1. Stock performance

The evaluation of stock performance is essential for investors seeking to navigate inflationary pressures and make informed decisions regarding asset allocation within the Eurozone. Boyd et al. (2001) find that higher rates of inflation are associated with higher variability in stock returns. From this, we can conclude that the rate of inflation has an impact on stock performance and will thus be relevant for this research. To further define stock performance, from this point on we will use the variable of stock return, to encompass the profitability of a stock in inflationary environments. In Europe, there is a stock index named Stoxx Europe 600, which represents 600 large, mid and small sized companies present in the Eurozone. Its composition follows a wide range of investment products and it is reviewed four times a year. The use of this index is as a broad and representable benchmark for European stocks, and will thus be investigated on their performance against inflation, i.e. it will be used as a proxy for the European market. As mentioned in Fama's (1981) 'proxy hypothesis', which explains the prevalence of negative stock returns to inflation, I expect this relation to be negative. This can indicate however that stocks can be a good performing asset class in periods of low inflation. Moreover, I make use of the Stoxx Europe 600 instead of smaller stocks, since this is a steadier measure of performance. I will also try to distinguish whether there is a significant difference in stock performance in between different sectors.

### 2.2.2. Bond performance

Bonds offer unique characteristics and benefits that make them a significant component of an investment portfolio. A bond is a transferable debt security for a loan issued by governments or corporations (VanGuard, 2016). Investment in bonds are subject to the interest rate and credit risk, but most importantly for this paper, it is also subject to inflation risk. Empirically, inflation risk is priced into the bond on the basis of expected inflation, but it is subject to unexpected drops and rises in the inflation rate (Kang and Pflueger, 2015). Intuitively, this would mean that in general bonds would not be a good hedge against shocks in inflation. Wydler (1989) conducted a research in Switzerland, doing research over a dataset of 60 years providing evidence that indeed bonds provide no hedge against inflation. As mentioned in the introduction, in 1997 the United States Government started issuing Treasury Inflation-Protected Securities (TIPS). Multiple studies find that the TIPS provide a secure hedge against inflation (on the basis of CPI) and that there is little profit to be made from hedging to other likewise inflation measures (Bekaert and Wang, 2010; Barnes et al. 2010). Also mentioned before, several countries in the Eurozone have issued likewise securities. Unfortunately, these securities have proven to be less liquid and less accurate in comparison to the TIPS. Illiquidity will cause problems for an investor, especially in times of market distress, because they will be unable to sell their bonds at the desired prices. Inaccuracy of following the inflation is evidently a problem when an investor's goal is to have bought the bond as a hedge for inflation. However, because these inflation-indexed bonds are more related to European inflation, I will lay my focus on these securities when assessing their performance in mitigating inflation risk in the Eurozone. In this thesis, I will investigate the performance of several European Inflation-Linked Bonds (ILBs), which will be specified in the data section.

### 2.2.3. Commodities

Many studies have conducted research on the inflation hedging properties of commodities (Spierdijk and Umar, 2015; Tiwari et al., 2018), which find a strong co-movement of inflation rates and commodity returns. Not surprising to the average investor, gold seems to provide a good hedge against inflation. Generally, when inflation is low, gold prices are fairly unresponsive and when inflation is high, gold prices exhibit significant responses (Valadkhani et al., 2022). Moreover, when other asset classes encounter large fluctuations, the price of gold is relatively more stable, while preserving their purchasing power over a long time horizon. Dempster and Carlos (2010) found that when CPI exceeded 5%, the real price of gold had risen by almost 15%. Furthermore, they examined the performance of gold in mitigating inflation risk in a portfolio that already contained inflation hedges, such as the TIPS mentioned earlier in this paper. Through portfolio optimisation they found that adding gold to a portfolio containing TIPS still remains beneficial, through the benefits of diversification. For this reason, gold is one of the commodities that I want to include in my research. By this same token, I want to include silver in my research as well, although I expect there to be some issues of multicollinearity. Silver and gold are classified as precious metals, however other commodity classes tend to have strong relationships with inflation as well. Zaremba et al. (2019) test the relationship of inflation with various indexes, namely energy, agricultural and industrials, all showing significant co-movement with inflation. For energy resources, oil tends to have the highest correlation with inflation, as prices increase as inflation rises. Likewise, corn and copper follow this pattern for the latter two commodity classes. For this reason, these commodities will be included in my research. Since the common investor generally does not aim to actually receive the commodity (i.e., due to transportation costs and stocking costs). The data included in this research is on the basis of derivatives of the aforementioned commodities. This will be further specified in the data section.

#### 2.2.4. Real Estate

The inclusion of real estate in investment portfolios has gained prominence as investors seek diversification, stable returns, and a possible hedge against inflation in the market. Salisu et al. (2020) conduct research on the inflation hedging properties of real estate, among others. They find that real estate and stocks are good hedges against inflation. The latter being contradictory to the literature earlier mentioned, where stock returns are showing signs of a negative relationship to the inflation rate. Moreover the research of Salisu et al. (2020) found that investment in gold will not be a profitable asset in hedging inflation in your portfolio, which also defies our earlier findings. These contradictory results provide even more incentive to include all these assets in my research. Again, like commodities, in my research I am not looking to invest in the actual assets, since this brings along more technicalities than the average investor is willing to bare. Accordingly, in my analysis I will include property funds, including publicly traded real estate securities, which will be more specified in the data section.

### 2.3 Optimal Asset Allocation Strategies

Determining the optimal asset allocation strategy within a portfolio is a critical decision for investors seeking to maximise returns while managing risk in the ever-changing investment landscape. The four asset classes described above are chosen on the base of availability, i.e., liquidity and accessibility to the average investor. Strategies that seem to be effective in periods with high inflation deem ineffective in periods with low inflation (Nawrocki & Evensky, 2003). In a low inflation environment, where preserving capital and achieving steady returns are key objectives, a conservative allocation strategy that focuses on fixed-income securities may be appropriate. Stocks tend to perform well relative to inflation, with exclusion of times where there is severe distress (Boudoukh & Richardson, 1993). Providing this, we should be cautioned by the difference in periods of low inflation and high inflation. Bonds and other fixed-income instruments provide relatively stable income streams and act as a hedge against potential volatility in investment markets. Additionally, diversification across asset classes, including a moderate allocation to equities, can help maintain the potential for long-term growth while managing downside risks. On the other hand, in a high inflation environment, where the erosion of purchasing power becomes a concern, investors often turn to assets that have historically demonstrated inflation-hedging characteristics. Tangible assets like real estate and commodities, such as gold or energy-related products, have shown potential in preserving value during periods of rising prices (Dempster & Artigas, 2010). Nevertheless, it is important for investors to carefully assess their risk tolerance and investment objectives when determining the optimal asset allocation strategy in either low or high inflation environments.

**2.4 Hypothesis**

As literature indicates, there is no consensus on the one best strategy for hedging inflation, especially in the Eurozone. To investigate the relation between different asset classes and inflation and consequently, the best allocation strategy, I have stated the following hypotheses:

HYPOTHESIS I:

H0: There is no significant difference in the performance of different asset classes in mitigating inflation risk in the Eurozone.

H1: There is a significant difference in the performance of different asset classes in mitigating inflation risk in the Eurozone.

Or mathematically, as derived from the regression formula (1) in the methodology section:

H0: $\beta1\_1 = \beta1\_2 = \ldots = \beta1\_n$

H1: At least one $\beta1\_i \neq \beta1\_i$

Not surprisingly this hypothesis is backed up by aforementioned literature in the previous paragraphs of this section. As said before, I expect the different asset classes to react differently on the basis of return to the inflation risk (Eurozone CPI), due to different characteristics. This argument is derived from literature such as Fama (1981), which for example states a persistent phenomenon where stock returns and inflation have a negative relationship. Followed by Dempster and Carlos (2010), which expect gold and inflation to have a significant positive relationship. Thus, I expect to reject the null hypothesis. In the most likely case of rejecting the first null hypothesis, I will try to assemble a portfolio which closely follows inflation and therefore mitigates inflation risk in the Euro area. As established in the literature review and equivalently backed up by several researches, different financial asset classes perform differently in response to inflation. My prediction to hypothesis I is thus rejection of the null hypothesis. Consequently, due to the differences in performance, it is almost evident that the next null hypothesis will be rejected.

HYPOTHESIS II:

H0: There is no portfolio allocation performing better to minimise inflation risk in the Eurozone.

H1: There is a portfolio allocation performing better to minimise inflation risk in the Eurozone.

This hypothesis is not necessarily formed with a main goal to reject the null hypothesis, since this is highly likely, but to provide answer to the question which portfolio allocation, i.e., use and magnitude of which asset classes, will help best in mitigating inflation risk. Provided by Dempster and Carlos (2010), they state that even though TIPS perform greatly in mitigating inflation risk, a portfolio can still benefit from diversification. In our case, I expect IBLs to perform somewhat similarly to TIPS in mitigating inflation risk. However, just like the research of Dempster and

Carlos (2010), I expect adding different asset classes to increase overall performance of the portfolio in mitigating inflation risk. Lastly, I want to examine whether there is a cost to mitigating inflation risk. Especially keeping in mind that IBLs tend to perform less accurately in mitigating inflation risk and are generally less liquid as compared to TIPS.

Despite the fact that some portfolios may perform better in minimising inflation risk, i.e., rejection of the null hypothesis under hypothesis II, it may come with the cost of diminishing overall returns. To that end, the second and last hypothesis (III) is formed to evaluate whether mitigating inflation risk comes at a price.

HYPOTHESIS III:

H0: There is no cost in minimising inflation risk in a portfolio regarding inflation in the Eurozone.

H1: There is a cost in minimising inflation risk in a portfolio regarding inflation in the Eurozone.

This null hypothesis will be either rejected or accepted on the portfolio optimisation framework explained in the methodology section, more specifically whether there is a difference in the result of formula 6 and 7. Intuitively, I expect there to be some cost in mitigating inflation risk, since customarily, lower risk results in higher cost. Bekaert and Wang (2010), a study previously mentioned in the literature review, find that the inflation risk premium, i.e., the compensation for bearing inflation risk, is substantial over time. The case being mutually exclusive, the reversal should be valid. In other words, when an investor is not bearing inflation risk, it comes at the cost of the inflation risk premium and thus equals lower returns. This in turn would imply that the null hypothesis under hypothesis III will be rejected.

## 3. DATA

The data used in this paper is retrieved from the Bloomberg Database. It encompasses stock data, namely that of the Stoxx Europe 600 Index. which is an index similar to the S&P500 Index, but in the Eurozone. It tracks the return of Europe's 600 largest companies listed on the stock exchange, spread out over 17 European countries. The Stoxx 600 Europe is analysed as a sole variable, but is also divided into different sectors to analyse the effect of inflation on the separate industry sectors. Moreover and more importantly for this research, among other variables it consists of the inflation rate (CPI) as published by the 'Central Bureau of Statistics' (CBS).

The Eurozone was established on the 1st of January, 1999. Therefore, the timespan of the dataset will run thereafter. The descriptive statistics of the dataset is depicted in the table below. As can be inferred from the table below, the dataset contains several asset classes, as portrayed in the research question. The asset classes and the respective choices of their representers are chosen on the basis of existing literature. Meaning, for example for commodities, the commodities incorporated in the dataset are chosen on the basis of their characteristics and how they act in response to inflation.

The original dataset composed of the timeline January, 2000 until May, 2023. The rows with missing variables are deleted so that all variables are taken into account equally. This led to exclusion of the first years, where data of a few variables were either not available or not present yet. Thus the new dataset is composed of data ranging from November, 2005 until May, 2023. The data provided is monthly data, since even though much daily data is available for the asset classes, the CPI is only available on the basis of monthly data.

| **Table 1: Descriptive statistics of the Dataset** |
| --- |
| Where variable ECCPEMUY is the European inflation index, BEIG_X are the ILBs with different maturities, followed by the commodities gold, silver, corn and copper, and two equity indexes and where SXXP_X is the Stoxx 600 Europe (SXXPIndex) divided by sector. |

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| ECCPEMUYIn~x | 211 | 2.05 | 2.13 | -.60 | 10.6 |
| SXXPIndex | 211 | 340.34 | 68.34 | 172.92 | 487.8 |
| BEIGFTIndex | 211 | 119.54 | 9.22 | 98.94 | 137.79 |
| BEIG1TIndex | 211 | 198.72 | 25.78 | 153.67 | 251.30 |
| BEIG3TIndex | 211 | 190.73 | 22.04 | 148.09 | 231.24 |
| XAUCurncy | 211 | 1303.29 | 376.64 | 493.08 | 1990 |
| XAGCurncy | 211 | 19.64 | 6.74 | 8.24 | 47.91 |
| C1Comdty | 211 | 463.42 | 149.46 | 187.50 | 818.25 |
| HG1Comdty | 211 | 316.35 | 69.24 | 141 | 475.1 |
| ECMPANAEqu~y | 211 | 28.11 | 7.06 | 8.26 | 41.15 |
| IPRPNAEquity | 211 | 31.99 | 7.66 | 15.17 | 47.17 |
| SXXPHCARGI~x | 211 | 18267.83 | 3896.83 | 10359.91 | 26629.42 |
| SXXPBMATGI~x | 211 | 14180.76 | 3860.68 | 6295.32 | 25923.84 |
| SXXPREALGI~x | 211 | 4509.06 | 744.51 | 2343.05 | 7267.7 |
| SXXPUTILGI~x | 211 | 10192.62 | 2446.15 | 7128.26 | 17122.91 |
| SXXPENERGI~x | 211 | 9902.20 | 2542.64 | 5109.24 | 14882.6 |
| SXXPINDUGI~x | 211 | 12180.17 | 2265.86 | 7868.57 | 16535.42 |
| SXXPFINLGI~x | 211 | 11651.6 0 | 1955.90 | 8563.43 | 15728.29 |
| SXXPTECHGI~x | 211 | 10304.89 | 2718.07 | 7238.87 | 17084.82 |
| SXXPFDBVGI~x | 211 | 15017.9 | 3577.96 | 7833.75 | 21444.61 |
| SXXPRETLGI~x | 211 | 9045.79 | 896.59 | 6412.02 | 10747.17 |
| SXXPTELCGI~x | 211 | 8169.23 | 1886.59 | 4456.92 | 12590.79 |

An overview of the variables and what they precisely stand for, i.e., from which indexes they are retrieved from, can be found in the appendix. As you can see in table 1, the amount of observations for each variable is equal to 211. It is derived from the amount of months that the data collection is based on and thus corresponding to the years 2005 until 2023. Rows with missing variables are deleted, which is essential for every variable to be taken into account equally.

For the first variable, ECCPEMUYIndex, which is equal to inflation in the Eurozone, we observe a mean of 2.05. This is almost equal to the inflation target of the ECB of 2% (European Central Bank, 2021). However, this is of course a mean and although the ECB states that both positive and negative deviations from this target are 'undesirable', we can infer from the descriptive statistics that this happens to be the case every so often. For our timeline, the inflation rate ranges between a negative inflation rate of -0.06% and an inflation rate as high as 10.6%. The large variation results from the inclusion of two large inflationary periods in the dataset, namely the 2008 banking crisis and the Covid crisis (the graph can be found in appendix 2). This large variation in inflation rate rises the inflation risk for an investor and thus emphasises the importance of this thesis. The remainder of the numbers in the table show no irregularities for further explanation, but for each variable the respective mean, standard deviation, minimum and maximum are likewise depicted in the table.

Table 2 below provides more information regarding the goal of this thesis. In this table, the asset classes and their average return and standard deviation are shown. The average returns are calculated on the basis of yearly returns. What is instantly noticeable is that the average yearly return of the inflation-linked bonds with a maturity of 1-year is almost equal to the mean of the inflation variable in the previous table, namely a return of 2.17% as opposed to a yearly inflation rate of 2.05%. This, to a certain extent, backs up the fact that ILBs uphold the purchasing power of an investor (Chopra et al., 2021). Besides aiming to mitigate inflation risk, we want to achieve this while having the highest possible returns. This causes our eye to shift to other asset classes in the table, such as the commodities where average returns are high. Although not surprisingly, these high returns are accompanied by relatively high standard deviations. So, this is where the portfolio optimisation comes into view.

| **Table 2: Average returns and standard deviation of the asset classes** |
|---|
| Where 'Return_X' is equal to the return of variable X between time *t* and time *t+1*. The variables are grouped per asset class and show the average returns and their standard deviation. |

| Asset Class | Variable | Average Return | Std. dev |
|---|---|---|---|
| **Inflation-Linked Bonds** | Return_BEIGFTIndex | 1.77% | 2.14 |
| | Return_BEIG1TIndex | 2.17% | 4.56 |
| | Return_BEIG3TIndex | 2.23% | 2.99 |
| **Commodities** | Return_XAUCurncy | 8.85% | 14.73 |
| | Return_XAGCurncy | 10.79% | 26.86 |
| | Return_C1Comdty | 11.19% | 22.98 |
| | Return_HG1Comdty | 6.97% | 32.94 |
| **Real Estate** | Return_ECMPANAEq | 3.59% | 20.10 |
| | Return_IPRPNAEquity | 2.09% | 23.12 |
| **Stocks** | Return_SXXPIndex | 3.07% | 18.81 |
| | Return_SXXPHCARGI | 3.69% | 13.62 |
| | Return_SXXPBMATGI | 2.20% | 26.45 |
| | Return_SXXPREALGI | -5.38% | 13.47 |
| | Return_SXXPUTILGI | -0.98% | 12.01 |
| | Return_SXXPENERGI | -1.95% | 16.09 |
| | Return_SXXPINDUGI | 3.90% | 6.85 |
| | Return_SXXPFINLGI | 1.62% | 11.01 |
| | Return_SXXPTECHGI | 2.91% | 8.94 |
| | Return_SXXPFDBVGI | 4.69% | 8.27 |
| | Return_SXXPRETLGI | -0.28% | 8.39 |
| | Return_SXXPTELCGI | 0.03% | 0.81 |

## 4. METHODOLOGY

Throughout this thesis, I will use various methods to test my hypothesis and their respective significance. In this section, these methods will be described. The main research is conducted on the basis of backtesting. I will analyse historical data and their performance compared to past inflation, which is the grounds of future application of the portfolio optimisation.

### 4.1 Regression Analysis

Multiple regression analyses will be performed to test the relation between inflation and the various asset classes. The formulas for each regression are displayed later in this section. The performance of each asset class will be regressed against the European inflation rate and their coefficients are analysed to assess the relation between each variable to inflation. Moreover, the coefficient of the R-squared of the regression is assessed to determine what proportion of the variation in asset performance can be explained by inflation. If these results are statistically significant, we have base ground for either accepting or rejecting the first null hypothesis. The general formula for a simple linear regression model is as follows.

$$Y_{\mathrm{i},t} = \beta_0 + \beta_1 X_t + \epsilon_{\mathrm{i},t} \qquad (1)$$

$Y_{i,t},$ is the dependent variable with observation i in time t. $\epsilon_{i,t}$ is the zero mean disturbance term and lastly, $\beta_0$ is the constant, $\beta_1$ is the slope coefficient and $X_i$ is the independent variable. The dependent variable in this formula in this case will be switched and regressed for each different asset class. The fitted value for the slope coefficient will display the strength and the direction of the relationship to the independent variable, in our case the European inflation rate. To apply the general linear regression model to our thesis I provide the following formulas.

$$\textit{Stock Performance} = \beta 0 + \beta 1 * \textit{Inflation} + \varepsilon \qquad (2)$$

$$\textit{Bond Performance} = \beta 0 + \beta 1 * \textit{Inflation} + \varepsilon \qquad (3)$$

$$\textit{Real Estate Performance} = \beta 0 + \beta 1 * \textit{Inflation} + \varepsilon \qquad (4)$$

$$\textit{Commodity Performance} = \beta 0 + \beta 1 * \textit{Inflation} + \varepsilon \qquad (5)$$

Where inflation is equal to the Eurozone CPI as provided in the descriptive statistics. Stock performance is measured on the grounds of returns, divided on the basis of industry sectors and the Stoxx Europe 600 Index. Formula 2 is thus the general formula for multiple regressions concerning the different variables comprising stock returns. Likewise, the performance of dependent variables in formulas 3-5 are measured on the grounds of returns, i.e, the generic difference of prices between time $t$ and $t+1$ will be calculated on the basis of the inflation in time $t$ and $t+1$. The prospective β1s in the regression models will be compared to reject or accept null hypothesis I and thus provide a basis to continue the research for hypothesis II and II.

### 4.2 Portfolio optimisation

To optimise the portfolio allocation based on the results from the regression analysis, we adopt the approach of the study by Frazzini and Pedersen (2014). This methodology utilises characteristics in the cross section of equity returns to design an optimised portfolio allocation strategy. The formulas involved in the portfolio optimisation process are described as follows.

$$\max_{w_i} E_t[u(r_{p,t+1})] = E_t\left[u\left(\Sigma w_{i,t} r_{i,t+1}\right)\right] \tag{6}$$

$w_i \geq 0$ *for all i's*

$$\max_{w_i} E_t[u(r_{p,t+1})] = E_t\left[u\left(\Sigma w_{i,t} r_{i,t+1} - \pi_t\right)\right] \tag{7}$$

$w_i \geq 0$ *for all i's*

Where each asset class has a return of $r_{i,t+1}$ and we try to choose the portfolio weights, namely $w_{i,t}$, to maximise the portfolio's return, $r_{p,t+1}$. Formula 6 depicts the formula used in general portfolio optimisation. It maximises the returns of the portfolio by adjusting the weights. The formula described thereafter is a variation of formula 6. It depicts the portfolio optimisation formula as described by Frazzini and Pedersen (2014), but it includes the factor for inflation risk and will thus provide the optimal portfolio weights while correcting for inflation.

### 4.3 Tests for significance

To test for significance of the results, I will conduct a parametric test, namely the t-test as depicted in formula 8. The significance of the observed mean is tested, where $s$ is the standard deviation and $N$ is the sample size. The t-test is distributed according to a t-distribution with $N-1$ degrees of freedom. Following the t-statistic and comparing it to the critical t-value, the hypotheses can either be accepted or rejected.

$$t - stat = \frac{\mu}{\frac{s}{\sqrt{N}}} \sim N(0,1) \qquad (8)$$

# 5. RESULTS

In this section, I will provide results to either accept or reject the hypotheses stated in section 2.4 (Hypothesis I to III). Following the acceptance or rejection of these hypotheses, I will provide an answer to the main research question of this paper: How do different asset classes perform in mitigating inflation risk and what is the optimal allocation of each asset class in a portfolio to hedge against inflation in the Eurozone? This section is structured as follows: I will first conduct a simple regression, which will lead to acceptance or rejection of Hypothesis I. Then I will establish a risk/return matrix to see whether some portfolios perform better than others and in what aspect as an answer to Hypothesis II. Lastly, I will analyse the different optimal portfolios by means of the portfolio optimisation by Frazzini and Pedersen (2014) method as described in the methodology section with respect to inflation to reject or accept Hypothesis III.

## 5.1 Regression results

The table below shows the results from running the regressions from variable returns to inflation. In the table, the results of the regression are depicted. Take into account that this table is formed from several multiple regressions where the variable under 'Variable' is taken as the dependent variable and subsequently the inflation rate 'ECCPEMUYIndex' is the independent variable. As we want to see how the return of a given variable reacts relative to a given percentage of inflation. This follows from formulas 2 to 5 as described in the methodology section.

| **Table 3: Regression table of the asset classes return with respect to the Eurozone inflation rate** |
|---|
| Where variable ECCPEMUY is the European inflation index, BEIG_X are the ILBs with different maturities, followed by the commodities gold, silver, corn and copper, and two equity indexes and where SXXP_X is the Stoxx 600 Europe (SXXPIndex) divided by sector. |

| Variable | Coefficient | Std. err. | T | 95% Confidence | interval |
|---|---|---|---|---|---|
| Return_SXXPIndex | 3.14*** | 0.62 | 1.50 | 1.92 | 4.35 |
| Return_BEIGFTIndex | 1.11*** | 0.24 | 3.88 | 0.64 | 1.58 |
| Return_BEIG1TIndex | 1.29** | 0.41 | 1.58 | 0.48 | 2.11 |
| Return_BEIG3TIndex | 1.27*** | 0.37 | 1.82 | 0.55 | 1.99 |
| Return_XAUCurncy | 4.29*** | 0.89 | 0.37 | 2.53 | 6.05 |
| Return_XAGCurncy | 3.34*** | 1.09 | 15.58 | 1.19 | 5.49 |
| Return_C1Comdty | 8.66** | 0.86 | 2.17 | 6.97 | 10.36 |
| Return_HG1Comdty | 5.34*** | 0.61 | 2.77 | 4.14 | 6.54 |
| Return_ECMPANAEq | -2.47** | 0.80 | -10.99 | -4.05 | -0.90 |
| Return_IPRPNAEquity | -1.67** | 0.77 | -6.75 | -3.18 | -0.15 |
| Return_SXXPHCARGI | 1.04 | 0.69 | 0.01 | 0.00 | 2.40 |
| Return_SXXPBMATGI | 3.59*** | 0.85 | 0.03 | 1.91 | 5.26 |
| Return_SXXPREALGI | -4.10*** | 0.75 | -0.12 | -5.57 | -2.63 |
| Return_SXXPUTILGI | -0.35 | 0.78 | 0.00 | -1.89 | 1.19 |
| Return_SXXPENERGI | -0.49 | 0.83 | -0.01 | -2.13 | 1.16 |
| Return_SXXPINDUGI | 2.07*** | 0.59 | 0.03 | 0.91 | 3.23 |
| Return_SXXPFINLGI | 1.79*** | 0.53 | 0.03 | 0.74 | 2.84 |
| Return_SXXPTECHGI | 3.87*** | 0.82 | 0.05 | 2.27 | 5.48 |
| Return_SXXPFDBVGI | 0.23 | 0.77 | 0.00 | -1.30 | 1.75 |
| Return_SXXPRETLGI | -2.62*** | 0.27 | -0.11 | -3.15 | -2.09 |
| Return_SXXPTELCGI | -4.69*** | 0.68 | -0.08 | -6.03 | -3.35 |

Note *, ** and *** demonstrate that values are significant at the 10%, 5%, and 1% levels, respectively.

The coefficients in Table 3 depict the change in value for each return variable with respect to a 1% change in inflation rate in the Eurozone. From the results we can conclude that when the inflation rate rises, the price of ILBs goes up, with the highest coefficient for the 1-year ILBs. Likewise, the commodity prices of all four chosen commodities are positively correlated to inflation, where the commodity gold takes the lead. This is in agreement with the before-mentioned literature of (Valadkhani et al., 2022), where gold prices exhibit significant responses to the inflation rate. Contrary to our literature, the equity return indexes show a negative relation to inflation. Regarding stock returns, the results from literature were both contradictory and inconclusive, which gave incentive to specify per industry sector. The overall Stoxx 600 Europe gives a positive relation to inflation, while breaking up this index in different sectors gives divergent results. The sectors Health Care, Construction & Materials, Industrial Goods & Services, Financial Services, Technology and Food & Beverages show a positive relationship and the sectors Utilities, Real Estate, Energy, Telecommunications and Retail show a negative relation to inflation rate. Intuitively, the most surprising result is the negative coefficient in the Energy sector for the Stoxx 600 Europe, as the oil and gas prices rose through the roof in the Covid Crisis, which is also a period of high inflation. Nonetheless, we can see that the result is not significant, even at the 10% level. Likewise, the results for the sectors Health Care, Utilities and Food and Beverages are insignificant. All other results however, are significant, most even at the 1%-level.

The coefficients show that the change in inflation rate has a different effect on the behaviour of different asset classes. Not surprisingly following our literature review and general intuition, the null hypothesis under Hypothesis I can be rejected, since the different variables have a different reaction to the inflation rate on the basis of both sign and magnitude. Thus, there is a significant difference in the performance of different asset classes in mitigating inflation risk in the Eurozone.

**5.2 Results for portfolio optimisation**

The results from the regression model in table 3 show that the stock price variables from the Stoxx 600 Health Care, Utilities, Energy and Food and Beverages are insignificant. From this we can assume that the prices of these stocks are not significantly influenced by the inflation rate. However, these variables are not excluded from the portfolio optimisation process since this non-relation can prove to be beneficial in the diversification process. In this section, I want to establish a portfolio that mitigates inflation risk by conducting the portfolio optimisation process by Frazzini and Pedersen (2014) while correcting for inflation. Initial thought was to investigate the performance of asset classes by making a distinction between periods of high inflation and periods of low inflation. However, by the time you as an investor want to adapt to a certain high or low inflationary period, your current portfolio may have already taken a big hit. Therefore, I take into account the overall best performing portfolio over a timespan of 1 year. For the securities, I first formed a covariance table, which can be found in the appendix. Since it is extremely difficult for the average investor to short a stock, the process for portfolio optimisation used in both 5.2 and 5.3 had a no shorting constraint. The results for the portfolio that is corrected for inflation and thus has the highest return given the constraint of inflation rate is as follows:

**Table 4: Optimal portfolio allocation for mitigating inflation risk**

This table shows the optimal portfolio weight for the asset classes used throughout this paper. It optimises the Sharpe Ratio while taking into account the constraint of at least following the inflation rate.

| Securities | Weight | Return | Volatility | Min | Max | Total return |
|---|---|---|---|---|---|---|
| return_BEIGFTIndex | 0% | 1.77% | 2.14 | 0 | 100 | 0.00% |
| return_BEIG1TIndex | 0% | 2.17% | 4.56 | 0 | 100 | 0.00% |
| return_BEIG3TIndex | 0% | 2.23% | 2.99 | 0 | 100 | 0.00% |
| return_XAUCurncy | 25% | 8.85% | 14.73 | 0 | 100 | 2.21% |
| return_XAGCurncy | 0% | 10.79% | 26.86 | 0 | 100 | 0.00% |
| return_C1Comdty | 12% | 11.19% | 22.98 | 0 | 100 | 1.37% |
| return_HG1Comdty | 2% | 6.97% | 32.94 | 0 | 100 | 0.16% |
| return_ECMPANAEquity | 0% | 3.59% | 20.10 | 0 | 100 | 0.00% |
| return_IPRPNAEquity | 0% | 2.09% | 23.12 | 0 | 100 | 0.00% |
| return_SXXPIndex | 0% | 3.07% | 18.81 | 0 | 100 | 0.00% |
| return_SXXPHCARGIndex | 21% | 3.69% | 13.62 | 0 | 100 | 0.76% |
| return_SXXPBMATGIndex | 0% | 2.20% | 26.45 | 0 | 100 | 0.00% |
| return_SXXPREALGIndex | 0% | -5.38% | 13.47 | 0 | 100 | 0.00% |
| return_SXXPUTILGIndex | 0% | -0.98% | 12.01 | 0 | 100 | 0.00% |
| return_SXXPENERGIndex | 0% | -1.95% | 16.09 | 0 | 100 | 0.00% |
| return_SXXPINDUGIndex | 17% | 3.90% | 6.85 | 0 | 100 | 0.67% |
| return_SXXPFINLGIndex | 0% | 1.62% | 11.01 | 0 | 100 | 0.00% |
| return_SXXPFDBVGIndex | 0% | 2.91% | 8.94 | 0 | 100 | 0.00% |
| return_SXXPRETLGIndex | 23% | 4.69% | 8.27 | 0 | 100 | 1.07% |
| return_SXXPTELCGIndex | 0% | -0.28% | 8.39 | 0 | 100 | 0.00% |
| return_SXXPTECHGIndex | 0% | 0.03% | 0.81 | 0 | 100 | 0.00% |
| | | | | | | |
| **Portfolio** | 100% | 6.24% | 2.96% | | | |
| **Sharpe** | 2.11 | | | | | |

The optimal portfolio allocation to mitigate inflation risk is divided among 6 variables of the researched asset classes. It contains the commodities Gold, Corn and Silver and the stocks from Stoxx 600 Europe in Health Care, Industrials and Retail.

Gold is the most prominent in this portfolio, which is in line with the research of Valadkhani et al., (2022) where gold is seen as one of the best properties to hedge against inflation. Moreover, the sectors of health care, industrials and retail seem to perform well in mitigating inflation risk. This is mostly backed up by existing literature, such as Bouri et al. (2023), who find that the material sector is indeed highly linked to inflation. Moreover, Luintel & Paudyal (2006) find that stocks in the retail sector tend to outperform when looking at inflationary periods, which is also in accordance with our results Lastly, health care could be explained by the fact that for example the Covid pandemic taken into account for this research relied a lot on the health care sector. Due to the higher demand for health care and all that surrounds it during the crisis, the stock returns in this sector generally increased more than others. Combining this high inflationary period and the fact that it makes up a large part of this dataset, it would be expected that it would take up a part of the weight allocation.

If we compare the results in table 4 to the regression results in table 3, we can see that almost all variables that are included in the portfolio have a positive coefficient in the regression results. This can be derived from the fact that in this portfolio we want to follow the inflation rate as least as closely as possible while receiving the highest possible return. Thus we can conclude that in our portfolio it is highly likely that variables that show a positive relation to the inflation rate will be included, which is the case here. Nevertheless, there is one variable, namely Stoxx 600 Europe Retail sector, which shows a negative coefficient in table 3 and a positive weight in table 4. Rationale behind this would be that the portfolio might benefit from diversification effects and certain risk characteristics and return scheme of the specific variable in addition to the others. The variables with a positive relation to inflation and that are included in the portfolio show in comparison to others generally a high coefficient. This also means that when inflation goes down, the return in the portfolio will decrease by a significant amount as well. Therefore, inclusion of a variable with a negative relationship to inflation can benefit the overall return of the portfolio in all cases, mostly due to diminishing effects in low inflationary periods. In table 3, we can see that corn, copper and gold have the highest coefficient, which explains why these three variables make up a significant part of the portfolio. Likewise, the industry and health care sector of the Stoxx 600 Europe make up a large part. The presence of these variables with high coefficients thus explain the significant role the retail sector plays in the portfolio, the weight of its presence most likely offsetting the effects due to diversification. Moreover, we can see in table 4 that the weights in the portfolio are divided among variables that generate the highest returns, which is logical since we are looking for a portfolio that follows inflation while generating high returns, of course while also taking into account the associated risk.

Following these results, we can reject the null hypothesis stated under hypothesis II. Since through the process of obtaining the results several portfolios could be constructed that resulted in higher inflation risk. The allocation of the weights in table 4 resulted in the least inflation risk and thus mitigates inflation the best over our study time period. This allocation could be used for future reference in mitigating inflation risk, since over the time period of the last 18 years this has proven to be the most optimal allocation.

The results from this section were derived from keeping the inflation risk to a minimum in all of the time periods. However, to conclude whether there is a cost to inflation, we continue to the next section, where we derive the optimal portfolio allocation regardless of this inflation risk and compare the two cases.

### 5.3 Cost of mitigating inflation risk

Following the covariance matrix in the appendix, the portfolio optimisation excluding the inflation rate process resulted in the weight allocation as seen in table 5.

| Table 5: Optimal portfolio allocation, general case |
|---|

This table shows the optimal portfolio weight for the asset classes used throughout this paper. It does not take into account the inflation rate, but it has assigned weights to recreate a portfolio with the most optimal Sharpe ratio and thus the best risk/return relationship.

| Securities | Weight | Return | Volatility | Min | Max | Total return |
|---|---|---|---|---|---|---|
| return_BEIGFTIndex | 0% | 1.77% | 2.14 | 0 | 100 | 0.00% |
| return_BEIG1TIndex | 0% | 2.17% | 4.56 | 0 | 100 | 0.00% |
| return_BEIG3TIndex | 0% | 2.23% | 2.99 | 0 | 100 | 0.00% |
| return_XAUCurncy | 57% | 8.85% | 14.73 | 0 | 100 | 5.07% |
| return_XAGCurncy | 1% | 10.79% | 26.86 | 0 | 100 | 0.08% |
| return_C1Comdty | 0% | 11.19% | 22.98 | 0 | 100 | 0.00% |
| return_HG1Comdty | 1% | 6.97% | 32.94 | 0 | 100 | 0.05% |
| return_ECMPANAEquity | 0% | 3.59% | 20.10 | 0 | 100 | 0.00% |
| return_IPRPNAEquity | 0% | 2.09% | 23.12 | 0 | 100 | 0.00% |
| return_SXXPIndex | 0% | 3.07% | 18.81 | 0 | 100 | 0.00% |
| return_SXXPHCARGIndex | 10% | 3.69% | 13.62 | 0 | 100 | 0.38% |
| return_SXXPBMATGIndex | 2% | 2.20% | 26.45 | 0 | 100 | 0.03% |
| return_SXXPREALGIndex | 0% | -5.38% | 13.47 | 0 | 100 | 0.00% |
| return_SXXPUTILGIndex | 0% | -0.98% | 12.01 | 0 | 100 | 0.00% |
| return_SXXPENERGIndex | 3% | -1.95% | 16.09 | 0 | 100 | -0.06% |
| return_SXXPINDUGIndex | 9% | 3.90% | 6.85 | 0 | 100 | 0.34% |
| return_SXXPFINLGIndex | 8% | 1.62% | 11.01 | 0 | 100 | 0.13% |
| return_SXXPFDBVGIndex | 0% | 2.91% | 8.94 | 0 | 100 | 0.01% |
| return_SXXPRETLGIndex | 7% | 4.69% | 8.27 | 0 | 100 | 0.31% |
| return_SXXPTELCGIndex | 2% | -0.28% | 8.39 | 0 | 100 | -0.01% |
| return_SXXPTECHGIndex | 0% | 0.03% | 0.81 | 0 | 100 | 0.00% |
| | | | | | | |
| **Portfolio** | 100% | 6.33% | 2.56% | | | |
| **Sharpe** | 2.47 | | | | | |

Table 5, shows the optimal portfolio weights while not taking into account the inflation risk, but solely looks at the portfolio that optimises the Sharpe ratio. The Sharpe ratio displays the return of an investment with its associated risk. By means of maximising the Sharpe ratio in this portfolio optimisation process, we find the weight allocation that gives the highest return with the minimal standard deviation. As can be seen in the table, the Sharpe Ratio for this portfolio is equal to 2.47 and thus considered to be a very good investment. The portfolio consists for the larger part of the commodity Gold and moreover of Health Care, Industrials, Financial, Retail, Energy and Telecommunication stocks and the commodities Silver and Corn, in descending order.

If we compare the results under 5.3 to the portfolio weights allocation in 5.2, we find that the Sharpe Ratio under the scenario where we mitigate inflation is lower than when we do not take this risk into account. This means that if you as an investor try to minimise this risk, it will result in a lower return on your investment given the risk level. The difference in allocation presents a shift from 2.47 in the normal case and 2.11 in the risk-adjusted case. The return in the risk-adjusted case is lower, namely 6.24% as opposed to 6.33%.

**Table 6: Portfolio comparison**

This table shows the difference in portfolio returns, where 'Portfolio 1' stands for the portfolio that mitigates inflation risk and 'Portfolio 2' stands for the portfolio without taking into account inflation risk.

| Date | Portfolio 1 | Portfolio 2 | CPI | | T-test |
|---|---|---|---|---|---|
| 30/12/2005 | 4.09 | 3.24 | 2.3 | | 0.57** |
| 31/01/2006 | 2.00 | 6.10 | 2.3 | | |
| 28/02/2006 | 0.18 | -0.88 | 2.4 | | |
| 31/03/2006 | 1.65 | 2.82 | 2.4 | | |
| 28/04/2006 | 4.25 | 7.55 | 2.2 | | |
| 31/05/2006 | 1.29 | -0.69 | 2.4 | | |
| 30/06/2006 | -0.94 | -2.41 | 2.5 | | |
| 31/07/2006 | 1.27 | 2.09 | 2.5 | | |
| … | … | … | … | | |
| 31/10/2022 | 0.51 | -0.67 | 9.9 | | |
| 30/11/2022 | 2.33 | 5.00 | 10.6 | | |
| 30/12/2022 | 2.13 | 2.01 | 10.1 | | |
| 31/01/2023 | 2.92 | 3.38 | 9.2 | | |
| 28/02/2023 | -2.24 | -3.04 | 8.6 | | |
| 31/03/2023 | 4.05 | 4.65 | 8.5 | | |

The table above shows the difference in portfolio returns of the 2 aforementioned cases. Portfolio 1 is equal to the portfolio in table 4 and portfolio 2 is equal to the portfolio mentioned in table 5. We can see that in most cases the returns of portfolio 1 are lower than that of portfolio 2, which we expect since we concluded that there is a cost to mitigating inflation risk in the form of lower returns. However, what we also see is that, for example at date 28/02/2006 as can be seen in table 6, when inflation rises and the returns of portfolio 2 is negative, the portfolio that we created that mitigates inflation risk is showing positive returns. The T-test depicted on the right of the table shows that the difference between portfolio returns over the time period is statistically different from zero at the 5%-level. Moreover, in time periods where returns of both portfolios are negative, we see that in almost all cases portfolio 1 shows a less negative return than portfolio 2, meaning negative shocks to returns in this portfolio are also lower.

## 6. CONCLUSION

This paper examined the relationship between the European inflation rate and several asset classes: Stocks, bonds, real estate and commodities. The aim of this paper was to investigate whether it is possible to provide a hedge against inflation by investing in several asset classes. Moreover, its main goal was to research whether there is a cost to mitigating inflation and its magnitude.

The results of this paper show that the price of many of the inspected variables are significantly influenced by the change in inflation rate. The portfolio that performed best in minimising inflation risk consists of the commodity gold, the Stoxx 600 Europe Retail, the Stoxx 600 Health Care, the Stoxx 600 Industrials, the commodity corn and the commodity copper, in this order. This result is for the larger part as expected while diving into existing literature. The optimal allocation strategy when not taking into account the inflation risk, provided different results. This portfolio consists of the commodity gold, Stoxx 600 Health Care, Stoxx 600 Industrials, Stoxx 600 Financials, Stoxx 600 Retail, Stoxx 600 Energy Stoxx 600 Telecommunication, the commodity silver and the commodity corn. Although there is some overlap in asset classes and variables used in the portfolios, there are differences in variables and magnitude of weight allocation. Consequently, there is a difference in the return and Sharpe Ratio of both portfolios. The weight allocation of the normal portfolio as opposed to the inflation risk-adjusted portfolio provides higher average returns and a higher Sharpe ratio, meaning that there is indeed a cost to inflation.

However, real returns are not the only means of assessing the performance of a portfolio. An investor's individual risk level and exposure to what kind of risks need to be taken into account when establishing a suitable portfolio allocation tendered to personal preferences. As can be seen in the results, the difference between returns comes down to a relative loss of 0.09%, which might be worth taking the loss for some investors.

This paper battles several limitations, such as exclusion of several other asset classes, for example currencies or swaps. Moreover, other factors that could influence the relationship between inflation and the asset classes are not taken into account. Take for example interest rates or other economic indicators or market conditions. Future research could investigate these relationships and can include more variables into the research. Moreover, the European inflation rate as established by the ECB does not fully represent the purchasing power in separate European countries. Further research could dive deeper into this material. The weight allocation of the portfolios in this paper is based on historical data, future research could focus on using this historical data for backtesting and making a predictive model to allocate portfolio weights. For now the conclusion remains, there is indeed a cost to inflation

# A. APPENDIX

## 1. Explanation of variables

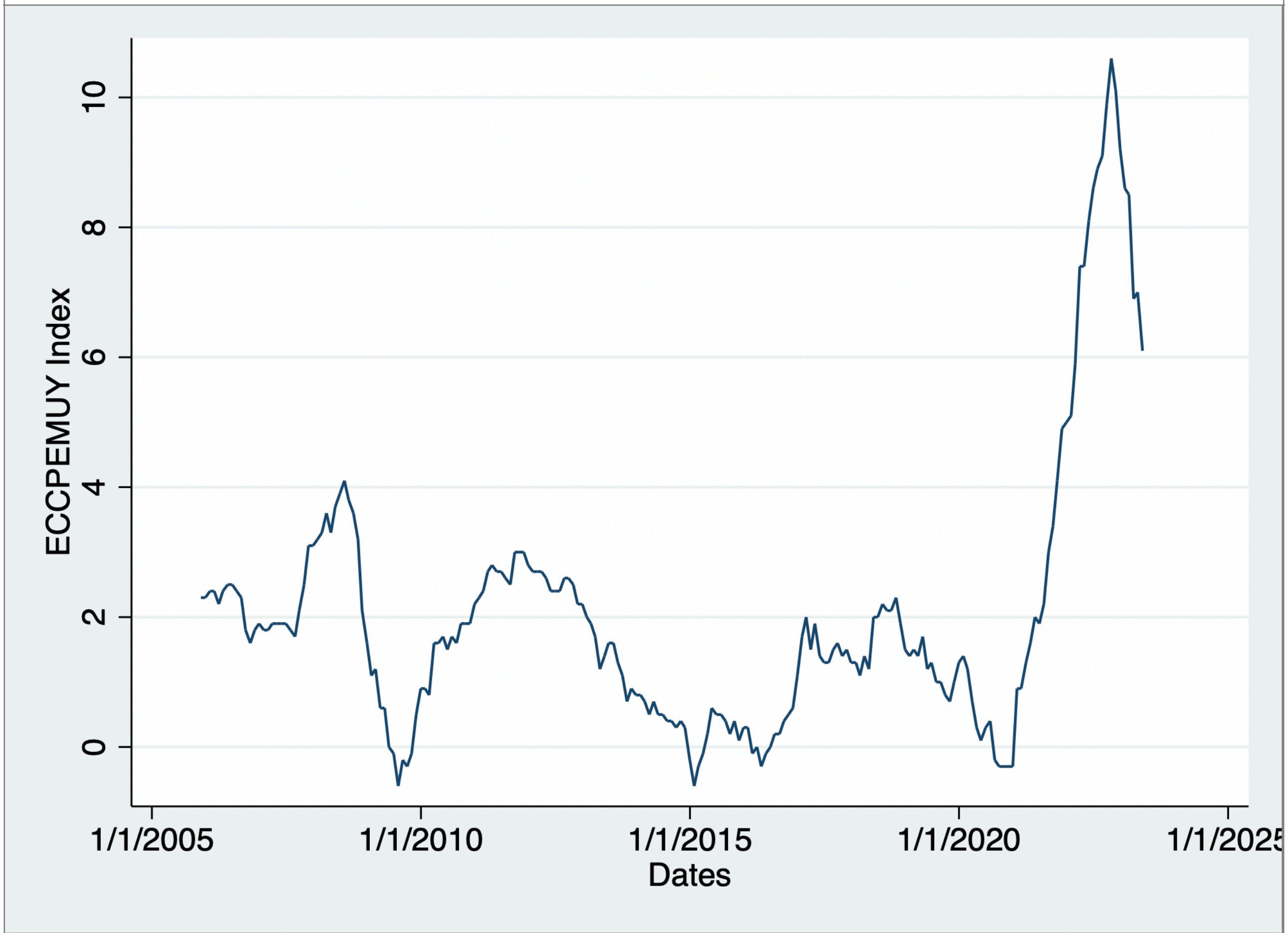
**Table 6: Explanation of variables**

This table provides an overview of the variables named throughout this thesis grouped by asset class and additional information

| Asset Class | Variable | Information |
|---|---|---|
| **Inflation-Linked Bonds** | BEIGFTIndex | Inflation-Linked bond, Eurozone, 5 year maturity |
| | BEIG1TIndex | Inflation-Linked bond, Eurozone, 1 year maturity |
| | BEIG3TIndex | Inflation-Linked bond, Eurozone, 3 year maturity |
| **Commodities** | XAUCurncy | Gold |
| | XAGCurncy | Silver |
| | C1Comdty | Corn |
| | HG1Comdty | Copper |
| **Real Estate** | ECMPANAEquity | European Property Fund |
| | IPRPNAEquity | Commercial Real Estate European Union |
| **Stocks** | SXXPHCARGIndex | Stoxx 600 Europe Health Care |
| | SXXPBMATGIndex | Stoxx 600 Europe Materials |
| | SXXPREALGIndex | Stoxx 600 Europe Real Estate |
| | SXXPUTILGIndex | Stoxx 600 Europe Utilities |
| | SXXPENERGIndex | Stoxx 600 Europe Energy |
| | SXXPINDUGIndex | Stoxx 600 Europe Industrials |
| | SXXPFINLGIndex | Stoxx 600 Europe Financials |
| | SXXPTECHGIndex | Stoxx 600 Europe Technology |
| | SXXPFDBVGIndex | Stoxx 600 Europe Food & Beverages |
| | SXXPRETLGIndex | Stoxx 600 Europe Retail |
| | SXXPTELCGIndex | Stoxx 600 Europe Telecommunications |
| | SXXPIndex | Total Stoxx 600 Europe |
| **Inflation rate** | ECCPEMUYIndex | Inflation Rate (CPI) in the Eurozone (by the ECB) |

2. Inflation rate graphically depicted over time

| **Graph 1: European Inflation rate over time** |
| --- |
| The inflation rate in the Eurozone dating back until 2005 until present day. |



3. Covariance table

**Table 7: Covariance Matrix of the Asset Classes**

| | EC CP | retu rn_ | ret urn | ret urn | ret urn | retu rn_ | retu rn_ | retu rn_ | retur n_H | retur n_E | retu rn_I | retu rn_ | retu rn_ | retu rn_ | ret urn | retu rn_ | ret urn | ret urn | ret urn | ret urn | retu rn_ | retu rn_ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ECCPEMUYIndex | 4,52 | | | | | | | | | | | | | | | | | | | | | |
| return_SXXPIndex | -0,91 | 18,38 | | | | | | | | | | | | | | | | | | | | |
| return_BEIGFTIndex | 0,09 | 0,73 | 0,42 | | | | | | | | | | | | | | | | | | | |
| return_BEIG1TIndex | -0,40 | 2,91 | 0,75 | 2,87 | | | | | | | | | | | | | | | | | | |
| return_BEIG3TIndex | -0,15 | 1,81 | 0,65 | 1,91 | 1,40 | | | | | | | | | | | | | | | | | |
| return_XAUCurncy | -0,17 | -0,44 | 0,47 | 1,44 | 0,99 | 24,52 | | | | | | | | | | | | | | | | |
| return_XAGCurncy | -0,89 | 6,75 | 1,05 | 2,64 | 1,84 | 36,63 | 87,61 | | | | | | | | | | | | | | | |
| return_C1Comdty | -0,45 | 2,76 | 0,91 | 0,29 | 0,68 | 8,63 | 22,24 | 81,97 | | | | | | | | | | | | | | |
| return_HG1Comdty | -1,67 | 12,91 | 1,02 | 1,59 | 1,33 | 11,63 | 29,39 | 14,79 | 58,90 | | | | | | | | | | | | | |
| return_ECMPANAEquity | -0,93 | 22,26 | 1,72 | 5,00 | 3,52 | 1,42 | 12,21 | 9,64 | 17,47 | 73,44 | | | | | | | | | | | | |
| return_IPRPNAEquity | -2,71 | 17,73 | 0,96 | 4,64 | 2,91 | 3,03 | 10,69 | 6,29 | 13,28 | 32,76 | 31,44 | | | | | | | | | | | |
| return_SXXPHCARGInd ex | 0,58 | -8,82 | -0,34 | -1,14 | -0,74 | -1,19 | -6,31 | -4,46 | -11,92 | -12,91 | -9,18 | 12,29 | | | | | | | | | | |
| return_SXXPBMATGInd ex | -1,05 | 5,04 | 0,43 | -0,09 | 0,11 | 9,57 | 22,64 | 11,25 | 27,84 | 3,61 | 3,16 | -6,79 | 34,32 | | | | | | | | | |
| return_SXXPREALGInd ex | -0,94 | -0,08 | -0,15 | -0,18 | -0,11 | 1,43 | 0,21 | -4,17 | 1,33 | 2,68 | 2,08 | -0,25 | -0,92 | 12,99 | | | | | | | | |
| return_SXXPUTILGInde x | 0,37 | -3,68 | -0,04 | 0,32 | 0,12 | 1,91 | 0,97 | 0,42 | -6,51 | -1,77 | -1,32 | 1,87 | -3,33 | -0,69 | 8,83 | | | | | | | |
| return_SXXPENERGInd ex | 1,07 | -0,72 | 0,33 | -1,31 | -0,46 | -0,91 | 1,19 | 3,83 | 2,77 | 1,16 | -4,13 | -1,45 | 7,55 | -0,84 | -0,06 | 16,74 | | | | | | |
| return_SXXPINDUGInd ex | -0,34 | 3,39 | 0,21 | 0,94 | 0,60 | 1,69 | 4,49 | -0,51 | 3,61 | 3,06 | 3,71 | -3,33 | 2,26 | 0,49 | -1,73 | -1,85 | 4,22 | | | | | |
| return_SXXPFINLGInde x | -0,78 | 3,44 | -0,01 | 0,41 | 0,14 | -0,16 | 2,55 | 1,77 | 4,35 | 5,29 | 4,85 | -2,76 | 2,10 | -0,19 | -1,32 | -2,62 | 1,11 | 5,41 | | | | |
| return_SXXPFDBVGInd ex | 0,03 | -7,20 | -0,19 | -0,52 | -0,30 | 0,78 | -3,55 | -3,27 | -10,07 | -8,53 | -5,31 | 6,66 | -6,81 | -0,15 | 2,24 | -1,16 | -2,00 | -2,56 | 9,57 | | | |
| return_SXXPRETLGInd ex | -0,33 | -1,46 | -0,31 | -0,25 | -0,20 | 0,09 | -3,30 | -4,72 | -4,00 | -2,09 | -0,40 | 0,92 | -4,04 | 2,01 | -0,18 | -1,52 | -0,30 | -0,75 | 2,26 | 9,22 | | |
| return_SXXPTELCGInd ex | -0,06 | -5,87 | -0,26 | -0,60 | -0,35 | -0,59 | -6,31 | -0,27 | -9,77 | -4,30 | -5,58 | 3,32 | -6,78 | 0,44 | 3,41 | 1,13 | -2,77 | -2,84 | 3,07 | 0,97 | 11,93 | |
| return_SXXPTECHGInd ex | -0,40 | 2,06 | -0,11 | 0,72 | 0,29 | -0,58 | 2,12 | -4,54 | 0,67 | -1,85 | 1,48 | -1,02 | -0,44 | 0,21 | -1,13 | -3,77 | 2,16 | 1,56 | -1,39 | 0,45 | -2,38 | 10,46 |

# REFERENCE LIST

Bardong, F., & Lehnert, T. (2009). TIPS, inflation expectations, and the financial crisis. Journal of Fixed Income, 19(1), 7-26.

Barnes, M. L., Bodie, Z., Triest, R. K., & Wang, J. C. (2010). A TIPS Scorecard: Are They Accomplishing Their Objectives?. Financial Analysts Journal, 66(5), 68-84.

Bekaert, G., & Wang, X. (2010). Inflation risk and the inflation risk premium. Economic Policy, 25(64), 755-806.

Boudoukh, J., & Richardson, M. (1993). Stock returns and inflation: A long-horizon perspective. The American economic review, 83(5), 1346-1355.

Bouri, E., Nekhili, R., Kinateder, H., & Choudhury, T. (2023). Expected inflation and US stock sector indices: A dynamic time-scale tale from inflationary and deflationary crisis periods. Finance Research Letters, 103845.

Boyd, J. H., Levine, R., & Smith, B. D. (2001). The impact of inflation on financial sector performance. Journal of monetary Economics, 47(2), 221-248.

Chopra, M., Mehta, C., & Srivastava, A. (2021). Inflation-linked bonds as a separate asset class: Evidence from emerging and developed markets. Global Business Review, 22(1), 219-235.

Cussen, M. (2022, January 25). Top 5 Ways to Hedge Against Inflation. Investopedia. https://www.investopedia.com/articles/investing/060916/top-5-ways-hedge-against-inflation.asp

Dempster, N., & Artigas, J. C. (2010). Gold: Inflation hedge and long-term strategic asset. The Journal of Wealth Management, 13(2), 69.

European Central Bank. (2021, November 10). Two per cent inflation target. https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html

European Investors VEB. (2022, March 29). Inflation-linked obligaties. VEB.net. https://www.veb.net/obligaties/inflation-linked-obligaties

International Monetary Fund. (2023). World economic outlook update, January 2023. https://www.imf.org/en/Publications/WEO/Issues/2023/01/31/world-economic-outlook-update-january-2023

Fama, E. F. (1981). Stock returns, real activity, inflation, and money. The American economic review, 71(4), 545-565

González, M. D. L. O., Jareño, F., & Skinner, F. S. (2016). Interest and inflation risk: Investor behavior. Frontiers in psychology, 7, 390.

Halton, C. (2022) Inflation risk. Retrieved April 10, 2023, from https://www.investopedia.com/terms/i/inflationrisk.asp

Jones, E. (2016). Competitiveness and the European financial crisis. New York, Oxford University Press.

Kang, J., & Pflueger, C. E. (2015). Inflation risk in corporate bonds. The journal of finance, 70(1), 115-162.

Morgan, D. P., & Stranahan, H. A. (2012). The Fed's Enhanced Communication Strategy and the Behavior of Financial Market Participants. Federal Reserve System. Retrieved April 10, 2023, from https://www.federalreserve.gov/pubs/feds/2012/201206/201206pap.pdf

Nawrocki, D. N., & Evensky, H. (2003). Dynamic asset allocation during different inflation scenarios. Journal of Financial Planning, 16(10), 42.

Reichling, D. (2022). Stocks, inflation, and market power. Investigating stocks' inflation hedging ability in the European market

Royal, J. (2022, February 15). Inflation hedges to protect against rising prices. Bankrate.com. https://www.bankrate.com/investing/inflation-hedges-to-protect-against-rising-prices/

Salisu, A. A., Raheem, I. D., & Ndako, U. B. (2020). The inflation hedging properties of gold, stocks and real estate: A comparative analysis. Resources Policy, 66, 101605.

Spierdijk, L., & Umar, Z. (2015). Stocks, bonds, T-bills and inflation hedging: From great moderation to great recession. Journal of Economics and Business, 79, 1-37.

Tiwari, A. K., Cunado, J., Gupta, R., & Wohar, M. E. (2018). Are stock returns an inflation hedge for the UK? Evidence from a wavelet analysis using over three centuries of data. Studies in Nonlinear Dynamics & Econometrics, 23(3), 20170049

Valadkhani, A., Nguyen, J., & Chiah, M. (2022). When is gold an effective hedge against inflation?. Resources Policy, 79, 103009

Wydler, D. (1989). Swiss stocks, bonds, and inflation, 1926-1987. Journal of Portfolio Management, 15(2), 27

Zaremba, A., Umar, Z., & Mikutowski, M. (2019). Inflation hedging with commodities: A wavelet analysis of seven centuries worth of data. Economics Letters, 181, 90-94.

Zhang, A., & Ewald, C. O. (2010). Optimal investment for a pension fund under inflation risk. Mathematical Methods of Operations Research, 71(2), 353.