Erasmus University Rotterdam

Master Thesis Financial Economics

Defending Against Inflation

Which asset classes are the best inflation hedges?

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Abstract

This paper investigates how an investor can hedge inflation with different asset classes. Because an investor has to forecast the inflation rate to see in which asset he or she has to invest, we first start with selecting a model to forecast inflation. With that we will perform multiple regressions on the quarterly and yearly horizon to find out if we can hedge the expected and unexpected inflation with stocks, commodities, real estate and/or currencies. Because we expect that the relations are time varying, we also look at the results through time. Our results show that the best choice to hedge expected and unexpected inflation would be energy related commodities and gold, though these results should be taken with some caution because the relations are not stable through time.

Keywords: Inflation, hedging, assets, stocks, commodities, real estate, currencies

1. Introduction

While US inflation is picking up, the policy of the central bank of the US, the FED, remains loose. Inflation is running over 2% annually, but the nominal interest rate (the Federal Funds Rate) is kept close to zero, and thus real interest rates are negative. Besides that, and probably due to the zero interest rate policy of the FED, the US money supply (M1 and M2) is growing at a fast pace. Milton and Schwartz (1963) argued that an easy money policy and a growing money stock, like we are experiencing now, are accompanied by inflation. So future inflation expectations are rising.

Intuitively, in an inflationary environment, where the purchasing power of the home currency is diminishing, investors, and perhaps even savers, want to change their cash into assets that are a hedge against inflation. The US government is providing inflation linked bonds, but commodities, real estate and stocks are tangible assets and are perceived as a hedge against inflation. Also strong foreign currencies can be purchased to hedge the diminishing value of the home currency. So which asset is the best inflation hedge?

Although this last question has been answered in existing literature, we have some contributions to the relevant literature. First of all, where in existing literature only 1 or sometimes 2 proxies for expected inflation is used, we use multiple proxies and look for the best way to forecast inflation, which is needed for our research. Secondly we don't use every asset classes as a whole, but also divide them in smaller groups. For example commodities are split in to different kinds of commodities. Third, because we expect that the results are time-varying and thus not stable, we also show how the results vary through time.

We start with section 2, where we elaborate more on the theory behind using assets as an inflation hedge and also describe the relevant literature that is written about this subject. After that we discuss in section 3 the data we are going to use. Section 4 shows the methodology we use for our research. Because we have to forecast the inflation rate, we have included section 5, where we show the best way to forecast inflation. In section 6 we will show and discuss our results. Section 7 shows our results through time and we end with the conclusion in section 8.

2. Theory

2.1 The Fisher Effect

According to Fisher (1930), the nominal interest rate can be expresses as the sum of an expected inflation rate and an expected real return. When the market is efficient, and thus a rational processor of the information that is available at $t-1$, it will set the price of a given asset j so that the expected nominal return on $t = 0$ equals sum of the expected inflation rate and expected real return, or;

$$E(R_{jt}) = E(\tau_{jt} \mid \phi_{t-1}) + E(\pi_t \mid \phi_{t-1}) + \varepsilon_{jt} \tag{2.1}$$

where $E(R_{jt})$ is the nominal return on asset j from $t-1$ to t, $E(\tau_{jt} \mid \phi_{t-1})$ is the expected real return on asset j based on the information ϕ_{t-1} available at $t-1$and $E(\pi_t \mid \phi_{t-1})$ is the expected inflation rate based again on the information ϕ_{t-1} available at $t-1$. Thus the markets sets the asset price of j at $t-1$, based on the information available, so that the expected rate of return is the sum of the expected real return and the expected rate of inflation.

Fisher also suggested that the real and monetary sectors of economy are largely independent, and thus that expected inflation and expected return are unrelated. Given this assumption, Fama and Schwert (1977) argued that it's possible to study the relationship between expected nominal returns and expected inflation, without building a model for the expected real returns.

2.2 Theory and Relevant Literature

Because stocks are a claim against real assets like factories, equipment and inventories, stocks are considered as an hedge against inflation. However contrary to this believe, most literature suggests that the relation between inflation and stock returns is negative. For example, Bodie (1976) used a annual, quarterly and monthly holding period during the 1953-1972 period and found that stocks are negatively related to both expected and expected inflation. Moreover the author states that to use stocks as an inflation hedge, one must sell them short. More evidence supporting this came from Lintner (1975) and

Nelson (1976). Further research done by Fama & Schwert (1977), Gultekin (1983) and Barnes et al (1999) also showed that stock returns are negatively correlated with both expected and unexpected inflation.

A possible explanation was given by Fama (1965); he argued that due to the adverse effects of inflation on real economic activity, the relation is negative. This is the so-called proxy effect. Moreover, Fama (1981) argued that because unexpected inflation is related to negative shocks in aggregate output, and negative shocks are bad for equities, equities and unexpected inflation should be negatively correlated.

However by increasing the holding period or investment horizon to 5 years, Boudoukh & Richardson (1993) found for US and UK stocks found a positive relation between inflation and stock returns. Although the correlation between US and UK stocks was relatively low, they found similar results in both countries. However later on, by applying a VAR aprooach, Engsted & Tanggaard (2002) tried to replicate the results from Boudoukh & Richardson (1993) for US stocks but found in contrary to the results from Boudoukh & Richardson (1993) that by increasing the horizon the relationship between inflation and stock returns weakens.

So perhaps commodities would be a better choice; they are directly linked with inflation. When the price of commodities increases, prices in general increases and thus inflation increases. Commodities however seems to be highly speculative, mainly due to leverage. When buying a commodity contract the margin that has to be paid is very low, in many cases as little as 5-15%. However as suggested by Greer (1978), when the leverage factor is removed, commodities are not riskier than stocks. In fact it seems that a diversified commodity basket is less risky than a diversified basket of stocks.

Based on return, risk and liquidity, Bird (1984) researched if commodities are a better hedge against inflation than other asset classes. He concluded that during the 1959-1980 period, commodities were ranked intermediately, but showed good performance during the 1973-1980, indicating that the relation is not stable. According to Herbst (1985) hedging inflation with a small number of futures is not practicable and feasible. Furthermore, it seems that price changes in commodities are not adequately reflected in inflation changes. Taxes, wages, rents, services, manufactured goods and other excluded commodities are probably more influencing changes in inflation than commodity futures. However, investing

in a commodity basket, like the Goldman Sachs Commodity Index (GSCI), should give better results, as argued by Lummer and Siegel (1993). They stated that investors who expect a high probability of rising inflation should hedge this by investing in the GSCI.

Also real estate should exhibit some hedge against inflation; when prices in general are increasing, we can expect that real estate prices will also increase. By using real house prices, and not some kind of proxy like most other researchers have done, Hartzell et al (1987) showed that real estate tend to be a full hedge against both expected and unexpected inflation during the 1973-1983 period. In line with this research, Miles & Mahoney (1997) showed with a 10 year investment horizon that commercial real estate is a meaningful hedge against unexpected inflation. Also Rubens et al (1989) found similar results.

Another way to invest in real estate is through Real Estate Investment Trusts (REIT), which are stock listed entities that invest in real estate. Most studies, like that from Murphy & Kleiman (1989), Park et al (1990) and Gyourko and Keim (1992), argued that REITs have a large equity component, and thus behave with regular stocks, so that REITs are also negatively correlated with inflation. A more recent study done by Adrangi et al (2004) argued that although this equity component is declining, REITs are still not a good hedge against inflation.

Gold is perceived as an inflation hedge and is becoming a more and more attractive asset because it has been rising steadily from 2001. During the inflationary seventies gold rose spectacularly, indicating it was some kind of safe-haven against the diminishing US dollar. However as Worthington and Pahlavani (2007) argued, the quality of the hedge depends on a stable long term relationship between inflation and the gold price. They divided their long research period (1875-2006) in several smaller periods due to structural changes in both the gold market and the measurement of the inflation rate, and found that the most significant changes occurred when the gold standard was closed and during the inflationary seventies. By incorporating these breaks, their results suggests that gold is a inflation hedge in the post-war and post-1970s period.

More evidence indicating that gold is an inflation hedge was found by Ghosh et al (2002). Their results, found by performing a cointegration regression during the 1976-1999

period, indicated that gold can be regarded as a long term inflation hedge. However on the short term, the gold price seems to be dominated by other influences, for example the convenience yield, leasing rate and of course the supply and demand dynamics.

A possible explanation for gold as an inflation hedge was given by Capie et al (2005); as gold cannot be produced by the authorities that produce, or print, currencies like the US Dollar, gold cannot be debased. Authorities can increase the money supply, diminishing the home currency and creating inflation, but cannot increase the supply of gold. This would thus indicate that gold is some kind of safe-haven.

Domestic inflation and the value of the home currency are correlated in two ways. First, when the money supply increases, it will diminish the value of the home currency because there is more supply, creating inflation (see for example Frankel (1979)). Secondly when the value of the home currency diminish, domestic produced goods will be cheaper on the world market, leading to higher exports and thus more economic growth, which will accelerate inflation (see for example Kahn (1987)). Although it's domestic inflation and the home currency are negatively related (see Kim (1998)), there is no research performed on the possibility that foreign currencies would be a hedge against domestic inflation.

We have selected three papers that we explain in more detail because they are doing almost the same as we have done; looking at more asset classes.

For the 1953-1971 period, Fama & Schwert (1977) looked at the relation between asset returns and the expected and unexpected inflation rate. They used the interest rate on a treasury bill as the expected inflation rate. The assets chosen were an equally weighted portfolio of all New York Stock Exchange (NYSE) stocks, an value weighted portfolio of all NYSE stocks and the return on privately held real estate (measured as the Home Purchase Price component of the CPI). Their results are indicating that stocks are negatively related to the expected inflation rate and, although less consistent, also to unexpected inflation rate. Thus contrary to the Fischer effect stocks seems to be a bad choice when protection yourself against inflation. Private real estate however, seems to be a complete hedge against both the expected and unexpected inflation rate. However it should be noted, as the authors do, that the relation for private real estate is spuriously because it takes one to three months before the actual transactions are reflected in the index.

Froot (1995) went a step further; he created pre-existing portfolios of stocks (foreign and domestic), bonds (foreign and domestic), currencies and a diversified one, and calculated the optimal inflation hedge ratio, where also the variation of the portfolios were taken into account. Adding assets can increase the portfolio variation and thus this would increase the portfolios risk, so adding assets that hedge inflation is not always a good choice. First of all the exposures of the pre-existing portfolios on inflation and unexpected inflation were calculated during the 1973-1993 period. The unexpected inflation rate is calculated by taking the difference between the actual inflation rate and the expected inflation rate. The latter is calculated by taking the past inflation rate and the US treasury bill interest rate. With the exception of the currencies portfolio, all other portfolios showed negative exposures to inflation. For unexpected inflation, all portfolios showed negative relations. After that the author added the Goldman Sachs Commodity Index (GSCI), the Commodities Research Bureau Spot Index (CRB), Gold, Oil, an index of primarily commodity producing companies stocks, two REIT indices (S&P sub index and the index form the Evaluation Associates) and a proxy for real estate prices (namely monthly survey series of value of residence properties), to see which asset can protect against inflation and lowers the variance of the portfolio. The author concludes that commodities with a high energy component, for example oil itself or the GSCI which has a large stake in oil, exhibit strong inflation hedging properties as it reduce the total portfolio variance significantly. However gold, the CRB Index, commodity linked stocks and particularly real estate indexes exhibit weak hedges. Due to the negative correlation between stocks and correlation, it seems that commodities are in general better hedges against inflation than stocks.

More recent research is done by Gorton & Rouwenhorst (2006). They simply started with looking at the monthly, quarterly, yearly and the 5 year correlation between stocks (the S&P500), commodity futures (an equally weighted performance index), bonds (the Ibbotson corporate bond total return index) and inflation (CPI) between 1959-2004. The correlations between stocks and inflation for all four holding periods were negative, however only significant at a 5% level for the monthly and quarterly holding period. On the monthly horizon the correlation was -0.15, and on the quarterly horizon -0.19. Also for bonds, all correlations were negative and with the exception of the 5 year holding period all significant. Commodities however showed positive correlations with inflation on all horizons. The one year and 5 year holding period showed significant correlations of 0.29 and 0.45 respectively.

For all three asset classes it seems that the correlations tend to increase with the holding period. By using the 90-day T-bill yield as expected inflation rate, the authors also looked at the quarterly correlations between stocks, bonds, commodity futures, the change in expected inflation and unexpected inflation. The results suggest that both stocks and bonds have significant negative correlations with the change in expected inflation (-0.10 and -0.51 respectively) and unexpected inflation (-0.23 and -0.35 respectively). On the other hand, commodity futures show significant positive correlations with both the change in expected inflation (0.22) and unexpected inflation (0.25).

3. Data

All of our data is obtained through Datastream. The data is gathered on a monthly basis because we will use monthly overlapping data, and than transformed into quarterly and yearly returns. By using monthly overlapping data we can get more out of the data we use. For example, normally when using a quarterly horizon, you have the periods January – March, April – June and so on, but by using monthly overlapping data, you get January – March, February – April, March – May and so on. So by doing so, we increased the number of observations.

For inflation the Consumer Price Index (CPI) is used, which is defined by the United States Bureau of Labor Statistics. The CPI measures the average change in prices of a basket of goods and services for consumers. For expected inflation, we have obtained the University of Michigan Survey and the US Consumer Survey. Both surveys asks a certain number of households/consumers to give their inflation expectations for the next year. For two of our expected inflation models we used two interest rates; on the quarterly horizon we used the 3 month treasury bill and for the yearly horizon the one year treasury bill.

For stocks we have included first the broadest, most liquid index, the S&P 500, which holds the 500 biggest companies listed in the US. Because most research showed that domestic stocks are negatively correlated with inflation, we have also included some foreign indices. We started with the MSCI World Index, which includes over 6000 stocks from all the developed markets in the world. However because for example Froot (1995) stated that inflation in the developed countries is highly correlated, we have also included the MSCI AC World Index. This index incorporates both developed and emerging markets. In both indices

the US has a high weighting, for example in the MSCI World around 48%, and we have thus also included the MSCI World and MSCI AC World without the US, to see if foreign stocks can be used as a hedge against domestic inflation. Because both indices are normally denominated in USD, we have also included both indices that are denominated in the home currencies of all countries that are included. Inflation is negatively correlated with the home currency, and thus some exposure to both foreign stocks and currencies may be a good hedge against inflation.

For commodities we have included 3 indices; the Commodity Research Bureau (CRB) index, the Goldman Sachs Commodity Index (GSCI) and the Continuous Commodity Index (CCI). The main difference can be found in the difference of the weightings used; the CCI has a equal weighing for each commodity in the index, the CRB had an equal weighting until 2005 (after 2005 oil got a weighting of 23%) and the GSCI uses a weighting based on the worldwide commodity production). So the GSCI gives more weight to more important commodities like oil. Because it may be possible that certain group of commodities, like energy or agriculture, may offer a better protection against inflation than all commodities combined, we have also included the sub-indices of the GSCI and CCI. The GSCI has the following sub-indices; Energy, Precious Metals, Industrial Metals, Agriculture and Livestock. The CCI has: Energy, Grains & Oilseeds, Industrials, Precious Metals, Livestock and Softs. Just like the indices, the sub-indices of the GSCI and CCI differ in weighting; the CCI has an equal weighting where the GSCI has not. We have also included 3 individual commodities; Oil, Copper and Gold. Oil is chosen because it is one of the most important commodities in the world because it's one of the major sources of energy (that's why the GSCI and CRB are overweighting it). Copper seems to be, just like oil, related to economic activity, and because economic activity is again related to inflation, we have included it. Gold is perceived as the ultimate inflation hedge and thus an obvious choice.

The most obvious choice for real estate would be the Case-Shiller Composite. We have included it, however the monthly data that is available is limited. Moreover, in the last decade a bubble developed in US real estate, that collapsed in 2007, influencing a big part of the data. We have also included the FTSE/NAREIT All Equity REIT Index and the FTSE/NAREIT All REIT Index. These two indices are composed of Real Estate Investment Trusts (REIT), which are companies that invest in US real estate and are traded on the US stock exchange.

Another possible inflation hedge would be a basket of foreign currencies. We have selected three baskets of foreign currencies. The first one is the Bank of England USD Index which consists of the Euro (30%), Japanese Yen (30%), Canadian Dollar (25%), British Pound (10%) and some minor currencies. Secondly the USD against the SDR exchange rate. The SDR, or Special Drawing Rights, is a reserve asset defined and maintained by the International Monetary Fund (IMF). It is not really a currency by itself, but it's a basket of the following currencies: the US Dollar (42%), Euro (38%), Japanese Yen (9%) and the British Pound (11%). We have also created also our own baskets of foreign currencies. The basket holds, on a equally basis, the most actively trades currencies; the Euro, Japanese Yen, British Pound, Swiss Franc, Australian Dollar and. Canadian Dollar

Table 3.1: Data Descriptive Statistics

	Asset	Data available from	Average Return*	Standard Deviation*
Inflation	Consumer Price Index	1950	3,62%	1,18%
Stocks	S&P 500	1964	7,45%	15,20%
	MSCI World Index in (USD)	1970	7,70%	15,36%
	MSCI World Index (Home)**	1970	6,62%	14,34%
	MSCI AC World Index (USD)	1988	6,73%	16,30%
	MSCI AC World Index (Home)**	1988	6,79%	14,99%
	MSCI World Index Ex US (USD)	1970	8,86%	17,80%
	MSCI World Index Ex US (Home)**	1970	6,54%	15,05%
	MSCI AC World Index Ex US (USD)	1988	6,12%	18,47%
	MSCI AC World Index Ex US (Home)**	1988	5,83%	16,03%
Commodities	CRB Index	1951	2,41%	8,78%
	S&P GSCI Commodity Index	1970	12,28%	20,33%
	S&P GSCI Energy Index	1983	9,36%	31,55%
	S&P GSCI Precious Metals Index	1973	11,04%	23,23%
	S&P GSCI Industrial Metals Index	1977	7,72%	24,13%
	S&P GSCI Agriculture Index	1970	6,43%	21,47%
	S&P GSCI Livestock Index	1970	4,35%	19,58%
	CCI Index	1974	3,77%	12,77%
	CCI Energy Index	1983	8,26%	27,92%
	CCI Grains & Oilseeds Index	1971	6,98%	22,25%
	CCI Industrials Index	1971	7,41%	18,57%
	CCI Precious Metals Index	1986	8,17%	18,25%
	CCI Livestock Index	1971	4,98%	18,06%
	CCI Softs Index	1971	7,64%	20,07%
	Crude/Brent Oil	1982	11,38%	37,49%
	Copper	1977	9,67%	26,99%
	Gold	1968	11,28%	20,93%
Real Estate	FTSE/NAREIT All Equity REIT Index	1972	5,86%	19,13%
	FTSE/NAREIT ALL REIT Index	1972	2,81%	19,60%

	Case-Shiller Composite 10	1987	3,87%	3,14%
Currencies	Bank of England USD Index	1975	-0,78%	7,50%
	SDR/USD Exchange Rate	1979	-0,43%	5,69%
	Currency Basket	1975	-0,81%	4,08%

* Annualised Monthly Return and Standard Deviation.

** Home means that the stocks are denominated in their home currency.

Table 3.1 shows the descriptive statistics of the data used. The average inflation rate from 1950 is around 3.6%, so to hedge the inflation rate, that percentage has to be earned at least. The returns between the stock indices don't differ that much; they are all around 6-8%. Holding foreign stocks in USD seems to increase the return, but also the standard deviation. The GSCI seems to earn very high returns in contrast to the CCI and the CRB index. This is probably due to the weightings the GSCI has given to certain commodities like oil and gold. With the exception of the CRB index and the CCI, the standard deviations of commodities seems to be higher than that of stocks, probably due to the fact that commodities are driven more by demand and supply, where stocks are driven by earnings and dividends. For real estate the returns are quite low, where for the REIT indices the standard deviations are quite high, even higher than the broad stock market indices. The Case-Shiller Composite has a low standard deviation, but one must keep in mind that both return and standard deviation are spoiled by the bubble that developed in real estate in the last decade. The returns for the currencies are negative, however this was expected because inflation has a negative influence on the US Dollar. So holding foreign currencies would give a positive return, although not that high. Against the low returns, the standard deviations of the returns seems to be quite high.

4. Methodology

4.1 Forecasting Inflation

As stated above, we first have to forecast the inflation rate. We will use 8 models to see which one performs the best for forecasting inflation. The models that are build by a regression have been corrected for autocorrelation and heteroskedasticity if present.

The first model is the most simple one; it's the random walk, which means that we use the inflation rate of the last period as the inflation rate for the next period. So for example when forecasting inflation on a quarterly horizon, we use the inflation rate of the period January until March to forecast the period April until June. Inflation seems to be highly autocorrelated and thus using the random walk makes sense.

The second model is an autoregressive model with one lag, or the AR (1) model. This seems to be just like the random walk, however with this model, we use a out of sample rolling regression with a fixed window of 10 years to forecast the inflation for the next period. The regression will give us the coefficient that will be used to forecast the next period inflation. Because we use a rolling fixed window, for each next month (remember we use monthly overlapping data), will have new, and probably better coefficient to forecast the inflation rate of the next period. This way however creates the problem of autocorrelation, we have corrected for this by using the Newey-West HAC (heteroskedasticity and autocorrelation) option.

An optimized autoregressive model, or AR (X) model is our third model. The (X) stands for the optimal number of lags. The optimal number of lags are found by using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Adding more lags always increases the model's goodness of fit, so using an infinite number of lags would give us the best model. However by increasing the number of lags, it does not mean that the model really performs better because a lot of noise is added. The AIC and BIC gives a penalty for adding lags, and thus indicates what the optimal number of lags would be. Although the AIC and BIC can be calculated manually, EViews provide them when performing a regression, which is performed out of sample and rolling. Again the Newey-West HAC option has been used to deal with heteroskedasticity and autocorrelation.

For the fourth and fifth model an interest rate is used. Fama (1975) argued that through nominal interest rates, information can be obtained about the future inflation rate. So for the fourth model we use the interest rate of the appropriate length (for the quarterly horizon the 3 months treasury bill and for the yearly horizon the 1 year treasury bill), and because inflation is highly autocorrelated (again we have corrected with the Newey-West HAC option), we also add the past inflation rate. Both variables are combined in a out of sample rolling regression of 10 years, or:

$$E(\pi_t) = a + \beta_1 \pi_{t-1} + \beta_2 i_{t-1} + \varepsilon_t \tag{4.1}$$

where $E(\pi_t)$ is the expected inflation rate, π_{t-1} the inflation rate one period back and i_{t-1} the interest rate one period back (3 months for the quarterly horizon and 1 year for the yearly horizon). The fifth model is also an out of sample rolling regression of 10 years that only uses the interest rate, or in formula form:

$$E(\pi_t) = a + \beta_1 i_{t-1} + \varepsilon_t \tag{4.2}$$

The University of Michigan Survey and the US Consumer Survey are used as the seventh and eighth model. Because both surveys are asking only the yearly expectations, we have transformed them also into quarterly expectations by using the following formula:

$$E(\pi_{4,t}) = (E(\pi_{12,t}) + 1)^{\frac{3}{12}} - 1 \tag{4.3}$$

where $E(\pi_{4,t})$ is the quarterly expected inflation rate, and $E(\pi_{12,t})$ the yearly expected inflation rate obtained from the survey.

The last model is a simple moving average of 4 periods back, meaning that the average inflation rate of 4 periods back is used to forecast back. So more or less, this model is an expanded version of the random walk that only uses one period back.

To evaluate the models, we will use the Mean Squared Error (MSE) and the Diebold-Mariano (DM) statistic. The MSE is simply the mean of the squared forecast error, thus;

$$MSE = \frac{1}{N} \sum_{t=1}^{N} (\pi_t - E(\pi_t))^2 \tag{4.4}$$

To see if a model is significant better than for example the random walk, the DM statistic is used. The DM statistic uses the MSE of two models, and subtract those from each other, creating a loss differential. After that the loss differential is regressed on a constant, where the standard errors are corrected for autocorrelation and heteroskedasticity. For example the DM statistic for model 1 versus model 2 would be found by;

$$(MSE_{\mathrm{mod}el1,t} - MSE_{\mathrm{mod}el2,t}) = DM_t + \varepsilon \tag{4.5}$$

When the DM_t statistic is significantly positive, model 2 performs significantly better than model 1. Model 1 performs of course significantly better when the DM_t statistic is significantly negative.

4.2 Inflation and Asset Returns

We will start with the relation between inflation and the different assets, therefore performing the following regression, where R_{jt} is the nominal return on asset *j*, α_j the constant, β_j the beta, π_t is the inflation rate and ε the error term;

$$R_{jt} = \alpha_j + \beta_j \pi_t + \varepsilon_{jt}. \tag{4.6}$$

Of course this is with perfect foresight; inflation and asset return are known. So for an investor this is useless, that's why we go further with an model to forecast the expected inflation rate. However this first regression will provide some feeling how inflation and asset returns are correlated.

As stated above (section 2.1), Fama and Schwert (1977) argued that without building a model for expected returns, we can examine the relationship between expected nominal returns and expected inflation.

$$R_{jt} = \alpha_j + \beta_j E(\pi_t) + \varepsilon_{jt}, \tag{4.7}$$

where R_{jt} is the nominal return on asset *j* and $E(\pi_t)$ is the expected inflation rate. The coefficient β_j will give the relation between the nominal asset return and the expected inflation rate. According to Boudoukh et al (1994), the most common statement of the Fisher Model is that the expected nominal returns on all assets move one-to-one with expected inflation. Thus when regressing asset returns on inflation, we expect that β_j = 1. Because the forecast error, or unexpected inflation may also influence the returns, the above formula can be expanded to see how the nominal rate of return of asset *j* relates to the expected inflation and the unexpected inflation rate.

$$R_{jt} = \alpha_j + \beta_{1j} E(\pi_t) + \beta_{2j}(\pi_t - E(\pi_t)) + \varepsilon_{jt}, \tag{4.8}$$

where β_{2j} gives the relation between the nominal return of asset *j* with the unexpected inflation rate. Note that all standard errors are corrected for autocorrelation and heteroskedasticity.

5. Forecasting Expected Inflation

As we have explained, we have build 8 different models to forecast inflation. By using the mean squared error and the Diebold-Mariano statistic, we can decide which model performs the best and thus which one we are going to use. However, first we have to decide how many lags we're going to choose for the two optimized AR models.

Table 5.1: The AIC and BIC for the AR (X) models

	Lags	AIC Eviews	BIC Eviews
Quarterly	1	-7,184	-7,171
	2	-7,255	-7,236
	3	-7,353	-7,328
	4	-7,381	-7,348
	5	-7,462	-7,424
	6	-7,507	-7,462
	7	-7,527	-7,476
	8	-7,533	-7,475
	9	**-7,544**	**-7,479**
	10	-7,542	-7,471
	11	-7,538	-7,460
	12	-7,533	-7,448
Yearly	1	-4,884	-4,870
	2	-5,031	-5,012
	3	-5,158	-5,126
	4	-5,163	-5,129
	5	**-5,190**	**-5,149**
	6	-5,187	-5,140
	7	-0,519	-5,133
	8	-5,184	-5,121
	9	-5,173	-5,102
	10	-5,160	-5,081

Table 5.1 shows the AIC and BIC values from EViews. On the quarterly horizon, 9 lags seems to be optimal because it gives the lowest AIC and BIC value. For the yearly horizon, the optimal lags seems to be 5, again because that gives the lowest AIC and BIC values. So now we can compare the 8 models.

In the first column of table 5.2 is stated from when the data is available. Although the University of Michigan Survey and the US Consumer Survey gives us the real expectations of inflation, the period for which the data is available is rather short. Based on this, we rather use an other model for our research.

Table 5.2: Data Availability & Mean Squared Errors

	Model	Data Available From	Mean Squared Error
Quarterly	Random Walk	1950	0,550
	AR (1) Model	1960	0,348
	AR (9) Model	1960	**0,335**
	Past Inflation + Interest Rate Model	1964	0,352
	Interest Rate Model	1964	0,443
	University Of Michigan Survey	1978	0,398
	US Consumer Survey	1978	0,413
	Movering Average (4)	1950	0,451
Yearly	Random Walk	1950	5,578
	AR (1) Model	1960	3,417
	AR (5) Model	1960	**3,034**
	Past Inflation + Interest Rate Model	1972	3,628
	Interest Rate Model	1972	4,688
	University Of Michagan Survey	1979	3,192
	US Consumer Survey	1979	3,802
	Movering Average (4)	1960	5,785

The results of the mean squared errors are in the second column. The mean squared errors give us an indication how good the model performs against the true rate of inflation. The lower the error, the better. For both horizons, the AR optimized model seems to perform the best. Although some of the differences are not that big; on the quarterly horizon also the AR (1) and Past Inflation + Interest Rate models seems to perform quite good. Also on the yearly horizon the AR (1) and Past Inflation + Interest Rate models seems to perform quite well. Based on the mean squared errors it seems that all models, with the exception of the Moving Average model on the yearly horizon, seems to perform better than the random walk.

Table 5.3 shows the Diebold-Mariano (DM) statistics for the expected inflation models against the random walk, to see which models perform statistically better than the random walk. A positive DM coefficient indicates that the model performs better than the random walk because the model's error is smaller than that of the random walk, while a negative coefficient indicated that the random walk is performing better.

On the quarterly horizon, we see that the AR (1) model, AR (9) model, Past Inflation + Interest Rate model, the University of Michigan Survey and the US Consumer Survey performs significantly better than the random walk. The DM coefficient is also positive for

the Interest Rate model and the Moving Average (4), however the former is not significantly better at all, and the latter is only significantly better at a 10% level.

Table 5.3: Diebold-Mariano Statistics: Random Walk vs Models

	Model	DM Coefficient	DM t-Statistic
Quarterly	AR (1) Model	0,147	2,823 ***
	AR (9) Model	0,160	2,722 ***
	Past Inflation + Interest Rate Model	0,168	2,651 ***
	Interest Rate Model	0,077	0,978
	University Of Michigan Survey	0,223	2,829 ***
	US Consumer Survey	0,207	2,876 ***
	Movering Average (4)	0,092	1,794 *
Yearly	AR (1) Model	0,693	1,749 *
	AR (5) Model	1,076	1,550
	Past Inflation + Interest Rate Model	1,434	1,813 *
	Interest Rate Model	0,374	0,688
	University Of Michigan Survey	1,062	1,797 *
	US Consumer Survey	0,453	0,930
	Movering Average (4)	-1,778	-2,030 **

*** significant at a 1% level
** significant at a 5% level
* significant at a 10% level

The results are quite different on the yearly horizon; only the DM coefficient for the Moving Average (4) is significant at a 5% level, however the coefficient is negative, indicating that the random walk performs significantly better than that model. For the other models, the DM coefficients are positive, indicating they are performing better than the random walk. However the AR (1) model, Past Inflation + Interest Rate model and the University of Michigan Survey are only significantly better at a 10% level, while the other models are not performing significantly better at all.

Because the longer period shows almost no significantly better performing models while the short period does, it seems that the short period can be better forecasted than the longer period. Of course this is quite obvious; it's easier to forecast the weather of tomorrow than that of next week. The same applies for forecasting inflation.

So which model performs significantly the best? Table 5.4 shows the DM statistics of the models against the models. For both yearly and quarterly horizon we have selected the AR (1) model, the AR (9) model and the Past Inflation + Interest Rate model. Although the University of Michigan Survey and US Consumer Survey performed significantly better at the

quarterly horizon than the random walk, we don't selected them because the data is only available for a short period. The same applies for the University of Michigan Survey on the yearly horizon. We still selected the AR (5) for the yearly horizon while it performed not significantly better than the random walk. We have done this because the AR (5) model has the lowest mean squared error and the second highest DM statistic, indicating that it performs better than the random walk, although not significantly.

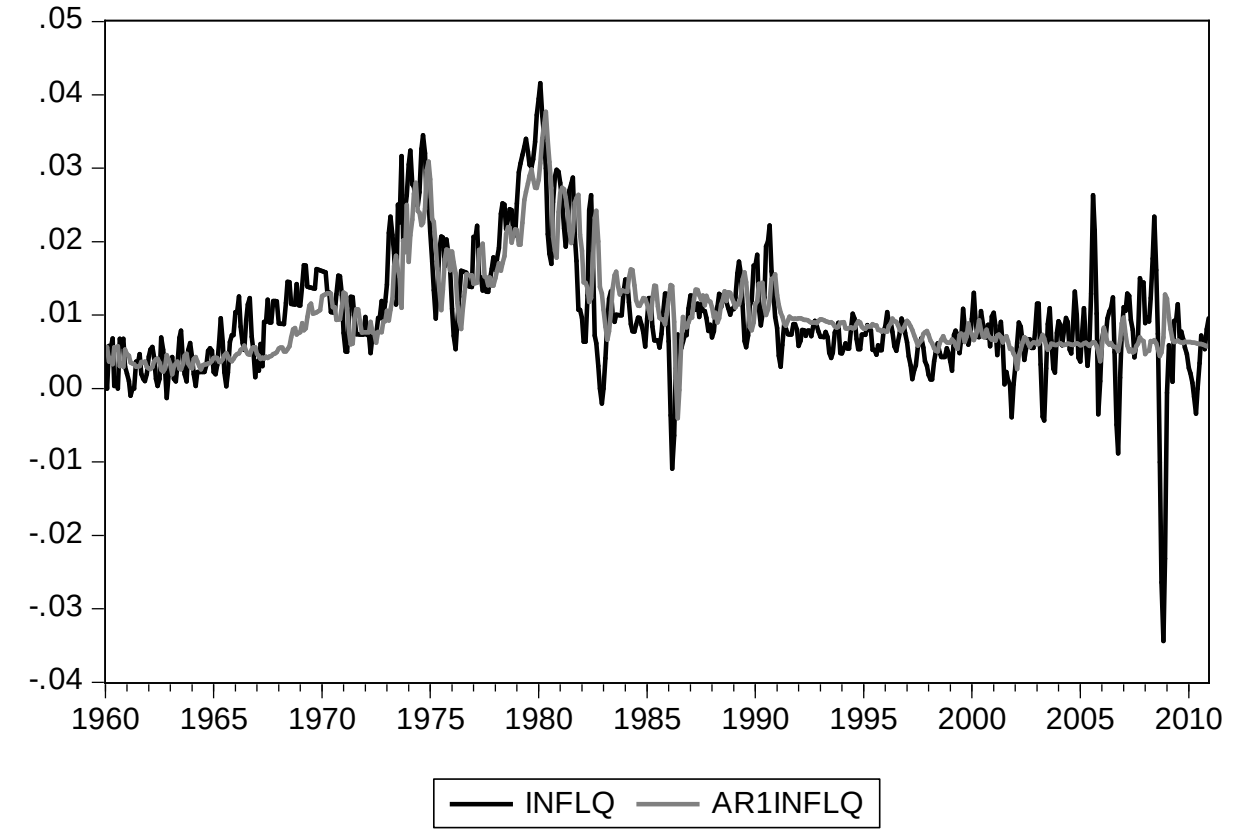
Table 5.4: Diebold-Mariano Statistics: Models vs Models

	Model	DM Coefficient	DM t-Statistic
Quarterly	AR (1) - AR (9)	0,013	0,622
	AR (1) - Past Inflation + Interest Rate	0,017	0,721
	AR (9) - Past Inflation + Interest Rate	0,005	0,132
Yearly	AR (1) - AR (5)	0,383	0,622
	AR (1) - Past Inflation + Interest Rate	0,482	0,715
	AR (5) - Past Inflation + Interest Rate	-0,081	-0,099

The positive DM coefficients indicates that on the quarterly horizon, the AR (9) model performs better than the AR (1) model, but the Past Inflation + Interest Rate model performs better than both the AR (1) and AR (9) model. However none of the DM coefficients are significant, and thus we cannot tell which one model performs significantly better than the other. For the yearly horizon, it is the same story. Although the AR (5) seems to performs the best versus the others because of the positive coefficient, it is not performing significantly better.

So which model are we going to choose? Because we want to keep our models as simple as possible and none of the models are significantly outperforming the others, we have chosen the AR (1) model as the expected inflation proxy. The University of Michigan Survey might be a better choice because it consists of real expectations, however the data is only available for a short period, and thus not suitable for long term research. Despite this, we are still going to use the University of Michigan Survey to see if the results are in line with that of the AR (1) model.

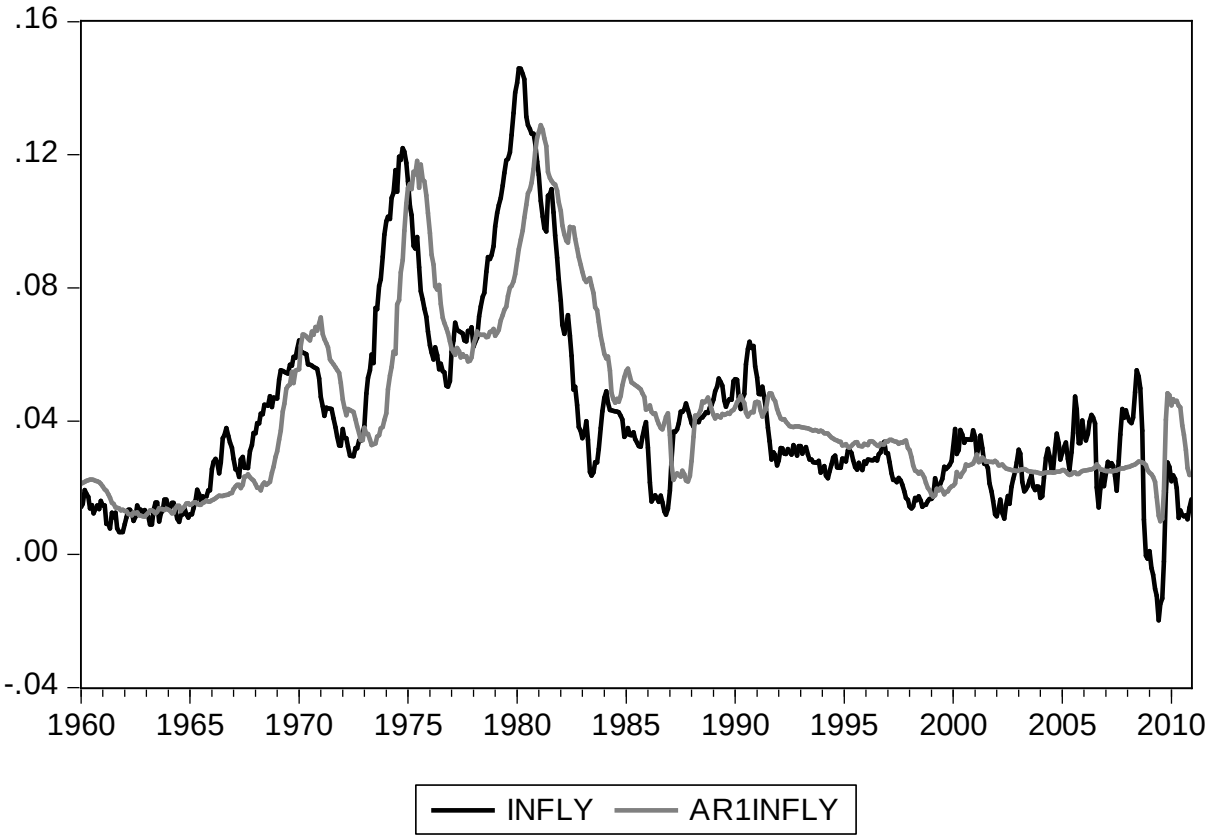
Graph 5.1: Actual Inflation and Expected Inflation (AR (1) Model) Quarterly



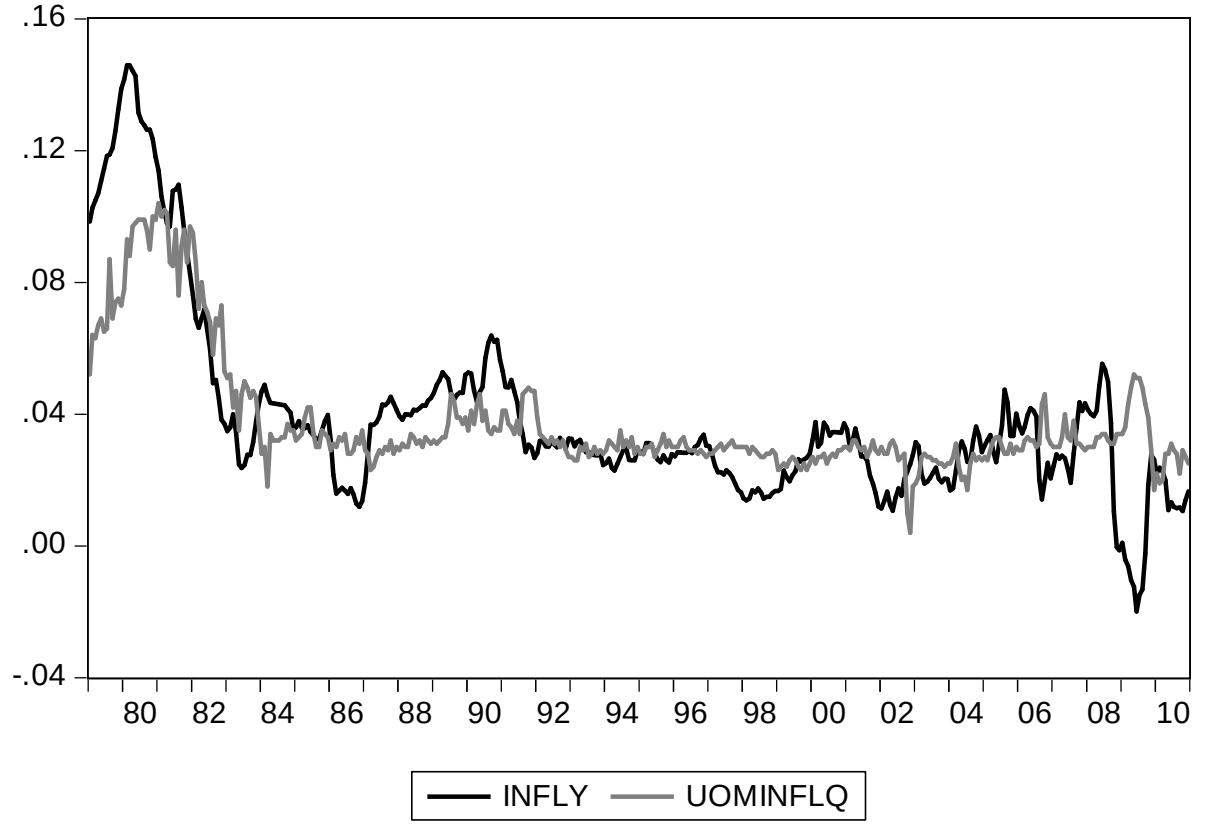
As you can see from graph 5.1, quarterly inflation is quite volatile. Especially the last decade seems to be volatile. Probably due to the two crisis we have experienced; that of the IT-bubble and the recent credit crisis. The AR (1) model is behaving more like a moving average, thus behaves less volatile, causing the unexpected inflation rate to be quite large, especially for the last decade. Remember however that this model seems to the best performing one, so the other models would be even less good than this one. Because the quarterly horizon is quite short, the model seems to be lagging the actual inflation rate on turning points only for a short term, just a quarter.

In contrary to the quarterly horizon, the yearly inflation rate seems to be less volatile (graph 5.2), although again the last decade seems to be quite volatile. However because this is a longer period, the model forecast seems to be lagging the actual inflation rate for a longer period, namely for a year. Therefore the unexpected inflation rate, or forecast error, seems to be rather big.

Graph 5.2: Actual Inflation and Expected Inflation (AR (1) Model) Yearly

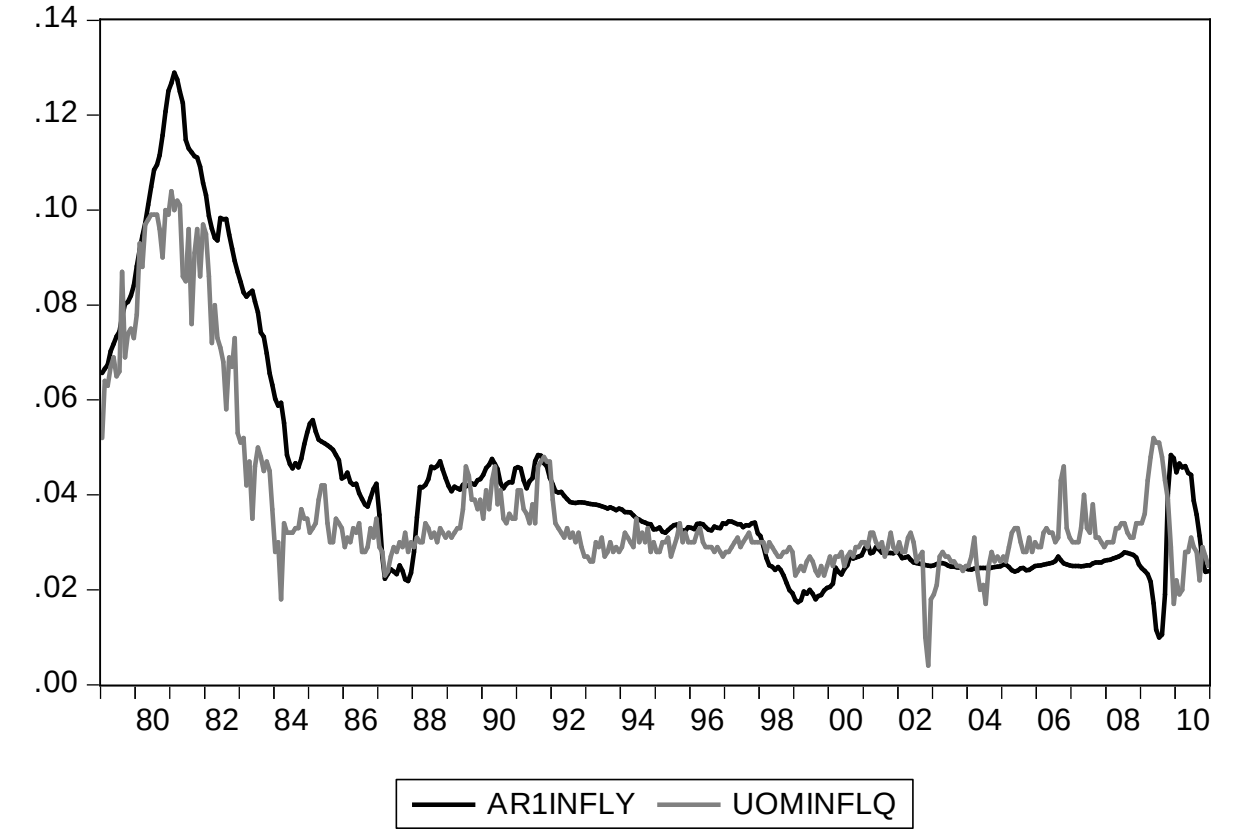


Graph 5.3: Actual Inflation and Expected Inflation (University of Michigan Survey) Yearly



Graph 5.3 shows that the expected inflation rate of the University of Michigan Survey seems to be lagging the actual inflation rate for a year. So this means that the expectations for next years inflation rate are mainly based on the inflation rate of last year, just like the Random Walk and the AR (1) model. Therefore the forecast error or unexpected inflation rate is also quite big, however the University of Michigan Survey seems to forecast the last decade better than the AR (1) model.

Graph 5.4: Expected Inflation (AR (1) Model & University of Michigan Survey) Yearly



When we compare the expected inflation rate of the AR (1) model with that of the University of Michigan Survey (graph 5.4), we see, with some exceptions, that the peaks and troughs are quite similar. The expected inflation rate of the University of Michigan Survey seems to be more volatile than that of the AR (1) model. The biggest exception is during the recent credit crisis where the models were forecasting the opposite. During the 1979-1989 period the AR (1) is forecasting higher inflation rate, but the direction of the inflation rate (rising or declining) of both models seems to be quite similar. Also during the 1989-2008 period the direction is the same, but now also the expected inflation rate is quite similar.

6. Inflation and Asset Returns

6.1 Relation between inflation and asset returns

We're starting first with the relationship between the inflation rate and asset returns; table 6.1.1 shows the quarterly coefficients, or betas, when performing the regression of asset returns on the actual inflation rate. Keep in mind that this useless for investors because an investor want to forecast the next periods inflation rate and than decide to buy or sell certain assets to defend against the forecasted inflation rate.

Table 6.1.1: Asset Returns and Inflation Quarterly

The nominal return of asset class *j* is regressed on the actual inflation rate π for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_j \pi_t + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

	Asset	Beta	t-Statistic	
Stocks	S&P 500	-0,645	-0,555	
	MSCI World Index in (USD)	-0,381	-0,293	
	MSCI World Index (Home)	-0,392	-0,334	
	MSCI AC World Index (USD)	3,385	1,134	
	MSCI AC World Index (Home)	2,607	1,067	
	MSCI World Index Ex US (USD)	-0,070	-0,063	
	MSCI World Index Ex US (Home)	-0,037	-0,027	
	MSCI AC World Index Ex US (USD)	4,235	1,705	*
	MSCI AC World Index Ex US (Home)	2,828	1,211	
Commodities	CRB Index	1,826	2,496	**
	S&P GSCI Commodity Index	5,302	3,640	***
	S&P GSCI Energy Index	18,077	9,293	***
	S&P GSCI Precious Metals Index	3,308	1,782	*
	S&P GSCI Industrial Metals Index	2,085	1,201	
	S&P GSCI Agriculture Index	2,620	2,466	**
	S&P GSCI Livestock Index	0,646	0,893	
	CCI Index	1,816	1,850	*
	CCI Energy Index	16,571	11,869	***
	CCI Grains & Oilseeds Index	2,029	1,853	*
	CCI Industrials Index	2,227	1,529	
	CCI Precious Metals Index	3,362	1,861	*
	CCI Livestock Index	0,612	0,783	
	CCI Softs Index	1,494	1,702	*
	Crude/Brent Oil	18,609	7,247	***
	Copper	2,538	1,272	
	Gold	3,027	2,042	**
Real Estate	FTSE/NAREIT All Equity REIT Index	0,089	0,055	
	FTSE/NAREIT ALL REIT Index	-0,560	-0,336	
	Case-Shiller Composite 10	0,694	1,004	

Currencies	Bank of England USD Index	-0,008	-0,304	
	SDR/USD Exchange Rate	-0,034	-0,092	
	Currency Basket	0,347	2,041	**

*** significant at a 1% level
** significant at a 5% level
* significant at a 10% level

The broadest stock market of the US, the S&P 500, shows a negative beta, just like most of the literature suggested, although not significantly. Also the MSCI World, both with and without the US currencies, gives negative betas, again not significant. The betas of the MSCI world denominated in US dollars or in their home currencies seems to be again negatively and not significant. Surprising are the positive betas we found for the MSCI AC World, which incorporates also developing countries. Although they are not significant (with the exception of the MSCI AC World Ex US (USD) that is significantly on a 10% level), the positive betas are suggesting that the MSCI AC World is positively related with inflation and thus a hedge against inflation. A possible explanation can be that while the inflation in developed countries is highly correlated, the inflation rate between developed and developing countries is not. However the MSCI AC World is only available from 1988, where the MSCI World is available from 1970. Table 6.1.2 shows the results when performing the same regression on all chosen stock indices, but than from 1988-2010.

Table X612: Asset Returns and Inflation Quarterly 1988-2010

The nominal return of asset class *j* is regressed on the true inflation rate π for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_j \pi_t + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

	Asset	Beta	t-Statistic	
Stocks	S&P 500	2,523	1,012	
	MSCI World Index in (USD)	3,236	1,309	
	MSCI World Index (Home)	2,467	1,013	
	MSCI AC World Index (USD)	3,385	1,134	
	MSCI AC World Index (Home)	2,607	1,067	
	MSCI World Index Ex US (USD)	4,049	1,689	*
	MSCI World Index Ex US (Home)	2,607	1,139	
	MSCI AC World Index Ex US (USD)	4,235	1,705	*
	MSCI AC World Index Ex US (Home)	2,828	1,211	

*** significant at a 1% level
** significant at a 5% level
* significant at a 10% level

All betas are now positive, indicating that the relation between inflation and stocks is not stable, and alter through time (more on that see section 7). Investing in developed or in

developing countries thus does not make a difference. Perhaps due to globalization, the inflation rates all over the world are more or less correlated. If you as an investor want to invest in stocks to defend against inflation, we would choose foreign stocks, denominated in the US Dollar, because the MSCI World Ex US (USD) and MSCI AC World Ex US (USD) are both significant at a 10% level.

Back to table 6.1.1 where commodities are showing some interesting results. First of all are all betas positive, indicating a positive relation between commodities and inflation,. The GSCI Energy, CCI Energy and oil have very high betas and are all significant at a 1% level. Also the GSCI Index, where oil has a big weighting, is significant at an 1% level, although its beta of 5.03 is lower than that of the energy sub indices and oil. The CRB index, GSCI Agriculture and Gold are also showing strong relations because they are significant at a 5% level. The CCI, GSCI Precious Metals Index, CCI Grains & Oilseeds and the CCI Softs index are at a 10% level significant. This was expected because the CPI is based on overall prices, and when commodity prices are rising, general prices will also increase, although this can take a while. So overall, commodities and especially energy related commodities seems to be good choice when defending against inflation.

For real estate we find no significant relations. The FTSE/NAREIT All Equity REIT Index and Case-Shiller Composite have positive betas, where the FTSE/NAREIT All REIT Index has a negative one. So although we see mixed results, all three betas are not significant, and thus not different from zero.

Our equally weighted currency basket shows a positive significant beta with inflation, indicating a positive relation. This is not what we expected; when inflation picks up, the value of the home currency diminishes, and thus we expected that investors turn to foreign currencies. However our currency basket holds only the currencies of other developed countries, and as we have mentioned before, the inflation rate between developed countries seems to be highly correlated. So perhaps the relation is the other way around; investors turn to the US Dollar which is considered as a safe haven. This would mean that investors have to short foreign currencies, and hold US Dollars. The betas of the other two currency indices are not supporting this, because they are negative, however they are not significant different from zero. The differences between the three baskets is probably due to the weightings given to the foreign currencies. Although positive, we can't consider the US

Dollar as an inflation hedge because the beta is below 1, and thus not keeping pace with the inflation rate.

Table 6.1.3: Asset Returns and Inflation Yearly

The nominal return of asset class *j* is regressed on the true inflation rate π for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_j \pi_t + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

	Asset	Beta	t-Statistic	
Stocks	S&P 500	-0,869	-1,306	
	MSCI World Index in (USD)	-0,812	-1,135	
	MSCI World Index (Home)	-0,660	-0,993	
	MSCI AC World Index (USD)	2,310	1,020	
	MSCI AC World Index (Home)	2,261	1,009	
	MSCI World Index Ex US (USD)	-0,625	-0,779	
	MSCI World Index Ex US (Home)	-0,341	-0,517	
	MSCI AC World Index Ex US (USD)	2,671	1,129	
	MSCI AC World Index Ex US (Home)	2,536	1,108	
Commodities	CRB Index	1,252	2,410	**
	S&P GSCI Commodity Index	3,018	3,414	***
	S&P GSCI Energy Index	12,406	6,233	***
	S&P GSCI Precious Metals Index	4,435	2,401	**
	S&P GSCI Industrial Metals Index	0,971	0,942	
	S&P GSCI Agriculture Index	2,463	2,878	***
	S&P GSCI Livestock Index	0,544	1,160	
	CCI Index	0,802	1,702	*
	CCI Energy Index	11,673	6,046	***
	CCI Grains & Oilseeds Index	1,888	2,734	***
	CCI Industrials Index	1,304	1,511	
	CCI Precious Metals Index	0,598	0,288	
	CCI Livestock Index	0,622	1,127	
	CCI Softs Index	0,597	0,392	
	Crude/Brent Oil	12,873	5,791	***
	Copper	0,874	0,804	
	Gold	4,151	2,849	***
Real Estate	FTSE/NAREIT All Equity REIT Index	-0,993	-1,106	
	FTSE/NAREIT ALL REIT Index	-0,568	-0,697	
	Case-Shiller Composite 10	0,688	0,574	
Currencies	Bank of England USD Index	0,246	0,913	
	SDR/USD Exchange Rate	0,400	1,354	
	Currency Basket	0,256	1,760	*

*** significant at a 1% level

** significant at a 5% level

* significant at a 10% level

Table 6.1.3 shows the results on the yearly horizon. For stocks we see the same results as on the quarterly horizon: The S&P 500 and MSCI World are having negative betas, where the MSCI AC World has positive ones. This is again due to the data availability of the

MSCI AC World Index. When we would run the same regression for the S&P 500 and MSCI World from 1988, we would get similar results as the MSCI AC World. None of the betas are significant, see table 6.1.4.

Table 6.1.4: Asset Returns and Inflation Yearly 1988-2010

The nominal return of asset class *j* is regressed on the true inflation rate π for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_j \pi_t + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

	Asset	Beta	t-Statistic
Stocks	S&P 500	1,970	0,854
	MSCI World Index in (USD)	2,023	0,865
	MSCI World Index (Home)	1,739	0,744
	MSCI AC World Index (USD)	2,310	1,020
	MSCI AC World Index (Home)	2,261	1,009
	MSCI World Index Ex US (USD)	2,547	1,054
	MSCI World Index Ex US (Home)	2,109	0,900
	MSCI AC World Index Ex US (USD)	2,671	1,129
	MSCI AC World Index Ex US (Home)	2,536	1,108

*** significant at a 1% level

** significant at a 5% level

* significant at a 10% level

Also for commodities we see similar results; all betas are positive. The GSCI, GSCI Energy and Oil are performing again strong, with high significant betas. Also the GSCI Agriculture, CCI Grains & Oilseeds and Gold are having positive betas that are significant at a 1% level. The beta of the CRB Index is again positive at an 5% level and that of the CCI on a 10% level.

Real estate shows again no significant betas. The FTSE/NAREIT All Equity REIT Index and FTSE/NAREIT All REIT Index are having negative betas, that of the Case-Shiller Composite is positive.

The betas of the USD Index and SDR/USD exchange rate are now, just like our currency basket, also positive, which is again not what we expected. Although only the beta of our currency basket is significant at a 10% level, the relation between the US Dollar and inflation seems to be positive, even on a longer horizon. Note that the beta is still below one, indicating that the returns of the US Dollar while shorting foreign ones are not keeping pace with the inflation rate.

So the only significant results we have found so far are that for commodities. Energy related commodities, especially oil, seems to be a great hedge against inflation both on a

yearly and a quarterly horizon. Also gold and agriculture would be a good choice. Stocks, although we have find positive, but not significant, betas from 1988, seems to be not a good choice for hedging inflation. Also real estate, especially when investing in REITs, doesn't seems to be a good investment when inflation is picking up. Although we have seen significant positive betas between the US Dollar, when shorting foreign currencies and holding US Dollars, and the inflation rate, it still cannot be considered as an inflation hedge because the beta is below zero, indicating that the returns are not keeping up with inflation.

6.2 Relation between expected inflation and asset returns

So far we have only looked at the relation between inflation and asset returns. For an investor it is key to forecast inflation so that for the next period he or she could decide in which asset to invest or to invest not. As we have said, we are using an AR (1) model to forecast inflation. The unexpected inflation rate is simply the forecasting error.

Table 6.2.1: Expected (AR (1) Model), Unexpected Inflation and Inflation Yearly

The nominal return of asset class *j* is regressed on the expected inflation rate E(π) and the unexpected inflation rate (π - E(π)) for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_{1j} E(\pi_t) + \beta_{2j} (\pi_t - E(\pi_t)) + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

		Expected Inflation		Unexpected Inflation		
	Asset	**Beta**	**t-Statistic**	**Beta**	**t-Statistic**	
Stocks	S&P 500	-0,200	-0,290	-2,265	-2,439	**
	MSCI World Index in (USD)	-0,375	0,509	-1,635	-1,619	
	MSCI World Index (Home)	0,020	0,029	-1,939	-2,118	**
	MSCI AC World Index (USD)	3,600	1,166	1,766	0,711	
	MSCI AC World Index (Home)	4,135	1,400	1,461	0,607	
	MSCI World Index Ex US (USD)	-0,646	-0,816	-0,586	-0,481	
	MSCI World Index Ex US (Home)	0,149	0,220	-1,263	-1,330	
	MSCI AC World Index Ex US (USD)	2,348	0,684	2,810	1,045	
	MSCI AC World Index Ex US (Home)	3,118	0,984	2,288	0,909	
Commodities	CRB Index	0,170	0,457	3,474	3,830	***
	S&P GSCI Commodity Index	0,637	0,797	7,498	5,998	***
	S&P GSCI Energy Index	0,929	0,327	18,129	6,957	***
	S&P GSCI Precious Metals Index	2,064	1,488	9,380	3,792	***
	S&P GSCI Industrial Metals Index	-0,877	-1,038	4,576	3,135	***
	S&P GSCI Agriculture Index	0,223	0,286	6,678	5,049	***
	S&P GSCI Livestock Index	0,092	0,197	1,395	1,846	*
	CCI Index	-0,069	-0,159	3,055	4,414	***
	CCI Energy Index	0,429	0,145	16,351	6,667	***
	CCI Grains & Oilseeds Index	-0,024	-0,036	5,519	4,668	***
	CCI Industrials Index	-0,250	-0,328	4,254	3,718	***
	CCI Precious Metals Index	-4,191	-1,310	2,558	1,028	

	CCI Livestock Index	0,329	0,587		1,178	1,228	
	CCI Softs Index	-0,464	-0,624		2,612	2,812	***
	Crude/Brent Oil	4,575	1,567		17,229	6,660	***
	Copper	-1,259	-1,350		5,040	3,146	***
	Gold	1,752	1,447		8,682	4,879	***
Real Estate	FTSE/NAREIT All Equity REIT Index	0,147	0,182		-1,920	-1,557	
	FTSE/NAREIT ALL REIT Index	0,057	0,063		-2,978	-2,342	**
	Case-Shiller Composite 10	-1,633	-1,173		1,765	1,193	
Currencies	Bank of England USD Index	0,801	2,984	***	-0,917	-2,336	**
	SDR/USD Exchange Rate	0,740	3,232	***	-0,601	-1,739	*
	Currency Basket	0,303	2,019	**	0,158	0,719	

*** significant at a 1% level

** significant at a 5% level

* significant at a 10% level

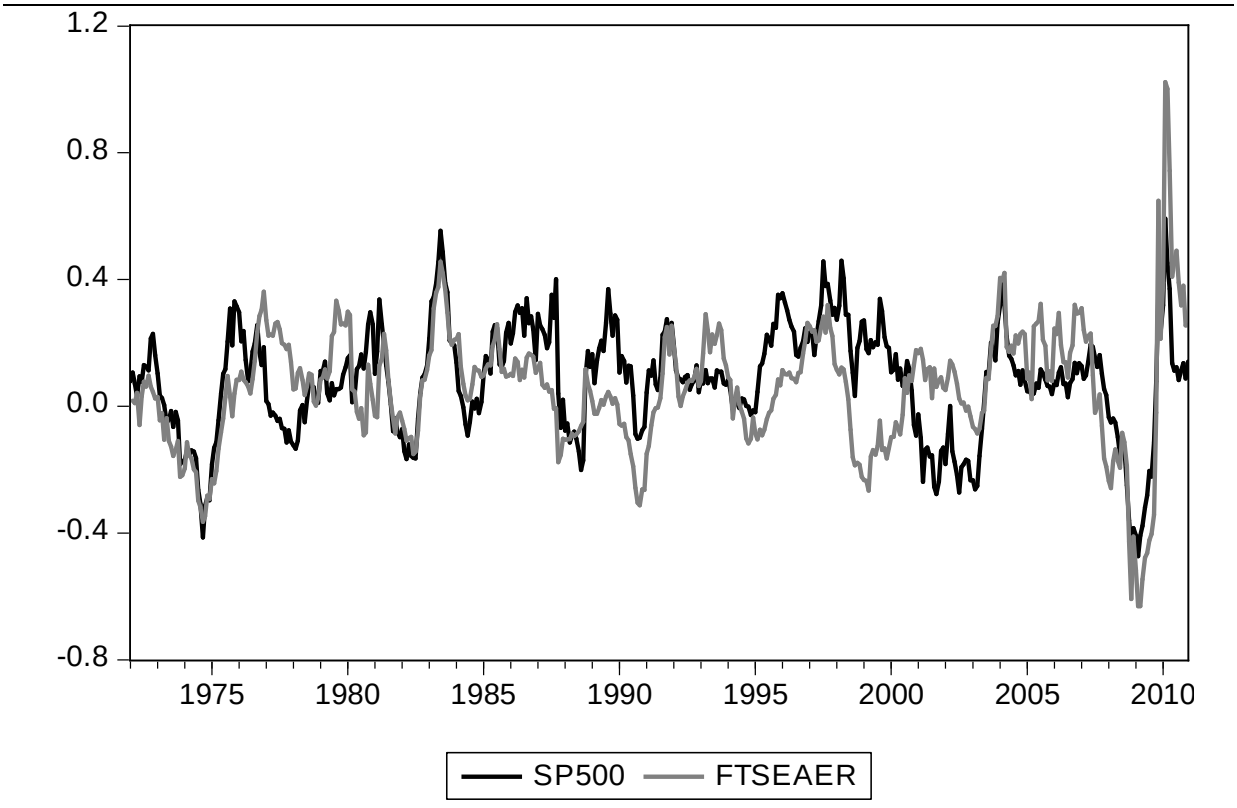
For expected inflation we find almost no significant betas. The only significant betas can be found for the currencies; all three indices have positive and significant betas, indicating that the relation between the expected inflation rate and the returns on the US Dollar, when shorting foreign currencies and holding US Dollars, is positive. Again the betas are below one, and thus are the returns not keeping up with the inflation rate. When we look at the second column of table 6.2.1 for currencies, we see that, with the exception of our currency basket (however that beta is not significant at all), that the returns are negatively correlated with the unexpected inflation rate. So perhaps foreign investors are turning to the US Dollar as some kind of safe haven when they expect higher domestic inflation. When the unexpected inflation rate in the US then seems to be positive, foreign and domestic investors turn to other currencies than the US Dollar, because they might fear that the inflation rate in the US is going to be higher than domestic inflation.

The MSCI AC World Indices are having positive betas for expected inflation, however they are not significant,. Again this is due to the data availability; the S&P 500 and MSCI World betas are close to zero and not significant. The unexpected inflation betas are showing two significant betas; the S&P 500 and the MSCI World denominated in the home currencies are having significant negative betas, suggesting that stock returns are negatively related to unexpected inflation. Stocks seems to be bad choice when defending against inflation.

Also commodities doesn't exhibit a strong hedge against expected inflation. Although some have positive betas (mainly energy and precious metals) suggesting that they are a

good hedge against expected inflation, they are not significant. The unexpected inflation betas are showing better results. With the exception of the GSCI Livestock, CCI livestock and the CCI precious metals, all betas are positive and significant, with again energy related commodities showing very high betas. It might be strange that the CCI Precious Metals beta is not significant, because the GSCI Precious Metals and Gold are having significant betas, but that's again to the weightings given; Gold is given a high weighting in the GSCI Precious Metals, and in the CCI Precious Metals an equally weighting, just like the other metals included.

Graph 6.2.1: S&P 500 and FTSE/NAREIT All Equity REIT Index Returns



For real estate the Case-Shiller composite is showing a negative expected inflation beta and a positive beta for unexpected inflation. But both betas are not significant. Keep in mind that a lot of the data is spoiled by the bubble in real estate. The FTSE/NAREIT All Equity REIT Index and FTSE/NAREIT All REIT Index are showing results quite similar to what we have seen for stocks; the expected beta is around zero, the unexpected negative (although again not significant). This comes not really unexpected because REITs are trading on the stock market, and it seems that those are highly correlated with the broad stock market, which is

also suggested by Gyourko and Keim (1992) and others. When we compare the S&P 500 with FTSE/NAREIT All Equity REIT Index (see graph 6.2.1), we see a quite high correlation.

When looking at the quarterly horizon we see quite similar results (table 6.2.2); for stocks we found almost no significant results, the only exception is the MSCI AC World Index Ex US denominated in the US Dollar currency, which has a positive beta with unexpected inflation. Most expected inflation betas are now, in contrary to the yearly horizon, negative for stocks. The unexpected inflation betas are again, due to the data availability, positive for the MSCI AC World Indices and around zero for the S&P 500 and MSCI World Indices.

Table 6.2.2: Expected (AR (1) Model), Unexpected Inflation and Inflation Quarterly

The nominal return of asset class *j* is regressed on the expected inflation rate $E(\pi)$ and the unexpected inflation rate $(\pi - E(\pi))$ for period *t*, or in formula; $R_{jt} = \alpha_j + \beta_{1j} E(\pi_t) + \beta_{2j} (\pi_t - E(\pi_t)) + \varepsilon_{jt.}$ If necessary, the t-statistics are corrected for heteroskedasticity and autocorrelation.

		Expected Inflation		Unexpected Inflation		
	Asset	Beta	t-Statistic	Beta	t-Statistic	
Stocks	S&P 500	-0,671	-0,877	-0,617	-0,324	
	MSCI World Index in (USD)	-0,828	-0,857	0,081	0,040	
	MSCI World Index (Home)	-0,682	-0,766	-0,093	-0,050	
	MSCI AC World Index (USD)	-0,650	-0,186	3,784	1,545	
	MSCI AC World Index (Home)	0,152	0,042	2,853	1,176	
	MSCI World Index Ex US (USD)	-0,831	-0,767	0,783	-0,374	
	MSCI World Index Ex US (Home)	-0,529	-0,583	0,404	0,237	
	MSCI AC World Index Ex US (USD)	-1,794	-0,454	4,838	2,116	**
	MSCI AC World Index Ex US (Home)	-0,706	-0,174	3,181	1,428	
Commodities	CRB Index	-0,020	-0,036	3,846	4,091	***
	S&P GSCI Commodity Index	0,541	0,472	10,223	7,573	***
	S&P GSCI Energy Index	3,073	0,750	19,966	8,664	***
	S&P GSCI Precious Metals Index	2,732	1,124	3,919	2,063	**
	S&P GSCI Industrial Metals Index	-0,671	-0,459	4,790	2,188	**
	S&P GSCI Agriculture Index	0,561	0,383	4,747	3,713	***
	S&P GSCI Livestock Index	-0,746	-0,887	2,084	2,464	**
	CCI Index	-0,693	-0,855	4,570	4,236	***
	CCI Energy Index	1,262	0,365	18,369	10,923	***
	CCI Grains & Oilseeds Index	-0,238	-0,188	4,402	3,484	***
	CCI Industrials Index	-0,931	-0,701	5,534	3,265	***
	CCI Precious Metals Index	-3,811	-1,004	4,507	2,759	***
	CCI Livestock Index	-0,582	-0,545	1,862	2,211	**
	CCI Softs Index	-0,246	-0,226	3,316	2,909	***
	Crude/Brent Oil	6,533	1,381	20,086	7,391	***
	Copper	-1,316	-0,860	6,335	2,581	**
	Gold	3,116	1,601	2,937	1,887	*
Real Estate	FTSE/NAREIT All Equity REIT Index	-1,058	-1,102	1,286	0,510	
	FTSE/NAREIT ALL REIT Index	-1,282	-1,021	0,193	0,073	

	Case-Shiller Composite 10	-0,679	-0,518	0,855	1,199	
Currencies	Bank of England USD Index	0,447	0,969	-0,450	-0,901	
	SDR/USD Exchange Rate	0,416	1,080	-0,448	-1,082	
	Currency Basket	0,269	1,099	0,422	2,060	**

*** significant at a 1% level
** significant at a 5% level
* significant at a 10% level

For commodities, a lot of the expected inflation betas seems to be negative, with the exception of the energy and gold related indices. All unexpected inflation betas are again positive, and almost all are significant at a 5% level. Only gold is significant at a 10% level, suggesting that gold is a better unexpected inflation hedge on the yearly horizon. Again the energy related indices and off course oil it self are having very high unexpected inflation betas.

Real estate shows again almost the same results as stocks. Negative expected inflation betas and positive unexpected inflation betas, although not significant.

We see again positive expected inflation betas, but now not significant for all three basket. Also the USD Index and the SDR/USD Exchange rate are showing negative unexpected inflation betas but are now not significant. Surprising is the negative and significant beta for our currency basket, indicating that the USD would rise versus foreign currencies with unexpected inflation on a quarterly horizon.

So we can conclude so far that, on a annual horizon, only shorting foreign currencies versus the US dollar would provide a hedge against expected inflation. But because the betas are smaller than zero, it won't fully hedge expected inflation; a leveraged position would be needed. Moreover on an annual basis, shorting foreign currencies would be a bad choice against unexpected inflation, because the betas are negative. A better choice for unexpected inflation would be commodities, especially energy and gold related. They are showing significant unexpected betas on both quarterly and yearly horizon, and although not significant, also positive betas for expected inflation. Stocks and real estate showed mixed and not significant results and are thus probably a bad option for hedging inflation.

So far we have used our AR (1) model as expected inflation proxy. Actual inflation expectations are gathered by the University of Michigan Survey, and, although the available

data is rather short, we want to see if our results so far change when using that as the expected inflation rate.

Table 6.2.3: Expected, Unexpected Inflation (University of Michigan Survey) and Returns Yearly

		Expected Inflation			Unexpected Inflation		
	Asset	Beta	t-Statistic		Beta	t-Statistic	
Stocks	S&P 500	-0,523	-0,527		0,898	0,603	
	MSCI World Index in (USD)	-1,280	-1,328		1,479	1,016	
	MSCI World Index (Home)	-0,471	-0,550		1,148	0,824	
	MSCI AC World Index (USD)	-3,914	-0,961		2,414	1,274	
	MSCI AC World Index (Home)	-2,420	-0,570		2,339	1,181	
	MSCI World Index Ex US (USD)	-0,312	-0,392		1,716	1,304	
	MSCI World Index Ex US (Home)	-0,312	-0,392		1,716	1,304	
	MSCI AC World Index Ex US (USD)	-5,168	-1,219		2,802	1,446	
	MSCI AC World Index Ex US (Home)	-2,471	-0,560		2,620	1,826	
Commodities	CRB Index	-1,862	-4,448	***	3,087	5,357	***
	S&P GSCI Commodity Index	-3,389	-4,139	***	9,213	9,148	***
	S&P GSCI Energy Index	-8,672	-1,946	*	12,792	5,429	***
	S&P GSCI Precious Metals Index	2,147	0,737		6,794	2,244	**
	S&P GSCI Industrial Metals Index	-3,505	-3,769	***	5,852	4,644	***
	S&P GSCI Agriculture Index	-0,623	-0,472		4,348	4,861	***
	S&P GSCI Livestock Index	-0,707	-1,259		1,932	3,445	
	CCI Index	-1,643	-2,777	***	4,048	7,402	***
	CCI Energy Index	-7,301	-1,824	*	12,068	5,478	***
	CCI Grains & Oilseeds Index	-0,648	-0,707		4,218	4,462	***
	CCI Industrials Index	-2,164	-2,213	**	5,550	5,179	***
	CCI Precious Metals Index	-9,404	-3,148	***	0,727	0,442	
	CCI Livestock Index	-0,429	-0,498		1,248	1,610	
	CCI Softs Index	-1,730	-1,558		2,373	2,367	**
	Crude/Brent Oil	-7,917	0,109		13,373	4,992	***
	Copper	-4,199	-3,871	***	6,414	4,951	***
	Gold	2,390	0,376		5,921	2,414	**
Real Estate	FTSE/NAREIT All Equity REIT Index	-9,261	-1,843		0,275	0,103	
	FTSE/NAREIT ALL REIT Index	-11,143	-2,258	**	-0,804	-0,313	
	Case-Shiller Composite 10	-6,065	-4,284	***	0,809	0,975	
Currencies	Bank of England USD Index	1,650	1,552		-0,768	-1,195	
	SDR/USD Exchange Rate	0,914	1,092		-0,619	-1,264	
	Currency Basket	0,035	0,064		0,142	0,426	

*** significant at a 1% level

** significant at a 5% level

* significant at a 10% level

When using the University of Michigan Survey as expected inflation rate we find some differences when using our AR (1) model. On the yearly horizon (table 6.2.3), we find first of all, although not significant, that all stocks indices are positively correlated with

unexpected inflation and negatively correlated with expected inflation, where we first found more mixed results.

Secondly, we see some differences for commodities with respect to expected inflation; where we first found no significant results, these results suggests that most commodities are negatively correlated with expected inflation. We even found significant betas for all three broad commodities indices. Gold seems to be, although not significant the only with a positive sign. In line with our earlier results, most of the commodities seems to be significantly positively correlated with unexpected inflation.

When looking at real estate, we see that all three have a negative relation with expected inflation, although the FTSE/NAREIT All Equity REIT Index coefficient is not significantly. The unexpected inflation coefficients differ, but are all not significantly different from zero.

For currencies we see no significant relationships for both expected and unexpected inflation, but they seems to be positively correlated with expected inflation. The results are in line when using the AR (1) model as expected inflation proxy.

Table 6.2.4: Expected, Unexpected Inflation (University of Michigan Survey) and Returns Quarterly

		Expected Inflation			Unexpected Inflation		
	Asset	**Beta**	**t-Statistic**		**Beta**	**t-Statistic**	
Stocks	S&P 500	-1,207	-0,837		1,585	0,731	
	MSCI World Index in (USD)	-1,915	-1,307		2,240	1,004	
	MSCI World Index (Home)	-1,229	-0,980		1,809	0,886	
	MSCI AC World Index (USD)	-9,943	-1,956	*	3,609	1,775	*
	MSCI AC World Index (Home)	-8,585	-1,717	*	2,797	1,373	
	MSCI World Index Ex US (USD)	-2,296	-1,470		2,956	1,299	
	MSCI World Index Ex US (Home)	-1,019	-0,892		2,186	1,171	
	MSCI AC World Index Ex US (USD)	-11,454	-2,044	**	4,502	2,363	**
	MSCI AC World Index Ex US (Home)	-9,121	-1,708	*	3,031	1,593	
Commodities	CRB Index	-2,373	-2,384	**	3,899	3,053	***
	S&P GSCI Commodity Index	-4,436	-2,520	**	11,166	9,575	***
	S&P GSCI Energy Index	-6,138	-0,791		18,543	6,900	***
	S&P GSCI Precious Metals Index	3,156	0,714		2,752	1,819	*
	S&P GSCI Industrial Metals Index	-2,583	-1,159		4,898	2,096	**
	S&P GSCI Agriculture Index	-0,788	-0,350		3,071	1,879	*
	S&P GSCI Livestock Index	-0,539	1,399		1,887	1,982	**
	CCI Index	-2,153	-1,522		4,538	3,537	***
	CCI Energy Index	-8,941	-1,301		17,101	8,080	***
	CCI Grains & Oilseeds Index	-0,912	-0,455		3,057	1,628	
	CCI Industrials Index	-2,789	-1,260		6,036	3,233	***
	CCI Precious Metals Index	-18,674	-3,972	***	4,031	3,107	***
	CCI Livestock Index	-0,174	-0,094		0,625	0,575	

	CCI Softs Index	-1,763	-1,017		2,937	2,432 **
	Crude/Brent Oil	-4,863	-0,564		19,107	6,457 ***
	Copper	-3,991	-1,659	*	6,487	2,542 **
	Gold	3,150	0,861		2,292	1,728 *
Real Estate	FTSE/NAREIT All Equity REIT Index	-1,498	-0,863		2,462	0,910
	FTSE/NAREIT ALL REIT Index	-0,962	-0,541		1,821	0,607
	Case-Shiller Composite 10	-4,465	-2,259	**	0,784	1,589
Currencies	Bank of England USD Index	1,391	1,974	**	-0,817	-1,630
	SDR/USD Exchange Rate	1,255	2,160	**	-0,715	-1,848 *
	Currency Basket	0,307	0,916		0,447	2,101 **

*** significant at a 1% level

** significant at a 5% level

* significant at a 10% level

When looking at the quarterly horizon (table 6.2.4) when using the University of Michigan Survey as the expected inflation rate, we see no shocking differences with the results from the yearly horizon. Stocks are again negatively correlated with expected inflation and positively with unexpected inflation. Commodities, with the exception of gold, are negatively related with expected inflation and positively with unexpected inflation. Unexpected inflation seems to be positively correlated with real estate, but not significant, and negatively correlated with expected inflation. Again currencies have a positive coefficient with respect to expected inflation, where the results with respect to unexpected inflation differs.

So we can argue that there are differences when using the AR (1) model or the University of Michigan Survey as the expected inflation rate. However keep in mind the differences in the data availability, that of the University of Michigan Survey is quite short. We have shown that our AR (1) model predict the actual inflation rate better than that of the University of Michigan Survey, so as an investor it's probably better to use the AR (1) model, but the University of Michigan Survey is probably easier to obtain. When combining both the AR (1) model and University of Michigan Survey results, we can argue that only gold remains as a hedge against inflation; it's the only asset class that has positive betas in all tables for both expected and unexpected inflation, although the betas for expected inflation were not significant. But also energy related commodities seems to exhibit strong inflation hedging capabilities.

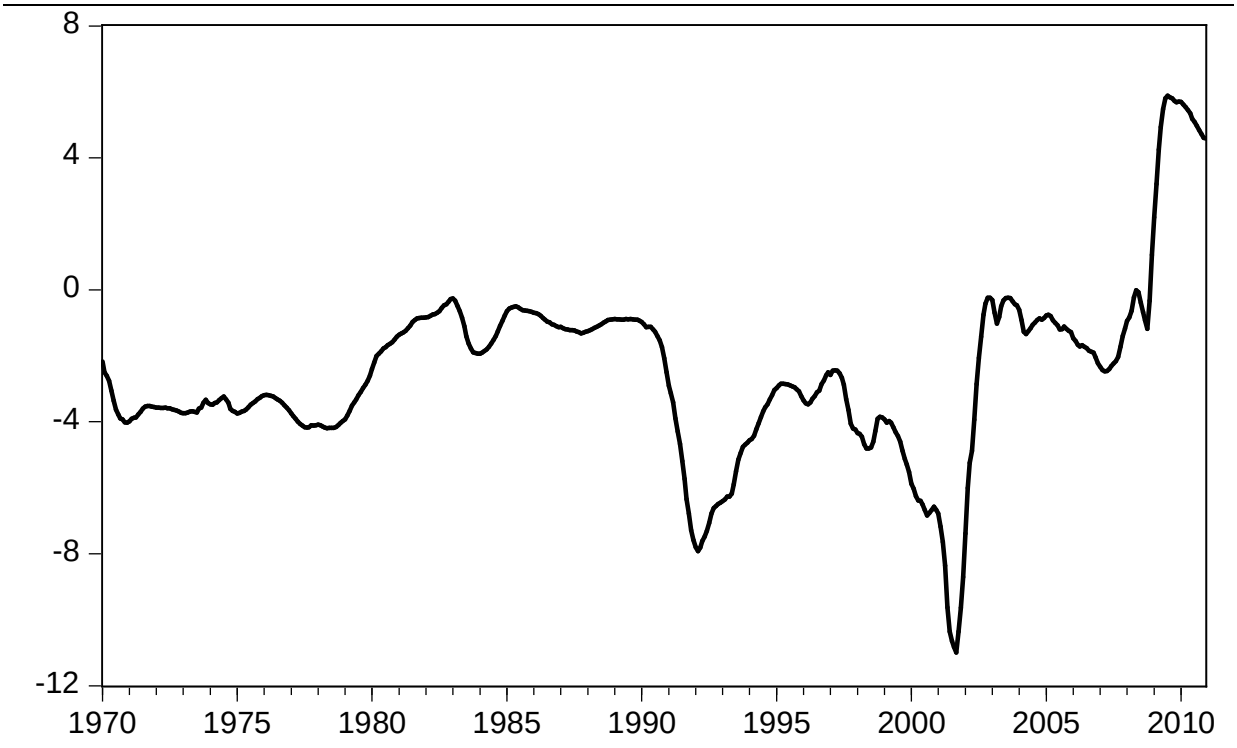
7. Relation between Inflation and Asset Returns Through Time

As we already have seen, the relationship between inflation and stock returns are not stable. When running the full period regression we found negative betas, where when we would run the regression from 1988, we found positive ones. That's why we have are going to examine how the betas alter through time. This way we can see if and how the relation alters through time. We will use the indices that provide us the most available data; for stocks we look at the S&P 500, for commodities at the CRB index and for currencies the USD Index from the Bank of England. We are skipping real estate because the only data available for a long period are the REIT Indices, and because those are highly correlated with stocks, it makes no sense. We will perform the same regressions as in section 6, however now with a fixed window of 10 years, rolling through time.

7.1 Inflation and Asset Returns

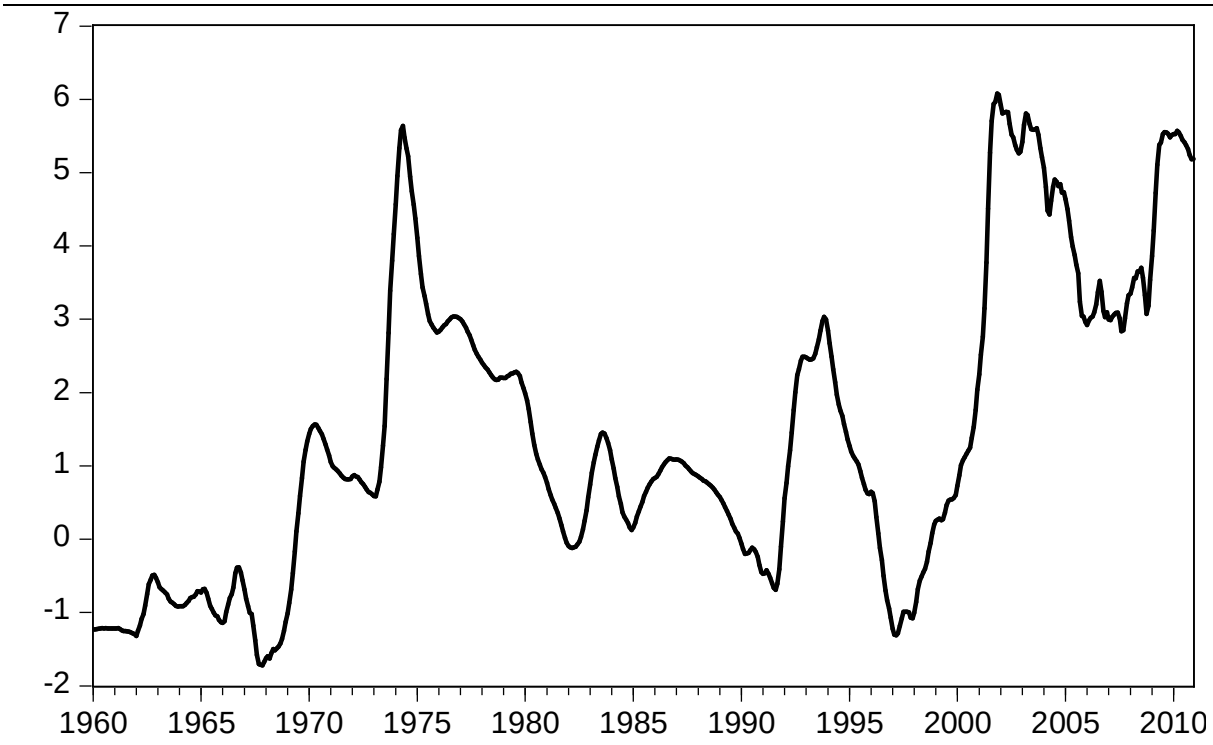
We start first with only looking at the relation between asset returns and the actual inflation rate, like we have done in section 6.1.

Graph 7.1.1: S&P 500 Rolling Coefficients



Graph 7.1.1 shows that the beta between the S&P and inflation was below zero until 2008. After that the beta turns positive. This is probably due the last decade. Since the bursting of the IT bubble, stocks returns and the inflation rate were both positive, during the credit crisis of 2007-2009, we experienced deflation and stocks crashed, and after that, in March 2009, inflation again picked up together with stocks returns. So all these observations are indicating a positive relation between stocks and inflation. So the question is whether this was a unique decade, and the relation between stocks and inflation is normally negative, or that the relation has changed. The spike down around 2003 is also explainable; stocks crashed due to the IT bubble, where inflation remained positively, creating a huge negative relation between both.

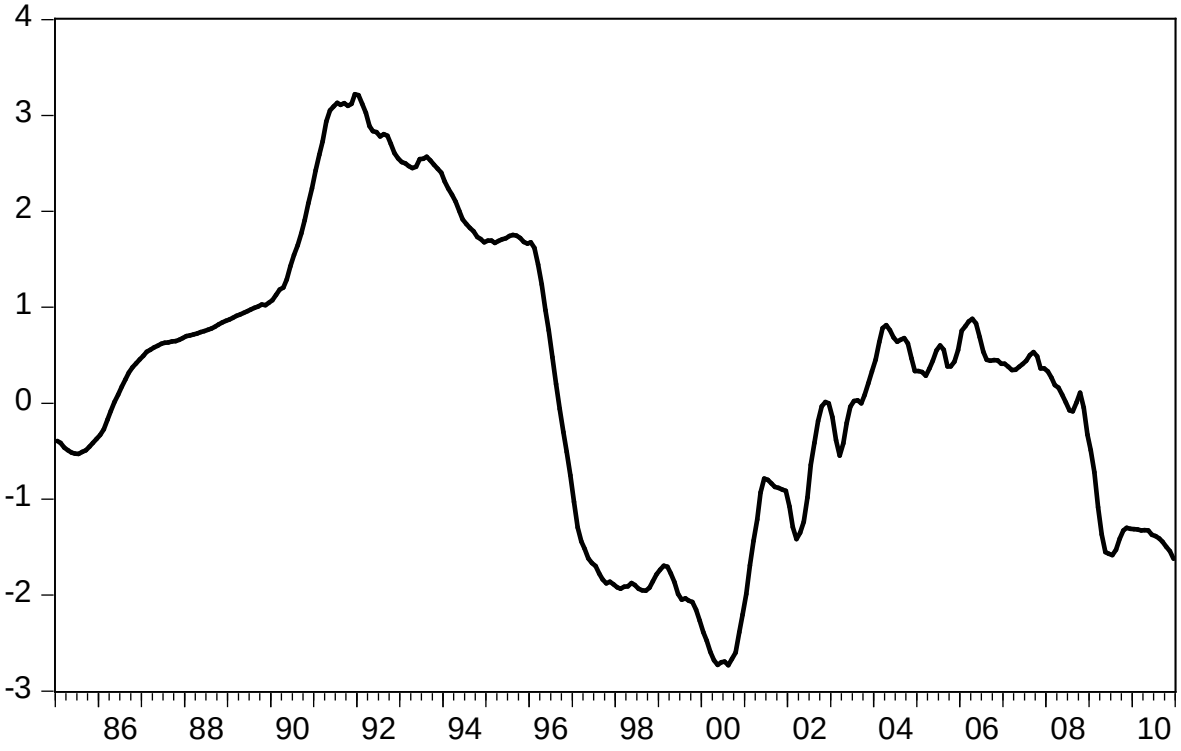
Graph 7.1.2: CRB Rolling Coefficients



For commodities we see mostly a positive beta, with some exceptions; during 1960-1970 inflation was already picking up where commodities still declined. In 1998 commodities were still in the bear market that started in 1980, while inflation remained positive. The spike around 1975 can be explained by exploding commodity prices while inflation was increasing moderately. During the inflation peak around 1980, inflation was rising faster

than the returns of commodities, thus the beta was decreasing, as can be seen from graph 7.1.2. The other peak around 2003 was where the bull market in commodities started while inflation was moderate.

Graph 7.1.3: USD Index Rolling Coefficients

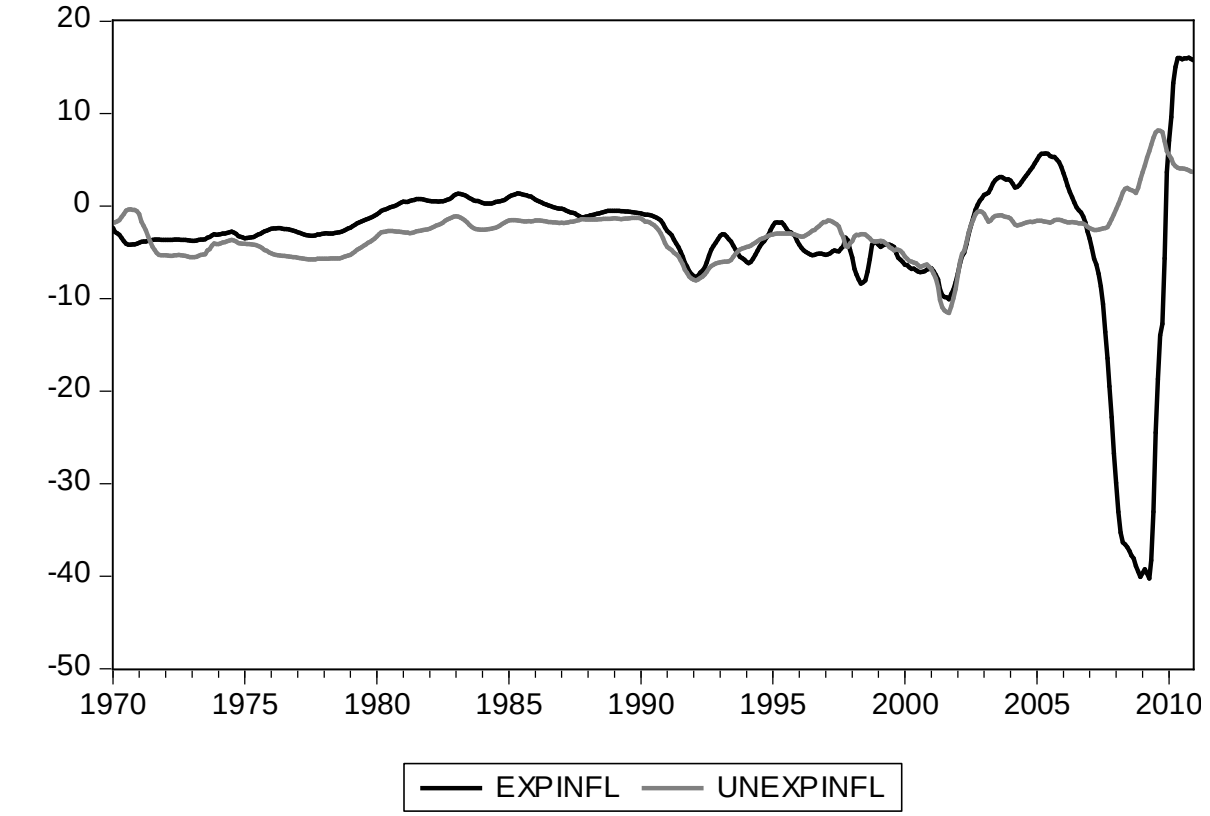


The USD Index beta is quite unstable (graph 7.1.3), being first positive, than turning negative, than again for a short period positive and again negative. In contrary to stocks and commodities, which have huge bull and bear markets, are the returns on the USD Index very unstable. This can explain the very unstable relation between inflation and the USD Index.

So what can we conclude so far? Although not very stable, Inflation and stocks seems to be negatively related, however the last decade shows a positive beta. For commodities it's the opposite; not very stable but positively correlated. The relation between the USD index and inflation seems to be not stable at all. So as an investor, you have to keep in mind that our results suggest that for example commodities can be used as an hedge again inflation, but that there are periods where they will perform better as an hedge against inflation (for example during a bull market in commodities with rising inflation) and that there are periods where they will perform not that good as an inflation hedge.

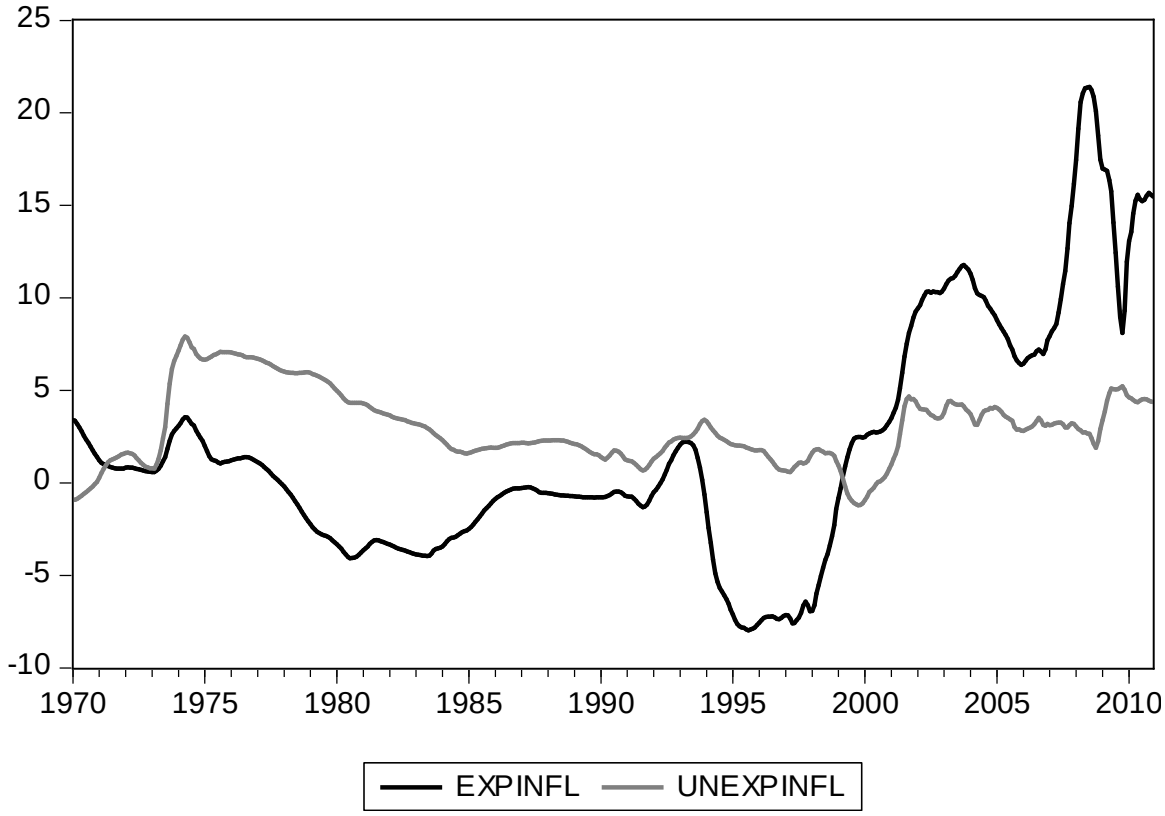
7.2 Expected Inflation, Unexpected Inflation and Asset Returns

Graph 7.2.1: S&P 500 Rolling Coefficients



The relationship between stock returns, expected inflation and unexpected inflation seems to be quite stable until 2003. Before 2003 the betas of expected and unexpected inflation seems to be negatively around -5 and 0 (see graph 7.2.1). After that the relations is very unstable with a very big spike down for expected inflation during the credit crisis. Perhaps the sudden deflation spike was not expected at all, creating huge forecast errors. After that inflation came back and created the opposite effect, causing the expected inflation to spike up again.

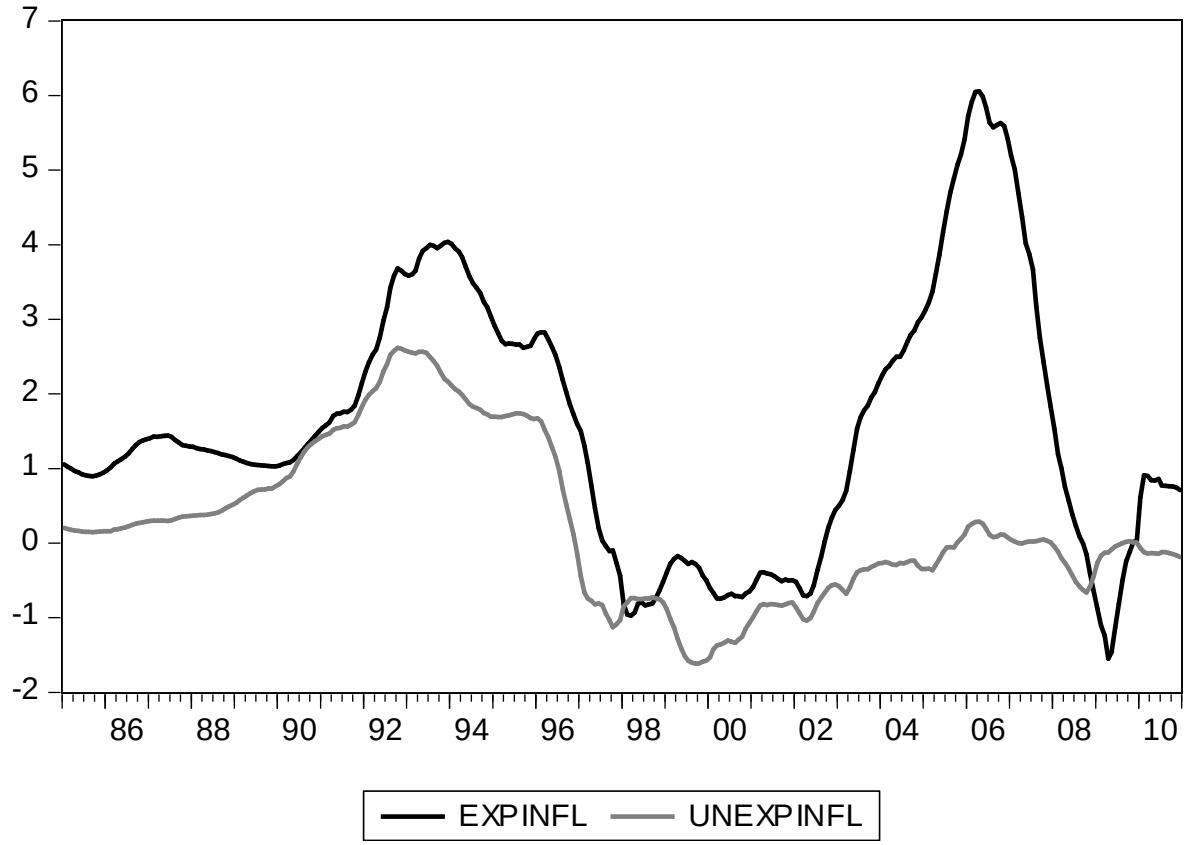
Graph 7.2.2: CRB Rolling Coefficients



Graph 7.2.2 shows the relation between expected inflation, unexpected inflation and the CRB Index. The unexpected inflation beta is positively and quite stable around 0 and 5. The expected inflation beta however is very unstable, until 2000 moving around zero, however after that, probably because the bull in commodities started, the beta turned positive, spiking around 2008. Because the unexpected inflation beta seems to be quite stable, hedging unexpected inflation by the CRB Index seems to a good choice.

Also the betas for the US Dollar Index are very unstable, see graph 7.2.3 on the next page. Although the expected inflation beta and unexpected inflation beta are moving mostly in the same direction, they are moving from positive to negative, and than turning again positive. That of expected inflation seems to be more positively territory, where the beta of the unexpected inflation is more in negative territory.

Graph 7.2.3: USD Index Rolling Coefficients



So when looking at the relation between stock returns, expected inflation and unexpected inflation trough time we can say the only stable relation is between the CRB Index and unexpected inflation. Stocks were showing for both expected and unexpected inflation a stable relation until 2000, however the last decade altered the betas a lot. Currencies are very unstable and thus seems to be risky when choosing as an inflation hedge. Commodities seems to be the best choice, also through time, but still they seems to perform better during a bull market in commodities than in a bear market. Perhaps this is not that surprising; when the economy grows, there is more demand for commodities. Both are causing higher inflation and thus commodities and inflation seems to be positively related.

8. Conclusion

In this thesis we investigated if it's possible to hedge inflation (both expected and unexpected) by investing asset classes. Because an investor has to forecast inflation to see in which asset he or she has to invest, we started by building models to forecast the inflation rate. After that we looked how inflation, expected inflation and unexpected inflation correlate with stocks, commodities, real estate and currencies. Also because relations tend to change, we have researched how the relations develop trough time.

For stocks we have showed that for the full period they seems to be mostly negatively correlated with inflation, expected inflation and unexpected inflation. However when looking at the relation through time we found results that suggests that, in contrary to most literature, for the last decade the relationship seems to be altered; stocks are now positively correlated inflation and unexpected inflation. The expected inflation beta was not stable during the last decade, turning from positive to negative and again positive. Choosing between foreign or domestic stocks, denominated in the US Dollar or in the home currency, doesn't made any difference.

Commodities would be a better choice for hedging inflation. They are positively correlated with inflation and unexpected inflation, which is line with recent literature. For expected inflation the results seems to differ; although we found no significant results, energy related commodities, especially oil, and gold have positive betas. However when using the University of Michigan Survey as expected inflation rate, only gold holds positive betas for expected inflation. The unexpected beta seems to be positive through time, however the expected beta is only positive for the last decade.

Currencies and especially real estate showed mixed, and mostly not significant, results. If one would use currencies as an inflation hedge, he would have to hold US Dollars, while shorting foreign currencies. However the relationship between currencies and inflation is very unstable, indicating that it would be not a good choice to use currencies as an inflation hedge. Real estate itself didn't provide any good results, although we have to keep in mind that our dataset was rather short and was spoiled by the recent real estate bubble. Also REITs can not be used as an hedge again inflation because they are behaving more like stocks do.

So in contrary to the Fisher Effect, selecting an asset class as an inflation hedge is not that easy. Especially the last decade altered a lot, probably due to the IT bubble and the recent credit crisis. It also depends on which model or survey is chosen as a proxy for expected inflation. If one must choose, we would recommend energy related commodities and gold. They have shown mostly positive betas for inflation, expected inflation and unexpected inflation, on both a short and a long horizon.

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