A Multi Asset Perspective for an Inflation Replicating Portfolio: Part I

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Abstract

This paper is a first of a series where we aim at exploring a more efficient approach to hedge against inflation risk or replicate its returns, and by efficient we mean to do better than simply buying Inflation Linked Bonds which potentially require to pay a high inflation risk premium.
Our work led us to ask by what standards we could measure if an asset or a strategy is a good inflation hedge or inflation replicator. While we found that there were several definitions to inflation hedge, we decided to use the one introduced by Fama and Schwert (1977) where an asset is considered to be a perfect inflation hedge if its returns have betas of unity in a multivariate time series regressions of returns on expected and unexpected inflation. We also used the Erb & Campbell (2005) definition of unexpected inflation which is the actual change of the year over year rate of inflation. Both definitions are practical and easy to check for anyone who had access to inflation data.
In addition to exploring the hedging capacity of traditional asset classes, we extended our work to some multi asset classes and equity factors like the Fama-French factors. Drawn by the idea of building an inflation driven portfolio, we found that it was crucial to be able to identify inflation regimes first, then select the assets that returns suit best the inflation objective and contexte.

Introduction

Inflation replication is a recurrent theme in portfolio construction, as it is common for investors to seek a return objective above realized inflation or to ensure that their assets are not subject to impairment due to an increase in inflation rates. Like in retirement investing this objective is either explicitly formalized like in defined benefits or contributions schemes, where investors may need to hedge their financial assets once they get into the retirement zone[1].

[1]During accumulation, investors contribution as a portion of their income is often indexed to inflation, but once they land into the retirement phase, investors assets have structurally little to no exposure to inflation.

While buying inflation linked bonds is the natural answer to a perfect hedge, it is not necessarily the cheapest option left to the investors, because it requires them to pay a high inflation risk premium[2].

Also, if investors could access to inflation hedges through linkers only, they may struggle to achieve their targeted returns, as they would have to allocate a significant portion of their portfolio to low yielding assets.

Through our work, we aimed at finding a better alternative to buying linkers, and most particularly to identify if some multi-asset classes might provide some inflation hedging capacity while offering a better potential for returns.

This begs the question of when one can consider that an asset or a strategy are a good hedge against inflation? By far, this was the most difficult task to tackle.

Spierdijk and Umar (2010), when checking whether commodities were a good hedge against inflation, reviewed the different measures of inflation hedging capacity as approached by the academic literature, and there were so many.

Amongst the most common approaches, there was the Fama and Schwert 1977 definition, where an asset is considered as a perfect inflation hedge if the asset has betas of unity in a multivariate time series regression of returns on expected and unexpected inflation.

We were also interested in Erb & Campbell (2005) definition of what one can consider as unexpected inflation. First, this was interesting from the perspective that what investors care about the most, is particularly unexpected inflation rather than the expected one, as assets current returns embed already some information on the expected level of inflation. Whereas, the unexpected component of inflation which is not reflected in asset prices, is the inflation part that is more likely to harm investors' returns. Also, inflation shocks are generally attributed to movements of its unexpected component, rather than its expected part.

While we could have used the differential between the inflation rate forecast[3] and the 1-year forward inflation return as a measure of unexpected inflation, we preferred to rely on Erb & Campbell (2005) definition, which considers that unexpected inflation is the actual change of the year over year rate of inflation.

As this paper is the first one of a series, to answer the question of how we can build a multi asset inflation replicating portfolio, we mainly dedicate this part to providing some background on US inflation movements, because we feel that this is crucial to understand the drivers behind inflation dynamic and the potential relationships between inflation and asset classes movements.

From there, most of the paper focuses on inflation regimes classification by using available data like asset classes returns, and how those asset classes returns relate to inflation movements across those different regimes.

[2]The rate differential between nominal bonds and inflation linkers referred as the breakeven, embeds for its most part the expected inflation but also an inflation risk premium term, as nominal bond bear an inflation risk for which investors should be compensated.

[3]We generally prefer not to rely on forecasts, they are potentially subject to frequent revisions and changes of methodology

To strike the balance between various inflation regimes and data availability for the largest set of asset classes, most of our analysis are performed over the period starting in 1985 and ending in the late of 2018.

Finally, as we draw our first results around the relationships between asset returns and inflation movements, we perceive our first ideas about how we can build this replicating portfolio. Our first intuition is that an inflation tracking portfolio that really seeks to replicate inflation through tracking-error minimization, requires a different approach than a portfolio that seeks a long term return above an inflation target.

1 Inflation Cycle

1.1 Historical data exploration

In this section, we provide some selected background about major historical trends and events that influenced the US Consumer price index from the beginning of 1970 up to end 2018. We do not analyze US inflation before 1970 as it is less practical for us to contrast it with a broad set of asset classes returns during that time, and as we intend to do it for the purpose of this study, we may say however, that US inflation was mostly stable during the Gold standard[4] that was applicable up to 1971.

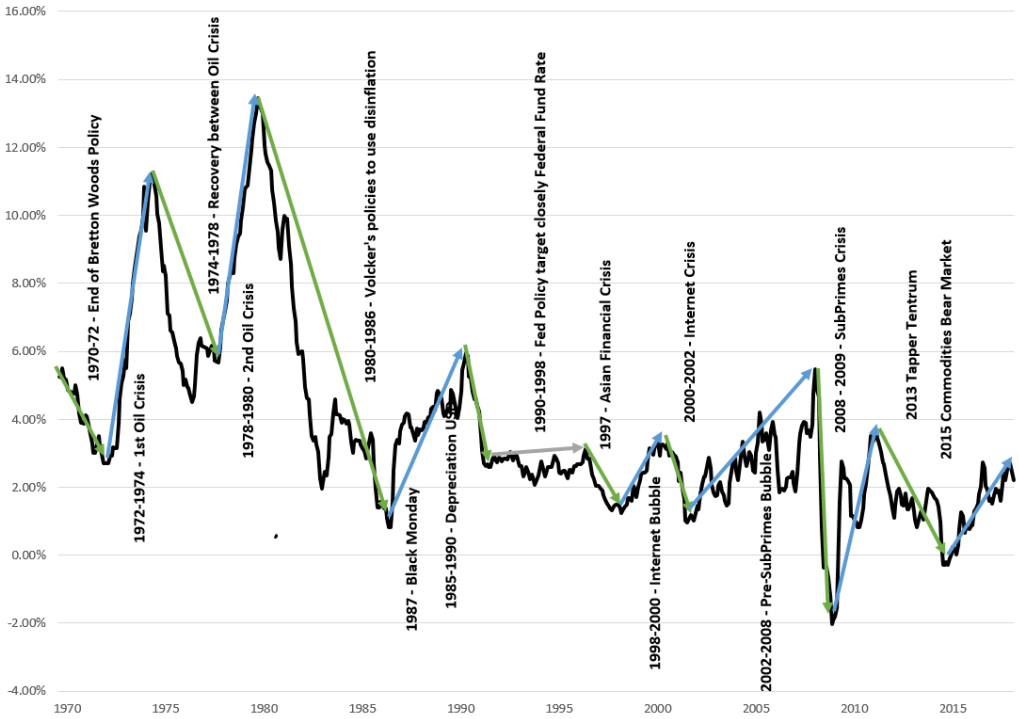

Figure 1: Historical inflation regime and main economic events related

Three main phases are drawn from this analysis and are explained as follows:

1. Two Oil shocks over a decade 1970-1980: in this period, US inflation was subject to two massive upward shocks related to the oil crises. The first one, hit the world economy in 1973, where in response to the Arab-Israeli war, members of the Organization of Arab Petroleum ceased their oil exports to most countries amongst which the US. Considered as the most significant oil embargo in history, this shortage made Oil barrel prices to jump by 4 in less than 6 months. In response to that US consumer prices increased dramatically.

[4]Gold standards were aimed as a monetary policy where following the Bretton Woods agreement the USD and gold prices were pegged.

In 1979, while the first oil shock was fresh in memory, the Iranian revolution resulted in a decrease in oil production output, hitting once again the oil supply chain. But, while this shortage represented only 4% of the usual oil production, market panic doubled barrel prices in less than 12 months. Both crises resulted in a massive rise of US inflation.

2. during the period before the oil crisis, the inflation was relatively stable. This situation can be explained by two main events: first the replacement of the Gold Standard policy[5] by the Petrodollars[6] systems and second the end of the controls of oil prices set under Nixon presidency and the external political events in the Middle East.

3. during the period after both oil crisis, the US currency policies began to be a major driver of inflation with for example the Volcker's policies to use disinflation after 1980 or more recently the Federal Reserve quantitative easing. To visualize the impact of the currency policies, the following figure will propose to make the link between inflation dynamic and the USD index:

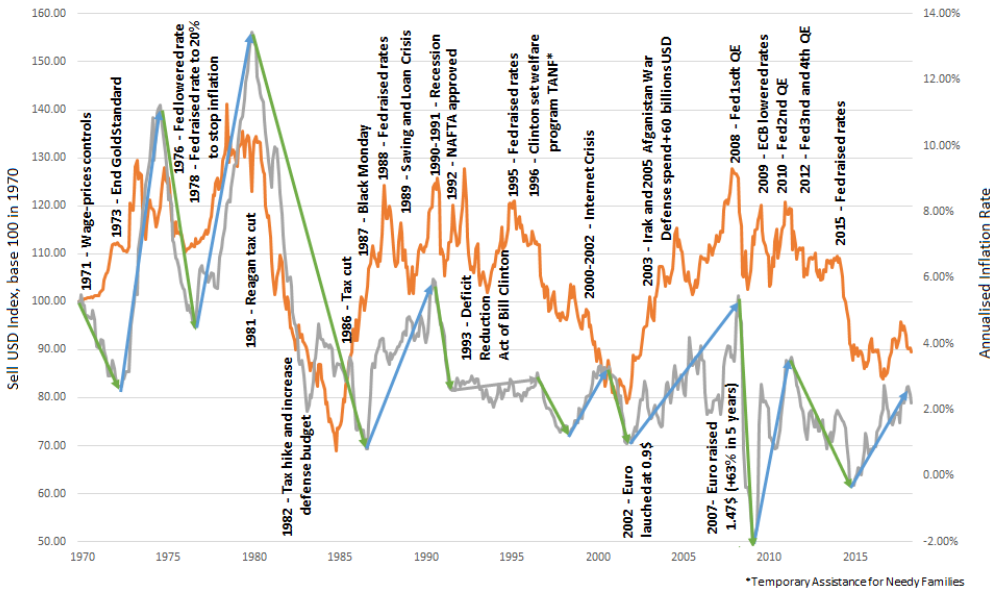

Figure 2: Historical inflation regime and events related

[5]The Gold Standard is a monetary policy proposing to use gold as a monetary unit with a fix rate against USD. Having a long history in the United States and in developed countries, this system was used following Bretton Woods agreements to introduce peg policy between gold and USD. The recognized advantage are the long-term stability of price and ultimately inflation as it controls the money supply and avoid hyper-inflation situation. However the system appears untenable over long term and was use for example by French government to reduce the US economic influence. As a consequence, the president Nixon decided to end the international fixed rate in 1971 and modified then the monetary system to abandon the conversion between gold and dollars.

[6]After the end of the Gold Standard monetary policy, the demand of dollars internationally began to drop and Nixon set a deal with the Organization of the Petroleum Exporting Countries (OPEC) to fix a rate between oil and USD in exchange of military support.

As a response to the second oil crisis at the end of the 70s, the Federal Reserve and its chairman Paul Volcker proposed raises of federal interest rate from 11% in 1979 to close to 20% in 1981 to reverse inflation dynamic. With his success, Volcker changed to way that inflation was perceived by consumers[7] as well as government and open a door to more controls of the inflation expectation using interest rate.

After the sub-primes crisis of 2007-2008, the inflation drop massively and enter into negative space leads Federal Reserve using Quantitative Easing (QE) to stabilize the economy and try resuming inflation. The interest rate at this time was already close to 0 and in the contrary of European Central Bank (ECB), which lower rate until negative term, the Federal Reserve directly search another answer via injection of liquidity in the US economy.

The first stage began in November 2008 with the purchase from the Federal Reserve of 600 billion of Mortgage-Backed Securities (MBS) and continue until 2010 for a total amount of more than 2 trillion of USD. The economy present some signs of recovery before to start failing as the QE impact lowered. A second stage happened then in 2010 by the purchase of 600 billion of US Treasuries until June 2011. In 2012, the Federal Reserve announced a long-term plan to purchase 40 billion USD every month which leads to positive economic impacts and a control of the policy to target an annualized inflation of 2%.

1.2 Inflation Regimes Clustering

Seeing that asset returns might react differently across the different inflation cycles, we think that being able to segment those cycles might offer a powerful tool for an inflation replication purpose. In this section, we will suggest then, two types of classification.

The first classification, is a rule based one which consists of identifying a new cycle if the dynamic of the annualized rate of inflation, changes during at least three consecutive months[8]. The following table exhibits the resulting classification:

[7] The first perception of the important interest rate increase leads to many protests against Federal Reserve until 1982 where the economic growth began to resume.

[8] The logic of the rule based classification is pretty simple and intuitive: for example to switch from a decreasing inflation cycle to a growth cycle, the increase of the annual rate of inflation should be noticed at least over three consecutive months. A minimal duration for the cycle is set for half a year, in order to smooth noisy data. As in the previous figures, the cycles of growing inflation were highlighted in blue while cycles of declining inflation are represented in green.

Begin Date	End Date	Duration (years)	Annualized Inflation in the beginning of the period	Annualized Inflation in the end of period	Variation	Remarks
02/1970	08/1972	2.5	5.26%	2.70%	-2.57%	End of Bretton Woods policy
09/1972	11/1974	2.2	2.93%	11.23%	8.30%	1st Oil Crisis
12/1974	03/1978	3.2	10.90%	5.67%	-5.23%	Disinflation between Oil Crisis and Petrodollars
04/1978	05/1980	2.1	6.15%	13.16%	7.01%	2nd Oil Crisis
06/1980	12/1986	6.5	13.01%	0.82%	-12.19%	Volcker's policies in the Fed: interest rate increase and disinflation used as guidance
01/1987	11/1990	3.8	1.55%	5.86%	4.31%	Black Monday market shock in 1987 and raise of Federal interest rate in 1988

Figure 3: Identification of Inflation Regime - Rule Based - 1/2

Begin Date	End Date	Duration (years)	Annualized Inflation in the beginning of the period	Annualized Inflation in the end of period	Variation	Remarks
12/1990	01/1992	1.1	5.25%	2.60%	-2.66%	Fed policy to target closely Federal Funds Rate
02/1992	12/1996	4.8	2.82%	2.84%	0.03%	
01/1997	10/1998	1.7	2.84%	1.36%	-1.48%	
11/1998	07/2000	1.7	1.42%	3.35%	1.93%	Internet and Technology Bubble
08/2000	05/2002	1.7	2.92%	1.01%	-1.91%	Internet Crisis
06/2002	08/2008	6.2	1.24%	4.86%	3.62%	Inflation pre-Subprimes Crisis
09/2008	07/2009	0.8	4.63%	-1.81%	-6.44%	Subprimes Crisis
08/2009	09/2011	2.1	-1.57%	3.45%	5.02%	First Federal Reserve Quantitative Easings
10/2011	04/2015	3.5	3.26%	-0.30%	-3.56%	Economy slow-down and long-term plan of Federal Reserve to continue Quantitative Easing
05/2015	06/2018	3.1	-0.10%	2.71%	2.81%	Economy resume and Federal Reserve began to raise US rate

Figure 4: Identification of Inflation Regime - Rule Based - 2/2

Consistent with the previous historical analysis, the following classification of inflation cycles highlights the main economic and monetary events since 1970. Different events impacted then the inflation dynamic, as the monetary policy decisions (Bretton Woods, Petrodollars), commodities shocks (both oil crisis), equity market shocks like the Black-Monday[9], the Tech Bubble, and the Sub-Prime crisis, or the interest rate movements (Federal Reserve rate and quantitative easing policies).

However the observation of these macroeconomic cycles and monetary adjustments were essentially ex-post and could not have been used to classify the current nor the future state of the inflation cycle. To be able to predict the contemporaneous inflation state, we explore the possibility of using a more instantaneous classification approach that rely on tradable asset classes as US cash, bonds, equity factors, commodities and foreign currencies, for which the price is instantaneously available[10].

[9]For more details, see 'A brief history of the 1987 Stock Market Crash with a discussion of the Federal Reserve Response' from Mark Carlson in the Federal Reserve Board. The main link between equity market movements and inflation shocks consist of the uncertainty around the macroeconomic decline of the US trade balance.

[10]More details about the used asset classes you can refer to the appendix A.

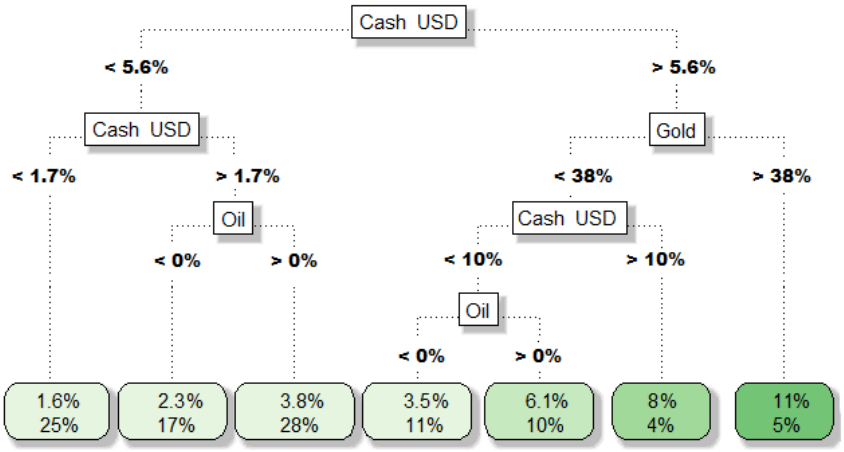

Figure 5: Identification of Inflation Regime - CART representation
Caption: The final classification is outputted in the bottom of the figure with the prediction and historical proportion of the time spend in the inflation regime.

To that end we use the Classification And Regression Tree (CART) algorithm, also called decision tree, to process a large amount of asset classes returns to identify those inflation cycles and determine whether there are common characteristics across a subset of asset classes per regime. The previous figure shows the results of this classification, where seven inflation states were identified according to three main variables which are the cash(USD 3 months cash rate), the gold and oil annual returns.

The results show that the most predictive variable across all our asset classes, to classify the inflation regime might be the annual US Cash return. For example, the figure shows that an annual cash return below 1.7% is potentially associated with a low inflation regime where the annual rate of inflation is below 1.6%. This is consistent with the application of low interest rates policy to control for inflation. This regime represents about 25% of our sample period, and corresponds to the current regime we have been having since the 2000s.

On the opposite side, regimes with high inflation rates coincide with both high interest rates and high returns for gold and oil prices. This situation represents about 5% of the sample period, and was highly contributed by the 2 oil shocks periods, where the cash rates returns were higher than 5.6% and gold price returns were higher than 38%. The predicted annualized inflation was then around 11%.

Between the two ends of the inflation regime spectrum, oil and cash returns allowed for a granular inflation regime classification through five other states with where the annual rate of inflation is between 2.3% and 8%. The details of this classification are presented in the following figure summarizing the predicted inflation over time[11]:

[11] As for the first approach, a threshold of 6 months duration is set to define a regime.

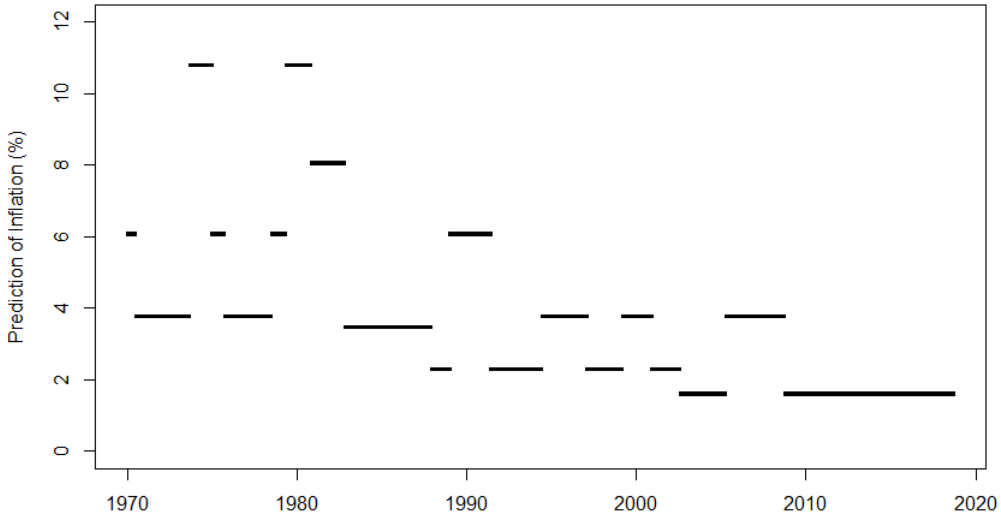

Figure 6: Inflation Regime Classification - CART prediction

More generally, the tree classification highlights the presence of distinct patterns between asset returns and inflation regimes, consistent with the previous historical analysis highlighted in figures 1 and 2.

2 Are Asset Classes returns correlated with Inflation returns?

2.1 Correlation Analysis

To strike the balance between data availability for a large set of asset classes and the occurrence of different inflation regimes[12] we choose to perform our analysis from 1985 onward. In this way, 28 asset classes are available and include:

- US Cash 3 months,
- US Government Bonds 10 years,
- Fama-French styles factors as market, size (Small Minus Big = SMB), value (High Minus Low = HML), profitability (Robust Minus Weak = RMW), investment policies (Conservative Minus Aggressive = CMA),
- Commodities indexes for precious metal as Gold or Silver, energy as Oil but also Food and Textiles as Corn or Cotton,
- Developed currencies index against USD as AUD, CAD, EUR, GBP, JPY, MOK, CHF and NZD.

As in Hoevenaars et al., 2008, we calculated the Pearson correlation of the nominal returns of these asset classes with realized inflation and highlighted which ones exhibited the highest correlation. To do so, our first analysis consisted of displaying the historical correlation matrix between the 1year CPI return (inflation return) with the 1 year asset classes nominal return:

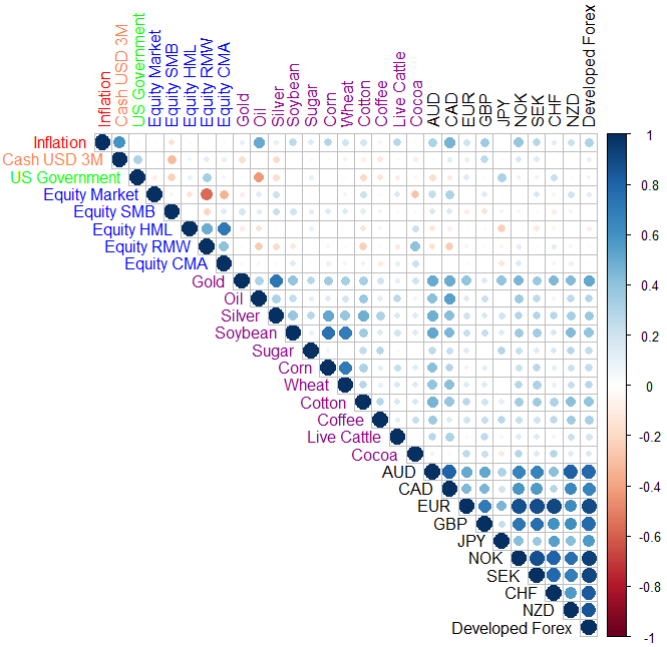

Figure 7: Asset Classes correlation with Inflation

[12]Refer to appendix A for more details about the asset classes and their available data.

The correlation results show that the asset classes exhibiting the highest correlation with inflation appear to be the cash USD 3 months (0.59), the oil price (0.50) and CAD against USD currency (0.46). The correlation between the short term cash and the rate of inflation is very likely to be a direct consequence of the relationship between the FED monetary policy and inflation policy as explained previously. Similarly the high degree of correlation between oil prices and inflation rate is mostly attributed to the latest part of the second oil shock episode as highlighted in Figure 1. Whereas the high correlation between the CAD /footnoteCurrency contracts refer to spot prices against USD with inflation is potentially due to the fact that Canada is one of the biggest US Oil exporter[13] and that its local currency is indirectly influenced by US inflation through oil prices.

To complete this correlation analysis, we performed a Principal Component Analysis (PCA) presented in the Appendix C. The PCA helps to identify the main driver of the variance decomposition. The results will be used later in the regression analysis.

2.2 Regression Analysis

Using an Ordinary Least Square (OLS) regression method, we perform a first linear regression to replicate inflation using the available asset classes. The asset classes with the most significant inflation replication capacity are the cash 3 months, the Fama-French equity factors which are the value and the investment factors, as well different commodities (Oil, Corn, Wheat and Live Cattle), and the CAD currency. The presence of cash, oil and CAD are consistent with the previous analysis, while Corn, wheat and live cattle commodities futures present a new opportunity to replicate inflation through future contracts. It's worth noting that they are also part of the composition of the CPI index. Finally the three Fama-French equity factors offer an interesting alternative for inflation replication as they can both serve to implement an equity and inflation exposure.

[13]US crude oil imports from Canada are estimated around 37%. This could justify the correlation between CAD/USD and oil index over the period which is estimated at 0.54.

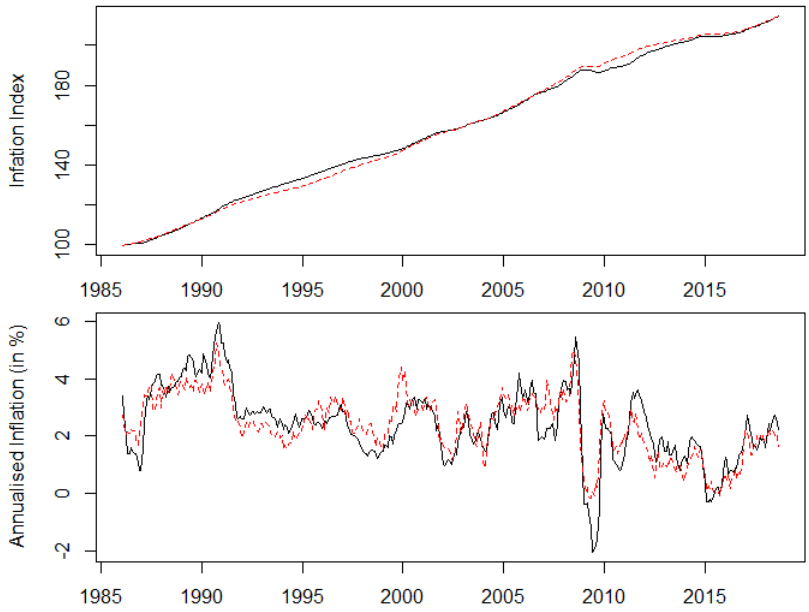

Figure 8: Predicting Inflation using OLS Regression

The prediction from the OLS regression provides interesting results as the proportion of the explained variance through the R-square was estimated at $R^2 = 73\%$.

To manage the potential multicollinearity between asset classes returns, we perform a second type of regression using the Partial Least Squares (PLS) method. This regression mainly reduces the space on which inflation is projected on the variable space.

As shown in Appendix C using the Principal Component Analysis (PCA), the three first principal components provide both a better understanding of correlation between the asset classes and a consistent inflation prediction as:

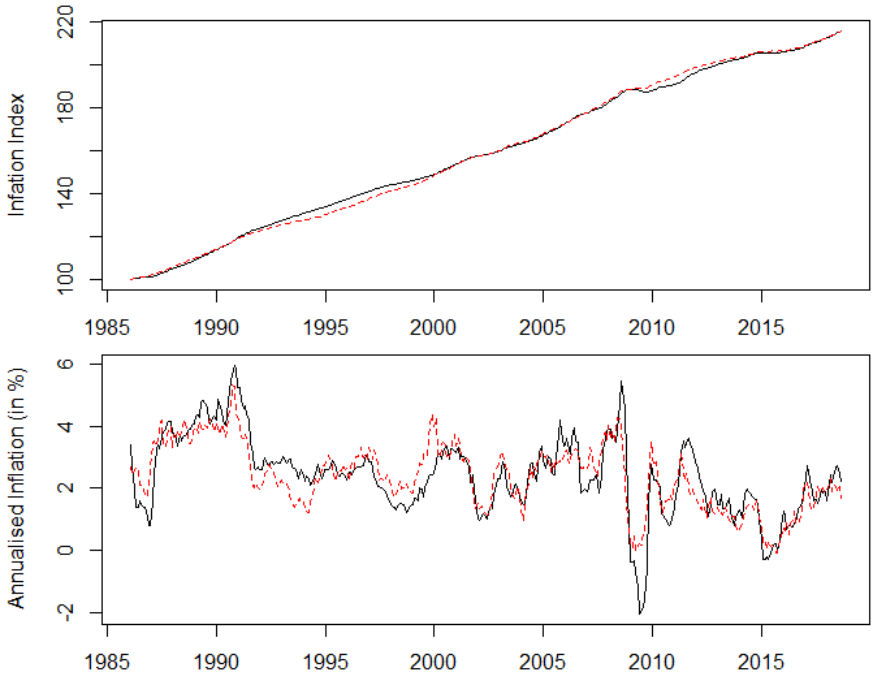

Figure 9: Inflation Prediction using PLS Regression

The variance explained by the three first factorial axes provides an R-square of $R^2 = 68\%$, aligned with the results of the OLS regression.

The main reason for concern for these two regressions is the impact of outliers on the results. First between 1990 and 1994, the predicted inflation was lower than the observed one that moved from 2% to 6% in late 1990. As mentioned in Figure 1, an explanation could be attributed to the unexpected support of the FED to target more closely interest rates in response to inflation decline.

And secondly in 2009, the observed annual rate of inflation landed in negative territory for the first time in our sample, opening for a deflation era, whereas the prediction resulting from the asset classes was more predicting a 0% inflation.

This situation could be related to the unexpected scale of the sub-prime crisis which led the Federal Reserve to drastically cut interest rates (from about 5% to 0% in less than a year) and to implement later an unprecedented quantitative easing to reboost inflation.

These exogenous events could have been hardly predicted through available data on tradable assets, and this could set the potential limitations of an inflation predictive model, where central bank policies as answers for unprecedented events and their consequences on inflation are simply unpredictable.

Conclusion

This preliminary work which first consisted in providing some background on US inflation history, and on identifying the existing relationship between asset returns and inflation across different regimes, made it clear that any portfo-

lio construction that aims at offering an inflation related objective, requires an inflation regime classification in the first place, because asset returns react differently across those regimes.While this classification, proves to be very challenging particularly when the regimes are driven by exogenous and unexpected events, it would likely help to select the asset classes that suit best the targeted inflation objective. So, ideally one needs to identify the inflation regime we are in, then select the assets offering the best inflation replicating capacity within that regime. Some assets, like short term cash seem to be closely tied to inflation dynamics across all regimes, however this is less obvious for most assets, like commodities, where strong correlation with inflation could be largely attributed to few disproportionate events like the 2 oil shocks. Nevertheless, this difficulty is exactly the challenge we are aiming to solve. We think that it's possible to use other assets than ILBs to capture inflation properties, and this is exactly what we identified through the high correlation between some assets and inflation returns. We also believe that it's possible to replicate inflation in a cost effective way by investing into assets through futures exposure that allow for more flexibility in terms of capital allocation. This is what will investigate in our future work regarding this topic.

A Appendix: Details about data

The inflation index considered in this article is the US CPI Index. The data of annualized inflation rate are available since June 1927.

The asset classes used to replicate the inflation index are listed below with their date of first availability:

1. Cash USD 3 Months (BY3M) since December 1920,
2. Bond US Government 10 Years (BRI10) since December 1920,
3. Equity Fama-French Factors: Market Risk-Neutral, Size (SMB) and Value (HML) since June 1927 & Profitability (RMW), Investment Policies (CMA) since 1964,
4. Commodities indexes as:

- Gold since December 1920,
- Oil since December 1946,
- Silver, Soybean, Sugar, Corn, Wheat, Cotton, Coffee, Cocoa and Live Cattle since December 1981,

5. Currencies against USD as:

- AUD, CAD, EUR, GBP, JPY, NOK, SEK, CHF, NZD since December 1920. To summarize the variation of developed currencies, an equal-weighted index have also been created.

All the data are available on a monthly frequency.

B Appendix: Inflation cycle clustering by K-Means

An alternative methodology to classify inflation regimes could be performed through a K-Means algorithm. The idea is to cluster homogeneous periods using the asset classes that are mostly correlated to inflation.

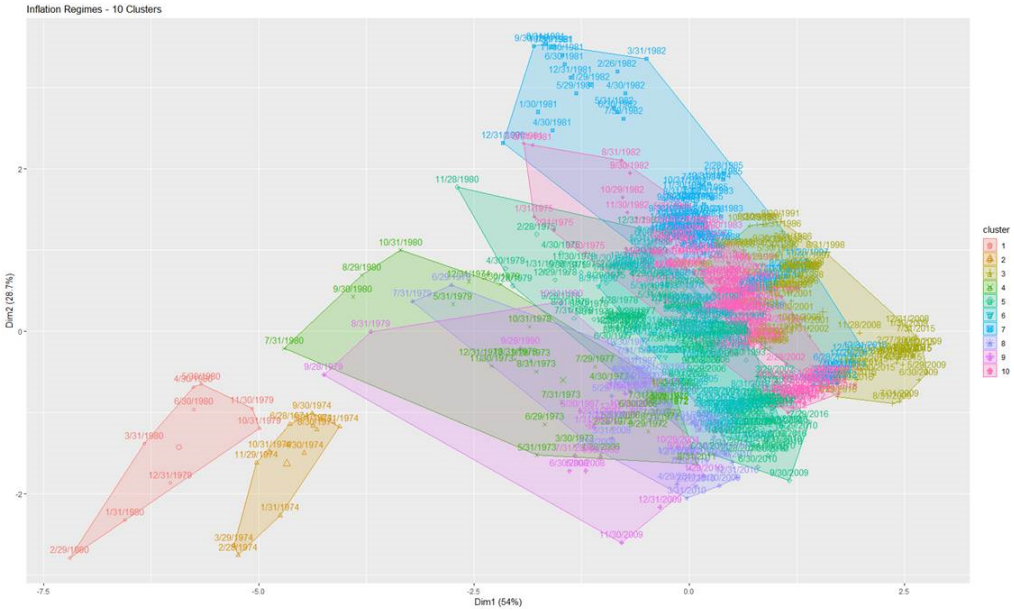

Figure 10: Classifying Inflation Regime through K-Means

Similarly, K-Means identified the main historical inflation episodes as the first oil crisis (in dark-yellow) and the second one (in red) in the bottom left corner of the graphic. The clusters represented at the opposite side of the graph gathered post-crisis years from 1981 to 1985 (in light blue) with more recent periods since 2017 where the inflation reached its lowest levels. Finally post crisis inflation growth episodes are highlighted in purple for periods such as the late of 1979 (post second oil crisis), 1987 to 1990 (Growing inflation after the Black Monday) or even the end of 2009 and beginning of 2010 (post subprime crisis).

The regime classification method provides a useful way to detect patterns across different inflation regimes and could be therefore used to integrate new information from asset classes to identify to what regime subgroup the current asset movements are the closest.

However, the complexity of visualization of the subgroups in high dimension in addition to the difficulty of explanation across the different classifications, led us to prefer decision trees to perform inflation classification regimes.

C Appendix: Analysis of principal component

The Principal Component Analysis is a statistical tool used to reduce the dimension of a set of correlated variables and provide a representation reduced to the main components contributing the variance. In this article, the methodology was applied to identify the main components across asset classes in order to replicate inflation.

The following graphic represent the percentage of variance explained by the first principal components of the analysis:

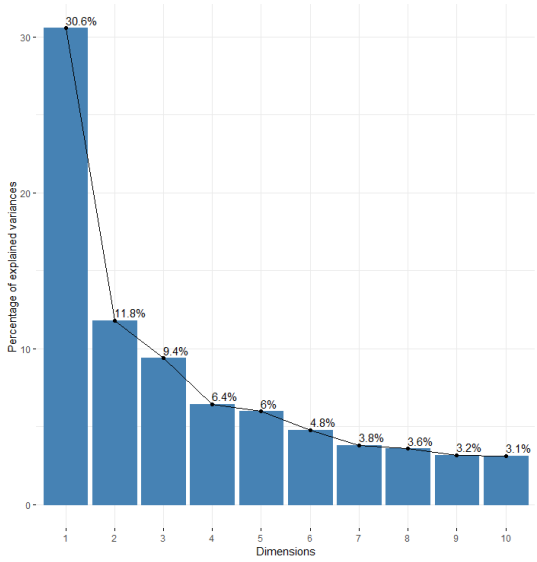

Figure 11: PCA - Percentage of variance explained by principal component

Using the 28 asset classes available after 1983 to replicate inflation, more than 50% of the variance is explained by the three first principal components.

Our analysis and ultimately the PLS regression will then be based on these 3 first components. We will try to provide on the following pages an interpretation of the different axis using coordinate in graphical representation as well as the indicators of the quality of representation and the contribution to the axis that we define below:

- The variable coordinates in the graphic represent the correlation with the principal components and can highlight opposite tendencies,
- The quality of representation (or CO2 for cosinus square) represents how well the variable is represented for each axis. Indeed sometimes the correlation of a variable with the axis may be important because the quality of representation is low and the result deduced can be a counteract, so it may need validation. The quality of representation of one variable across all principal component axis sum to 100%, so here with 28 axis an average quality is 3.5% and then the quality can be interpreted as under-represented in the axis if below this threshold and over-represented if behind the threshold,

- The contribution to the axis creation represents how the variable contributes to each axis. The sum over all variables for one axis is 100% so with 28 variables, a contribution higher than 3.5% can be considered as an over-contribution and for a lower than this threshold, as an under-contribution.

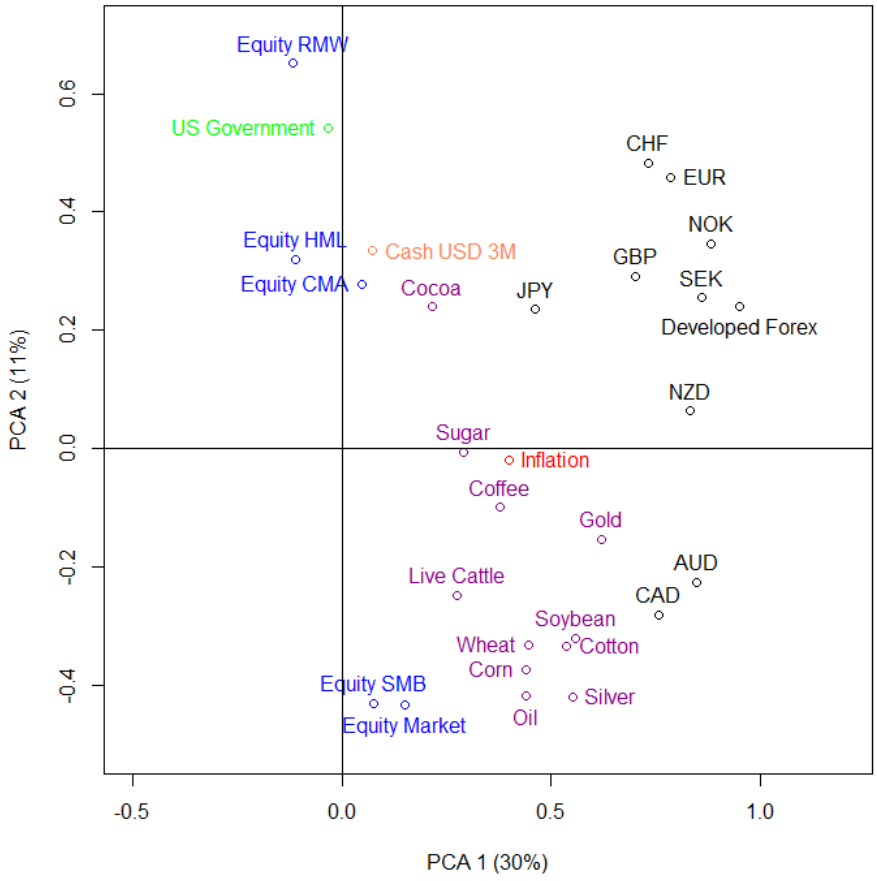

Figure 12: PCA - Representation Axis 1 and 2

The first axis can then represents the exposure to currency market. The interpretation is confirmed with the best quality of representation and axis contribution for the equal weighted developed currency index:

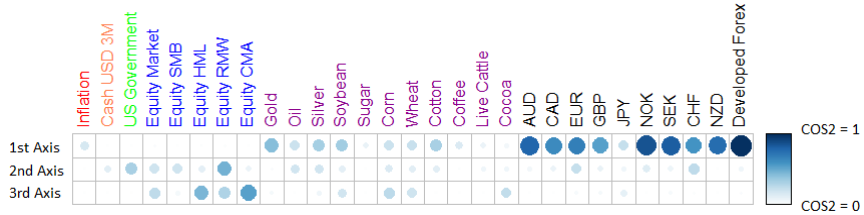

Figure 13: PCA - Quality of Representation for the three first axis

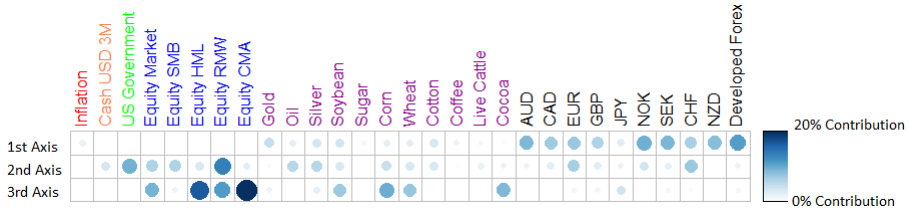

Figure 14: PCA - Contribution to the axis creation of the three first axis

The second axis represents the exposure to income like asset classes. The profitability equity factor and US Government Bond at the top with the best quality of representation and axis contribution are then opposed to more cyclical asset classes as the market beta, the size factor, the Oil and silver prices amongst commodities.

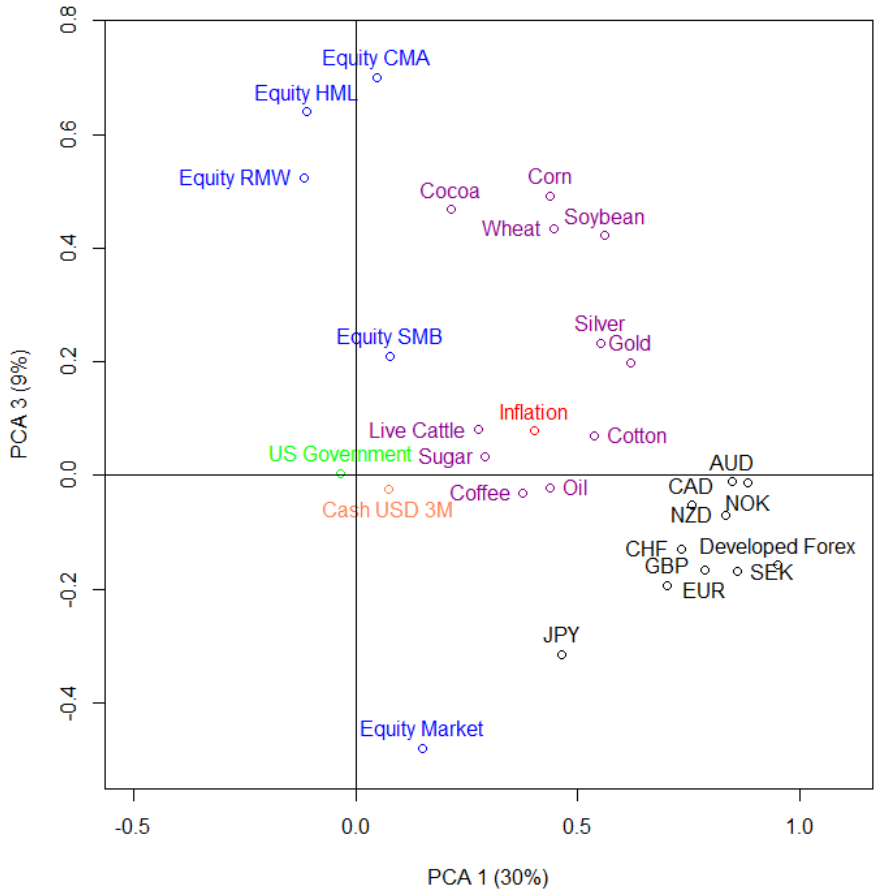

Figure 15: PCA - Representation Axis 1 and 3

The third axis represents the exposure to factors as conservative-minus-aggressive also called the investment factor (CMA), the value factor (HML), robust profitability (RMW). These three equity factors have then the best quality of representation and contribution to the axis and are opposed the equity market factor. The inflation asset class is positively correlated to the third

component

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