Alternative inflation hedging strategies for ALM

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Alternative Inflation Hedging Strategies for ALM

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"*If I have seen further it is by standing on the shoulders of giants*"
-Sir Isaac Newton, 1676-

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Résumé :

La disparitions graduelle des peurs liées à l'inflation pendant l'ère de la «Grande Modération» macroéconomique est aujourd'hui chose révolue : la crise financière américaine des «Subprimes», la «Grande Récession» ainsi que la crise des dettes souveraines qui s'en est suivie ont abouti à un nouvel ordre économique caractérisé par une volatilité accrue de l'inflation, un accroissement des chocs dans les prix des matières premières et une défiance envers la qualité de la signature de certains émetteurs souverains pour n'en mentionner que trois caractéristiques. De la réduction des émissions de titres souverains indexés sur l'inflation aux taux réels négatifs jusqu'à de très longues maturités, cette nouvelle donne tend à mettre en péril aussi bien les stratégies conventionnelles de couvertures inflation que les stratégies directionnelles purement nominales . Cette thèse a pour but d'investiguer les effets de ces évènements qui ont changé la donne macro-financière et d'évaluer leurs conséquences en terme de couverture inflation aussi bien dans la gestion actif-passif des investisseurs institutionnels que sur l'épargne des particuliers. Trois stratégies alternatives de couverture sont proposés pour y faire face.

Descripteurs : *Couverture Inflation, Allocation de Portefeuille, Investissements Alternatifs, Matières Premières, Taux Réels, Inflation Sous-Jacente, Global Macro, « Passage de l'inflation », Allocation Stratégique, Assurance de Portefeuilles, Grande Récession.*

Abstract:

Gone are the days when inflation fears had receded under years of "Great Moderation" in macroeconomics. The US subprime financial crisis, the ensuing "Great Recession" and the sovereign debt scares that spread throughout much of the industrialized world brought about a new order characterized by higher inflation volatility, severe commodity price shocks and uncertainty over sovereign bond creditworthiness to name just a few. All of which tend to put in jeopardy both conventional inflation protected strategies and nominal unhedged ones: from reduced issues of linkers to negative long-term real rates, they call into question the viability of current strategies. This paper investigates those game changing events and their asset liability management consequences for retail and institutional investors. Three alternative ways to achieve real value protection are proposed.

Keywords : *Inflation Hedging, Portfolio Allocation, Alternative Investment, Commodities, Real Rates, Core Inflation, Global Macro, Inflation Pass-through, Strategic Allocation, Portfolio Insurance, Great Recession.*

Principales abréviations

ADF: Augmented Dickey–Fuller test.

ALM: Asset Liability Management.

AR: Auto Regressive.

BEI: Breakeven Inflation rate.

BS: Black-Scholes

CHS: Core versus Headline Swap.

CI: Core Inflation.

CMS: Constant Maturity Swap.

CPI: Consumer Price Index.

CPPI: Constant Proportion Portfolio Insurance.

CW: Constant Weight.

DIHTS: Dynamic Inflation Hedging Trading Strategy.

EMH: Efficient Market Hypothesis.

FFF: Fixed-For-Float.

FR: Fail Rate.

GDP: Gross Domestic Product.

HI: Headline Inflation.

HmC: Headline minus Core inflation.

ILB: Inflation Linked Bond.

IR: Information Ratio.

IRF: Impulse Response Function.

LT: Long Term.

MV: Minimum Variance.

NAV: Net Asset Value.

OAT: Obligation Assimilables au Trésor.

OECD: Organization for Economic Co-operation and Development.

OTM: Out of The Money.

P&L: Profit and Loss.

PFE: Perfect Forecast Environment.

PLGF: Profit or Loss Given Default.

REIT: Real Estate Investment Trusts.

RPI: Retail Price Index.

S&P-GSCI: Standard & Poor-Goldman Sacks' Commodity Index.

ST: Short Term.

SVAR: Structural Vector Auto Regressive.

T-Bill: Treasury Bill.

TIPS: Treasury Inflation Protected Securities.

ToR: Turnover Ration

VAR: Vector Auto Regressive.

VECM: Vector Error Correction Model.

WI: Weight Index.

ZC: Zero Coupon.

ZCIIS: Zero Coupon Inflation Index Swaps.

ZCNB: Zero Coupon Nominal Bond.

ZCS: Zero Coupon Swap.

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A foreword on the Genesis of the Project

As of January 2009, all French retail banks were authorized to distribute the "Livret A", a more than two century old savings account initially designed to rebuild French people's savings after Napoleon's lengthy and costly continental wars. Until then, the distribution of this state-sponsored savings account had been restricted to a trio of banks comprised of the Banque Postale and the Caisses d'Epargnes for the "Livret A" and the Crédit Mutuel for the "Livret Bleu". The breakup of the exclusive distribution rights had been ordered a little over two years prior by the European Commission (European Comission, 2006) in application of Articles 43 and 49 of the Rome Treaty, of which France had been found to be in breach: "The Commission fears that these special rights may infringe the Treaty by raising obstacles to the freedom of establishment and freedom to provide services (Articles 43 and 49) and "The Commission's objective is to create the conditions for fair competition on the liberalized market in savings products in France, and particularly to remove any barriers to the entry of new operators into the market." Banks which had been left out claimed victory even if it turned out to be a Pyrrhic one.

This momentous regulatory change could not have occurred at a worse time for them: markets were reeling from the ongoing meltdown of the financial system caused by the US subprime crisis and individual investors had witnessed their equity portfolios' value being almost complete wiped out. Meanwhile, sovereign rates bottomed out as investors fled to safety. Risk aversion was rife and rising and inflation surged in proportions which had not been seen in decades. In this context, the offering of a then AAA-state guaranteed, liquid and inflation protected investment attracted crowds. Indeed, in the months following the liberalization, tens of billions of deposits a month were removed from balance-sheet savings accounts and flowed into the almost off-balance sheet "Livrets A". As the crisis continued and soon engulfed the Eurozone's peripheral sovereign issuers, its success became lasting and banks were left grappling with a pincer movement made of both diminishing deposits and massive inflation liabilities. Had inflation kept rising at the time, it could well have been a modern day Trafalgar for French retail banks having claimed victory a bit too early.

As time goes on, an increasing share of those deposits on "Livrets A" are flowing to the Caisse des Depots et Consignations, further straining banks' balance sheets. But the real concern has been on the part that is left to private banks but which still has to be remunerated at least as much as the current level of headline inflation, thereby generating a more than a hundred billion euro inflation liability problem. Its sheer size meant that it could not possibly be hedged by investing in sovereign inflation-linked bonds, issuances of which were too small and already in high demand, forcing asset-liability management desks to turn to inflation derivatives in order to hedge this risk. To make matters even worse, the contemporaneous demise of Lehman Brothers and the ensuing severe restructuring of the financial sector dealt a double blow to large inflation hedgers as the number of trading houses quoting French inflation derivatives fell and new rules regarding counterparty risk severely curtailed the maximum credit exposure any of the remaining houses could have, thus restricting even further the potential supply of hedging securities. The quest to find alternative inflation-hedging strategies had become a vital concern. As Crédit Agricole SA's asset-liability management division had the single largest inflation exposure, it was only natural for them to begin exploring alternative solutions and Mr. Patrick Fincker, then head of interest rate risk, thus proposed to finance a PhD on this issue, the achievements of which are detailed hereunder. As he left for CA-CIB in June 2012, the project was transferred to Mr. Philippe Ithurbide, Global Head of Research and Strategy of Amundi AM, who supervised the project through to its completion while its scope was broadened to address the needs of investors seeking more diverse inflation-hedging solutions.

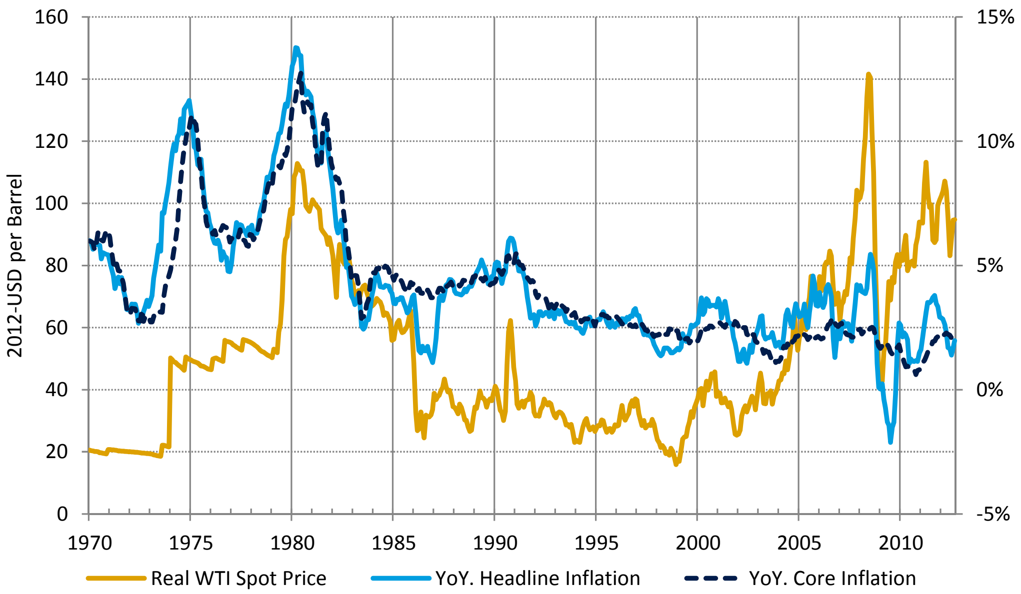
Introduction: Going Forward under Immoderate Macroeconomics

1. THE DRIVERS OF INFLATION HEDGING

Inflation hedgers worldwide can be divided between those that are compelled by law or contract to do so and those who choose to do so as an investment strategy: in the first category we will find institutional investors such as British pension funds, which have to offer pensioners a guaranteed real value for their retirements, and, in the second category, we will find their American peers which choose to offer real return targets to their investors. As economic realities cannot be written in black and white, we will find a swarm of investors in the middle ground which are somewhat driven by imperative and partly driven by strategy: this last category includes French retail banks hedging their inflation-linked retail savings products or insurers which offer policies that, by law, are guaranteeing real values. As both of these are exposed to short-run inflation liabilities, they have the option not to fully hedge this inflation and therefore keep the risk on their books. This combination of imperative and strategic decisions has generated a massive influx of money into inflation hedging assets which could be defined as "*too many dollars chasing too few [securities]*". This steady increase in the demand for inflation hedging assets as inflation remains muted overall begs for an answer.

As Volcker's monetary tightening drive in the late seventies took its toll on the rampant inflationary pressures in the US economy, the "*Great Inflation*" era seemed to have come to a close (Meltzer, 2005). But as investors were ushered into a new era of receding inflation and overall macroeconomic stabilization, the days of cheap oil were numbered: emerging economies were showing signs of economic take-off. As those countries transformed their economies and caught-up with more advanced ones, so did their oil consumption. Depressed oil prices in the decades following the oil shocks (Mabro, 1987) as a result of both economic difficulties (Hamilton, 2011) and large offshore discoveries in the eighties led to a dramatic underinvestment in oil production whose consequences would only be felt at the end of the noughties: an ever rising demand became no match for the growth in production. As the financial cataclysm hit the world's most advanced economies, crude oil prices returned to a high and volatile state, driving inflation upward in most countries and threatening to annihilate any timid sign of economic recovery. Throughout this period, the very nature of inflation drivers had changed as headline inflation indices faced a roller-coaster ride of a very different nature from the one experienced in the seventies (Blanchard & Gali, 2007): core inflation was now flat for every advanced economy (van den Noord et André 2007) and (Clark et Terry 2010).

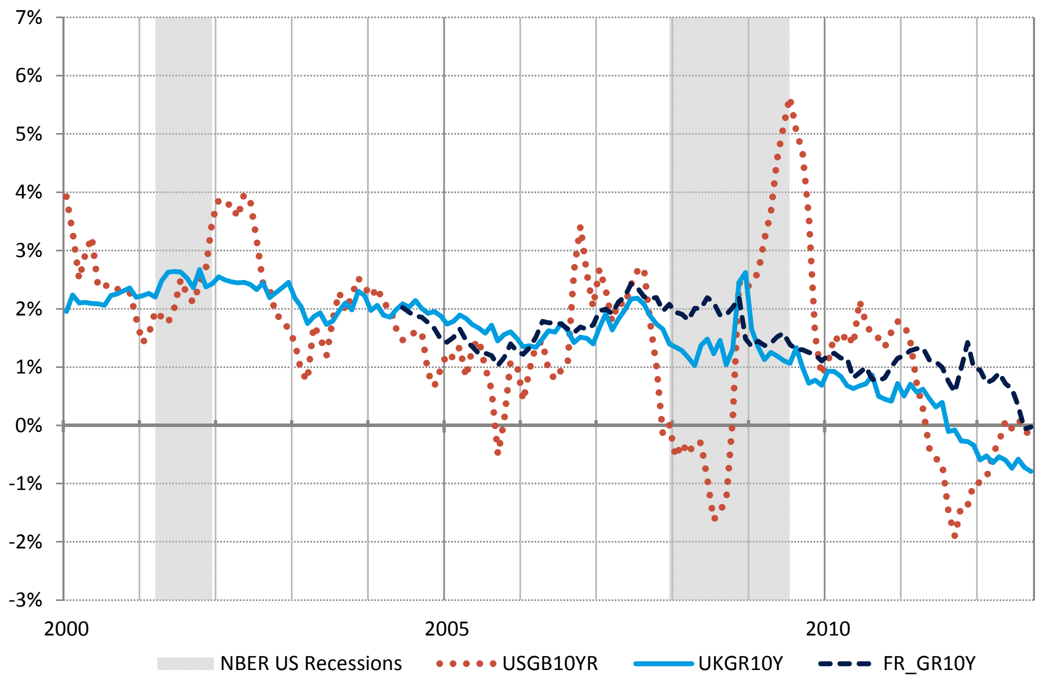
Figure 1: Crude oil and inflation over forty years in the US



Source: Dow Jones & Company/FRED

The subprime crisis and the ensuing "*Great Recession*" (Farmer, 2011) have had a lasting impact in the form of depressed economic activity and non-existent wage increases contemporaneously with inflation creeping upward (Levanon, Chen, & Cheng, 2012). While the effects of the non-conventional monetary policies implemented in the wake of the financial crises have not yet shown any clear signs in terms of inflationary activity, negative long-term real rates became a pressing reality for asset liability managers: the dangers posed by ever growing unhedged inflation liabilities seem all the more acute as constantly increasing flows of investors spooked by the surge in inflation and the financial market crash sought inflation protection. There are few reasons for this demand to abate as the populations in advanced economies age while seemingly being unable to reform their increasingly fragile redistributive pension systems, the consequences of which will most probably be an increase in the demand for private pension schemes, which have embedded purchasing power guarantees, synonymous of inflation protection (Zhang, Korn, & Ewald, 2007). As the prospect of stable and moderate inflation fades, with it vanishes the underpinning of inflation-linked bond issues by sovereign states. As the macroeconomic paradigm shifts and the future of the primary inflation-linked market is challenged, the time to rethink inflation hedging has come.

Figure 2: Real sovereign 10 year yields for France, the UK and the US

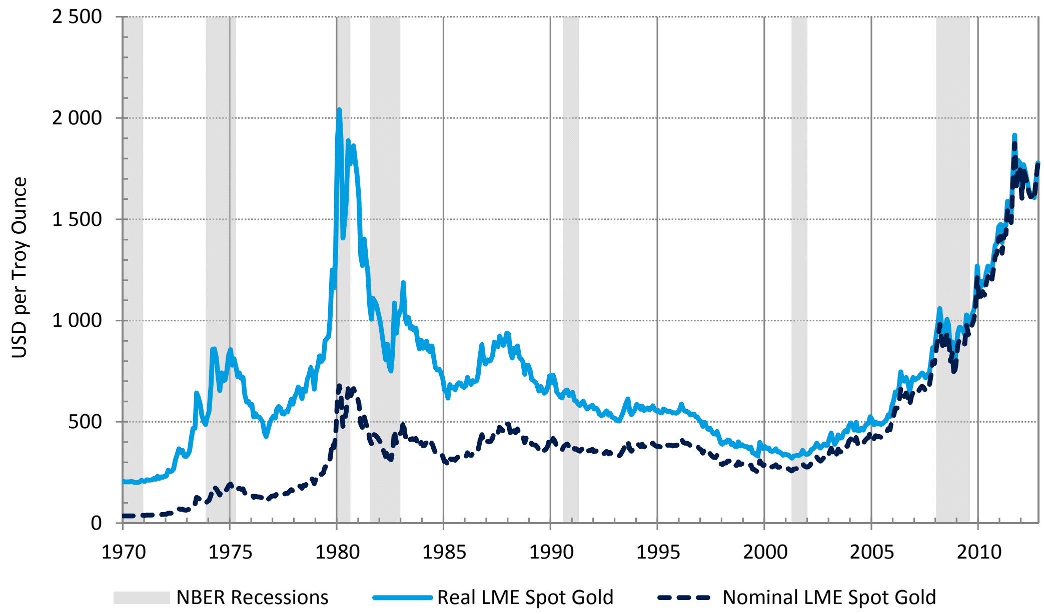


Source: Datastream / Bloomberg / FRED

2. The conventional portfolio allocation to hedge inflation

Gold has remained largely synonymous with inflation protection for centuries if not millennia. Wars, empires, industrial revolutions, gold standard, stock market and real estate bubbles and crashes came and went but the magic of gold remained largely intact. Unsurprisingly therefore, time passed without burnishing the real value of the yellow metal which to this day maintains its position as the grail of real value (Dempster & Artigas, 2010). But gold itself is not immune to boom and bust phenomena. Even though gold's very long-term inflation hedging properties are undeniable, its propensity to attract feverish investor confidence, especially in time of economic turmoil, makes it a highly unsuitable asset to hedge inflation when it comes to accounting or as a guarantee of purchasing power. While gold remained the asset of choice for state coffers then central banks with infinite horizon, the same logic cannot apply to individual investors as J.M. Keynes famously remarked: "*In the long run we are all dead*". Through one's lifetime, the value of gold will have gone up or down and will take years if not decades before a correction occurs, which is most likely substantially longer than our desired investment horizon.

Figure 3: Real and nominal gold prices over fifty years.

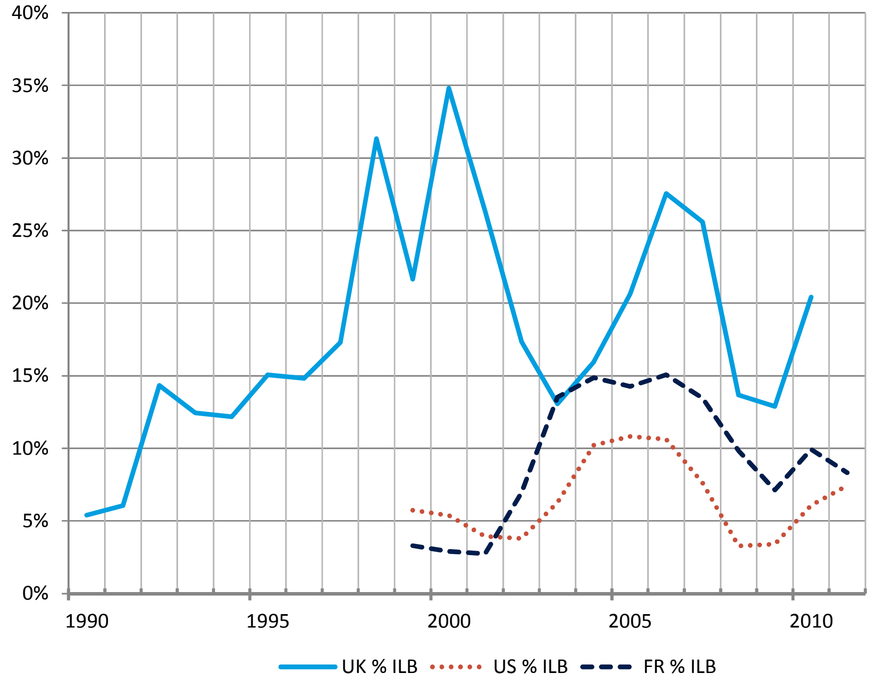


Source: Datastream/FRED

Hardly a week goes by without an article on a new inflation hedging asset class or a new allocation technique. But in truth, there is no more a magic inflation hedging allocation than there is a silver bullet: inflation is solely linked to explicitly inflation-linked securities such as linked bonds or swaps. All other asset classes have only time-varying hedging capabilities and therefore offer limited protection (Attié & Roache, 2009). Linked bonds have accordingly become the core of inflation hedging literature and make up the bulk of inflation hedged portfolios today (Bodie Z. , 1988). Yet, this one and only solution remains unsatisfactory for many investors: linked bonds are available in limited supply and accordingly suffer from low returns and less than optimal liquidity and depth compared to their nominal equivalents (D'Amico, Kim, & Wei, 2008). This is partly due to the fact that more than thirty years after their introduction in the United Kingdom, the issuance of private linked bonds has remained largely marginal and therefore confined to a few sovereign or quasi-sovereign issuers (Garcia & Van Rixtel, 2007). The problem has become all the more acute as the current sovereign crisis has raised credible questions on the opportunity for sovereign issuers to stick to their real issue policy in the face of rising costs as inflation crept up and long-term real rates, which have turned negative, have become the norm for many large nominal sovereign issuers.

As good times bring on bad habits, the *"Great Moderation"* era (Stock & Watson, 2003) of the decades preceding the subprime crises was no exception. This period witnessed an exceptional context of low and stable inflation which progressively relaxed the inflationary fears of the seventies and smothered memories of the high and volatile inflation which had characterized it. Rising inflation volatility at the turn of the last decade brought back those fears believed to be long lost and resulted in a new wave of interest in inflation protection. But the most pernicious effect of this new context was yet to come as nominal rates went down contemporaneously with inflation shooting up: purely nominal un-hedged strategies started to backfire dangerously and required a profound rethink of their use. Moreover, as central banks all over the OECD countries started to implement unconventional monetary tools and expand their balance sheets, there were fears that the problem could only get worse as *quantitative easing* and *Twists* become household names (Baumeister & Benati, 2010). This new investment climate motivated researchers to move into a new era of alternative hedging strategies that would neither be linker based nor dependent on a macroeconomic moderation hypothesis that had shown its limits.

Figure 4: The share of linkers in sovereign issues for France, the UK and the US



Source: UK-DMO / FR-AFT / US-Treasury

3. MOVING AWAY FROM LINKERS WITH PORTFOLIO INFLATION INSURANCE

One of the most enduring testimonies of the financial meltdown brought about by the subprime mortgage crisis in the US can be found in the elevated level of risk aversion worldwide (Caceres, Guzzo, & Segoviano Basurto, 2010). The ensuing European sovereign crisis only fueled an additional flight to quality syndrome which had gripped investors fleeing the hazardous combination of an equity bear market of historic proportions and the first significant spikes in headline inflation for at least two decades. The combination of both of these factors resulted in increased demand for at least inflation protected investments, if not theoretically nominal and real risk-free products, namely investment grade linkers. But the rise in the demand for them was not to be matched by an equivalent rise in their issuance as sovereign treasuries were themselves battling with rising financing costs precisely as a result of this inflation linkage. The very *raison d'être* of linkers had backfired badly as they turned out to be more expensive to issue than their nominal counterparts in times of rising inflation. This inevitably leads to the return of the question that had plagued inflation protection research in its nascent phase: the availability problem of linkers.

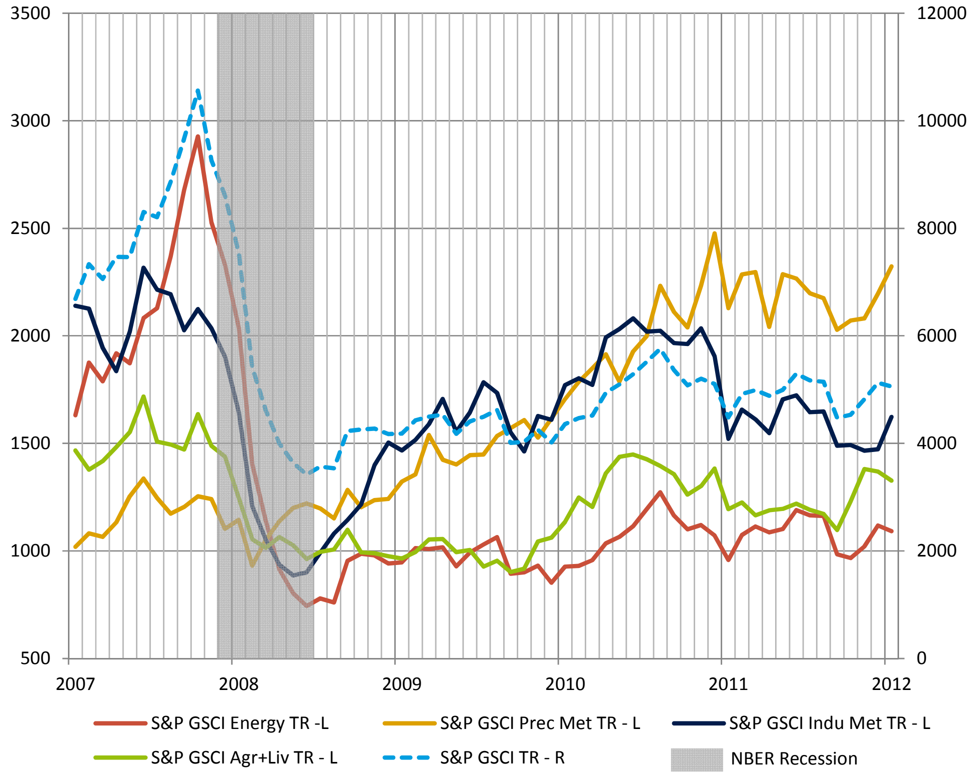
Considering the overwhelming *debt overhang* problem which looms over most sovereign issuers from industrialized countries, it is becoming increasingly clear that inflation will eventually be the last available weapon left in the state's arsenal to fight bulging balance-sheets. Resorbing debt through monetary erosion will probably lead to a revision of sovereign issue policies which could in turn lead to some reduction in the share of linkers in new issues if not an outright reduction in their output. By the look of issues in the last couple of years, this policy shifting is in fact probably already underway. Yet, the foreseeable scarcity of new inflation-linked bonds could be bypassed if we were capable of replicating linkers with purely nominal assets which would also have inflation hedging capacities (Brennan & Xia, 2002). There is a large body of literature *on natural inflation hedging assets* (Amenc, Martellini et Ziemann 2009) such as commodities or listed real estate (REITs) which delves into their potential resilience to both expected and unexpected inflation shocks and their ex-ante optimal allocation in inflation hedging portfolios. But none of these alternative asset classes has a guaranteed value at maturity or even a real (and nominal) floor like linkers do. Moreover, as most of the demand for inflation hedging assets comes from asset-liability-management desks, it adds another layer of complexity as they require not only a real floor but also a certain level of real return to match part of their funding costs. Clearly, not all of these requirements can be met simultaneously, but a mitigation approach can be found in the application of portfolio insurance (Leland, 1980) to our problem.

This asset management classic from the seventies is transposed into real asset protection in the form of the *Dynamic Inflation Hedging Trading Strategy* (DIHTS) derived from *Constant Proportion Portfolio Insurance* (CPPI). This new framework developed in (Fulli-Lemaire, A Dynamic Inflation Hedging Trading Strategy, 2012) envisages the inclusion of strong real return yielding assets with high volatility ones like Equities, Commodities and REITs to hedge a fundamentally low inflation volatility risk. It enables the real upside of these alternative assets to be captured, while significantly limiting the downside risk. The intrinsic limit of this strategy would be the persistence of negative long-term real rates which impede the inception of the strategy. This is unfortunately the case in the current investment environment, in which the combination of low nominal rates as a result of non-conventional monetary policies, coupled with temporarily higher than officially targeted inflation, are yielding negative real rates until very long maturities. This approach has been extended by (Graf, Haertel, Kling, & Ruß, 2012) in their optimal product design under inflation risk for financial planning.

4. A GLOBAL MACRO APPROACH TO ALLOCATE COMMODITIES

The decade long commodity bull-run which came to a close in the summer of 2008 had seen crude oil prices breach the psychological barrier of one hundred dollars a barrel for the first time in current value since the two oil shocks of the seventies (Baffes & Haniotis, 2010). The ensuing "*Great Recession*" brought an abrupt end to a decade which witnessed the rise of emerging countries, whose growing commodity consumption had spurred their prices to reached unprecedented peace-time levels. Commodities had become known as the inflation hedging crisis-robust alternative investment class of choice. By 2012, more than 400 billion dollars of commodities had found their way into investors' portfolios, a more than tenfold increase in a decade according to a Barclays commodity survey (Barclays Capital, 2012). Their appeal only momentarily waned as losses on commodity investments mounted during the recession-induced global fall in demand and lost their luster as the investment class which had withstood the first part of the financial crisis unscathed. Contrarian's triumph was short lived as a combination of government intervention to support growth in emerging countries, persistent geopolitical tensions throughout the Middle East and resurging concerns on the timing of *peak oil* rapidly hit back at the bear run and promptly sent the Brent benchmark crude index hovering back above $100 a barrel. As recession gripped Europe and slowing growth worldwide took their toll on industrial metals, demand for agricultural commodities climbed as droughts, floods, and conflicts damaged crops and stocks. As in all turbulent times, demand for precious metals soared.

Figure 5: Commodities before and after the *Great Recession*

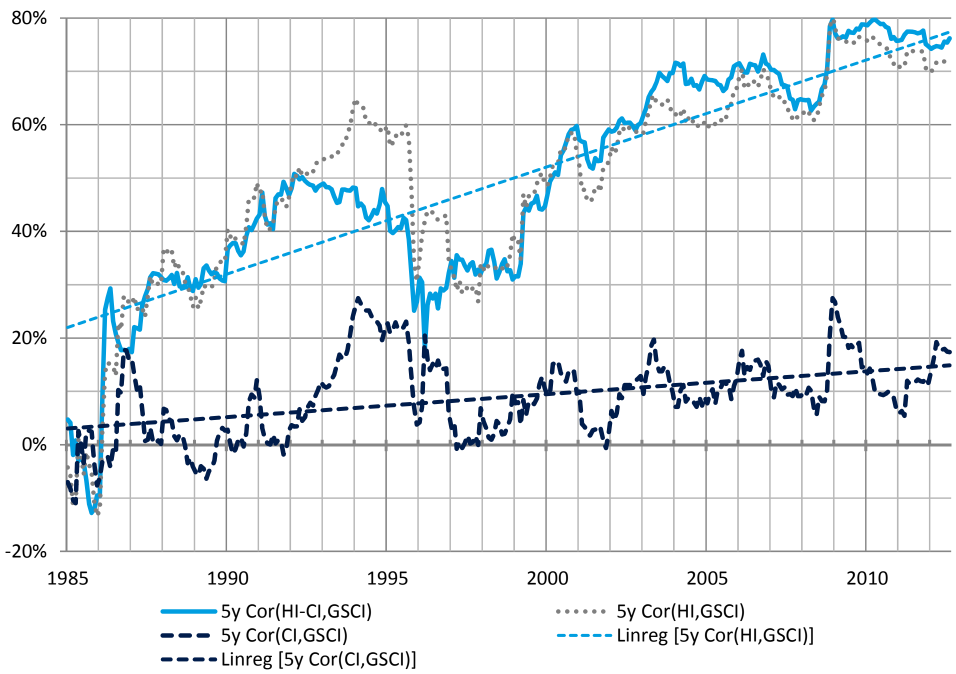


Source: Datastream/FRED

The underlying motive behind commodities' pivotal role in inflation protected portfolio allocations, apart from their obvious high risk-high reward profile, begs for an answer which is to be found in the nature of the relationship between investable asset classes and inflation. When it comes to inflation linkage, they can be separated into inflation-driving and inflation-driven ones. On the one hand, as commodity price changes feed directly into inflation and, conversely, cash rate hikes counteract it when they are used as monetary policy tools, they both naturally qualify as inflation drivers. On the other hand, since bond investment dwindles under rising inflation or, inversely, real estate investments should go up as rents adjust to inflation, it firmly anchors them in the inflation-driven side of our categorization of investment classes. It is worth noting that equities also mostly behave as inflation-driven assets even if its impact seems particularly investment-horizon dependent: as they are stores of relative value, which entitles their holders to the share of a real assets' cash flows, they should be inflation neutral at the long end as nominal cash flows gradually adjust to inflation over time, but should be negatively impacted in the short run until the inflation adjustment takes place.

From a portfolio protection point of view, investing in inflation-driving assets seems the prudent choice as they should perform better at hedging inflation risk in both the short and the long end, therefore providing investors with an inflation-protected liquidity option on their investment at any time. Commodities thus arose as the potentially lucrative real-return yielding alternative asset class even if their price variations are significantly more volatile than those of the liability benchmark they are intended to outperform (Bodie Z. , 1983). In this context, are current allocation techniques performing satisfactorily or should we endeavor to find a radically new approach that would take into account the inflation driving factor? (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012) goes down this path in applying advances in macroeconomics to achieve an efficient allocation.

Figure 6: The evolving correlation between commodities and inflation in the US



Source: Datastream

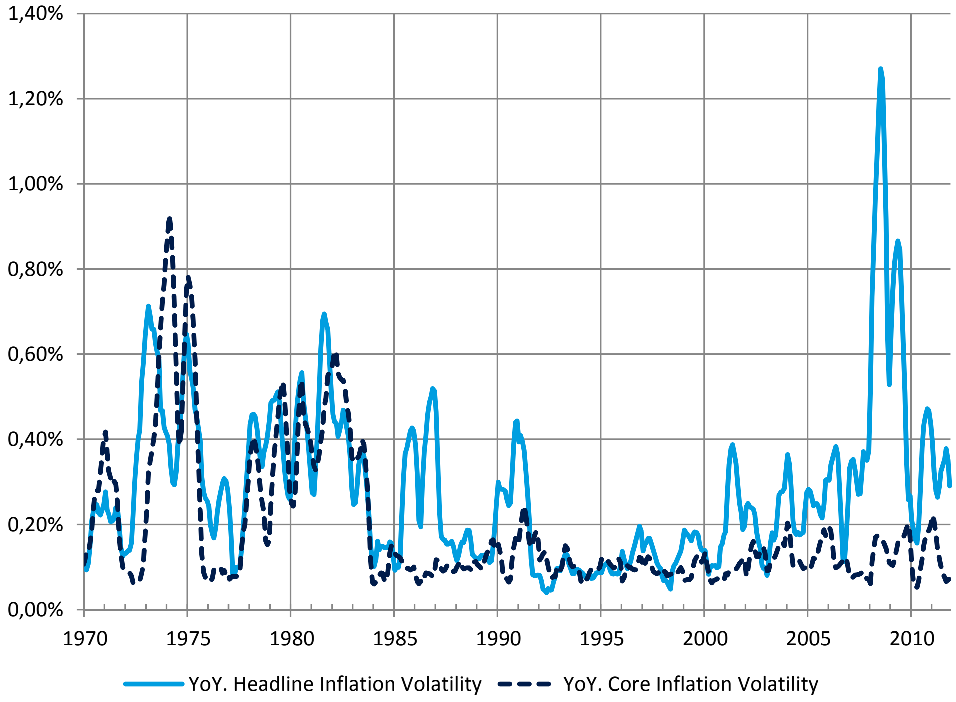
As commodity prices rose, economic agents' perception of their impact on inflation seems to have amplified. Indeed, their increasing influence on the Consumer Price Index (CPI), a proxy measure for headline inflation, has been extensively documented by econometricians and macroeconomists in the last two decades (Blanchard & Gali, 2007). It appears that around the mid-nineties a macroeconomic paradigm shifting began to unfold in the following way: while the pass-through of exogenous commodity price shocks into headline inflation increased by a half, the equivalent pass-through into core inflation seems to have ceased. While these results should have profound implications for liability-driven commodity investors, there is still a clear gap in the literature on this subject as no one seems to have exposed the financial implications in terms of allocation technique those economists have paved the way for. This is especially true of the link between investable commodities and inflation liabilities: we therefore proceed toward our macro-driven allocation by first evidencing a link between the headline to core inflation spread and tradable commodities. We subsequently intend to exploit this link in three ways: Firstly by devising an efficient strategic allocation using core inflation forecasts to determine the commodities' natural weight in the portfolio as dictated by our macro approach. Secondly by testing a tactical allocation strategy which would time the inflation pass-through cycle to dynamically determine the optimal share of commodities in the allocation. And finally by proposing a strategy to arbitrage core inflation-linked derivatives by cross-replicating them with commodity portfolios. In light of those results, one could still wonder whether headline indexation is suitable for all investors since its mean reverts to core inflation in the medium term. Should some investors opt for a reference swap for their liabilities?

5. Swapping Headline for Core Inflation

Longer-term investors exposed to inflation during the financial crisis probably felt stuck between anvil and hammer as in the short run, surging commodity prices pushed their inflation-linked liabilities higher while their assets dwindled in mark-to-market as a result of falling equity and other alternative fair values. Meanwhile, persistently low nominal rates and even negative real rates threatened the stability of their balance sheet in the longer run. To a certain degree, this asset-liability gap could be closed with the alternative inflation hedging techniques previously exposed. Yet, deviating from the most plain vanilla assets to embark on the world of either structured solutions as proposed in (Fulli-Lemaire, A Dynamic Inflation Hedging Trading Strategy, 2012) or through a refined use of alternative asset classes as in (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012) is certainly not risk-free even though it offers a certain degree of risk mitigation. Be it in the portfolio insurance scheme or the pass-through partial hedging technique, both of these solutions incorporate an increased reliance on risky asset classes such as commodities which can at times experience brutal swings in value. The rollercoaster ride that commodity investors have gone through in the last decade is particularly enlightening on the dangers of such endeavors. Considering the macroeconomic paradigm shift exposed in the second chapter, and in particular the muted response of core inflation to exogenous commodity price shocks and the mean reversal of headline to core inflation yielding a lower relative volatility for the latter, it raises the question of whether we should invest in headline inflation-linked investments at all. That is obviously only the case if we can bear to hold our investment for a sufficiently long period of time for the pass-through cycle to operate fully.

In other words, not all inflation hedgers should be treated equals as long-term players with investment horizons that extend beyond that of the expected duration of the mean-reverting process should choose to target core inflation despite their headline inflation liabilities. The pass-through cycle rarely exceeds five years and seems to have even been shortened in the last decade compared to the average duration of pension funds' investment horizons which can extend to several decades. This liability duration criteria therefore draws a wedge between long-term and short-term inflation hedgers as the former should seek core inflation protection while the latter should strive to obtain a headline inflation hedge. The obvious pitfall of this methodology is that to this date, no core inflation-linked asset exists. Deutsche Bank (Li & Zeng, 2012) recently announced the launch of an investable proxy for core inflation which paves the way for an outright core-linked market which would be the equivalent of the headline-linked market that materialized at the turn of the last century in the US, a little over a decade after its British counterpart appeared.

Figure 7: The volatility spread between headline and core inflation in the US.



Source: FRED

To make-up for the lack of an investable asset, we could go forward by imagining a core versus headline inflation swap that would see long-term players receive a fixed rate for the spread between headline and core inflation and short-term players be on the other end of the trade (Fulli-Lemaire & Palidda, Swapping Headline for Core Inflation: An Asset Liability Management Approach, 2012). Long-term players would most obviously have to roll swaps in order to have a continuous cover which maturity cannot extend beyond the one of short-term players. Since core inflation is particularly sluggish over short horizons, we are particularly focusing on the strategy that would see long-term players invest in linkers whereas short-term players would invest in nominal bonds and both parties would engage on opposite sides of the inflation spread fixed-for-float rate swap. Long-term players would obtain a real rate and a core floor plus a fixed risk premium while short-term players would achieve a nominal return minus a fixed rate and a volatile-inflation-part hedge. They would still remain at risk on the core inflation part which looks like a reasonable risk for short to medium maturities but should benefit from much higher real returns as a result of this accepted risk. This approach would offer both a synthetic core-linked asset for long-term hedgers and offer enhanced returns for short-term hedgers. Their demand for inflation hedges is currently severely curtailed by extremely low real rates at the maturity they could invest in. In essence, it yields an intermediated commodity investment for short-term players which would boost their return on a risk-adjusted basis. The second additional benefit of this new derivative would be the onset of a market curve for core inflation that could be derived from the trading of these swaps and enable easy mark-to-market valuation of other core-linked securities in balance sheets, therefore also easing the way for future issuances of truly core-linked assets in the primary market. The last hurdle these products would face is the potential disequilibria between the potential demand from long-term and short-term players, the former probably massively outweighing the latter. Any supply and demand market disequilibrium between long-term sellers of headline inflation and short-term sellers of core inflation could be matched by the intermediation of market makers which could price the derivative based on the cross hedging potential of commodities since we have also showed in (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012) that the inflation spread is highly co-integrated with commodity indices.

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Chapter 1, A Dynamic Inflation Hedging Trading Strategy using a CPPI

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1. INTRODUCTION

The demand for inflation hedges from pension funds has spurred the academic literature on optimal portfolio allocation and investment strategies for durations up to several decades. These types of long haul strategies are designed to match future liabilities that must be provisioned but that do not require specifically that the mark to market value of their investments matches that of their liabilities in the short run. In this paper, we set ourselves in the different context of commercial banks that need to hedge their inflation liabilities arousing from retail products such as guaranteed power purchasing saving accounts, term deposits, or even asset management structured products. All of these guarantees are immediately effective and their duration rarely exceeds a decade. Moreover, a constant access to liquidity is required for these open funds which can face partial or total redemption any time during their lifetime.

This new framework requires the construction of an investment strategy that must have a positive mark to market real value at its inception and throughout its life. Also, because of the constraints resting on the inflation linked market we expose in our first part, we seek to develop a strategy that would be purely nominal, that is entirely free of inflation indexed products which are costly and therefore reduce the potential real return. After summarizing the possible alternative inflation hedges in a second part, we explore the feasibility of adapting portfolio insurance techniques to the inflation hedging context in order to honor our guarantees while exploiting the inflation hedging potential of alternative asset classes. We seek to avoid the use of derivative instruments which costs can be prohibitive considering the scale of the liabilities. Combining all the above-mentioned points, we introduce our Dynamic Inflation Hedging Trading Strategy (DIHTS) and backtest its performance on a long US historical dataset which we use both for historic simulation and bootstrapped simulation.

2. INFLATION HEDGING AND PORTFOLIO INSURANCE

2.1. Motivations for seeking alternative hedges, a review of the existing literature

Corporations which are structurally exposed to inflation would most naturally like to hedge their liabilities by the purchase of inflation linked financial assets, or by entering in derivative contracts which would outsource the risk. But these two natural solutions rely on an insufficiently deep and insufficiently liquid market for the first one and is excessively costly for the second one as a result of an unbalanced market:

On the demand side of the inflation financial market, the need for inflation protected investments is spurred by four main drivers which are pension funds because of their inflation liabilities arousing from explicit power purchasing guaranteed pensions, retail asset managers providing inflation protected funds, insurance companies hedging their residual inflation liabilities and, mostly in continental Europe, commercial banks exposed to state guaranteed inflation indexed saving accounts. The bulks of those liabilities have long to very long durations and amount to the equivalent of hundreds of billions of Euros. On the supply side of the market for inflation-linked bonds, there is a very limited pool of issuers which is comprised mostly of sovereign or quasi-sovereign entities. There are very few corporate issuers of inflation linked bonds as there are very few corporations that have a structural long net exposure to inflation to the exception of maybe utilities engaging in Public-Private-Partnerships or real-estate leasers which tariffs are periodically adjusted on an inflation basis by law or contract. And even in those cases, it is not obvious that those companies have an interest in financing their operations on an inflation-linked basis which in nominal term is a floating rate. In fact, very few choose to. This limited pool of issuers is subject to changing budget policies, issuance strategies and current deficits which result in a fluctuating primary supply. Moreover, most of the buyers in the primary market acquire those assets on a hold to maturity basis or for immediate repo, rendering the secondary market relatively more illiquid than the one of their nominal counterparts, as is evidenced in the working paper (D'Amico, Kim, & Wei, 2008).

The derivative market for inflation is characterized by relatively high transaction costs as a result of shallow depth at reasonable price. Since on the one hand the sellers of those instruments will either have to hedge their trading books on the shallow and illiquid primary inflation market or assume the full inflation directional risk as a result of cross-hedging on nominal assets but on the other hand face a huge demand, the required premiums are very high. There has been since the mid 2000 a liquid market for exchange traded inflation swaps which has enabled to price inflation breakeven rates. There is to this day no liquid exchange traded market for inflation options as most of the deals are done in an Over-The-Counter basis. If the domestic supply of inflation linked instruments is not sufficient to meet the demand, as it is often the case, there is little international diversification can do as inflation is mostly a domestic variable which correlation to other foreign equivalents can be fickle, even in the case of monetary unions or currency pegs where foreign exchange is not an issue like in the Euro-Area. The recent Euro-area sovereign crisis has made this point all the more acute.

This gap between supply and demand in the inflation financial market has spurred the interest in alternative inflation hedging techniques that could solve the depth, cost and liquidity issues that have plagued the inflation financial market. Academic literature dating back from as far as the seventies has explored the use of a portfolio of real investments as an inflation hedge. Various asset classes such as equities (Z. Bodie 1976), commodities (Z. Bodie 1983), real estate (Rubens, Bond et Webb 2009), REITS (Park, Mullineaux et Chew 1990), and more recently dividend indices(Barclays Capital Research 2008) have been examined as potential real hedges to inflation. Even exotic assets such as forest assets (Washburn et Binkley 1993) and farmland (Newell et Lincoln 2009) just to mention two of them have also been explored but offer very limited interest with respect to the added complexity their investment requires.

The first emission of a long term CPI linked bond by a private US financial institution in the late eighties has led to a string of papers starting with (Z. Bodie 1990) which aimed at finding the optimal strategic asset mix these new assets enabled. Similarly, the first issuance by the United States treasury of inflation protected securities in 1997, following the first issuance by the British treasury of inflation linked gilts in 1981 have generated a renewal of interest in their role as inflation risk mitigation and diversification assets. The latest of which is the (Brière and Signori 2010) paper. These studies are of limited help for the purpose of this work as they still rely for a significant fraction of their investment strategies on inflation linked assets, which we are precisely trying to avoid doing. They nonetheless offer a first alternative to fully inflation protected investments, and therefore offer a potentially higher degree of returns, at the cost of a more hazardous hedging method.

Another stream of academic literature has focused on the optimal allocation for inflation hedging portfolios using only nominal assets and using various approaches to determine the optimal allocation like the recent (Amenc, Martellini et Ziemann 2009) paper which devised a global unconstrained nominal inflation hedging portfolio that would use a Vector Error Correcting Model to determine the optimal ex-ante allocation of the various potential inflation hedging asset classes mentioned before. This kind of strategy would solve the availability problem of the inflation linked assets, but would fail to bring any kind of guaranteed value to the portfolio, be it in real or nominal terms, and because of that, fails to meet our Asset Liability Management (ALM) constraints. In fact, the hedging potential of all the above-mentioned asset classes has proved to be horizon sensitive and dependent on the macroeconomic context. (Attié & Roache, 2009) have studied the time sensitivity of the inflation hedging potential of various asset classes and have shown in particular that some asset classes like commodities react better to unexpected inflation shocks than others, like most obviously nominal bond. More generally, the inflation betas has also proved to be unstable over time and can exhibit strong local decorrelations, rendering the inflation hedging exercise risky considering for example that the volatility of most of these asset classes is far superior to that of the Consumer Price Index we are precisely trying to hedge.

Using an error correction framework to optimize the portfolio allocation might have solved part of the problem by incorporating into the model those dynamics in asset price levels and returns that might otherwise have been overlooked as outliers by more general VAR models, but these classes of models are tricky to calibrate and would most probably result in statistically insignificant estimations, and accordingly, wrong allocations. Moreover, they would also most probably fail to detect in a timely manner small macroeconomic regime changes that could have a lastingly impact on the structure of the inflation betas. This might in turn jeopardize the overall inflation hedging potential of the portfolio if for example one of the invested assets suffered a significant fall in value as none of them has a guaranteed value at maturity like a bond, credit risk apart. Overall, this type of strategies would still fall short of a totally guaranteed value for the portfolio as would be the case with a real zero coupon bond.

2.2. Adapting Portfolio Insurance techniques to the real world

The limitations in term of guaranteed terminal value for the classic Markowitz approach to optimal portfolio selection based on the benefit of diversification have motivated the quest for portfolio insurance strategies in the seventies (Leland, Who Should Buy Portfolio Insurance? 1980). In purely nominal terms, the optimal tradeoff between the enhanced returns on risky assets and the low returns on assumed risk-free nominal bonds is known as the "two fund theorem". The optimization can also be further constrained by incorporating guaranteed nominal-value-at-maturity characteristics. Doing so yields the so called Dynamic Portfolio Insurance Strategies (Perold et Sharpe 1988) which includes: Buy and Hold, Constant Mix, Constant Proportion and Option Based Portfolio Insurance. But can such guaranteed-values-at-maturity strategies be transposed to the real world?

The simplest solution would be to mimic a two fund strategy in the real world: it would be implemented using a real risk free zero coupon bond and either a diversified portfolio of real assets or a call on the real performance of a basket of assets. The call option could also be either bought or replicated using an adaptation of the ideas exposed in(Leland et Rubinstein, Replicating Options with Positions in Stocks and Cash 1981). Such strategies would unfortunately be highly intensive in inflation indexed products use and would therefore not solve our availability problem, without even taking into account the low real returns these strategies would probably yield.

Using a call option on nominal assets, as opposed to real assets, would only partly solve the problem as the risk-free part is either made of zero coupon bonds which are available in limited supply or synthetic bonds made of nominal zero coupon bonds combined with a zero coupon inflation index swap which have greater supply but very low real returns. It could also be envisaged to combine a risk free zero coupon nominal bond and an out of the money call option on inflation. It would almost exactly be a replication of an inflation index bond as we will explain in the next subsection.

A last possibility would involve the transposition of the CPPI technique of (Black et Jones 1987) in the real world by using the above mentioned techniques to dynamically manage a cushion of inflation indexed bond and a portfolio of real return yielding assets. As was mentioned before, this strategy would still rely on indexed assets. The inflation hedging portfolio insurance problem would therefore be solved without investing in inflation linked assets or derivatives if it were possible to generate a portfolio that could mimic the cash-flows of an inflation-linked-bond as we will try to prove in the next subsection.

To sum up, any real portfolio insurance strategy would involve a capital guaranteeing part and a real performance seeking investment made of a diversified portfolio or a derivative and without explicit capital guarantees at maturity. Depending on the strategy used, the guaranteed capital part would either have a real guarantee embedded, or simply a nominal guarantee which would have to be complemented by a real guarantee attained to the detriment of the performance seeking part.

Trying to do without the IL instruments, we want to replicate the cash flow of an ILB with a Fisher Hypothesis. This replication can be achieved using an adapted OBPI technique as mentioned in the previous subsection and the theoretical justification is provided below:

Replicating the cash flows of an ILB is equivalent to fully hedging a nominal portfolio on a real basis. To do so, we need to invest a fraction α of the notional of the portfolio N in a zero coupon nominal bond of rate $\tau^{N}_{0,T}$ and buy a cap to hedge the residual risk. Out of simplicity, N is assumed hereunder to have a unit value. Using the Fisher framework (Fisher 1907), we can decompose the nominal bond's rate into a real rate $\tau^{R}_{0,T}$, an inflation anticipation $\mathbb{E}_0(\pi_{0,t})$ and an inflation premium $p_0(\pi_{0,t})$:

$$1+\tau^{N}_{0,T} = \left(1+\tau^{R}_{0,T}\right)\left(1+\mathbb{E}_0(\pi_{0,T})\right)\left(1+p_0(\pi_{0,T})\right)$$

The nominal bond's allocation α should then be defined such that its inflation components equalize the ILB's one. We obtain the following equation by ignoring the cross product :

$$\alpha\left(1+\mathbb{E}_0(\pi_{0,T})\right)\left(1+p_0(\pi_{0,T})\right) = \left(1+\mathbb{E}_0(\pi_{0,T})\right) \quad \Rightarrow \quad \alpha = \frac{1}{1+p_0(\pi_{0,T})}$$

We are left with a residual amount $(1-\alpha)$ out of which we can buy the option without shorting.

Let $\pi^{r}_{0,T}$ be the realized inflation between 0 and T, let S_0 be the initial spot rate for inflation equal to $\mathbb{E}_0(\pi_{0,T})$ under the rational expectation hypothesis and let $c_{0,T\,;\,K}$ be the cap premia of strike K and maturity T at 0 be expressed as a percentage of the notional.

By a simple absence of arbitrage opportunity hypothesis, we can rule out ITM strikes:

$$\nexists K \leq S_0 \ \text{ such that } \ c_{0,T\,;\,K} \leq (1-\alpha)$$

When short selling is also prohibited, we have strikes that are OTM or at best ATM. This would constitute a partial hedge in which we would remain at risk on the spread:

$$\text{Residual Risk} = \begin{cases} -(K-S_T)^{+}, & \text{if } S_T \in [S_0, K] \\ 0 \quad \text{otherwise} \end{cases}$$

If we can borrow at rate $\tau^{BN}_{0,T}$, we can then fully hedge our portfolio. Ignoring the cross products, we obtain under those assumptions the nominal return N^{R}:

$$N^R = \alpha\,\tau^R_{0,T} + \mathbb{E}_0(\pi_{0,T}) + \left(\pi^r_{0,T} - \mathbb{E}_0(\pi_{0,T})\right)^+ - (1 - \alpha - c_{0,T\,;\,S_0})(1 + \tau^{BN}_{0,T})^T$$

The real return R^R is thus:

$$R^R = \alpha\,\tau^R_{0,T} + \mathbb{E}_0(\pi_{0,T}) + \left(\pi^r_{0,T} - \mathbb{E}_0(\pi_{0,T})\right)^+ - (1 - \alpha - c_{0,T\,;\,S_0})(1 + \tau^{BN}_{0,T})^T - \pi^r_{0,T}$$

Applying the cap-floor parity, we have :

$$\mathbb{E}_0(\pi_{0,T}) - \pi^r_{0,T} + \left(\pi^r_{0,T} - \mathbb{E}_0(\pi_{0,T})\right)^+ = \left(\mathbb{E}_0(\pi_{0,T}) - \pi^r_{0,T}\right)^+$$

Which gives us the following result for the real rate:

$$R^R = \alpha\,\tau^R_{0,T} + \left(\mathbb{E}_0(\pi_{0,T}) - \pi^r_{0,T}\right)^+ + (1 - \alpha - c_{0,T\,;\,S_0})(1 + \tau^{BN}_{0,T})^T$$

Nota bene: This return is not necessarily positive.

In fact, since call options on inflation are not liquid exchange-traded instruments but OTC products, there is a high probability that the call premium would be sufficiently high to render the real return of the strategy very low at best if not negative at worst. This is not inconsistent with empirical observations that have been made on real bonds: some TIPS issuances in 2010 have had negative real rates.

The replication of the ILB cash flows by a combination of a nominal bond and a call option on inflation still fails to fully satisfy our objective of getting rid of the dependency on the inflation financial market because of the call option. To relax this constraint, it might be possible to manage the option in a gamma trading strategy without having to outrightly buy the derivative. The obvious challenge to overcome is that the natural underlying of the call option is an inflation indexed security, which brings us back to our previous hurdle. To overcome this latest challenge, it could be possible to envisage a cross-hedging trading strategy to gamma hedge the call on purely nominal underlings as will be exposed in the next subsection. (Brennan et Xia 2002) proposed a purely nominal static strategy that would both replicate a zero coupon real bond and invest the residual fraction of the portfolio in equity while taking into account the horizon and the risk aversion of the investor in a finite horizon utility maximization framework. We would like to extend the scope of this work to dynamic allocation.

3. THEORETICAL CONSTRUCTION OF THE DIHTS

3.1. The DIHTS as an alternative strategy

To achieve this inflation hedging portfolio insurance, we would like to capitalize on the popular CPPI strategy to build a dynamic trading algorithm that would be virtually free of inflation linked products and derivatives, but still offer a nominal and a real value-at-maturity guarantee: we propose a strategy which we will call the Dynamic Inflation Hedging Trading Strategy (DIHTS).

The risk-free part of the DIHTS portfolio would be invested in nominal zero coupon bonds which maturity matches that of our target maturity. The ideal asset for our strategy would be a floating rate long duration bond but since too few corporate or sovereign issuers favor this type of product, we cannot base a credible strategy relying on them. We could swap the fixed rate of the bond for a floating rate with a Constant Maturity Swap (CMS) as this type of fixed income derivative does not suffer for the limited supply and its cost implications like inflation indexed ones as it boasts a much boarder base of possible underlings in the interest rate market. Also, contrary to the inflation financial market, there are players in the market which are naturally exposed to floating rate and who wish to hedge away this risk by entering in the opposite side of a CMS transaction, therefore enhancing liquidity and driving the cost down for such products. But, we have to accept bearing huge costs if the portfolio is readjusted as long rates move up or have to forfeit the capital guarantee at maturity by synthesizing the CMS by rolling positions on long duration bonds. Either which of these options are hardly sustainable.

Be it a fixed or a floating rate bond, a nominal security does offer only a limited inflation hedging potential: even if the Fisher framework exposed previously can let us hope that an increase in expected future inflation will drive rates up, the economic theory tells us that the Mundell-Tobin effect will reduce the Fisher effect and therefore reduce the inflation hedging potential of nominal floating rate asset, which, though not capped as in fixed rate assets, will still fail to hedge entirely the inflation risk. The residual part of this risk has to be hedged away by incorporating the real guarantee in the diversified part of the portfolio which is made up of potential inflation hedging asset classes which we will limit to three: equities, commodities and REITS. Subsequent work could exploit a finer distinction between commodities by dividing them in for example four sub-classes: soft, industrial metals, precious metals and energy. The tactical allocation of the portfolio will be made according to a systematic algorithm which doesn't allow for asset manager input as a first step. Eventually a more complex asset allocation algorithm could be added. We assume, as in the portfolio insurance literature, that there is no credit risk in either one of the fixed income assets we hold. The value at maturity of these assets is therefore their full notional value. We do not assume any outright hypothesis on the guaranteed value-at-maturity for the diversification asset, but as in any CPPI strategy, a maximum resilience has to be set at a desired level which we will denote μ. The parameter could be set specifically for each asset class, but we will assume only a single one for simplicity.

If we add a martingale hypothesis for the price process P_t of the other asset classes:

$$P_{t+\theta} = \mathbb{E}_t(P_t)$$

This "limited liability" assumption becomes equivalent to a value-at-maturity hypothesis for the diversified portfolio which we can write for GP_T being the guaranteed value at maturity:

$$\mathbb{E}_t(GP_T) = \mu \cdot P_t$$

By further assuming that expected inflation can be obtained by the use of BEIs derived from ZCIIS, we can compute the initial fixed income fraction of the DIHTS which we will denote α_0.

Let $\pi^r_{t,t+\tau}$ be the realized inflation between t and t+ τ, and let $\pi^e_{t,t+\tau_\theta}$ be the expected inflation between t and t+ τ at time θ. We have:

$$\pi^r_{t,t+\tau} = \pi^e_{t,t+\tau_\theta} + \varepsilon_{t,t+\tau}$$

Let's further assume that:

$$\forall\theta < t, \qquad \mathbb{E}_\theta\left(\varepsilon_{t,t+\tau}\right) = 0$$

We then assume that:

$$\pi^e_{t,t+\tau_\theta} = BEI_{t,t+\tau_\theta}$$

This assumption simplifies the problem of the computation of the inflation expectation in a rational anticipation framework: since in the Fisher framework we have:

$$\left(1 + BEI_{t,t+\tau_\theta}\right) = \left(1 + \pi^e_{t,t+\tau_\theta}\right)\left(1 + p_\theta\left(\pi^e_{t,t+\tau_\theta}\right)\right)$$

The above assumption is equivalent to considering that the risk premiums are nil, which is a prudent hypothesis since they are non-negative: we therefore never underestimate the inflation risk. This hypothesis will have a further justification when we'll discuss the definition of the DIHTS' floor.

The use of DIHTS in an ALM strategy as it is presented here is better fitting for long term investors who wish to diversify away from zero-coupons inflation derivatives yielding back in bullet both the inflated principal and the real performance at maturity. It would be better fitting for retail oriented asset managers or pension funds. Investors wishing to diversify away from year-on-year type of inflation derivatives would rather use a strategy which cash flow profile still matches that of their liabilities which could for example require that the instrument pays the accrued inflation on the notional, and eventually a real coupon, on a yearly basis such that the instrument is at a yearly real par. Such strategies would benefit from an enhanced version of DIHTS using couponed bonds and eventually CMS-like fixed income derivatives in overlay to replicate our targeted benchmark instrument while still exploiting the same general principal as for the simpler strategy presented here. Henceforth, we will focus only on bullet repaying strategies since the marking-to-market allows us to theoretically adjust the notional of the fund at a current value, therefore without risking incurring a loss in case of partial or total redemption from the fund.

As previously defined, α denotes the fraction of the fund invested in risk free nominal assets. Let $(\alpha_0, 1 - \alpha_0)$ be the initial global allocation of the DIHTS and *NPV* denotes the net present value of the two fractions. All rates from now on are given in annual rate. At inception:

$$(1-\alpha_0)\cdot\mu+\alpha_0=\left(\frac{1+\pi_{0,T}^{e}}{1+\tau_{0,T}^{N}}\right)^{T}$$

We therefore have

$$\alpha_0=\left(\left(\frac{1+\pi_{0,T}^{e}}{1+\tau_{0,T}^{N}}\right)^{T}-\mu\right)\frac{1}{1-\mu}$$

Let $A_{t,T}$ represent the ZC zero coupon bonds fraction of equivalent tenor (T-t), invested at time t and maturing at time T (for a ZCNB, only the nominal at maturity counts):

Let NAV_t^{ZCNB} represent the NAV of the zero coupon part, we have:

$$NAV_t^{ZCNB}=\frac{A_{t,T}}{\left(1+\tau_{t,T}^{N}\right)^{T-t}}$$

Let ω_t be the weights of the ex-ante optimal allocation of the diversified portfolio, let Ω_t be the vector of the value of the assets of the portfolio and let P_t be the price vector of the selected asset classes. From now on, the star will denote the post optimization value of the parameter. We have at inception:

$$\omega_0^*=\frac{\Omega_0^*}{1-\alpha_0}$$

$$1-\alpha_0=\omega_0^{*\prime}\cdot P_0$$

We then define NAV_t^{PTF} as:

$$NAV_t^{PTF}=\Omega_{t-1}^{*}{}'\cdot\frac{P_t}{P_{t-1}}$$

And NAV_t^{Lb} as:

$$NAV_t^{Lb}=\frac{\left(1+\pi_{0,t}^{r}\right)^{t}\left(1+\pi_{t,T}^{e}\right)^{T-t}}{\left(1+\tau_{0,T}^{N}\right)^{T-t}}$$

For any $t > 0$, we define the net asset value of the strategy NAV_t:

$$NAV_t = NAV_t^{PTF} + NAV_t^{ZCNB} - NAV_t^{Lb}$$

Before any reallocation we have:

$$\alpha_t = \frac{NAV_t^{ZCNB}}{Nav_t^{PTF} + Nav_t^{ZCNB}}$$

Let $NAV^G{}_t$ be the implicitly guaranteed net asset value of the strategy taking into account the loss resilience parameter μ:

$$NAV^G{}_t = \mu \cdot NAV_t^{PTF} + NAV_t^{ZCNB} - NAV_t^{Lb}$$

The strategy remains viable as long as $NAV_t > 0$. If the floor is breached, the fund is closed before the maturity or a zero coupon inflation hedging security would have to be bought at a loss.

A global reallocation is necessary if $NAV^G{}_t < 0$ and in which case, we have to add a new trench of ZCNB such that:

$$\alpha_t{}^* = \underset{\alpha_t}{\operatorname{argmin}}\{NAV^G{}_t(\alpha_t) > 0\}$$

In case we have:

$$NAV^G{}_t(0) > 0 \quad \text{we set} \quad \alpha_t = 0$$

Since the expected returns on the diversified part of the portfolio are potentially higher than those on the fixed income part, we set α at the lowest possible value that verifies $NAV^G{}_t > 0$. In order not to reallocate constantly the global parameter at the slightest market movement, we set a tolerance parameter η under which no global reallocation is done:

$$\alpha_t{}^* = \alpha_t \quad if \quad |NAV^G{}_t| < \eta \ or\ if \ \ \alpha_t = 0\ and\ NAV^G{}_t > 0$$

Obviously, any global reallocation would trigger a reallocation of the diversified portfolio weights. It is a sufficient but not necessary condition as it may be more optimal to do so more frequently as we will expose in the next subsection.

The breaching of the DIHTS' floor is obtained when it is not possible to reallocate the global parameter such that the guaranteed net asset value becomes positive:

$$\forall \alpha > 0, \qquad NAV^G{}_t(\alpha) < 0$$

If such an event were to occur, the diversified portfolio would already have been entirely liquidated and the remaining net asset value could as before be used to buy a string of ZCIIS to insure the real guarantee at maturity of the portfolio. The gap risk and the liquidation cost would probably result in a negative real return. Gap risk apart, the downside risk would be curtailed by the fact that we had taken ZCIIS BEIs when computing the NAV and not directly the expected inflation which would have been lower.

3.2. Optimal allocation of the diversified portfolio

The diversification portfolio is allocated in order to hedge both the residual expected inflation and the unexpected inflation, while also yielding the real excess return that is targeted. Once the global allocation parameter α is set, we can compute the residual expected inflation and eventually set a targeted real excess return. According to our hypothesis, we have no input regarding the value of the unexpected inflation which ex-ante conditional expectation is nil.

Out of all the possible portfolio optimization criteria, we will limit ourselves to envisaging allocating the diversified portfolio according to three criteria: a Constant Weight scheme (CW), a minimum-variance (MV) and an Information Ratio (IR). We introduce the following definitions: Let $\bar{R}$ be the targeted real return scalar, R_k be the realized return vector over the period k for the different asset classes and Σ_t be the variance-covariance matrix of the return vector at time *t*. Let ω_{X_t} be a portfolio allocation at time *t* and $\omega_{X_t}{}^*$ be the optimal one according to the *X* criteria used. Let π_k^r be the realized inflation over the k period, $\pi_{k_t}^e$ be the expected inflation over the *k* period at time *t* and R_t^{ZCNB} be the nominal return on the fixed-income investment.

The MV optimization criterion is defined by the following loss function L at time t:

$$L_{MV}\left(t, \omega_{MV_t}, \bar{R}, \pi_k^e, \mathbb{E}_t(R), \Sigma_\mathrm{t}\right) = {\omega_{MV_t}}' \cdot \Sigma_\mathrm{t} \cdot \omega_{MV_t}$$

We therefore obtain the optimal portfolio according to the MV criterion by minimizing L:

$${\omega_{MV}}_t^* = \underset{\omega_{MV_t}}{\operatorname{argmin}}\left\{L_{MV}\left(t, \omega_{MV_t}, \mathbb{E}_t(R), \Sigma_\mathrm{t}\right)\right\}$$

The IR optimization criterion is defined such that:

$$IR\left(t, \omega_{IR_t}, \bar{R}, \pi_k^e, \mathbb{E}_t(R), \Sigma_\mathrm{t}, R_t^{ZCNB}\right)$$
$$= \frac{{\omega_{IR_t}}' \cdot \mathbb{E}_t(R_T) - \bar{R} - \left(\pi_{t,T}^r - {\pi_T^e}_t\right) - \frac{1}{1-\alpha_t}\left({\pi_T^e}_t + \pi_{0,t}^r - \alpha_t \cdot R_t^{ZCNB}\right)}{{\omega_{IR_t}}' \cdot \Sigma_\mathrm{t} \cdot \omega_{IR_t}}$$

We therefore obtain the optimal portfolio according to the IR criterion by maximizing the IR:

$${\omega_{IR}}_t^* = \underset{\omega_{IR_t}}{\operatorname{argmax}}\left\{IR\left(t, \omega_{IR_t}, \bar{R}, \pi_k^e, \mathbb{E}_t(R), \Sigma_\mathrm{t}, R_t^{ZCNB}\right)\right\}$$

The first criterion required at least the estimation of the variance-covariance matrix of the investable assets and the second one requires in addition the estimation of those average returns. The ex-post inflation forecasting error and therefore the shortfall probability are trickier to compute since they require for example a model to compute simulated trajectories and perform Monte-Carlo estimation. The CW method being blind, it is obviously the less demanding in term of input.

In the next section on empirical estimation, we will rely on historical estimations of the key optimization inputs out of simplicity considerations. Forecasting errors will be assumed to be nil (rational expectation hypothesis). A slightly more comprehensive approach to allocating our portfolio would involve the modeling of the joint distribution of inflation and investable assets from a macro or an econometric perspective in order to make forecasts (or simulations).

Unfortunately, as we will expose thereafter, no such simulation tool is available today.

Had a more accurate model to forecast economic and financial variables over a horizon spanning from five to ten years been available, it could be envisaged to reuse previously published models like (Amenc, Martellini et Ziemann 2009) Vector Error Correction Model (VECM) or more simpler VAR based models to generate scenarios on which we could perform both our allocation optimization and the back-testing of our strategy on simulated scenarios. Using this scenario generator, we could perform an estimation of the expected values of the unknown parameters with a Monte Carlo procedure, using only data available at time t. The $SF\mathbb{P}$ would for example be obtained in such a way if we remark that:

$$SF\mathbb{P}\big(t, \omega_{SF\mathbb{P}_t}, \bar{R}, \pi_k^e, \mathbb{E}_t(R), \Sigma_t\big) = \sum_{k>t}^{T} \mathbb{P}_t\big(\omega_{SF\mathbb{P}_t}{}' \cdot \mathbb{E}_t(R_k) - \bar{R} - \big(\pi_k^r - \pi_{k_t}^e\big) < 0\big)$$

$$= \mathbb{E}_t\left(\sum_{k>t}^{T} \mathbb{1}_{\left(\omega_{SF\mathbb{P}_t}{}' \cdot \mathbb{E}_t(R_k) - \bar{R} - \left(\pi_k^r - \pi_{k_t}^e\right) < 0\right)}\right)$$

Using such a procedure would also enable the allocation of pre-determined real return targeting portfolios which would in turn enable the construction of an efficient frontier $\mathcal{G}(\sigma_t \; ou \; SF\mathbb{P} \, ; \bar{R}\,)$ which would sum up in graphic form the tradeoff between targeted real return, or achieved real return, and the empirical short fall probability.

4. EMPIRICAL ESTIMATIONS OF THE PERFORMANCE OF THE STRATEGY

4.1. Methodology and data sources

To empirically test the efficiency of the global allocation principle independently from the optimization method used to allocate the diversified portfolio, we adopted the same allocation technique for both the diversified fraction of the investment and for the standard benchmark portfolio. Portfolios were simulated over the longest available timeframe on US data spanning three decades from 1990 to the end of 2010.

Using the results from these portfolio simulations, we computed the Failure Rate (FR), the Information Ratio (IR) and the Turnover Ratio (ToR) for the different strategies. The FR is defined as the percentage of times a portfolios breaks the real par floor, the IR is the Sharpe ratio applied to a pure inflation benchmark and the ToR is the percentage of the initial value of the fund that is reallocated during the life of the strategy. To have a measure of the potential Profit and Loss (P&L) of the benchmark portfolio returns in case of failure of the DIHTS, we measure the P&L Given Failure (PLGF). Nota bene, this indicator is obviously measurable only if the DIHTS does fail.

For the three previously selected allocation methods, we then tested the impact on the overall strategy performance on the choice of a shorter investment horizon based on our central scenario of $\mu = 50\%$ and $\eta = 1\%$. We then computed the sensitivity analysis of the DIHTS to the choice of μ and η in our 10 year investment horizon base scenario (results presented in the working paper version). We also plotted the comparative real return profile of the DIHTS compared to the benchmark portfolio allocated with the same technique for various investment horizons in our baseline scenario. Eventually, we constructed an efficient frontier based on our real return compared to a risk measure (the volatility of the NAV).

The various portfolios values were computed on end-of-period values at a monthly frequency obtained from the Bloomberg data services: for the diversified and benchmark portfolios the S&P-GSCI-TR total return commodity index, the S&P500-TR total return broad US equity index, the FTSE-NAREIT-TR traded US real estate total return index and the Barclays Capital Long U.S. Treasury Index (the last being only for the benchmark portfolio). For our zero-coupon and mark-to-market computation, we used the US sovereign ZC-coupon curve computed also by Bloomberg. CPI inflation was measured using the standard official measure. The longest overlapping availability period for all of these data stretches from 1988 to 2011.

Forward inflation expectations used to compute the floors were obtained using market values derived from the Zero Coupon Inflation Indexed Swaps curve (ZCIIS) which is available from June 2004 to the 2011. Prior estimations of expected inflation were obtained using the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters (SPF) for future US inflation at 1 and 10 year horizon available for the entire 1988 to 2010 period.

To compute our historical estimation of the covariance matrix and the expected returns for Inflation, S&P500-TR, S&P-GSCI-TR, FTSE-NAREIT-TR, we used a longer dataset going back to 1985 so that we could compute them on a moving time-frame of five years. This value was chosen as a rule of thumb reflecting empirical estimation of the smallest period usable to compute our parameters with the least noise possible while not being too long to be able to reflect relatively rapidly persistent changes in the correlation structure we hope to exploit, or avert depending on our current position.

4.2. Historical Backtesting results

The first striking results of this study is that as we can see from the analysis of any of the horizon sensitivity analysis presented in tables 1 is that the efficiency of the DIHTS compared to the benchmark portfolio is stronger for medium investment horizon of 5 to 7 years, whereas for longer ones, the effect tends to diminish as the benchmark portfolio failure rate drops. Shorter horizons were not modeled as in some cases interest rate from inception to maturity being lower than the expected inflation, the strategy could not have been initiated. The less striking result is that a classical portfolio of our alternative asset classes does offer a relatively good inflation hedge over long horizons, whilst failing at shorter ones. Comparatively, in our baseline scenario, the DIHTS never fails over the same range of maturities and ensures through its life a positive real mark to market. Again, as could have been expected after the following analysis, the IR for the DIHTS is persistently higher over the entire range of investment horizons, but as the maturity lengthens, the difference diminishes.

The main drawback of this study is that reallocations are done at no trading costs. The performance indicated here is in effect purely theoretical. This is why the ToR ratios are computed in order to have an idea of the potential trading cost implications. On this aspect, the DIHTS does underperform its benchmark portfolio by a relatively small measure, even if this conclusion has to be nuanced by the large and relatively higher volatility of the ToR for the DIHTS compared to its benchmark. The choice of our baseline scenario is comforted by the parameter sensitivity analysis which clearly indicates that a conservative estimate for μ = 50% reduces failure rates at the 10 year horizon tested.

Table 1: Horizon sensitivity of the DIHTS vs. the Benchmark Portfolio for the historical simulation allocated by IR.

Horizon (Years)	Fail Rate		IR		ToR	
	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF
5	0,00%	20,73%	59,48% *(30,2%)*	24,35% *(32,65%)*	7,17% *(3,2%)*	7,36% *(1,39%)*
6	0,00%	21,55%	48,70% *(26,2%)*	22,55% *(20,50%)*	8,91% *(3,5%)*	9,30% *(1,75%)*
7	0,00%	9,47%	38,41% *(18,3%)*	20,82% *(11,31%)*	10,29% *(3,9%)*	11,45% *(2,03%)*
8	0,00%	8,28%	32,06% *(13,6%)*	18,42% *(10,61%)*	11,18% *(3,9%)*	13,57% *(2,03%)*
9	0,00%	9,66%	29,30% *(13,6%)*	15,91% *(9,53%)*	12,08% *(3,7%)*	15,87% *(2,10%)*
10	0,00%	7,52%	25,56% *(12,4%)*	13,89% *(7,95%)*	13,33% *(3,5%)*	18,55% *(2,36%)*

Table 2: Allocation horizon sensitivity analysis for the DIHTS for the historical simulation allocated by IR.

Horizon (Years)	ZCN	SPX	REIT	GSCI
5	31,6% *(22,2%)*	32,2% *(16,5%)*	19,8% *(12,9%)*	14,7% *(10,9%)*
6	29,0% *(19,7%)*	33,6% *(14,4%)*	20,3% *(10,9%)*	15,7% *(9,2%)*
7	25,9% *(16,4%)*	35,2% *(11,5%)*	20,6% *(8,3%)*	17,2% *(7,3%)*
8	22,7% *(12,9%)*	36,8% *(8,7%)*	21,2% *(6,9%)*	18,3% *(6,8%)*
9	20,3% *(9,8%)*	38,0% *(6,9%)*	22,4% *(7,1%)*	18,3% *(7,8%)*
10	17,8% *(6,9%)*	39,3% *(7,1%)*	23,8% *(8,3%)*	18,3% *(9,4%)*

The tolerance parameter η = 1% impact seems to be of lesser importance but it is clear the ToR versus FR arbitrage could be of significance had trading costs been accounted for as can be seen in tables 4 to 6. The CW allocation is rather surprisingly less ToR intensive compared to the other allocation methods but achieves lower IR performance. This could be attributed to the volatility of the estimation of future expected returns and volatility which require important shifts in allocation.

Figure 8: Performance comparison for the historical simulation allocated by IR

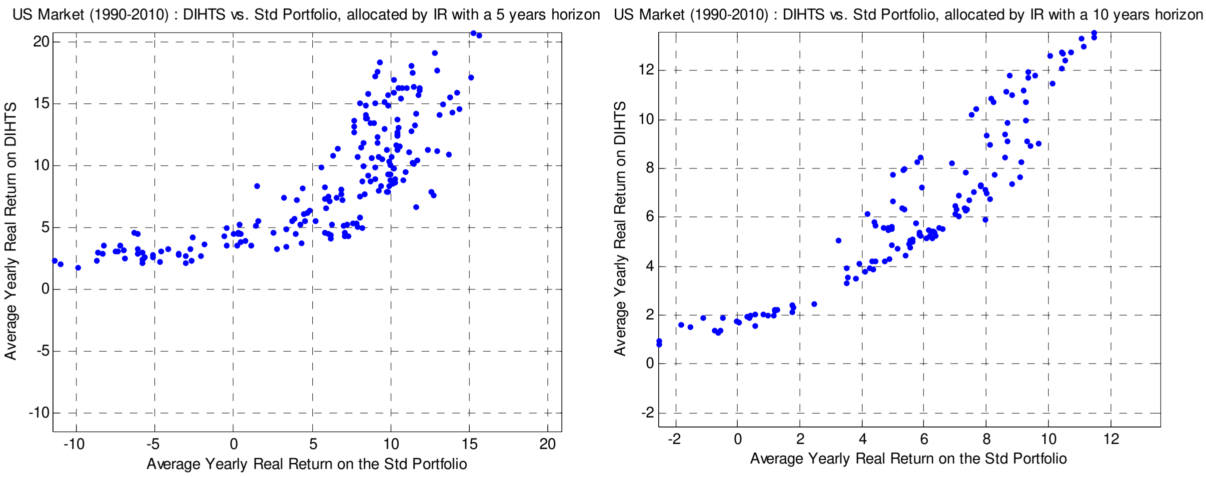
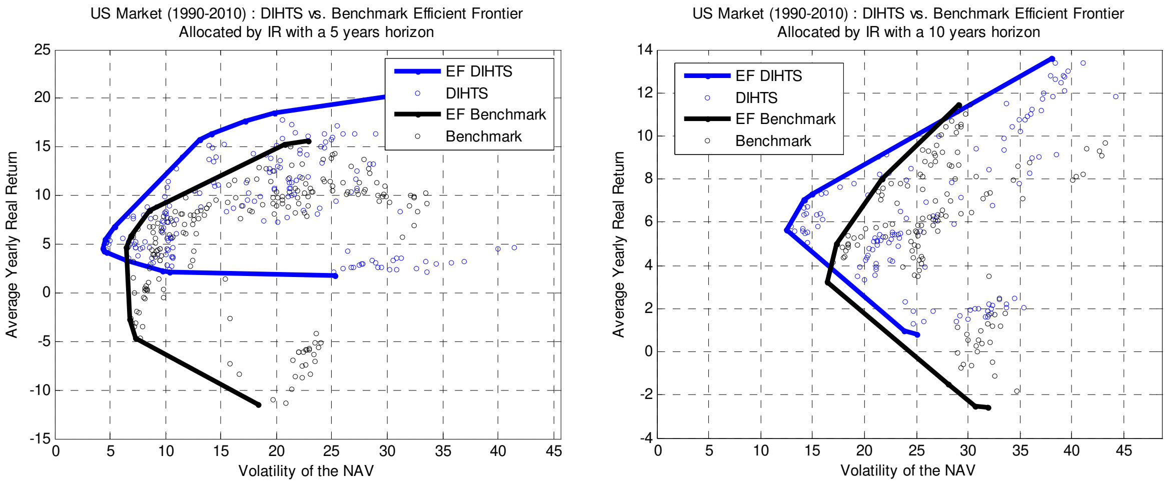
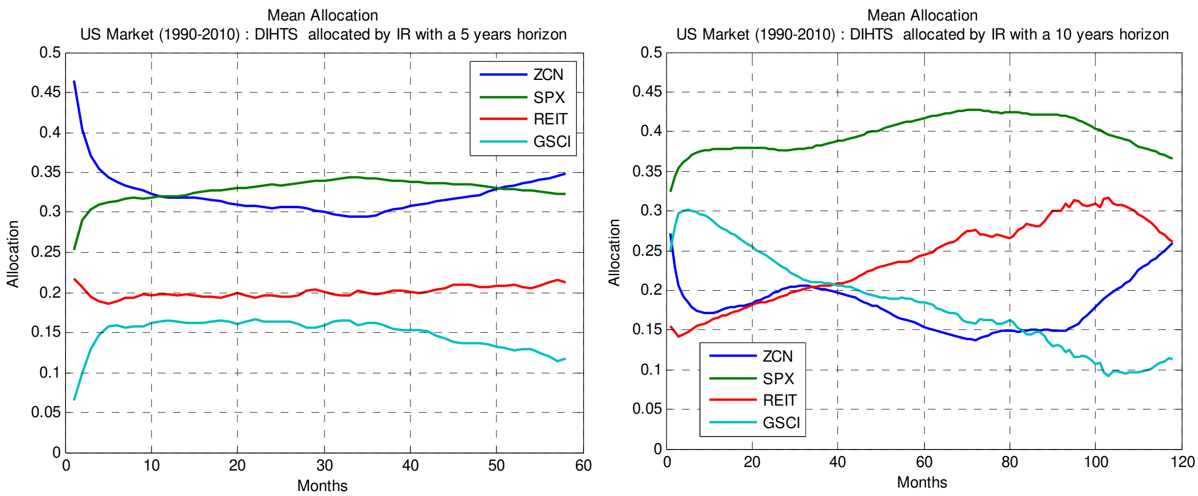


Figure 9: Efficient frontier estimation for the historical simulation allocated by IR



The graphical representation of the comparative real performance of the strategy at medium maturities as can be seen in figure 4 appears to show the classical CPPI "call-like" optional risk profile in which the strategies holds in tough times whilst potentially achieving higher returns in favorable ones. As fewer negative results are experienced for longer investment horizons, the risk profile is less clear to establish but is consistent with the previous analysis in the IR case. The analysis of our empirical determination of the real efficient frontier of our strategy reinforces the previous conclusions as to the relative efficacy of the DIHTS in medium term and its less clear performance gains for longer horizons as can be seen in figure 5: at the five years horizon, the DIHTS frontier is systematically shifted towards the upper left corner compared to its benchmark whist at the ten year horizon, it is shifted to the left in the IR case.

Figure 10: Mean dynamic allocation for the historical simulation of the DIHTS allocated by IR



Consistently with our prior findings, we actually observe in the baseline scenario a better performance for the IR than with the MV and even better performance compared to the CW in term of achieved IR. It is therefore interesting to note that the DIHTS, with its conditional allocation does offer better than expected results in the most favorable circumstances, which is very uncommon in the plain vanilla derivative instruments it is supposedly mimicking. To sum up, the DIHTS achieves inflation hedging and delivers real returns in all the backtest simulations for any targeted maturity whist consistently achieving higher returns that its benchmark, thus justifying the validity of our approach.

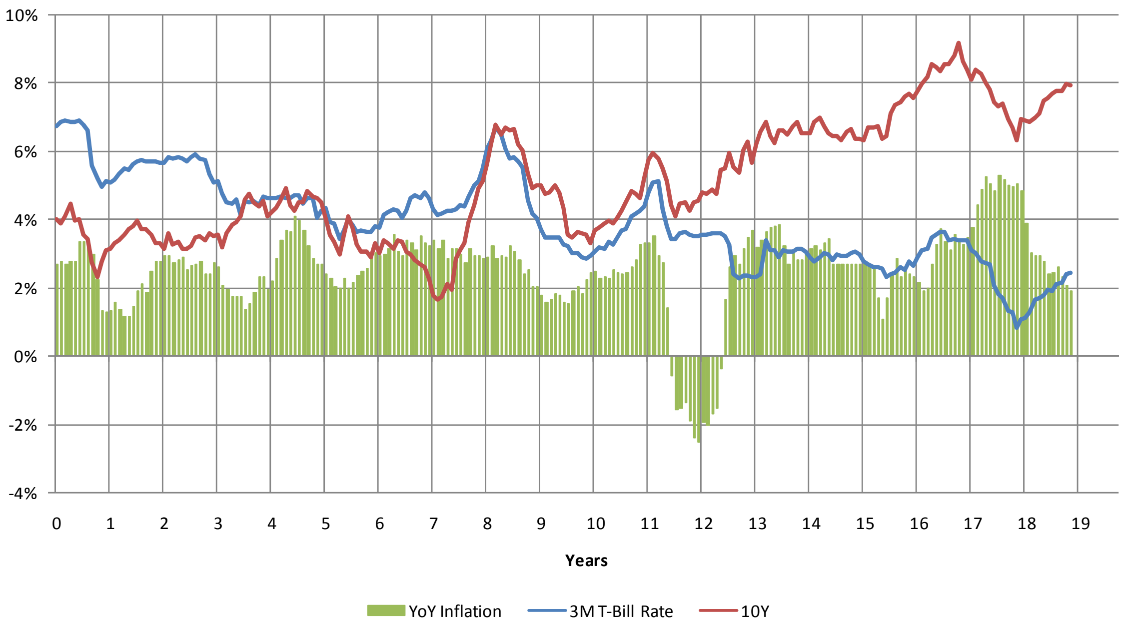
5. BLOCK BOOTSTRAPPING BASED EVALUATION OF THE DIHTS

5.1. Principle

The main shortfall of the previous empirical estimation of the performance of the DIHTS is that it relies on the historical time series which represent only one scenario in a backtesting approach. Moreover, the historical time span studied here corresponds to a very specific context of a downward trending inflation and its associated risk premium. We therefore have a context in which long horizon inflation hedging techniques were beaten by classic allocations since inflation tended to be systematically under its expected value ex-ante. In such a context, investing in long duration nominal assets accordingly yields strong real returns. Considering for example the vast amount of liquidity injected by central banks in the financial market by the various unconventional monetary policies of the last couple of years, the still untamed government spending generating large deficits and a looming sovereign crisis, it is very hard to imagine that inflation will keep following the same path it followed over the past twenty years. A backward looking approach is therefore clearly insufficient. Yet, it is probable that fundamental economic relations will still more or less link the various asset classes and we can hope that our approach can hold in such a context. Exploiting simulated stressed scenarios could therefore be informative if they are credible. But since we do not have a credible simulation tool, we choose to bootstrap the existing dataset using a block method to retain as much as we can of the existing correlation structure of our dependent vector time series.

As a make-up solution we simulate a universe of scenari by using a multidimensional time series block-bootstrapping method. Log-returns are computed on our longest comprehensive dataset and using the automatic block-length selection algorithm of (Politis et White 2004) with its associated Matlab code written by Dr. Andrew Patton from the LSE, we generate a new set of trajectories by integrating the resulting series of return blocks. This technique would partially preserve the correlation structure of our time series which are by nature strongly dependent. The obvious shortfall of this approach is that some intrinsic adjustment mechanisms could take place at a horizon way too great to be captured by the bootstrapped which has to be of limited length to ensure a sufficient range of scenari. To stress test the resilience of the strategy, we simulated 200 times a 20 year bootstrapped vector time series. Out of this 4000 year of simulated scenari, we ran for each of the 200 paths from 120 to 180 different 5 to 10 year portfolio simulations. As in the previous section on historical backtesting, we presented the results of this exercise on graphic format and tables summarizing the comparative performances, and the average allocation of the portfolio.

Figure 11: Example of a joint simulation of nominal rates and inflation using block bootstrapping



Out of the universes of scenari we generated, some will be extraordinarily adverse. It is worth mentioning that since those scenari are obtained from real past returns, they do constitute credible “black swans” events worse evaluating, especially since recent turmoil have taught us that such improbable events do actually occur rather frequently. There are obvious intrinsic shortfalls to this methodology: we puts into question the rational expectation hypothesis as when the simulated path crosses over from one block of returns to the other, there is no reason to believe expectations will hold. It is an especially acute problem for the fixed income market where we should see forward rates converging towards spot rates. Even though from a purely numerical point of view, correlation structures should be mostly preserved. Though imperfect, this method is the only credible alternative to historical backtesting. It generates extreme scenarios with intrinsic structural breakpoints in term of correlations and rational expectation, but might be informative for stress testing. If we analyze the example provided here under, we can observe during the first years of the simulated path an inverted rate curve, a short negative long real rates period, a monetary contraction driven by a short term rate spike followed by a fall in inflation, the inversion of the nominal curve, a prolonged deflation then a sustained inflationary period with a monetary loosening period and a spike in inflation with significant real rates and inflation risk premium.

All these events have been observed in the past, though possibly of lesser magnitude and duration, but are consistent and could be analyzed in term of stress testing of the strategy. There are obvious intrinsic shortfalls to this methodology: the quasi-random path simulated in our selected example shows that though short term interest rates did fall synchronously with the year on year inflation, they then remained at above 3% whilst inflation went into negative territory. There is hardly any credible monetary policy that springs to mind that would justify such a move. Yet, as adverse and improbable as it may seem, such an approach is clearly informative.

5.2. Results

If we first look at both the five year and ten year DIHTS versus Benchmark plot, it is difficult to see any significantly different pattern at first glance. It is not as clear as in the previous case that we have a clear optional-like payoff profile with an asymmetrical distribution. In fact, the distribution shows remarkable similarity, except maybe for highly negative returns. We do observe large numbers of FR for the

DIHTS but reassuringly, the PLGF is also negative, indicating that the benchmark would probably haven't fared better in such adverse environments. We also observe a significant number of DIHTS simulations which end-up below the real floor at maturity whilst they never broke the real floor during their lifetime up to the before-last valuation of their mark-to-market. Since this represents the gap risk resulting from the mark-to-market at a low frequency (monthly here), we have included those cases in the computation of the failed rate. Moving to higher frequency estimation would probably eliminate much if not all of these below zero points as in the conventional CPPI.

Figure 12: Performance comparison for the bootstrapped simulation allocated by IR.

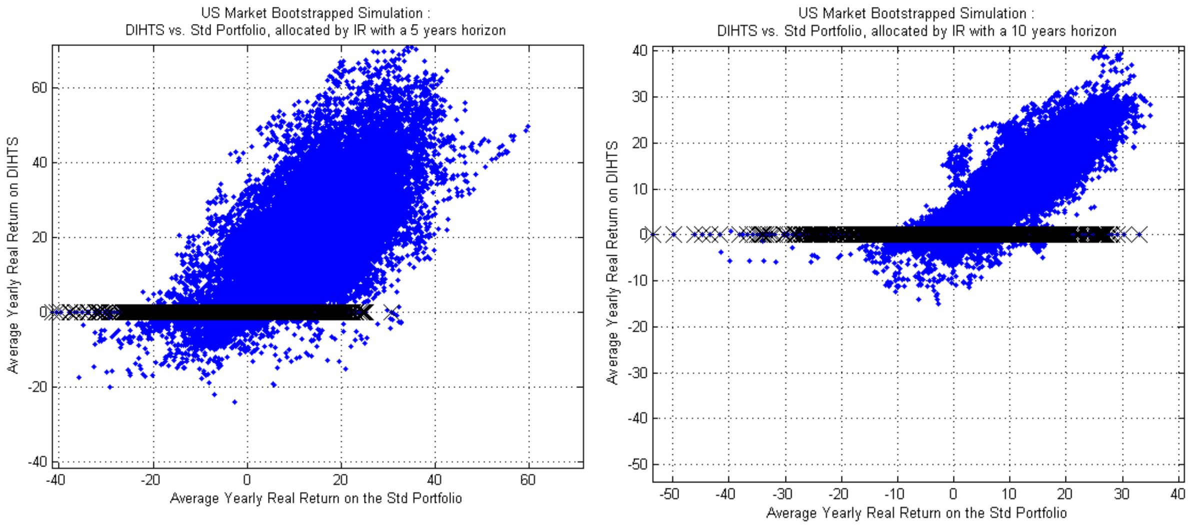
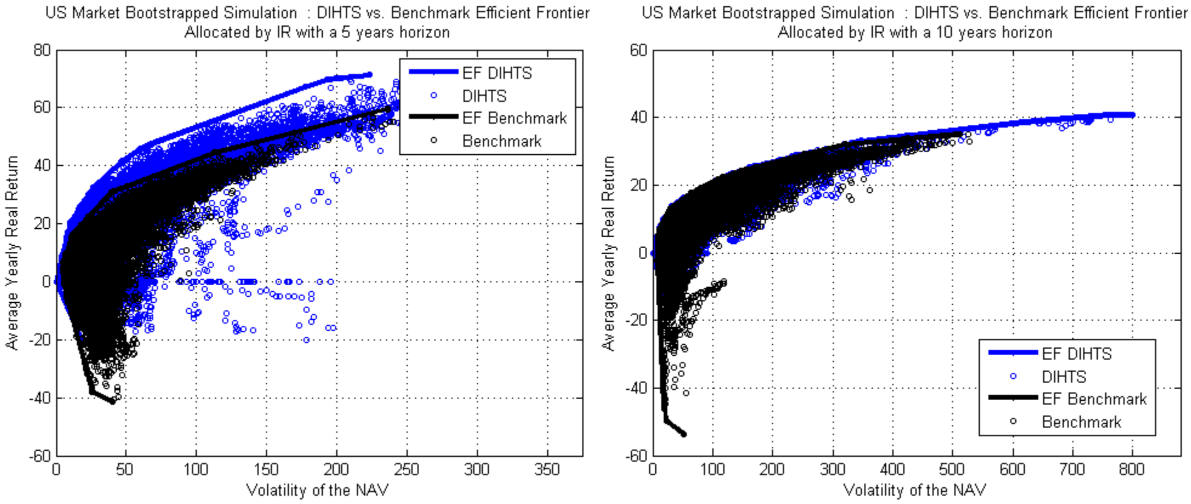


Figure 13: Efficient frontier estimation for the bootstrapped simulation allocated by IR.



Looking then at the efficient frontier empirical estimation, we have once again as in the previous case better results for the five year with frontiers pushed to the northwest for all the allocation methods. For the ten year cases, there seems to be no significant difference between the efficient frontiers of the benchmark portfolio and the DIHTS but for the very adverse cases as before. Nota bene: the efficient frontiers of the DIHTS passes through the (0,0) point because in case of a breach of the real par, the strategies are terminated and an arbitrary (0,0) return variance couple is entered.

Figure 14: Mean dynamic allocation for the historical simulation of the DIHTS allocated by IR.

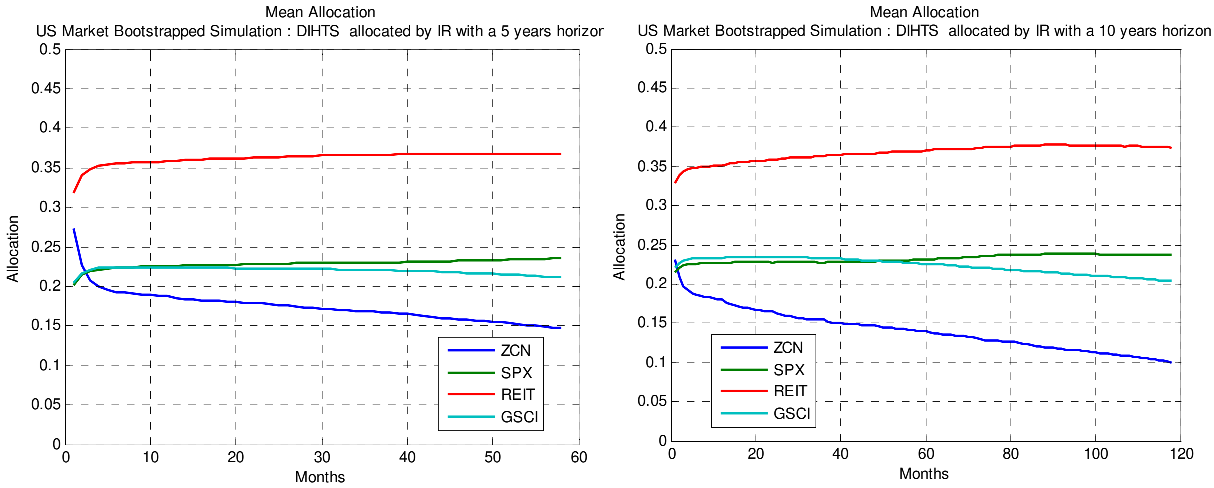
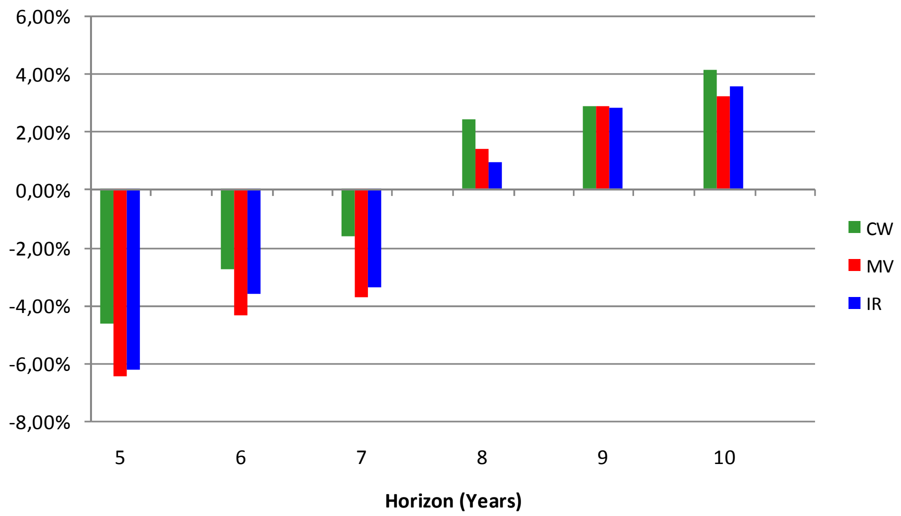


Figure 15 : Horizon sensitivity of the (DIHTS – Benchmark) Fail Rate enhancement



The average allocation of the portfolio shows a progressive substitution of the nominal bond to the benefit of the other asset classes which exhibit upward trending means for all classes in the five year computation. In the case of the ten year horizon, the REIT allocation exhibits a downward trend in the MV allocation and so does the GSCI in the IR allocation. There is no clear explanation for these phenomena.

Table 3: Horizon sensitivity of the DIHTS vs. the Benchmark Portfolio for the bootstrapped simulation allocated by IR

Horizon (Years)	Fail Rate		IR		ToR		PLGF
	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF	
5	9,93%	16,17%	56,05% *(21,4%)*	51,79% *(19,95%)*	8,10% *(4,9%)*	6,17% *(2,38%)*	-7,03% *(13,31%)*
6	10,55%	14,19%	45,52% *(18,8%)*	47,95% *(21,36%)*	9,13% *(4,9%)*	7,79% *(3,02%)*	-5,82% *(12,81%)*
7	8,83%	12,24%	25,64% *(15,2%)*	31,05% *(21,26%)*	10,66% *(5,3%)*	9,37% *(3,77%)*	-5,92% *(14,60%)*
8	9,63%	8,70%	29,69% *(9,0%)*	32,00% *(9,78%)*	11,68% *(6,1%)*	11,27% *(4,69%)*	-1,01% *(12,55%)*
9	13,33%	10,55%	22,52% *(6,2%)*	21,03% *(4,92%)*	13,26% *(6,6%)*	13,63% *(5,61%)*	-4,56% *(12,93%)*
10	12,14%	8,60%	4,94% *(7,0%)*	4,89% *(6,91%)*	15,44% *(8,2%)*	16,14% *(7,61%)*	-2,09% *(13,75%)*

Table 4: Allocation horizon sensitivity analysis for the DIHTS for the bootstrapped simulation.

Horizon \ Allocation	ZCN	SPX	REIT	GSCI
5	17,3% *(10,7%)*	22,5% *(5,7%)*	35,5% *(6,1%)*	21,6% *(6,6%)*
6	17,1% *(10,2%)*	22,9% *(5,9%)*	35,7% *(5,9%)*	21,4% *(6,4%)*
7	15,9% *(8,7%)*	21,9% *(6,3%)*	37,0% *(6,5%)*	22,7% *(6,9%)*
8	15,8% *(7,5%)*	25,3% *(5,7%)*	35,9% *(5,8%)*	20,1% *(6,1%)*
9	14,9% *(5,8%)*	24,8% *(5,5%)*	35,9% *(5,7%)*	20,4% *(6,1%)*
10	14,5% *(5,0%)*	23,2% *(5,5%)*	36,3% *(5,7%)*	21,3% *(5,9%)*

In term of comparative performance to the benchmark, we have computed the excess rate of failure of the DIHTS over its benchmark for the three allocation methods for horizons ranging from 5 to 10 years. The results are presented in the figure 2 above. We observe that in term of FR, the DIHTS achieves a significant reduction for maturities ranging from 5 to 7 years and then underperforms its benchmark significantly for maturities of 8 years and over.

The PLGFs do seem to follow the same pattern as they exhibit fairly negative figures for short maturities and tend to diminish as the maturity lengthens. They end up close to zero for the CW and MV case and remain negative for the IR which is the overall best performer. The IR ratios yield little discriminative value as the differences between the ones of the DIHTS and those of its benchmark are negligible. The ToRs are also fairly close, but it is rather encouraging as it removes partly the trading cost caveat.

6. CONCLUSION

Inflation hedging has been a broad cyclical concern in Asset Liability Management for almost every type of financial institution and states alike. Be it for hedging on the short or the long part of the curve depending on their type of liabilities, virtually every player has had to grapple with an unbalanced market and all the costs and liquidity problems associated with it. Three decades of development of the primary inflation linked market have failed to quench the demand for inflation linked securities as its growth has been largely outpaced by the one of the potential demand for such instruments, adding extra pressure on hedgers. Recent spikes in headline inflation in OECD countries have spurred once again the quest for alternative hedging techniques as many sovereign issuers, constituting the bulk of the emitters, might rethink their emission policies. Some have already done so in the face of growing servicing cost and mounting public debt, the enduring testimony of the 2008-2009 financial crises.

This paper presents a novel way of hedging inflation without having to use inflation linked securities or other kind of derivatives through the transposition of a classic portfolio insurance strategy called CPPI. The Dynamic Inflation Hedging Strategy offers the promise of an implicitly guaranteed real par value for the portfolio whilst also delivering real returns at a much lower cost than comparative inflation-linked strategies would offer. The first empirical backtesting results of the potential of the DIHTS obtained for a set of US data have showed encouraging results. With conservative parameter choice, the strategy delivers on its promises and never breaks the floor at any investment horizon and for any of the thousands of overlapping periods tested. The strategy is able to save the par value in rough markets conditions and delivers strong real performance in more auspicious ones.

In the light of the results obtained by running a simulation exercise using a bootstrapping method with all the caveats before mentioned, we can reasonably upheld the rather optimistic results obtained in the historical simulation back-testing as we are able to prove a significant outperformance of the DIHTS over its benchmark in term of rate of failure for horizons of five to seven years, whilst it unfortunately suffers greater losses for longer targeted maturities. Contrary to our first estimation, the bootstrapping simulation exercises shows that the DIHTS can fail in cases of extremely adverse scenari, the like of which we have never seen before though.

Further work on this subject might involve taking on the most severe caveat of this study: the absence of trading cost. The exceptionally strong performance of the strategy clearly demonstrates the need to take them into account in a realistic way. It is a an especially difficult problem since the length of the period studied would force the use of time varying trading cost as markets have evolved dramatically in recent times, especially since the early nineties in terms of liquidity and trading costs. Another aspect that could be envisaged would be to run the experiment on better simulation universes if they were to materialize since the back-testing bootstrapping techniques suffer from important caveats. It is especially important as the period studied in the historical simulation involves mostly decreasing inflation and risk premiums which tend to biases upward our results. Eventually, it could also be possible to enhance the allocation by incorporating more advanced models into the framework or using predictive allocation variables to market-time the alternative asset classes. The breakdown of the general asset classes we are investing on into more subtle sub-indexes might also yield enhanced performance in term of tracking error of the CPI.

To conclude, this paper does successfully proves that transposing systematic trading rules to achieve a real portfolio insurance through the use of the DIHTS is both feasible and generates higher real returns that a classic portfolio approach benchmark would. The framework developed here is also sufficiently flexible to allow for asset managers input in term of tactical allocation for the diversified part of the portfolio. Obviously, the strategy would still suffer from the main shortfall of the

CPPI, as it only insures a hedge up to a certain level of negative performance. The gain in term of real return come at a cost: there is “no free lunch” for “black swans”

Chapter 2, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy

1. INTRODUCTION

The intricate relationship between crude oil prices and macroeconomic variables, inflation in particular, has been extensively studied in the last decade. Following the seminal work of (Blanchard & Gali, 2007), it has been commonly accepted that the pass-through of exogenous oil price shocks to output and inflation has greatly diminished since the nineties, thereby severely reducing their role as drivers of long-term inflation and economic crisis. Moreover, (Clark et Terry 2010) and (van den Noord et André 2007) have shown that the transmission of oil price shocks into core inflation has now basically ceased, thereby greatly differentiating the behavior of core and headline inflation. Yet, to the best of our knowledge, no research paper has focused precisely on the implications in terms of commodity allocation for inflation hedging portfolio management that this macroeconomic shift implies.

The question of the optimal allocation of commodities in an inflation hedging portfolio has been central to academic research since the end of the era of cheap oil in the seventies in the United States. The first article directly addressing this issue was (Bodie & Rosansky, 1980) which advocates the inclusion of commodities as natural inflation hedges. Commodities can be included in a standard portfolio optimization framework for two main reasons: firstly, commodities have offered potentially strong nominal returns and are a source of performance enhancement on a risk-adjusted basis as they are potentially decorrelated from other standard asset classes. Secondly, commodities seem to offer interesting inflation hedging properties. Yet, commodities are cyclical and can suffer from very sharp downturns, of magnitudes that greatly dwarf inflation variations, thus rendering their inclusion into inflation hedging portfolios non-trivial.

The mainstream of academic literature over recent decades has been made up of response function analysis following the seminal work of (Campbell & Viceira, 2002) which introduced the use of structural Vector Autoregressive Models (VAR) allowing the computation of response functions to inflationary shocks, regime change or more complex scenarios in the case of Markov Switching models. It has recently expanded into the co-integration universe with the use of Vector Error Correction Models (Amenc, Martellini et Ziemann 2009). Though such works may offer some interesting insights, their statistical justification is quite weak and their out of sample efficiency remains to be proved. In fact, such models do not try to exploit the relationship between commodity price shocks and inflation but rather tend to measure the potential unexpected-inflation hedging resilience of an asset class, were such an event to occur.

Since no publicly available, global macro approach using pass-through literature to allocate commodities has been proposed, we investigate this issue in this article: we will attempt to define a natural commodity allocation derived from their expected contribution to headline inflation trends using forward core values as an allocation metric. The first section of the article will be dedicated to a review of the literature concerning changes in the pass-through, its measurement and commodity allocation research. The second section will investigate the impacts of this shift into financial securities' pricing and correlation structure, then propose strategies aimed at exploiting them. Finally, the last section will evaluate three possible exploitations of our findings: a strategic allocation framework, a tactical allocation framework and a commodities and fixed income derivative arbitrage.

2. SHIFTING PARADIGM, VANISHING PASS-THROUGH AND ALLOCATION ISSUES

2.1. The macroeconomic literature of the shifting paradigm

One of the great macroeconomic paradigms of the twentieth century was that exogenous oil shocks were harbingers of macroeconomic chaos in the form of surging inflation, restrictive monetary policies and severe drop in output. Collective memories of the two major oil shocks in the seventies largely fed into this. However, a recent stream of literature has challenged this assumption on the basis of new evidence pointing at a much reduced role for oil price shocks in terms of being a generator of macroeconomic volatility. The seminal article of (Blanchard & Gali, 2007) completes this literature by trying to measure and explain the diminishing macroeconomic impact of oil shocks since the eighties as compared to the seventies. Using *a structural vector autoregressive* (SVAR) model, they estimate *impulse response functions* (IRF) to exogenous oil price shocks. Their rolling timeframe estimation results point at a clear reduction in the impact of shocks since the mid-eighties. In a later paper, (Blanchard and Riggi 2009) estimated a simpler new-Keynesian model derived from these observations aiming at explaining the causes of the shift. The authors evaluate and model three possible explanations found in the literature: a reduction in the energy intensity of output, a relaxation of the real wage rigidity or the effectiveness of new central bank monetary policies. These hypotheses can in turn be explained by their respective literature:

The decline in energy intensity of US output measured by (Wing, 2008) could be the result of both intra-industries energy efficiency improvement and inter-industries sectorial reorientation of productive capacities toward less energy intensive ones such as services.

The vanishing real wage rigidity is documented in (Card & Hyslop, 1997) which showed that between the seventies and the eighties, an increasing number of employees were not receiving inflation neutralizing raises, therefore upholding the belief that inflation “greases the wheels of the labor market” by eroding in time the downward nominal wage rigidity.

The increased effectiveness of central bank monetary policies has been largely attributed to the successes of inflation targeting monetary policies introduced in the early nineties. By also using an SVAR to calibrate a general equilibrium model, (Boivin & Giannoni, 2006) have shown that compared to the eighties, monetary policy exogenous shocks seem to have a much lesser impact in term of volatility of inflation and output. Also, the reduced size and increased frequency of monetary shocks seem to point at a more proactive and efficient policy response. All of these elements tend to demonstrate an enhanced credibility of central banks at achieving price stability.

The most interesting aspect of this macro-shift for our purpose can be found in the first of Blanchard's papers cited (Blanchard and Riggi 2009). The authors note that by comparing the results obtained over the twenty years or so before and after 1980, the contribution of oil shocks to economic fluctuations remained flat for GDP and employment, declined by half for wage inflation and the GDP deflator while it increased by almost a half for CPI inflation. But most importantly, these observations are consistent with the core CPI remaining stable as oil price shocks are passed on to the energy component of the CPI and, according to their estimate, account for up to sixty percent of its volatility. This brings us to our second point: the vanishing pass-through of energy price shocks from headline to core prices.

2.2. The vanishing pass-through

Exogenous oil shocks are, by conventional wisdom, the main drivers of CPI inflation: this passage of changes in the prices of energy to the general price level in the economy as measured by the CPI has been dubbed the *inflation pass-through of energy prices*. While it was indisputably fairly large until the late seventies, it is then quite amusing as (Hooker, 1999) noted that the very nature of this close relationship broke down at the very moment when (Hamilton, 1983) published its landmark paper on the link between oil prices and macroeconomic variables.

There is an extensive body of literature that delves into this vanishing pass-through and provides a variety of possible explanations and ways to measure it: (De

Gregorio, Landerretche, & Neilson, 2007) extend the (Blanchard & Gali, 2007) paper by incorporating a much larger set of 34 countries, including emerging ones and estimate the pass-through using IRFs derived from an SVAR analysis and an enhanced Philips curve with oil parameters. They conclude that it has fallen significantly since the mid-seventies for all developed countries and, to a smaller extent, in emerging markets. This reduction has been the result of both a decline in the economic intensity of oil use and the impact of favorable exchange rates as the latest oil shock has been demand-driven (therefore resulting in an appreciation of exporting countries' currencies). Both of these new arguments still fail to explain a significant part of the reduction of the pass-through as the authors conclude. Using an equivalent methodology, (Chen, 2009) points out the degree of trade openness as the only statistically significant additional explanatory variable included in his analysis, but still fails to explain a large part of the pass-through decline.

The other interesting aspect of this pass-through is the transmission of energy price variations from headline to core inflation. The oil-inflation paradigm previously exposed would have those variations reflected immediately in headline CPI and then progressively transferred into core CPI measures as economic agents gradually adapt their prices to a change in energy input prices. This transmission mechanism would end-up closing the gap between both indicators. In essence, it would be a headline to core inflation pass-through. In fact, core CPI measures are often disregarded by financial professionals as merely lagged estimates of headline CPI. But as all paradigms seem doomed to fail, (van den Noord et André 2007) showed that during the recent crisis, core inflation's reaction to headline spikes remained totally muted in both the US and Europe. Once again, the reduction in energy intensity is identified as the main explanation of this, but so is the fact that this recent crisis occurred at a time of economic slack compared to previous ones in the seventies in particular. (Clark et Terry 2010) went down this path using a more complex time-varying-parameters and stochastic-volatility-Bayesian-VAR methodology to precisely estimate the pass-through of energy prices variations to core inflation in the US. They estimate that since approximately 1975, core CPI in the US had gradually become less responsive to changes in energy prices. By 1985, the pass-through had been reduced to nil.

2.3. The case for a commodities allocation in asset liability management

Commodities have been exchanged in spot and futures format since immemorial times and were most certainly the subject of the first derivative trades. Yet, they have only recently attracted the attention of portfolio managers as a strategic investment class. In fact, the first meaningful articles on the issue of incorporating commodities into an investment portfolio are contemporaneous with the first major oil shocks since the Second World War and the surging inflation that accompanied them. Back then, they had already been studied in conjunction with inflation: in the early eighties, (Greer, 1978), (Bodie & Rosansky, 1980) and (Bodie Z. , 1983) explore their inflation hedging potential. Since then, the number of articles exploring the potential of commodities as an alternative asset class both for performance enhancement and liability management is simply astonishing. The impressively long bull-run of commodities in the previous decade certainly helped as contrarian showed (Daskalaki & Skiadopoulos, 2011) in their out of sample analysis.

The benefits of a commodity allocation are usually described as investing in an asset class with equity-like returns and low correlation with traditional equity-bond-cash portfolios (Conover M. C., Jensen, Johnson, & Mercer, 2010). The question of the correlation of this specific asset class to other more conventional ones has been studied in depth by (Chong & Miffre, 2010). However, it is regrettable that linkers were excluded from this analysis even though there is an obvious historical depth availability issue. More specifically, the potential of commodities to hedge against unexpected inflation has been explored in (Attié & Roache, 2009) even though (Erb & Harvey, 2006) note that a specific distinction should be made between commodities as a whole and commodity indices which experience a fairly different kind of return and correlation profile. After the energy component, the second most studied commodity sub-index has been precious metals which also exhibit interesting inflation hedging potential in times of severe downturn and "flight to safety" phenomenon (Conover M. C., Jensen, Johnson, & Mercer, 2010). Lastly, the tactical value of commodities in a general portfolio optimization framework was shown in (Fuertes, Miffre, & Rallis, 2010) to name just one of the many articles on this subject.

The inflation hedging potential of commodities has fueled research into their inclusion in liability driven investment strategies. (Hoevenaars, Molenaarb, Schotman, & Steenkamp, 2008) justify their inclusion in a simulated Asset Liability Management (ALM) analysis for both their risk diversification benefits and their inflation hedging capacities. The same is true for the long only investment approach of (Amenc, Martellini et Ziemann 2009) and (Brière and Signori 2010). However, all these papers ignore the macro aspect of the allocation. This type of approach combining a liability (a.k.a. an inflation risk) and a macroeconomic tactical allocation can be found for example in the long-short macro-timing of the commodity allocation of (Jensen, Johnson, & Mercer, 2002).

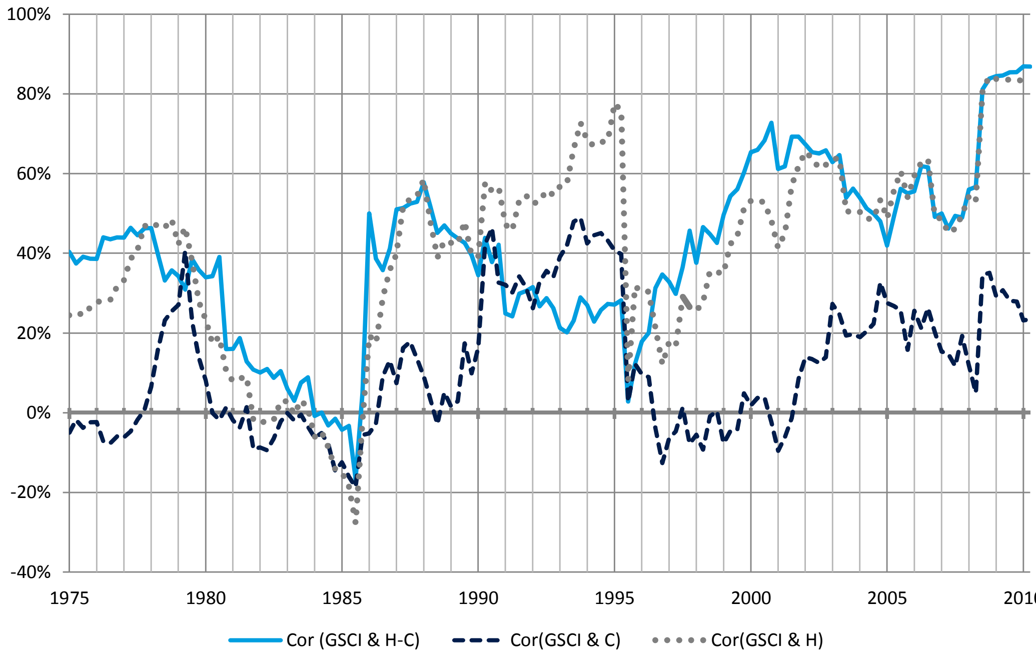
To the best of our knowledge, no research has focused specifically on the allocation implications of the commodities-to-inflation pass-through previously exposed in terms of inflation protected portfolios. Yet, if we are to believe (Brière and Signori 2010) and (Attié & Roache, 2009), commodities do offer a relatively good inflation hedge up to a certain horizon, after which their hedging potential seems to gradually wane. Could this be a result of the pass-through of commodity price inflation to core prices? Considering for example the previously mentioned academic research into the pass-through, could we envisage looking at the core versus headline inflation cycles as an indicator for the timing of the allocation?

3. FINANCIAL ASSET CONSEQUENCES OF THE SHIFTING MACRO-STRUCTURE

3.1. Historic correlations analysis

A first impression of the impact of the pass-through in terms of asset prices can be assessed by calculating the correlation between a commodity index on the one hand and headline inflation, core inflation and the difference between the two on the other hand.

Figure 16: Rolling time frame correlation analysis between commodities and inflation indices



We plotted in Figure 1 those three measures for quarterly data over the 1975-2010 period using a 20-quarter rolling time frame and using the GSCI-TR (*the Goldman Sachs Total Return Commodity Index*). From this first rough insight, we can grasp that the correlation between the commodity index and core inflation (*dark blue dashed line*) is on average quite low and unstable through time. The correlation between headline inflation and the commodity index (*grey pointed line*) is also unstable but secularly increasing over times, even though it is subject to brutal regime changes in terms of correlation levels. We can speculate that they appear to be synchronous with severe macro or oil specific events (or both) such as the 1985-86 counter oil shock (Mabro, 1987) or the US 1992 recession (Hamilton, 2011). The correlation between the commodity index and the volatile fraction of the inflation index a.k.a. the headline vs. core spread (*solid light blue line*) has more or less been continuously rising since the mid-eighties and has risen above 80% in recent years. Its trend has been so closely linked to its headline counterpart that it has even gone up to the point of being indistinguishable from it in the last ten years.

Consistently with prior literature, our computation exhibits a new correlation regime that began in the nineties: core inflation appears weakly correlated with commodities but is somewhat upward trending. Headline inflation's correlation with commodities appears very strong and its evolution has been matched by the correlation between the inflation spread and commodities. But how will it evolve going forward? Is it a transient state as a result of the current market turmoil or is it a stable long term-trend? The last subsections will delve into this issue with a co-integration analysis to try to answer this point. The previously exposed literature gave an economic explanation for the link between spot oil prices and headline inflation or for the absence of it when it comes to core inflation and our simple correlation analysis does seem to support an investment strategy. We will therefore explore the possibilities in terms of inflation hedging strategies that this new framework enables in the next subsection.

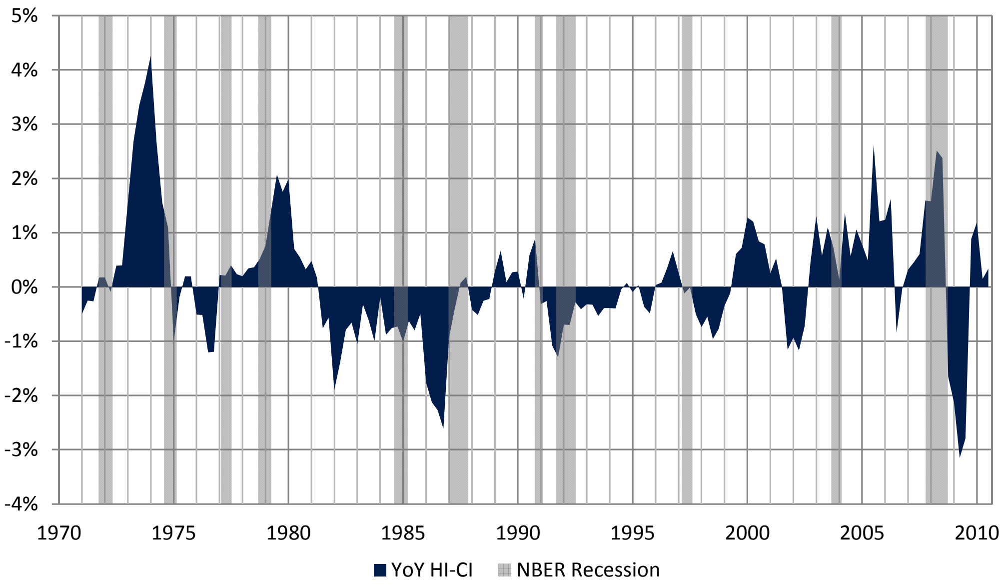
3.2. Pricing implications of the pass-through

The estimated level of the pass-through should drive our strategy in the following way: should an exogenous energy price shock hit the economy, headline inflation (HI) would spike contemporaneously with the commodities index while core inflation (CI) would remain stable. The difference between the returns of the CI and HI index should initially also be highly correlated with the commodity index, while the correlation of the CI to the same index should be low. Then, after a certain lag, two scenarios are possible:

Either the pass-through does operate and the general price level in the economy adapts, therefore diminishing the hedging potential of commodities as the CI catches up with core HI and eventually overshoots it. If this scenario were true, then the evolution between CI and HI (both in level and in correlation to commodities) should be an indicator of the allocation: during the first part of the cycle we should be relatively long on commodities, while we should gradually short the position towards the end of the cycle. The commodities in the allocation should gradually be substituted for other kinds of asset which would be more prone to hedge the CI as it becomes dominant towards the end of the cycle.

Or the pass-through doesn't operate and the CI response to the spiking of commodities remains muted. If this were the case, CI would remain – ceteris paribus – flat while the HI should eventually mean revert towards CI. If this alternative scenario were true, then the joint evolution between CI and HI (both in level and in correlation to commodities) would also be a different indicator for the allocation: the CI-HI correlation should remain high throughout the cycle. If our objective is primarily an inflation hedge, then we should calibrate a strategic commodity allocation to correspond to the forecasted residual spread between CI and HI.

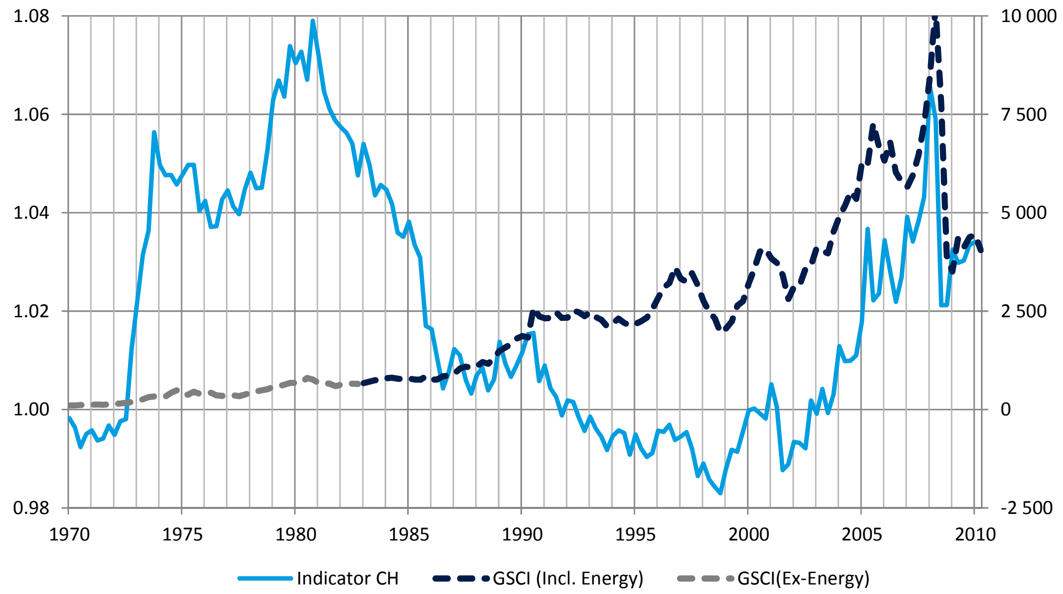
Figure 17: Year on year headline minus core inflation over forty years



Therefore, if the pass-through does operate, we should have a *tactical allocation indicator* whereas if it doesn't, we should have a *strategic allocation indicator*. We shall evaluate those two options in the next section. In accordance with our prior hypothesis, we compute the tactical indicator as the integrated difference between the returns on CI and HI (*light blue continuous line*). We obtain Figure 2 by superimposing with a different axis the contemporaneous evolution of the GSCI_TR index (*dark blue dashed line*). We also separately represented the GSCI_TR prior to the inclusion of energy commodities in December 1982 (*light grey dashed line*) when their liquidity was deemed sufficient.

As could be expected from the correlation analysis, there seems to be no clear relation between those two time series up until the late nineties, when there are clear hints of comovements, if not an outright cointegration relationship. In fact, considering the methodology employed by the statistical body on the one hand, and the computation of the commodity index, it is not initially obvious that such a relationship could hold. We are de facto comparing a consumer price derived index to a financial market derivative transaction based index, both of which could easily answer to very different drivers: the GSCI_TR could be very sensitive to market manipulation or short-term adjustments, whereas the other index could be subject to seasonal effects (we chose not to use a seasonally adjusted indicator).

Figure 18: A Comparison of the GSCI TR index and the integrated difference of CI and HI



This kind of argument could also offer a tentative alternative explanation for the weak relationship early on in the period: at this moment in time, commodities financial markets were much less developed, more illiquid and trading costs were extremely high. Such events would put a serious drag on the returns of the GSCI_TR during much of the seventies and eighties whereas the consumer price index did not suffer from such disadvantages.

3.3. Cointegration analysis as a predictor of long-term trends

As any investor knows or should know, "*past performance is no guarantee of future results*". The main caveat of our study lies in the fact we have until now tried to justify with fundamental macroeconomic arguments the existence and the evolution of the correlation structure we have exposed previously but we have not provided any indisputable proof that would ensure the persistence of the correlation through time. And there is clearly none. Still, we could partially reinforce our econometric assumptions by running a cointegration test to evaluate the potential for shifts in the current structure or its probable persistence which a strong cointegration relation would favor.

Tableau 5: ADF tests for unit root

Variable:		Indicator_CH		GSCI_TR	
Range	**Test option**	**ADF t-statistic**	**AR(1) estimate**	**ADF t-statistic**	**AR(1) estimate**
1970-2010	No deterministic part	0.013 ***	1.000	-0.120 ***	0.998
	Constant plus time-trend	-2.064 ***	0.945	-2.953 ***	0.839
1970-1995	No deterministic part	-0.549 ***	1.000	0.741 ***	1.012
	Constant plus time-trend	-2.435 ***	0.916	-2.056 ***	0.899
1995-2010	No deterministic part	0.917 ***	1.001	-0.235 ***	0.993
	Constant plus time-trend	-2.420 ***	0.562	-2.554 ***	0.382
2000-2010	No deterministic part	0.353 ***	1.001	-0.667 ***	0.966
	Constant plus time-trend	-1.244 ***	0.157	-0.778 ***	0.446

Note : */**/*** denotes the significance at the 10%/5%/1% level

Using the cointegration framework developed by (Granger & Newbold, 1974), we explore the possibility of a spurious regression by testing for cointegration using the (Johansen, 1988) test after having performed an integration test using (Said & Dickey, 1984). Since there are multiple possible structural breakpoints in the correlation structure, we will perform the test using several timeframes as before.

Firstly by testing over the entire sample, then on several sub-samples which represent our areas of interest. The choice of those breakpoints is derived from the pass-through literature, not an endogenous selection like (Andrews, 1993).

We can therefore perform the regression analysis and test for spurious regressions using the Johansen Test as is presented in Table 2.As expected, the regression analysis yields a low Adjusted R^2 for the overall period studied and for the 1970-1995 period. However, it gives a higher Adjusted R^2 for the 1995-2010 and the 2000-2010 period. The last of the two periods' R^2 is slightly smaller (contrary to our correlation analysis) partly because of the adjustment of the R^2 to the sample size (which is smaller in the second case). All the regressions are significant to the 99% threshold except for the first one over the entire 1970-2010 period.

In order to check for long-term trends which would uphold the case for long-term stability, we check the validity of a cointegration hypothesis using a Johansen test. We first check for evidence of integration in our time series using the Augmented Dickey-Fuller (ADF) test with constant and time trend whose results are exhibited in Table 1. The first and most unsurprising conclusion we have is that can we reject the null hypothesis (I(0)) for both our time series and at any period in time. Our result is statistically significant at the 1% level. The second conclusion we can reach is that the process driving our two time series is almost perfectly integrated of order 1 since we obtain AR(1) parameter estimates insignificantly different from 1 in the case of the estimations with neither constants nor time-trends. If we include those parameters, as could have been expected, we obtain parameter estimates significantly different from 1, especially in the more recent estimates.

As we expected, the cointegration hypothesis is upheld according to our Johansen Test for the 2000-2010 period and weakly rejected for the other sample periods. More precisely, we can reject the cointegration hypothesis for the 1970-2010 period at the 95% level, and we upheld the hypothesis for the 2000-2010 period at the same level. For both the 1970-1995 and 1995-2010 period, we have weak evidences of cointegration (significant only at the 90% level). We can therefore conclude that according to our study, the cointegration seems to have begun in the early 2000 and is still holding today. It is consistent with literature on the macroeconomic model. We should therefore expect our strategic allocation strategy to perform better in a historic backtest for the 2000-2010 timeframe and less so before that. Inversely, we should expect our tactical allocation to outperform in the preceding period and underperform in the more recent period.

Table 1: Long-run equilibrium and cointegration test results

Dependent Variable:		**Core Headline Inflation Indicator**			
Range:		1970-2010	1970-1995	1995-2010	2000-2010
#Observations:		163	100	63	43
Independent Variables					
Constant		1.024	1.041	0.967	0.971
		(0.003)	(0.004)	(0.003)	(0.006)
GSCI_TR	(x10^6)	-1.907	-14.764	9.784	9.224
	(x10^6)	(0.956)	(3.069)	(0.740)	(1.116)
Adj. R^2		2.41%	19.10%	73.83%	61.91%
Fisher		3.981 ++	23.136 +++	174.875 +++	68.267 +++
p-value		0.048	5.5E-06	1.1E-19	2.4E-10

Note : +/++/+++ denotes the significance at the 90%/95%/99% level

Johansen Test for constant plus time-trend:

Statistic	**Null**				
Trace	**r< = 0**	20.702 **	8.863	10.494	10.908
	r< = 1	2.645	3.460 *	3.458 *	5.218 **
Eigen	**r< = 0**	18.057 **	5.403	7.035	5.690
	r< = 1	2.645	3.460 *	3.458 *	5.218 **

Note : */**/*** denotes the significance at the 90%/95%/99% level using critical values generated using MacKinnon (1994, 1996)

4. EMPIRICAL ESTIMATIONS OF ALLOCATION AND ARBITRAGE APPLICATIONS

4.1. Strategically allocating commodities in inflation hedging portfolios

Building on the previously mentioned macroeconomic literature on the absence of pass-through into core inflation of commodity price shocks and its asset pricing implication in terms of asset correlations we briefly explored in the previous section, we aim to formalize the following strategic allocation for commodities:

We have shown that the spread between HI and CI is highly correlated to commodities whereas their correlation to core inflation is negligible. The allocation of commodities in our inflation hedged portfolio should accordingly be targeted at hedging this fraction of the inflation risk. We therefore built a two fund portfolio with a first allocation intended to hedge core inflation, while the second one is aimed at hedging the residual inflation spread. If commodities proved to be a natural investment to hedge the inflation spread, finding a core inflation hedging asset will be more arduous for two reasons: firstly, there is no asset as of today with cash flows linked to core inflation and secondly, core inflation is an economic concept which is very poorly correlated to any tradable security. However, since core inflation displays very low volatility on short to medium horizons, we could envisage a partially unhedged strategy in which we would remain at risk on the core inflation part as forecasts should not be too far off the ex-post realized value because of the low volatility.

We then define the following long-only strategy in which we secure with a nominal bond investment the expected core-inflated value of our investment while remaining at risk on unexpected core inflation –defined as the difference between ex-post realized and ex-ante forecast– and playing the natural cross-hedging of commodities with the inflation spread to hedge it. We should therefore achieve an extreme event hedging of headline inflation while benefiting from the real rate premium derived from the nominal bond investment.

To perform the backtesting of our proposed strategic allocation we used fixed-income and commodity data obtained from Bloomberg. Inflation data were retrieved from the FRED database. We use forecasted core inflation data either obtained from the survey of professional forecasters when it is available or computed using a very conservative hypothesis of stability in level and a term-structure shaped by the headline forward curve when it is not. We use only information available at the time of the investment to avoid "back-trading" or data mining biases. This dataset is available only from 1990 onward, thus constraining us.

The zero coupon bond whose maturity matches our target investment one is allocated such that it terminal value equals the expected core-inflated value of our investment fraction of the portfolio. Let CI be the forecasted core inflation and $\tau_{0,t}^{ZCN}$ be the zero coupon nominal rate, we can therefore write the fixed income allocation as:

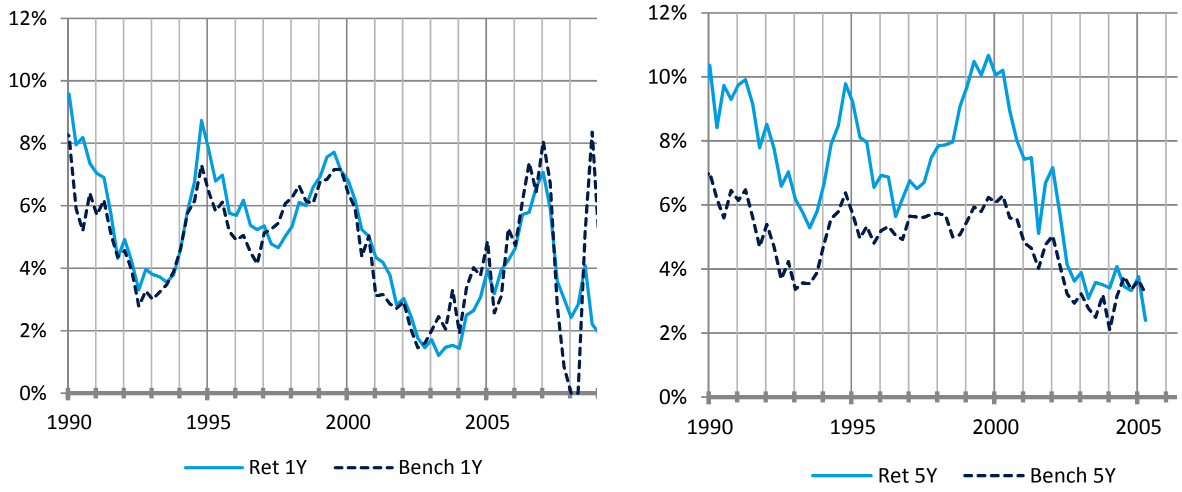
$$FI_{0,t} = \left(\frac{1 + CI_{0,t}}{1 + \tau_{0,t}^{ZCN}}\right)^t$$

Tableau 6: A commodity enhanced bond portfolio vs. a linker benchmark

Maturity	**1Y**		**2Y**		**3Y**		**4Y**		**5Y**	
Portfolio	Alt.	Bench.	Alt.	Bench.	Alt.	Bench.	Alt.	Bench.	Alt.	Bench.
					1990-2010					
Average	5.18%	4.87%	5.51%	5.26%	5.98%	4.43%	6.59%	5.44%	7.18%	4.94%
Std.	2.20%	2.10%	4.31%	3.34%	5.89%	2.92%	7.72%	5.69%	11.24%	6.13%
IR	0.140		0.291		1.394		1.307		1.769	
					2000-2010					
Average	3.66%	3.88%	4.05%	4.19%	4.60%	3.80%	5.04%	4.39%	5.64%	4.10%
Std.	1.77%	2.16%	2.98%	2.96%	4.81%	2.08%	8.60%	5.08%	13.00%	6.25%
IR	-0.145		-0.180		0.763		0.615		1.059	

The residual part of our investment is allocated in commodities and we will assume its performance is equal to that of the GSCI_TR total return index. We will define the benchmark against which we will test our strategy as a pure investment in linkers with a maturity matching that of the investment horizon. The return of the benchmark is therefore equal to the real rate defined at inception plus the accrued headline inflation over the life of the linker and floored at zero to respect TIPS characteristics. Real rates are defined as the difference between the US nominal zero coupon sovereign rate and the breakeven inflation of matching duration. The performance of the strategy compared to its benchmark is presented in Table 6 and the performances for two target maturities are represented as an illustration in Figure 19.

Figure 19: Out of sample evaluation of the strategic allocation vs. a benchmark portfolio.



For maturities above three years, our alternative strategy consistently beats its benchmark in terms of Information Ratio (IR) and mean absolute return for both time periods studied here, albeit with higher volatility. The strategy's performance is increasing through time except at the four year horizon, though the difference with the three year is clearly not statistically significant. Contrary to our pass-through hypothesis, the strategy does perform better during the 1990-2010 period than in the 2000-2010 period. It is probably explained by the severe counter-performance of nominal bonds contemporaneous with spiking inflation during the 2008-2009 US financial crisis as a result of flight to quality. The same is probably true for the one and two year horizon investment underperformance with respect to the benchmark in the 2000-2010 period as a result of severely depressed nominal rates. Real rates even went negative at times during the height of the crisis.

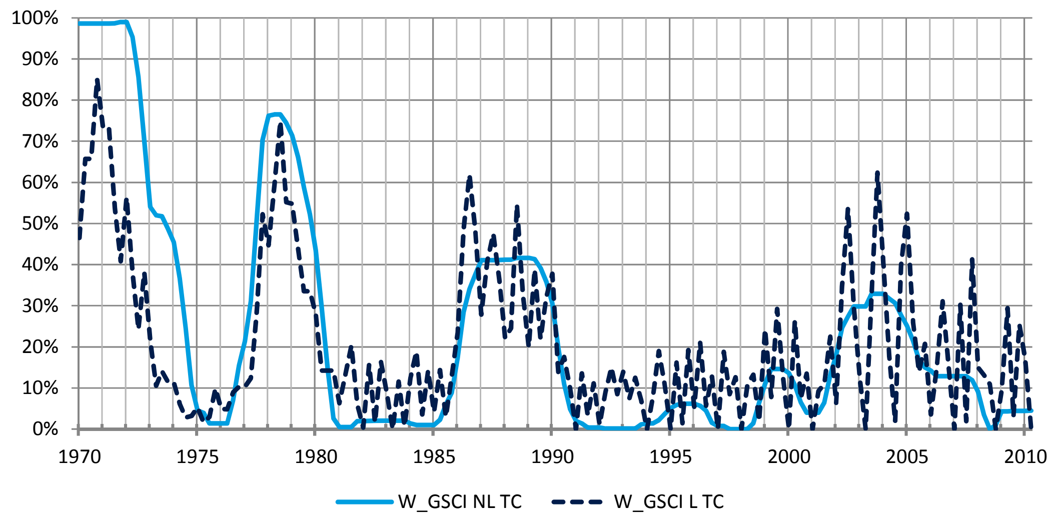
Our strategic allocation for commodities derived from the pass-through hypothesis seems to be supported by this backtesting exercise though we must point out several important caveats: firstly, commodities have enjoyed an exceptional bull-run through much of the period studied and it certainly biased upward the returns of our strategy by generating abnormal real returns. Secondly, the heredity of the *Great Moderation* has resulted in decreasing inflation and inflation risk premium throughout the period studied, therefore making realized unexpected inflation negative on average, thus also boosting our strategy's performance. And thirdly, the absence of available data prior to 1990 impedes the computation of the strategy's performance during a period of higher pass-through which would have been interesting for comparison purposes.

4.2. Tactically allocating commodities in inflation hedging portfolios

The second potential application for the pass-through literature in term of portfolio management we would like to explore in this article is the market-timing power of the pass-through indicator: considering our asset pricing hypothesis relative to the pass-through cycle, we could envisage to use its estimation in order to time the cycle by going long on commodities when the gap between HI and CI widens (increase in the inflation spread) and reduce our exposure to commodities when the gap closes as either the pass-through operates or simply HI is falling as it mean revers towards CI. We will be using low frequency data as there is too much noise below the quarterly frequency to monitor such a slowly evolving macroeconomic variable. The particularity of this tactical allocation approach is that we will try to time commodities' contribution to inflation regardless of any maximization of their potential nominal or real return.

The first assessments of our strategy that we will be conducting consist in an ex-post comparison of the optimal commodity allocation in a commodity and cash portfolio versus the pass-through indicator. We construct a quarterly rebalanced portfolio made up of both GSCI_TR and theoretically risk-free US sovereign three month T-Bills which optimal ex-post commodity allocation is performed by maximization of the portfolio's Sharpe ratio. The obvious pitfall of this methodology is that we clearly do not want to be running a "back-trading" exercise but rather capture only low frequency "fundamental" movements as opposed to high frequency market timing moves. To achieve this goal, we run the optimization using trading cost which penalizes too frequent "opportunistic market-timing trades" while favoring long time trend reallocations. Since those results would still be too volatile to capture the phenomena we target, we used both proportional trading cost and nonlinear trading costs (which evolve with the square of the trade size) following (Amihud & Mendelson, 1986) and (Vayanos, 1998). This adjunction enables to obtain a credible allocation in terms of asset turnover with a reasonably high trading cost of up to 5% of turned-over assets (which is still considerably higher than what current trading costs are on average). The smoothed (nonlinear) allocation curve obtained (*light blue continuous line)* is plotted along with the linear trading costs curve (*dark blue dashed line*) in Figure 5.

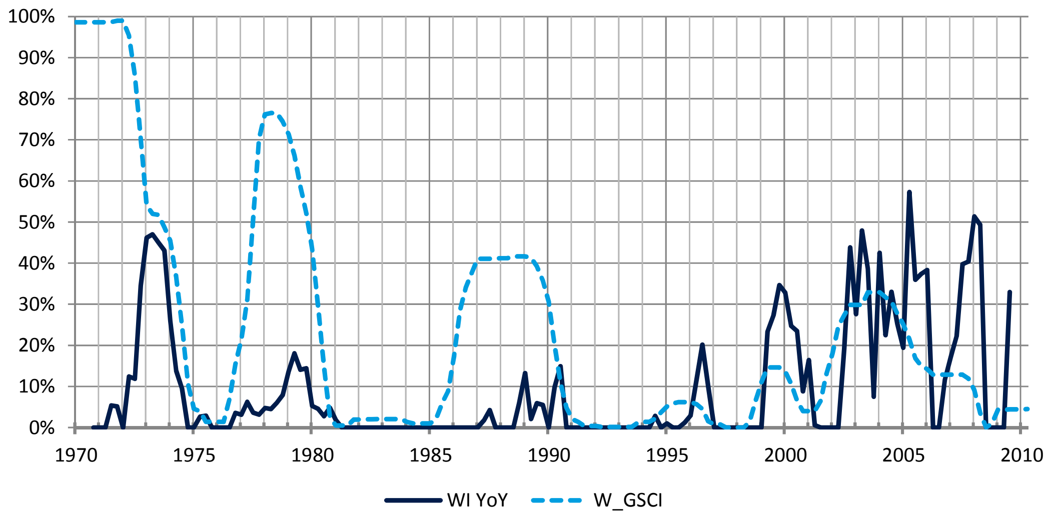
Figure 20: Optimal ex-post commodity allocation using proportional and nonlinear frictions



Since our working hypothesis would suggest that the difference between the rate of the CI and HI inflation is related to the optimal commodity allocation, we built the following allocation indicator (WI) as follows: the WI equals the yearly average of the ratio of the difference of the HI and the CI (if positive and 0 otherwise) over the HI if positive (0 otherwise). We then take the min of WI and 1 and the max of the previous condition and 0. The result is presented in Figure 6 (*continuous dark blue line*).

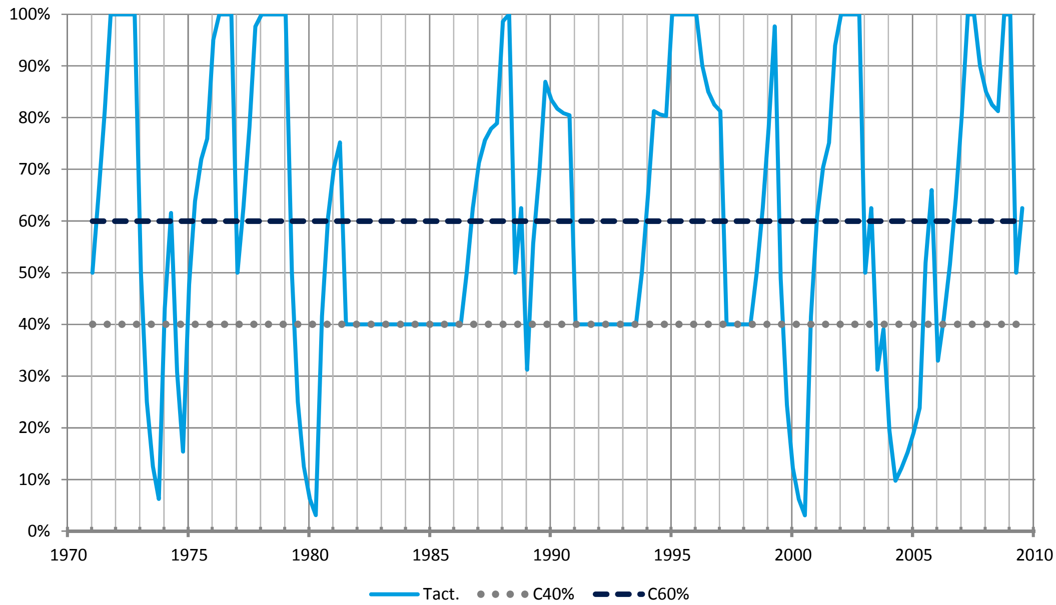
Comparing our optimal ex-post commodity allocation with the WI indicators we built yields the following observations: the three clear episodes of high allocation or commodities in our simulated portfolio in the early seventies, late seventies and eighties ended contemporaneously with a peaking followed by a sharp decrease of our indicator. It is slightly less clear but still apparent for the three latter episodes of higher commodity allocation in the 1990-2002 period. It then becomes completely uncorrelated in the 2002-2010 period during which our indicators becomes much more volatile and thus becomes less useful from an allocation point of view as its exploitable signal seems drowned with noise. These observations are consistent with our tactical allocation hypothesis which stated that the indicator should be more efficient at times when the pass-through does operate. Since the econometric literature we previously exposed dates this cessation to the early nineties, it is therefore logical that the WI should be good at timing commodities downturns before that and less so afterwards.

Figure 21: Optimal ex-post GSCI_TR allocation using nonlinear frictions



The second logical step to test the efficiency of our proposed indicator would be to conduct an out of sample ex-ante exploitation of it. To do so, we construct a quarterly rebalanced portfolio with a 40% commodities and 60% cash strategic allocation.

Figure 22: Out-of-sample quarterly rebalanced tactical GSCI allocation using the CH indicator



We then deviate tactically from this strategic allocation according to the WI indicator input: if the indicator goes up, we increase the allocation by 25%. If it goes down, we reduce it by half and if the indicator is at zero, we go back to the 40% strategic allocation. The resulting tactical allocation is plotted in Figure 7 (*light blue continuous line*). We benchmark it against the 40%-60% commodities-cash allocation (*gray dotted line*). Since on average our tactical allocation is 60%-40% commodities-cash allocated, we also benchmark it on this alternative allocation (*dark blue dashed line*) to control for the extra commodity weight given in our tactical allocation. The results from these simulated portfolios are shown in Table 4.

Table 7: Quarterly rebalanced out-of-sample tactical evaluation vs. constant weight benchmark portfolio

	1970-2010			1970-1990			1990-2010			2000-2010		
Ptf.	**Alt.**	**C60%**	**C40%**	**Alt.**	**C60%**	**C40%**	**Alt.**	**C60%**	**C40%**	**Alt.**	**C60%**	**C40%**
Mear	2.64%	2.24%	1.96%	3.69%	3.19%	2.78%	1.72%	1.40%	1.24%	1.75%	1.42%	1.17%
Std.	(7.50%)	(6.30%)	(4.23%)	(5.35%)	(5.23%)	(3.49%)	(8.89%)	(7.04%)	(4.69%)	(10.57%)	(8.04%)	(5.33%)
IR		0.129	0.169		0.168	0.299		0.100	0.102		0.080	0.100

Whichever time period is considered, the tactically allocated portfolio consistently beats both benchmarks. The spread in performance as measured by the IR between our tactical allocation and its benchmarks is also greater for the 40% commodity allocation than it is for the 60% commodity allocation. The difference is especially large during the 1970-1990 timespan (78% larger) and small in the 2000-2010 period (25% larger) compared with an average of 31% on the entire sample.

Those out of sample simulation results seem to once again uphold our tactical pass-through allocation hypothesis in the sense that our alternative portfolio performs better when the pass-through is larger and less so when it is not. It is worth noting that in this last timing exercise, we did not account for trading costs which would inevitably drag down the performance of a tactical allocation compared to a strategic allocation which requires less frequent therefore less costly portfolio rebalancing. The outcome would most probably still be positive in the high pass-through period but the tactical allocation could backfire in the more recent period considering the relatively low IR. If the WI indicator does seem to add tactical value to a commodity strategy, it should nonetheless be used in conjunction with a battery of other indicators and not on a standalone basis to achieve the best possible allocation.

4.3. Arbitraging core linked securities

Lastly, the changing US macroeconomic landscape should push many long-term liability driven investors towards a swap of references from headline to core inflation as (Fulli-Lemaire & Palidda, Swapping Headline for Core Inflation: An Asset Liability Management Approach, 2012) expose. As can be seen in Table 5, for medium to long horizon investors who can benefit from natural time averaging processes, the difference between indexing on a headline or on a core index is completely insignificant as the average spread stands at around 10 bp per annum. Meanwhile, swapping the HI reference for the CI would yield a 19% reduction in benchmark volatility over the entire period. If we focus more particularly on the last decade, we can achieve a 58% reduction.

Table 2: CI vs. HI risk reduction

Timeframe	Δ(HI,CI)		Volatility		Volatility Reduction
	Mean	Std.	HI	CI	
1970-2010	0.02%	2.15%	3.40%	2.75%	-19.15%
1970-1990	0.01%	1.86%	3.22%	2.78%	-13.49%
1990-2010	0.03%	2.39%	2.91%	1.70%	-41.82%
2000-2010	0.10%	3.15%	3.79%	1.58%	-58.25%

As we mentioned earlier on, the drive to move liability indexation towards core inflation is currently curtailed by the lack of investable core-linked assets and therefore a lack of a market reference to enable marking-to-market of such Liability Driven Investments (LDIs). The strong potential demand for such securities drove *Deutsche Bank* to launch the first investable core proxy in September 2012 (Li & Zeng, 2012) in the form of a long-short linkers-energy commodities index which serves as a reference for trading fixed-for-float "core-proxy" inflation swaps. It is thus most probable that we will see CI-linked securities issued in the near future if the derivative market for core inflation takes off, as it did for HI-linked securities decades before. The relative cheapness of issuing CI linked securities could in particular attract cash-strapped sovereign issuers eager to attract new investors and reduce their financing cost volatility arising from the HI-link.

To compensate for the lack of an investable CI security, investors wishing to hedge core inflation could either invest in a nominal bond portfolio and buy a fixed-for-float core swap overlay as in (Li & Zeng, 2012) or invest in a linkers portfolio and swap the HI for CI as in (Fulli-Lemaire & Palidda, Swapping Headline for Core Inflation: An Asset Liability Management Approach, 2012). Using our correlation analysis findings, we could hope to arbitrage those derivatives by building a replicating commodity portfolio. It is a complex problem as pricing such an instrument would require a mark-to-model approach to price the CI leg using an incomplete market cross-hedging framework.

5. CONCLUSION

The dramatic macroeconomic shift we have witnessed over the last decade has gradually reshaped our understanding of the relationship between macroeconomic variables and changes in commodity prices. The academic community has in particular delved into the disappearing pass-through of commodity price shocks into core inflation, and the far reaching consequences it has in terms of monetary policy conduct, especially so when it comes to dealing with surging crude oil prices and headline inflation. While macroeconomists and econometricians unraveled the breakdown in the pass-through, little concern was given about its consequences in terms of the allocation of commodities into inflation hedging portfolio management. This article endeavored to provide a first tentative answer to this question. The main take away from this paper can be summed-up in three arguments:

Firstly, we have established that in terms of asset pricing and as a consequence of the disappearance of the pass-through, relative variations in the core inflation index to the headline inflation index have been strongly cointegrated with financial commodity prices since the early 2000s. It opens the way for a natural commodity allocation in a core driven global macro strategy.

Secondly, we have shown in a back testing simulation exercise that as a consequence of the strong correlation between commodities and the spread between headline and core inflation, we can use forecasted core inflation data to determine an efficient strategic commodity allocation for an inflation hedged portfolio.

Thirdly, we concluded that since core inflation is on average only marginally different from headline inflation for medium to long term investors, but experienced significantly lower inflation in the last decade, we probably will experience in the near future the development of a core linked securities market. All the more so since the issuance of the first core-proxy linked derivative this year. This would pave the way for an arbitrage strategy involving core versus headline inflation swaps and a cross-replicating commodity portfolio.

The principal issues this paper has either failed to resolve or ignored are the following:

Firstly, we have showed that timing the pass-through cycle does not seem to yield an efficient tactical commodity allocation in the current macroeconomic environment. By comparison, we were able to test that in the past, with an effective pass-through operating, the indicator we constructed displayed an ability to correctly generate a significant alpha by efficiently driving the commodity allocation to match the dynamic of commodities with respect to inflation.

Secondly and lastly, we must mention that as a caveat to this study, the various backtesting exercises we ran were significantly positively impacted by what is probably an exceptional coincidence of secularly decreasing inflation and inflation risk premium with a historic bull run for commodities. One might wonder if the "*brave new world*" we were ushered into thanks to unconventional monetary policies, rapidly growing emerging countries and *peak-oil* will long leave the macroeconomic status quo untouched with a muted pass-through.

Chapter 3, Swapping Headline for Core Inflation: An Asset Liability Management Approach

1. INTRODUCTION

Whether inflation indexation should be performed based on core rather than headline inflation benchmarks or on CPI rather than RPI indices has been a core concern for central banks and pension funds, academics and practitioners alike. To this day, most inflation-targeting central banks around the world display headline inflation targets to anchor expectations, and some have even switched from core to headline targeting in the last decade or so in order to have targets that are directly understandable by politicians, financial markets practitioners and the general public: South Korea switched to headline targets in 2007 (Bank of Korea, 2006) and Thailand might follow suit (McCauley, 2007), leaving South Africa's and Norway's central banks as the only two displaying explicit core targets out the 23 of them using inflation-targeting. Still, academics used to present core inflation as the most efficient monetary policy target as in (Mishkin & Schmidt-Hebbel, 2007) or (Wynne, 1999). More recent works like (Gregorio, 2012) or (Walsh, 2011) tend to challenge that assumption in light of recent events where food inflation displayed persistency, especially in less advanced countries. But in spite of this tide of evidence pointing towards headline inflation indexation, we defend in this paper the idea that the time may have come to rethink our long-term inflation hedging strategies and move towards a core indexation of long-term inflation liabilities to the greater benefit of those seeking protection from monetary erosion.

Econometric studies in all major economies (van den Noord et André 2007), and for the US in particular (Clark et Terry 2010) have evidenced that while headline inflation has been increasingly affected by exogenous commodity price shocks since the late eighties, their pass-through into core prices has dramatically reduced to become statistically nil after the mid-nineties. It thus creates a drive to allocate commodities in inflation hedging portfolios as they naturally hedge the spread between the stable core and the volatile headline indices (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy 2012). But investing in commodities is still a complex and risky adventure for which not all types of investors have the adequate mandate or appetite to engage themselves into it. Yet, headline inflation has been shown to be mean reverting to its core peer in the medium term (Gelos & Ustyugova, 2012), and since the pass-through differential previously exposed results in a lower relative volatility of core inflation indices as compared to headline ones, we argue in this paper for a risk reduction in asset-liability-management strategy in the form of a shift from headline to core inflation indexation of long-term inflation liabilities commonly found in pension funds and liability driven asset managers. The rationale of this move being that the commodity-shock driven volatility effect of headline inflation spikes is averaged out over time, making long-term hedgers indifferent between both inflation liability targets while achieving a theoretically much less costly hedge because of the lower volatility of a core inflation benchmark. The obvious caveat of this alternative strategy is that no such outrightly core-inflation-indexed security exists today: there are no core yielding assets that could match consumer-price-indexed linked bonds in enabling investors to obtain headline inflation linked cash-flows. Though it is worth mentioning that Deutsche Bank recently introduced an investable core-proxy index (Li et Zeng 2012) that could well be the frontrunner of a primary core-linked security market.

In the meantime, to make up for the lack of a core-linked asset, we propose to overlay the traditional liability management investment portfolio with a swap to transfer the difference between the headline and the core inflation in return for a fixed rate that would be paid to long-term investors by short-term hedgers which cannot benefit from such long duration averaging processes. That is why short-term investors cannot be at risk on the volatile part of the inflation index but can be at risk on the core inflation which is extremely sluggish over short horizons and variations of which are, to a large extent, capped by those of the nominal rates: we therefore argue for a nominal investment strategy coupled with the receiving end of the inflation spread from the swap for short-term investors, and a linker investment coupled with the other end of the swap transaction for long-term investors, which would obviously have to roll their positions to match the maximum investment horizon of their short-term counterparties. The market for such a swap will most likely be unbalanced as short-term investor demand might be inferior to long-term players' offers. This would accordingly render the fair value of the swap priced under an efficient market hypothesis on synthetic forwards potentially inadequate as market-makers in the form of investment banks' trading desks might be necessary to support the market.

If such were the case, since this derivative is unarbitrable as it cannot be hedged on any market underlier because of the core inflation exposure, we would propose a cross-hedging strategy on commodities as the difference between core and headline inflation is highly correlated to them (Fulli-Lemaire, 2012), and has been increasingly so in the last twenty years. The pricing of the security would therefore be made on a cross-hedging cost basis under an incomplete market framework. The cross-hedging dimension will not be touched in this paper as we will remain under the efficient market hypothesis which includes the assumption that the security is outrightly arbitrable. We shall deviate slightly from this framework in the last section to introduce the optional setting which could constitute the basis for the cross-hedging strategy, but only in order to enhance the swap pricing by introducing the risk asymmetry between fixed and floating swap spread investors which justifies the existence of the risk premium that long-term investors are precisely trying to capture.

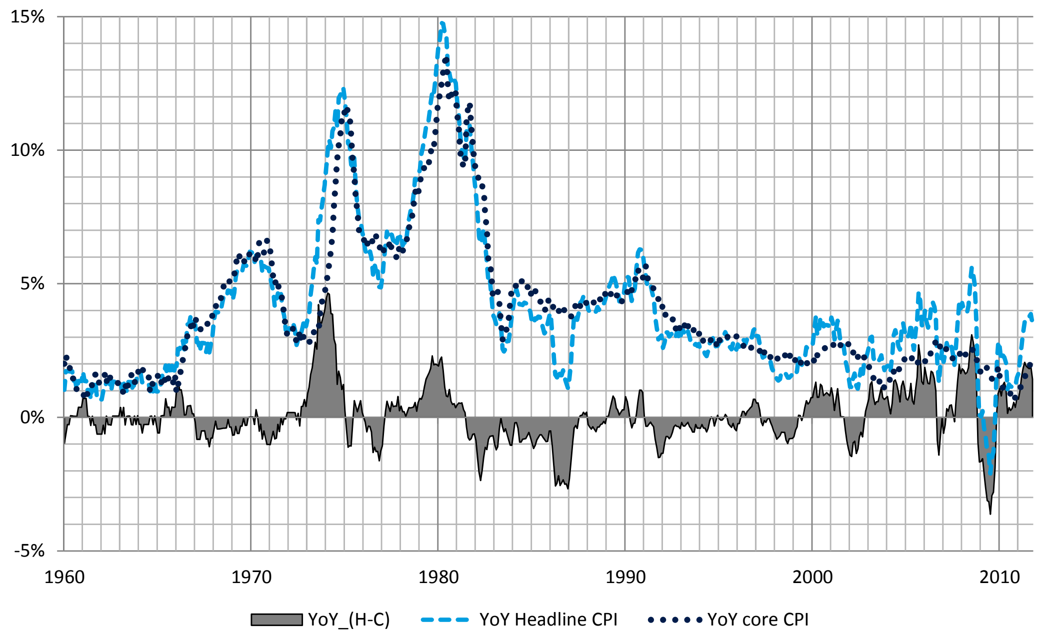
The core versus headline swap would thus yield both an intermediated commodity investment for inflation protection buyers which cannot do so directly, and would also permit the construction of a market curve for core inflation as linkers enabled the construction of a headline one a decade ago in the US, which would potentially ease the way for core-linked securities issuances.

2. Shifting structure of headline and core inflation and long-term liabilities implications

2.1. Macro and econometric analysis

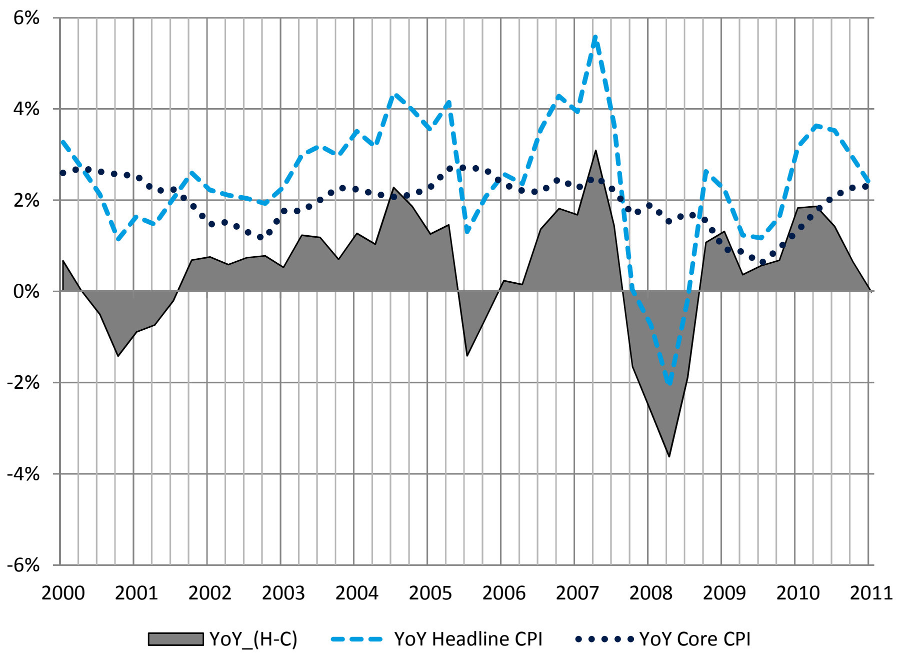
The first and foremost difficulty in addressing the issue of core inflation, as any practitioner's paper such as (Mankikar & Paisley, 2002) or any scholarly paper such as (Bermingham, 2007) never fails to mention, is the lack of a common definition of core inflation, not mention an unambiguous way to measure it (Wynne, 1999). For the purpose of this paper, we shall skip this otherwise interesting debate in macroeconomic and monetary policy by using the commonly accepted official definition of the core US inflation as measured by the *Bureau of Labor Statistics* and published by the *Saint Louis Federal Reserve* in the form of the *Consumer Price Index for All Urban Consumers, "All Items Less Food & Energy, Not Seasonally Adjusted"* (CPILFENS). We shall also use its headline counterpart, the "*Consumer Price Index for All Urban Consumers: All Items"* (CPIAUCNS).

Figure 23: Core vs. Headline inflation in the US over a 50-year period



Until quite recently, core inflation was assumed to be a lagged indicator of headline inflation as it supposedly reflected monetary effects driving long-term price trends without the noise added by short-term effects captured by the headline inflation measure. Moreover, core inflation was assumed to be driven by the performance of headline inflation with a lag during which the inflation pass-through operated by gradually closing the gap between the two indicators. As an illustration of this phenomenon, Figure 1 presents the trend in the US core and headline inflation indices' year-on-year returns over half a century and the oil shocks of the seventies can clearly be seen as the ideal case study of this phenomenon: we have an initial shock in commodity markets, immediately followed by a steep rise in headline inflation which in turn drives core inflation upward until it closes the gap in a little over two years. The Headline-minus-Core (HmC) spread then turns briefly negative and the cycle goes on, with the mean reverting to around zero. Throughout the first forty years of the period studied, albeit for a very brief moment during the oil shocks of the seventies, this spread remained marginal compared to the overall level of both inflation indices. This theory thus seemed to hold fairly well until the turn of the century, at which point it could no longer explain the subsequent sequence of events: Figure 24 zooms-in on those last ten years or so on which we will focus in this paper.

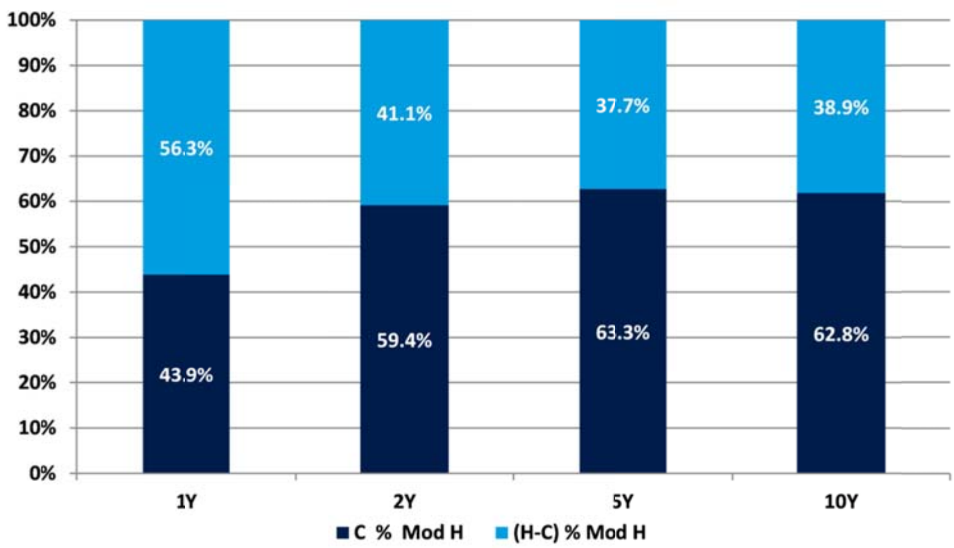
Figure 24: Core vs. Headline Inflation in the US over the last decade



During this period, inflation levels remained historically low following the end of the "*Great Moderation*" era (Stock & Watson, 2003): core inflation in particular remained very stable around 2% per annum whilst headline inflation, which had hovered around 2.4% p.a. in the decade before the crisis, started to become more volatile as it rose then fell at the turn of the decade. But throughout this period, core inflation seemed unmoved by event seemingly driving the headline inflation. Moreover, the spread between the two indices rose to a significant fraction of the core level for a sustained period of time, which in itself was historically unheard of: the pass-through had clearly ceased to operate in the way it used to. Econometrists used to believe that exogenous oil price shocks were the main drivers of macroeconomic variables' volatility as in (Hamilton, 1983). Yet, as (Hooker, 1999) noted, this straightforward causal relationship ceased to be unequivocally statistically significant in the mid-eighties as a major paradigm shift ongoing at the time profoundly altered the nature of the links between those exogenous commodity price shocks and both inflation measures by differentiating their responses to them: macroeconomic variables such as output or core inflation were less responsive whilst headline inflation became increasingly impacted by them. This diminishing overall impact of exogenous oil price shocks since the mid-eighties was extensively studied by macroeconomist following the seminal article of (Blanchard & Gali, 2007) which provided some explanations to what might be the causes of this reduction which they attributed to better monetary policies, reduced energy intensiveness and nominal wage rigidity relaxation. The consequences of which were indeed measured by (van den Noord & André, 2007) and (Clark et Terry 2010) in the following manner: since approximately the mid-eighties, the pass-through of exogenous oil price shocks into headline inflation was increasing while the pass-through into core inflation had most probably ceased to operate in the mid-nineties.

As emerging economies steadily increased their commodity consumption throughout the latter part of the twentieth century, the growth of which vastly outmatched the rise in production required to contain prices, we witnessed a dramatic increase in their overall prices, in particular on energy and agricultural commodities. It thereby fuelled a more than a decade long commodity bull-run of historic proportions which started in the mid-nineties and is still fairly active today but for a short break due to the US subprime crises and the ensuing "*Great Recession*" (Farmer, 2011) which had dented consumption and depressed prices for a short while before they resumed their steady rise. Combined with an increasingly powerful pass-through into headline inflation, rapidly rising and volatile commodity prices spurred headline inflation indices in a clearly different pattern from the way it affected core inflation, which did not seem to be responding to commodity price shocks impacting headline inflation as it used to: since roughly the beginning of the crisis, we have seen huge swings in headline inflation with a year-on-year peak-to-trough range of 6.34% compared to a mere 0.94% for core inflation. Correlation between headline and core inflation, estimated by five year rolling window, halved from a fifty-year average of 70.34% to a mere 36.66% in the last decade.

Figure 25: Breakdown of the variance of the realized inflation into core and non-core components



As can be seen in the previous (Figure 25), the HmC spread now contributes a significant amount of total inflation volatility. In the last ten years, it ranged from almost 2/3 of the total variance (adjusted for the covariance term for comparison purposes) over a one-year horizon to over a third for longer durations. This structural change in the US economy and its repercussions through the integration in global financial markets has an interesting econometric effect for the purpose of this paper in the form of the appearance of a co-integration relationship between commodity indices and the volatile fraction of inflation as measured by the HmC spread identified in (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy 2012). It evidences a secular increase in the trend of the correlation between commodity indices and this volatile fraction of the headline inflation. In the last couple of years, the correlation measured over twenty quarters has settled over 80%. In addition, it evidences that since the end of the nineties, a long-term relationship in the form of co-integration between the two variables has been very statistically significant. This econometric analysis opens the way for an inflation hedging application of the previously evidenced properties.

2.2. Risk reduction using a core vs. headline inflation swap

As can be deduced from the previous subsection, this paradigm shift has broken the relationship between core and headline inflation as we used to know and results in a significant difference between anchoring liabilities to a headline or to a core inflation reference. The two oil shocks from the seventies and the eighties apart, this historically high and persistent instability of the volatile component of inflation has resulted in a significant gap risk between the two references at redemption for a liability driven investment approach, not to mention a significant spread in benchmark volatility levels as can be seen in the previous (Figure 3). Since we can attribute much of this instability to shocks in commodity markets, investing directly in them could solve the problem as there is little alternative inflation hedging investment apart from being fully invested in inflation linked bonds or swaps (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy 2012). Yet, the complexity and risks associated with commodity investing easily could annihilate the usefulness of such a hedging strategy, and have a strong potential for disaster. Moreover, even if structured products replicating commodity indices performances makes it much simpler to invest in commodities nowadays, such type of investments are not within the reach and mandate of most institutional investors like pension or mutual funds and retail asset managers. A less risky indirect investment strategy looks increasingly desirable and is proposed hereunder.

In essence, we can drive a wedge between two classes of inflation hedgers depending on the target maturity of their investment: long-term investors wishing to benchmark their strategies on a core index will place themselves as headline inflation sellers in the *Core vs. Headline Swap* (CHS) while short-term hedgers will favor a headline indexation and will therefore be on the receiving end of the more volatile headline inflation leg. Since there is a maturity mismatch between those two investor classes, deals will either have to be intermediated by a bank which will perform the inter-temporal intermediation, or more simply, its duration will be constrained by the short investor horizon. Long-term investors will have to roll their short-term positions as it is customary in ALM for many other fixed-income investment issues. The rest of the paper will focus on this second possibility.

Let FR represent a fixed rate settled at inception such that the Mark-To-Market (MtM) value of the swap be nil. The CHS can then be written as:

$$CHS = Swap(HI \mid CI + FR)$$

It can be rewritten in a Fixed-For-Float (FFF) format:

$$CHS = Swap(HI - CI \mid FR)$$

Long-term investors will therefore pay the HmC spread and receive a fixed rate while short-term investors will place themselves at the other end of the deal. In such a FFF format, it can easily be seen that from a risk perspective, the spread payers face a more risky deal (even through the spread can turn negative at times). For such a reason, there will obviously be a risk premium included in the determination of the fixed rate to the benefit of float payers.

Since we know that variations in the HmC spread should be strongly correlated with variations in investable commodity indices, this swap could be cross-hedged with a synthetic cross-replicating commodity portfolio. If such were the case, this instrument could be marketed by investment banks acting as intermediaries between institutional investors and commodity markets. It would therefore answer institutional investors' risk-versus-benefit problem of a direct investment in commodities while providing them with an instrument to hedge the gap risk between the two inflation indices. Yet, pricing such an instrument is a true challenge in itself for two reasons:

Firstly, both legs of the swap are settled through monthly fixing of the core and the headline inflation which results in significant pricing complexity arising from the time gap risk. There is little novelty in it as time-gaps are standard difficulty in fixed income asset pricing. What is relatively new in this case is that since there is no marketable security linked to core inflation to this day as they are securities linked to the headline inflation such as Treasury Inflation Protected Securities (TIPS), we obviously neither can price the core leg of the swap in a direct mark-to-market approach nor hedge it on any underlier.

Secondly, as we mentioned in the preceding point that there are no marketable securities linked to core inflation but that we do know that the net cash flows of the swap being the HmC spread and that it is probably highly correlated to commodity indices, we can envisage a cross-hedging of the swap on a cross-replicating commodity portfolio. Such a hedging strategy based on correlations would add an extra "decorrelation risk" that has to be borne by the sellers of the derivative and which should be measured as accurately as it possibly can be in order to price it.

We will then proceed in three steps: Firstly, the instrument will be priced in a "*Perfect Foresight Environment"* (PFE) using realized values of the variables in order to perform a backward-looking simulation exercise to assess the viability of the strategy assuming there is no pricing issue. Secondly, placing ourselves in an "*Efficient Market Hypothesis*" (EMH), we will assume the core inflation index is investable and construct a synthetic future curve for it from which we will derive a no-arbitrage pricing of the security. Last but not least, we will introduce the optional framework required to perform the cross-hedging while abstaining from further developing the cross-replicating portfolio and the pricing it yields, as this would constitute another paper in itself. We shall nonetheless offer an alternative pricing to the previously exposed no-arbitrage one by adopting the (Korn & Kruse, 2004) formula which we hope will enhance the pricing of the swap by factoring in better the risk premium as it is an adaptation of the Black-Scholes (Black & Scholes, 1973) framework to price inflation derivatives.

3. Fair value pricing of the swap under an efficient market hypothesis

3.1. Backward-looking pricing

As a first test of the usefulness of the CHS strategy, we will in this first subsection run a simple validation exercise: under a PFE, pricing issues are shunned by using the ex-post price of the security derived from the ex-post values of the core and the headline inflation indices, which in turn yields the ex-post optimal swap rate. From these values, we can derive the returns for buyers and sellers of the inflation spread.

Before that, we have to propose strategies for our two potential types of participants in the trade to which we will henceforth refer to as Long-term (LT) and Short-term (ST) hedgers. We will define the following strategies for them:

The *LT* strategy is defined by a long position in inflation-linked bonds of matching maturity and a short position on the inflation spread which ensures a real return, a core inflation floor and the fixed swap rate.

The *ST* strategy is defined by a long position on nominal bonds of ad hoc maturity and a long position on the inflation spread. It therefore yields a nominal return and an inflation spread floor minus the fixed rate paid for the hedging swap.

We therefore have LT participants which have passive short positions on the core-headline spread while achieving a core floor while ST participants remain at risk on the core inflation rate whilst they are wholly covered against the inflation spread. LT hedgers should benefit from the sale of the swap by capturing the risk premium associated with the volatility spread between headline and core inflation, while at the same time “average-out” the spikes of the spread over the various rolls. On the other side of the deals, ST buyers are at risk on the core inflation part which at their short-medium horizon is completely manageable considering the extra income investing in “volatile inflation”-hedged nominal assets brings.

We then define the benchmark strategies against which we will compare our alternative one as a pure investment in linkers for both short-term and long-term participants. In real terms, the cash flows for both portfolios are netted on a different benchmark: a core inflation one for LT and a headline inflation one for ST investors. We therefore have the following nominal and real returns for LT (LTR and CLT), ST (STR and RST), and real returns for the short (RRR) and long (CRR) benchmark:

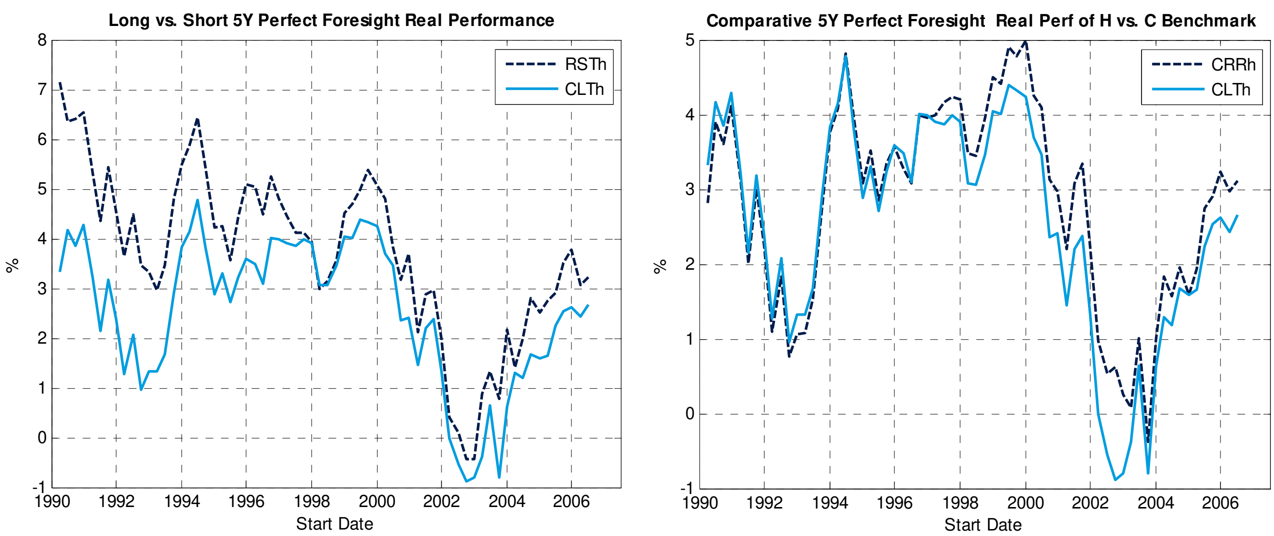
$$\text{Nominal investor returns: } \begin{cases} LTR = RR + CI + SR \\ STR = NR + (HI - CI) - SR \end{cases}$$

$$\text{Real investor returns: } \begin{cases} CLT = RR + SR \\ RST = NR - CI - SR = RR - SR + [E(HI) - CI\,] \end{cases}$$

$$\text{Real benchmark returns: } \begin{cases} CRR = RR + [HI - CI\,] \\ RRR = RR \end{cases}$$

The results obtained from this backward-looking simulation of the portfolios derived from our strategy are presented in the Figure 26 below. We have the nominal and real returns for short-term participants (STRh and RSTh) and long-term ones (LTRh and CLTh) and the real returns on the ST and LT benchmark portfolios (RRRh and CRRh).

Figure 26: PFE pricing, LT vs. ST and vs. Benchmark real performance for a 5-year horizon



As could have been expected, over the five-year investment horizon example presented in the previous figure, there is a clear performance spread between our LT and ST portfolios to the benefit of the latter. It is a logical reflection of the risk-return premium associated with a nominal investment. On the benchmarked comparison for the LT investor, there seems to be little interest in engaging in the alternative strategy as the benchmark performs better overall throughout the sample period even though the alternative strategy is purely deterministic with respect to its indexation while the benchmark is not.

The same conclusion can be found again in the backward looking pricing exercise results presented in the Table 3: since there is no risk added in engaging in the swap in a perfect foresight environment (as it is entered at the precise value at which it will be settled) there is no clear incentive to sell the volatile fraction of the headline inflation as there is no added risk premium to be captured by LT investors. This becomes increasingly less so as the maturity of the deal increases for LT investors and there is even an added volatility compared to the benchmark strategy. It is obviously the opposite for the ST investors (albeit over very short investment horizon) and with also a larger volatility at any horizon considered here.

Table 3: ILB + Swap vs. ILB for LT investors in the perfect foresight environment

Horizon	1 Y		2Y		5Y		10Y	
ST Portfolio	RSTh	RRRh	RSTh	RRRh	RSTh	RRRh	RSTh	RRRh
Mean	1.81%	1.85%	2.41%	2.18%	3.72%	2.55%	5.51%	3.38%
Std.	2.24%	1.64%	2.09%	1.42%	1.68%	1.45%	1.17%	0.93%
IR	-0.01		0.13		1.06		1.50	
Ex-post max Real Premium	-0.04%		0.23%		1.17%		2.13%	

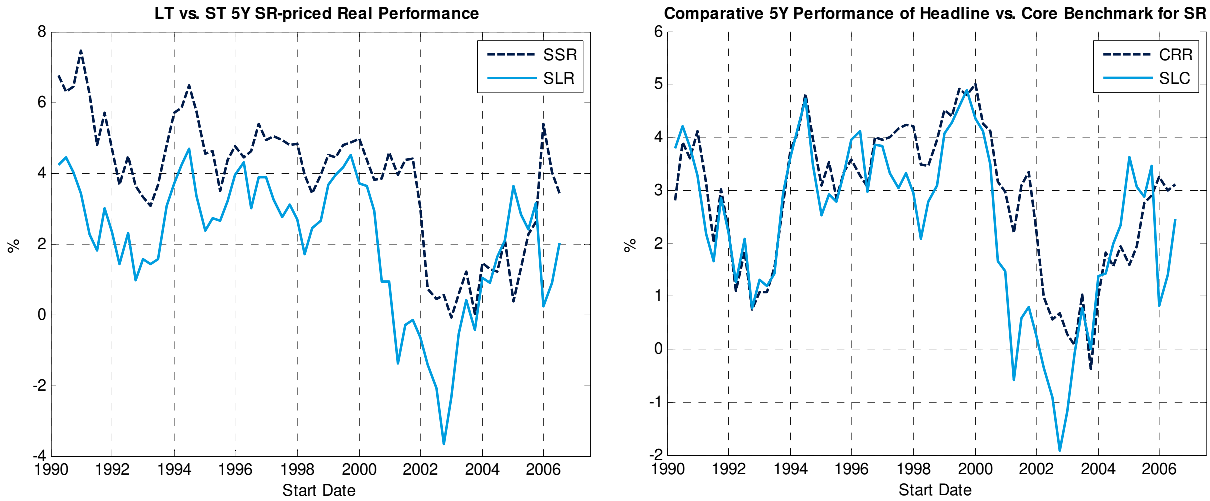
LT Portfolio	CLTh	CRRh	CLTh	CRRh	CLTh	CRRh	CLTh	CRRh
Mean	1.85%	2.07%	2.18%	2.40%	2.55%	2.83%	3.38%	3.71%
Std.	1.64%	1.84%	1.42%	1.33%	1.45%	1.33%	0.93%	1.04%
IR	-0.20		-0.32		-0.68		-1.13	
Ex-post min Risk Premium	0.21%		0.22%		0.28%		0.33%	

But what is certainly the most interesting result that can be obtained from this simulation exercise lies in the last line of the tables for LT and ST investors presenting the minimum and maximum ex-post risk premium that can be added to the fixed-rate fair values without underperforming both benchmarks. We can therefore conclude that pricing issues apart, there is room to trade for both investors for deals with maturities that strictly exceed one year as the minimum required ex-post risk premium is under the maximum premium for those horizons.

3.2. Forward-looking pricing using synthetic futures

Using the same strategies as before, we now perform a pricing exercise by no-arbitrage valuation under an efficient market hypothesis. In order to so, we compute the fair-value swap rate using simulated future prices derived from anticipations published by the survey of professional forecasters for core and headline inflation as there were no liquid listed securities even for headline inflation at the time. For the earlier part of the sample in which there was no core forecast available, we reconstructed it assuming the most simple continuity hypothesis with a slope derived from the headline curve.

Figure 27: Futures based pricing, LT vs. ST and vs. Benchmark real performance for a 5-year horizon



For this dataset, we compute outrightly the swap rate and use it to obtain the nominal and real returns on our LT (SLT and SLC) and ST (SST and SSR) portfolio with the same benchmarks as before. We present in (Figure 27) the results in the five-year horizon case.

Again, we see a positive spread in favor of ST investors compared to LT ones as the nominal investment pays off. We also underperform our benchmark portfolio in the LT case. Since we placed ourselves in an EMF and we used expectations to compute the spread value, there is no reason to believe the risk premium was included in the computation and, in light of those arguments, the results seem all the more logical. The performance in (Table 2) presented hereunder reinforces this assumption:

Table 4: ILB + Swap vs. ILB for LT investors in using simulated futures for pricing

Horizon	1 Y		2Y		5Y		10Y	
ST Portfolio	SSR	RRR	SSR	RRR	SSR	RRR	SSR	RRR
Mean	2.07%	2.07%	2.61%	2.41%	3.87%	2.83%	5.81%	3.72%
Std.	1.94%	1.84%	1.86%	1.33%	1.80%	1.33%	1.05%	1.04%
IR	0.00		0.16		0.90		1.54	
Ex-post max Real Premium	0.00%		0.20%		1.04%		2.09%	
LT Portfolio	SLC	CRR	SLC	CRR	SLC	CRR	SLC	CRR
Mean	1.60%	2.07%	1.99%	2.41%	2.38%	2.83%	3.00%	3.72%
Std.	2.10%	1.84%	1.85%	1.33%	1.58%	1.33%	1.15%	1.04%
IR	-0.19		-0.26		-0.48		-1.11	
Ex-post min Risk Premium	0.47%		0.42%		0.45%		0.72%	

The results we found in this exercise are in accordance with the previous one: there is only a marginal increase in the performance of the LT strategy in terms of information ratios (corresponding to an increase in gross return coupled with a decrease in the volatility). Once again, the difference between the ex-post minimum and maximum risk premium upholds the belief that there is room to trade strictly above the two year horizon in this case.

It is therefore necessary to seek an alternative pricing of the swap rate which would include a strong risk-premium to outperform our benchmark strategies for LT investors while preserving the outperformance of ST ones at the same time. Considering the previously exposed min-max risk premium range computes ex-post, there is room to maneuver. Such an increase in the SR would increase the return for LT investors without changing the volatility of the returns as the rate is fixed at inception. Since our pricing using simulated forwards cannot take into account this characteristic of the trade, in the subsequent and last section of this paper, we will envisage a pricing of this premium using an option-theory derived model based on a modified version of the Black-Scholes formula (Korn & Kruse, 2004). We hope it will be more adequate to take into account the difference in volatility levels between the core and headline underlier of the swap, which should in turn necessarily result in a pricing premium to the benefit of the inflation spread seller.

4. THEORETICAL PRICING OF THE INSTRUMENT USING A BLACK-SCHOLES APPROACH

4.1. Structuring the derivative for Black-Scholes Pricing

By placing ourselves in an EMH, we implicitly assumed that the value of the swap should be a direct reflection of the mark-to-market value of the underlying securities, which obviously implies that these securities are investable whereas they precisely are not. Our security is therefore clearly unarbitrable. When we made the assumption that the market for such an instrument would be balanced between sellers and buyers, we shunned that difficulty as only the pricing issue remained: none of the parties actually has to compute a dynamic hedge of the security through its lifetime from inception to settlement and no one therefore needed to invest in the underlying securities. But, on the one hand, as we exposed in the previous section, this conceptual framework is clearly insufficient as it fails to correctly price-in the risk premium in the fixed rate and it is also insufficient in the case of market makers intermediated trades: traders will have to dynamically hedge the security throughout its lifetime and therefore will need to have an investable underlying to create the replicating hedging portfolios. The following option-derived (Mark-to-Model) pricing framework deviates from the EMH as it breaks the *Absence of Arbitrage Opportunity* (AAO) assumption. Its aim is to better apprehend the risk asymmetry which underscores the risk premium which we are trying to price. But without the cross-correlation element, we will still fall short of the investable asset requirement identified above.

Without losing generality, we will restrict ourselves to the pricing of a Zero Coupon Swap (ZCS) as any other type of couponed swap can be decomposed as a sum of ZCS. The CHS premium can therefore be written as:

$$s_{CHS_{t,T}} = N \cdot \mathbb{E}_t\left(\left(\pi^H_{0,T} - \pi^C_{0,T} - SR_{0,T}\right)e^{-\tau\cdot(T-t)}\right)$$

At inception, we want to set the swap Rate (SR) such that the swap premium is nil. Let $SR_{0,T}$ be such that:

$$s_{CHS_T} = 0 \quad \Rightarrow SR_{0,T} \; = \; \mathbb{E}_0\left(\pi^H_{0,T} - \pi^C_{0,T}\right)$$

As before, we will use our simulated futures for both underlyings to make-up for the lack of an historic dataset.

The natural way to price the swap would be to separate the discrete, low frequency gap-hedging problem from the cross hedging problem as is customary in fixed-income literature: we would, begin with, ignore the discrete fixing problem of inflation linked -securities as we assume the price is derived from Breakeven Inflation rates (BEI) equivalents which are traded in almost continuous time. We would then define a synthetic underlying of our swap to be V with $V_{0,T} = \left(\pi^H_{0,T} - \pi^C_{0,T}\right)$ which would represent the volatile fraction of inflation. Yet, such an underlying would obviously not be an investable asset even though (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy 2012) deduced that it could be cross-hedged fairly well on commodities futures.

In order to simulate the hedging of the swap, we would like to be able to compute sensitivities to investable securities or to a synthetic one that can be cross-hedged. Since the current stochastic literature has been constructed for the pricing of inflation caps and floors (Korn & Kruse, 2004), we shall rewrite our instrument in order to make it a function of these instruments we know how to price. We shall therefore perform the following transformation:

Let H be the headline inflation rate, let C be the core inflation rate, let FR_H be the fixed headline inflation rate and let FR_C be the fixed core inflation rate then:

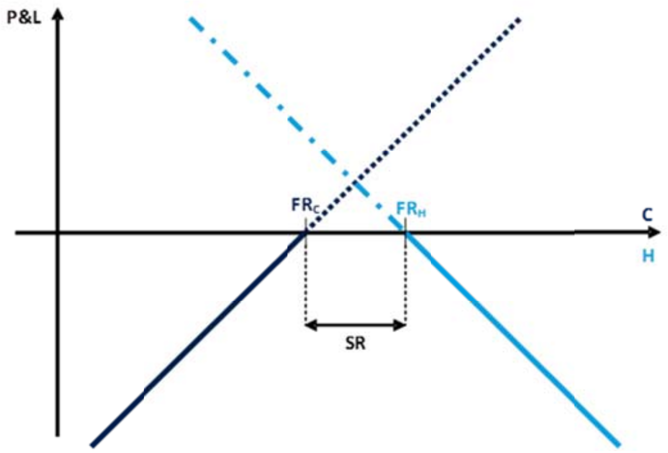
We have set SR such that at inception:

$$Swap_{t=0}(H|C+SR) = 0$$

Then, $\forall FR_H, FR_C \in \mathbb{R}, such\ that\ SR = FR_H - FR_C$:

$$Swap_{t=0}(H|C+SR) = \mathbb{E}_0\left(\left(H-(C+SR)\right)\cdot e^{-\tau\cdot T}\right) = \mathbb{E}_0\left((H-C-FR_H+FR_C)\cdot e^{-\tau\cdot T}\right)$$
$$= \mathbb{E}_0\left((H-FR_H)\cdot e^{-\tau\cdot T}\right) - \mathbb{E}_0\left((C-FR_C)\cdot e^{-\tau\cdot T}\right)$$

Figure 28: Core vs. Headline Cap/Floor risk profile



Therefore:

$$\forall FR_H, FR_C \in \mathbb{R} \mid SR = FR_H - FR_C,$$
$$Swap(H|C+SR) = Swap(H|FR_H) - Swap(C|FR_C)$$

Since we have by cap-floor parity:

$$\begin{cases} Swap(H|FR_H) = Floor(H|FR_H) - Cap(H|FR_H) \\ Swap(C|FR_C) = Floor(C|FR_C) - Cap(C|FR_C) \\ Swap(H|C+SR) = Swap(H|FR_H) - Swap(C|FR_C) \end{cases}$$

$$\Rightarrow Swap(H|C+SR) = Floor(H|FR_H) - Cap(H|FR_H) - Floor(C|FR_C) + Cap(C|FR_C)$$

By placing ourselves as the receiver of the inflation spread and wishing to hedge its trade, we are therefore short of the swap. Since option prices are by definition non-negative, we only wish to hedge:

$$Hedge = -Floor(H|FR_H) - Cap(C|FR_C)$$

Using the modified Black-Scholes formula of (Korn & Kruse, 2004), we derive the option prices for both options assuming the Core and Headline inflation indices respect the following geometric Brownian motion:

$$\begin{cases} dH(t) = (\tau_N - \tau_R) \cdot H(t) \cdot dt + \sigma_H \cdot H(t) \cdot dW_H(t) \\ dC(t) = (\tau_{NC} - \tau_R) \cdot C(t) \cdot dt + \sigma_C \cdot H(t) \cdot dW_C(t) \end{cases}$$

Where $\tau_{NC}$is constructed such that:

$$\tau_{NC} = \pi_C + \tau_R$$

We can therefore create the replicating portfolios for both options by computing the deltas of both options:

$$\Delta H = \delta_H \ and \ \Delta C = \delta_C$$

Since C is not an investable asset, we compute the investment in $V = H - C$:

$$\begin{cases} \Delta H = \delta_H \\ \Delta C = \delta_C \\ \Delta V = \Delta(H - C) \end{cases} \Rightarrow \begin{cases} \Delta V = \delta_C \\ \\ \Delta H = \delta_H - \delta_C \end{cases}$$

We therefore obtain the replicating portfolios for our options composed of the two underlyings, one of which is not outrightly investable. For the purpose of this paper, we shall limit ourselves to using the initial pricing of the security obtained through the use of the (Korn & Kruse, 2004) modified Black-Scholes framework. We shall skip the otherwise interesting aspect of the dynamic gamma hedging using the replicating portfolios which requires a more complex cross-hedging strategy on commodities using the existing literature on incomplete markets and which will be the subjects of another paper.

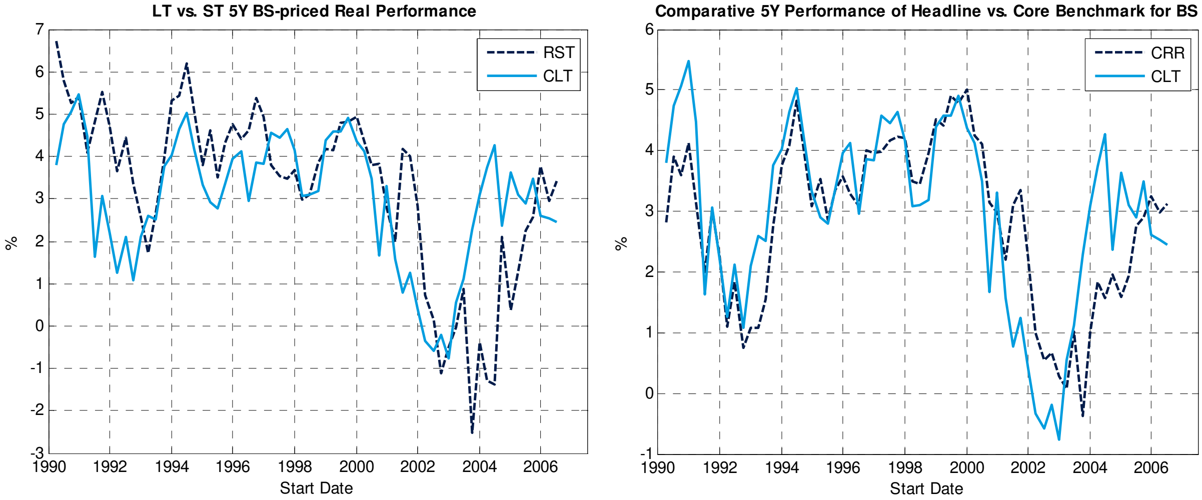
In the hypothesis of a two-sided long versus short-term investor deal, only the swap rate value is needed as there are no reasons to hedge the derivative. But in the case of an intermediated deal where the seller is not hedging any cash flows but is trading the security on a market-making basis, hedging this risk on the market is of the essence. As hedging the security becomes critical, there is no way we can skip the cross-hedging cost dimension which would have to be included in the analysis and requires a switch in pricing method towards a hedging-cost approach.

4.2. Pricing results using the modified Black-Scholes framework

We present in this sub-section the results of this pricing exercise which is meant to test whether an optional method can adequately price-in the risk premium we exposed in the previous sections. In accordance with the previously exposed validations, we place ourselves in the same long versus short-term investor framework and we now price the swap rate using the (Korn & Kruse, 2004) modified Black-Scholes framework to incorporate the risk-premium.

Reassuringly for our proposed strategy, the BS-priced portfolio for our long-term investor (CLT) displays somewhat better results that the benchmark (CRR) strategy with equivalent maturity in this five year investment horizon benchmark case. Also, the spread between LT and ST real returns has narrowed to the point where hardly any sign can clearly be given to it. The following Table 5 presents the general performance results for our key durations.

Figure 29: BS pricing, LT vs. ST and vs. Benchmark real performance for a 5 year horizon



The option derived pricing seems in effect to be much better at factoring in the risk premium as our LT alternative strategy is above its benchmark except for the 10 year case for which the IR is very slightly negative. The ten year case negative result should be taken with precaution since our sample size makes this last caveat probably not that strong: a much longer sample or a simulation exercise would be needed to attain the necessary length in order to have significantly robust statistical result.

Table 5: BS results

Horizon	1 Y		2Y		5Y		10Y	
ST Portfolio	RST	RRR	RST	RRR	RST	RRR	RST	RRR
Mean	1.59%	2.07%	2.10%	2.41%	3.26%	2.83%	5.26%	3.72%
Std.	2.13%	1.84%	2.15%	1.33%	2.02%	1.33%	1.27%	1.04%
IR	-0.251		-0.187		0.329		1.134	
Ex-post max Real Premium	-0.47%		-0.31%		0.43%		1.54%	
LT Portfolio	CLT	CRR	CLT	CRR	CLT	CRR	CLT	CRR
Mean	2.07%	2.07%	2.49%	2.41%	3.00%	2.83%	3.66%	3.72%
Std.	2.05%	1.84%	1.71%	1.33%	1.49%	1.33%	1.00%	1.04%
IR	0.003		0.059		0.162		-0.069	
Ex-post min Risk Premium	-0.01%		-0.09%		-0.16%		0.06%	

The ST performance seems to suffer slightly for very short durations (under two years) but still outperforms its benchmark above that horizon. Overall, we once again have a strong case for our strategy over medium horizons and less good over very short horizons if we consider the ex-post min-max risk-premium range.

5. CONCLUSION

Inflation hedging for long-term investors has remained an elusive problem despite the introduction of inflation linked securities in the bond market in the early eighties, followed by indexed swaps in the derivative market at the turn of the millennia. Even if these novel asset classes have become mainstream tools for institutional investors like insurance companies and pension funds, long-term investors have been left grappling with diminishing real returns and insufficient liquidity to match their liabilities. Forays into alternative hedging strategies involving exotic asset classes and complex products has long been held for good reasons as a receipt for disaster as institutional investors never truly should have a mandate to invest in hedging strategies too far from their liabilities. And indeed, as the perfect financial storm hit at the end of the decade, many were probably left wondering why they ever had attempted such an endeavor, even if the dismal performance of linkers could have provided a comfort of some sort, though obviously not to their claimants.

Considering the previously exposed econometric arguments, and the sobering counter-performance of linkers and alternatives alike in the last decade, this paper proposes a new kind of approach to long-term inflation hedging in the form of a differentiation of benchmark between long and short-term investors. In light of the results presented, our novel strategy consisting of an investment in nominal assets for short duration and buying the volatile fraction of the inflation index makes sense for short-term investors while investing in linkers and selling the spread for long-term hedgers turn out to be a clear enhancement of the pure linker strategy which is currently the benchmark of the industry.

Again, as we clearly laid out in the paper, the market for such a derivative might not be in equilibrium and would require an intermediation in the form of market makers. These traders would need an investable underlier for the swap to hedge their residual position. As the core inflation index is currently not investable but the swap spread used in the security has been shown to be strongly correlated to commodities, a cross-correlation approach might be relevant and offers interesting opportunities for traders who would deal the core-headline swap presented here. Exploring this novel trading strategy would be an interesting natural extension of this paper.

General Conclusion

When the initial tremors of the impending housing crash struck financial markets in the summer of 2007, the worst financial crisis since the Great Depression era had claimed its first victims in the form of the demise of American quantitative equity market-neutral hedge funds (Khandani & Lo, 2007). Over the following year, real estate prices plunged and subprime mortgage holders massively defaulted on their loans, which in turn prompted the default of the structured investment vehicles owning them and thereby sealing the fate of the banks holding on to those securities. As the inescapable sequence of events unfolded, it was increasingly clear that one of the longest bull runs in recent history had abruptly come to an end. By the time equity markets had gone from peak to trough in mid-2009, hundreds of FDIC insured banks had failed in the US and all but two of the US investment banks were left standing, while much of the rest of the financial sector was under one form of government support or another in the US and throughout much of the world. Financial practitioners and academics were left contemplating the remains of decades of reckless financial innovation, daring leverage, regulatory arbitrage and blistering growth which had come momentously crashing down in September 2008. The demise of Lehman Brothers virtually froze the vital interbank financial market and obliged central banks and governments to provide support to an already severely battered financial system. Clearly, "*This Time was Different*" (Reinhart & Rogoff, 2009): as the banking paradigm shifted from "*too big to fail*" to "*too interconnected to fail*" (Espinosa-Vega, 2009), central banks came back to center stage as "*lenders of last resort*" by injecting trillions in emergency liquidity funding. Those game changing events compelled regulators and legislators to rewrite the rulebook of financial regulation, which became known as the Dodd–Frank Act (Congress of the United States of America, 2010), the Vickers report (Chow & Surti, 2011), the Basel III framework (BIS, 2011) and Solvency II (European Comission, 2009) to name but a few. Their implementation will have profound effects on the way financial institutions will operate and manage their businesses in the future, even though their sheer complexity might prove a hindrance to their effectiveness at stemming global systemic crises of the like we saw in the late-2000s as their most famous critic explains (Haldane, 2012). Striking the right balance will be an arduous task: "*The main challenge, here, is to find the right trade-off between a sophisticated system, fine-tuned to each marginal change in systemic risk, and an approach based on simple-to-communicate triggers and easy-to-implement rules*" as (Blanchard, Dell'Ariccia, & Mauro, Rethinking Macroeconomic Policy, 2010) state. But most disturbingly, while macroprudential stability became the chief concern of central banks throughout the crises and was clearly the sole motive of their massive market interventions during them, central bankers did not have their mandate explicitly redefined in light of their new found legitimacy as the last stand of macroprudential stability in rough seas (Borio, 2011). Rewriting the central bankers' rulebook is clearly of the essence and it is therefore imperative to rethink the instruments central banks will be entitled to use for efficiently achieving this (Goodhart, 2008). Failing to do so would inevitably damage the credibility they painfully acquired in recent decades, the consequences of which would be hard to measure, in particular when it comes to anchoring future inflation expectations.

As the "*perfect financial storm*" (Blanchard, The Perfect Storm, 2009) receded, its aftermath revealed a profoundly changed macroeconomic landscape to which investors have yet to adapt (Orr, 2012). If the "*Great Moderation*" era (Stock & Watson, 2003) of the twenty years or so before the onset of the crisis had been characterized by a major reduction in the volatility of macroeconomic variables, in particular by low and stable inflation, the crisis period was clearly of a very different nature as headline inflation volatility surged to levels which had been unseen in decades. This massive spike in volatility was initially driven by the record commodity bull run which ended shortly before the "*Great Recession*" (Farmer 2011) gripped many economies, which in turn contracted demand for most commodities, thus further increasing volatility levels as prices went down. Compared to the previously calm waters investors had navigated in the previous decade, basically every investment class took a severe hit from the bursting of the housing bubble in the US: as investments in equities, REITs, corporate bonds and obviously commodities went down in flames, the clear winners that escaped unscathed from the investors' bloodbath were the true safe-haven asset classes composed of precious metals and high quality sovereign debt securities. The "stagflation" macroeconomic context of the few years following the crisis was somewhat reminiscent of the 1970s era in terms of real price levels, but was significantly different as the commodity price hike was demand driven and not supply constrained as in the oil embargo of the "*Great Inflation*" era (Blanchard & Riggi, 2009). The hallmarks of the post-crisis macroeconomic environment are to be found in the negative long-term sovereign real rates of most advanced economies. This is the result of the joint effect of the flight to quality affecting sovereign bonds, on which yields have fallen as investors flock to auctions on the one hand and inflationary pressures, which have not been satisfactorily tamed on the other hand. Worryingly, this macroeconomic context also shows some similarities with the post-Asian-crisis Japan of the late nineties even though the restructuring of the financial sector, at least in the US, has been swift and profound whereas "*zombie lending*" banks had plagued the Japanese economy for at least a decade after the crisis (Caballero, Hoshi, & Kashyap, 2008). But with any sign of recovery still far away on the horizon for many economies, the era of negative long real rates looks increasingly likely to last, along with the depressed output gap and the severe unemployment comparable for some countries to those suffered during the "*Great Depression*" of the 1930s. Commodity spot prices have also remained stubbornly high, further adding pressure on the shoulders of monetary-policy makers as they scale-up quantitative easing, while remaining unsure of its long-term effects on inflation and inflation expectations.

Looking "*through a glass, darkly"* would be fitting to describe analyzing the expected future macro-financial environment as it has become particularly difficult nowadays considering how much the prevalent *status quo* has been challenged by the policy decisions and the events in the past few years since the onset of the crisis. This imperative necessity to revise commonly accepted policies in light of the recent crisis could not have been made clearer than in the IMF chief economist Olivier Blanchard's landmark white paper on the current state of the macroeconomic environment (Blanchard, Dell'Ariccia, & Mauro, Rethinking Macroeconomic Policy, 2010). In this paper, he begs the question whether we should increase our inflation target in light of the crisis: "*The crisis has shown that large adverse shocks can and do happen. In this crisis, they came from the financial sector, but they could come from elsewhere in the future—the effects of a pandemic on tourism and trade or the effects of a major terrorist attack on a large economic center. Should policymakers therefore aim for a higher target inflation rate in normal times, in order to increase the room for monetary policy to react to such shocks? To be concrete, are the net costs of inflation much higher at, say, 4 percent than at 2 percent, the current target range? Is it more difficult to anchor expectations at 4 percent than at 2 percent?*" Embarking on such a journey down the path of markedly higher inflation would certainly mean threading through unchartered waters, an endeavor which monetary policy authorities have not been shy of in the post-crisis era, stretching the breadth of their mandate if not exceeding it altogether in the case of the ECB *Outright Monetary Transaction* mechanism for example. Whatever the outcome of this debate, market players will have to adapt their policies which had been tailored for the now long gone "*Great Moderation*" era. The risk managers of institutional investors are not exempt as the nature of both their assets and their liabilities have been profoundly altered by those events: the liabilities side of their balance sheet suddenly appeared more dangerous as the inflation risk surged while the assets side dwindled as a result of dismal market performances and dangerously low real rates. Those joint forces jeopardize their long-term stability and thereby threaten their very existence. This year witnessed pension funds in the UK going under as they were in a stranglehold over the asset-liability gap. It is then high time we rethink inflation hedging before we find ourselves "stuck between a rock and a hard place" and this paper provides three possible alternative ways of doing this.

The first alternative solution proposed here consists in adapting current structured solutions in the form of portfolio insurance to provide additional cover for inflation risk. This research was motivated by two macro-financial constraints currently affecting inflation hedging strategies: Firstly, the very low real rates that investments in inflation-linked bonds yield are a hindrance for many long-term institutional investors such as pension funds which must deliver significant real returns. This sheer weakness of real returns has pushed many players into unhedged nominal strategies, which leaves them severely exposed to inflation shocks, especially if they are long-lasting as would be the case in monetary policy paradigm change as is hinted above.

The second constraint hindering effective large scale inflation hedging is the dearth of linkers: as sovereign treasuries battle with an increasingly acute debt overhang problem, monetary erosion increasingly appears as the only possible getaway. This has been especially true since current rock-bottom real rates render nominal issues cheaper than real ones, thus limiting the will of states to issue inflation-linked securities. A chronic short supply of linkers would negatively affect the liquidity of the secondary market for linkers, which would in turn make hedging strategies more costly to implement, and even more costly to adjust, thereby impeaching the realization of dynamically efficient strategies. The use of a nominal portfolio insurance solution with real floors as is exposed in (Fulli-Lemaire, A Dynamic Inflation Hedging Trading Strategy, 2012) offers a way of completely relaxing our dependency on linkers: combining the dynamic trading of the purely nominal asset side of our portfolio to match a marked-to-market liability modeled by the real floor inflated with breakeven-inflation rates, we are able to offer a guaranteed real floor to investors up to a certain threshold of real losses as in the conventional CPPI. Were the strategy to break the floor, we have the contingency option of liquidating our portfolio and buying zero-coupon inflation swaps, thus curtailing the downside risk. Deploying the DIHTS strategy in the current market environment would be difficult because of the negative real rates currently prevailing throughout most advanced economies, which are still in the investment grade club as a result of the flight to quality phenomenon currently gripping fixed-income markets. A make-up solution could be found in a partial relaxation of the dependency on linkers by devising a CPPI based on real bonds, thereby offering enhanced real returns with an inflation floor as in the iCPPI of (Graf, Haertel, Kling, & Ruß, 2012). This hybrid class of structured products would not be restricted by the level of real rates and would reduce the share of linkers as compared to the current fully hedged portfolio strategies. It would ideally complement the DIHTS when market conditions hinder its inception.

The second alternative solution explored here aims at exploiting current advances in macroeconomics to allocate commodities in inflation hedged portfolios: since exogenous commodity price shocks feed into headline inflation, this asset class has been regularly branded as the “natural inflation hedge” (Z. Bodie 1983) since at least the late seventies. Yet, commodities as an asset class are significantly more volatile than inflation and their correlations with consumer price indices has been subject to significant time variability, not to mention boom and bust phenomena as we fairly recently witnessed. Yet, it is nonetheless true that this asset class enables portfolio managers to achieve greater diversification (Conover M. C., Jensen, Johnson, & Mercer, 2010) as it is weakly correlated with either conventional or alternative asset classes (Chong & Miffre, 2010). But what is perhaps the most significant aspect of commodity investing for us lies in the fact that although they seem to offer interesting unexpected inflation-hedging potential for long-term investors (Attié and Roache, Inflation Hedging for Long-Term Investors 2009), even their hedging capabilities seem to wane beyond a certain horizon (Brière and Signori 2010), which seems puzzling. One of the possible classic solutions to enhance the hedging potential of commodities and which could solve this puzzle would be to move from a static VAR-based strategic allocation to a dynamic one. This kind of dynamic tactical allocation has been central to modern asset management and has been extensively developed to allocate commodities in conventional portfolio allocation using momentum indicators to generate alphas for example. To the best of our knowledge, no global-macro commodity allocation trading strategy for inflation hedging portfolios has been proposed in the literature and it is precisely what we aimed to achieve here. The starting point of this research has been a relatively novel development in macroeconomics: until fairly recently, exogenous commodity price shocks were assumed to propagate homogeneously between headline and core price indices, albeit with a lag, as a result of the transmission mechanism to which we referred as the headline-to-core inflation pass-through (Hamilton, 1983). But roughly since the counter oil shock of the mid-eighties, this economic paradigm had to be revisited as exogenous oil price shock after this date did not seem to have such a profound impact on other macro-variables as it used to. The authoritative white paper of (Blanchard & Gali, 2007) estimated that as a result of a combination of better monetary policies, reduced energy intensity of output and relaxation of nominal wage rigidities, exogenous oil price shocks do not propagate nowadays in the economy as they did with significant consequences during the oil-shock driven high inflation period of the seventies. Yet, they also showed that although the macroeconomic consequences of oil shocks have declined, the impact on headline inflation of those shocks has actually increased. This finding is corroborated by our correlation study between headline inflation indices and commodity indices which exhibit a significant secular increase throughout the nineties and noughties. The defining moment for the definition of our novel strategy came with the articles of (van den Noord and André 2007) and (Clark et Terry 2010), which estimated for a large set of countries that the pass-through of exogenous commodity price shocks into core inflation had been null and statistically significantly so since the mid-nineties. Indeed, our correlation analysis again corroborates these findings in two ways: firstly, the correlation with core inflation of commodity indices has remained exceptionally low in a period of high volatility and the spread between core and headline inflation has been strongly co-integrated with commodity indices since the early nineties whereas it was not so beforehand. The combination of those findings sets the stage for our strategy in the sense that it provides commodities with a natural allocation technique which can be determined exogenously: since we know that core inflation exhibits both low volatility and a weak correlation with commodities, we can allocate the latter to hedge the difference between the expected value for headline inflation and core inflation. The residual core inflation exposure can be either eliminated by swapping it at fixed rate (Li & Zeng, 2012) or by leaving it unhedged and investing in nominal-rate yielding assets such as bonds or cash securities. Our backtesting of this strategy has yielded significant strong alphas compared to a conventional linkers portfolio in a risk-adjusted basis as the downside risk looks fairly limited. Additionally, we exposed in our paper (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012) a tactical allocation strategy which aims at optimizing the commodity allocation depending on the pass-through cycle of headline inflation mean reverting to its core anchor through time. Backtesting of this strategy revealed that it did exhibit strong outperformance in the previously high headline-to-core inflation pass-through environment, but failed to yield significantly strong alphas on a risk-adjusted basis in the current environment.

The third and last alternative proposed here consists in drawing a wedge between inflation hedgers according to their targeted investment maturity in order to differentiate whether headline or core linked assets would be the optimal hedging security for them. In our previous paper (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012), we exposed the pass-through literature which we used to allocate commodities in inflation hedging portfolios. In the following paper (Fulli-Lemaire & Palidda, Swapping Headline for Core Inflation: An Asset Liability Management Approach, 2012), we strive to go further, questioning the liability benchmark itself in light of the current macro and econometric literature. We have previously shown that core inflation now seems unaffected by exogenous commodity price shocks (Clark et Terry 2010) strongly driving headline inflation indices (Blanchard & Gali, The Macroeconomic Effects of Oil Shocks: Why are the 2000s So Different from the 1970s?, 2007). Moreover, (Gelos & Ustyugova, 2012) have shown that for most advanced countries, headline inflation indices are mean reverting towards core inflation ones over relatively short horizons. Eventually, we have shown (Fulli-Lemaire, Alternative Inflation Hedging Portfolio Strategies: Going Forward Under Immoderate Macroeconomics, 2012) that, since the mid-nineties, headline and core inflation have exhibited markedly different volatility patterns as the latter has remained stubbornly stable whereas the former has experienced an exceptional burst of volatility. Considering those findings together, it becomes absolutely clear that inflation protection buyers, such as pension funds or insurance companies, hedging long-term liabilities should definitely opt for a core based liability benchmark as they have a sufficiently long investment horizon to benefit from the mean-reverting process of the core versus headline inflation spread which smooths-out headline inflation's short-term deviations from the core reference and exhibits an overall much weaker volatility level. Obviously, short-term hedgers like retail asset managers selling yearly marked-to-market inflation protected structured products cannot benefit from this time-averaging process and must anchor their liabilities to headline inflation, thus driving a wedge between long-term and short-term hedgers in respect of their targeted liability benchmarks. The obvious pitfall of our proposed strategy for long-term players is that, to this day, no outrightly core-linked asset exists even though an investable proxy of the US core inflation index has been launched by Deutsche-Bank (Li & Zeng, 2012). We have therefore explored whether a new kind of derivative could achieve a better asset allocation for both parties by synthetizing a truly core-linked asset: were long-term investors to acquire a portfolio of headline inflation-linked bonds, they could then swap the spreads between the headline and the core indices in return for a fixed rate. This would in turn generate a core plus real-return yielding portfolio as if it were composed of purely core-linked assets. On the other side of the deal, short-term investors would receive the spread between both indices and pay the fixed rate while they would be fully invested in nominal securities. It would give them a portfolio that has an unhedged exposure to core inflation whilst they are being fully hedged against the spread between both inflation references. This strategy would be particularly interesting for them since core inflation has exhibited very sluggish behavior over short horizons, and is therefore an absolutely manageable risk, while they are fully hedged against the volatile fraction of inflation, which would obviously be a much harder exposure to bear unhedged. Long-term investors would have to roll over their swaps to achieve a continuous hedge as its maturity cannot exceed that of short-term players, which is standard practice in asset-liability management anyway. This dual strategy would be an effective make-up solution for the lack of outrightly core-linked assets for long-term investors and a way to enhance real returns of short-term investors at the same time. Incidentally, trading this swap would provide a market reference for a core-inflation linked securities primary market, the premise of which has been set by the inception of the investable US core inflation proxy, motivation for which feeds on the same reasoning as the one previously exposed. The pricing of the swap rate would be the true hurdle of our strategy since we have no market references for the core inflation underlier, even though the survey of professional forecasters provides a reliable quarterly expectation figure in the US. The fair value pricing based on those expected values would probably be insufficient since it would not include the risk premium long-term investors seek in return for bearing the risk of the floating leg of the swap (even though there are themselves hedged against it if they hold the matching linkers portfolio as we proposed). The article briefly exposes an alternative pricing of the swap rate in the form of a commodity cross-hedging valuation: since the underlier of the swap, namely the headline minus core spread, has been shown in (Fulli-Lemaire, Allocating Commodities in Inflation Hedging Portfolios: A Core Driven Global Macro Strategy, 2012) to be strongly correlated with commodities indices, we could price the cross-replicating commodity portfolio which would in turn yield a synthetic price for the security. In any case, were such core-linked markets to develop, we would probably have to rewrite the current asset-liability management practices to reflect this shift. We could in particular envisage shifting indexation of long-term liabilities such as pension contracts towards a core benchmark since a regime change would at worst bring core inflation back more closely in line with its headline counterpart as it was previously in the seventies.

As always, whether a new round of quantitative easing turned out to be one too many, or because the sovereign debt overhang problem suddenly became unbearable, or because the monetary policy paradigm changed or because of any other unforeseen game-changing event were to strike, investors having gone into both conventional or alternative inflation hedging strategies would be left hoping for the best and bracing for the worst as only time will tell which one was cleverest. But clearly, as the current macro-financial status quo is being severely challenged, waiting idly by unhedged would be quite a rash choice.

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Annex 1: *DIHTS*

A. Historical Simulation Results

Figure 30: Performance comparison of the DIHTS vs. the benchmark portfolio.

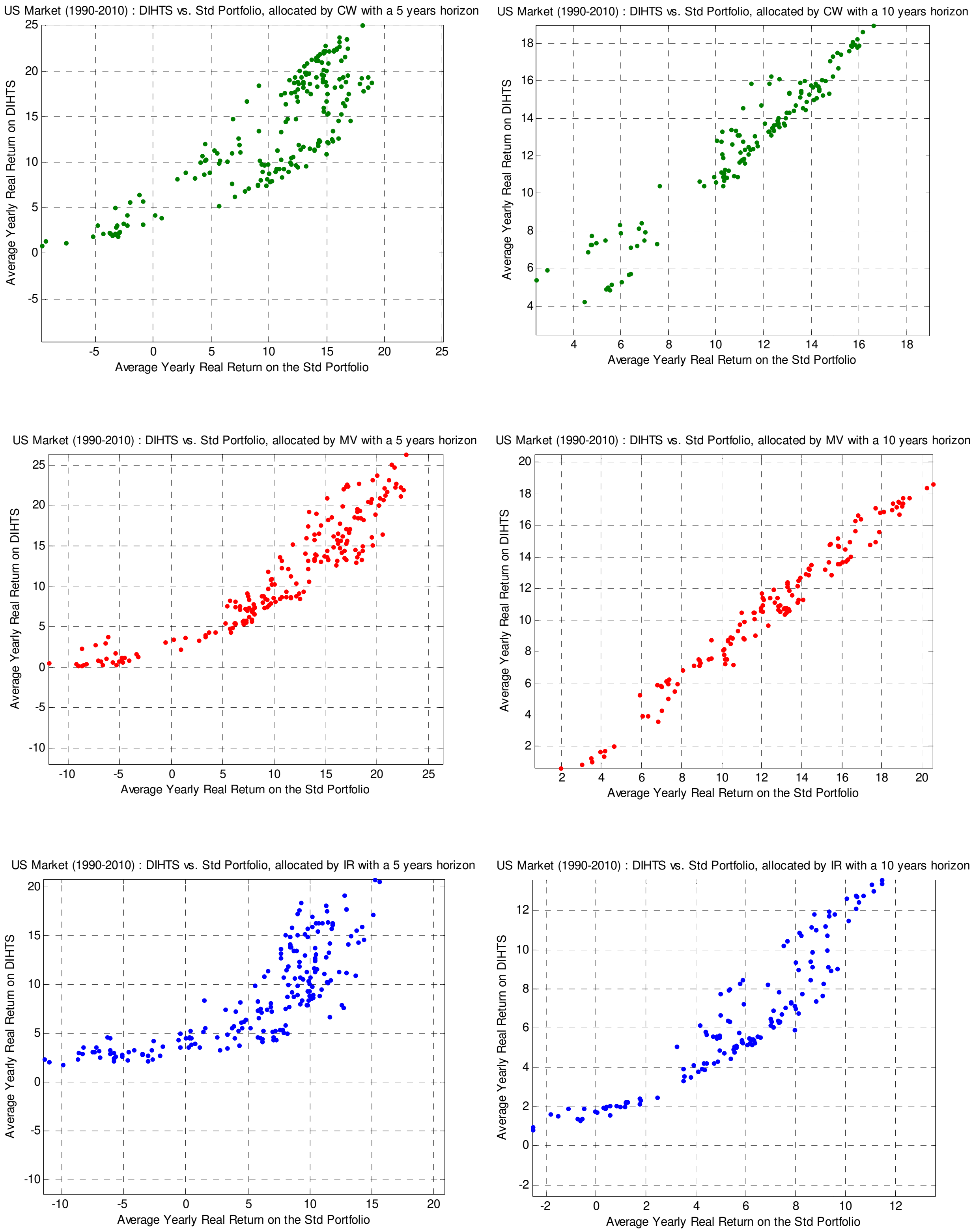


Figure 31: Efficient frontier estimation of the DIHTS vs. the benchmark portfolio.

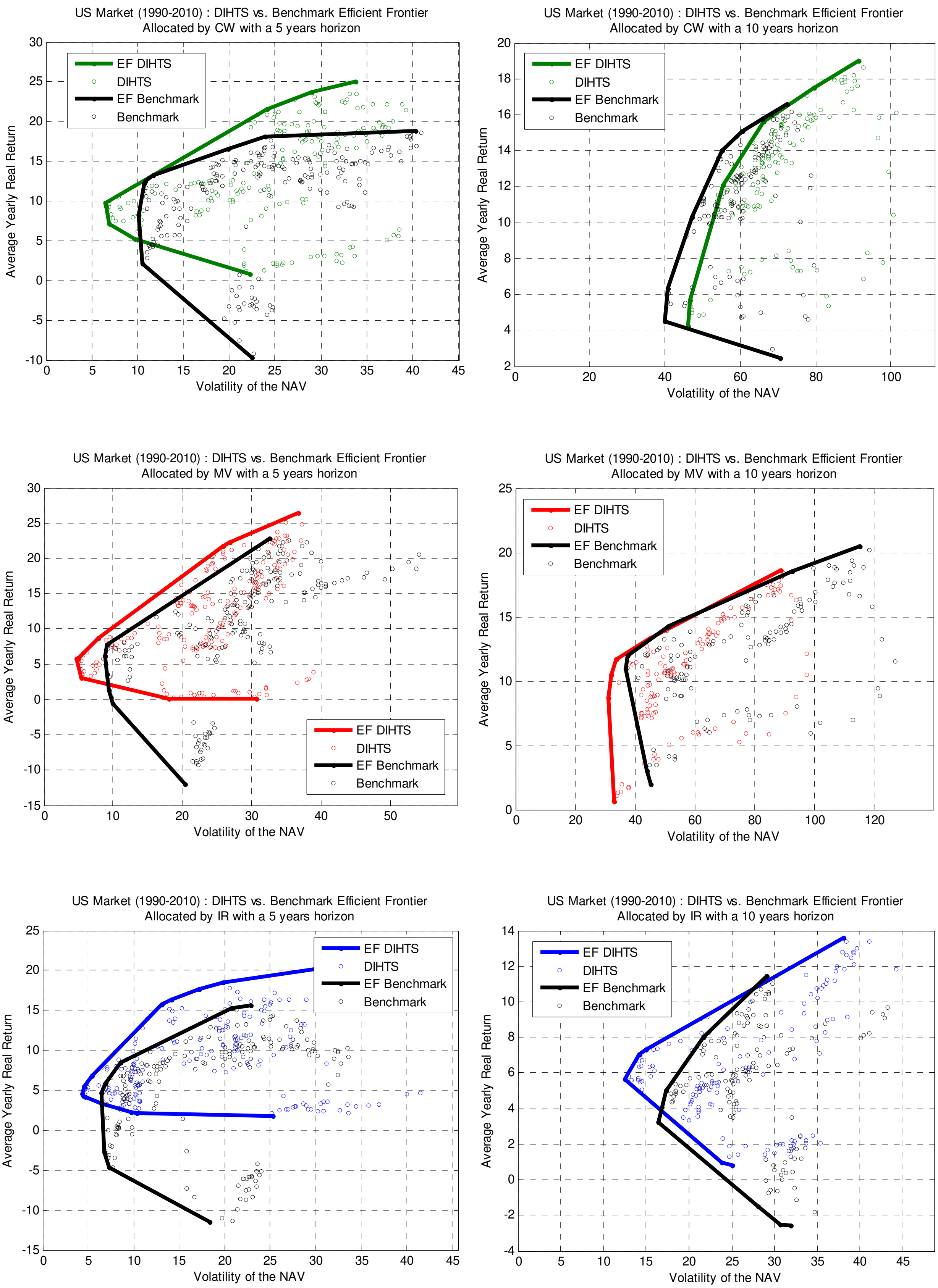


Figure 32 : Estimation of the mean Alpha values of the DIHTS and its 90% confidence interval

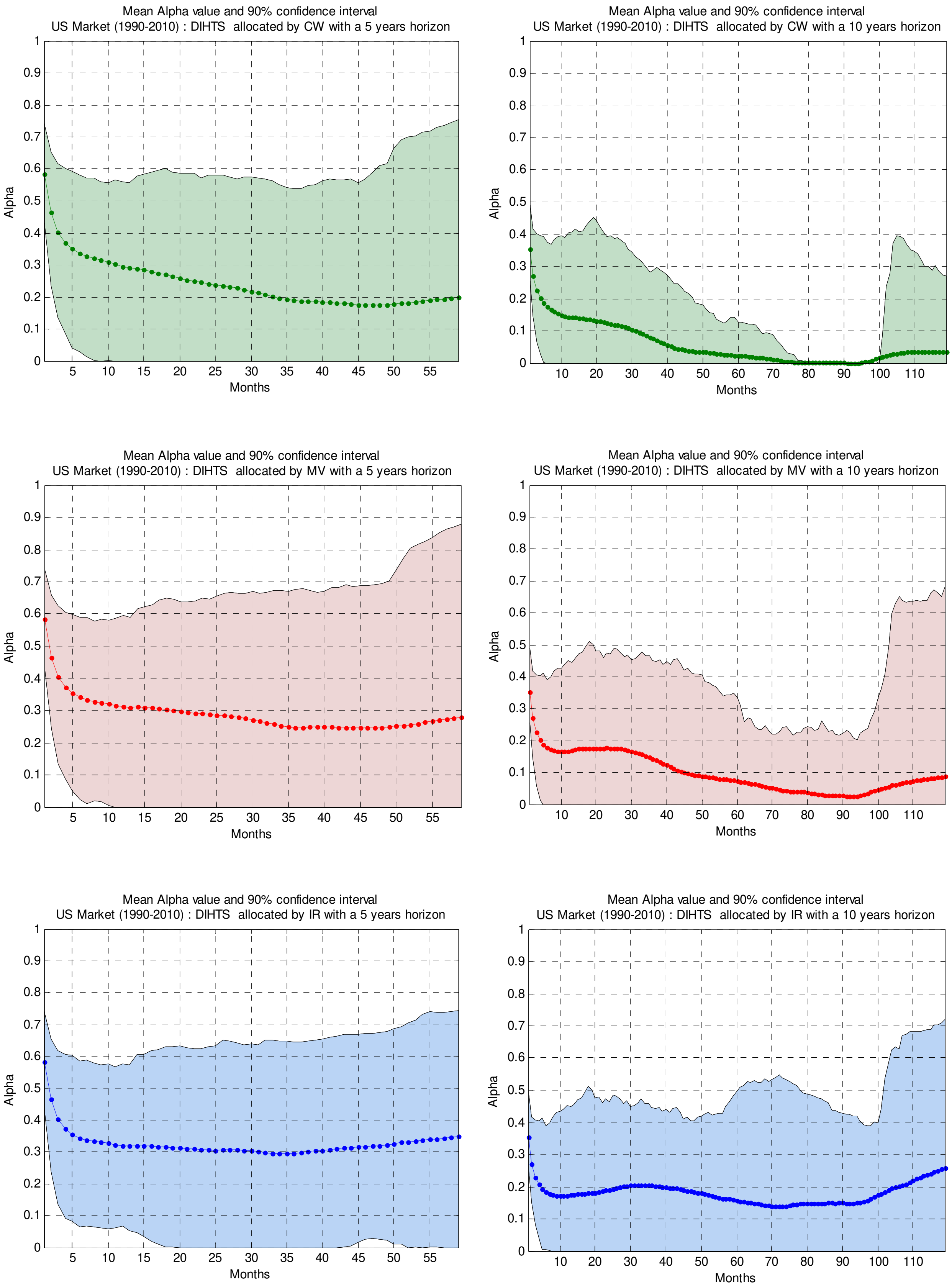


Figure 33: Mean dynamic allocation of the DIHTS.

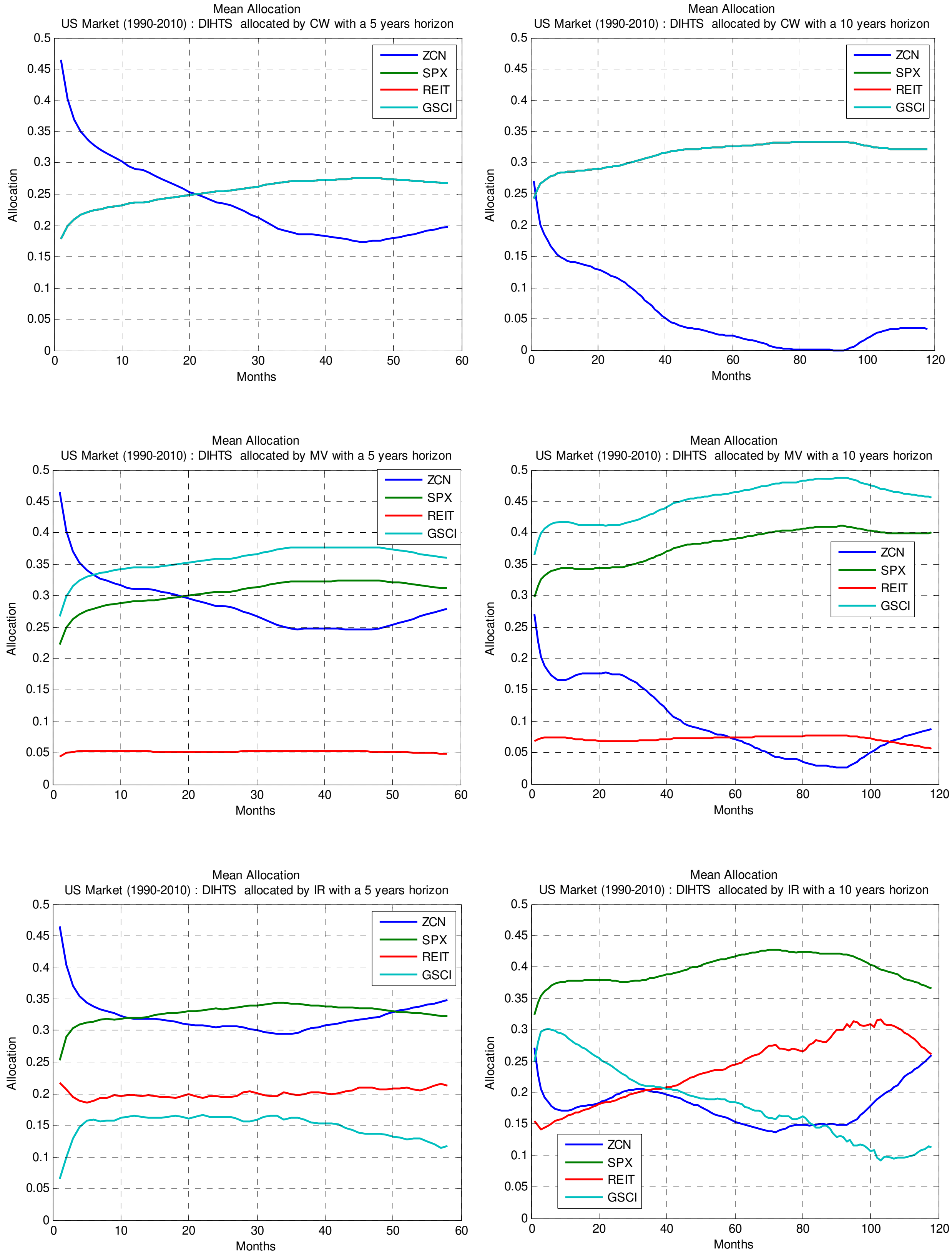


Table 8: Horizon sensitivity analysis of the DIHTS vs. the Benchmark Portfolio

CW

Horizon	Fail Rate		IR		ToR	
(Years)	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF
5	0,00%	12,44%	60,27% (28,6%)	33,80% (21,93%)	5,46% (1,8%)	3,65% (0,63%)
6	0,00%	1,66%	44,03% (18,0%)	28,96% (11,57%)	6,89% (1,8%)	4,79% (0,87%)
7	0,00%	1,18%	34,23% (12,4%)	24,52% (7,61%)	8,65% (1,8%)	6,09% (1,02%)
8	0,00%	1,91%	26,89% (8,2%)	20,27% (6,50%)	10,45% (1,8%)	7,47% (0,97%)
9	0,00%	0,00%	21,56% (5,8%)	17,13% (5,05%)	12,24% (1,8%)	9,00% (0,96%)
10	0,00%	0,00%	17,92% (4,2%)	14,80% (3,63%)	14,22% (2,2%)	10,83% (1,32%)

MV

Horizon	Fail Rate		IR		ToR	
(Years)	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF
5	0,00%	13,47%	53,80% (27,1%)	29,69% (26,33%)	6,09% (2,2%)	6,59% (1,29%)
6	0,00%	8,84%	42,26% (21,5%)	26,17% (15,03%)	7,66% (2,5%)	8,53% (1,64%)
7	0,00%	0,00%	34,10% (14,0%)	22,11% (8,11%)	9,62% (2,7%)	10,74% (2,09%)
8	0,00%	1,27%	27,85% (10,5%)	18,47% (6,20%)	11,70% (2,6%)	13,11% (2,35%)
9	0,00%	0,00%	22,37% (8,6%)	15,82% (5,05%)	13,70% (2,5%)	15,75% (2,78%)
10	0,00%	0,00%	18,56% (6,5%)	13,72% (3,86%)	15,90% (2,9%)	18,99% (3,86%)

IR

Horizon	Fail Rate		IR		ToR	
(Years)	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF
5	0,00%	20,73%	59,48% (30,2%)	24,35% (32,65%)	7,17% (3,2%)	7,36% (1,39%)
6	0,00%	21,55%	48,70% (26,2%)	22,55% (20,50%)	8,91% (3,5%)	9,30% (1,75%)
7	0,00%	9,47%	38,41% (18,3%)	20,82% (11,31%)	10,29% (3,9%)	11,45% (2,03%)
8	0,00%	8,28%	32,06% (13,6%)	18,42% (10,61%)	11,18% (3,9%)	13,57% (2,03%)
9	0,00%	9,66%	29,30% (13,6%)	15,91% (9,53%)	12,08% (3,7%)	15,87% (2,10%)
10	0,00%	7,52%	25,56% (12,4%)	13,89% (7,95%)	13,33% (3,5%)	18,55% (2,36%)

Table 9: Horizon sensitivity analysis of the allocation for the DIHTS.

CW

Horizon (Years)	ZCN	SPX	REIT	GSCI
5	23,5% *(22,2%)*	24,9% *(14,3%)*	24,9% *(10,2%)*	24,9% *(7,9%)*
6	19,0% *(19,7%)*	26,6% *(12,2%)*	26,6% *(8,3%)*	26,6% *(6,2%)*
7	13,9% *(16,4%)*	28,3% *(9,2%)*	28,3% *(5,5%)*	28,3% *(3,4%)*
8	9,9% *(12,9%)*	29,7% *(6,2%)*	29,7% *(2,6%)*	29,7% *(0,7%)*
9	7,6% *(9,8%)*	30,5% *(3,6%)*	30,5% *(0,3%)*	30,5% *(1,5%)*
10	5,7% *(6,9%)*	31,2% *(1,4%)*	31,2% *(1,6%)*	31,2% *(3,3%)*

MV

Horizon (Years)	ZCN	SPX	REIT	GSCI
5	28,1% *(22,2%)*	29,9% *(17,3%)*	5,3% *(14,9%)*	35,0% *(13,9%)*
6	24,1% *(19,7%)*	31,7% *(15,9%)*	5,7% *(13,9%)*	37,2% *(13,3%)*
7	19,3% *(16,4%)*	33,7% *(14,2%)*	6,1% *(13,1%)*	39,7% *(12,9%)*
8	14,9% *(12,9%)*	35,5% *(13,1%)*	6,6% *(12,8%)*	41,9% *(13,1%)*
9	12,3% *(9,8%)*	36,5% *(12,7%)*	6,9% *(13,0%)*	43,3% *(13,6%)*
10	9,8% *(6,9%)*	37,6% *(12,8%)*	7,2% *(13,6%)*	44,6% *(14,3%)*

IR

Horizon (Years)	ZCN	SPX	REIT	GSCI
5	31,6% *(22,2%)*	32,2% *(16,5%)*	19,8% *(12,9%)*	14,7% *(10,9%)*
6	29,0% *(19,7%)*	33,6% *(14,4%)*	20,3% *(10,9%)*	15,7% *(9,2%)*
7	25,9% *(16,4%)*	35,2% *(11,5%)*	20,6% *(8,3%)*	17,2% *(7,3%)*
8	22,7% *(12,9%)*	36,8% *(8,7%)*	21,2% *(6,9%)*	18,3% *(6,8%)*
9	20,3% *(9,8%)*	38,0% *(6,9%)*	22,4% *(7,1%)*	18,3% *(7,8%)*
10	17,8% *(6,9%)*	39,3% *(7,1%)*	23,8% *(8,3%)*	18,3% *(9,4%)*

Table 10: Parameter sensitivity analysis for the DIHTS.

CW

Eta \ Mu		10%		30%		50%		70%		90%	
0%	**FR**	0,0%		0,0%		0,0%		5,3%		6,0%	
	ToR	9,1%	*(1,8%)*	13,1%	*(2,8%)*	14,3%	*(2,1%)*	12,2%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,9%	*(4,0%)*	20,4%	*(4,1%)*	17,9%	*(4,1%)*	17,2%	*(6,2%)*	17,4%	*(6,1%)*
0.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	5,3%	*(0,0%)*	6,0%	*(0,0%)*
	ToR	9,0%	*(1,8%)*	13,1%	*(2,8%)*	14,3%	*(2,1%)*	12,2%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,9%	*(4,1%)*	20,4%	*(4,1%)*	17,9%	*(4,2%)*	17,2%	*(6,2%)*	17,4%	*(6,1%)*
1%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	5,3%	*(0,0%)*	6,0%	*(0,0%)*
	ToR	8,8%	*(1,8%)*	12,9%	*(2,8%)*	14,2%	*(2,2%)*	12,2%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,8%	*(4,1%)*	20,5%	*(4,1%)*	17,9%	*(4,2%)*	17,2%	*(6,2%)*	17,4%	*(6,1%)*
1.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	5,3%	*(0,0%)*	6,0%	*(0,0%)*
	ToR	8,8%	*(1,8%)*	12,8%	*(2,8%)*	14,2%	*(2,2%)*	12,2%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,8%	*(4,1%)*	20,5%	*(4,1%)*	17,9%	*(4,2%)*	17,2%	*(6,2%)*	17,4%	*(6,1%)*
2%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	5,3%	*(0,0%)*	6,0%	*(0,0%)*
	ToR	8,7%	*(1,8%)*	12,7%	*(2,8%)*	14,1%	*(2,2%)*	12,2%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,8%	*(4,1%)*	20,5%	*(4,1%)*	17,9%	*(4,2%)*	17,2%	*(6,2%)*	17,4%	*(6,1%)*
2.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	5,3%	*(0,0%)*	6,0%	*(0,0%)*
	ToR	8,7%	*(1,8%)*	12,5%	*(2,7%)*	14,1%	*(2,2%)*	12,1%	*(1,8%)*	11,5%	*(1,5%)*
	IR	22,8%	*(4,1%)*	20,5%	*(4,1%)*	0,179	*(4,2%)*	0,172	*(6,2%)*	0,174	*(6,1%)*

MV

Eta \ Mu		10%		30%		50%		70%		90%	
0%	**FR**	0,0%		0,0%		0,0%		9,0%		11,3%	
	ToR	10,0%	*(2,3%)*	14,3%	*(3,8%)*	16,0%	*(2,8%)*	13,7%	*(2,9%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,1%)*	21,2%	*(5,6%)*	18,6%	*(6,5%)*	17,4%	*(7,7%)*	16,8%	*(7,7%)*
0.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	9,0%	*(0,0%)*	11,3%	*(0,0%)*
	ToR	9,9%	*(2,3%)*	14,2%	*(3,8%)*	15,9%	*(2,8%)*	13,7%	*(2,9%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,1%)*	21,2%	*(5,6%)*	18,6%	*(6,5%)*	17,5%	*(7,7%)*	16,8%	*(7,7%)*
1%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	9,0%	*(0,0%)*	11,3%	*(0,0%)*
	ToR	9,8%	*(2,3%)*	14,0%	*(3,8%)*	15,9%	*(2,9%)*	13,7%	*(3,0%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,1%)*	21,2%	*(5,7%)*	18,6%	*(6,5%)*	17,4%	*(7,7%)*	16,8%	*(7,7%)*
1.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	9,0%	*(0,0%)*	11,3%	*(0,0%)*
	ToR	9,7%	*(2,2%)*	13,9%	*(3,8%)*	15,8%	*(2,9%)*	13,7%	*(3,0%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,1%)*	21,2%	*(5,7%)*	18,6%	*(6,5%)*	17,4%	*(7,7%)*	16,8%	*(7,7%)*
2%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	9,0%	*(0,0%)*	11,3%	*(0,0%)*
	ToR	9,6%	*(2,3%)*	13,7%	*(3,8%)*	15,8%	*(3,0%)*	13,7%	*(3,0%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,2%)*	21,2%	*(5,7%)*	18,6%	*(6,5%)*	17,5%	*(7,8%)*	16,8%	*(7,7%)*
2.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	9,0%	*(0,0%)*	11,3%	*(0,0%)*
	ToR	9,5%	*(2,3%)*	13,6%	*(3,8%)*	15,7%	*(3,0%)*	13,7%	*(3,0%)*	12,8%	*(3,5%)*
	IR	23,4%	*(5,1%)*	21,2%	*(5,7%)*	0,186	*(6,5%)*	0,175	*(7,8%)*	0,168	*(7,7%)*

IR

Eta \ Mu		10%		30%		50%		70%		90%	
0%	**FR**	0,0%		0,0%		0,0%		25,6%		20,3%	
	ToR	9,6%	*(2,3%)*	12,1%	*(2,4%)*	13,5%	*(3,6%)*	11,3%	*(2,8%)*	11,1%	*(2,0%)*
	IR	26,7%	*(7,8%)*	29,1%	*(11,0%)*	25,6%	*(12,4%)*	19,8%	*(13,5%)*	20,6%	*(12,0%)*
0.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	25,6%	*(0,0%)*	20,3%	*(0,0%)*
	ToR	9,5%	*(2,3%)*	12,0%	*(2,4%)*	13,5%	*(3,5%)*	11,3%	*(2,8%)*	11,1%	*(2,0%)*
	IR	26,7%	*(7,8%)*	29,1%	*(11,0%)*	25,6%	*(12,4%)*	19,7%	*(13,4%)*	20,6%	*(12,0%)*
1%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	25,6%	*(0,0%)*	20,3%	*(0,0%)*
	ToR	9,4%	*(2,4%)*	11,7%	*(2,2%)*	13,3%	*(3,5%)*	11,3%	*(2,8%)*	11,1%	*(2,0%)*
	IR	26,7%	*(7,8%)*	29,2%	*(11,1%)*	25,6%	*(12,4%)*	19,7%	*(13,4%)*	20,6%	*(12,0%)*
1.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	25,6%	*(0,0%)*	19,5%	*(0,0%)*
	ToR	9,3%	*(2,3%)*	11,5%	*(2,0%)*	13,2%	*(3,5%)*	11,3%	*(2,8%)*	11,1%	*(1,9%)*
	IR	26,6%	*(7,8%)*	29,2%	*(11,1%)*	25,5%	*(12,4%)*	19,7%	*(13,4%)*	20,7%	*(11,8%)*
2%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	25,6%	*(0,0%)*	19,5%	*(0,0%)*
	ToR	9,2%	*(2,3%)*	11,3%	*(1,9%)*	13,1%	*(3,6%)*	11,2%	*(2,7%)*	11,1%	*(1,9%)*
	IR	26,6%	*(7,7%)*	29,3%	*(11,2%)*	25,5%	*(12,4%)*	19,8%	*(13,4%)*	20,7%	*(11,8%)*
2.5%	**FR**	0,0%	*(0,0%)*	0,0%	*(0,0%)*	0,0%	*(0,0%)*	25,6%	*(0,0%)*	19,5%	*(0,0%)*
	ToR	9,1%	*(2,2%)*	11,1%	*(1,9%)*	12,9%	*(3,3%)*	11,2%	*(2,7%)*	11,1%	*(1,9%)*
	IR	26,6%	*(7,7%)*	29,3%	*(11,2%)*	0,255	*(12,4%)*	0,198	*(13,5%)*	0,207	*(11,8%)*

B. Bootstrapped Simulation Results

Figure 34: Performance comparison of the bootstrapped DIHTS vs. the benchmark portfolio.

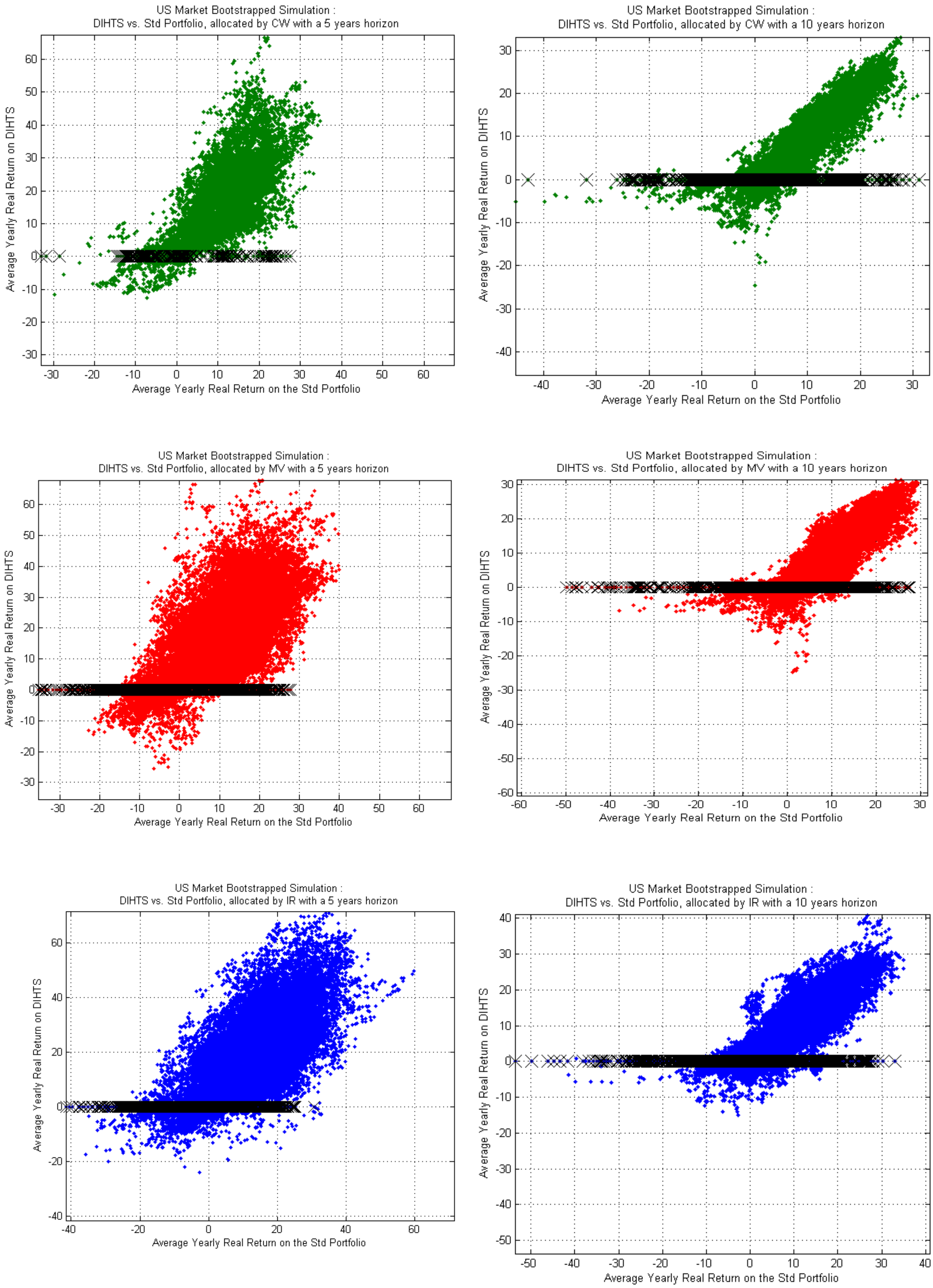


Figure 35: Efficient frontier estimation for the bootstrapped DIHTS vs. the benchmark portfolio.

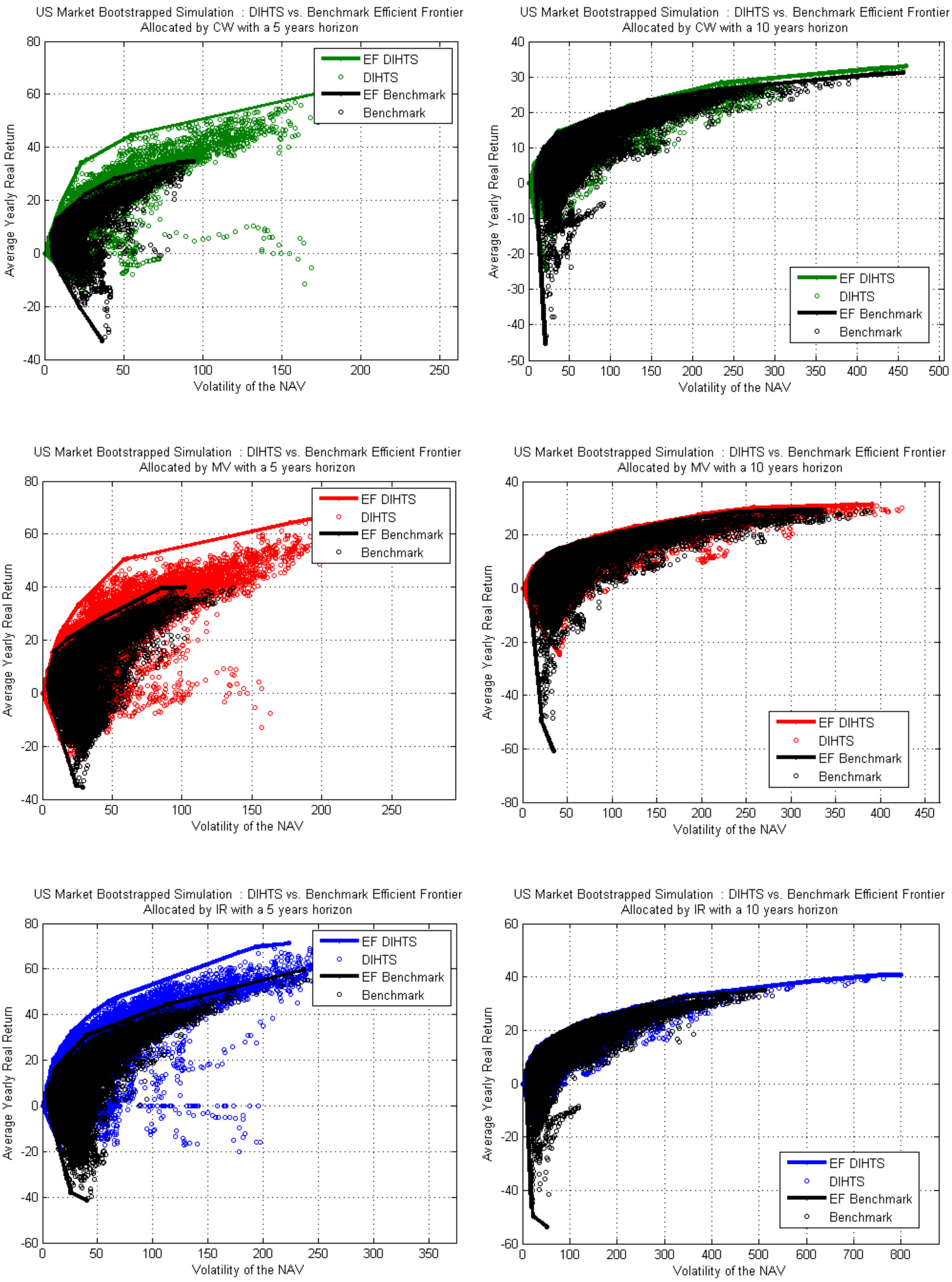


Figure 36: Estimation of the mean Alpha values of the bootstrapped DIHTS and its 90% C.I.

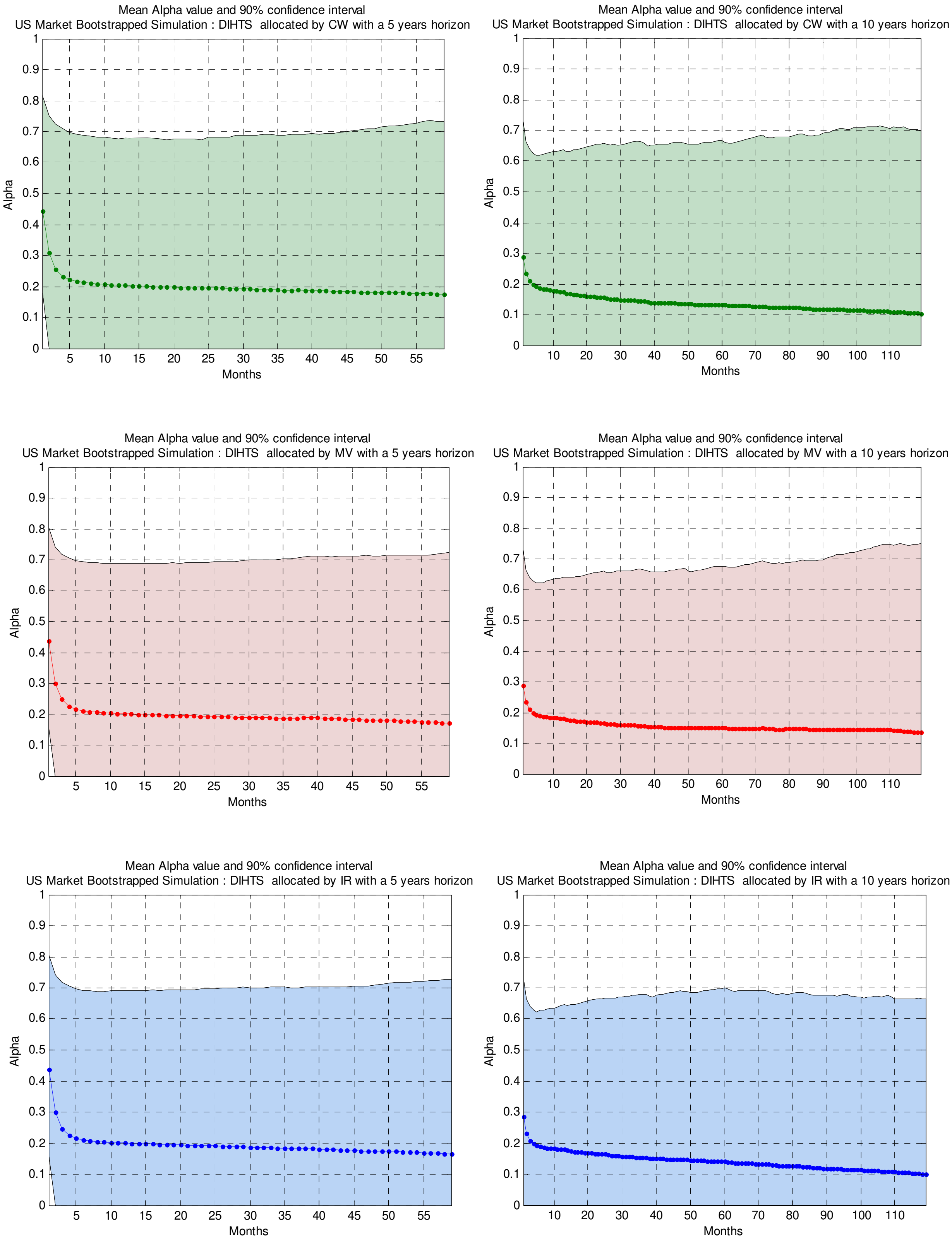


Figure 37: Mean allocation of the Bootstrapped DIHTS

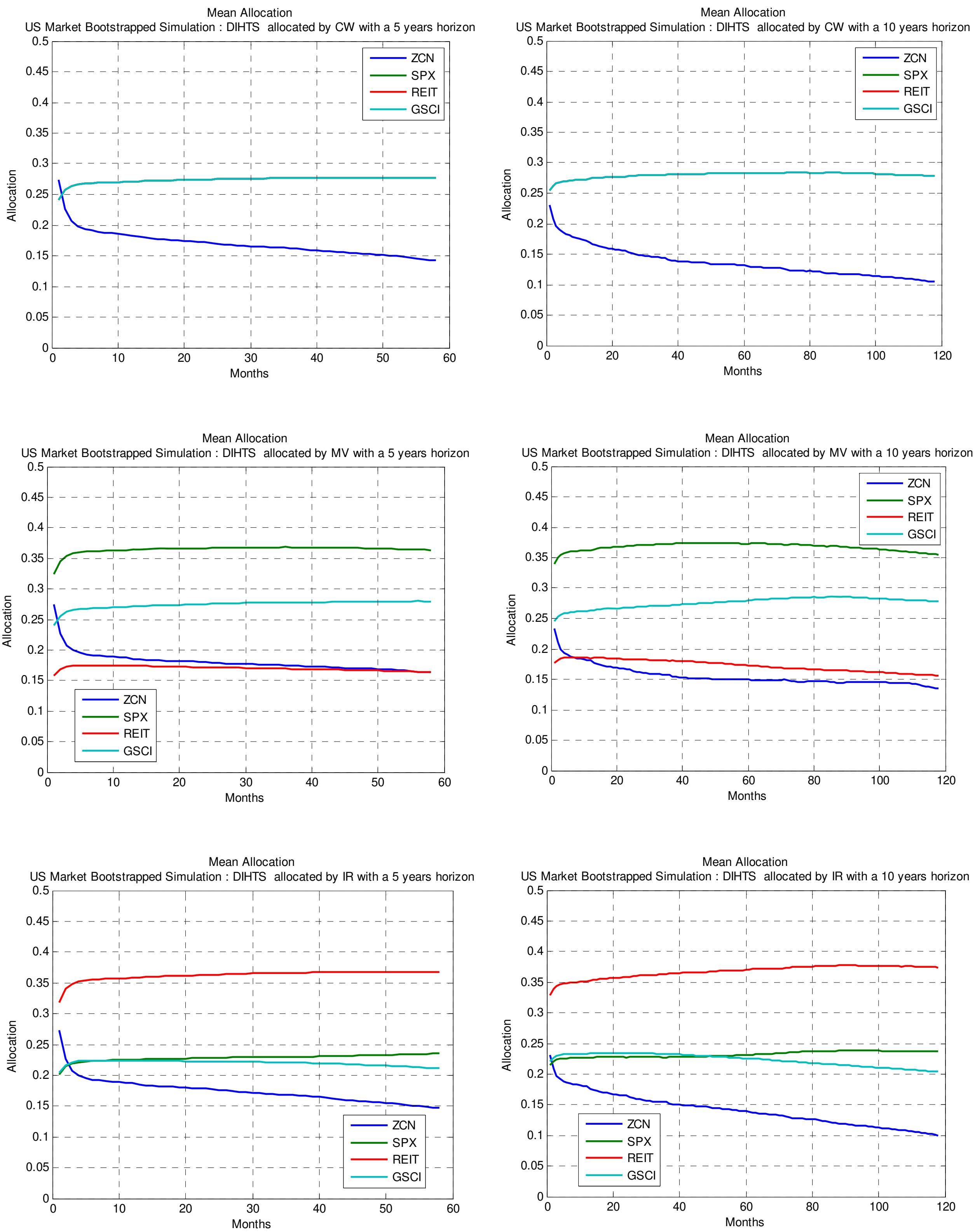


Table 11: Horizon sensitivity of the bootstrapped DIHTS vs. the benchmark portfolio.

CW

Horizon (Years)	Fail Rate		IR		ToR		PLGF
	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF	
5	7,92%	12,58%	59,01%	70,32%	6,57%	3,80%	-5,47%
			(30,2%)	*(33,59%)*	*(3,5%)*	*(0,91%)*	*(13,27%)*
6	8,33%	11,10%	46,28%	46,80%	7,40%	4,95%	-2,90%
			(22,6%)	*(22,92%)*	*(3,4%)*	*(1,23%)*	*(11,42%)*
7	7,78%	9,39%	39,24%	38,24%	8,76%	6,31%	-1,49%
			(10,6%)	*(10,16%)*	*(3,7%)*	*(1,73%)*	*(10,13%)*
8	7,42%	4,99%	20,53%	20,57%	9,90%	7,91%	0,85%
			(3,2%)	*(3,09%)*	*(4,0%)*	*(2,28%)*	*(9,56%)*
9	10,31%	7,43%	12,85%	12,91%	11,09%	9,45%	-1,18%
			(1,0%)	*(0,81%)*	*(4,7%)*	*(3,11%)*	*(11,20%)*
10	10,42%	6,29%	8,94%	9,44%	12,51%	11,26%	0,52%
			(0,7%)	*(0,66%)*	*(5,4%)*	*(3,75%)*	*(10,42%)*

MV

Horizon (Years)	Fail Rate		IR		ToR		PLGF
	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF	
5	10,10%	16,58%	122,92%	107,33%	7,60%	5,71%	-6,54%
			(80,4%)	*(73,70%)*	*(4,2%)*	*(1,82%)*	*(13,00%)*
6	10,23%	14,58%	30,46%	32,15%	8,53%	7,14%	-4,75%
			(8,6%)	*(9,03%)*	*(4,2%)*	*(2,59%)*	*(11,31%)*
7	9,81%	13,55%	31,91%	31,01%	10,05%	8,69%	-3,87%
			(13,2%)	*(12,77%)*	*(4,7%)*	*(3,36%)*	*(8,96%)*
8	10,44%	9,03%	24,90%	24,30%	11,86%	11,01%	-0,30%
			(1,8%)	*(2,90%)*	*(5,8%)*	*(4,39%)*	*(9,52%)*
9	13,63%	10,76%	-22,30%	-19,70%	12,85%	12,97%	-1,47%
			(31,5%)	*(27,87%)*	*(6,5%)*	*(5,69%)*	*(11,59%)*
10	13,45%	10,25%	15,60%	11,31%	14,04%	14,39%	-0,26%
			(5,2%)	*(4,49%)*	*(7,3%)*	*(5,97%)*	*(9,95%)*

IR

Horizon (Years)	Fail Rate		IR		ToR		PLGF
	DIHTS	PTF	DIHTS	PTF	DIHTS	PTF	
5	9,93%	16,17%	56,05%	51,79%	8,10%	6,17%	-7,03%
			(21,4%)	*(19,95%)*	*(4,9%)*	*(2,38%)*	*(13,31%)*
6	10,55%	14,19%	45,52%	47,95%	9,13%	7,79%	-5,82%
			(18,8%)	*(21,36%)*	*(4,9%)*	*(3,02%)*	*(12,81%)*
7	8,83%	12,24%	25,64%	31,05%	10,66%	9,37%	-5,92%
			(15,2%)	*(21,26%)*	*(5,3%)*	*(3,77%)*	*(14,60%)*
8	9,63%	8,70%	29,69%	32,00%	11,68%	11,27%	-1,01%
			(9,0%)	*(9,78%)*	*(6,1%)*	*(4,69%)*	*(12,55%)*
9	13,33%	10,55%	22,52%	21,03%	13,26%	13,63%	-4,56%
			(6,2%)	*(4,92%)*	*(6,6%)*	*(5,61%)*	*(12,93%)*
10	12,14%	8,60%	4,94%	4,89%	15,44%	16,14%	-2,09%
			(7,0%)	*(6,91%)*	*(8,2%)*	*(7,61%)*	*(13,75%)*

Table 12: Horizon sensitivity analysis of the allocation for the bootstrapped DIHTS.

CW

Horizon \ Allocation	ZCN	SPX	REIT	GSCI
5	16,8% *(10,9%)*	26,9% *(1,8%)*	26,9% *(1,4%)*	26,9% *(2,7%)*
6	16,2% *(10,3%)*	27,1% *(2,4%)*	27,1% *(0,6%)*	27,1% *(1,9%)*
7	15,0% *(8,6%)*	27,7% *(1,7%)*	27,7% *(1,1%)*	27,7% *(2,4%)*
8	14,5% *(7,3%)*	27,7% *(1,8%)*	27,7% *(0,7%)*	27,7% *(1,9%)*
9	14,3% *(5,9%)*	27,5% *(1,2%)*	27,5% *(1,0%)*	27,5% *(2,1%)*
10	14,5% *(5,1%)*	27,4% *(1,0%)*	27,4% *(0,7%)*	27,4% *(1,6%)*

MV

Horizon \ Allocation	ZCN	SPX	REIT	GSCI
5	17,9% *(10,8%)*	35,6% *(6,9%)*	16,9% *(7,3%)*	26,9% *(7,8%)*
6	17,6% *(10,1%)*	36,1% *(7,3%)*	16,5% *(7,4%)*	27,0% *(7,8%)*
7	16,6% *(8,7%)*	36,9% *(7,3%)*	16,7% *(7,5%)*	27,5% *(7,9%)*
8	16,1% *(7,4%)*	35,2% *(6,6%)*	16,8% *(6,8%)*	29,4% *(7,2%)*
9	16,3% *(5,6%)*	35,8% *(6,7%)*	16,3% *(7,1%)*	28,4% *(7,4%)*
10	16,9% *(5,1%)*	35,8% *(7,2%)*	15,8% *(7,4%)*	27,8% *(7,7%)*

IR

Horizon \ Allocation	ZCN	SPX	REIT	GSCI
5	17,3% *(10,7%)*	22,5% *(5,7%)*	35,5% *(6,1%)*	21,6% *(6,6%)*
6	17,1% *(10,2%)*	22,9% *(5,9%)*	35,7% *(5,9%)*	21,4% *(6,4%)*
7	15,9% *(8,7%)*	21,9% *(6,3%)*	37,0% *(6,5%)*	22,7% *(6,9%)*
8	15,8% *(7,5%)*	25,3% *(5,7%)*	35,9% *(5,8%)*	20,1% *(6,1%)*
9	14,9% *(5,8%)*	24,8% *(5,5%)*	35,9% *(5,7%)*	20,4% *(6,1%)*
10	14,5% *(5,0%)*	23,2% *(5,5%)*	36,3% *(5,7%)*	21,3% *(5,9%)*

Annex 2: *CHS*

A. Synthetic futures pricing of the security for other maturities

Figure 38: SR pricing of the swap rate over a 1-year horizon

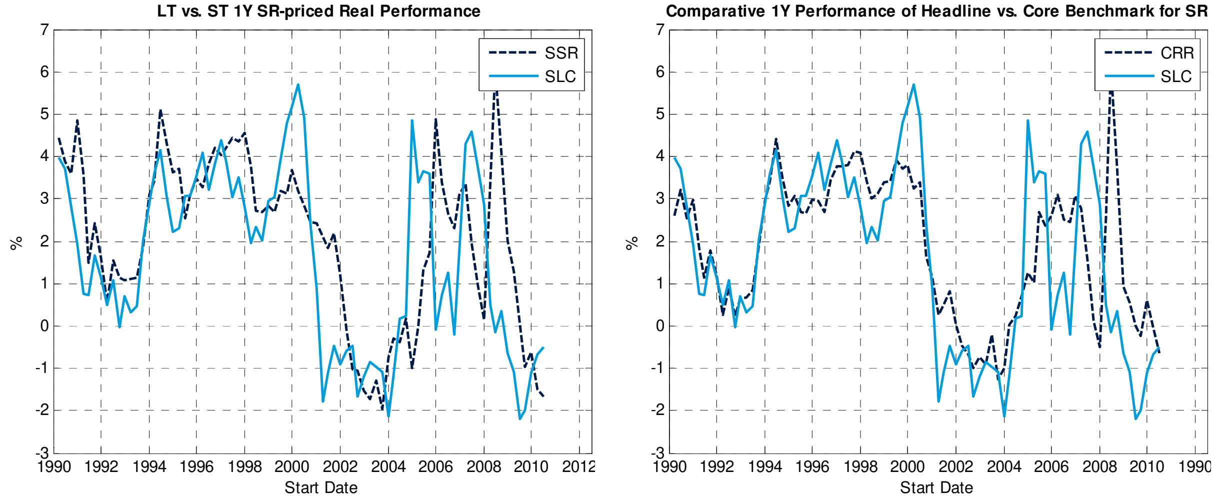


Figure 39: SR pricing of the swap rate over a 2-year horizon

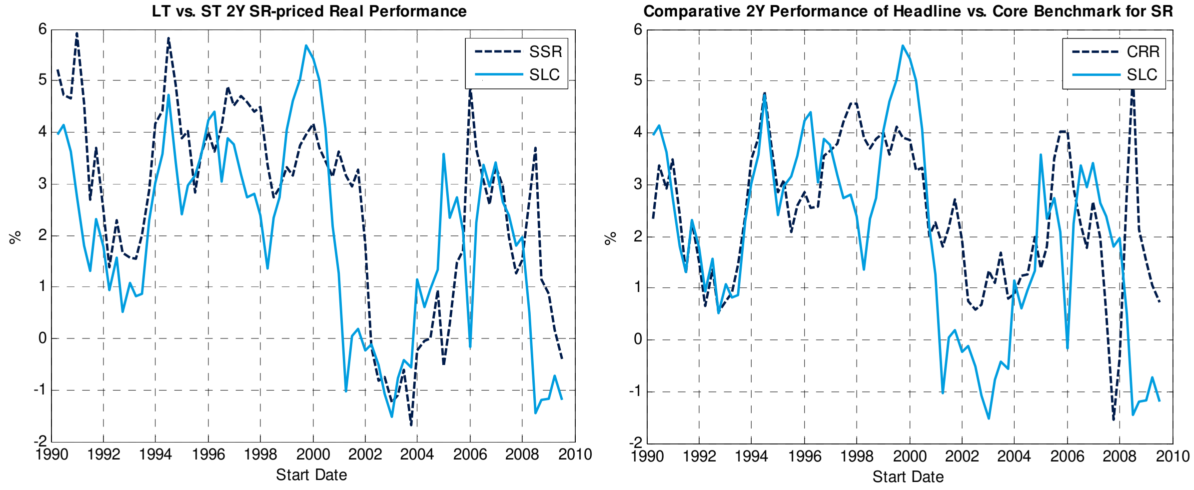
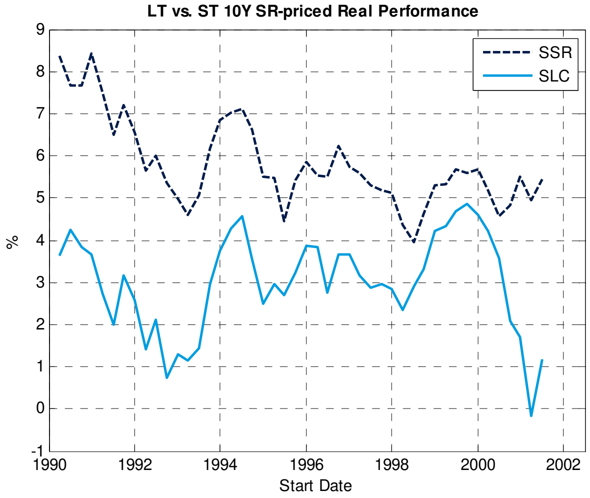
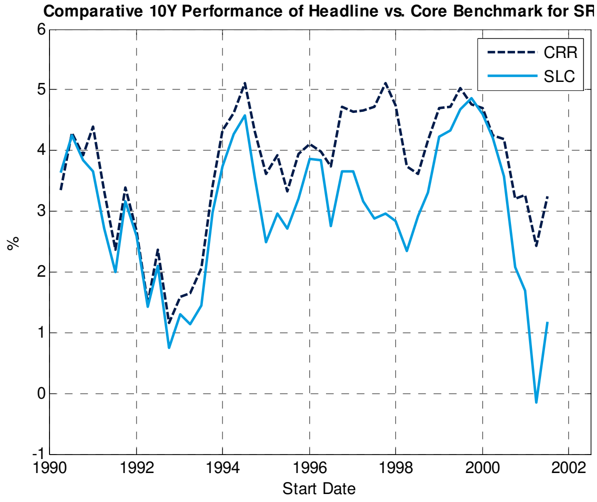


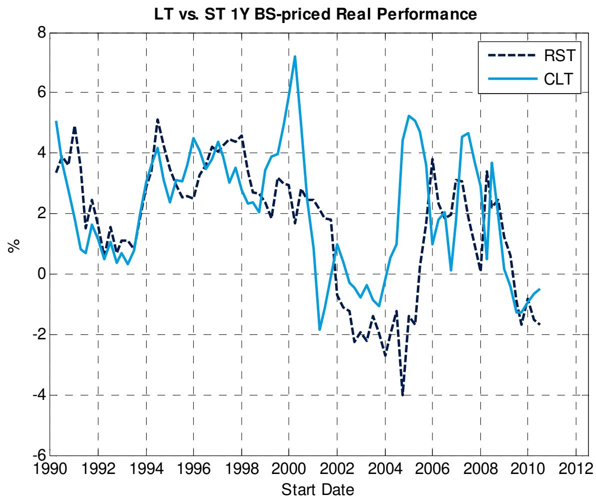
Figure 40: SR pricing of the swap rate over a 10-year horizon





B. Black-Scholes pricing of the security for other maturities

Figure 41: BS pricing of the swap rate over a 1-year horizon



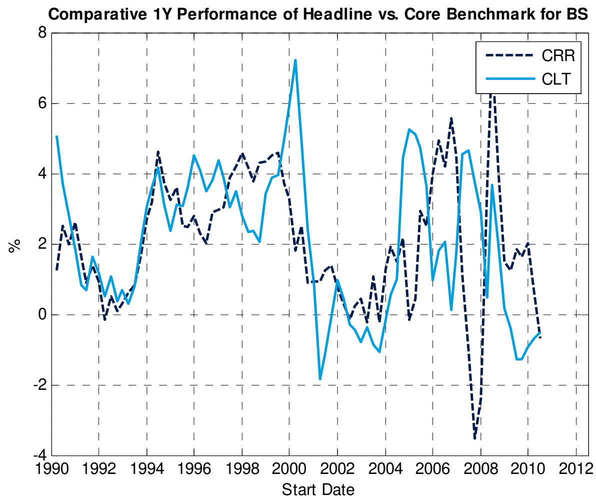


Figure 42: BS pricing of the swap rate over a 2-year horizon

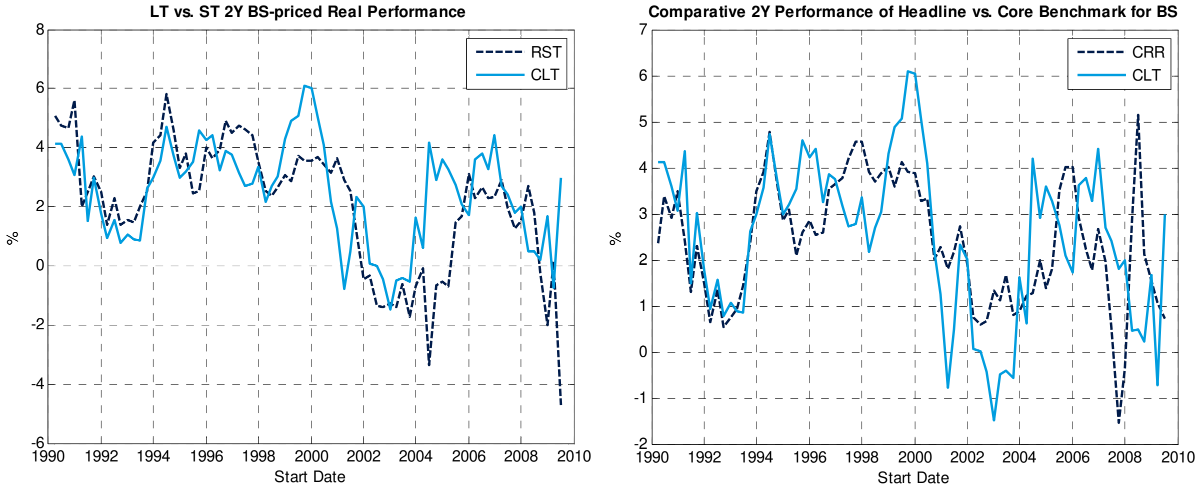
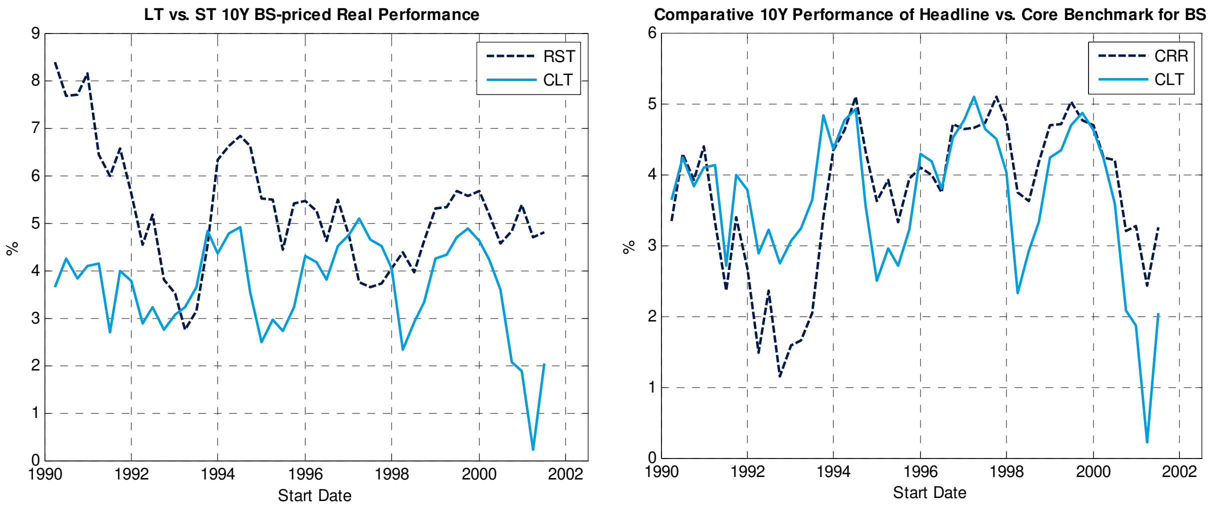


Figure 43: BS pricing of the swap rate over a 10-year horizon



Index

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Résumé :

La disparitions graduelle des peurs liées à l'inflation pendant l'ère de la «Grande Modération» macroéconomique est aujourd'hui chose révolue : la crise financière américaine des «Subprimes», la «Grande Récession» ainsi que la crise des dettes souveraines qui s'en est suivie ont abouti à un nouvel ordre économique caractérisé par une volatilité accrue de l'inflation, un accroissement des chocs dans les prix des matières premières et une défiance envers la qualité de la signature de certains émetteurs souverains pour n'en mentionner que trois caractéristiques. De la réduction des émissions de titres souverains indexés sur l'inflation aux taux réels négatifs jusqu'à de très longues maturités, cette nouvelle donne tend à mettre en péril aussi bien les stratégies conventionnelles de couvertures inflation que les stratégies directionnelles purement nominales . Cette thèse a pour but d'investiguer les effets de ces évènements qui ont changé la donne macro-financière et d'évaluer leurs conséquences en terme de couverture inflation aussi bien dans la gestion actif-passif des investisseurs institutionnels que sur l'épargne des particuliers. Trois stratégies alternatives de couverture sont proposés pour y faire face.

Descripteurs : *Couverture Inflation, Allocation de Portefeuille, Investissements Alternatifs, Matières Premières, Taux Réels, Inflation Sous-Jacente, Global Macro, « Passage de l'inflation », Allocation Stratégique, Assurance de Portefeuilles, Grande Récession.*

Abstract :

Gone are the days when inflation fears had receded under years of "Great Moderation" in macroeconomics. The US subprime financial crisis, the ensuing "Great Recession" and the sovereign debt scares that spread throughout much of the industrialized world brought about a new order characterized by higher inflation volatility, severe commodity price shocks and uncertainty over sovereign bond creditworthiness to name just a few. All of which tend to put in jeopardy both conventional inflation protected strategies and nominal unhedged ones: from reduced issues of linkers to negative long-term real rates, they call into question the viability of current strategies. This paper investigates those game changing events and their asset liability management consequences for retail and institutional investors. Three alternative ways to achieve real value protection are proposed.

Keywords : *Inflation Hedging, Portfolio Allocation, Alternative Investment, Commodities, Real Rates, Core Inflation, Global Macro, Inflation Pass-through, Strategic Allocation, Portfolio Insurance, Great Recession.*