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Can Risk Models Extract Inflation Expectations from Financial Market Data? Evidence from the Inflation Protected Securities of Six Countries*

Arben Kita†and Daniel L. Tortorice‡

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Abstract

We consider an arbitrage strategy which exactly replicates the cash flow of a sovereign inflation-indexed bond using inflation swaps and nominal sovereign bonds. The strategy reveals a violation of the law of one price in the G7 countries which is largest for the eurozone. Testing the strategy's exposure to deflation, volatility, liquidity, economic and policy risks suggests that the observed pricing differential is an economic tail risk premium which is more pronounced in the eurozone. We conclude that inflation expectations implied by models that view this pricing differential as compensation for risk are likely to be accurate and useful for policy-making.

JEL Codes: G12, G15, G18, H63

Keywords: Inflation-Indexed Bonds, Nominal Bonds, Law of One Price, Mispricing, Limits to Arbitrage

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1 Introduction

A large literature in macroeconomics pursues the accurate measurement of inflation expectations. These expectations are useful for many reasons. First, policy makers care about inflation expectations as they believe that increased inflation expectations can be a self-fulfilling prophecy that in and of itself generates inflation. Second, in periods of deep recession deflation risk is a serious concern and inflation expectations are one key way to gauge the possibility of deflation. Thirdly, the real interest rate – and the potential for a long term decline in the real interest rate – is of both academic and policy interest to macroeconomists. Finally, many macroeconomic models make predictions for the path of inflation expectations and accurate measures can be used to estimate and evaluate these models.

One common measure of inflation expectations is the break-even inflation rate, the difference between the yield on a treasury bond and the yield on an treasury inflation protected security (TIPS) of the same maturity. However, it is well know that as a pure measure of inflation expectations this break-even inflation rate suffers from many problems. As noted by Fleckenstein et al. (2014), the break-even inflation rate differs systematically from inflation rates implied by the inflation swap market. One explanation for this divergence is that TIPS pay higher yields because of an increased exposure to a risk factor like liquidity risk. However, the divergence also leads to a substantial arbitrage opportunity possibly due to market segmentation and the limits of arbitrage to reduce this mispricing.

The question of whether or not the mispricing is a compensation for risk or purely the limits of arbitrage is an important one. There is a substantial literature (e.g. Christensen et al. (2010)) which backs out break even inflation rates from Treasury and TIPS data by modeling the mispricing as a compensation for risk. In this paper we bring data to bear on this question. We calculate the mispricing for a large number of nominal and inflation protected securities in the US, Europe and Japan. We then examine the drivers of mispricing and test for the limits of arbitrage in explaining the mispricing. We examine the arbitrage strategy's exposure to deflation risk, volatility risk, liquidity risk, economic risk, and policy risk. We also examine the sensitivity of the mispricing to the funding costs of arbitrageurs.

First, we apply a replication strategy where we use the market prices of inflation swaps and nominal sovereign bonds to derive a synthetic nominal bond that replicates exactly the cash flow of the sovereign inflation-indexed bond for six of G7 countries. The first part of our analysis closely follows Fleckenstein et al. (2014) who apply a similar arbitrage strategy for the U.S. linkers. Our analysis spans the period 02 February 2007 to 30 November 2012.[1] Our analysis includes 25 matches for the United States, 5 matches for the United Kingdom, 3 matches for Japan, 4 matches for Germany, 5 matches for France and 5 matches for Italy, yielding a total of 47 nominal bonds. We obtain our data from Bloomberg system.

We find evidence of a pricing anomaly that is substantial for most securities in all the countries, on average the synthetic bond which perfectly replicates the cash flow of the inflation-indexed bond is cheaper than the nominal bond. The average pricing anomaly in the sample of U.S. nominal bonds is $1.67, less than the figure of $3.13 reported by Fleckenstein et al. (2014) using data for an earlier period.[2] The reduction in the magnitude of the average mispricing might imply that the pricing anomaly has diminished with time, as the amount of capital available to arbitrageurs increases. We examine this conjecture later in this paper. An alternative notion that we investigate is that the risk factors to which the mispricing is exposed, for example the possibility of an extended period of low economic growth and deflation, have subsided with the settling of the financial crisis and the now more normal functioning of financial markets. The lowest average pricing anomaly in our sample is $1 for France followed by Japan with mispricing of $ 1.74 and the UK $1.93. Italy displays the largest pricing anomaly of $8.71 followed by Germany with $3.12.

We then examine the factors which correlate with this mispricing. We find that the mispricing is well modeled as an explanation for risk. Specifically, the arbitrage strategy appears to be exposed to volatility risk (as measured by the VIX) and deflation risk (as measured by inflation risk premia). This result is due to the fact that the less liquid TIPS require compensation to be held in these states. On the other hand, we find little evidence that when arbitrageurs have more capital that the measured mispricing narrows. This result suggests that limits to arbitrage does not solely explain the mispricing. These results lend support to structural models of the treasury and TIPS markets which model the mispricing as a compensation for risk to back out a break even inflation rate. Next, using a structural VAR, we consider the reaction of the mispricing to an unexpected change in the short term interest rate. We find that this change reduces the mispricing in the short run but increases it in the long run. This result gives more credence to the risk explanation of the mispricing because one would think a pure arbitrage opportunity would widen as the cost of funding to arbitrageurs increases.

[1] For some securities we have slightly shorter time period with the shortest being 21 March 2012 to 06 December 2012 for a pair from Germany and 24 July 2011 to 27 November 2012 for a pair from the United States.

[2] We follow the literature and express the mispricing in U.S. dollars per 100 notional.

Once we establish the correlation of the mispricing with risk factors, we then treat the eurozone crisis as an ideal environment to investigate these risk factors in more detail. During the sample period, relative to the US, U.K and Japan, the eurozone was exposed to more economic risk: e.g., default, deflation and downside economic risk. Take for example, Italy– with the largest mispricing of \$8.71– a eurozone country whose credit rating was downgraded by Moody's on 4th October 2011 from Aa2 to A2, and by the end of the sample period on 13th July 2012 had a further downgrade to Baa2 owing to the size of its public debt. On average we find the eurozone countries to have over two times larger mispricing than the non-euro countries. The average mispricing for the eurozone countries is \$3.95 while the non-euro countries display a mispricing of \$1.67. Additionally, the mispricing is more highly correlated with the risk factors we isolate and the magnitude of the coefficients are larger, allowing us to conjecture that the pricing anomaly reported in this paper is an economic tail risk premium rather than an arbitrage opportunity.

The reminder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 describes the replicating strategy. Section 4 describes the data. Section 5 discusses the econometric strategy and results. Section 6 examines the results for the eurozone and Section 7 concludes.

2 Literature review

The pricing of inflation-indexed bonds has been studied extensively in the literature (see Roll (1996); Barr and Campbell (1997); Evans (2003); Roll (2004); Buraschi and Jiltsov (2005); Christensen et al. (2010); Andonov et al. (2010); Pflueger and Viceira (2011b), among others). The zero-arbitrage relationship between the US Treasury inflation-indexed bonds TIPS and nominal treasury bonds was originally analyzed by Fleckenstein et al. (2014). Later studies by Haubrich et al. (2012) and Fleckenstein (2013) confirm their key findings. In this literature, mispricing is attributed primarily to investors' preferences for the safety and liquidity of nominal treasury bonds Longstaff (2004); Bansal et al. (2010). Our results corroborate the findings of Fleckenstein et al. (2014) and Fleckenstein (2013) that the convenience yield attributed to nominal treasury bonds does not extend to inflation-indexed bonds. The present study differs from Fleckenstein et al. (2014) in several respects. First, our analysis extends to international markets by including six of G7 countries and extends the sample period through 2012 to include the eurozone crisis period. We also consider a relatively large sample of 47 pairs of bonds. Further, our analysis is at individual security level rather than in aggregate to avoid any possible systematic patterns that can influence the pricing anomaly if analyzed in aggregate. Finally we focus on the arbitrage strategy's exposure to deflation, volatility, liquidity, economic and policy risks.

One of the first attempts to estimate the inflation risk premium was proposed by Campbell and Shiller (1996). Their inferred inflation risk premium, based on the nominal term premium, ranged between 50 and 100 bps. In later studies Campbell and Viceira (2001) using data on nominal bond prices and inflation report that the inflation risk premium increases with the maturity of the nominal bonds, ranging from 35 bps for the three-month T-bill to over 1.1% for the 10-year horizon. Buraschi and Jiltsov (2006) infer the inflation risk premia from both nominal and real risk premia of the U.S. term structure of interest rates and report that the 10-year inflation risk premium is on average 0.7% and varies from 0.2% to 1.4% over a 40-year period. Ang et al. (2008) find that the inflation risk premium declined to 0.15% after the 2001 recession but started to bounce back to about 1% in December 2004. Chernov and Mueller (2012) propose a model of the term structure of inflation expectations and find that inflation risk premia can be positive or negative. Authors report a premium of 0.2% for one-year to 2% for 10-year maturity when the model includes inflation forecasts from surveys, but estimates change to -0.07% to -0.3% when forecast are excluded from the model estimation.

The literature reports differing findings on the magnitude of the inflation risk premium. D'Amico et al. (2016) using realized inflation series, nominal and TIPS yields, as well as survey forecasts of short rates apply a three-and four-factor Gaussian term structure model of interest rates and inflation. When the liquidity factor is excluded they find a negative inflation risk premium in the range of -100 to -50 bps. However, once the liquidity factor is included in the model, inflation risk premium estimates become positive and in the range of 0 and 1%, depending on the correlation of the liquidity factor with the other factors. By applying an eight-factor term structure model to both nominal and real yields Adrian and Wu (2010) corroborate the negative inflation risk premium found by D'Amico and colleagues. Haubrich et al. (2012) estimate a term structure model of real and nominal yields using data on nominal Treasury yields, survey forecasts of inflation, and inflation swap rates. Their estimated 10-year inflation risk premium is between 28 and 62 bps with an average of 48 bps over the sample period 1982-2009.

It also appears that theres no consensus in the literature on the direction of the inflation risk premium. Campbell et al. (2009) reason that TIPS risk premia should be low or even negative. D'Amico et al. (2016) on the contrary claim that the risk premium should be positive. Evans (1998) notes that, depending on how the real pricing kernel covaries with inflation, the inflation risk premium can be both positive or negative. Similarly, Hördahl and Tristani (2012) argue that when the pricing kernel is simply consumption growth, this correlation is negative, implying a positive inflation risk premium. However, authors note that in more general models this simple intuition is not corroborated as the pricing kernel depends on the marginal utility of consumption, not just consumption growth. In particular, Hördahl et al. (2008) calibrate a general equilibrium model with habit persistence and nominal rigidities and find that the inflation risk premium is positive and small at around one-year maturity and essentially zero for all other maturities.

We complement these studies on the inflation risk premium by obtaining market-based information estimates of the premium from nominal Treasury yields, TIPS, and inflation swaps markets, and survey forecasts of inflation for each of the G7 countries. Further, we explicitly distinguish between the post-financial and Euro-crisis period as an ideal environment to study the deflationary pressures in the eurozone with respect to the rest of the market. Studies mentioned above may not be directly comparable to ours due to differences in sample periods, estimation methods, and datasets used. In particular, our estimates are based on nominal yields, TIPS and inflation swaps market information over a more recent and relatively low inflation period but with potentially rising deflationary pressures for some of the analyzed nominal and inflation-linked sovereign bond pairs. Our sample includes the financial crisis and ends in December 2012, after the euro-crisis appeared to have calmed, to get inflation risk premium estimates both during and after the period of distressed market functioning. This setting provides us with unique environment to study the time series properties of the liquidity premium in the market for inflation protection and its relation with inflation risk premium. D'Amico et al. (2016) and Grishchenko and Huang (2013) on the other hand do not include data beyond March 2007 similarly Fleckenstein et al. (2014) spans through November 2009. Gürkaynak and Wright (2012) document significant pricing discrepancies with comparable maturity bonds trading at quite different prices in November and December of 2008. Fleckenstein et al. (2014) also document that TIPS market during that period represented exceptional arbitrage opportunities.

Our paper also relates to the extensive deflation literature of which more recent ones include Christensen et al. (2010) who by using an arbitrage-free term structure model with spanned volatility report that TIPS implied deflation option has spiked during the recent financial crisis and Fleckenstein et al. (2017) who extract the objective distribution of inflation from the market prices of inflation swaps and options to study the nature of deflation risk.

This paper also contributes to the literature on the persistence of mispricing. Gromb and Vayanos (2002) and Ashcraft et al. (2010) show that margins, haircuts and other frictions may induce deviations from the law of one price. Brunnermeier and Pedersen (2009) examine the effect of liquidity on security prices. Duffie (2010) examines the relationship between slow-moving capital and mispricing in financial markets. Deviations from the law of one-price have been rationalized in the literature in several ways, including liquidity effects, liquidity risk premia, and arbitrage risk premia. Haubrich et al. (2012) and Christensen and Gillan (2011) characterize the component of the inflation-indexed bond price that cannot be explained using a formal asset pricing model as a liquidity risk premium. We test the predictions of the slow-moving-capital theory by examining the relationship between the change in the capital available to arbitrageurs and the levels and differences of a mispricing measure as well as the exposure of the arbitrage strategy to various risk factors.

3 Arbitrage Strategy

The arbitrage strategy that we follow has been long recognized and applied by practitioners.[3] The investor buys an inflation-indexed bond at a price of V. The coupon is s per semiannual period. The coupon paid at time t is adjusted by an inflation factor, sI_t. On maturity at time T the repayment of principal is $100I_T$. The investor also executes a series of zero-coupon inflation swaps, with maturity dates and notional amounts matching each of the coupon payments for the inflation-indexed bond. At $t < T$, the cash flow of the inflation swap is $s(1+f)^t - sI_t$, where f is the fixed inflation swap rate. The constant aggregated cash flows for the two streams is $sI_t + s(1+f)^t - sI_t = s(1+f)^t$. Likewise at T, the cash flow of the inflation swap is $(s+100)(1+f)^T - (s+100)I_T$, and the aggregated cash is $(s+100)(1+f)^T$. By executing zero-coupon inflation swaps with maturities and notional amounts matching the indexed cash flows from the inflation-indexed bond, the investor can convert all of the indexed cash flows into fixed cash flows.

The investor also purchases a nominal Treasury bond with a maturity date of T matching the inflation-indexed bond with a coupon of c, at a price of P. To match exactly the two streams of fixed cash flows, the investor takes either a long position or a short position of $c - s(1+f)^t$ in Treasury STRIPS for each coupon payment date. The mispricing is the

[3] See Financial Times blog of April 4 2012, Wall Street Journal April 27, 2010, among others, that discuss this strategy.

difference between P and V. Table A.1 in Appendix A provides a specific example showing the actual cash flows resulting from applying the arbitrage strategy on a British Gilt starting on 16 June 2008 to 27 October 2009 that replicates the 4.25 percent coupon nominal bond maturing on December 7, 2027.

The arbitrage strategy is executed in the same way for all six countries included in the study. The number of days between the maturity of each inflation-indexed bond and the nominal bond with the nearest maturity is defined as maturity mismatch. To adjust for maturity mismatch, the yield to maturity on the synthetic bond is applied to obtain the price of a hypothetical synthetic bond that would match precisely the maturity of the nominal Treasury bond in the pair. For any maturity mismatch, the cash flows of the synthetic bond always match those of the underlying nominal bond precisely, by construction. The mispricing is analyzed for each security individually to avoid any possible systematic patterns that can influence the mispricing if analyzed in aggregate.

4 Data

The data comprises daily closing prices for sovereign government nominal bonds, government inflation-indexed bonds, strips and inflation swaps for six countries: the United States, United Kingdom, Japan, Germany, France and Italy. The observation period is 02 February 2007 to 30 November 2012 for the majority of the securities analyzed.[4] We obtain the data from Bloomberg. The inflation-indexed bonds and nominal bonds have various maturities from 2008 to 2032. The nominal and inflation-indexed bond daily prices are adjusted for accrued interest, following the standard conventions.

Inflation swaps are quoted in terms of a constant rate on the contract's fixed leg. The traded maturities are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25 and 30 years for the US, UK and Japan. For the eurozone countries, the longest maturity for an inflation swap is 25 years. We interpolate for intermediate swap maturities.

We match the inflation-indexed bonds and nominal bonds as closely as possible, based on their respective maturities. The maturity mismatch is defined as the number of days between the maturity of the inflation-indexed bond, and the maturity of the nominal bond with the closest maturity. We examine all sovereign inflation-indexed nominal bond issues

[4] For some securities we have slightly shorter time period with the shortest being 21 March 2012 to 06 December 2012 for a pair from Germany or 24 July 2011 to 30 November 2012 for a pair from the United States.

for six of G7 countries available on Bloomberg system for the time period analyzed yielding 25 pairs of bonds for the US, 5 pairs for the UK, 3 pairs for Japan, 4 pairs for Germany, 5 pairs for France and 5 pairs for Italy.

In addition to the bond market data used to calculate the mispricing, we use several variables to examine whether the observed pricing anomaly correlates with financial or macroeconomic variables. This analysis is important because although the arbitrage strategy is profitable if held to maturity a widening of the mispricing may require an arbitrageur to liquidate the strategy prematurely, incurring significant losses (see Shleifer and Vishny (1997)). For example if inflation, particularly anticipated inflation, induces a rapid reduction in the value of the underlying assets, this effect wold reduce the arbitrageurs' engagement in this trading strategy. Further, the relation of financial and macro variables with the observed pricing anomaly would also reveal important information on market's assessment of deflation risk and other relevant economic tail risks.

The following variables are all obtained from the Bloomberg system for each country. The first variable we use is the 10-year swap spread, as a principal proxy for the credit risk of the banking system. Next, we obtain CDS spreads for each country in our analysis. CDS spreads should capture all relevant information concerning the altered risk of default for each country. Since CDS insures holders against any financial looses resulting from a credit event, it provides a quantitative measure of the risk associated with sovereign debt. Additionally, we use CDS prices to examine the extent to which default risk contributes to the mispricing. These portfolios will provide information on the extent to which default risk contributes to the mispricing. Finally we collected the VIX an (option-implied volatility index) for the stock market of each country. VIX is widely considered as the "fear index" since it reflects market's assessment of the risk of a large downward movement in the stock market an interpretation we will use in our subsequent results.

Next we collect data on the inflation risk premia (IRP). We use market participant's conventional definition of inflation risk premium, the difference between the inflation swaps and expected inflation rates. Higher inflation swap rate than the expected inflation rate implies positive inflation risk premium and vice versa. Since there is no theoretical reason for inflation risk premium not to be negative the occurrence of this scenario can be therefore viewed as a deflation risk premium.[5]

[5]To measure inflation expectations we take data from: the University of Michigan survey data for the U.S.; Bank of England Survey of External forecasters; Bank of Japan Inflation Outlook of Enterprises (Tankan) for the Japan; and European Central Bank (ECB) inflation forecasts for the eurozone countries. University of Michigan data can be accessed from the Federal Reserve Bank of Philadelphia website

We also examine the impact of several macroeconomic variables on the mispricing variable. We are particularly interested in the ability of macroeconomic variables to explain time series variation in the mispricing and to capture realized macroeconomic risk over time. These variables are oil prices, overnight bank lending rates, industrial production, government deficits, and inflation expectations. Oil prices are Crude Oil (West Texas Intermediate) spot prices. We use oil prices to capture the state of the global economy. Given that during the time period of this study oil prices tended to rise on good economic news, higher oil prices should be associated with improved expectations of economic conditions. Overnight bank lending rates are the Fed Funds rate from FRED for the US, for Japan, it is the basic loan rate, for the UK and the EURO area countries we use Libor and Euribor. We use the overnight bank lending rate as a potential measure of the cost of funding for banks and other financial institutions investing in the bond markets. Industrial production is used because it is available monthly and gives an indication as to the state of the economy. Inflation expectations are used here because increased inflation expectations could increase demand for inflation protected securities and also be consistent with an improved outlook on the economy. Finally, we examine the role of government deficits as they can be associated with larger default risk and potentially affect bond prices.[6]

Lastly, we are also interested in the role arbitrageurs play in reducing the mispricing. To that end we collect data from Bloomberg system on the HFRX hedge fund indices. As sub categories we examine the HFRX macro-strategy index, relative value hedge fund index, the all fixed-income convertible arbitrage index, the fixed-income sovereign index and the global index return. We choose these hedge fund categories because they are the hedge funds most likely to engage in the type of arbitrage strategy that would reduce the mispricing. We have also explored the role that supply of bonds– defined as new issuance of nominal debt and inflation linked debt relative to total government debt– as an additional institutional factor.[7]

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https://www.philadelphiafed.org/research-and-data/real-time-center/survey-of-professional-forecasters/; Bank of England website http://www.bankofengland.co.uk/research/Pages/onebank/datasets.aspx; Tankan is available at https://boj.or.jp/en/statistics/tk/index.htm; ECB data is available at https://www.ecb.europa.eu/stats/prices/indic/forecast/html/table_hist_hicp.en.html.

[6]Data on oil prices, the Fed Funds rate and industrial production come from the Federal Reserve Economic Database (FRED). Overnight bank rates for Japan, UK and the Euro countries come from Bloomberg. Data on inflation expectations come from the Survey of Professional Forecasters administered by the Federal Reserve Bank of Philadelphia for the U.S. and the European Central Bank for the Euro area countries. Data are available at: https://www.philadelphiafed.org/research-and-data/real-time-center/survey-of-professional-forecasters/data-files and http://www.ecb.europa.eu/stats/prices/indic/forecast//html/index.en.html respectively. Finally, data on government deficits come from the Organization for Economic Co-operation and Development (OECD), https://data.oecd.org/gga/general-government-deficit.htm.

[7]Following Greenwood and Vayanos (2008) and Pflueger and Viceira (2011a) a supply is defined as

However, we have not found it to be significant in the regressions so have omitted the results.

5 Results

Table 1 reports summary statistics for the pricing anomaly for each of the 47 sample pairs of inflation-linked and nominal bonds. The pricing anomaly reported in table 1 is substantial. By country the Italian pairs exhibit the highest average mispricing of \$8.71. The corresponding figures for Germany, UK, Japan, the US and France are \$3.12, \$1.93, \$1.74, \$1.67, \$1 respectively. The average dollar mispricing for the US is lower than the figure of \$3.13 reported by Fleckenstein et al. (2014) for an earlier period. We conjecture that there is a tendency for the pricing anomaly to diminish over time, partly as a consequence of an increase in the amount of capital available to arbitrageurs. On average, nominal bonds are dearer than their synthetic counterparts that hedge the inflation risk. Among the 47 pairs, however, there are eight cases where the average daily price of the synthetic bond exceeds the average daily price of the nominal bonds. There are only four pairs for which the price of the synthetic bond never exceeded the price of the nominal bond. Distributional properties of the mispricing however, suggest that there might be limits to this arbitrage strategy. The standard deviation of the pricing anomaly tends to be relatively large suggesting that volatility in the mispricing might deter investors from engaging in this type of arbitrage strategy. This evidence motivates the investigation on the determinants of the pricing anomaly and the limits to arbitrage which we report in Section 6.[8]

To further examine the time-series properties of the average mispricing, Figure 1 plots the time-series of the equally weighted-average dollar mispricing for all inflation-indexed and nominal bond pairs for each country. Figure 1 suggests that the mispricing is persistent, and is not a phenomenon associated solely with the financial crisis of 2008-09. Nevertheless the peak of the mispricing appears to coincide with the Lehman Brothers default in Autumn 2008.

These findings provide initial insights on the potential explanations for this pricing anomaly. To first determine whether the observed pricing anomaly correlates with the risks

Supply=D^{TIPS}/D_t where D^{TIPS} is the face value of the outstanding inflation-indexed bonds and D_t is the total government debt. Change in supply is defined as $\triangle Supply_t$= $(D_t^{TIPS} - D_{t-1}^{TIPS})/D_{t-1}^{TIPS} - (D_t - D_{t-1})/D_{t-1}$.

[8] Table A2 in Appendix A reports more detailed information on the average mispricing for each pair examined in this study.

in the financial markets we run the following regression:

$$\Delta ln(mispricing)_{it} = \alpha + \beta x_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

The left hand side variable is the change in the log mispricing variable defined as the log bond price minus the log synthetic bond price. The right had side variables $x_{i,t}$ include the swap spread, the VIX, the 5-year inflation risk premium, the return on the global hedge fund index and the bid-ask spread for the inflation protected securities. Results are presented in table 2.

We find that many of these variables are significantly correlated with the mispricing. We start with swap spreads which have been long used as a measure of systemic credit and illiquidity risk on the financial system (See Duffie and Singleton (1997)).[9] The swap spread enters negatively. We view an increasing swap spread as indicating reduced demand for corporate securities and increased demand for sovereign securities. This demand flows asymmetrically into inflation-protected securities, naturally lowering the mispricing Secondly, the VIX enters positively. We again interpret this as arbitrageurs being exposed to risk, in this case volatility risk which increases the mispricing when the risk rises. Similarly, the inflation risk premium enters positively. When investors are willing to pay more to insure against inflation risk the mispricing widens. This suggests that the arbitrage strategy is exposed to short term inflation risk. Intuitively this makes sense, in regimes of increased uncertainty investors are wiling to pay more to insure against inflation risk. These times are ones in which the mispricing widens.

On the other hand, we find no significant evidence that hedge fund returns correlates with the mispricing. We will explore this proposition in more detail in the paper and again we will find little support for the slow moving capital hypothesis to explain the mispricing. Furthermore, we do not find significant evidence that the reported pricing differential correlates to the illiquidity risk in the market for inflation protection as proxied by linkers' bid-ask spreads. This evidence together with the large standard deviations of the mispricing reported in table 1 cast doubt on the view whether this is a pure arbitrage opportunity and that the institutional factors might provide an explanation. In column two of table 2 we present the same results controlling for country and time (year) fixed effects and the results

[9] Other measures of systemic risk such as the spread between three-month Libor rates and the overnight index swap (OIS) rate, the CDX index which captures the average CDS spread for investment grade bonds result highly correlated with the swap spreads and do not provide a significant incremental contribution in explaining the relation of the pricing anomaly with the macro-financial systemic risk.

are very similar. The fixed effects are able to control for country specific factors that are constant over time. This would include, for example, institutional factors that are specific to the countries we examine.

Next we explore the role of country default risk in explaining the mispricing. We conjecture that if the pricing differential accounts for premium in case the issuer fails to meet her obligations than this should be reflected in its correlation with the country-specific CDS premium. We run the regression (1) but now subtract off the CDS premium for insuring against sovereign default from the mispricing. We do this to see if any of the above identified risk factors are proxying for exposure to default risk. CDS spreads should capture all relevant information concerning the altered risk of default for each country. In addition, CDS spreads should also capture the impact of the adopted policy measures such as the ECB's securities market programme (SMP) or any rescue loan supplied to financially distressed countries on the bond markets. The results are in table 3. One can see that the coefficients from the two regressions are very similar which suggests that default is not an important determinate of the mispricing. However, while the VIX variable was significant in the previous regression, they are no longer significant once one controls for default risk through the CDS premium. This result suggests that volatility is correlated with sovereign default risk. We also find that the swap coefficient is smaller and significantly different than in the regression not factoring in CDS premium. Part of the mispricing premium appears due to sovereign default risk that lessens in the presence of stronger foretasted economic activity.

However, quantitatively the CDS premium is small relative to the mispricing. Figure 2 plots the monthly average of the mispricing and the monthly average of the mispricing minus the CDS variable. One can see that the plots are almost identical whether or not the CDS premium is subtracted from the mispricing or not. This result suggests strongly that default risk – even in Europe where default was seen as a real possibility – is not the reason that there is mispricing between inflation indexed and nominal government bonds. If investors were concerned about default risk they could purchase CDS insurance for their portfolio and still make almost the same arbitrage profit.

We also conjecture that macroeconomic risks factors will correlate with this pricing anomaly. Specifically, in periods of increased inflation expectations the demand for the relatively cheap inflation protected securities will rise narrowing the pricing anomaly. On the other hand, in periods of expected deflation the demand will switch leading to a widening of the mispricing. In Table 4 we augment our baseline regression with several macroeconomic variables: oil prices, short term interest rates, government deficits, and survey based inflation expectations. We find that increased oil prices are correlated with a reduction in the mispricing. We interpret this as higher oil prices being associated with an increase in world demand. This leads investors to expect stronger economic activity going forward reducing the risk exposure of the mispricing strategy. Other macroeconomic variables are not correlated with the mispricing. Deficits, short-term interest rates, and industrial production all enter the regression insignificantly as do one year ahead median inflation expectations and the measures of disagreement and uncertainty.[10] It appears that with the exception of oil prices – financial market variables as opposed to more general macroeconomic variables are important in determining the mispricing.

Finally in table 5, we look at the ability of the variables in our baseline regression to forecast the change in mispricing. We find that increased volatility and lower liquidity leads to an increase in the mispricing. This result is consistent with increased volatility leading investors to reduce their exposure to the mispricing strategy. Additionally, decreased liquidity (through higher bid-ask spreads) leads to a lower return from the arbitrage strategy. This would lead to fewer investors exploiting the arbitrage and a widening of the mispricing. Again the inflation risk premium is positive here suggesting that the mispricing is exposed to increased inflation risk leading the mispricing to widen.

In table 6 we regress the factors we used to explain the mispricing on the nominal bond and the synthetic bond separately. If there were no arbitrage opportunity then the factors should have an equal effect on both the nominal and the synthetic bond. First, we see that an increase in the swap spread leads to increased prices in the synthetic bond market but has little to no effect in the nominal bond market. The improved economic news related to an increased swap spread potentially leads to investors wanting to hedge inflation risk with inflation protected bonds. Because this news has only a small effect on the nominal bond market it leads to a fall in the mispricing. Similarly the VIX has a large positive effect on nominal bond prices but no effect on the synthetic bond market. This may be a flight to safety effect that widens the mispricing consistent with, Longstaff (2004), Krishnamurthy (2002) and Bansal et al. (2010) who argue that investors value the liquidity and safety of treasury bonds, i.e. the liquidity preference theory.

To investigate whether policy actions such as changes in the short-term interest rates

[10] Inflation expectations are based on survey data. Each forecaster reports a probability distribution over possible future values of inflation. From these data we calculate the forecaster's expected inflation $E_i\pi$ and the standard deviation of the agents forecast $\sigma_i(\pi)$. Disagreement is defined as the standard deviation of each forecasters expected inflation $\sigma(E_i\pi)$ and uncertainty is defined as the mean of the standard deviation of each forecaster's forecast, $E[\sigma_i(\pi)]$.

to maintain inflation targets affect the pricing differential, figure 3 plots the response of the mispricing to an increase in the short-term interest rate. If the pricing differential is a result of a pure arbitrage opportunity, we expect changes in the policy measures to have a marginal impact on the mispricing or perhaps widen the mispricing as the cost of fund to arbitrageurs increases. However, if the pricing differential acts as compensation for bearing inflation risk, changes in policy actions should have the effect on them. An unanticipated increase in interest rates may signal that policy makers expect inflation to be higher and the economy to be stronger in the future. As a result, the riskiness of the arbitrage strategy has been reduced.

We identify this change from a structural VAR, the estimation procedure of which we describe in Appendix B. We find that the increase in the short term rate lowers the mispricing in the short run (one to five months) but in the long run (1- year) leads to an increase in the mispricing. Presumably, an increase in the short term interest rate affects the nominal bond market more than the synthetic bond market leading to a larger fall in nominal bond prices. However, in the long run prices rebound and the mispricing ends up higher than before the shock. A possible interpretation of these results is that in the short run, an unexpected increase in the short term interest rate raises inflation expectations which lowers the mispricing through increased demand for inflation protected securities. However, eventually the increased interest rates lower economic activity and inflation, as evidenced by lower oil prices, leading to a rebound in the size of the mispricing. These results, then, are consistent with our original conjecture concerning the effect of macroeconomic variable that increased inflation expectations lower the mispricing as investors demand inflation protection to hedge against inflation rise, however when inflation expectations subside with weakened economic activity the demand dissipates.

5.1 Slow Moving Capital and Institutional Explanations

One proposed explanation for the limits of arbitrage is the lack of capital to narrow the arbitrage opportunity to zero. According to this slow moving capital theory, when more capital becomes available to arbitrageurs we should see a narrowing in the mispricing. Table 7 regresses the change in mispricing on lag returns (four) of various hedge fund indices. The indices represent global, macro strategy, relative value, convertible arbitrage, volatility, high yield, and fixed income sovereign hedge fund returns. We find no consistent evidence that past positive hedge fund returns result in lower mispricing. Of the six significant returns

– four are negative and two are positive. Importantly, we find no evidence that sovereign or relative value hedge funds returns are correlated with the mispricing. These results cast doubt on slow moving capital to explain the mispricing.

6 Eurozone Crisis

We view the eurozone crisis as an ideal environment to study the effects of the risk factors on the pricing differential. The euro area is informative due to the existence of numerous competing sovereign issuers– with different credit ratings and associated default probabilities– that issue obligations in the same currency, therefore the impact on yields of a fall in the credit rating of a particular issuer can be marked. The time period that our sample covers also lends well for this analysis as it covers the pre-and- post general financial markets distressed period and the euro crisis period including the late 2012 when the ECB's and other policy interventions appeared to have stabilized the credit market in the eurozone. Accordingly, we expect that the macro-financial, macroeconomic and policy measures to have substantially different effects on the eurozone pricing differential than with the non-eurozone pairs analyzed in this paper and to examine the behavior of the pricing anomaly in an environment with real economic tail risk and strong deflationary pressures.

The average pricing anomaly for the eurozone pairs is about \$4 which is considerably higher that the \$1.67 for the non-eurozone pairs. Figure 4 plots the time series of average and aggregate dollar mispricing for the eurozone countries and the average and aggregate mispricing for the non-eurozone countries. During 2011-12, when the crisis of confidence surrounding the Euro was at its peak the average mispricing for the eurozone countries is substantially higher than the average for the non-eurozone countries. Take Italy for example, whose secondary government bond market has the largest outstanding amount in the eurozone.[11] There the average mispricing jumps from \$7.8 for May 2008-December 2010 to \$10.74 for May 2011-August 2012, and then drops to \$3.31 for September-December 2012. This change of the mispricing for Italy coincides with rising sovereign credit risk in eurozone countries under financial stress and the CDS and bond market diverging signals as reported by Moody's on 21 December 2010 and 24 February 2011. Successively, Moody's on 17 Jun 2011 places Italy's Aa2 rating on review for possible downgrade and effectively downgrades it to A2 with negative outlook on 16 September 2011. A reversion for the eurozone countries

[11] Data on Italian bond market can be found at: https://www.mtsmarkets.com/data-and-participant-reports/market-data-reports

during the latter stages of 2012 coincides with a strengthening of support for the Euro on the part of the European Central Bank (ECB).[12] The corresponding figures for the same time period for the other two eurozone countries are \$3.23, \$2.82 and \$2.45 for Germany and \$1.13, \$1.79 and \$0.89 for France. The average mispricing for all three eurozone countries for May 2008-December 2010 is \$5.31, for November 2011-August 2012 \$4.27 and September 2012-December 2012 \$4.74. The corresponding figures for average mispricing for the non-eurozone countries were lower, and more stable, throughout this period, at \$1.88, \$1.79 and \$1.48 respectively.

During the eurozone crisis risk factors associated with the mispricing strategy: default risk, downside economic risk, deflation risk, were all more pronounced. If the mispricing between the nominal and synthetic bonds represents a compensation for risk then we would expect that the mispricing to be larger and more sensitive to risk factors in the eurozone countries particularly during the eurozone crisis. This indeed seems to be true. Table 8 redoes the analysis in table 2 – which examined the factors that correlated with the mispricing – restricting the regression to only the eurozone countries: Italy, France, and Germany. When we restrict the regression to the eurozone countries and the signs and significance of the coefficients do not change. However, the magnitudes become larger. For instance, the coefficient on the 10-Year swap spread is -0.015 versus -0.012 for all countries. More to the point, the coefficient on the VIX is 0.014 and the inflation risk premium (IRP) is 0.023 versus a value of 0.008 for both the VIX and IRP coefficients for all the countries. Again, our measure of liquidity, the bid-ask spread is not significant. The one clear difference between the eurozone regression and the baseline regression is that the hedge fund returns are now positive and significant. This suggests if anything hedge funds are exacerbating the mispricing as opposed to arbitraging it away. To summarize, the pricing anomaly is more pronounced in the eurozone area. This is consistent with the mispricing being a premium for taking on the risk associated with the possibility of persistent weak economic activity resulting from the ongoing euro crisis and fiscal consolidation in the eurozone.

[12] On March 05, 2012 the ECB provided additional three-year funding for the eurozone and on 30 July 2012 the governor of ECB Mario Draghi reassured the markets that ECB will continue with the support, but also warned that ECB cannot resolve the debt crisis. See https://www.moodys.com/credit-ratings/Italy-Government-of-credit-rating-423690 for Itali's credit rating.

7 Conclusion

Measuring inflation expectations is a key concern of economic policy makers. Central banks wish to prevent both a self-fulfilling inflation spiral brought on by increased inflation expectations and a self-fulfilling deflationary spiral brought on by deflationary expectations. A natural starting point in the measurement of inflation expectations is the break even inflation rate, the difference in yields, on matched nominal and inflation protected bonds. However, as noted by many academics and practitioners these break even inflation rates differ markedly from other measures of inflation expectations, particularly inflation swaps. On the whole the finance literature has viewed this departure as an arbitrage opportunity that calls into question no-arbitrage models of asset pricing. On the other hand, the macroeconomic literature has viewed this departure as a compensation for risk, specifically risk associated with holding less liquid inflation protected securities. Given the importance of inflation expectations and the dichotomous views in the macroeconomic and finance literature, it is surprising that no paper has yet performed a systematic study of the risk factors correlated with the pricing anomaly. This study is exactly what we have done in this paper.

We report new evidence that the pricing differential between sovereign nominal bonds and synthetic bonds that replicate nominal bonds' cash flow while hedging away the inflation risk is positive and persistent in all six of the countries that we analyzed. This mispricing occurs because the break-even inflation rate differs from the inflation rates implied by the swap market. We found that this mispricing correlated with volatility risk, inflation risk, and downside economic risk. We found little evidence that increasing the capital available to arbitrageurs reduced this mispricing. The mispricing was larger in the eurozone as was the magnitude of its correlation with the relevant risk factors. We interpret these results as being consistent with the mispricing being a compensation for risk. Models that model the mispricing as a compensation for risk are well-founded. And the inflation expectations implied by these models are likely accurate and useful for policy making.

Moving forward, this paper is supportive of the general notion that asset prices can be an important way to measure expectations, not only for inflation but for measures of future asset prices, economic activity, and interest rates. It suggests that features like segmented markets are less important in determining the asset prices and that potential arbitrage opportunities are more likely compensations for taking on risk. Consequently, reliable information on expectations can be extracted from financial markets with careful economic and financial modeling.

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8 Tables and Figures

8.1 Tables

Table 1: Summary statistics of mispricing

	Mean	Sdev	Min	Max	N
US	1.668	5.979	-20.951	35.110	911
UK	1.929	6.701	-14.486	25.263	229
JPN	1.738	2.343	-5.842	9.621	93
GER	3.121	2.013	-0.344	8.393	106
FRA	1.008	2.775	-6.432	10.497	226
ITA	8.712	9.484	-1.132	31.923	255
EU	3.948	7.347	-14.486	31.923	816
Non-EU	1.674	5.739	-20.951	35.110	1004

This table reports the summary statistics for the dollar indexed-bond-nominal bond mispricing for the 47 pairs of six of G7 countries. The mispricing is measured in dollars per $100 notional. Mean, Sdev, Min, Max and N report the average dollar mispricing for each pair we analyze, its standard deviation, the highest and lowest mispricing values and the number of monthly estimations for each security for each country respectively. The sample period spans from 2 February 2007 to 30 November 2012.

Table 2: Mispricing and Risk Factors

	Mispricing	Mispricing
10 year Swap Spread	-0.001*	-0.012***
	(0.001)	(0.004)
VIX	0.009***	0.008***
	(0.002)	(0.002)
Inflation Risk Premium	0.002**	0.008***
	(0.001)	(0.002)
Hedge Fund Returns	-0.028	0.032
	(0.018)	(0.021)
Illiquidity	0.005	0.004
	(0.006)	(0.008)
Country FE	No	Yes
Year FE	No	Yes
Constant	0.002	0.032***
	(0.002)	(0.010)
Adj. R-squared	0.02	0.05
N	1742	1742

This table regresses the change in mispricing on a variety of explanatory variables. The explanatory variables used to control for the systematic risk are the ten-year swap spread (10 year Swap Spread) for each country, VIX is the is the index of implied volatilities on equity index options for each country our proxy for the market's uncertainty, Inflation Risk Premium is the five-year Inflation Risk Premium (IRP) for each country and is estimated as the difference between the inflation swap and the expected inflation, as discussed in section 4; the expected inflation for five years comes from University of Michigan survey for the US; UK's expected inflation survey reported by BoE; Japan is used NATAKA survey reported in bank of Japan; and finally for the EU countries the expected inflation is the ECB survey. Hedge Fund Returns is the HFRX Hedge Fund global index return. Finally, Illiqudity is the bid-ask spreads of the inflation-indexed bonds of each security in our sample. Country FE denotes if country fixed effects are used to account for country specific factors that are constant over time. Year FE denotes if year fixed effects are used to account for time specific factors that are constant across countries. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

Table 3: Mispricing and Default Risk

	Mispricing	Mispricing_CDS
10 yearr SwapSpread	-1.306***	-0.973***
	(0.221)	(0.209)
VIX	0.733***	0.035
	(0.237)	(0.223)
Inflation Risk Premium	0.781***	0.722***
	(0.151)	(0.142)
Hedge Fund Returns	3.041	1.743
	(2.241)	(2.113)
Illiquidity	0.028	0.342
	(0.564)	(0.532)
Constant	3.591***	2.719***
	(0.586)	(0.553)
County FE	Yes	Yes
Year FE	Yes	Yes
Adj. R-squared	0.05	0.03
N	1742	1742

This table regresses the mispricing and the difference between the pricing differential and the CDS value for insuring against sovereign default. The explanatory variables are same as in table 2. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

Table 4: Macro variables and Inflation Expectations

	Mispricing	Mispricing
10 year Swap Spread	-0.012***	-0.011**
	(0.003)	(0.004)
Hedge Fund Returns	0.022	0.039*
	(0.020)	(0.023)
VIX	0.005*	0.003
	(0.003)	(0.003)
Inflation Risk Premium	0.007***	0.009***
	(0.002)	(0.002)
Illiquidity	0.007	0.009
	(0.008)	(0.008)
Δlog(Oil Price)	-0.021**	-0.021**
	(0.009)	(0.010)
ΔOvernight Bank Lending Rate	0.015***	0.010
	(0.005)	(0.006)
Δlog(Industrial Production)	0.021	0.061
	(0.038)	(0.058)
ΔGovernment Budget Deficit	-0.001	-0.002
	(0.001)	(0.001)
ΔMedian Inflation Expectations		-0.004
		(0.005)
ΔInflation Uncertainty		0.001
		(0.001)
ΔInflation Disagreement		0.002
		(0.003)
Constant	0.035***	0.030**
	(0.010)	(0.012)
Country FE	Yes	Yes
Year FE	Yes	Yes
Adj. R-squared	0.06	0.07
N	1742	1428

This table replicates the results in table 2 adding macroeconomic variables to examine the exposure of the mispricing to macroeconomic risk factors. The macroeconomic variables reported in this table are: Δlog(Oil Price) denotes log-changes in crude oil (West Texas Intermediate) spot prices. ΔOvernight Bank Lending Rate is the overnight bank lending rates which for the Fed Funds are rates from FRED for the US, for Japan, it is the basic loan rate, for the UK and the EURO area countries we use Libor and Euribor. Δlog(Industrial Production) is the industrial production our proxy on the state of the economy. Government deficits (ΔGovernment Budget Deficit) are used as they can be associated with larger default risk and potentially affect bond prices. Inflation expectations (ΔMedian Inflation Expectations) are used here because increased inflation expectations could increase demand for inflation protected securities and also be consistent with an improved outlook on the economy. Finally, ΔInflation Uncertainty is defined as the mean of the standard deviation of each forecaster's forecast, $E[\sigma_i(\pi)]$ for next year and ΔInflation Disagreement is defined as the standard deviation of each forecasters expected inflation $\sigma(E_i\pi)$. Δ denotes the first difference of the variables. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

Table 5: Forecasting the Change in Mispricing

	Mispricing	Mispricing
10 year Swap Spread$_{t-1}$	-0.000	-0.002
	(0.001)	(0.004)
VIX$_{t-1}$	0.006**	0.005**
	(0.002)	(0.002)
Inflation Risk Premium$_{t-1}$	0.002*	0.004**
	(0.001)	(0.002)
Hedge Fund Returns$_{t-1}$	-0.013	0.020
	(0.021)	(0.020)
Illiquidity$_{t-1}$	0.009	0.014*
	(0.006)	(0.007)
Constant	-0.001	0.011
	(0.002)	(0.012)
Country FE	No	Yes
Year FE	No	Yes
Adj. R-squared	0.01	0.02
N	1742	1742

This table examined the ability to forecast the mispricing using lags of the relevant risk factors. The explanatory variables are same as in table 2. The time subscripts $_{t-1}$ denotes lag one in variables. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

Table 6: Factors on Nominal and Synthetic Bond

	Nominal_Bond	Synthetic_Bond	Mispricing
10 year Swap Spread	-0.004	0.008**	-0.012***
	(0.003)	(0.004)	(0.002)
VIX	0.007**	-0.001	0.008***
	(0.003)	(0.004)	(0.002)
Inflation Risk Premium	0.001	-0.007***	0.008***
	(0.002)	(0.002)	(0.001)
Hedge Fund Returns	0.001	-0.031	0.032
	(0.028)	(0.036)	(0.021)
Illiquidity	-0.021***	-0.025***	0.004
	(0.007)	(0.009)	(0.005)
Constant	0.016**	-0.016*	0.032***
	(0.007)	(0.009)	(0.005)
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adj. R-squared	0.02	0.01	0.05
N	1742	1742	1742

This table decomposes the effect on the mispricing into effects on the nominal bond and the synthetic bond. The explanatory variables are same as in table 2. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

Table 7: Hedge Fund Regressions

	Misp Global	Misp Mcr	Misp Rv	Misp Conv	Misp Vol	Misp Yield	Misp Sov
lag 1	-0.032	-0.003	-0.040	-0.057	0.026	-0.035*	-0.078
	(0.026)	(0.031)	(0.045)	(0.043)	(0.022)	(0.021)	(0.056)
lag 2	-0.046**	-0.014	-0.024	-0.001	-0.127***	-0.044	-0.059
	(0.022)	(0.036)	(0.034)	(0.028)	(0.030)	(0.031)	(0.040)
lag 3	0.056**	0.017	0.016	0.009	0.044**	-0.008	0.007
	(0.024)	(0.026)	(0.041)	(0.035)	(0.021)	(0.020)	(0.034)
lag 4	-0.000	-0.073**	0.023	0.019	0.060***	0.019	0.005
	(0.017)	(0.032)	(0.027)	(0.019)	(0.019)	(0.022)	(0.026)
Constant	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
FE	No	No	No	No	No	No	No
Adj. R^2	0.01	0.01	0.01	0.02	0.02	0.01	0.02

This table regresses future mispricing on lag changes in various hedge fund returns. All hedge fund returns are subcategories of the HFRX Index. Global denotes the HFRX global index returns, the MCR extension stands for the HFRX Macro-Strategy Index, RV denotes the HRFX Relative Value Arbitrage Index, Conv denotes the HFRX Fixed-Income Convertible Arbitrage Index.Vol is the HFRX Volatility Strategies Index. Yield denotes the HFRX Fixed Income Alternative Yield Index and finally, Sov is for the HFRX Fixed-Income Sovereign Index. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

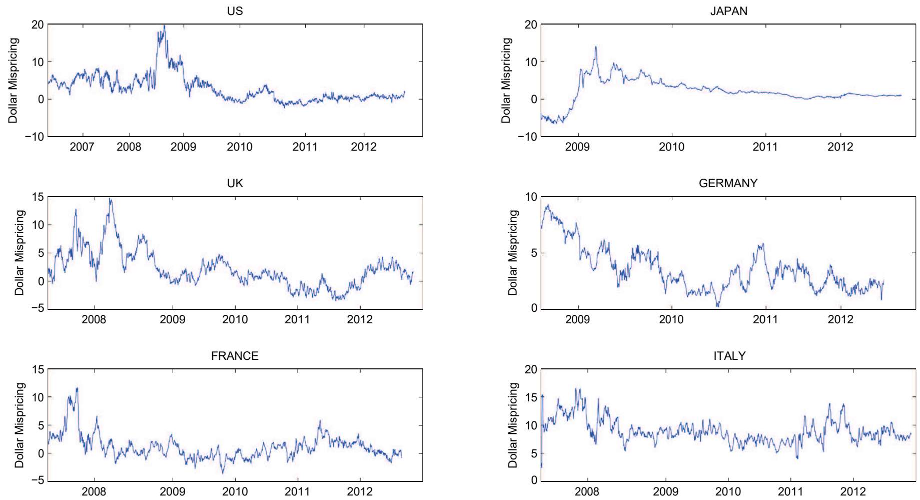
Table 8: Mispricing in the Eurozone Countries

	Mispricing	Mispricing
10 year Swap Spread	-0.014**	-0.015**
	(0.006)	(0.007)
VIX	0.013***	0.014***
	(0.004)	(0.004)
Inflation Risk Premium	0.024***	0.023***
	(0.005)	(0.006)
Hedge Fund Returns	0.055*	0.080**
	(0.033)	(0.038)
Illiquidity	0.009	0.012
	(0.006)	(0.009)
Country FE	No	Yes
Year FE	No	Yes
Constant	0.029**	0.031**
	(0.014)	(0.015)
Adj. R-squared	0.10	0.11
N	572	572

This table replicates the results for table 2 restricting the sample to only the eurozone countries (France, Germany and Italy). The explanatory variables are same as in table 2. The sample period spans from 2 February 2007 to 30 November 2012. Significance levels : * : 10%, ** : 5%, and *** : 1%.

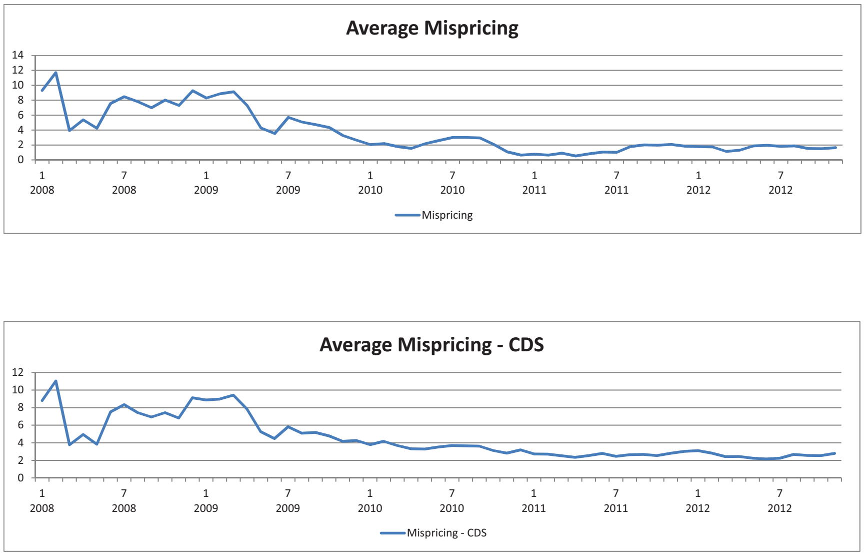
8.2 Figures

Figure 1: Time-series of mispricing by country



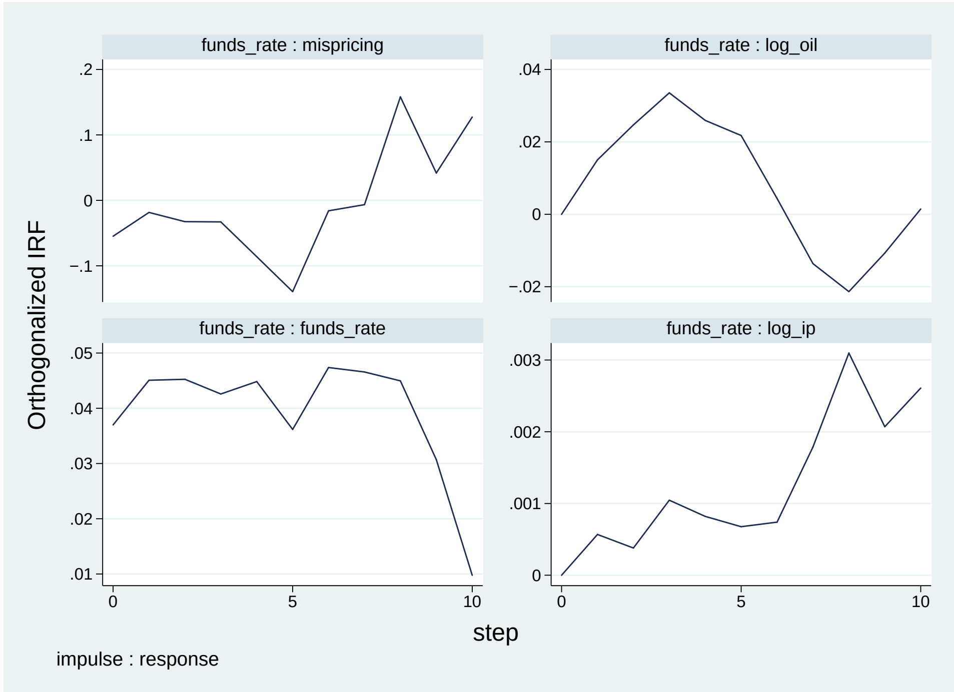
This figure plots the time series of the dollar nominal bond and indexed bond mispricing for all six countries in the study. From the top-left to the bottom-right are the United States, Japan, United Kingdom, Germany, France and Italy. The mispricing is expressed in units of dollars per $100 notional across the pairs included in the sample. The sample period spans from 2 February 2007 to 30 November 2012.

Figure 2: Mispricing with and without CDS



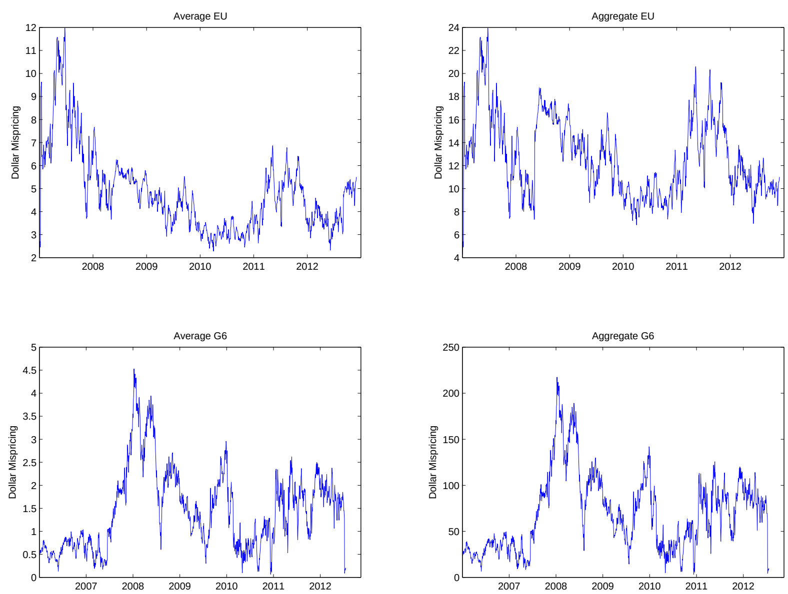
This figure plots the time series of the average dollar mispricing for all six countries in the study in the top panel. The bottom panel plots the difference between the pricing differential and the CDS spreads for all six G7 countires. The sample period spans from 2 February 2007 to 30 November 2012.

Figure 3: Response of the Mispricing to an increase in short term interest rates



This figure plots the response of the mispricing to an increase in the short-term interest rate. We identify this change from a structural VAR the estimation procedure of which we describe in Appendix B. The sample period spans from 2 February 2007 to 30 November 2012.

Figure 4: Mispricing by Eurozone and Non-Eurozone



This figure plots the average and aggregate mispricing for the eurozone countries (top two figures) and the G7 countries (bottom two figures) separately. The sample period spans from 2 February 2007 to 30 November 2012.

A Appendix

Table A.1: Example of the Synthetic Treasury Bond Replicating Strategy

Date	Nominal Bond	Inflation Linked Bond	Swaps	Strips	Total
0	-120.065	-121.167	0	0	-114.806
1	4.25	1.25	3.0863	99.502	4.25
2	4.25	1.25	2.949	98.919	4.25
3	4.25	1.25	2.9375	97.832	4.25
4	4.25	1.25	2.954	96.28	4.25
5	4.25	1.25	3.0145	94.101	4.25
6	4.25	1.25	3.0535	91.481	4.25
7	4.25	1.25	3.0715	88.537	4.25
8	4.25	1.25	3.0885	85.327	4.25
9	4.25	1.25	3.1085	81.865	4.25
10	4.25	1.25	3.1285	79.336	4.25
11	4.25	1.25	3.156	75.147	4.25
12	4.25	1.25	3.1835	71.973	4.25
13	4.25	1.25	3.203333	69.47	4.25
14	4.25	1.25	3.223167	67.029	4.25
15	4.25	1.25	3.243	63.895	4.25
16	104.25	101.25	3.2534	61.732	104.25

This table represents the cash flow of the synthetic Treasury bond replicating strategy for the British Gilt. The example is based on market prices for December 30, 2008. Cash flows are in dollars per $100 notional. Data refers to the number of semiannual periods in which the corresponding cash flows are paid.

Table A.2: Summary Statistics for Indexed Bond and Nominal Bond Mispricing

Country	Bond	Mean	Std Dev	Min	Max	N
US	9128273T7 Govt	0.473818	0.608301	-0.75807	1.56932	260
	9128274Y5 Govt	1.149634	1.997438	-2.30539	5.83507	509
	9128276R8 Govt	-0.49711	3.365862	-6.75494	12.9232	1031
	9128277J5 Govt	-8.57818	2.435065	-16.2667	-2.4167	789
	912828HW3 Govt	0.614417	0.720675	-1.264	2.24355	690
	912828BW9 Govt	0.132251	1.76571	-3.47038	3.21973	489
	912828KM1 Govt	0.650291	1.011809	-2.25216	1.99604	425
	912828DH0 Govt	0.169442	1.025245	-2.40485	2.34732	760

	912828MY3 Govt	0.685582	0.466232	-0.74717	1.99447	676
	912828ET3 Govt	0.918346	1.511814	-2.5179	3.76841	478
	912828FL9 Govt	-0.17754	1.320126	-3.02284	2.45119	349
	912828GD6 Govt	0.427902	1.756713	-3.45436	3.83675	738
	912828GX2 Govt	-1.06327	1.996	-4.42326	2.65476	608
	912828HN3 Govt	1.778408	2.191727	-2.258	15.2301	1254
	912828JE1 Govt	2.794045	2.424485	-0.16315	16.2104	1124
	912828JX9 Govt	0.295088	2.297528	-4.19241	5.14224	989
	912828LA6 Govt	0.366177	1.325034	-2.40788	3.41761	859
	912828MF4 Govt	1.915639	1.079385	-0.57304	4.46032	729
	912828NM8 Govt	5.651621	2.960364	-0.68702	13.1158	623
	912828PP9 Govt	4.275123	1.666725	-0.1526	7.95571	483
	912828QV5 Govt	3.786666	1.936576	-0.81146	9.16555	352
	912810FR4 Govt	2.763792	14.76704	-23.5621	43.3745	1518
	912810FS2 Govt	3.27054	9.306411	-15.7327	35.9954	1518
	912810PS1 Govt	7.256481	5.052304	-3.90816	29.4104	1518
	912810PZ5 Govt	3.886574	2.928073	-1.21567	15.2888	1000
UK	EF2659706 Govt	10.2992	6.158193	-1.11305	28.0361	1169
	EF372237 Corp	1.754571	3.79779	-8.86609	17.0083	1169
	EH600918 Corp	-0.37957	3.56943	-7.13103	12.0705	1066
	EI684934 Corp	-6.57564	4.693748	-16.6222	3.24268	393
	EG196397 Corp	-1.27766	4.690193	-11.9449	14.9609	1169
JPN	ED361990 Corp	1.872471	3.336213	-6.49681	13.9764	962
	ED970564 Corp	1.858236	1.052301	-0.16523	5.01058	640
	EF315225 Corp	1.261708	0.740351	-0.36436	2.71647	446
GER	EF3134212 Govt	4.620606	2.158364	0.562132	9.28116	906
	EI639514 Corp	2.87287	0.99461	0.99194	6.3381	425
	EH8565820 Govt	1.902064	1.49165	-1.53496	6.14725	802
	EJ0993182 Govt	1.646408	1.42641	-1.4361	7.43587	186
FR	EI540344 Corp	2.746088	1.368635	-0.1394	6.39208	484
	EF081090 Corp	2.934133	2.261963	-0.61744	12.2952	1134
	EI112670 Corp	0.89512	1.29581	1.29581	-2.02165	745
	EH212767 Corp	0.818301	2.261909	-4.26618	12.4649	1134
	EC182706 Corp	-1.33829	3.420107	-9.98226	15.7638	1134

ITA	ED327992 Corp	1.533497	1.508123	-2.24357	7.27873	1176
	EI548734 Corp	3.810467	1.962579	-0.86918	9.55976	459
	EF504151 Corp	5.065591	2.67445	-2.21454	18.4674	1184
	EH378395 Corp	3.01773	2.802823	-1.96346	15.4255	936
	EI230886 Corp	8.879322	2.921224	3.18259	17.1478	648

This table reports the summary statistics for the dollar-index and nominal bond mispricing for the 48 pairs of six G7 countries. The mispricing is measured in dollars per \$100 notional. The sample period spans from 2 February 2007 to 30 November 2012.

B Structural VAR

Let $q_t = \{m_t, i_t, ip_t, oil_t\}$ be the vector of variables: the mispricing, overnight interest rate, industrial production and oil price. We can write the vector auto regression (VAR) in matrix form:

$$q_t = Bq_{t-1} + u_t \;\text{ with } Var(u_t) = \Sigma$$

where u_t are the forecast errors of the VAR. We assume there are four structural disturbances in the economy $\varepsilon_t = \begin{pmatrix} \varepsilon_t^1 \\ \varepsilon_t^i \\ \varepsilon_t^3 \\ \varepsilon_t^4 \end{pmatrix}$ with $Var(\varepsilon_t) = I$ which relate to the forecast errors by $u_t = S\varepsilon_t$. Here ε_t^i is the shock to the short term interest rate. We assume that S is a lower triangular matrix. This implies that the shocks to the short term interest rate do not effect industrial production and oil prices within the month and that the central bank does not respond to the mispricing in setting interest rates. We then have

$$\Sigma = SS'$$

and therefore S can be recovered using the Cholesky decomposition on the estimate of the forecast error variance-covariance matrix. Finally we can calculate impulse responses using the dynamic system setting $q_0 = \overrightarrow{0}$.:

$$q_t = Bq_{t-1} + S\varepsilon_t$$