Inflation-Indexed Bonds in the Eurozone

Ph.D. Dissertation

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Abstract

The thesis consists in two papers exploiting thorughly the inflation-indexed bond markets in the Eurozone. In the first paper, after presenting some empirical stylized facts about the European sovereign inflation-indexed markets we address the effectiveness of nominal and real rational expectation hypothesis and of inflation-expectation hypothesis. Then, we document the existence of a liquidity premium and of a default premium for France, Italy and Germany, moving from a market based measure of inflation.
The second paper is about yield curve modeling and forecasting. We provide a three-factor yield curve model delivering estimates for nominal term structure of France, Germany and Italy, from January 2000 to December 2016 and for real term structure of France and Italy from July 2003 to December 2016. The framework is the latent factor model with time varying level, slope and curvature. The overall fitting performances is good and the identification is consistent with many shapes assumed by the term structure. After the empirical estimation we forecast the yield curve by forecasting the factors and we compare them with several standard competitors. Lastly, we document for the first time a significant liquidity issue on short-term real bond spreads and of a default premium affecting more heavily real spreads as compared to nominal across various maturities.

Contents

Thesis Details

Thesis Title:	Inflation-Linked Bonds in the Eurozone
Ph.D. Student:	Jacopo Sorbo
Supervisor:	Prof. Alessandro Missale

The main body of this thesis consist of the following papers.

[A] J. Sorbo, “Inflation-Linked Bonds in the Eurozone”.

[B] J. Sorbo, “Eurozone Nominal and Real Sovereign Term Structure”.

This thesis has been submitted for assessment in partial fulfillment of the PhD degree. The thesis is based on the submitted scientific papers which are listed above. Parts of the papers are used directly or indirectly in the extended summary of the thesis.

Preface

This thesis summarizes much of the effort, thinking and feelings part of my last four years. It would not have been possible without the help and support of many people, to whom I want to express my gratitude.

First and foremost, I am deeply indebted to my supervisor, Alessandro Missale, who helped me much more than what it is required to a supervisor. He provided invaluable guidance and support throughout the years, teaching me what doing research means. And I need to thank him even more for being present and available, for the time he spent whenever I knocked at his door, for the encouragement he provided and for the brightness of the revisions.

During the PhD I had the privilege of spending some of my time in the Economics and Financial Markets Unit of the European Stability Mechanism in Luxembourg. I would like to thank Juan Rojas and Angel Gavilan, for the possibility they gave me to join this resolving European institution and to write part of the second chapter of this thesis in that stimulating environment.

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I would like to extend my gratitude to the staff at the Economics, Management and Quantitative Methods of the L.A.S.E.R. Doctoral School.

Many thanks go to all my classmates and friends who contributed to make my last four years more pleasant. In particular, a special mention goes to my dearest officemates at the Department: Andrea, Danilo and Veronica and at the ESM: Carmine, Kimi and Lorenzo, for all the advices, encouragement and support that only those who pass through the PhD experience can provide. I would like to thank also all my other friends and kins, for reminding me that there is an entire life outside the PhD.

Finally, I thank my family who have always supported me unconditionally, encouraging me to do what I really like, knowing that I have such a safe place where to go back makes my life much easier. In particular I would like to thank my parents Angela and Giuseppe and my grandmother, Wally, for have taugh me the value of education, independent

thinking and the dedication in achieving daunting goals while always maintaining a positive outlook. They probably would have never thought that I would embark on a journey that would last so long and bring me to many different countries. Without their unfaltering love and support, I could never have done it.
I take advantage of this last revision to mention Maura, who recently came into my life. She quickly became a lovely cornestone making everithing so much better.
Lastly, I would like to thank the two anonymous referees in charge of revising this work. They provided usefull comments which definitely improved the quality of this thesis.

Jacopo Sorbo
November, 2017

Part I

Introduction

Introduction

The aim of this thesis is to provide a thourough analysis of infltion-indexed bond markets in the Eurozone. Inflation-linked bonds gained popularity in recent years but scholarly interest on the topic is focused just on the U.S. and the U.K markets. The thesis wants to fill this gap providing a comprehensive investigation of the phenomenon across the Eurozone. The focus is on the first three major European issuers of inflation-linked bonds: France, Germany and Italy, respectively the third, the fourth and the sixth largest issuers worldwide. In the first chapter, after providing some stylized facts about real bonds markets and compare them with nominal bonds markets across the Eurozone, we test and reject the nominal and real rational expectations hypothesis of the term structure, suggesting that investors in inflation-indexed bond market face a time-varying risk premium that reflects a time-varying real interest rate risk premium adn possibly also a time-varying liquidity premium. Moreover, we explore the source of time variation in euro area nominal and real bond markets, documenting the presence of both liquidity and default premia for France, Germany and Italy.

In the second chapter we develop a three-factor yield curve model delivering estimates for nominal and real term structure of France, Germany and Italy. The framework is the Nelson-Siegel latent factor model with time varying level, slope and curvature. After finding good overall fitting performace across countries we check for the forecasting performance of the Nelson-Siegel latent factor model specification with a selection of natural competitors. Lastly, we provide empirical evidence of a significant effect of liquidity risk on short-term real bond spreads and of a default premium affecting more heavily real spreads as compared to nominal across various maturities.

Part II

Papers

Paper A

Inflation-Linked Bonds in the Eurozone

Jacopo Sorbo

The layout has been revised.

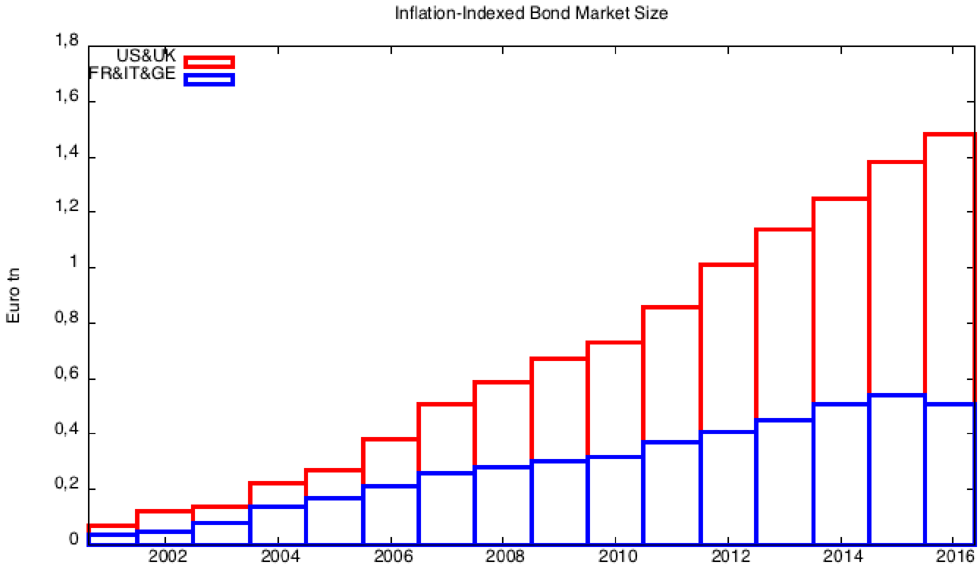
Abstract

The aim of this paper is to provide a thourough analysis of inflation-indexed bond markets in the Eurozone. After presenting some empirical stylized facts about the European sovereign inflation-indexed markets we move to address the effectiveness of nominal and real rational expectation hypothesis. Furthermore, we document the existence of a liquidity premium and of a default premium for France, Italy and Germany.

1 Introduction

The aim of this paper is to provide a thourough analysis of inflation-indexed bond [1] markets in the Eurozone. Inflation-linked bonds gained popularity in recent years. As showed in Figure **A.1**, the global volume has increased more then tenfold since the beginning of the century with the U.S., the U.K., France, Italy, Japan and Germany as the largest issuers worldwide. Scholarly interest on the topic is widespread and longstanding but focused only on the U.S. and the U.K. markets. Nowadays, after almost fifteen years since the launch of the French OATei in October 2001, data are rich enough both in cross-sectional and time series dimension to allow for a comprehensive investigation of the phenomenon across the Eurozone.

Fig. A.1: Inflation Indexed Bond Market Size



Inflation-linked bonds share certain features with equities, in that they provide protection against inflation and also possess bondlike features, such as promised fixed payments. Generally speaking, increased interest in real bonds is due both to theoretical and empirical reasons. By a theoretical angle, governments, central banks and private investors can be interested in understanding thoroughly how European inflation-linked

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[1] Throughout the paper *inflation-indexed*, *inflation-linked*, *real-return bonds*, *index-linked*, *real bonds*, *inflation bonds* or the short-form nickname *linkers* will be used interchangeably, with nothing meant by the choice of one rather than another.

bond markets work. Goverments can be interested because indexing sovereign debt allows sounder practice in public debt management, like mathcing asset and liabilities and allows also to reduce the overall debt service. Central banks can be interested in using sovereign linkers to derive a market-based measure of real interest rate and of inflation expectations, in order to better gauge monetary policy decisions. In this framework, a complete comprehension of the inflation-indexed markets should allow central bankers understanding whether long-term breakeven inflation rates are unbiased proxy of inflation expectations, or whether one ore more time-varying risk premia play a role in their path. Private investors, both institutionals and retails, can be interested because sovereign linkers provide full hedge against inflation risk and allow to diversify the optimal portfolio.

The practical reasons why interest about inflation-linked bonds aroused relate to their distinctive behaviour. European real bonds exploited higher returns on average and lower yield volatility, as compared with nominal bonds and equity. Furthermore, they are recognised as a unique asset for their negative correlation with other asset classes. Despite all these features, several puzzles are still open. First of all, is unclear how short term real interest rate affects long-term real yield. Then, is even questionable whether the risk premia embodied in inflation-linked bonds are constant or time-varying and which of them is the largest in magnitude. Lastly, is worth of attention quantifying the presence of a liquidity and/or a default premium. Nevertheless, the existing literature on the topic is devoid of a comprehensive analysis about Eurozone inflation-indexed bonds. An attempt to fill this gap is provided in the following sections.

Section 2 presents a review of the current literature, almost completely devoted to U.S. TIPS[2] and U.K. GILTS[3]. Section 3 briefly describes data. Section 4 identifies several stylized facts about European linkers. Section 5 investigates the predictability of excess returns testing nominal and real rational Expectations Hypothesis of the term structure. While return predictability of US and UK real bonds has been tested by Pflueger et al. 2011, this is the first article to provide direct empirical evidence for predictability of returns in real bonds across the Eurozone. Section 6 checks for the presence of liquidity and default premia and Section 7 concludes.

2 Literature Review

The existing studies dealing with inflation-indexed bonds are almost completely devoted to U.S. and U.K. markets, mainly why these countries were the only to provide datasets rich enough to be used in empirical research in both time series dimension and cross sectional dimension.

A first attempt to analyze the impact of real bonds on sovereing debt was by Campbell

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[2] TIPS is the acronyme for Treasury Inflation-Protected Securities, the inflation-indexed bond issued by the U.S. Treasury.

[3] GILT stands for index-linked bonds issued by the U.K. Treasury.

and Shiller (1996). In the paper is presented a methodology to build-up artificially severall indexed-bond yields using short-term T-bill rate and CPI inflation. They try also to investigate how different could have been the returns on indexed bonds from that on nominal U.S. securities, how the financing cost for the federal government could have been affected issuing inflation-linked debt and, lastly, how the information content of real bonds could have helped in formulating monetary policy decisions.

Shen (1998), checks for the presence of an inflation risk premium in the U.K. using almost twenty years of GILTS data and depicted how this premium waved during the 1990s.

Roll (2004), provides an extensive analysis of TIPS returns moments, correlations and volatilities from the beginning of the issuance program, in 1997, to the end of 2003.

Garcia and Van Rixtel, (2006) exploit the connections between indexed securities and central bank. They point-out the rationales for and against the issuance of real bonds and show how these bonds can be used to better monitor investors' inflation expectations.

Campbel, Shiller and Viceira (2009), analyze in depth the U.S. and the U.K. real bond markets after ten-year from TIPS launch, documenting the paths of long-term real yields, of break-even inflation rates and of daily nominal and real returns. The authors check also for the covariance of these returns with equity and document empirically the existence of a risk premium.

To have a wider angle on inflation-linked securities, an essential reference is the book by Deacon, Derry and Mirfendereski (2004), which represents an extensive review of indexed debt markets throughout the world.

Pfluefger and Viceira, (2011), analyze empirically the Expectations Hypothesis in nominal and real bonds from the U.S. and the U.K. rejecting both of them. They find also strong evidence in favour of a time-varying nominal and real risk premium.

Again Pflueger and Viceira (2016), evaluate the liquidity differential between nominal and real bond yields and provide an estimation of a liquidity premium in the U.S. and the U.K. bond markets.

3 Data

Various datasets have been used to run all the analyses thrughout the paper. The building block of each dataset are yields of nominal and inflation-indexed bonds issued by France, Italy and Germany, since 2001, 2003 and 2006 to 2016. All series have been retrieved through Reuters Datastream and Bloomberg. All yields are sampled at monthly frequency. All countries in the sample use as a reference inflation measure the Harmonized Consumer Price Index tobacco excluded (HCPIx) provided monthly by Eurostat. Expected inflation is proxied with the long-term survey of professional forecasters (SPF) provided by the European Central Bank. Data about the 10-year inflation swap for the euro area and the monthly CDS quotes are retrieved through

Reuters Datastream.

4 Inflation-Indexed Bond Markets: Stylized Facts

This section presents a comprehensive analysis of French, Italian and German inflation-indexed bonds market.

The European market represents the third inflation-linked largest markets worldwide, after the U.S. and the U.K. Real bonds are free from deflation risk since French, Italian and German Treasury have established a floor in the event of deflation. The reference index chosen by each country is the HCPI excluded tobacco. Inflation-indexed bonds accrue inflation hinging on its first release, not counting any subsequent revisions.

Each Panel of Figure **A.2**, shows two series. The red-bars represent the percentage ratio between the outstanding amount of inflation-indexed securities and the overall government debt. The blue-bars relate the outstanding inflation-linked debt to GDP.

France have been the first Eurozone country to issue inflation-linked bonds anchored to euro area inflation, the OATei, since 2001. The market grew steadily, with a pike in 2008, when about the 12% of the marketable debt was indexed, and now settles at 10%, as from the first Panel of Figure **A.2**.

Italy, after a minor inflation-linked issuance in 1983, started a new issuance program with the BTPei in October 2003. Even the Italian ratio of real bonds over government debt increased constantly throughout all our reference period, reaching the 12% of the whole marketable debt in 2016. The second Panel of Figure **A.2** shows this path.

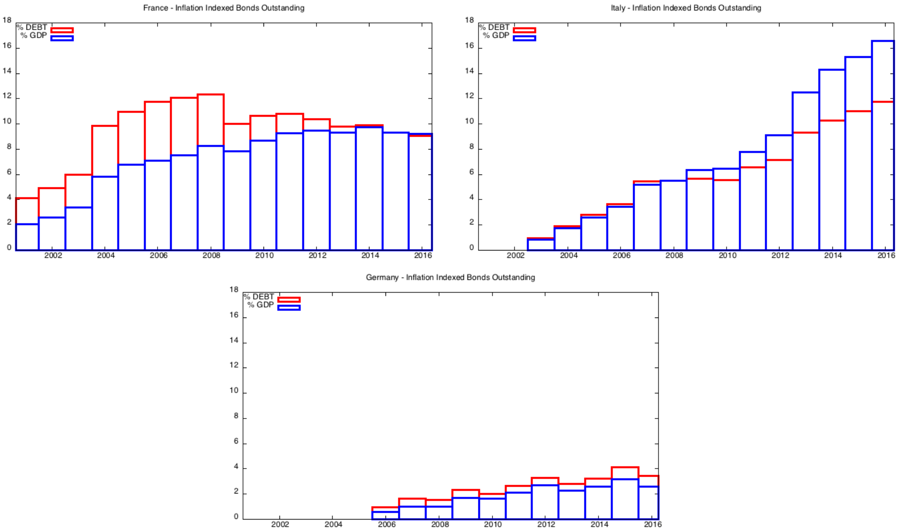
Germany started issuing inflation-linked bonds, named Bundei, in 2006. Since the end of the II world war to 1999, when the country joined the European Monetary Union (EMU), a ban on any kind of indexation for financial securities was enlisted in the Federal Constitution, so the Bundei is the first indexed asset issued in Germany after 1945. German linkers are initially placed in smaller volumes across a number of months, followed by smaller increases until each security approaches the benchmark threshold of euro 10 to 15 billion. As from the third Panel of Figure **A.2**, inflation-indexed securities are currently still far below the 10% of the overall German marketable debt and, after a moderate growth started in 2009, are waving around the 4%. An overview of the gross issuances path of each country is provided in Figure **A.3**.

In our analysis the focus is on 10-year maturity yields why this maturity represents the usual benchmark to analyze long-term bond markets.This section provides some stylized facts about 10-year nominal and real yields.

Figure **A.4** plots the yields on 10-year nominal and inflation-indexed bonds over the period from February 2003 to December 2016.

French yields are depicted in the first Panel of Figure **A.4**. The graph shows a decline in both nominal and real long-term interest rates, exhibiting three peaks, the first in 2007, the second in 2008, after the Lehman crisis and the third in the last months of

Fig. A.2: Inflation Indexed Bonds Outstanding. France, Italy and Germany



2011 when, during the European sovereign crisis, Standard&Poor's[4] stripped France of it's AAA, downgrading it's debt of one notch. The gap between the two series remained almost constant across years. This gap corresponds to the breakeven inflation rate, namely the yield spread between nominal and inflation-indexed bonds with equal maturity. Breakeven inflation reaflects the overall inflation compensation requested to hold nominal bonds, comprising both the expected level of inflation and a premium to compensate for inflation risks.

Figure **A.4**, second Panel, plots nominal and real yields for Italy, since 2006 to 2016. The graph delivers several interesting results. Both series exhibit an upward trend from 2006 to 2009 since when they start to decline. Another upward path started in 2011, with a first peak in September. The reason is the sovereign downgrade by S&P of two notches, from A+ to A-.

The second peak, November and December 2011, identifies the worst point of the sovereign crisis in Italy, characterized by a government's change and by the approval of an emergency austerity budget of Euro 30 billions. Nonetheless, the long-term financing cost remains near the huge threshold of 7% for two months. After these troubled periods the trend for both nominal and real yields sloped downward getting back to pre-crisis level in 2014. The turmoil affected substantially the breakeven inflation rate and nullified it in the crisis period, ashappened in the U.S. during the Lehman Crisis. This latter fact, suggests the presence of a liquidity premium embodied in real rates,

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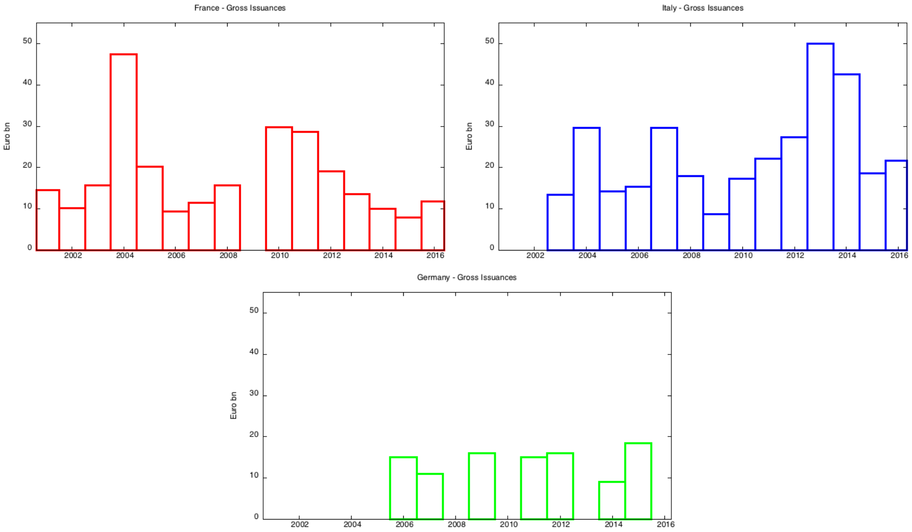
[4] henceforth, S&P

Fig. A.3: Inflation-Indexed Bonds - Gross Issuances



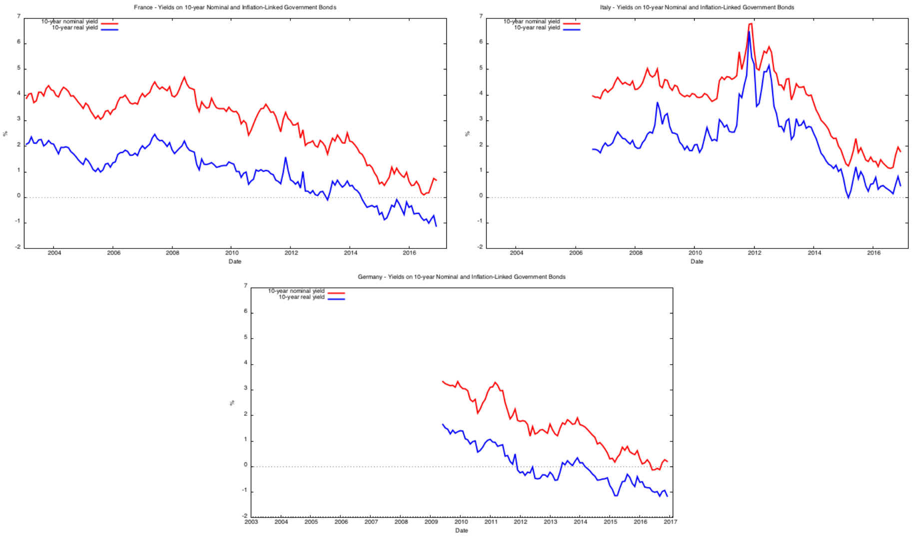
capable of drive indexed yields very close to their equivalent nominal and eventually, a default mechanism affecting heavier the less liquid bonds, namely the real ones.

Figure **A.4**, third Panel, shows the nominal and real yields history for Germany, since 2009 to 2016. The two curves exhibit a downward trend, reaching even negative values. The sizeable decline of German long-term cost of financing, approximately 300 basis points of reduction, can be explained by the "safe heaven" effect characterizing Eurozones' core countries. This phenomenon is a portfolio rebalancing effect on safer assets that, pushing up prices originates yields' fall.

Table **A.1** provides summary statistics for nominal and real 10-year bonds issued by France, Italy and Germany along with the sample period. All values are expressed in percentage per year. As we can see, across all the issuance period Italy experienced the highest average nominal and real yields, 3.78% and 2.24%, Germany the lowest, 1.59% and 0.02%, and France is in between with 2.90% and 0.95%. The same path characterize the standard deviations.

Table **A.2** shows the correlation coefficients of the same series for France, Italy and Germany. We see that nominal and real bonds are strongly and positively correlated within each country, with a coefficient of 0.96 for all our sample. If we look at the correlation between countries, we notice that all the series are again positively correlated but the coefficients decrease in magnitude, especially Italian nominal and real bonds appear to be less correlated with the corresponding French and German securities.

Fig. A.4: Yields on 10-Year Nominal and Real Government Bond. France, Italy and Germany



The first Panel of Figure **A.5**, shows the 10-year breakeven inflation rate of each country computed as the difference between the 10-year nominal yield and the 10-year real yield.

Red line relates to France. It shows an almost constant path around the 2% in breakeven inflation from the beginning of the sample to the first peak occured in 2009. Then, a slight decrease preceeded the second pike, in 2011. Since then, the series exhibit a smoothed and constant decline up untill mid 2016.

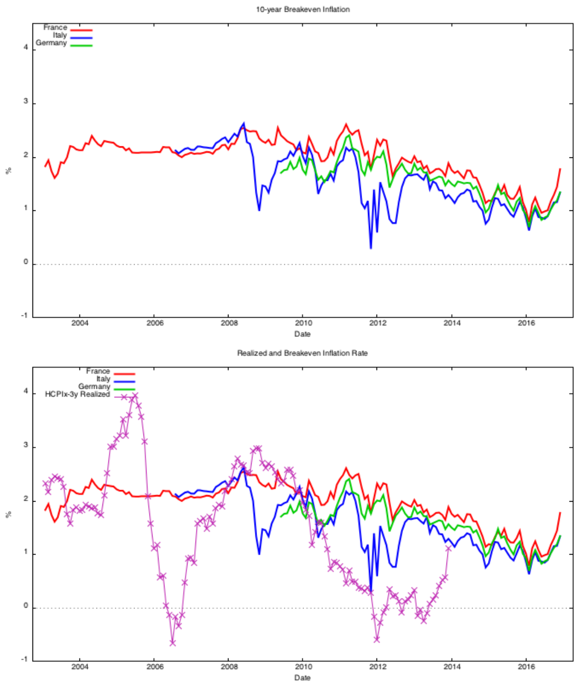
Italy, the blue line, shows a flat path since 2006 to 2008, when the breakeven inflation sharply declined. Then, after a period of recovery, the rate collapses again during the sovereign crisis of 2011. After 2013 the path is similar to the concurrent series.

The green line highlights German rate. In this case the breakeven inflation waves around 1.5% for the all sample period.

The second Panel of Figure **A.5**, plots the breakeven inflation rate of all countries along with the subsequently realized 3-year inflation rate computed on the HCPI, tobacco excluded, the reference for each bond indexation.

Subsequently realized inflation matchs satisfactorily the flat path of breakeven inflation after the first French issuance, the upward path started in 2006 lasted for two years, the four-year downward path started in 2008 and the last period of recovery.

Fig. A.5: Breakeven Inflation Rates



5 Nominal and Real Expectations Hypothesis

The aim of this section is to address empirically the magnitude and time-variation of the term risk premium in both nominal and real European sovereigns.
The starting point is the well-known rational expectations hypothesis of the term structure of interest rates[5] (henceforth, EH).

5.1 The Expectations Hypothesis

The expectations hypothesis of the term structure of interst rates says that a risk-neutral investor should be indifferent in invest in a long-term n-period bond and hold it until maturity, or buy and roll over a sequence of short-term discount bonds over the entire life of the long-term bond. Thus, it implies that the excess return on an n-period

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[5] for a detailed treatise of the various definition of rational expectations hypothesis, a valuable resource is Campbell, Lo, MacKinlay, 1996, chapter 10.

bond over a short term bond should be constant over time and there should not be any particularly good time to hold short-term or long-term bonds.

The EH is a longstanding topic among financial economists who formulated it in many ways trying to address empirically it's validity. In the extensive literature on EH, many emprical tests often rejected it, especially when related to nominal bonds. Campbell and Shiller (1991) present regression results for different combinations of maturities and holding periods and resoundingly reject the expectations hypothesis for U.S. nominal bonds. Fama and Bliss (1987), Cochrane and Piazzesi (2005) and others have also presented robust empirical evidence that nominal Treasury bond risk premia vary over time. However, Campbell (1999) highlighted that the expectations hypothesis is harder to reject on nominal government bonds in a cross-section of other developed economies. Up utill now, real EH have been tested and rejected only on U.S. and U.K. data, by Pflueger et. al, 2011. In the same paper they were able to reject the nominal EH across the same countries just at the lowest confidence level. The following sections constitute the first attempt to provide an empirical estimation of the real EH across the Eurozone.

5.2 Bond Notations and Data

Notations

Before the analyses is worthwile to introduce some conventional notations[6] that will be used throughout the following subsections. $p_{n,t}$ represents the log price of a zero-coupon n-period nominal bond, and $y_{n,t}$ the bond's yield. These two variables are related according to:

$$y_{n,t} = -\left(\frac{1}{n}\right) p_{n,t} \tag{A.1}$$

The difference between a long-term yield, $y_{n,t}$, and a short-term yield, $y_{1,t}$, indicates the yield spread, $sp_{n,t}$:

$$sp_{n,t} = y_{n,t} - y_{1,t} \tag{A.2}$$

The log return on long-term bond, held for one period, is given by the change in its price, i.e.

$$\begin{aligned} r_{n,t+1} &= p_{n-1,t+1} - p_{n,t} \\ &= ny_{n,t} - (n-1)y_{n-1,t+1} \end{aligned} \tag{A.3}$$

where the second equality follows from (A.1).

The superscript IL denotes the corresponding variables for inflation-linked bonds, the superscript BEI denotes the corresponding variables for breakeven inflation.

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[6] the notation very much follows (again) Campbell, Lo, MacKinlay, 1996, chapter 10.

Data

Nominal and Real EH will be tested using government bond data for France, Italy and Germany. The analyses focuses on 10-year nominal and real yields, $y_{n,t}$, sampled at monthly frequency, to capture the longest and most representative features of inflation-linked bonds outstanding and to avoid daily noise. Inflation is measured with the HCPI tobacco excluded. Short-term nominal interest rate, $y_{1,t}$, is the 3-month yield of each country. Neither France nor Italy nor Germany issue inflation-indexed short-term bonds, so we decide to estimate empirically a proxy for the short-term real rate.

Assuming zero inflation risk and any liquidty premium over the first quarter, the short-term real interest rate is:

$$\hat{y}^{IL}_{1,t} = y_{1,t} - \mathbb{E}(\pi_{1,t}) \tag{A.4}$$

Then, if inflation expectations over the next quarter are rational the ex-ante real short rate is the fitted value from the following regression:

$$y_{1,t} - \pi_{1,t+1} = \alpha + \beta_1(y_{1,t-1} - \pi_{1,t}) + \beta_2 y_{1,t} + \beta_3 \bar{\pi} + \varepsilon_{t+1} \tag{A.5}$$

where

- $y_{1,t} - \pi_{1,t+1}$ is the current quarter realized real rate
- $y_{1,t-1} - \pi_{1,t}$ is the last quarter's realized real rate
- $y_{1,t}$ is the nominal 3-month rate
- $\bar{\pi}$ is the inflation rate in the previous year

Table **A.3** shows the results for Equation (A.5), estimated with monthly data, from January 2000 to December 2016. For each country in the sample are indicated the point estimates of the slope coefficients and the h.a.c. standard errors[7] in parenthesis. The table shows that for all our sample the main determinants of the ex-ante real rate are the nominal rate, with a positive coefficient of 1.09, 1.20 and 1.18 for France, Italy and Geramany respectively, and the annual inflation rate, with a negative coefficient of -0.23, -0.26 and -0.25. Overall, each regression can explain 16% of the real interest rate variation in Italian rate and 20% in French and German rates.The regressors are jointly significant throughout the sample.

Figure **A.6** displays the nominal short rate (red line) along with the predicted (green line) and realized real short rate (dotte line) for all countries. It shows that the predicted real short rate very much follows the nominal short rate.

Table **A.4** presents summary statistics for inflation, short-term nominal and real interest rates, nominal and real yield spreads[8], breakeven inflation and bond excess returns[9]

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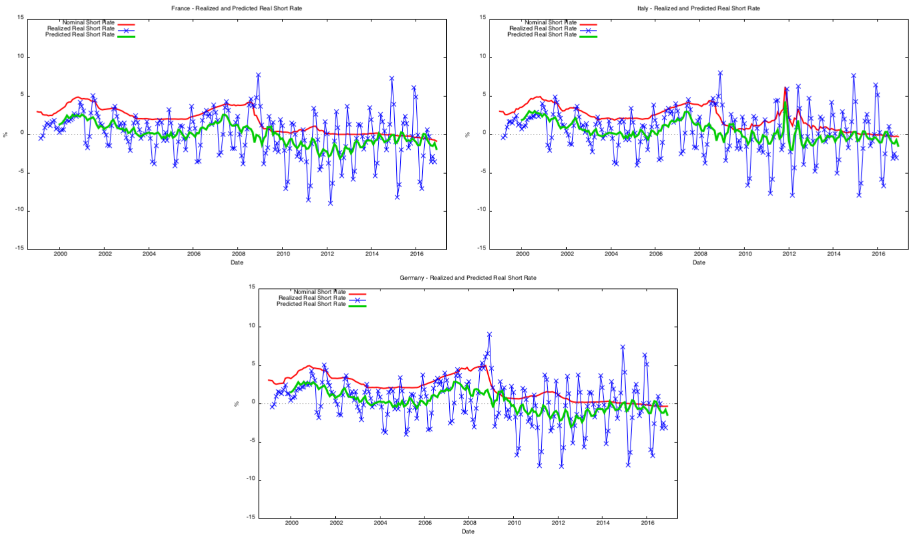
[7] Newey-West heteroskedasticity and autocorrelation consistent

[8] as defined from (A.2).

[9] as defined from (A.7).

Fig. A.6: Realized and Predicted Real Short Rate. France, Italy and Germany



for France, Italy and Germany respectively. The sample period starts in February 2003, August 2006 and June 2009 for France, Italy and Germany and ends up for all countries in December 2016. Even if the three samples differ, values are similar across countries, especially between France and Germany. Italy exhibited the highest short term nominal and real interest rates, Germany the lowest. Furthermore, Germany experienced the lowest excess return on both nominal and inflation-linked bonds, with an average of 1.53% and 1.19% respectively, Italy the highest, 2.35% and 2.29%.
Volatilities are comparable throughout the sample, French and German excess returns standard deviations are almost identical, Italian excess returns were more volatile. For each sample period the nominal excess return is highly and positively correlated with the real excess returns. On the contrary, the real excess return appeared to be negatively correlated with the breakeven excess return. Table **A.5** shows these correlations.

5.3 Nominal Expectations Hypothesis

Applying the expectations hypothesis to nominal bonds in our analysis means that the expected excess return on 10-year nominal bonds over 3-month nominal bonds, the nominal bond risk premium, is constant over time. To verify it, should be checked if the following equation holds:

$$E_t[r_{n,t+1} - y_{1,t}] = \mu_n \tag{A.6}$$

The expectations hypohtesis says that the right-hand side of (A.6) cannot be predicted. However, current literature indicates that the nominal yield spread, computed as the difference between long-term and short-term yield, predicts nominal excess returns positively, suggesting that whenever the term spread is high the risk premium on long nominal bonds is higher. To test on European data wheteher nominal excess returns are predictable from nominal term spread, i.e. if the term spread contains a time-varying risk premium, has to be estimated the following regression:

$$er_{n,t+1} = \alpha + \beta sp_{n,t} + \varepsilon_{t+1} \tag{A.7}$$

where $er_{n,t+1} = r_{n,t} - y_{1,t}$ represents the excess return on nominal bonds and $sp_{n,t}$ is defined as from Equation (A.2). If the EH holds the $\beta-$coefficient in Equation (A.7) should be equal to zero.

Table **A.6** reports tests of the nominal EH on the countries analysed using the return-based regression with monthly data ranging from January 2000 to December 2016.

The first column of Table **A.7**, first Panel for France, second for Italy and third for Germany, reports the same regressions with the sample starting at the beginning of each indexed bonds issuance program.

The estimates of the slope coefficients from (A.7) yields to a rejection of the nominal expectation hypothesis in the long sample regressions for all countries. The rejection is at the highest confidence level for France and Italy and at the lowest confidence level for Germany. The short sample version, second column of Table **A.7**, displays very similar results both in terms of magnitude as in terms of statistical significance. These outcomes suggest that nominal bond risk premium varies predictably over time across all our countries even shrinking the reference period.

5.4 Real Expectation Hypothesis

Following the same approach, in this subsection the EH in real term will be formulated and tested. The EH for inflation-indexed bonds entails that real interest rate risk is constant.

If the real EH holds for inflation-indexed bonds the real interest rate risk premium is constant and the yield on long-term inflation-linked bonds should be equal to the average expected short-term real interest rate over the life of the bond plus a constant. Essentially, it means that investors cannot earn predicatable returns by shifting between long-maturity and short-maturity real bonds.

Expressed in terms of returns the EH for inflation-indexed zero-coupon bonds says that

$$E_t[r^{IL}_{n,t+1} - \hat{y}^{IL}_{1,t}] = \mu^{IL}_n \tag{A.8}$$

Analogously to the nominal case, the real EH will be tested by checking whether the real term spread predicts excess returns on real bonds:

$$er^{IL}_{n,t+1} = \alpha^{IL} + \beta^{IL} sp^{IL}_{n,t} + \varepsilon^{IL}_{t+1} \tag{A.9}$$

where $er^{IL}_{n,t+1} = r^{IL}_{n,t+1} - \hat{y}^{IL}_{1,t}$ is the log excess return on real bonds and $sp^{IL}_{n,t} = y^{IL}_{n,t} - \hat{y}^{IL}_{1,t}$ is the spread between long-term and short-term inflation-linked bonds as from Equation (A.2). To compute the spread between long-term and short-term real yields, we subtract from the 10-year inflation-indexed yield of each country the corresponding fitted real rate estimated empirically through Equation (A.5). The real EH implies that β-coefficient in Equation (A.9) should be zero. Any $\beta^{IL} \neq 0$ implies that μ^{IL}_n is time-varying and that the real yield reflects time-varying real risk premia. Being the spread in (A.9) the difference between long-term and short-term real yield it could not reflect any inflation risk. Thus, the risk premia associated to any $\beta \neq 0$ in Equation (A.9) are driven either by a real interest rate risk factor or by a liquidity risk factor or by a credit risk factor.

The thrid column of each Panel of Table **A.7** shows the results of testing real expectations hypothesis in France, Italy and Germany from Equation (A.9). Data consists again of quarterly returns sampled at monthly frequency. The coefficients on the real spread of Italy and Germany are bigger as compared to the corresponding coefficients on the nominal spread reported in column 2. All the slopes across countries are positive and statistically significant at the highest level.

These outcomes indicate that the risk premium on linkers varies predictably over time and suggest the presence of other risk premia, affecting just the inflation-indexed bond markets like real interest rate or liquidity factors.

An empirical assessment of the liquidity premium will be provided in Section (6).

5.5 Breakeven Inflation and the Inflation Expectation Hypothesis

After testing the nominal and real EH, it is worthwhile to examine the breakeven inflation, i.e. the difference between nominal and indexed yields with the same maturity. Following our notation:

$$BEI_{n,t} = y_{n,t} - y^{IL}_{n,t} \tag{A.10}$$

By a theoretical angle, it is known that holding either a nominal or an inflation-indexed bond exposes investors to different kinds of risk. Nominal bonds reflect real interest rate risk and inflation risk. Real bonds provide a full hedge against inflation risk but expose the investor to real interest rate risk and, given the market condition, contain also a liquidity risk. Both nominal and real bonds issued by France and Italy also embody a Default Premium.

Analitically,

$$y_{n,t} = rr_{n,t+1} + \mathbb{E}_t \pi_{n,t+1} + RP^{rr}_t + RP^{\pi}_{n,t} + RP^{DEF,n}_{n,t} \tag{A.11}$$

$$y^{IL}_{n,t} = rr_{n,t} + RP^{rr}_{n,t} + RP^{liq}_{n,t} + RP^{DEF,il}_{n,t} \tag{A.12}$$

- rr is the real rate
- $\mathbb{E}_t \pi_{n,t+1}$ stands for the expectations about future inflation
- RP_t^{rr} represents the real rate risk-premium
- $RP_{n,t}^{liq}$ is the liquidity premium
- $RP_{n,t}^{DEF}$ is the default premium

Combining Equation (A.10) with Equation (A.11) and (A.12) we have

$$BEI_{n,t} = \mathbb{E}_t(\pi_{n,t+1}) + RP_{n,t+1}^{\pi} - RP_{n,t+1}^{liq} + \left(RP_{n,t}^{DEF} - RP_{n,t}^{DEF,il}\right) \tag{A.13}$$

Equation (A.13) shows that the breakeven inflation proxies just for inflation expectations if and onfly if the inflation risk premium and the liquidity premium are equal to zero and if the default premium is the same for both nominal and inflation-indexed bond. This latter assumption is hard to believe. Thus, throughout the paper, we assume that the more illiquid bonds embody also a higher default premium. In this view, *ceteris paribus*, the less liquid bonds are more likely to default precisely because of their less liquidity. In view of this assumption, the latter term of Equation (A.13) is expected to be negative.

Whenever any of these risk premia are different from zero the beakeven inflation will be affected immediately. For example, if investors ask for a liquidity premium on real bonds, i.e. if they request a higher yield to hold inflation-indexed debt, breakeven inflation will be lower than it would be otherwise.

Breakeven inflation, can vary over time due to changes in expected inflation and possibly in the inflation risk premium and in the liquidity or the default premium. The latters, can generate also a variation in the expected excess return on breakeven inflation, computed as the difference between the excess return on nominal bonds and the excess return on real bonds with the same maturity. Analytically, the breakeven inflation excess return is defined as:

$$er_{t+1}^{BEI} \equiv (r_{n,t+1} - y_{t,1}) - (r_{n,t+1}^{IL} - y_{1,t}^{IL}) = nbei_{n,t} - (n-1)bei_{n-1,t+1} - bei_{1,t} \tag{A.14}$$

Under the assumption of constant inflation and liqudity risk premia, the left-hand side of Equation (A.14) equals a constant plus the return on expected inflation, computed as

$$n\mathbb{E}\pi_{n,t} - (n-1)\mathbb{E}\pi_{n-1,t+1} - \mathbb{E}\pi_{1,t} \tag{A.15}$$

where $\mathbb{E}\pi_{n,t}$ denotes n-period expected inflation at time t. If inflation expectations are rational, Equation (A.15) should be zero.

As suggested from Pflueger et al. (2011), the joint hypothesis of rational inflation expectations, a constant inflation risk premium and a constant liquidity premium constitutes the inflation expectations hypothesis. The suitable regression for testing the inflation expectations hypothesis is:

$$r_{t+1}^{BEI} = \alpha^{BEI} + \beta^{BEI} sp_{n,t}^{BEI} + \varepsilon_{t+1}^{BEI} \tag{A.16}$$

where $sp_{n,t}^{BEI} = BEI_{n,t} - BEI_{1,t}$ is the breakeven inflation spread. Again the testable hypothesis is wheather $\beta^{BEI} = 0$. If the inflation risk premium or the liqudity risk premium are time varying the slope coefficient, β^{BEI}, in Equation (A.16) should be different from zero. In particular, the breakeven spread $sp_{n,t}^{BEI}$ should reflect the inflation risk premium contained in the nominal yield spread $sp_{n,t}$.

The third column of Table **A.7**, shows the outcome of testing the inflation expectations hypothesis in France, Italy and Germany. The breakeven inflation spread predicts the difference in nominal and inflation-indexed bond excess returns. If bond market participants' inflation expectations are rational and liquidity premia are constant, these results are consistent with a time-varying inflation risk premium across all the countries analyzed. Moreover, there is evidence that if breakeven spread increases, inflation risk also increases and investors request a higher inflation risk premium for holding nominal bonds.

Since the breakeven inflation spread, the nominal term spread, and the real term spread are mechanically related by $sp_{n,t}^{BEI} = sp_{n,t} - sp_{n,t}^{IL}$, it also makes sense to test whether both the real term spread and the breakeven inflation spread jointly forecast the return on breakeven inflation. Equation (A.16) became:

$$er_{t+1}^{BEI} = \alpha^{BEI} + \beta^{BEI} sp_{n,t}^{BEI} + \beta^{IL} sp_{n,t}^{IL} + \varepsilon_{t+1}^{BEI} \tag{A.17}$$

Column 4 of each Panel of Table **A.7**, shows the regression from Equation (A.17) displaying that this additional regressor does not affect the predictive power or the coefficient estimate of the breakeven spread tested previously.

Interestingly, in this last regression we have, for the first time, different outcomes.

For France and Germany, the real term spread appears to predict breakeven returns positively at the highest level of statistical significance. This suggests that a widening of the real term spread forecasts an increase in the spread between nominal bond risk premia and inflation-indexed bond risk premia.

For Italy, the latter column of Table **A.7**, shows that the real term spread coefficient is -0.32 but is not statistically significant.

Overall, the results in Table **A.7** strongly support nominal and real bond returns predictability and breakeven inflation returns predictability on European data. These results confirm the hypothesis that the risk premium on nominal bonds is driven by both a time-varying inflation risk premium and a time-varying real interest rate risk premium. Indeed, an increase in breakeven inflation forecasts prositively an increase in nominal bond risk premia relatively to inflation-indexed bond risk premia. The rejection of the null hypothesis suggests that the effect of the real term spread on breakeven inflation returns might be related to liqudity and default factors.

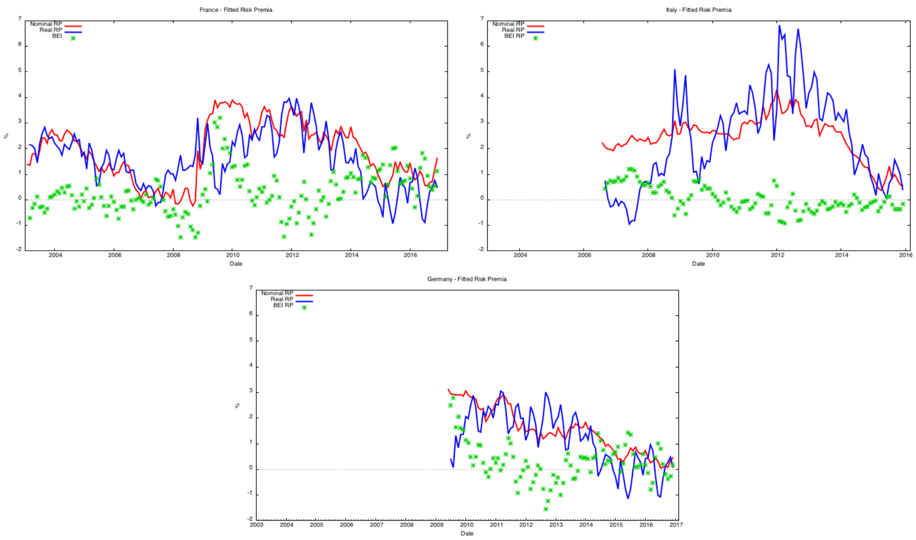
5.6 Historically Fitted Risk Premia

In order to better understand the economic significance of the bond return predictability examined throughout the section it is worth investigating the fitted time varying risk premia. Table **A.8** shows the mean and standard deviation of the fitted excess returns from the EH regressions shown in Table **A.7**. The first Panel reports results for France, the second for Italy and the third for Germany.

Table **A.8** shows that Italian securities, in the reference period, experienced a very high premium, almost identical to the average risk premium on nominal bond, which results in breakeven inflation risk premium close to zero. Breakeven inflation risk premium that for France and Germany is positive. The last column indicates that bond risk preamia exhibit lower variability over time, realtive to the overall variability of realized bond excess returns.

Figure **A.7** shows the fitted nominal and real term risk premia and their difference, the breakeven inflation term risk premium for France, Italy and Germany. The Figure shows that, for each country, nominal and real term risk premia have generally moved together, and that they exhibit variability over time, especially the real term premia. Again, the path of the two series of France and Germany is similar, slighlty declining. Italy, as expected, experienced a sudden increase in both the term premia, especially in the real one.

Fig. A.7: Fitted Risk Premia. France, Italy and Germany



The breakeven inflation risk series also shows time variation, implying that the magnitude of the changes in nominal and real bond term premia were not identical.

The subsection exploited the EH of the term structure of interest rates in European goverment nominal and real bond markets. It documents predicatbility of excess returns in both nominal and inflation-indexed bonds of all countries, rejecting both the nominal and the real expectations hypothesis. While return predictability of US and UK real bonds has been tested by Pflueger et al. 2011, this is the first article to provide direct empirical evidence for predictability of returns in real bonds across the Eurozone. It also provides evidence that brekeven inflation returns, computed as the difference between nominal bond excess returns and real bond excess returns are predictable.

The rejection of the real EH implies that investors in the inflation-indexed bond market face a time-varying premium that reflects a time-varying real interest rate risk premium and possibly also a time-varying liquidity premium and possibly a default premium. The rejection of these three kinds of excpectation hypothesis suggests that inflation risk, and the premium that investors demand for bearing it, also varies over time. Real and nominal bond risk premia appear to be positively related to the real and nominal term spread, respectively. When the real term spread increases, expected returns on inflation-linked bond returns increase and, interestingly, real bonds are also expected to outperform nominal bonds. When the nominal term spread increases, expected excess returns on nominal bonds increase.

Evidence against the real and nominal EH suggests that increases in the yields of long-term bonds, whether real or nominal, do not necessarily imply that expected future short-term interest rates have risen. The increase in yields, or the decline in bond prices, could be the result of an increase in the risk of long-term bonds and the risk premium that investors demand for holding them.

Lastly, from the analyses, a significant time variation emerges in nominal and real bond risk premia, suggesting a changing in investor perception of the risk of nominal and real bonds across all countries. In particular, the risk premium on Italian indexed bonds has been very similar on average to the average risk premium on concurrent nominal bonds. The historical positive average of linkers risk premium appears to be driven by the pikes occured during the financial crisis of 2008 and during the sovereign crisis of 2011.

The analyses also suggest that investors demand a risk premium on nominal bonds that also varies over time. This premium might reflect the changing perception of inflation or default risk by investors.

6 Risk Premia

Section (5) provided empirical evidence that returns on French, Italian and German nominal and real bonds in excess of short-term yields are predictable or, equivalently, that the exptected excess return on nominal and real European sovereigns is time varying.

This section addresses empirically the source of the excess return predictability in nominal and real Eurozone bonds.

6.1 Liquidity and Default Premium Estimation in Nominal and Real Bonds

Following the result of Section (5) and taking for granted the different conditions of nominal and real bond markets across the euro area, it is reasonable to assume the existence of a liquidity premium and of a default premium affecting negatively the breakeven inflation rates of our sample.

We interpret liquidity risk as a situation occuring when, for a certain period of time, a given financial asset cannot be traded quickly enough in the market without impacting it's market price. In our framework, due to the different trading volumes between nominal and real bonds, we assume the existence of a liquidity premium embodied in inflation-linked securities, although sovereign market is one of most liquid worldwide. Moreover, taking for granted that a default event would hit simultaneously both the nominal and the real bonds of a sovereign, sell on the market an indexed securities could be more difficult, *ceteris paribus*, taking into consideration also the liquidity differential.

To assess empirically the magnitude of the liquidy premium and of the default premium, we have two different approaches. The standard approach requires to regress the 10-year breakeven inflation rate onto one liquidity proxy and onto one default proxy, controlling for inflation expectations. The variable chosen to account for liquidity is the bid-ask spread. Bid-ask spread is an accepted measure of liquidity costs in exchange traded securities. Under competitive conditions, the bid-ask spread measures the cost of making transactions without delay. This is one of the possible driver of the liquidity premium characterizing our bond markets.

The variable chosen to account for the default is the 10-year Credit Default Swap, henceforth CDS. The CDS is a financial derivative contract which allows to transfer the risk of a sovereign default from the "protection buyer" to the "protection seller", in exchange for the payment of a regular fee. In the event of default, the buyer is fully compensated by receiving the difference between the notional amount of the loan and its recovery value from the protection seller.

Inflation expectations are proxied either through the inflation swap or through the Survey of Professional Forecasters provided by the ECB.

To better assess liquidity and default premia, we can run for each country a similar regression with two liquidity proxies and two default proxies, always controlling for inflation expectations.

The two variables chosen for liquidity are the same bid-ask spread and the synthetic minus cash breakeven inflation rate. This latter liquidity measure is computed as the difference between the fixed rate on a zero-coupon inflation swap and the actual breakeven

inflation rate. A zero-coupon inflation swap is a contract where the "inflation payer" pays cumulative inflation in exchange for a pre-determined fixed rate to the "inflation receiver", at maturity. The fixed rate is usually called synthetic breakeven inflation.
The synthetic-cash breakeven inflation proxies for variation in funding costs, or in the cost of arbitraging between the cash market and the inflation derivatives market. Relating to the U.S., Fleckstein et al. (2013), suggest that this variable reflects mispricing or arbitrage opportunities between the nominal and real bond markets.
Relying on this two liquidity proxies while controlling for inflation expectations, the estimated liquidity premium likely represents a combination of current ease of trading and the risk of a liquidity deterioration[10]. By a theoretical angle, we can say that the bid-ask spread captures the overall liquidity conditions of the market and the synthetic-cash breakeven spread represents both current liquidity conditions and liquidity risk.
To capture the default risk, in addition to the standard CDS we add also the quanto-Credit Default Swap (quanto-CDS). Quanto-CDS refers to the differential of CDSs on the same underlying, but quoted in different currencies. Following De Santis (2015) and Favero and Missale (2016), we define the quanto-CDS as the difference between French, Italian and German CDS quotes in US dollar and euros. This variable can be considered a measure of redenomination risk associated with the break-up of the euro area as perceived by the market. Clearly, this spread would be close to zero when market perceptions of Eurozone's break-up risks are minor.

6.2 Estimation Strategy

We will estimate our first set of regressions for each country as:

$$BEI_t = \alpha + \beta\pi_t^e + \gamma L_t + \delta D_t + \varepsilon_t \tag{A.18}$$

Let BEI_t be the 10-year breakeven inflation of each country, π_t^e a vector for inflation expectations, L_t a vector for liquidity proxy, and D_t a vector for default proxy. We have two variables to control for inflation expectations, (π^e), the inflation swaps and the Survey of Professional Forecasters.
After this, we will estimate the liquidity premium and the default premium regressing the breakeven inflation rates onto two liqudity proxies and onto two default proxies, while controlling for inflation expectations, in this case only through the Survey of Professional Forecasters.
The new baseline Equation is

$$BEI_t = \alpha + \beta\pi_t^e + \gamma L_t + \delta D_t + \varepsilon_t \tag{A.19}$$

We have that $\hat{\gamma}$ denotes the vector of slope estimates in Equations (A.19). The estimated liquidity premium in inflation-indexed yields over nominal yields is the negative of the

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[10] Amihud et. al, 2005

variation in the breakeven inflation, BEI_t, explained by the liquidity variables:

$$\widehat{LP}_t = -\hat{\gamma} L_t \tag{A.20}$$

Variables indicating less liquidity in the inflation-indexed bond market, i.e. the bid-ask spread and the synthetic-cash breakeven spread, should enter negatively in Equation (A.19).

To estimate the default premium we follow the same approach. $\hat{\delta}$ represents the vector of slope estimates in Equation (A.19). The corresponding default premium is the negative of the variation in the breakeven inflation explained by the default variables:

$$\widehat{DP}_t = -\hat{\delta} D_t \tag{A.21}$$

We expect that also the two default proxies exhibit negative coefficients. Moreover, we expect single-country default variable, i.e. the CDS, affecting more heavily peripheral country like Italy and, on the contrary, quanto-CDS impacting more on core countries, like France and Germany.

6.3 Data

Our dependent variable will be the 10-year breakeven inflation, computed as the difference between nominal and real yield with the same maturity.

Expected inflation is captured through the long-term survey of professional forecasters (SPF) provided by the European Central Bank. This measure is the survey of expectations for the rates of inflation in the euro area, for long-term horizons, provided by experts affiliated with financial or academic institutions based within the European Union.

The first proxy for market liquidity is the bid-ask spread. The second is the synthetic minus cash breakeven inflation.

Data about the 10-year inflation swap for the euro area and data on CDS and quanto CDS quotes are retrieved through Reuters Datastream.

The sample period of the whole analysis began in June 2009, when data for all countries became availlable, and ends up in December 2016.

All variables are sampled at monthly frequency. Table **A.9** shows summary statistics for all the variables included in this section for France, Italy and Germany, respectively. As expected, Italy exhibit both the highest yields and excess returns, in nominal and real terms, and Germany the lowest. We see also that, in our sample period, the breakeven inflation rate was of 1.79% for France, 1.38% for Italy and 1.66% for Germany. Mean and standard deviation of the two liqudity proxies of each country are comparable throughout the sample, and close to the same proxies for the U.S. and the U.K., as in Pflueger and Viceira (2016).

Huge difference emerges about the first default premium measure, the CDS. The sample mean of the Italian CDS, which amounts to 2.22%, is resoundingly higher as compared with the corresponding French and German CDS, which amounts to 1.00% and 0.56%, respectively. This indicates that the default risk affected heavier Italy and was very small for France and Germany.

On the contrary, the mean and the standard deviation of the quanto CDS are smaller on average in magnitude and comparable across countries. Sample mean amounts to 0.31%, 0.38% and 0.22% for France, Italy and Germany, respectively. This last statistic suggests that, at a fist sight, a euro area break up would affect the three countries almost in the same way.

6.4 Estimation Results

Table **A.10** shows the estimates of Equation (A.18), for France, Italy and Germany, respectively. The leftmost panels show the estimates of the regressions using the inflation swap to proxy for inflation expectations. The rightmost panel shows the same results but using the Survey of Professional Forecasters. In each version, we add first the liquidity proxy then, the default proxy. The last column of each Panel presents our benchmark estimate.

Results are quite similar throughout the sample. We see that both swaps and the survey are good proxies for inflation expectations and all the regressors enter with the correct signs. The higher R^2s of the leftmost Panels, suggest that a market-based measure of inflation expectations, like the inflation swap, can better perform in term of explanatory power than a survey based measure like the SPF. In addition, we see that both liquidity and default have a sizeable effect just for Italy.

In Table **A.11** we have the results for Equation (A.19). We see that the inflation expectations alone explains the 46%, the 11% and the 53% of the variability in French, Italian and German breakeven inflation.

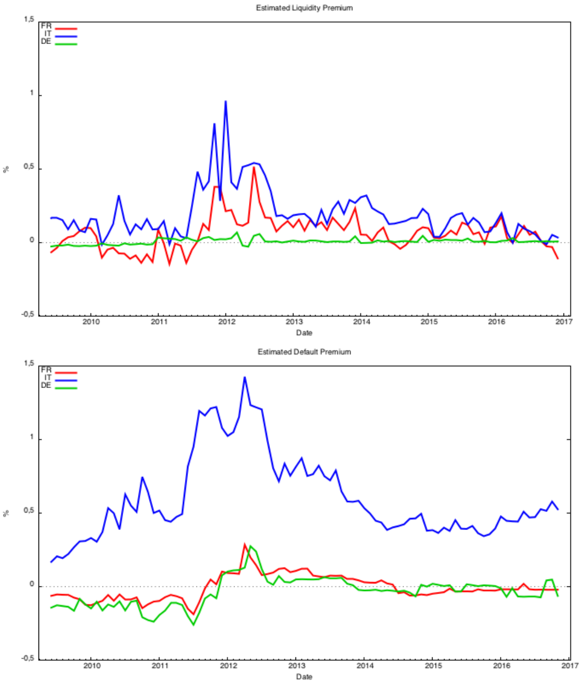
Looking at the column in between, we see that liquidity measures explain sizable variation in the breakeven inflation rates for France and Italy and is negligible for Germany. The R^2 of first two countries increases after including the two liqudity variables and reaches 59% and 55%, respectively. The synthetic-cash breakeven kept the sign and the significance level constant in all cases except from Germany.

The two default proxies increase the R^2 of Equation (A.19) of 5 percetage points for France and Germany and of 10 percentage points for Italy.

In the benchmark regressions, the last column of each Panel of Table **A.11**, the bid-ask spread is statistically significant just for France. Breakeven inflation decreases in the synthetic-cash breakeven for France and Italy, suggesting that inflation-indexed yields reflect a strong market-wide liquidity component. The two default proxies enter with the expected negative sing, (except for the French and German CDS, which anyway are not

significant), but show different significativity whithin countries. The CDS coefficient for Italy is statistically significant at the highest level, but the same coefficient for France and Germany is not. The situation is overturned for the quanto CDS. Italian coefficient is not statistically significant whilst French and German exhibit the significativity.
These outcomes suggest that liquidity and default factors are important for understanding the time series variability of breakeven inflation across all the countries in the sample. Figure **A.8** plots estimated liquidity premia for our countries, as from Equation (A.20) along with the corresponding default premia as from((A.21).

Fig. A.8: Estimated Liquidity and Default Premia



7 Conclusion

The paper explores thouroughly the European inflation-indexed bond market since the beginning of the issuance to 2016.
Then, we examined the Expectations Hypothesis of the term structure of interest rates documenting predicatbility of excess returns in both nominal and inflation-indexed bonds of all countries. We reject both nominal and real expectations hypothesis and we

provide for the first time empirical evidence for predictability of returns in real bonds, across the Eurozone. The rejection of the real EH implies that investors in the inflation-indexed bond market face a time-varying risk premium that reflects a time-varying real interest rate risk premium and possibly also a time-varying liquidity premium. We found that when the real and nominal term spread increases, expected returns on inflation-linked bond and nominal returns increase and, interestingly, real bonds are also expected to outperform nominal bonds.

We document large and positive French and Italian linkers risk premium that appears to be driven by two two pikes occured during the financial crisis of 2008 and during the sovereign crisis of 2011 suggesting that investors demand a risk premium on nominal bonds that also varies over time. In the last section, we explore the source of time variation in euro area nominal and real bond markets. We document the presence of both liquidity and default premia for France, Italy and Germany, respectively. Moreover, we document the twofold path of the default premium evaluating the single country default, affecting only Italy and the euro-area default affecting France and Germany.

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A Tables

Table A.1: Summary Statistics for Nominal and Real 10-Year Bonds

	Mean	SD	Min	Max	Sample
France Nominal	2.90	1.23	0.10	4.69	2003-2016
France Real	0.95	0.93	-1.11	2.47	2003-2016
Italy Nominal	3.78	1.35	1.13	6.79	2006-2016
Italy Real	2.24	1.24	0.00	6.50	2006-2016
Germany Nominal	1.59	1.03	-0.13	3.33	2009-2016
Germany Real	0.02	0.77	-1.16	1.65	2009-2016

Table A.2: Summary Statistics for Nominal and Real 10-Year Bonds

	FR, nominal	FR, real	IT, nominal	IT, real	GE, nominal	GE, real
FR, nominal	1.00	0.97	0.84	0.69	0.97	0.89
FR, real		1.00	0.80	0.67	0.95	0.92
IT, nominal			1.00	0.96	0.70	0.55
IT, real				1.00	0.51	0.37
GE, nominal					1.00	0.96
GE, real						1.00
2009:06-2016:12						

Table A.3: Forecasted Real Short Rate

	France	Italy	Germany
3-m Nominal	1.09***	1.20***	1.18***
	(0.16)	(0.20)	(0.16)
3-m Real	-0.13*	-0.14*	-0.14*
	(0.07)	(0.06)	(0.07)
Inflation	-0.23***	-0.26***	-0.25***
	(0.06)	(0.07)	(0.07)
p-value	0.00	0.00	0.00
R^2	0.20	0.16	0.20
2000:01-2016:12			

Table A.4: Sample Moments of Inflation, Interest Rates and Bond Returns

		FRA		**ITA**		**GER**	
		Mean	SD	Mean	SD	Mean	SD
Inflation	π	1.63	1.00	1.46	1.15	1.16	1.06
3-M Nominal	$y_{1,t}$	1.25	1.43	1.63	1.52	0.45	0.53
3-M Real	$y_{1,t}^{IL}$	-0.39	1.91	0.09	2.01	-0.83	1.84
Nominal Spread	$sp_{n,t}$	1.65	0.96	3.37	1.11	1.48	0.93
Real Spread	$sp_{n,t}^{IL}$	1.35	0.89	2.16	1.23	0.85	0.86
BEI Spread	$sp_{n,t}^{BEI}$	0.29	0.47	1.21	0.56	0.62	0.47
Nominal ER	$er_{n,t}$	1.87	2.27	2.35	3.42	1.53	2.05
Real ER	$er_{n,t}^{IL}$	1.53	2.48	2.29	4.39	1.19	2.39
BEI ER	$er_{n,t}^{BEI}$	0.30	2.15	0.06	3.00	0.31	2.24
		2003-2016		2006-2016		2009-2016	
Values in (%)							

Table A.5: Excess Return Correlations

France

	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$
$er_{n,t}$	1	0.77	0.32
$er^{IL}_{n,t}$		1	-0.35
$er^{BEI}_{n,t}$			1
2003:02-2016:12			

Italy

	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$
$er_{n,t}$	1	0.82	-0.14
$er^{IL}_{n,t}$		1	-0.67
$er^{BEI}_{n,t}$			1
2006:08-2016:12			

Germany

	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$
$er_{n,t}$	1	0.65	0.34
$er^{IL}_{n,t}$		1	-0.49
$er^{BEI}_{n,t}$			1
2009:06-2016:12			

Table A.6: Test of Nominal Expectations Hypothesis - Full Sample

$er_{n,t}$	France	Italy	Germany
$sp^{FR}_{n,t}$	5.10***		
	(0.65)		
$sp^{IT}_{n,t}$		2.65***	
		(0.86)	
$sp^{DE}_{n,t}$			0.85*
			(0.87)
p-value	0.00	0.00	0.00
R^2	0.24	0.04	0.01
(2000:01-2016:12)			

Table A.7: Test of Nominal and Real Expectations Hypothesis

France	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$	$er^{BEI}_{n,t}$
$sp_{n,t}$	5.38***			
	(0.72)			
$sp^{IL}_{n,t}$		4.50***		0.40
		(0.65)		(0.49)
$sp^{BEI}_{n,t}$			4.41***	4.69***
			(0.52)	(0.34)
p-value	0.00	0.00	0.00	0.00
R^2	0.25	0.22	0.30	0.31
2003:02-2016:12				

Italy	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$	$er^{BEI}_{n,t}$
$sp_{n,t}$	3.50**			
	(1.37)			
$sp^{IL}_{n,t}$		4.76***		-1.87*
		(1.07)		(1.05)
$sp^{BEI}_{n,t}$			1.67*	-0.32
			(0.86)	(1.41)
p-value	0.00	0.00	0.00	0.00
R^2	0.06	0.15	0.03	0.06
2006:08-2016:12				

Germany	$er_{n,t}$	$er^{IL}_{n,t}$	$er^{BEI}_{n,t}$	$er^{BEI}_{n,t}$
$sp_{n,t}$	3.73***			
	(0.83)			
$sp^{IL}_{n,t}$		4.36***		-1.37*
		(0.26)		(0.77)
$sp^{BEI}_{n,t}$			3.89***	3.08***
			(0.87)	(0.50)
p-value	0.00	0.00	0.00	0.00
R^2	0.18	0.24	0.18	0.23
2009:06-2016:12				

Table A.8: Fitted Risk Premia

	$E(\hat{y})$	$\sigma(\hat{y})$
France		
2003:02-2016:12		
Nominal Bonds	1.87	1.14
Real Bonds	1.56	1.08
BEI	0.30	0.85
Italy		
2006:08-2016:12		
Nominal Bonds	2.45	0.82
Real Bonds	2.41	1.85
BEI	0.04	0.48
Germany		
2009:06-2016:12		
Nominal Bonds	1.53	0.87
Real Bonds	1.19	1.08
BEI	0.31	0.76

Table A.9: Summary Statistics for Liquidity and Default Proxies

		FRA		**ITA**		**GER**	
		Mean	SD	Mean	SD	Mean	SD
Nominal Yield	$y_{n,t}$	2.07	1.08	3.54	1.51	1.81	0.92
IL Yields	$y_{n,t}^{IL}$	0.28	0.69	2.20	1.42	0.16	0.72
BEI	$BEI_{n,t}$	1.79	0.44	1.38	0.43	1.66	1.31
Nominal ER	$er_{n,t}$	2.36	2.35	2.89	3.58	1.65	2.07
Real ER	$er_{n,t}^{IL}$	1.75	2.78	2.84	4.64	1.25	2.42
BEI ER	$er_{n,t}^{BEI}$	0.60	2.36	0.05	3.14	0.37	2.14
Survey of Inflation	π^{e}	1.40	0.29	1.40	0.29	1.40	0.29
10-Year HCPI Swap		1.78	0.42	1.78	0.42	1.78	0.42
Bid-Ask Spread		0.02	0.01	0.03	0.05	0.01	0.01
Synthetic-Cash BEI		-0.01	0.16	0.40	0.34	0.21	0.15
CDS		1.00	0.49	2.22	1.04	0.56	0.46
quanto CDS		0.31	0.25	0.38	0.25	0.22	0.16
2009:06 - 2016:12							

Table A.10: Liquidity and Default Premia: Standard Approach

France							
BEI				BEI			
Swap	0.98***	0.99***	0.98***	Survey	1.03***	1.18***	1.26***
	(0.04)	(0.04)	(0.05)		(0.11)	(0.11)	(0.16)
Bid-Ask Spread		-2.73*	-3.39**	Bid-Ask Spread		-8.38***	-7.22**
		(1.14)	(1.48)			(2.27)	(2.77)
CDS			0.04	CDS			-0.08
			(0.05)				(0.11)
R^2	0.85	0.86	0.87	R^2	0.46	0.54	0.54
Italy							
BEI				BEI			
Swap	0.69***	0.83***	0.89***	Survey	0.48***	0.82***	1.42***
	(0.08)	(0.06)	(0.06)		(0.14)	(0.14)	(0.14)
Bid-Ask Spread		-4.18***	-1.82***	Bid-Ask Spread		-4.49***	-0.42
		(0.52)	(0.67)			(0.82)	(0.88)
CDS			-0.16***	CDS			-0.38***
			(0.03)				(0.05)
R^2	0.45	0.68	0.75	R^2	0.11	0.33	0.58
Germany							
BEI				BEI			
Swap	0.82***	0.82***	0.81***	Survey	0.92***	0.98***	1.07***
	(0.03)	(0.03)	(0.04)		(0.09)	(0.09)	(0.14)
Bid-Ask Spread		2.03	1.82	Bid-Ask Spread		-5.13**	-4.41*
		(1.25)	(1.44)			(2.37)	(2.53)
CDS			0.02	CDS			-0.14
			(0.07)				(0.16)
R^2	0.86	0.86	0.86	R^2	0.53	0.56	0.56
2009:06 - 2016:12							

Table A.11: Liquidity and Default Premia: Baseline Equation

	FR			**IT**			**DE**		
BEI									
Survey	1.02***	1.12***	1.19***	0.48***	1.00***	1.39***	0.92***	0.99***	0.95***
	(0.11)	(0.11)	(0.15)	(0.15)	(0.12)	(0.16)	(0.09)	(0.09)	(0.14)
Bid-Ask Spread		-6.21***	-4.68*		-1.24	0.55		-5.44**	-1.40
		(2.22)	(2.66)		(0.84)	(0.85)		(2.43)	(2.67)
Synthetic-Cash BEI		-0.66***	-0.43*		-0.81***	-0.53***		-0.11	0.04
		(0.18)	(0.23)		(0.12)	(0.13)		(0.18)	(0.17)
CDS			0.20			-0.25***			0.54
			(0.18)			(0.08)			(0.26)
Quanto-CDS			-0.65*			-0.09			-1.22***
			(0.34)			(0.38)			(0.37)
R^2	0.46	0.59	0.61	0.11	0.55	0.65	0.53	0.56	0.61
2009:06 - 2016:12									

Table A.12: Summary Statistics for Liquidity and Default Premia (%)

	LP		DP	
	Mean	SD	Mean	SD
France	0.06	0.11	0.00	0.08
Italy	0.19	0.16	0.60	0.28
Germany	0.01	0.01	-0.03	0.09

Paper B

Eurozone Nominal and Real Sovereign Term Structure

Jacopo Sorbo

The layout has been revised.

Abstract

Yield curve modeling and forecasting are topics of great importance in financial economics both by a theoretical and empirical angle. In this paper we develop a three-factor yield curve model delivering estimates for nominal term structure of France, Germany and Italy, from January 2000 to December 2016 and for real term structure of France and Italy from July 2003 to December 2016. The aim is to provide a thorough contribution to better understand the behavior of nominal and real interest rates across the Eurozone. Our framework is the latent factor model with time varying level, slope and curvature. The overall fitting performances is good and our identification is consistent with various shapes assumed by the term structure. After the empirical estimation we forecast the yield curve by forecasting the factors and we compare them with the standard benchmark. Lastly, we provide empirical estimation for liquidity and default on a selected sample of nominal and real maturities.

1 Introduction

Yield curve modeling and forecasting are topics of great importance in financial economics both by a theoretical and empirical angle. A yield curve is a relation between interest rates of debt instruments with different maturities at a given point in time. Theoretically, the yield curve determines the value that investors place today on payments at all future dates. Thus, it constitutes a key benchmark to understand how bond pricing, interest rate settings, portfolio's dynamics and changes in monetary policy propagate throughout financial markets. Pension funds, financial firms and government institutions are deeply interested in the behavior of the term structure. Pension funds, for instance, care about interest rates dynamics to evaluate their asset and liabilities. Financial firms need reliable estimations of interest rates to price derivatives. Government institutions may want to predict the effect of monetary policy. All these agents also use yield curves to build their different scenarios, task of utmost importance especially in the post-crisis period, across the euro-area.

For these reasons, the aim of this paper is to provide a thorough analysis on the behaviour of interest rates, developing a yield curve model for the three main Eurozone countries: France, Italy and Germany and then to check for its forecasting performance. The model chosen is the three-factor Nelson-Siegel model, henceforth NS. This will be interpreted as a latent factor model with three coefficients representing a time-varying level, slope and curvature factor, multiplied by constrained factor loadings, in the spirit of Diebold et al. (2006).

The NS model is widely used due to its good performance on fitting the observed term structure and its independence of arbitrage possibilities. Actually, nine out of thirteen central banks that report their curve estimation methods to the Bank of International Settlement (BIS) use either the NS model or one of its variation and also the European Central Bank (ECB) and the European Stability Mechanism (ESM) model the term structure of the Eurozone with an extension of the NS framework.

This paper shows nominal yield curve estimates for the three largest European economies: France, Germany and Italy and the corresponding real yield curve estimations for France and Italy. We cannot provide full estimation of the German real yield curve because the very restricted number of bond issuances, just seven in our reference period, do not allow for reliable yield curve estimates. Nominal yield curve ranges from January 2000 to December 2016 for the three countries in the sample, real yield curve estimates start in July 2003 for France and in July 2004 for Italy. Yield maturities range from 1 to 10 years. After the empirical estimation of the model, we forecast the yield curve by forecasting the factors to compare the various model performance.

Lastly, we extend the current literature about sovereign spreads, comparing for the first time nominal and real spread reaction to liquidity and default issues on selected maturities. Section 2 reviews the existing literature on the topic. Section 3 briefly displays the fundamentals of yield curve modeling. Section 4 describes data and shows empirical estimations of French, German and Italian yield curves. Section 5 focuses on forecasting. Section 6 checks for liquidity and default and Section 7 concludes.

2 Literature Review

The last three decades produced major advancements in theoretical modeling of the term structure of interest rates as well as their econometric estimation. The cornerstone of all yield curve models is the Nelson-Siegel representation. NS (1987) introduced a parametrically parsimonious model for the yield curve able to capture many features of the yield-maturity relation. Through this model, they were able to characterize the shape of the bill term structure and to predict yields at maturities beyond the range of the sample.

Bliss (1997) tested a three-factor model to explain observed changes in interest rates. This parsimonious factor model was a success, contrary to the low performance of the same approach in modeling stock returns.

Diebold and Li (2006) interpret the NS model in a dynamic fashion as a latent factor model with three coefficients representing a time-varying level, slope and curvature multiplied with an associated factor loading term. These factors are the key drivers of the yield curve. Later, in order to enforce arbitrage-free consistency over time in the NS framework, Christensen (2008) introduce a closely related generalized model on which the no-arbitrage condition can be imposed.

3 Yield Curve Modeling: Basics, Nelson-Siegel Framework and Stylized Facts

3.1 Yield Curve Modeling: Basics

The aim of this subsection is to display the basic concept about yield curve estimation. Theoretically, $p_t(\tau)$ represents the price of a τ-period zero-coupon bond at time t and $y_t(\tau)$ its continuously compounded zero-coupon yield. The discount curve is obtained, for each time, as follows:

$$p_t(\tau) = e^{-\tau y_t(\tau)} \tag{B.1}$$

From Equation (B.1), we can compute the instantaneous forward rate curve,

$$f_t(\tau) = -\frac{\partial(p_t(\tau))/\partial\tau}{p_t(\tau)} \tag{B.2}$$

Combining (B.1) and (B.2) we see that the relationship between the yield to maturity and the forward rate is

$$y_t(\tau) = \frac{1}{\tau}\int_0^{\tau} f_t(u)du \tag{B.3}$$

which implies that the zero-coupon yield is an equally-weighed average of forward rates. Given the yield curve or the forward curve, we can price any coupon bond as the sum of the present values of future coupon and principal payments[1].

In practice, yield curves are estimated through observed bond prices and converted in zero-yields for any requested maturity.

3.2 Yield Curve Modeling: Nelson-Siegel Model Framework

The model chosen to estimate the yield curve throughout the paper is the Diebold and Li version of the Nelson Siegel model (1987).

Nelson and Siegel (1987) propose a three-factor term structure model defined as follows:

$$y_t(\tau) = \beta_{1,t} + \beta_{2,t}\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - \beta_{3,t}e^{-\lambda_t\tau} \tag{B.4}$$

where $y_t(\tau)$ represents the zero coupon yield at time t with maturity τ and $\beta_{1,t}, \beta_{2,t}, \beta_{3,t}$, λ_t represent time-varying parameters.

Diebold and Li (2006) rearranged equation (B.4) in order to interpret $\beta_{1,t}, \beta_{2,t}$ and $\beta_{3,t}$ as Level, Slope and Curvature, obtaining

$$y_t(\tau) = L_t + S_t\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} + C_t\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau}\right) \tag{B.5}$$

To figure out this interpretations it is usefull to look at the loading of each factor.

The loading of the Level $L_t = \beta_{1,t}$ is equal to one and does not depend on the maturity τ; this means that the term structure is affected equally at all the maturities by L_t.

The loading of the Slope, $S_t = \beta_{2,t}$ is equal to $\frac{1-e^{-\lambda_t(\tau)}}{\lambda_t(\tau)}$. Generally, the slope is computed as the long-term interest rate minus the short-term interest rate. It is straightforward notice that if $\tau \to 0$ the loading goes to one and if $\tau \to \infty$, the loading goes to zero. For this reason, S_t affects primarily the curves in the short-run and that is why this factor is identified with the slope.

The loading of the Curvature, $C_t = \beta_{3,t}$, is equal to $\frac{1-e^{-\lambda_t(\tau)}}{\lambda_t(\tau)} - e^{-\lambda_t(\tau)}$. The curvature is twice the two-year yield minus the Slope. As from Figure B.1 the factor starts in zero, then gradually increases and converges to zero again. For this reason, C_t is considered the factor governing the curvature of the term structure and has the greatest impact on medium-term yields.

The last parameter is λ_t. It affects both the rate of exponential decay and the maturity at which the loading on C_t reaches its maximum. A large value of λ_t generates a fast decay and fits the yield curve better at short maturities. Conversely, a low value of λ_t causes a slow decay of the term structure and a better fitting of the yield curve at long maturities. It is common practice in yield curve literature fix the value of λ. Diebold

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[1] See Diebol et al. 2006, section 2.1

et al (2006) assign to this parameter the value of 0.0609, to maximize the loading at 30 months.
Figure B.1 shows graphically the loadings of L_t, S_t, C_t, λ_t as function of time.[2]
If we compute the limiting behavior of equation (B.5) we see that:

$$\lim_{\tau \to 0} y_t(\tau) = L_t + S_t \tag{B.6}$$

$$\lim_{\tau \to \infty} y_t(\tau) = L_t \tag{B.7}$$

Equation (B.6) identifies the short term rate and Equation (B.7) the long term rates.

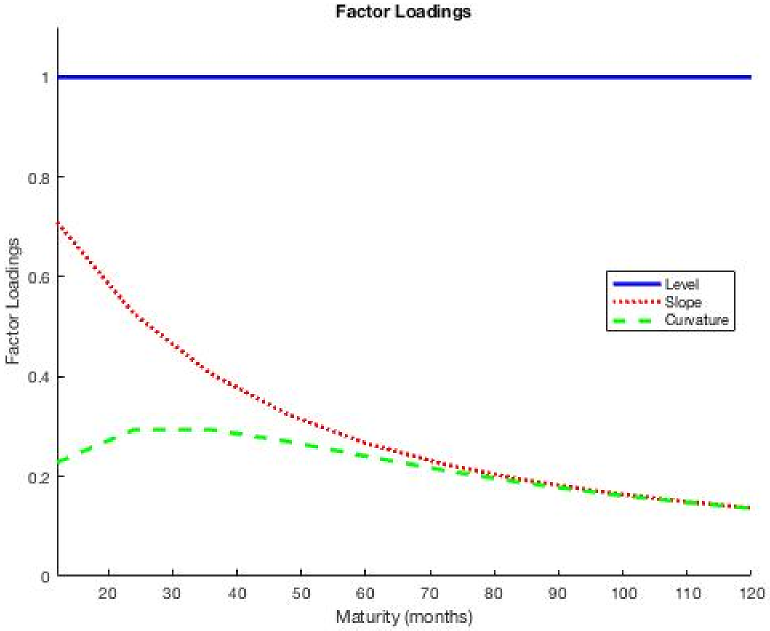

Fig. B.1: Factor Loadings

3.3 Yield Curve Modeling: Stylized Facts

A crucial dare in modeling yield curve is the ability to summarize the information at any point in time, for a large number of traded bonds, through a parsimonious model.

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[2] λ_t is constant as 0.0609

The model should guarantee good fit on the historical stylized facts of the average shape of the yield curve and good performance on forecasting future interest rates. Trying to fulfill these goals, the strategy is assuming the existence of a few latent, i.e. unobservable, factors governing the pricing of all tradable bonds and thus the shape of the whole curve.

The most important stylized facts in yield curve estimation, that should be captured by the model to be consistent, are the following:

1. *average path*: the path of the average yield curve should be increasing and concave.
2. *types of paths*: theoretically, yield curve can assume many shapes. A yield curve can be upward or downward sloping, humped or inverted, conditional on market conditions.
3. *yield dynamics*: yield dynamics are persistent and long rates are generally more persistent than short rates. So we expect that the factor governing the long rates exhibits an higher level of persistency as compared to short and medium term unobservable factors.

Throughout the paper, we will show that this approach is consistent with all the above-mentioned stylized facts and also that the factor-based interpretation allows both to replicate many yield curve shapes and to fit the curve of each country.

4 Modeling the Term Structure of France, Germany and Italy

This section is devoted to estimate the nominal term structure of France, Germany and Italy and the real term structure of France and Italy in a time series of cross sections, following the approach described above.

4.1 Data

We use monthly estimates of zero-coupon yields for French, German and Italian government bonds, from the Banque de France, the Bundesbank and Bloomberg, respectively. All Forward rates are obtained through Bloomberg.

For the model specification including the macroeconomic factors, data used are the monthly expectations for GDP growth and for the inflation rate of each country provided by Consensus economics, sampled at monthly frequency.

The reference period for nominal yield curves starts in January 2000 and ends up in December 2016. The reference period for real yield curves starts in July 2003 for France and in July 2004 for Italy. We cannot provide full estimation of the German real yield curve because the limited number of Bundei issuances would not lead to reliable yield curve estimations.

Data are pooled into fixed maturities of 12, 24, 36, 48, 60, 72, 84, 96, 108, and 120 months; in case a particular maturity were not availlable we have interpolated the yields.

The first three Panels of Figure B.2 shows the three-dimensional plot of market based

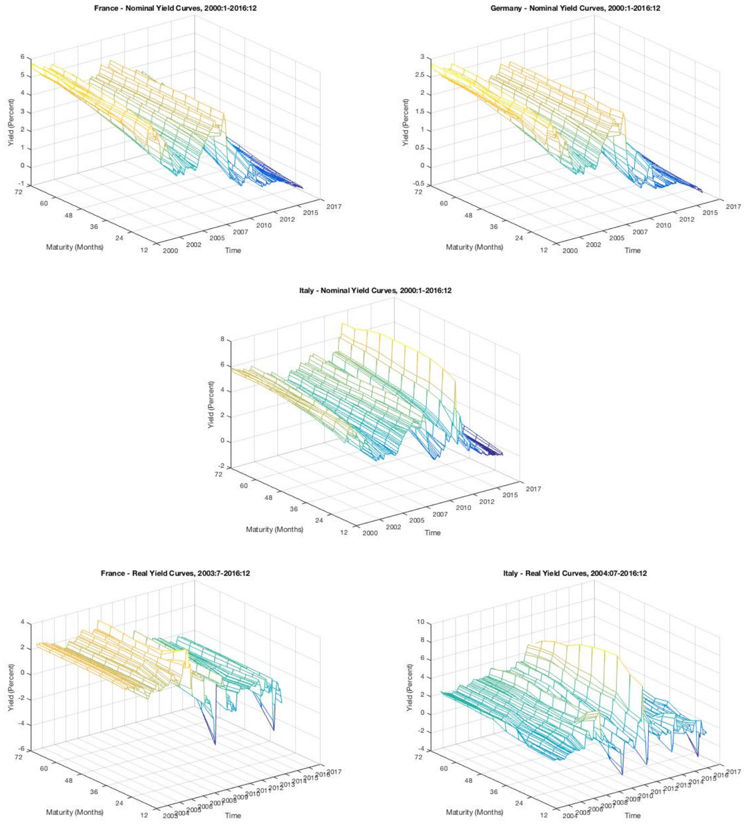

Fig. B.2: Yield Curves, Monthly Yields with Maturity 1 to 10 year.

French, German and Italian nominal yield curve, respectively. The latter two Panels depicts the corresponding real curve for France and Italy. All the curves exhibit in each reference period a sizable intertemporal variation, much more in their level but also in their slope and curvature. France and German nominal curves have a very similar path. Nevertheless, the two curves have different scale. Italy experienced the most fluctuating path in both nominal and real curve due to the sovereign crisis of 2011. There is also a

sizeable difference between the French real curve and the Italian real curve.
In Table B.1, we present descriptive statistics for each maturity of the nominal and real yields along with the three factors. For each country, the factors are computed as follows. The level corresponds to the 10-year yield, the long-term factor. The slope is the difference between the 10-year yield and the 1-year yield and stands for the short-term factor. The the curvature is obtained doubling the 2-year yield and subtracting the slope and aims to characterize the medium-term path of the yield curve. The last three columns include sample autocorrelations at displacements of 1, 12, and 30 months. From these descriptives we can extract several stylized facts about the yield curve of France, Germany and Italy and compare them with those listed in Section (3.3).
On average, the three yield curves are upward sloping, concave and can assume a variety of shapes through time; as expected, yield dynamics are more persistent than spread dynamics. The level of the yield curves is highly persistent and exhibits small variation relative to its mean. The Italian level is more persistent than any single yield. Across countries, the slope is less persistent than any other yield but highly variable relative to its mean and the curvature displays the largest variability.
We can argue that long rates are less volatile and more persistent than short rates.

4.2 Fitting yield curves

In this subsection, we fit the yield curve of each country via NS model,

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \tag{B.8}$$

Through (B.8) we estimate the model parameters $\theta = [\beta_{1t}, \beta_{2t}, \beta_{3t}]$ using OLS for each period t.

We apply OLS to monthly yield for each country in the sample and we obtain a time series of estimates of $[\hat{\beta}_{1t}, \hat{\beta}_{2t}, \hat{\beta}_{3t}]$ and a corresponding panel of residuals, or pricing errors. We can evaluate the "fitting" performance of our model by different angles. In Figure B.3 and B.4 we see that the implied average fitted yield curve (the line) and the average actual yield curve (the dots) are quite close for all countries both for nominal and real data, bolstering the appraisal about the good fit capability of the model.
In FigureB.5, B.6 and B.7 we display the ability of the three-factor model to capture the various shapes that French, German and Italian yield curve have assumed in a selection of dates.
Figure B.8 and B.9 plot the residuals of each regression and suggest good fitting performance for both nominal and real models across all countries in the sample.

Table B.2 and show descriptive statistics of the in-sample fit. The overall performance is good; mean error is negligible at all maturities and standard deviation is very small across yields and countries. When considering the persistence of the pricing errors

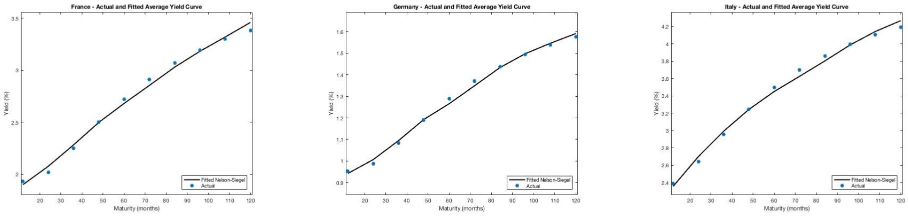

Fig. B.3: Nominal Yield Curve - Actual (data-based) and Fitted (model-based) Average.

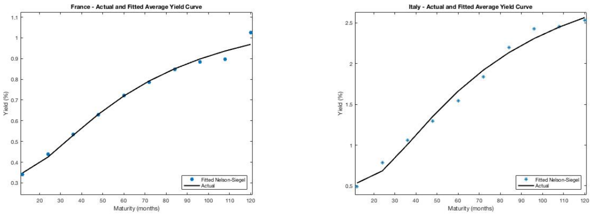

Fig. B.4: Real Yield Curve - Actual (data-based) and Fitted (model-based) Average.

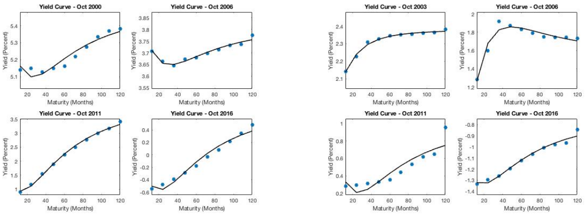

Fig. B.5: France, Nominal and Real Fitted Yield Curves and Actual Yields - Selected-dates

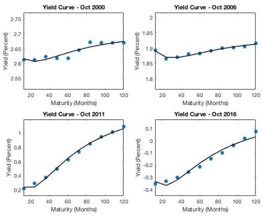

Fig. B.6: Germany, Nominal Fitted Yield Curves and Actual Yields - Selected-dates

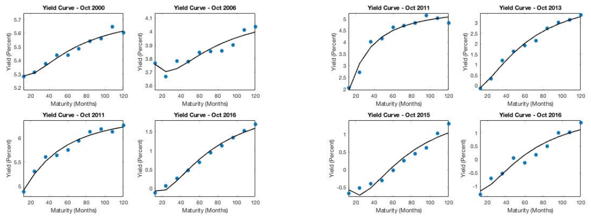

Fig. B.7: Italy, Nominal and Real Fitted Yield Curves and Actual Yields - Selected-dates

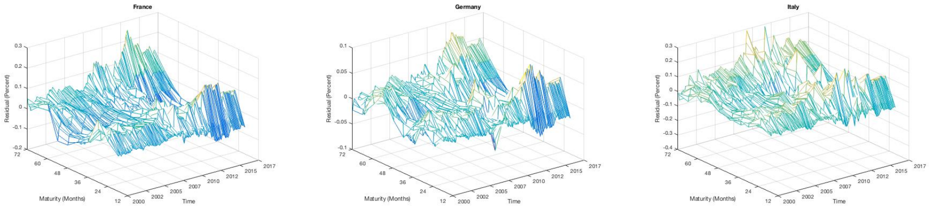

Fig. B.8: Yield curve NS residuals, 2000.01-2016:12.

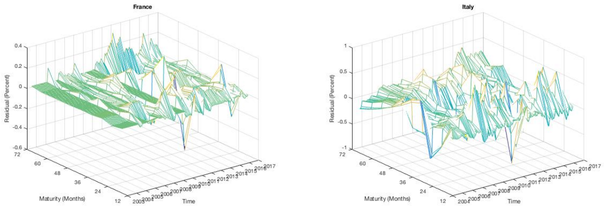

Fig. B.9: Real Yield curve NS residuals, 2000.01-2016:12.

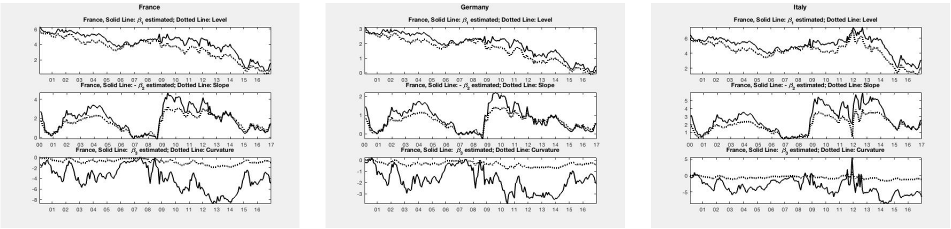

Fig. B.10: Nominal Level, Slope and Curvature: Model-based vs. data-based.

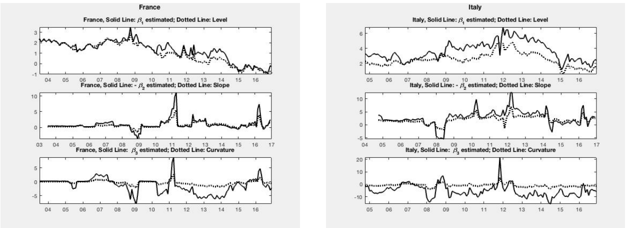

Fig. B.11: Real Level, Slope and Curvature: Model-based vs. data-based.

we should take into account that can be due to persistent tax and liquidity effects[3]. In Figure B.10 and B.11 we plot $[\hat{\beta}_{1t}, \hat{\beta}_{2t}, \hat{\beta}_{3t}]$ for each country,along with the empirical level, slope and curvature as defined earlier. The figures confirm the idea that the three factors in our model correspond to level, slope and curvature. The correlations between estimated and empirical factors are all greater than 0.85 and can be found in Table B.3. In Table B.4 we present descriptive statistics for the estimated factors. From the autocorrelation coefficient, we can see that the level is the most persistent, and that the slope is more persistent than the curvature. ADF tests suggest that $\hat{\beta}_{1t}$, $\hat{\beta}_{2t}$ and $\hat{\beta}_{3t}$ may have a unit roots, for all countries. The left column of each Panel of Figure B.12 and Figure B.13 provide visual representation of the factor autocorrelation along with the proper 95% confidence bands.

5 Forecasting Yield Curve Factors

In Section 4 we estimated for each country the time series of the three unobservable factors modeling it as an AR(1).

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[3] Bliss 1997b

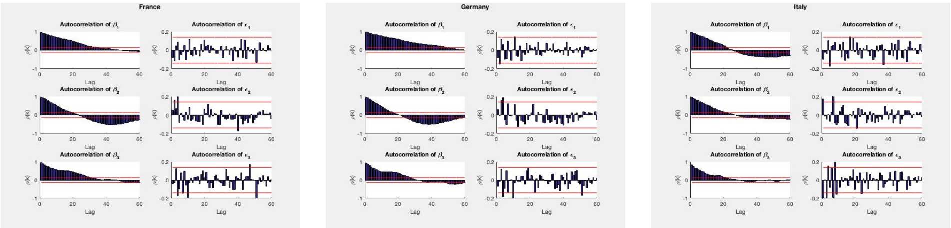

Fig. B.12: Nominal Level, Slope and Curvature: Autocorrelations and Residual autocorrelations.

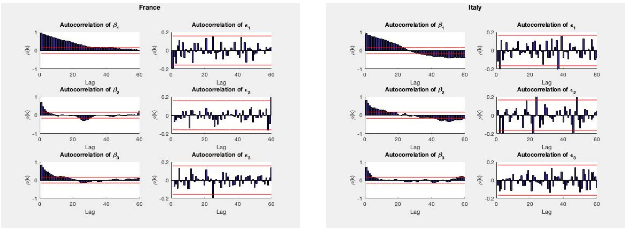

Fig. B.13: Real Level, Slope and Curvature: Autocorrelations and Residual autocorrelations.

This specifications derives directly from Equation (B.8):

$$\hat{y}_{t+h|t}(\tau) = \hat{\beta}_{1,t+h|t} + \hat{\beta}_{2,t+h|t}\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + \hat{\beta}_{3,t+h|t}\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \tag{B.9}$$

where

$$\hat{\beta}_{1,t+h|t} = \hat{\alpha}_i + \hat{\gamma}_i\hat{\beta}_{it}, i = 1, 2, 3 \tag{B.10}$$

and $\hat{\alpha}_i$ and $\hat{\gamma}_i$ are obtained by regressing $\hat{\beta}_{it}$ on an intercept and $\hat{\beta}_{i,t-h}$.
We compare this model specification, which constitutes our benchmark, with six other models, to gauge the forecasting performance. The six competitors of our Nelson-Siegel are sampled into two groups: yield-based models and macro-models. The three yield based models are the AR(1) on yield levels, the VAR(1) on yield levels and an AR(1) model based on the Principal Component Analysis of the whole term structure.
The AR(1) on yield level is defined as

$$\hat{y}_{t+h/t}(\tau) = \hat{\alpha}(\tau) + \hat{\gamma}y_t(\tau) \tag{B.11}$$

The VAR(1) on yield levels is defined as

$$\hat{y}_{t+h/t}(\tau) = \hat{\alpha}(\tau) + \hat{\Gamma}y_t \tag{B.12}$$

here Γ represents the matrix of the coefficients including also the first lag of each yield at the various maturities.

The macro-models include many regressors related to the macroeconomic and the financial conditions of each country in the VAR(1) specification. The model labelled "VAR Macro" include as a macro-factors the monthly expectations of the GDP of each country, the inflation of the Eurozone and the volatility index (VIX) proper of each equity market. The model labelled "VAR Macro Global" add to "VAR Macro" specification the volatility index (VIX) on US equity and the 10-year US Treasury yield. Lastly, the model labelled "Fama-Bliss Forward" includes the forward rates of each country. We decided to include as a macro-factors only the expectations on the GDP and on the inflation rate provided by Consensus Economics to keep all our analyses at monthly frequency. That would not have been possible if we had decided to include other public finance indicators like primary deficit or gross debt, which are officially released at least at quarterly frequency. We consider this different kind of specification for a future version of the paper. The rightmost Panels of Figure B.12 and B.13 shows that the AR(1) process has good performance on fitting the three latent factor of both nominal and real curves for each country in the sample, being the autocorrelation coefficients very small for level, slope and curvature. Tables from B.4 to B.16 provide results of the forecasting performance of a selection of models, for maturities of 12, 36, 60 and 120 months and a forecast horizons of 1, 3, 6 and 12 months. We first compare the NS AR(1) model with our yield-only models: the AR(1), the VAR(1) and the autoregressive model based on the first factor extracted from a Principal Component Analysis (PCA) regression. Then, are listed the coefficients about the macro-models. We see that at for all our forecasting horizon the performance of the various models are quite similar across countries. We can say in addition that, the models with macro variables seems to have a better performance at horizons of 1 and 3 months. At longer horizons the NS model seems to have better performance of both yield-only models and macro-models. As expected, the magnitude of the Root Mean Squared Error (RMSE) increases constantly as the forecasting horizon increases and the performance on nominal forecasted yields are better then those on real yields. Figure from B.15 to B.17 provide visual representation of the Cumulative Squared Prediction Error (CSPE) on nominal 10-year yield for France, Germany and Italy, relative to our benchmark, the NS model. The first three Panels of each figures represents the three yield-only models and the latter Panels the macro-models. The chosen horizons are 3-, 6- and 12-months. The way to interpret the CSPE is to consider better than the benchmark any model whenever its line is above the zero-line. We can argue that for France and Germany macro-models performance are good at 3-months horizon but decreasing when the forecasting period is up to 6-months. Yield-only models experienced good performance, in terms of CSPE for France and Germany almost at any forecasting horizon and worst performance for Italy, where the best-performing is the simple AR(1).

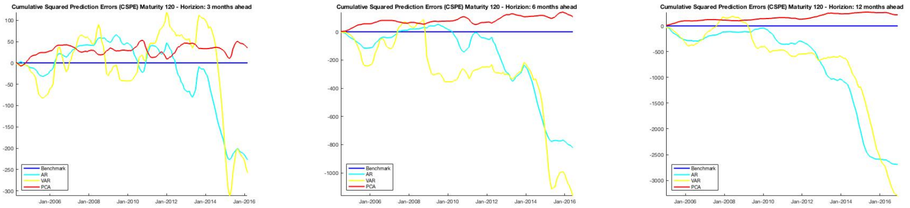

Fig. B.14: France - CSPE on Nominal Yields - Yield-only Models

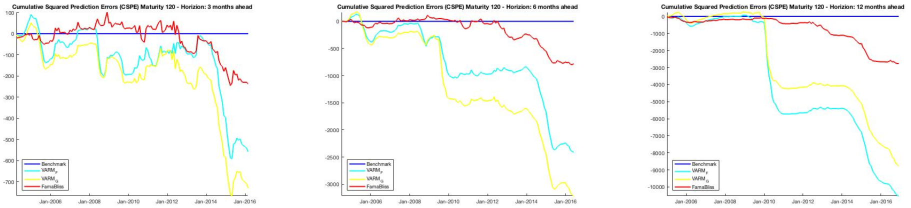

Fig. B.15: France - CSPE on Nominal Yields - Macro Models

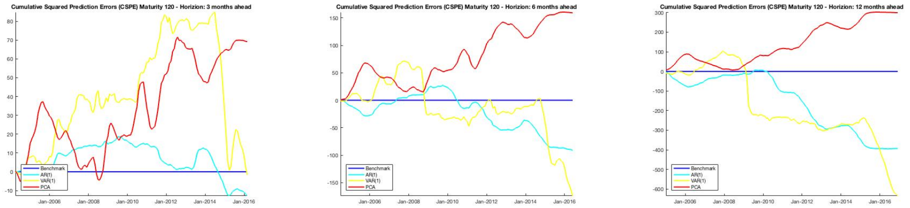

Fig. B.16: Germany - CSPE on Nominal Yields - Yield-only Models

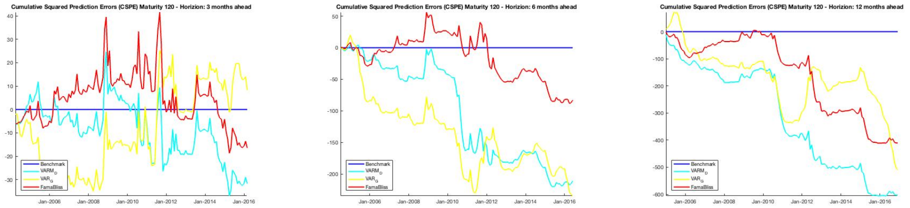

Fig. B.17: Germany - CSPE on Nominal Yields - Macro Models

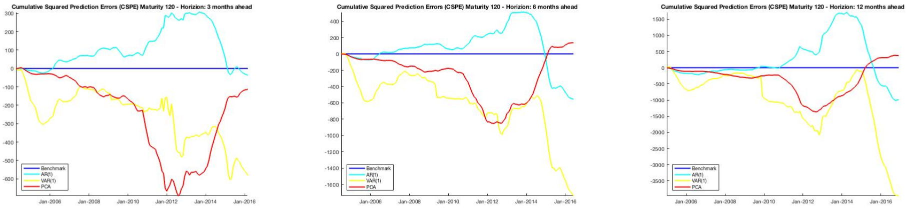

Fig. B.18: Italy - CSPE on Nominal Yields - Yield-only Models

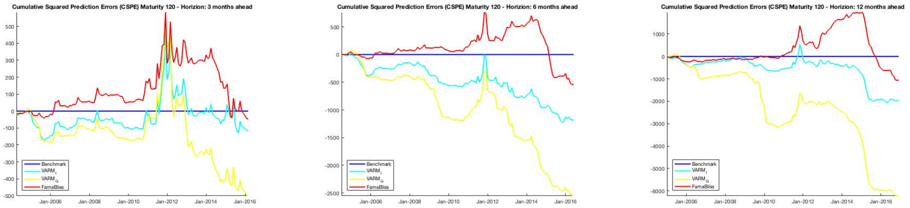

Fig. B.19: Italy - CSPE on Nominal Yields - Macro Models

6 Nominal and Real Spread Analysis

This section will assess wheather a liquidity or a default premium is affecting nominal and real sovereign yield spread of France and Italy on a selection of maturities. The current literature is almost completely devoted to investigate whether nominal spread is sensitive to liqudity or default issues. In this paper, we extend the analysis to consider real spreads. The sovereign spread is computed as the difference between the interest rate of the country and the interest rate of Germany on bonds of the same maturity. Here we use the interest rate from the term structure, on 2-, 5- and 10-year maturity. In the Eurozone, Germany is seen as the largest and most creditworthy nation, which means that its bonds are treated as the benchmark for comparison. Spreads capture two factors: default premium and liquidity premium. Higher bond spreads may be due to higher default risk or liquidity risk (in principle, country spreads could capture also cross country differences in inflation risk premia but this should be negligible since all bonds refer to the same refence index and thus should have the same likely good in hedging against inflation). Nominal spread stands for the difference between the n-year maturity yield of country-i and that of Germany. Real spread stands for the difference between the n-year maturity real yield of country-i and that of Germany. Our reference countries are France and Italy. A visual representation of nominal and real spreads, along with the corresponding CDS spreads, is provided in Figure B.20 and B.21. On our view, it is reasonable that the default premium and the liquidity premium are the main components positively affecting both nominal and real yield spreads of our countries. To assess the relative importance of these risk premia we regress the 2-year, 5-year and 10-year French and Italian yield spreads, computed as the difference between each yield and the corresponding German, onto one liquidity proxy spread and onto one default proxy spread. Our reference equation is:

$$sp_t^{i,n} = \alpha + \beta L_t i, n + \delta D_t^{i,n} + \varepsilon_t \tag{B.13}$$

where:

- $sp_t^{i,n}$ stands for the spread between the n-year maturity yield of country-i and that of Germany.
- L_t stands for the difference between the bid-ask spread of country i and that of Germany.
- D_t stands for the spread between the n-year maturity CDS of country-i and that of Germany.

The variable chosen to account for liqudity is the bid-ask spread. Bid-ask spread is an accepted measure of liquidity costs in exchange traded securities. Under competitive conditions, the bid-ask spread measures the cost of making transactions without delay. This measure is commonly considered as a driver of the liquidity premium characterizing bond markets. The variable chosen to account for the default premium is the difference between French and Italian Credit Default Swap (CDS) relative to Germany, taken at 2-, 5- and 10-year maturity, i.e. the CDS spread. The CDS is a financial derivative contract which allows to transfer the risk of a sovereign default from the protection buyer to the protection seller, in exchange for the payment of a regular fee. In the event of default, the buyer is fully compesated by receiving the difference between the notional amount of the loan and its recovery value from the protection seller. Table B.17 provides the estimation results for equation (B.13) which are quite interesting. We see that both French and Italian nominal bid-ask spreads are not statistically significant, except for the 5-year Italian nominal spread. On the other hand, the real liquidity spread is highly statistically significant for both countries, and Italy exhibits a liquidity issues even on the longest maturity of the real spread. Default affects in the same way both nominal and real spreads of all maturities throughout countries. Coefficients for the real bond spreads are larger in magnitude across the various maturities, suggesting the preponderance of the default premium as compared to the liqudity premium. A possible reason of the higher default premium experienced by real bonds can be the lower volume of the inflation-indexed markets, which accounts for the 12% on average of the whole marketable debt. Another issue can be the market segmentation characterizing real-bonds holders. Indeed, real bonds are generally purchased by long-term investors looking for full-hedge against sudden inflation and perfect matching between long-term

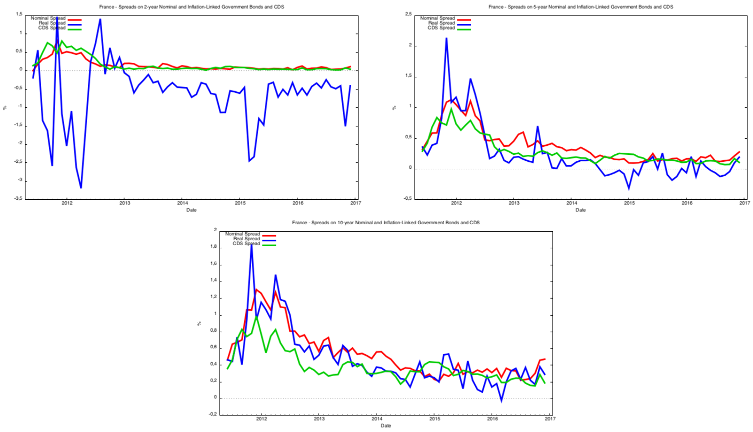

Fig. B.20: France - Nominal and Real Yield Spread and CDS Spread

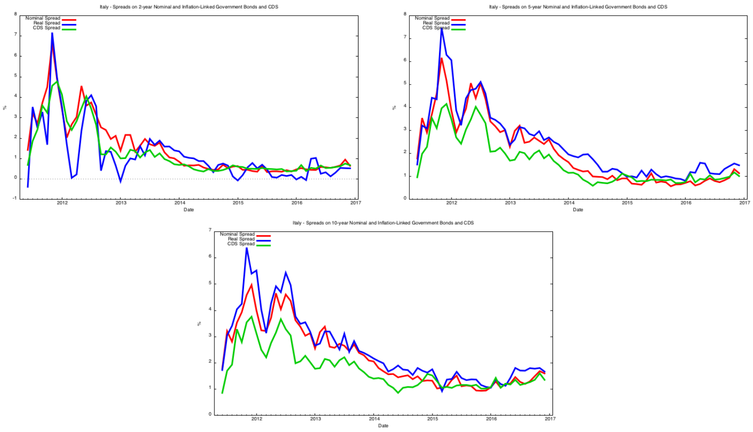

Fig. B.21: Italy - Nominal and Real Yield Spread and CDS Spread asset and liabilities. For these reasons, is it possible that less liquid bonds, like the inflation-indexed, may carry out more risk beacuse they cannot be easily liquidated. As a robustness check, we add-up an interaction term between the liquidity and the default proxy to Equation (B.13), which anyway is not statistically significant in any specifications across countries.

Lastly, we estimate the model in a different specification, computing the difference between real and nominal spreads. The equation is as follows:

$$sp_t^{i,n} = \alpha + \beta L_t i, n + \delta D_t^{i,n} + \varepsilon_t \tag{B.14}$$

where:

- $sp_t^{i,n}$ stands now for the difference between the n-year maturity real yield spread of country-i and n-year maturity nominal yield spread of the same country.
- L_t stands for the difference between real and nominal bid-ask spread of country i and that of Germany.
- D_t stands for the spread between the n-year maturity CDS of country-i and that of Germany.

Table B.18 provides the results for Equation (B.14), which is estimated only to the two longest maturities, 5- and 10-year.

The outcomes indicate that measuring the difference between real and nominal bonds, the liquidity is statistically significant at the highest level for both French and Italian spreads. This result is consistent with the hypothesis that the default probability affects the nomianl and real sprads in the same way, the result is somehow in contrast to the greater sensitivity to the CDS spread of the real spread shown in Table B.17.

The result for France is difficult to interpret as the impact of the CDS spread on the real-nominal yield spread is negative which suggests that the CDS spread has a stronger impact on the nominal spread contrary to the result in Table B.17.

The only explanation for this result is the possible slower reaction to risk in the indexed-bond market in France, as holders of such bonds may have longer horizons and be motivated by inflation-risk hedging. This is plausible considering the benchmark role played by French inflation-indexed bonds.

7 Conclusion

In this chapter we provide empirical estimates of the nominal and the real sovereign term structure of France, Germany and Italy. The model chosen is the three-factor Nelson-Siegel model, in the spirit of Diebold et al. (2006). This framework allows to capture the various shapes of the yield curve achieving dimensionality reduction and summarizing all the bond markets information throughout the three parameters: level, slope and curvature. We found that the overall fitting performance is good for both nominal and real yield curve, across countries. Moreover, we check for the forecasting performance of our reference model and we compare it with several competitors, either yield-only or with macro variables included. We see that the Nelson-Siegel model used to estimate the three parameters tend to have better performance as long as the forecasting horizon increases. Lastly, we examine the sovereign bond yield spreads, extending the standard analysis focused only on nominal spreads to real spreads. We provide empirical evidence of a significant effect of liquidity risk on short-term real bond spreads and of a default premium affecting more heavily real spreads as compared to nominal across various maturities. This result is however not robust to a different specification that considers the difference of the two yield spreads.

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A Tables

Table B.1: Yield Curve Descriptives

Maturity	Mean	SD	Min	Max	$\hat{\rho}(1)$	$\hat{\rho}(12)$	$\hat{\rho}(120)$
France Nominal							
12	1.902	1.691	-0.678	5.140	0.984	0.725	0.312
24	2.078	1.677	-0.576	5.265	0.981	0.739	0.373
36	2.284	1.658	-0.490	5.264	0.979	0.748	0.411
48	2.501	1.626	-0.437	5.306	0.979	0.753	0.425
60	2.682	1.583	-0.364	5.316	0.977	0.752	0.430
72	2.855	1.544	-0.266	5.361	0.977	0.751	0.426
84	3.031	1.512	-0.177	5.407	0.977	0.747	0.417
96	3.184	1.484	-0.073	5.656	0.976	0.743	0.408
108	3.321	1.439	0.033	5.695	0.975	0.736	0.392
120 (Level)	3.461	1.395	0.133	5.764	0.974	0.729	0.368
Slope	1.558	0.867	0.022	3.253	0.972	0.494	-0.219
Curvature	2.599	3.856	-2.576	10.169	0.987	0.733	0.303
France Real							
12	0.342	1.564	-4.353	3.785	0.889	0.490	0.239
24	0.438	1.412	-3.168	3.213	0.925	0.602	0.379
36	0.534	1.323	-1.883	2.734	0.951	0.686	0.488
48	0.628	1.247	-1.686	2.664	0.955	0.694	0.489
60	0.722	1.181	-1.490	2.646	0.954	0.690	0.480
72	0.785	1.141	-1.293	2.753	0.959	0.712	0.475
84	0.848	1.108	-1.990	2.859	0.963	0.728	0.464
96	0.883	1.085	-1.161	2.872	0.963	0.726	0.456
108	0.897	1.077	-1.145	2.877	0.962	0.725	0.453
120 (Level)	1.025	1.007	-1.007	2.922	0.960	0.713	0.412
Slope	0.683	0.934	-1.631	5.449	0.748	0.087	-0.067
Curvature	0.193	3.529	-10.244	7.547	0.885	0.476	0.283
2003:04-2016:12							
Germany							
12	0.942	0.894	-0.446	2.660	0.984	0.731	0.330
24	1.007	0.892	-0.415	2.680	0.981	0.748	0.397
36	1.095	0.901	-0.370	2.702	0.981	0.759	0.439
48	1.193	0.898	-0.342	2.723	0.979	0.767	0.466
60	1.266	0.877	-0.316	2.700	0.979	0.767	0.478
72	1.349	0.867	-0.265	2.757	0.979	0.771	0.484
84	1.433	0.859	-0.229	2.832	0.978	0.773	0.486
96	1.497	0.845	-0.179	2.865	0.978	0.773	0.483
108	1.546	0.822	-0.132	2.847	0.978	0.771	0.480
120 (Level)	1.592	0.802	-0.093	2.871	0.978	0.768	0.475
Slope	0.656	0.381	-0.075	1.413	0.965	0.378	-0.383
Curvature	1.402	1.945	-1.505	5.326	0.985	0.732	0.295
Italy							
12	2.357	1.533	-0.288	6.627	0.961	0.568	0.003
24	2.701	1.505	-0.100	7.138	0.953	0.563	-0.014
36	2.993	1.482	0.026	7.465	0.954	0.569	-0.010
48	3.244	1.443	0.159	7.570	0.955	0.578	-0.016
60	3.451	1.410	0.315	7.598	0.956	0.577	-0.038
72	3.6251	1.362	0.527	7.599	0.958	0.577	-0.049
84	3.802	1.323	0.679	7.603	0.958	0.577	-0.059
96	3.987	1.279	0.869	7.389	0.961	0.589	-0.057
108	4.142	1.242	1.043	7.058	0.962	0.598	-0.062
120 (Level)	4.267	1.218	1.193	7.081	0.963	0.600	-0.076
Slope	1.909	0.984	0.262	3.896	0.957	0.507	-0.068
Curvature	3.493	3.576	-2.339	13.822	0.953	0.512	-0.018
Italy							
12	0.489	1.389	-3.540	5.968	0.771	0.261	-0.122
24	0.786	1.293	-2.182	6.663	0.816	0.325	-0.167
36	1.058	1.234	-0.968	8.052	0.857	0.290	-0.129
48	1.295	1.204	-0.685	7.983	0.869	0.322	-0.221
60	1.542	1.233	-0.509	7.709	0.895	0.387	-0.213
72	1.839	1.166	-0.295	7.369	0.908	0.439	-0.212
84	2.195	1.173	-0.011	6.576	0.939	0.482	-0.156
96	2.424	1.144	0.100	6.394	0.951	0.519	-0.162
108	2.455	1.067	0.256	5.823	0.956	0.535	-0.156
120 (Level)	2.531	0.909	0.568	4.818	0.960	0.569	-0.149
Slope	2.043	1.406	-1.994	6.794	0.793	0.352	0.051
Curvature	-0.471	3.619	-10.034	14.163	0.785	0.322	-0.036
2004:10-2016:12							

Table B.2: Yield Curve Residuals, Descriptives

Maturity	Mean	SD	Min	Max	MAE	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	$\hat{\rho}(120)$
France Nominal									
12	-0.030	0.023	-0.088	0.010	0.031	0.038	0.900	0.642	0.285
24	0.056	0.048	-0.046	0.170	0.059	0.073	0.863	0.616	0.249
36	0.032	0.026	-0.026	0.109	0.033	0.041	0.676	0.263	0.102
48	0.000	0.023	-0.052	0.099	0.017	0.023	0.760	0.310	-0.147
60	-0.042	0.030	-0.117	0.030	0.043	0.052	0.774	0.423	0.231
72	-0.059	0.032	-0.148	-0.003	0.059	0.067	0.911	0.516	0.163
84	-0.039	0.032	-0.134	0.016	0.040	0.051	0.869	0.412	0.141
96	-0.013	0.026	-0.079	0.071	0.023	0.029	0.806	0.523	0.364
108	0.020	0.021	-0.037	0.079	0.024	0.029	0.773	0.398	0.210
120	0.075	0.058	-0.014	0.252	0.075	0.095	0.948	0.611	0.252
France Real									
12	-0.007	0.003	-0.082	0.149	0.020	0.031	0.616	0.085	0.013
24	0.013	0.084	-0.452	0.215	0.057	0.085	0.713	0.089	-0.141
36	0.004	0.077	-0.204	0.236	0.053	0.077	0.763	0.131	-0.407
48	-0.004	0.018	-0.072	0.046	0.010	0.018	0.715	-0.064	-0.045
60	0.002	0.073	-0.240	0.317	0.045	0.073	0.599	0.125	-0.041
72	-0.007	0.033	-0.126	0.142	0.023	0.034	0.557	0.074	-0.132
84	-0.003	0.040	-0.099	0.140	0.025	0.040	0.719	-0.157	-0.142
96	-0.015	0.025	-0.071	0.040	0.021	0.029	0.805	0.331	-0.065
108	0.039	0.045	-0.163	0.017	0.041	0.060	0.883	0.452	0.111
120	0.056	0.068	-0.045	0.315	0.059	0.088	0.759	0.431	0.050
Germany									
12	-0.010	0.012	-0.045	0.023	0.012	0.016	0.903	0.645	0.267
24	0.020	0.026	-0.0630	0.089	0.025	0.033	0.875	0.602	0.242
36	0.010	0.016	-0.038	0.046	0.016	0.019	0.745	0.256	-0.006
48	0.002	0.015	-0.036	0.062	0.012	0.015	0.837	0.436	-0.008
60	-0.023	0.016	-0.065	0.017	0.023	0.027	0.771	0.191	-0.085
72	-0.022	0.015	-0.064	0.006	0.022	0.026	0.895	0.480	0.019
84	-0.005	0.020	-0.057	0.047	0.016	0.021	0.921	0.555	0.133
96	0.004	0.013	-0.024	0.044	0.011	0.014	0.815	0.586	0.091
108	0.008	0.014	-0.039	0.044	0.013	0.016	0.850	0.328	0.142
120	0.016	0.027	-0.038	0.077	0.023	0.031	0.926	0.608	0.226
Italy Nominal									
12	-0.034	0.026	-0.114	0.080	0.036	0.043	0.640	0.233	0.069
24	0.061	0.060	-0.151	0.250	0.068	0.085	0.630	0.166	0.072
36	0.041	0.040	-0.072	0.163	0.047	0.057	0.766	0.097	0.002
48	0.000	0.039	-0.144	0.136	0.029	0.039	0.730	0.183	-0.251
60	-0.043	0.048	-0.185	0.175	0.053	0.064	0.672	0.076	0.026
72	-0.072	0.046	-0.193	0.139	0.074	0.086	0.800	0.312	-0.171
84	-0.059	0.061	-0.307	0.215	0.067	0.085	0.795	0.300	-0.124
96	-0.008	0.033	-0.132	0.068	0.026	0.034	0.669	0.021	-0.033
108	0.040	0.039	-0.208	0.163	0.046	0.055	0.693	0.112	-0.134
120	0.076	0.058	-0.136	0.290	0.081	0.095	0.722	0.295	0.069
Italy Real									
12	-0.047	0.101	-0.291	0.404	0.083	0.111	0.748	0.180	-0.185
24	0.102	0.256	-0.959	0.776	0.200	0.274	0.746	0.167	-0.126
36	0.049	0.189	-0.581	0.617	0.143	0.195	0.733	0.022	-0.069
48	-0.058	0.160	-0.339	0.475	0.138	0.170	0.702	-0.033	-0.002
60	-0.120	0.161	-0.596	0.402	0.165	0.201	0.704	-0.042	-0.093
72	-0.081	0.188	-0.505	0.469	0.177	0.204	0.845	0.284	-0.025
84	0.062	0.134	-0.245	0.515	0.111	0.147	0.791	0.243	-0.155
96	0.118	0.111	-0.144	0.488	0.132	0.162	0.860	0.263	-0.004
108	0.007	0.054	-0.160	0.147	0.043	0.055	0.772	0.163	-0.072
120	-0.032	0.209	-0.863	0.417	0.160	0.211	0.855	0.335	-0.181

Table B.3: Estimated Factors, Correlations

France				
	Nominal	L_t	S_t	C_t
	$\hat{\beta}_1$	0.962	·	·
	$\hat{\beta}_2$	·	0.957	·
	$\hat{\beta}_3$	·	·	0.994
	Real	L_t	S_t	C_t
	$\hat{\beta}_1$	0.949	·	·
	$\hat{\beta}_2$	·	0.951	·
	$\hat{\beta}_3$	·	·	0.986
Germany				
	Nominal	L_t	S_t	C_t
	$\hat{\beta}_1$	0.975	·	·
	$\hat{\beta}_2$	·	0.955	·
	$\hat{\beta}_3$	·	·	0.993
Italy				
	Nominal	L_t	S_t	C_t
	$\hat{\beta}_1$	0.946	·	·
	$\hat{\beta}_2$	·	0.969	·
	$\hat{\beta}_3$	·	·	0.988
	Real	L_t	S_t	C_t
	$\hat{\beta}_1$	0.859	·	·
	$\hat{\beta}_2$	·	0.919	·
	$\hat{\beta}_3$	·	·	0.939

Table B.4: Estimated Factors, Descriptives

	Factor	Mean	SD	Min	Max	$\hat{\rho}(1)$	$\hat{\rho}(12)$	$\hat{\rho}(120)$	ADF
France									
Nominal									
	$\hat{\beta}_{1t}$	4.184	1.363	0.482	6.255	0.967	0.661	0.217	-1.577
	$\hat{\beta}_{2t}$	-1.903	1.263	-4.771	0.187	0.967	0.421	-0.269	-1.258
	$\hat{\beta}_{3t}$	-3.956	2.269	-8.861	0.035	0.944	0.550	0.162	-0.916
Real									
	$\hat{\beta}_{1t}$	1.264	0.954	-0.910	3.486	0.942	0.603	0.205	-1.640
	$\hat{\beta}_{2t}$	-0.876	1.733	-11.119	3.761	0.709	0.004	-0.179	-4.467
	$\hat{\beta}_{3t}$	-1.289	2.705	-7.919	8.834	0.834	0.231	-0.105	-3.351
Germany									
Nominal									
	$\hat{\beta}_{1t}$	1.924	0.793	0.055	3.116	.0974	0.728	0.395	-1.729
	$\hat{\beta}_{2t}$	-0.8090	0.604	-2.201	0.270	0.958	0.358	-0.363	-1.563
	$\hat{\beta}_{3t}$	-1.744	1.014	-3.889	0.244	0.926	0.451	0.049	-1.122
Italy									
Nominal									
	$\hat{\beta}_{1t}$	5.015	1.159	1.919	7.462	0.959	0.552	-0.171	-1.141
	$\hat{\beta}_{2t}$	-2.589	1.522	-5.986	-0.158	0.962	0.481	-0.077	-1.092
	$\hat{\beta}_{3t}$	-3.451	2.267	-8.642	5.539	0.836	0.293	-0.023	-1.907
Real									
	$\hat{\beta}_{1t}$	3.651	1.251	1.171	6.837	0.916	0.583	-0.107	-0.893
	$\hat{\beta}_{2t}$	-2.695	2.784	-12.411	5.469	0.826	0.259	-0.021	-2.648
	$\hat{\beta}_{3t}$	-5.280	4.903	-15.815	21.671	0.732	0.004	-0.043	-3.024

Table B.5: Out-of-sample 1-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$		Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
France Nominal						**France Real**					
NS with AR(1)											
1 year	0.109	0.268	0.330	0.773	-0.066		0.787	2.901	0.887	0.441	0.121
3 years	0.099	0.164	0.314	0.544	-0.019		0.281	0.502	0.530	0.261	0.257
5 years	0.110	0.144	0.331	0.346	-0.071		0.185	0.322	0.430	0.360	0.006
10 years	0.080	0.120	0.282	0.124	0.022		0.091	0.160	0.302	0.094	-0.098
Yield-only Models											
AR(1)											
1 year	0.093	0.269	0.306	0.766	-0.052		0.741	2.576	0.861	0.553	0.146
3 years	0.093	0.162	0.306	0.545	-0.150		0.218	0.491	0.467	0.275	0.176
5 years	0.089	0.138	0.299	0.346	-0.023		0.158	0.286	0.397	0.263	0.035
10 years	0.082	0.117	0.286	0.072	-0.013		0.090	0.160	0.300	0.070	-0.094
VAR(1)											
1 year	0.081	0.209	0.284	0.750	-0.059		0.639	2.258	0.799	0.480	0.068
3 years	0.086	0.136	0.293	0.511	-0.005		0.181	0.318	0.426	0.261	-0.044
5 years	0.083	0.113	0.289	0.297	-0.069		0.135	0.248	0.368	0.215	-0.101
10 years	0.077	0.105	0.277	0.123	-0.074		0.086	0.160	0.293	0.001	-0.066
PCA											
1 year	0.096	0.262	0.309	0.767	-0.051		0.701	2.271	0.837	0.586	0.151
3 years	0.100	0.171	0.316	0.542	-0.004		0.210	0.377	0.458	0.267	0.212
5 years	0.087	0.127	0.294	0.343	-0.030		0.161	0.283	0.401	0.299	0.006
10 years	0.080	0.121	0.282	0.155	0.043		0.089	0.155	0.299	0.075	-0.035
Macro Models											
VAR Macro											
1 year	0.083	0.197	0.288	0.702	-0.089		0.704	2.384	0.839	0.560	0.148
3 years	0.085	0.144	0.292	0.596	-0.066		0.210	0.375	0.458	0.311	0.185
5 years	0.083	0.123	0.288	0.469	-0.069		0.149	0.263	0.386	0.275	0.057
10 years	0.079	0.106	0.280	0.194	-0.040		0.084	0.162	0.291	0.008	-0.095
VAR Global Macro											
1 year	0.076	0.179	0.275	0.657	-0.099		0.647	2.197	0.804	0.555	0.136
3 years	0.083	0.139	0.288	0.575	-0.061		0.194	0.350	0.440	0.314	0.217
5 years	0.082	0.115	0.287	0.419	-0.049		0.141	0.248	0.375	0.282	0.066
10 years	0.078	0.096	0.279	0.178	-0.075		0.082	0.149	0.287	0.018	-0.088
Fama-Bliss Forward											
1 year	0.094	0.269	0.306	0.766	-0.053		0.675	2.424	0.822	0.562	0.128
3 years	0.094	0.162	0.307	0.544	-0.017		0.193	0.358	0.440	0.239	0.185
5 years	0.090	0.137	0.299	0.345	-0.025		0.139	0.259	0.373	0.225	0.073
10 years	0.082	0.117	0.286	0.071	-0.001		0.085	0.147	0.291	0.019	-0.054
2000:01						*2003:07*					
2016:12						*2016:12*					

Table B.6: Out-of-sample 1-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Germany **Nominal**					
NS with AR(1)					
1 year	0.030	0.085	0.173	0.700	-0.068
3 years	0.029	0.056	0.170	0.617	-0.085
5 years	0.031	0.048	0.176	0.488	-0.080
10 years	0.022	0.035	0.149	0.2700	0.052
Yield-Based Models					
AR(1)					
1 year	0.026	0.085	0.162	0.689	-0.056
3 years	0.026	0.054	0.162	0.615	-0.083
5 years	0.025	0.043	0.160	0.484	-0.057
10 years	0.022	0.034	0.148	0.277	0.004
VAR(1)					
1 year	0.023	0.071	0.151	0.708	-0.058
3 years	0.024	0.047	0.155	0.610	-0.082
5 years	0.023	0.037	0.152	0.451	-0.055
10 years	0.020	0.029	0.141	0.247	-0.052
PCA					
1 year	0.027	0.083	0.163	0.699	-0.059
3 years	0.028	0.062	0.168	0.645	-0.067
5 years	0.025	0.040	0.158	0.461	-0.060
10 years	0.021	0.031	0.146	0.268	0.054
Macro Models					
VAR Macro					
1 year	0.024	0.080	0.154	0.612	-0.051
3 years	0.025	0.050	0.160	0.556	-0.082
5 years	0.025	0.041	0.158	0.436	-0.057
10 years	0.022	0.031	0.147	0.274	0.012
VAR Global Macro					
1 year	0.024	0.074	0.153	0.626	-0.059
3 years	0.025	0.048	0.158	0.557	-0.075
5 years	0.024	0.039	0.156	0.408	-0.059
10 years	0.020	0.029	0.143	0.226	-0.022
Fama-Bliss Forward					
1 year	0.026	0.085	0.162	0.688	-0.056
3 years	0.026	0.054	0.162	0.614	-0.085
5 years	0.026	0.043	0.160	0.482	-0.058
10 years	0.022	0.034	0.148	0.276	0.006
2000:01 *2016:12*					

Table B.7: Out-of-sample 1-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Italy **Nominal**						**Italy** **Real**					
NS with AR(1)											
1 year	0.400	1.302	0.632	0.417	0.005		1.802	3.567	1.342	0.396	-0.171
3 years	0.367	1.155	0.606	0.363	-0.005		0.960	2.690	0.980	0.173	-0.029
5 years	0.314	0.786	0.560	0.354	0.004		0.672	1.592	0.820	0.152	-0.045
10 years	0.181	0.317	0.425	0.463	0.118		0.165	0.259	0.406	0.466	-0.131
Yield-Based Models											
AR(1)											
1 year	0.407	1.486	0.638	0.405	-0.002		1.724	3.549	1.320	0.376	-0.169
3 years	0.367	1.229	0.606	0.353	-0.022		0.905	2.707	0.951	0.141	-0.053
5 years	0.292	0.857	0.541	0.371	0.006		0.666	1.811	0.816	0.191	-0.033
10 years	0.173	0.307	0.416	0.430	0.069		0.151	0.244	0.388	0.483	-0.083
VAR(1)											
1 year	0.360	1.173	0.600	0.470	-0.006		1.645	3.487	1.282	0.331	-0.166
3 years	0.337	1.034	0.580	0.344	-0.024		0.819	2.620	0.905	0.128	-0.030
5 years	0.275	0.747	0.524	0.310	0.005		0.612	1.798	0.782	0.182	-0.002
10 years	0.161	0.279	0.402	0.391	0.067		0.140	0.234	0.374	0.469	-0.080
PCA											
1 year	0.407	1.478	0.638	0.406	-0.006		1.901	3.809	1.379	0.363	-0.163
3 years	0.357	1.230	0.597	0.359	-0.014		0.955	2.851	0.977	0.184	-0.045
5 years	0.317	0.857	0.563	0.353	-0.010		0.814	1.773	0.902	0.177	-0.052
10 years	0.207	0.380	0.455	0.504	0.163		0.327	0.421	0.572	0.0.565	-0.093
Macro Models											
VAR Macro											
1 year	0.376	1.388	0.613	0.400	0.003		1.570	3.298	1.253	0.317	-0.146
3 years	0.351	1.205	0.592	0.330	-0.016		0.792	2.523	0.890	0.121	-0.027
5 years	0.285	0.861	0.534	0.338	0.015		0.595	1.712	0.771	0.166	0.006
10 years	0.169	0.305	0.411	0.426	0.067		0.132	0.215	0.364	0.447	-0.076
VAR Global Macro											
1 year	0.371	1.362	0.609	0.427	0.015		1.535	3.275	1.239	0.331	-0.151
3 years	0.351	1.194	0.593	0.354	-0.015		0.794	2.385	0.891	0.212	-0.026
5 years	0.285	0.862	0.534	0.341	0.004		0.592	1.521	0.770	0.288	0.012
10 years	0.168	0.311	0.410	0.431	0.022		0.127	0.209	0.357	0.472	-0.047
Fama-Bliss Forward											
1 year	0.407	1.486	0.638	0.405	-0.056		1.554	3.282	1.247	0.354	-0.163
3 years	0.368	1.229	0.606	0.352	-0.022		0.790	2.599	1.247	0.354	-0.163
5 years	0.293	0.857	0.541	0.482	0.006		0.599	1.798	0.774	0.215	-0.012
10 years	0.173	0.307	0.416	0.276	0.071		0.142	0.240	0.377	0.458	-0.078
2000:01 *2016:12*						*2004:07* *2016:12*					

Table B.8: Out-of-sample 3-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$		Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
France Nominal						**France Real**					
NS with AR(1)											
1 year	0.279	0.815	0.529	0.885	-0.055		1.356	3.196	1.165	0.604	0.075
3 years	0.232	0.449	0.481	0.740	-0.018		0.446	0.769	0.667	0.417	0.063
5 years	0.223	0.307	0.472	0.623	-0.054		0.296	0.521	0.544	0.440	-0.033
10 years	0.148	0.174	0.384	0.318	0.104		0.141	0.179	0.376	0.211	0.010
Yield-Based Models											
AR(1)											
1 year	0.260	0.801	0.510	0.881	-0.052		1.377	3.057	1.173	0.554	0.106
3 years	0.221	0.426	0.471	0.744	0.004		0.385	0.693	0.621	0.528	-0.038
5 years	0.193	0.294	0.439	0.618	-0.001		0.288	0.506	0.537	0.516	-0.048
10 years	0.163	0.181	0.404	0.348	-0.001		0.151	0.179	0.388	0.321	-0.079
VAR(1)											
1 year	0.268	0.773	0.518	0.862	-0.039		1.353	2.958	1.163	0.471	-0.023
3 years	0.238	0.462	0.488	0.774	-0.027		0.406	0.624	0.637	0.589	-0.110
5 years	0.208	0.309	0.456	0.685	-0.108		0.312	0.488	0.558	0.532	-0.072
10 years	0.165	0.204	0.407	0.568	-0.145		0.183	0.217	0.428	0.353	-0.201
PCA											
1 year	0.264	0.809	0.513	0.881	-0.048		1.182	2.527	1.087	0.616	0.082
3 years	0.232	0.466	0.482	0.748	-0.015		0.359	0.631	0.599	0.433	0.042
5 years	0.189	0.296	0.434	0.610	-0.031		0.277	0.481	0.526	0.411	-0.046
10 years	0.145	0.172	0.381	0.335	0.116		0.130	0.158	0.360	0.178	-0.065
Macro Models											
VAR Macro											
1 year	0.273	0.628	0.522	0.776	-0.089		1.320	2.706	1.149	0.521	0.150
3 years	0.252	0.523	0.502	0.697	-0.055		0.473	0.845	0.688	0.562	0.172
5 years	0.224	0.403	0.473	0.680	-0.112		0.341	0.558	0.584	0.479	0.137
10 years	0.186	0.244	0.432	0.657	-0.137		0.172	0.224	0.415	0.359	-0.165
VAR Global Macro											
1 year	0.253	0.596	0.503	0.751	-0.103		1.272	2.473	1.128	0.474	0.065
3 years	0.262	0.504	0.512	0.674	-0.084		0.445	0.754	0.667	0.522	0.203
5 years	0.244	0.377	0.494	0.622	-0.098		0.331	0.497	0.576	0.435	0.117
10 years	0.198	0.234	0.445	0.583	-0.122		0.190	0.273	0.436	0.230	-0.154
Fama-Bliss Forward											
1 year	0.261	0.801	0.511	0.881	-0.052		1.019	2.490	1.010	0.581	0.047
3 years	0.225	0.426	0.474	0.739	-0.001		0.305	0.513	0.552	0.511	-0.010
5 years	0.196	0.295	0.442	0.610	-0.008		0.237	0.374	0.487	0.530	0.082
10 years	0.164	0.181	0.405	0.346	-0.001		0.147	0.191	0.384	0.515	0.145
2000:01						*2003:07*					
2016:12						*2016:12*					

Table B.9: Out-of-sample 3-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Germany Nominal					
NS with AR(1)					
1 year	0.079	0.237	0.281	0.876	-0.072
3 years	0.071	0.151	0.266	0.802	-0.067
5 years	0.067	0.109	0.258	0.751	-0.075
10 years	0.046	0.064	0.214	0.570	0.013
Yield-Based Models					
AR(1)					
1 year	0.075	0.233	0.274	0.871	-0.065
3 years	0.066	0.141	0.257	0.798	-0.060
5 years	0.059	0.105	0.242	0.744	-0.072
10 years	0.046	0.065	0.216	0.596	0.034
VAR(1)					
1 year	0.073	0.223	0.271	0.855	-0.052
3 years	0.067	0.144	0.259	0.815	-0.058
5 years	0.058	0.098	0.240	0.787	-0.095
10 years	0.046	0.060	0.214	0.637	-0.122
PCA					
1 year	0.075	0.235	0.274	0.872	-0.064
3 years	0.071	0.163	0.266	0.817	-0.049
5 years	0.057	0.099	0.239	0.710	-0.086
10 years	0.041	0.057	0.202	0.545	0.039
Macro Models					
VAR Macro					
1 year	0.074	0.225	0.272	0.814	-0.052
3 years	0.070	0.146	0.265	0.752	-0.066
5 years	0.061	0.108	0.248	0.717	-0.084
10 years	0.048	0.065	0.219	0.604	0.024
VAR Global Macro					
1 year	0.072	0.196	0.268	0.809	-0.076
3 years	0.070	0.130	0.265	0.719	-0.061
5 years	0.062	0.095	0.248	0.677	-0.088
10 years	0.045	0.055	0.212	0.525	-0.109
Fama-Bliss Forward					
1 year	0.075	0.233	0.275	0.871	-0.066
3 years	0.067	0.141	0.259	0.795	-0.063
5 years	0.060	0.105	0.244	0.740	-0.076
10 years	0.047	0.065	0.216	0.595	0.034
2000:01 2016:12					

Table B.10: Out-of-sample 3-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$		Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Italy **Nominal**						**Italy** **Real**					
NS with AR(1)											
1 year	0.771	2.047	0.879	0.592	0.004		2.878	5.957	1.696	0.344	-0.064
3 years	0.628	1.450	0.793	0.535	0.085		1.534	3.807	1.238	0.305	0.086
5 years	0.527	0.939	0.726	0.551	0.153		1.092	2.238	1.045	0.386	0.056
10 years	0.326	0.539	0.571	0.466	0.239		0.315	0.510	0.561	0.626	-0.039
Yield-Based Models											
AR(1)											
1 year	0.780	2.104	0.883	0.586	0.010		2.583	5.545	1.607	0.349	-0.062
3 years	0.631	1.374	0.794	0.532	0.065		1.501	3.637	1.225	0.369	0.005
5 years	0.514	0.967	0.717	0.533	0.161		1.229	3.042	1.108	0.446	-0.016
10 years	0.329	0.505	0.573	0.519	0.198		0.326	0.564	0.571	0.627	-0.030
VAR(1)											
1 year	0.889	2.246	0.943	0.562	-0.039		2.465	5.421	1.570	0.359	-0.078
3 years	0.757	1.642	0.870	0.449	0.027		1.318	3.392	1.148	0.324	0.067
5 years	0.614	1.162	0.784	0.502	0.074		1.110	2.931	1.053	0.428	0.047
10 years	0.367	0.551	0.606	0.432	0.155		0.306	0.535	0.553	0.559	-0.002
PCA											
1 year	0.780	2.247	0.883	0.579	-0.004		3.121	7.589	1.767	0.355	-0.061
3 years	0.607	1.549	0.779	0.513	0.073		1.161	4.749	1.272	0.320	0.034
5 years	0.531	1.042	0.729	0.512	0.124		1.364	2.985	1.168	0.380	0.034
10 years	0.334	0.591	0.578	0.455	0.244		0.458	0.677	0.677	0.698	-0.135
Macro Models											
VAR Macro											
1 year	0.782	2.216	0.884	0.540	-0.023		2.636	5.581	1.623	0.459	-0.074
3 years	0.655	1.502	0.809	0.515	0.056		1.686	4.966	1.298	0.363	0.024
5 years	0.542	1.087	0.736	0.523	0.154		1.460	4.250	1.208	0.295	0.017
10 years	0.334	0.571	0.578	0.453	0.198		0.320	0.536	0.566	0.504	0.003
VAR Global Macro											
1 year	0.782	2.216	0.884	0.540	-0.023		2.636	5.581	1.623	0.459	-0.074
3 years	0.655	1.502	0.809	0.515	0.056		1.686	4.966	1.298	0.363	0.024
5 years	0.542	1.087	0.736	0.523	0.154		1.460	4.250	1.208	0.295	0.017
10 years	0.334	0.517	0.578	0.453	0.198		0.320	0.536	0.565	0.504	0.003
Fama-Bliss Forward											
1 year	0.834	2.451	0.913	0.508	-0.005		2.300	5.576	1.516	0.419	-0.076
3 years	0.728	1.790	0.853	0.513	0.025		1.209	3.522	1.100	0.396	0.040
5 years	0.601	1.279	0.775	0.532	0.085		1.031	2.887	1.015	0.503	0.037
10 years	0.361	0.591	0.601	0.504	0.103		0.311	0.544	0.558	0.592	-0.002
2000:01 *2016:12*						*2004:07* *2016:12*					

Table B.11: Out-of-sample 6-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$		Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
France **Nominal**						**France** **Real**					
NS with AR(1)											
1 year	0.570	1.671	0.755	0.041	-0.076		2.000	3.819	1.414	0.310	-0.016
3 years	0.419	0.815	0.647	-0.048	-0.027		0.628	0.921	0.792	-0.004	-0.003
5 years	0.388	0.406	0.623	-0.139	-0.004		0.416	0.663	0.645	0.015	-0.043
10 years	0.262	0.277	0.512	-0.017	-0.087		0.200	0.234	0.447	-0.070	-0.036
Yield-Based Models											
AR(1)											
1 year	0.541	1.601	0.736	0.038	-0.068		2.395	4.860	1.548	0.403	-0.049
3 years	0.404	0.716	0.635	-0.018	0.013		0.646	1.057	0.804	0.079	0.026
5 years	0.349	0.433	0.591	-0.060	-0.064		0.476	0.769	0.690	0.017	-0.061
10 years	0.319	0.363	0.565	0.138	-0.061		0.252	0.296	0.502	-0.049	-0.040
VAR(1)											
1 year	0.636	1.777	0.798	0.096	-0.087		2.822	5.222	1.680	0.322	0.144
3 years	0.505	0.996	0.710	0.017	-0.066		1.027	1.585	1.013	0.018	0.008
5 years	0.438	0.655	0.662	-0.065	-0.096		0.733	1.227	0.856	-0.059	-0.094
10 years	0.343	0.474	0.585	0.45	-0.053		0.351	0.512	0.592	-0.110	-0.139
PCA											
1 year	0.548	1.663	0.740	0.043	-0.071		1.828	3.241	1.352	0.225	0.020
3 years	0.422	0.847	0.650	-0.053	-0.033		0.556	0.844	0.745	-0.046	0.050
5 years	0.334	0.472	0.578	-0.104	0.003		0.415	0.636	0.645	0.006	-0.004
10 years	0.254	0.275	0.504	-0.010	-0.060		0.187	0.217	0.433	-0.126	0.046
Macro Models											
VAR Macro											
1 year	0.633	1.149	0.795	0.372	-0.027		2.672	4.804	1.635	0.283	0.123
3 years	0.535	0.684	0.731	0.058	0.095		1.044	1.950	1.022	-0.025	-0.052
5 years	0.480	0.528	0.693	-0.097	0.050		0.750	1.303	0.866	-0.073	-0.099
10 years	0.429	0.566	0.655	0.129	-0.078		0.392	0.702	0.626	0.071	-0.128
VAR Global Macro											
1 year	0.570	0.986	0.795	0.517	-0.072		2.926	7.048	1.635	0.127	0.028
3 years	0.574	0.668	0.731	0.123	0.014		0.918	1.443	1.022	0.011	-0.134
5 years	0.563	0.623	0.693	-0.098	-0.026		0.674	0.993	0.866	-0.003	-0.152
10 years	0.485	0.651	0.655	0.016	-0.117		0.446	1.104	0.626	0.144	-0.062
Fama-Bliss Forward											
1 year	0.541	1.610	0.736	0.038	-0.069		1.602	3.423	1.266	0.422	-0.070
3 years	0.404	0.716	0.635	-0.019	0.012		0.498	0.747	0.706	-0.019	0.003
5 years	0.348	0.433	0.590	-0.063	0.066		0.406	0.580	0.637	-0.094	-0.053
10 years	0.316	0.364	0.562	0.135	-0.063		0.260	0.319	0.510	-0.206	-0.110
2000:01 *2016:12*						*2003:07* *2016:12*					

Table B.12: Out-of-sample 6-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Germany **Nominal**					
NS with AR(1)					
1 year	0.157	0.466	0.396	0.033	-0.076
3 years	0.129	0.271	0.359	-0.057	-0.025
5 years	0.118	0.189	0.343	-0.057	-0.022
10 years	0.084	0.104	0.290	-0.013	0.022
Yield-Based Models					
AR(1)					
1 year	0.152	0.449	0.390	0.026	-0.076
3 years	0.122	0.241	0.349	-0.041	0.046
5 years	0.108	0.174	0.328	-0.004	0.093
10 years	0.090	0.112	0.301	0.032	0.043
VAR(1)					
1 year	0.169	0.487	0.411	0.077	-0.076
3 years	0.142	0.307	0.377	0.001	0.039
5 years	0.122	0.213	0.349	-0.018	-0.003
10 years	0.096	0.122	0.310	-0.065	-0.043
PCA					
1 year	0.153	0.464	0.391	0.029	-0.074
3 years	0.130	0.290	0.360	-0.056	0.017
5 years	0.103	0.170	0.321	-0.027	-0.014
10 years	0.073	0.090	0.270	0.034	-0.006
Macro Models					
VAR Macro					
1 year	0.172	0.487	0.414	-0.030	-0.047
3 years	0.144	0.285	0.380	-0.049	0.129
5 years	0.122	0.201	0.350	-0.039	0.203
10 years	0.099	0.121	0.314	-0.015	0.105
VAR Global Macro					
1 year	0.145	0.366	0.414	0.100	-0.058
3 years	0.139	0.221	0.380	0.030	0.039
5 years	0.125	0.164	0.350	-0.016	0.080
10 years	0.100	0.112	0.314	-0.092	0.070
Fama-Bliss Forward					
1 year	0.152	0.449	0.390	0.026	-0.077
3 years	0.122	0.241	0.349	-0.041	0.045
5 years	0.107	0.175	0.328	-0.006	0.093
10 years	0.090	0.112	0.300	0.029	0.047
2000:01 *2016:12*					

Table B.13: Out-of-sample 6-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Italy **Nominal**						**Italy** **Real**				
NS with AR(1)										
1 year	1.051	2.414	1.025	0.044	-0.075	3.179	5.588	1.783	0.004	-0.006
3 years	0.866	1.778	0.931	0.093	-0.060	1.679	5.231	1.296	-0.029	-0.036
5 years	0.761	1.350	0.872	0.052	-0.030	1.374	3.538	1.172	-0.065	-0.056
10 years	0.495	0.805	0.704	0.076	-0.020	0.479	0.674	0.692	-0.162	0.026
Yield-Based Models										
AR(1)										
1 year	1.809	2.315	1.044	0.026	-0.056	2.996	5.181	1.731	0.033	0.011
3 years	0.927	1.617	0.963	0.044	-0.065	1.830	4.786	1.353	0.192	-0.069
5 years	0.783	1.362	0.885	0.065	-0.050	1.484	4.030	1.218	0.240	-0.082
10 years	0.534	0.887	0.730	0.154	-0.047	0.522	0.772	0.722	-0.053	-0.083
VAR(1)										
1 year	1.407	2.506	1.186	0.230	-0.168	3.419	6.286	1.849	0.149	0.002
3 years	1.140	1.838	1.068	0.167	-0.132	2.179	5.012	1.476	0.073	-0.084
5 years	0.947	1.524	0.973	0.118	-0.106	1.835	4.219	1.355	0.062	-0.110
10 years	0.616	0.929	0.785	0.100	-0.069	0.561	0.786	0.749	-0.094	-0.085
PCA										
1 year	1.052	2.484	1.026	0.085	-0.086	3.240	5.835	1.800	-0.002	-0.063
3 years	0.827	1.807	0.909	0.137	-0.077	1.727	5.085	1.314	0.037	-0.053
5 years	0.758	1.346	0.871	0.095	-0.040	1.652	4.003	1.285	-0.035	-0.065
10 years	0.485	0.822	0.697	0.066	-0.081	0.580	0.876	0.762	-0.036	-0.067
Macro Models										
VAR Macro										
1 year	0.633	1.149	0.795	0.372	-0.027					
3 years	0.535	0.684	0.731	0.058	0.095					
5 years	0.480	0.528	0.693	-0.097	0.050					
10 years	0.429	0.566	0.655	0.129	-0.078					
VAR Global Macro										
1 year	1.227	2.888	1.042	0.263	-0.066	6.113	25.574	1.863	-0.021	-0.017
3 years	1.144	2.042	0.987	0.284	-0.058	3.469	9.575	1.653	0.043	-0.077
5 years	1.004	1.667	0.922	0.223	-0.035	4.727	22.151	1.719	0.043	-0.040
10 years	0.672	0.908	0.760	0.196	0.036	0.857	1.844	0.820	-0.027	-0.088
Fama-Bliss Forward										
1 year	2.181	3.238	1.477	0.039	0.095	2.989	6.043	1.729	0.063	0.022
3 years	1.920	2.555	1.386	0.180	0.095	2.325	8.230	1.525	0.422	-0.060
5 years	1.651	2.304	1.285	0.158	0.111	2.646	12.304	1.627	0.256	-0.034
10 years	1.150	1.713	1.072	0.059	-0.011	1.151	1.748	1.073	0.174	-0.087
2000:01 *2016:12*						*2004:07* *2016:12*				

Table B.14: Out-of-sample 12-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
France **Nominal**						**France** **Real**					
NS with AR(1)											
1 year	1.131	2.451	1.064	-0.120	-0.044		2.365	4.417	1.533	0.102	-0.032
3 years	0.732	1.057	0.855	-0.107	-0.082		0.873	1.468	0.934	-0.177	0.189
5 years	0.650	0.704	0.806	-0.225	-0.058		0.603	1.055	0.777	-0.175	0.172
10 years	0.452	0.622	0.672	-0.239	0.178		0.338	0.427	0.581	-0.287	0.020
Yield-Based Models											
AR(1)											
1 year	1.706	2.253	1.037	-0.133	0.028		3.314	6.563	1.820	0.282	-0.057
3 years	0.716	0.891	0.846	-0.030	-0.037		1.081	1.708	1.040	-0.243	0.235
5 years	0.627	0.680	0.792	-0.185	0.026		0.812	1.140	0.901	-0.266	0.241
10 years	0.639	0.908	0.799	0.219	0.245		0.517	0.571	0.719	-0.381	0.230
VAR(1)											
1 year	1.241	2.542	1.114	-0.082	-0.098		3.960	7.533	1.990	0.228	-0.145
3 years	0.980	1.320	0.990	-0.072	-0.190		2.226	5.845	1.492	0.019	-0.086
5 years	0.861	0.875	0.928	-0.083	-0.183		1.697	4.742	1.303	-0.016	-0.076
10 years	0.681	0.827	0.825	0.017	-0.099		1.014	3.557	1.007	-0.041	-0.005
PCA											
1 year	1.096	2.430	1.047	-0.110	-0.039		2.298	4.310	1.516	0.038	-0.045
3 years	0.737	1.089	0.858	-0.080	-0.090		0.821	1.369	0.906	-0.141	0.160
5 years	0.563	0.640	0.750	-0.172	-0.062		0.608	1.035	0.780	-0.119	0.124
10 years	0.437	0.607	0.661	-0.226	0.169		0.309	0.360	0.555	-0.220	-0.035
Macro Models											
VAR Macro											
1 year	1.515	1.998	1.231	-0.020	-0.190		4.294	10.080	2.072	0.148	-0.121
3 years	1.416	2.297	1.190	-0.159	-0.122		2.239	6.061	1.496	0.026	-0.081
5 years	1.357	2.242	1.165	-0.120	-0.099		1.690	4.383	1.300	-0.012	-0.089
10 years	1.183	2.043	1.088	-0.097	-0.114		1.023	2.766	1.011	-0.042	-0.078
VAR Global Macro											
1 year	1.217	2.296	1.103	-0.051	-0.138		15.918	14.146	3.990	-0.007	-0.014
3 years	1.246	2.358	1.116	-0.099	-0.108		1.716	3.672	1.310	0.010	-0.014
5 years	1.237	2.182	1.112	-0.105	-0.090		1.638	5.949	1.280	0.001	-0.036
10 years	1.059	1.829	1.029	-0.115	-0.059		2.457	18.227	1.568	-0.007	-0.016
Fama-Bliss Forward											
1 year	1.075	2.253	1.037	-0.134	0.025		1.798	4.352	1.341	-0.105	-0.024
3 years	0.718	0.890	0.847	-0.032	-0.042		0.873	1.342	0.934	-0.138	0.184
5 years	0.631	0.678	0.794	-0.191	0.028		0.688	0.985	0.829	-0.102	0.148
10 years	0.644	0.907	0.802	-0.223	0.262		0.485	0.507	0.696	-0.042	0.150
2000:01 *2016:12*						*2003:07* *2016:12*					

Table B.15: Out-of-sample 12-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Germany **Nominal**					
NS with AR(1)					
1 year	0.305	0.680	0.553	-0.113	-0.043
3 years	0.209	0.327	0.457	-0.091	-0.079
5 years	0.187	0.251	0.432	-0.187	-0.149
10 years	0.140	0.188	0.374	-0.237	-0.111
Yield-Based Models					
AR(1)					
1 year	0.296	0.630	0.544	-0.129	0.023
3 years	0.2000	0.280	0.447	-0.020	-0.013
5 years	0.182	0.252	0.426	-0.164	-0.061
10 years	0.167	0.225	0.409	-0.215	-0.035
VAR(1)					
1 year	0.321	0.740	0.567	-0.090	-0.080
3 years	0.257	0.445	0.507	-0.094	-0.149
5 years	0.225	0.337	0.474	-0.155	-0.219
10 years	0.184	0.229	0.429	-0.199	-0.220
PCA					
1 year	0.299	0.675	0.547	-0.107	-0.0035
3 years	0.213	0.349	0.462	-0.071	-0.096
5 years	0.162	0.219	0.402	-0.157	-0.138
10 years	0.119	0.159	0.345	0.204	-0.129
Macro Models					
VAR Macro					
1 year	0.385	0.740	0.620	-0.170	-0.003
3 years	0.261	0.367	0.511	0.016	0.087
5 years	0.216	0.287	0.465	-0.129	0.025
10 years	0.182	0.221	0.426	-0.255	-0.010
VAR Global Macro					
1 year	0.214	0.398	0.462	0.081	0.062
3 years	0.201	0.274	0.448	0.352	0.056
5 years	0.188	0.211	0.434	-0.003	0.043
10 years	0.175	0.171	0.419	-0.239	0.054
Fama-Bliss Forward					
1 year	0.296	0.630	0.544	-0.130	0.021
3 years	0.200	0.280	0.448	-0.021	-0.016
5 years	0.182	0.251	0.427	-0.167	-0.062
10 years	0.168	0.225	0.410	-0.256	-0.026
2000:01 *2016:12*					

Table B.16: Out-of-sample 12-month-ahead forecasting results

Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	Maturity	Mean	SD	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$
Italy						**Italy**					
Nominal						**Real**					
NS with AR(1)											
1 year	1.997	3.699	1.413	0.000	0.044		3.596	5.227	1.896	0.114	0.131
3 years	1.716	3.093	1.310	0.101	0.080		2.553	6.164	1.598	0.088	0.021
5 years	1.542	2.457	1.242	0.112	0.089		2.175	4.269	1.475	0.036	0.050
10 years	1.077	1.597	1.038	0.033	0.068		0.940	1.167	0.969	-0.090	0.022
Yield-Based Models											
AR(1)											
1 year	2.185	3.236	1.478	0.037	0.095		4.594	9.088	2.143	0.350	0.028
3 years	1.923	2.553	1.387	0.176	0.106		4.057	1.786	2.014	0.213	-0.014
5 years	1.649	2.305	1.284	0.155	0.043		4.228	2.286	2.056	0.131	-0.018
10 years	1.145	1.715	1.070	0.058	-0.026		1.163	1.482	1.079	0.077	-0.104
VAR(1)											
1 year	3.778	10.659	1.944	-0.034	-0.066		11.823	4.320	3.484	0.022	-0.014
3 years	2.521	3.497	1.588	0.146	-0.077		7.761	2.461	2.786	-0.048	0.066
5 years	2.021	2.519	1.422	0.231	-0.042		6.926	3.134	2.632	-0.020	0.072
10 years	1.352	1.790	1.163	0.114	-0.011		2.410	1.023	1.553	-0.005	0.008
PCA											
1 year	2.041	4.014	1.429	0.012	0.036		3.995	5.944	1.999	0.029	0.069
3 years	1.689	3.267	1.299	0.104	0.059		2.703	7.129	1.644	0.148	-0.032
5 years	1.559	2.618	1.249	0.126	0.074		2.755	5.393	1.660	0.071	0.076
10 years	1.051	1.579	1.025	0.07	-0.016		0.985	1.322	0.992	-0.087	-0.192
Macro Models											
VAR Macro											
1 year	2.097	4.423	1.448	0.101	0.012		8.415	2.632	2.901	0.077	-0.017
3 years	1.986	4.141	1.409	0.076	0.056		9.817	4.256	3.133	0.032	-0.009
5 years	1.662	2.801	1.289	0.124	0.001		5.015	4.643	7.082	-0.012	-0.002
10 years	1.214	1.775	1.102	0.059	0.039		2.826	11.892	1.692	-0.022	0.017
VAR Global Macro											
1 year	2.434	6.631	1.402	0.144	-0.028		6.113	2.557	1.863	-0.021	-0.017
3 years	2.423	5.387	1.557	0.157	0.013		3.469	9.575	1.653	0.328	-0.077
5 years	2.129	3.741	1.459	0.174	0.016		4.727	22.144	1.791	0.043	-0.040
10 years	1.508	2.103	1.228	0.005	0.041		0.875	1.844	0.820	-0.027	-0.088
Fama-Bliss Forward											
1 year	2.181	2.238	1.477	0.039	0.095		2.989	6.043	1.729	0.063	0.022
3 years	1.920	2.555	1.386	0.180	0.111		2.325	8.230	1.525	0.422	-0.060
5 years	1.651	2.304	1.285	0.158	0.052		2.646	12.304	1.627	0.256	-0.034
10 years	1.150	1.713	1.072	0.059	-0.011		1.151	1.748	1.073	0.174	-0.087
2000:01						*2004:07*					
2016:12						*2016:12*					

Table B.17: Nominal and Real Spread Analysis

	2-y Spread		5-y Spread		10-y Spread	
	bid-ask	cds	bid-ask	cds	bid-ask	cds
France						
Nominal	0.03	0.61***	1.07	1.06***	0.60	1.24***
	(0.41)	(0.05)	(0.81)	(0.07)	(1.12)	(0.12)
Real	0.60***	-1.34***	-0.04	1.62***	-0.02	1.54***
	(0.16)	(0.42)	(0.04)	(0.15)	(0.02)	(0.16)
Italy						
Nominal	0.99	1.05***	5.95***	1.25***	0.03	1.41***
	(0.68)	(0.06)	(1.36)	(0.05)	(2.20)	(0.07)
Real	0.85***	0.96***	0.06	1.44***	0.06*	1.61***
	(0.19)	(0.07)	(0.06)	(0.05)	(0.03)	(0.06)

Table B.18: Real minus Nominal Spread Analysis

	5-y Spread		10-y Spread	
	bid-ask	cds	bid-ask	cds
France				
	0.68***	-1.45**	0.66	-1.92***
	(0.18)	(0.41)	(0.16)	(0.48)
Italy				
	1.03***	-0.14*	1.03***	-0.16
	(0.18)	(0.08)	(0.18)	(0.10)

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