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Keywords: Term structure, volatility, density forecasting, no arbitrage

JEL codes: C32, C53, E43, E47, G12

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Expectations and term premia in EFSF bond yields*

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July 2022

Abstract

The European Financial Stability Facility (EFSF) was set up in June 2010 as a temporary crisis resolution mechanism. In October 2012, its tasks were taken over by European Stability Mechanism (ESM), a permanent institution with a capital-based structure. Liquidity conditions for EFSF bonds in the secondary market are different from those of large sovereign bond issuers, which affects bond pricing. This paper offers the first study of the term structure of EFSF bond yields and a decomposition into expected interest rates and risk premia, based on a state-of-the-art no-arbitrage term structure model. A joint model of the EFSF curve and the swap curve allows to further identify the liquidity and credit components of both yield curves and disentangle an additional element of liquidity typical of bonds. This component is closely related to the ECB monetary policy. This model can be extended to other supranational institutions.

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1 Introduction

We learn from asset pricing theory that the prices or values of claims are linked to the uncertainty of payments. To value an asset, we need to account for the 'risk' of its payments (Cochrane, 2010), such as credit risk or market liquidity. In recent years, after the implementation of unconventional monetary policies with asset purchases, we have witnessed that liquidity is playing a larger role in bond price dynamics, including bonds of large issuers like the German government. Smaller bond issuers, such as the EFSF or other supranational issuers have also been affected by worsening liquidity conditions. Disentangling credit and liquidity effects in yields is a key challenge. Investors search for yield pickup to increase return on the portfolio, and therefore they buy bonds with a liquidity premium at lower prices (Monfort and Renne, 2013). At the same time, they can arbitrage the relative liquidity premium between bonds with similar credit ratings (Longstaff 2009).

In this paper, we aim to offer a model of EFSF term structure for investors to help manage their bond portfolios taking account of liquidity. Furthermore, our model can be extended to other similar size issuers such as the Kreditanstalt für Wiederaufbau (KFW) or the European Investment bank (EIB). The European Financial Stability Facility (EFSF) was set up in June 2010 as a temporary crisis resolution mechanism, and in October 2012 its tasks were taken over by the European Stability Mechanism (ESM), a permanent institution with a new capital-based structure. The EFSF and ESM have disbursed €295 billion to five countries in the form of loans financed by bond issuance. Although the size of EFSF/ESM stock of debt makes them the biggest supranational non-bank issuer in the Economic and Monetary Union (EMU), it is still not enough to match the secondary market liquidity of a large liquid sovereign bond issuer.

We look at market liquidity in terms of bid-offer spreads, and we find that EFSF liquidity is only supported in some maturities. Regarding the credit risk of EFSF bonds, although the rating is high, it depends on a guarantee based on the capital keys of AAA rated sovereign issuers of the euro area, with the exception of France that acts as a marginal guarantor, having lost its AAA rating in 2012.

Policy action such as quantitative easing (QE) is another factor that determines the bond price, as QE adjusts the price level of the yield curve. If there is an increase in the bond's term premium related to credit concerns by market investors, the solvency of the debtors would be improved by the policy action. As a result, the term premium would narrow and the bond's price rise, all other things being equal. Moreover, investors' confidence would improve too, and it may trigger higher bond turnover, thus smaller liquidity premia as a result. Policy actions such as minimum holdings of central banks reserves and market microstructure can also affect bonds' liquidity premia. For example, the way liquidity proceeds from ECB asset purchases are reinvested in a specific country determines whether banks choose to re-invest them short term in low-risk domestic assets such as Bund repos, which often yield lower returns, or at the ECB deposit facility, thus making excess liquidity holdings at the central bank more attractive (Baldo et al, 2017, Krishnamurthy 2021).

Investors need a price to value bonds of new issuers, as was the case for the EFSF in 2012, or issuers that do not often trade. Therefore, having a liquid benchmark index is also important for bond pricing. For the euro area, the German Bund, is generally chosen, as it is a safe liquid asset. However, quantitative easing has also affected the liquidity of German bonds. We see more negative asset swap spreads, as an indicator of liquidity costs. These considerations led us to choose the swap curve as a benchmark, thanks to its large market sizes (Remolona and Wooldridge (2003)), and also because it is where hedging and positioning activity is used extensively (Dalla Fontana et al. 2019). In addition, swaps belong to the money market, so it is excluded from dynamics typical of bonds trading in capital market.

This paper's contribution is threefold. Firstly, it is the first study fitting a no-arbitrage model to the EFSF yield curve and offers a full decomposition of the observed historical EFSF yields into the expectation and term premia component. We find that the term premia on the EFSF curve has increased sharply during the 2011-2012 crisis and that they have also been on the rise in the more recent months. Secondly, when the term structure model is estimated jointly with the swap and spot curves, and with the assumption that the latter carries an additional premium stemming from an additional pricing factor, regression analysis shows that such an additional premium and pricing factor are related to liquidity and credit conditions. Furthermore, in a comparative study based on German and French government bond yields, we find that the liquidity/credit factor moves largely with a measure of liquidity that relates directly to ECB monetary policy (excess liquidity) and that credit is only significant for Germany and EFSF, though it is in relation to France's credit risk. Thirdly, this paper introduces a methodological contribution consisting of a novel approach to pricing the yield curves of small and medium-sized issuers. This is achieved by including a benchmark liquid curve in the model and specifying an additional factor that is ex-ante attributed to liquidity/credit.

The paper is organised as follows. Section 2 describes the no-arbitrage model used in the paper, Section 3 describes the data, Section 4 illustrates the decomposition of EFSF yields in expectations and term premia, Section 5 discusses the liquidity/credit pricing factor. Section 6 concludes. Further technical details are provided in the Appendix.

2 Model

Since the seminal work of Vasicek (1977), a large amount of research has focused on Gaussian Affine Term Structure Models (GATSM). Prominent contributions in this tradition include Duffie and Kan (1996), Dai and Singleton (2000), Duffee (2002), and Ang and Piazzesi (2003).

Let y_t denote a vector of yields on a set of zero-coupon bonds of maturity $\tau = 1, ..., N$. In the Duffie and Kan (1996) canonical term structure model, the yields are driven by an n-dimensional vector of unobservable risk factors S_t:

$$y_t = A_S^{\mathbb{Q}} + B_S^{\mathbb{Q}} S_t + \Sigma_y \varepsilon_t^y, \tag{1}$$

$$\Delta S_t = K_{0S}^{\mathbb{P}} + K_{1S}^{\mathbb{P}} S_{t-1} + \Sigma_S \varepsilon_t^{\mathbb{P}}, \tag{2}$$

where A_S^Q and B_S^Q are $N \times 1$ and $N \times n$ coefficient matrices, $K_{0S}^{\mathbb{P}}$ is a $n \times 1$ vector, $K_{1S}^{\mathbb{P}}$ is a $n \times n$ matrix, and Σ_y and Σ_S are lower triangular Cholesky factor matrices. The disturbances ε_t^y, $\varepsilon_t^{\mathbb{P}}$ are *i.i.d.* $N(0, I)$ vector processes and are mutually independent.

Equations (10)-(11) constitute a factor model in which the yields depend linearly on the factors S_t through the intercept vector A_S^Q and the factor loadings B_S^Q. These equations do not make explicit the role of the no-arbitrage assumption. Such an assumption further implies that A_S^Q and B_S^Q are (highly) nonlinear functions of certain deep parameters $\Theta_S^{\mathbb{Q}}$ $=\{K_{0S}^Q, K_{1S}^Q, \Sigma_S, \rho_{0S}, \rho_{1S}\}$, i.e. $A_S^{\mathbb{Q}} = A(\Theta_S^Q)$ and $B_S^{\mathbb{Q}} = B(\Theta_S^Q)$. Specifically, the elements in any generic row τ of $A_S^{\mathbb{Q}}$ and $B_S^{\mathbb{Q}}$ must obey a set of (highly) nonlinear restrictions ensuring that there are no arbitrage opportunities:

$$A_S^{\mathbb{Q}}(\tau) = -A_\tau/\tau, \; A_{\tau+1} = A_\tau + K_{0S}^{\mathbb{Q}\prime} B_\tau + 0.5 B_\tau' \Sigma_S \Sigma_S' B_\tau - \rho_{0S}, \tag{3}$$

$$B_S^{\mathbb{Q}}(\tau) = -B_\tau/\tau, \; B_{\tau+1} = B_\tau + K_{1S}^{\mathbb{Q}\prime} B_\tau - \rho_{1S}, \tag{4}$$

with initial conditions $A_0 = B_0 = 0$. The deep parameters $\Theta_S^{\mathbb{Q}}$ describe the evolution of the state variables under the so-called equivalent martingale measure:

$$\Delta S_t = K_{0S}^{\mathbb{Q}} + K_{1S}^{\mathbb{Q}} S_{t-1} + \Sigma_S \varepsilon_t^{\mathbb{Q}}, \tag{5}$$

as well as the dynamics of the instantaneous risk free rate r_t:

$$r_t = \rho_{0S} + \rho_{1S} S_t, \tag{6}$$

where $K_{0S}^{\mathbb{Q}}$ is a $n \times 1$ vector, $K_{1S}^{\mathbb{Q}}$ is a $n \times n$ matrix, ρ_{0S} a scalar, ρ_{1S} a $n \times 1$ vector, and $\varepsilon_t^{\mathbb{Q}}$ is an *i.i.d.* $N(0, I)$ vector process. With no loss of generality, we use the normalisation $\rho_{0S} = 0$ and ρ_{1S} =1 a $n \times 1$ vector of ones.

Here $\mathbb{Q}$ and $\mathbb{P}$ denote the risk neutral and physical measures of probability. Under the $\mathbb{P}$ measure agents' risk aversion implies that prices need to be predictable to some extent, producing the expected returns necessary to compensate investors for bearing risks. Under this measure, the states follow the dynamics described by (2). Under the $\mathbb{Q}$ probability measure, prices are a martingale, which resembles a hypothetical situation in which investors are risk-neutral. Under this measure, the states behave according to (5). The existence of the equivalent martingale measure $\mathbb{Q}$ is a necessary and sufficient condition of the absence of arbitrage. Conversion from the $\mathbb{P}$ to the $\mathbb{Q}$ measure can be achieved using a variable transformation described by a Radon-Nikodym derivative that, together with the risk-free rate (6), forms the pricing kernel.[1]

It is important to distinguish the assumption of absence of arbitrage and the additional specification restrictions inherent in a GATSM. In particular, there are other assumptions which are not required to guarantee the absence of arbitrage, but are needed to estimate the model or to compute quantities of interest. For example, the use of a vector autoregressive model of order 1, VAR(1), for the law of motion of the factors under the $\mathbb{P}$ measure.[2] Similarly, no arbitrage only requires the existence of a pricing kernel, but it does not determine the form of such kernel. A log-normal form is typically chosen, which provides tractability.[3]

These additional assumptions can improve efficiency, but can lead to misspecification.

[1] In particular, under the $\mathbb{Q}$ measure the price of an asset V_t that does not pay any dividends at time $t+1$ satisfies $V_t = E_t^{\mathbb{Q}}[\exp(-r_t)V_{t+1}]$, where r_t is the short-term rate. Under the $\mathbb{P}$ measure the price is $V_t = E_t^{\mathbb{P}}[(\xi_{t+1}/\xi_t)\exp(-r_t)V_{t+1}]$, where ξ_{t+1} is the Radon-Nikodym derivative. The term $(\xi_{t+1}/\xi_t)\exp(-r_t)$ is referred to as the stochastic discount factor (or pricing kernel).

[2] Duffee (2011b) shows that it is entirely possible for the factors to follow richer dynamics in the physical measure than in the risk-neutral measure and that this translates to the presence of hidden factors which -while not useful in explaining the cross-section of yields- can help explain their dynamics. Similarly, Joslin, Priebsch, and Singleton (2012) show that a VAR representation (under the physical measure) including measures of real economic activity and inflation captures better the dynamics of the term structure. In this paper, we illustrate the proposed approach using the simpler framework offered by yields-only models, but our approach can be naturally extended to models allowing for macroeconomic factors.

[3] In particular it is assumed that $\ln(\xi_{t+1}/\xi_t) = -0.5\Lambda_t'\Lambda_t - \Lambda_t'\varepsilon_t^{\mathbb{P}}$, which implies the stochastic discount factor is log-normal with conditional mean $-r_t$ $-0.5\Lambda_t'\Lambda_t$ and conditional variance $\Lambda_t'\Lambda_t$. Further assuming a linear price of risk $\Lambda_t = \lambda_0 + \lambda_1 S_t$, the relation between the coefficients of the factor dynamics under the two measures is: $K_{jS}^{\mathbb{Q}} = K_{jS}^{\mathbb{P}} - \Sigma_S\lambda_j;\quad j = 0, 1$. Once can also add a constraint on the variabillity of prices of risk, for example costraining their Sharpe Ratios as in Duffee (2010): $\sqrt{\Lambda_t'\Sigma_S^{-1}\Sigma_S^{-1}\Lambda_t} < c$.

2.1 A joint model of swap and spot rates

In the empirical application, the N-dimensional y_t vector of yields is partitioned into N^{swap} swap rates y_t^{swap} and N^{spot} spot rates y_t^{spot}:

$$y_t = \begin{bmatrix} y_t^{swap} \\ y_t^{spot} \end{bmatrix}. \tag{7}$$

In the data set we use, the first 2 principal components explain 99.79% of the total variability in the swap curve and the first 3 principal components explain 99.59% of the total variability in the joint swap and spot curve. Based on this finding, we set $n = 3$, i.e. three factors are driving y_t, and we further assume that while the short-term spot rate responds to all the three factors, the short-term swap rate only depends on the first two factors. This is implemented by augmenting the model with an equation for the instantaneous swap rate:

$$r_t^{swap} = \delta_{0S} + \delta_{1S} S_t, \tag{8}$$

where δ_{1S} is a 3-dimensional vector with the last element equal to 0. This implies that:

$$r_t^{spot} - r_t^{swap} = S_t^{(3)}, \tag{9}$$

i.e. the difference between the spot and swap rate is given by the third factor $S_t^{(3)}$.[4] It also implies that the entire swap curve will not depend on the third factor. As we shall see, the third factor prices the specific risks associated with the spot rates, which in our application are EFSF bonds.

2.2 Estimation

Traditional no arbitrage term structure models entail a high level of nonlinearity - evident in the restrictions (3) and (4) - that makes the estimation extremely difficult and often unreliable (Duffee (2011a,b), Duffee and Stanton (2012), Hamilton and Wu (2012)). Some recent literature has successfully addressed this issue. Hamilton and Wu (2012) propose a strategy to estimate such models using a series of transformations and OLS estimation. Christensen, Diebold and Rudebusch (2011) proposed a no-arbitrage term structure model based on the Nelson and Siegel (1987) exponential framework. In this paper, we use the representation proposed by Joslin, Singleton and Zhu (2011), which is equivalent to the canonical representation of Duffie and Kan (1996), but parametrised in such a way that estimation is considerably simplified.

[4] To be precise, it is $r_t^{spot} - r_t^{swap} = \delta_{1S} S_t^{(3)}$, but recall we are using a normalisation in which the autoregressive coefficients on the short-term rates are one, hence $\delta_{1S} = 1$.

Joslin, Singleton and Zhu (2011) (JSZ) derive the following equivalent representation for equations (1) and (2):

$$y_t = A_P^{\mathbb{Q}} + B_P^{\mathbb{Q}} P_t + \Sigma_y \varepsilon_t^y, \tag{10}$$

$$\Delta P_t = K_{0P}^{\mathbb{P}} + K_{1P}^{\mathbb{P}} P_{t-1} + \Sigma_P \varepsilon_t^{\mathbb{P}}. \tag{11}$$

In (10) and (11), the factors $P_t = W\tilde{y}_t$ are portfolios composed of N yields priced without error $\tilde{y}_t = A_S^{\mathbb{Q}} + B_S^{\mathbb{Q}} S_t$, and Σ_P is the Cholesky factor of their conditional variance. Details of the transformation leading from (1)-(2) to (10)-(11) can be found in the appendix. The advantage of the JSZ rotation stems from the fact that the least-squares projection of the observable factors $P_t^o = Wy_t$ onto their lagged values will nearly recover the maximum likelihood estimates of $K_{0P}^{\mathbb{P}}$ and $K_{1P}^{\mathbb{P}}$ to the extent that $P_t^o \approx P_t$. Moreover, the intercepts $A_P^{\mathbb{Q}} = A(\Theta_P^{Q})$ and the loadings $B_P^{\mathbb{Q}} = B(\Theta_P^{Q})$ depend on a smaller set of deep parameters $\Theta_P^{\mathbb{Q}} = \{k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_P\}$, where $\lambda^{\mathbb{Q}}$ are the (ordered) eigenvalues of $K_{1S}^{\mathbb{Q}}$ and $k_\infty^{\mathbb{Q}}$ is the first element of $K_{0S}^{\mathbb{Q}}$ (the remaining elements of this vector being zero).

Clearly, the model at hand is a linear Gaussian state space system. Equations (10) and (11) (or, in the equivalent canonical representation, equations (1) and (2)) are respectively the transition and measurement equation. Equations (5) and (6) are implicitly embedded in the model through the restrictions (3) and (4) on the factor loadings: it is these restrictions that impose the absence of arbitrage. Estimation can be performed via maximum likelihood.

3 Data

All data is at monthly frequency, with a monthly data point equal to the average of the daily data points in any given month. The swap curve y_t^{swap} is based on the 6-month Euribor swap rates, ranging from April 2000 to December 2020. The EFSF zero coupon equivalent rates are provided by the ESM and are obtained using Svensson's method, and range between April 2012 to December 2020. The spot curves y_t^{spot} of Germany and France are sourced from Bloomberg and are available from April 2000 to December 2020.

We select the most liquid maturities and include a swap rate with very short maturity as a proxy for the risk-free rate. Analysis of the fitting showed that a minimum of 6 maturities are needed per curve, and that the swap rates for Germany and France can be estimated with a 3-month rate, but this is not the case for the EFSF curve. The swap curves for Germany and France can be estimated up to the 20-year with a small fitting error, but that is not the case for the EFSF, as the long-term rate affects the yield decomposition assumption of the no-arbitrage model (relationship between short rate and long rate). Based on these considerations, we chose maturities of 1, 2, 3, 5, 7 and 10 years for the spot curves (EFSF, Germany, France) and 3-months and 1, 2, 3, 4, 5, 7 and 10 years for the swap curve.

Since the EFSF created significant market presence only in 2012, yields for the period 2000-2012 are not available. While estimation using a shorter sample is possible, the time series dimension of the EFSF yields is too limited to provide reliable results, and for this reason, we backcast the EFSF data to April 2000, using an average of the zero-coupon equivalent yields for the countries entering the EFSF guarantee, with weights given by the respective proportions of capital assigned to each country [5]. Specifically, the EFSF data set between April 2000 and March 2012 has been reconstructed using a 'synthetic' curve based on the capital keys by shareholder:[6]

$$y^{EFSF}_{t=2000/4:2012/3} = \frac{\Sigma^5_{i=1} w_i y^c_t}{\Sigma^5_{i=1} w_i}$$

We only used the first 4 shareholders with at least AA rating in order of share size (Germany, France, Spain, The Netherlands) with the following weights w_i: France=20.24; Germany=26.96; Spain= 11.8; Netherlands=5.7, which represents nearly 80% of the total capital.[7] The data for the curves Netherlands and Spain are from Bloomberg. The rationale behind this choice is that the EFSF rates tend to co-move with the core EMU countries.[8]

Figure 1 shows the historical curves by issuers, and Figure 2 shows the spreads between the swap and the spot rates. Our synthetic instrument shows a behaviour as expected before 2012. Between 2000 and 2009 the 10-year swap spread (Figure 2 and Table 4-timeline of events) was narrow like those Germany and France. The tight swap spreads for most countries are in line with a period of positive economic growth for the euro area, when inflation was also close or on target at 2%. After 2009 the financial and sovereign debt crises marked a regime change, especially for the sovereign issuers with credit risk. In 2012-13 a wider swap spread is also justified by the initial illiquidity of EFSF bond market.

[5] The capital keys are published on the ECB website.

[6] See http://esm.europa.eu

[7] From 2010 onwards, we took away Spain when the country lost the triple-A ratings, in line with the over-guarantees assumption.

[8] The correlation between the EFSF, Germany, and France curves is between 95.6% and 99.9%, depending on maturity. In the sample for which the actual EFSF is available, the synthetic and actual EFSF have a correlation between 96.7% and 98.8%, depending on maturity. Moody's upgraded EFSF's rating to AAA in June 2022 and Fitch affirmed EFSF's rating to AA in July 2022.

4 Decomposing the curve

4.1 Model implied yields and in sample fit

Estimation of the model provides the model-implied yields:

$$\tilde{y}_t = A_S^{\mathbb{Q}} + B_S^{\mathbb{Q}} S_t, \tag{12}$$

which depend on parameters belonging to the risk neutral measure $\mathbb{Q}$. These are model-based estimates of the actual yields, and are illustrated in Figure 3.

The difference between actual and model based yields:

$$y_t(\tau) - \tilde{y}_t(\tau) = \hat{\varepsilon}_t(\tau), \tag{13}$$

is the fitting error. A straightforward measure of in-sample fit of the model is simply given by the root mean squared errors:

$$RMSE(\tau) = \sqrt{\frac{1}{T}\Sigma_{t=1}^{T}\hat{\varepsilon}_t^2(\tau)},$$

which are reported in Table 1. The small fitting errors suggest that while EFSF rates are potentially problematic because of reduced liquidity at the shortest and longest maturities, the swap curve can be exploited as a (liquid) benchmark for pricing.

4.2 Instantaneous risk-free rate

The no-arbitrage model retrieves the instantaneous risk-free rates via equation (6), which we report in Figure 4. The short rate observations are aligned until 2007 and within the ECB 'corridor' (difference between deposit facility and marginal lending facility), which confirms our conjecture that swaps are the best proxy of the natural rate of interest, as they stay within the ECB corridor. In 2008, the swap rate rises due to the financial crisis. After 2008, the swap spread tightens again, all market rates fall after 2015, but only the swap rate stays within the ECB corridor. The historical behaviour suggests that short maturity swap rates have been closer to the ECB monetary policy stance than bond rates and they are less sensitive to regime changes.

We believe that the reason for this difference between swap and bonds is mainly due to the key characteristic of bonds as a cash-like instrument, which can be bought and sold immediately. Swaps do not require cash to enter because the notional is not exchanged. Yet, investors can take a directional position on future interest rates using swaps, the same as they would do with bonds. The purchase may require financing. If the investor holds cash, like asset managers, they may need to hold cash until the right opportunity to buy comes. In a negative interest rate environment this also carries a certain cost. Thus, either way, regardless of the type of investor, liquidity bears a cost and this cost is reflected in the bond yield, but not in the swap rate.

Other factors may affect the bond yield and not the swap. Bonds can be used as collateral that can be used by investors in the repo market or by banks to borrow money from the ECB. This lowers the financing cost, hence the cost of liquidity that is priced in the bond yield. Swaps and bonds have a different credit rating: one is reflective of banking risk and the other of sovereign risk. This may also affect the swap spread; we argue that it is minimally affected by credit factors, as swaps are mostly collateralised by highly rated bonds or cash. Eventually, it is the cost of holding collateral or cash to hedge the credit risk in a swap position that affects the spread. Once again, it is the liquidity cost to be priced in the swap spread and it is cash related to collateralisation. Finally, bonds can be used as HQLAs (high quality liquid assets) to meet capital requirements by regulators. Hence, this is another characteristic that precludes bonds and swaps from being substitutes for each other.

4.3 Expectations

The model implied yields can be further decomposed into an expectation component and a term premium. To compute the expectation component, we first compute the conditional expectations of the factors:

$$E_t[S_{t+\tau}] = \bar{S} + e^{K_{1S}\tau} \times (S_t - \bar{S}), \tag{14}$$

where $\bar{S} = -(K^{\mathbb{P}}_{1S})^{-1}K^{\mathbb{P}}_{0S}$.[9] Then using (6) it is possible to derive the conditional expectations of the short-term rate:

$$E_t[r_{t+\tau}] = \rho_{0S} + \rho_{1S}E_t[S_{t+\tau}]. \tag{15}$$

Finally, application of the expectations hypothesis gives the Expectations Hyphothesis (EH) consistent swap yields:

$$y^*_t(\tau) = \frac{1}{\tau}\sum_{j=1}^{\tau} E_t[r_{t+\tau}]. \tag{16}$$

Note that this expectation is computed under the physical measure $\mathbb{P}$.[10] Importantly, in the case of the swap curve the expectation is based only on 2 factors, i.e. $\rho_{0S} = 0,\ \rho_{1S} = [1\ 1\ 0]$.

[9] Note that $e^{K^{\mathbb{P}}_{1S}\tau} \approx (K^{\mathbb{P}}_{1S} + I)^{\tau}$ since $\ln(K^{\mathbb{P}}_{1S} + I)^{\tau} = \tau \ln(I + K^{\mathbb{P}}_{1S}) \approx \tau K^{\mathbb{P}}_{1S}$.

[10] The same expectation under the $\mathbb{Q}$ measure would almost coincide with $\tilde{y}_t(\tau)$, the (small) difference consisting in a Jensen's inequality term. This happens because under the $\mathbb{Q}$ measure, the EH holds and there are no term premia.

Instead, the expected spot curve is based on 3 factors , i.e. $\rho_{0S} = 0$, $\rho_{1S} = [1\ 1\ 1]$. Specifically, we have that:

$$y_t^* = y_t^{*swap} = \frac{1}{\tau}\sum_{j=1}^{\tau} E_t S_{1t+\tau} + \frac{1}{\tau}\sum_{j=1}^{\tau} E_t S_{2t+\tau} \tag{17}$$

and

$$y_t^{*spot} = y_t^* + \frac{1}{\tau}\sum_{j=1}^{\tau} E_t S_{3t+\tau}. \tag{18}$$

In what follows, we take the stand that $y_t^* = y_t^{*swap}$ represents a measure of the EH-consistent yields, while the term $\frac{1}{\tau}\sum_{j=1}^{\tau} E_t S_{3t+\tau}$ represents an additional expectation component that arises on the spot rates.[11]

4.4 Term premia

The term premia are the difference between the model-implied yields $\tilde{y}_t(\tau)$ and the EH-consistent yields:[12]

$$TTP_t^{spot}(\tau) = \tilde{y}_t^{spot}(\tau) - y_t^*(\tau), \tag{19}$$

The premia depend on parameters belonging to both the $\mathbb{Q}$ and the $\mathbb{P}$ measures. Note that in expression (19) we use the EH-consistent swap expected yields, not the expected spot yields, as a reference point.

Solving for the model implied yields $\tilde{y}_t^{spot}(\tau)$ and recalling from (13) that they differ from the observed yields by a measurement error, we have:

$$y_t^{spot}(\tau) = y_t^* + TTP_t^{spot}(\tau) + \hat{\varepsilon}_t^{spot}(\tau). \tag{20}$$

The expression above makes clear that $y_t^{spot}(\tau)$ can be decomposed in the EH-consistent expected swap rates y_t^* and a term premium. The term premia for the EFSF curve, for all maturities, are shown in Figure 5. Figure 6 shows the term premia for all the curves, at the 10-year maturity. A decomposition of yields into expectations and term premia can be found in Figure 7 and Figure 8.

The term premia change over time and are of course increase with maturity. Among all issuers considered, the lowest TTP_t^{spot} premium is Germany's, as one would expect from the safe haven. Both term premia and expectations decrease over time in all curves, with expectations leveling out at negative yield level after 2015.

[11] Refer also to corporate bond pricing literature, where defaultable bonds are priced by discounting future cash flows using a default - and liquid - adjusted short rate. Contributions in this tradition include Duffie-Sinleton (1999), Longstaff et al (2005), Driessen (2005).

[12] See equation (4) in Dai and Singleton (2002).

5 Pricing factors

The estimated S_t factors are shown in Figure 9, together with a naive data-based measure of level and slope of the curve. Specifically, the level is approximated with the 10-year yield while the slope is measured with the difference between the 10-year and 1-year yield. The last panel in the figure shows the third factor $S_t^{(3)}$, which coincides with the difference between the instantaneous risk-free spot and swap rates, as described in equation (9). This factor is particularly relevant as its cumulated forecasts represents the difference between the EH-consistent curves:

$$\frac{1}{\tau}\sum_{j=1}^{\tau} E_t S_{3t+\tau} = y_t^{*spot} - y_t^{*} \tag{21}$$

which is illustrated in figure (10). The figure shows the factor S_{3t} (in bold) together with the spreads $y_t^{*} - y_t^{*spot}$ for different maturities.

5.1 Determinants of the third factor

The factor S_{3t} determines a wedge between the EH-consistent rates of the spot and the swap curve. A time series plot of the third factor for the EFSF, Germany, and France yield curve is displayed in Figure (11). The EFSF's third factor moves similar to the one of Germany, while France's third factor peaks in 2012.

In this section we show that this factor can be interpreted as a liquidity/credit factor. Specifically, we estimate the following regression model:

$$S_{3t} = c + \phi_1 S_{3t-1} + \phi_2 \Delta CDS_t + \phi_3 \Delta XL_t + \phi_4 VSTOXX_t + \phi_5 D_t + \varepsilon_t,$$

where c is an intercept, ΔCDS_t is the change in credit default swaps rates, ΔXL_t is the change in a measure of excess liquidity,[13] $VSTOXX_t$ is the Euro STOXX 50 area volatility index by DB and Goldman Price, D_t is a set of dummy variables picking up extreme events in the dates August 2007 and November 2011, and ε_t is a white noise disturbance.[14] We estimate the model using OLS and correcting the standard error for heteroschedasticity via the White (1980) robust estimator. Results are displayed in Table 2.

For the sample starting in June 2011, time series of bid-ask spreads are also available, allowing to run the regression:

$$S_{3t} = c + \phi_1 S_{3t-1} + \phi_2 \Delta CDS_t + \phi_3 \Delta XL_t + \phi_4 VSTOXX_t + \phi_5 D_t + \phi_6 BA_t + \varepsilon_t,$$

[13] Specifically, XL_t is the ECB eurozone excess liquidity defined as deposits at the deposit facility net of the recourse to the marginal lending facility.

[14] As robustness test, the results are unchanged if we include the other two factors as explanatory variables in the regressions.

where BA_t is the bid-ask spread. Bid-asks are calculated by the ESM using MTS high frequency data. They are defined as the average of best-bid ask spreads relative to the best mid price at the same time, minute by minute within a particular day, provided that the spreads are below threshold spread. EFSF data not used due to limited availability. We estimate the model using OLS and correcting the standard error for heteroschedasticity via the White (1980) robust estimator. Results are displayed in Table 3.

Overall, our results provide mainly evidence for the importance of excess liquidity in reducing the third factor. These regression results show that the S_{3t} factor captures relative liquidity conditions of swap/bond markets. In Table 2, excess liquidity is significant for all the specifications. CDS is only significant for Germany and in one specification for EFSF related to French CDS. After 2011, the excess liquidity is an important determinant only for the EFSF (see Table 3). Germany's S_{3t} and EFSF S_{3t} moves with the risk sentiment as it is a safe haven asset, while the factor is linked to France's credit default risk. We also find that our results are not significantly altered by controlling for the volatility index.

6 Conclusions

In this paper, we fitted a no-arbitrage affine term structure model to the EFSF yield curve, and offered an historical decomposition of the observed historical EFSF yields into the expectation and term premia component. We have also fitted France and Germany government yield curves, which showed the robustness of the model to both liquid and non-liquid markets.

We found that the term premia on the EFSF curve increased sharply during the 2011-2012 crisis, and that it has also been on the rise at the end of 2020. Both term premia and expectations decrease over time in all curves, with expectations leveling out at negative yield level after 2015.

We also found that the relatively more illiquid curves – and specifically the one of supranational bonds – do show a larger liquidity/credit factor. Regression analysis confirmed starkly that the additional factor is related to liquidity and credit conditions.

Finally, the paper introduced a novel approach to price the yield curves of small issuers and / or illiquid markets. This is achieved by including in the model a benchmark liquid curve, and specifying an additional factor which is ex-ante attributed to liquidity.

Appendix A: derivation of the JSZ representation

To make this paper self-contained, we derive here the JSZ representation of the GATSM. A more rigorous and detailed description can be found in JSZ. The evolution of n risk factors (a n-dimensional state vector) is given by:

$$\Delta S_t = K_{0S}^{\mathbb{P}} + K_{1S}^{\mathbb{P}} S_{t-1} + \Sigma_S \varepsilon_t^{\mathbb{P}} \tag{22}$$

$$\Delta S_t = K_{0S}^{\mathbb{Q}} + K_{1S}^{\mathbb{Q}} S_{t-1} + \Sigma_S \varepsilon_t^{\mathbb{Q}} \tag{23}$$

$$r_t = \rho_{0S} + \rho_{1S} S_t, \tag{24}$$

where $\mathbb{Q}$ and $\mathbb{P}$ denote the risk neutral and physical measures, r_t is the short-term rate, Σ_S is the Cholesky factor of the conditional variance of the states and the errors are i.i.d. Gaussian random variables. The model-implied yield on a zero-coupon bond of maturity τ is an affine function of the state S_t (Duffie and Kan (1996)):

$$\widetilde{y}_t(\tau) = A_\tau(\Theta_S^{\mathbb{Q}}) + B_\tau(\Theta_S^{\mathbb{Q}}) S_t \tag{25}$$

where $\Theta_S^{\mathbb{Q}} = \{K_{0S}^{\mathbb{Q}}, K_{1S}^{\mathbb{Q}}, \Sigma_S, \rho_{0S}, \rho_{1S}\}$ and the functions $A_\tau(\Theta_S^{\mathbb{Q}})$ and $B_\tau(\Theta_S^{\mathbb{Q}})$ are computed recursively and satisfy a set of Riccati equations:

$$\begin{aligned} A_{\tau+1} &= A_\tau + K_{0S}^{\mathbb{Q}\prime} B_\tau + 0.5 B_\tau' \Sigma_S \Sigma_S' B_\tau - \rho_{0S} \\ B_{\tau+1} &= B_\tau + K_{1S}^{\mathbb{Q}\prime} B_\tau - \rho_{1S} \end{aligned}$$

with initial conditions $A_0 = B_0 = 0$. Here the use of the symbol $\tilde{}$ highlights that the yields $\widetilde{y}_t$ are assumed to be perfectly priced by the model, i.e. (25) does not contain any measurement error.

A preliminary result (Joslin, 2007) is that (22), (23), and (24) can be re-parametrised as follows:

$$\begin{aligned} K_{0S}^{\mathbb{Q}} &= (k_\infty^{\mathbb{Q}}, 0, ..., 0), & (26) \\ K_{1S}^{\mathbb{Q}} &= J(\lambda^{\mathbb{Q}}) \text{ (real Jordan form)}, & (27) \\ \Sigma_S &= \text{lower triangular}, \\ \rho_{0S} &= 0, \\ \rho_{1S} &= \mathbf{1} \text{ (vector of ones)}. \end{aligned}$$

The $\lambda^{\mathbb{Q}}$ are the (ordered) eigenvalues of $K_{1S}^{\mathbb{Q}}$. Note that in this case knowledge of $k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_S$ will be sufficient to compute the loadings so we can write $A(\Theta_S^{\mathbb{Q}}) = A(k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_S)$ and $B(\Theta_S^{\mathbb{Q}}) = B(\lambda^{\mathbb{Q}})$.

Now consider n linear combinations of N yields (that is, portfolios), and label them $P_t = W\widetilde{y}_t$. JSZ show that i) the state vector S_t which is in general unobservable can be replaced by the observable portfolios P_t by means of an invariant transformation, and ii) the Qdistribution of the observable portfolios P_t is entirely characterized by $\Theta_P^{\mathbb{Q}} = \{k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_P\}$ where Σ_P is the Cholesky factor of the conditional variance of P_t.[15]

To derive the JSZ rotation we start from getting a measurement equation in terms of the states P_t. Rewrite the measurement equation (25) by stacking by columns the equations for different yields:

$$\underset{N\times 1}{\widetilde{y}_t} = \underset{N\times 1}{A(\Theta_S^{\mathbb{Q}})} + \underset{N\times n}{B(\Theta_S^{\mathbb{Q}})}\,\underset{n\times 1}{S_t} \tag{28}$$

with $\widetilde{y}_t = [\widetilde{y}_t(\tau_1), ..., \widetilde{y}_t(\tau_N)]'$, $A(\Theta_S^{\mathbb{Q}}) = [A_{\tau_1}, ..., A_{\tau_N}]'$, and $B(\Theta_S^{\mathbb{Q}}) = [B'_{\tau_1}, ..., B'_{\tau_N}]'$. By premultiplying (28) by W the measurement equation can be stated as:

$$P_t = A_W + B'_W S_t, \tag{29}$$

where

$$A_W = WA(\Theta_S^{\mathbb{Q}}) \tag{30}$$

and

$$B'_W = WB(\Theta_S^{\mathbb{Q}}). \tag{31}$$

From (29) we can get an expression for S_t:

$$S_t = B_W'^{-1}(P_t - A_W), \tag{32}$$

and substituting (32) into the measurement equation (28) gives:

$$\widetilde{y}_t = A_p + B_p P_t \tag{33}$$

with:

$$A_p = (I - B(\Theta_S^{\mathbb{Q}})B_W'^{-1}W)A(\Theta_S^{\mathbb{Q}}), \tag{34}$$

$$B_p = B(\Theta_S^{\mathbb{Q}})B_W'^{-1}, \tag{35}$$

while using (29) to compute the conditional variance of P_t gives:

$$\Sigma_P \Sigma'_P = B'_W \Sigma_S \Sigma'_S B_W. \tag{36}$$

[15] The parameter k^∞ under Q-stationarity (and if the multiplicity of the first eigenvalue λ_1^Q is $m_1 = 1$) is related to the risk neutral long run mean of the short rate as follows: $k_\infty^Q = -\lambda_1^Q r_\infty^Q$. As a result, it is possible to define equivalently $\Theta_P^Q = r_\infty^Q, \lambda^Q, \Sigma_P$.

Note that since $B(\Theta_S^{\mathbb{Q}}) = B(\lambda^{\mathbb{Q}})$ and $B_W = WB(\Theta_S^{\mathbb{Q}})$, the matrix Σ_S can be derived under knowledge of $\lambda^{\mathbb{Q}}$ and Σ_P, and in turn knowledge of $k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_S$ yields the coefficients in $A(\Theta_S^{\mathbb{Q}}) = A(k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_S)$. It follows that knowledge of $\Theta_P^{\mathbb{Q}} = k_\infty^{\mathbb{Q}}, \lambda^{\mathbb{Q}}, \Sigma_P$ allows one to compute A_p and B_p. Turning to the equations (22), (23), and (24), applying (29) to both sides and then substituting S_{t-1} using (32) we obtain the JSZ canonical form corresponding to the measurement equation (33):

$$\Delta P_t = K_{0P}^{\mathbb{P}} + K_{1P}^{\mathbb{P}} P_{t-1} + \Sigma_P \varepsilon_t^{\mathbb{P}} \tag{37}$$

$$\Delta P_t = K_{0P}^{\mathbb{Q}} + K_{1P}^{\mathbb{Q}} P_{t-1} + \Sigma_P \varepsilon_t^{\mathbb{Q}} \tag{38}$$

$$r_t = \rho_{0P} + \rho_{1P} P_t. \tag{39}$$

The relation between the two representations is given by:

$$\begin{aligned}
K_{1P}^{\mathbb{Q}} &= B_W' K_{1S}^{\mathbb{Q}} B_W'^{-1}, && (40)\\
K_{0P}^{\mathbb{Q}} &= B_W' K_{0S}^{\mathbb{Q}} - K_{1P}^{\mathbb{Q}} A_W, && (41)\\
\rho_{1P} &= B_W^{-1} i, && (42)\\
\rho_{0P} &= -A_W \rho_{1P}, && (43)\\
K_{1P}^{\mathbb{P}} &= B_W' K_{1S}^{\mathbb{P}} B_W'^{-1}, && (44)\\
K_{0P}^{\mathbb{P}} &= B_W' K_{0S}^{\mathbb{P}} - K_{1P}^{\mathbb{P}} A_W, && (45)
\end{aligned}$$

where $K_{1S}^{\mathbb{Q}} = J(\lambda^{\mathbb{Q}})$ and $K_{0S}^{\mathbb{Q}} = k_\infty^{\mathbb{Q}} e_{m_1}$ with e_{m_1} a vector of zeros except for the entry m_1 which is one (m_1 being the multiplicity of the first eigenvalue λ_1^Q).

Now assume the portfolios (and therefore the yields) are measured with error. In this case we define the observed yields as $y_t = \widetilde{y}_t + \Sigma_y \varepsilon_t^y$. The definition of the portfolios stays the same: $P_t = W\widetilde{y}_t$ as before, but now these differ from the observed portfolios $P_t^o = Wy_t$ so one needs to filter out the unobserved states P_t. The state space system is:

$$\Delta P_t = K_{0P}^{\mathbb{P}} + K_{1P}^{\mathbb{P}} P_{t-1} + \Sigma_P \varepsilon_t^{\mathbb{P}} \tag{46}$$

$$y_t = A_p + B_p P_t + \Sigma_y \varepsilon_t^y. \tag{47}$$

The objects $K_{0P}^{\mathbb{P}}$ and $K_{1P}^{\mathbb{P}}$ can be concentrated out in a preliminary OLS step, A_p and B_p are parameterized by the vector of coefficients $\Theta_P^{\mathbb{Q}} = \{\lambda^{\mathbb{Q}}, k_\infty^{\mathbb{Q}}, \Sigma_P\}$ via (34), (35) and (36). Hence, the model is fully parameterized by:

$$\theta = (\lambda^{\mathbb{Q}}, k_\infty^{\mathbb{Q}}, \Sigma_P, \Sigma_y), \tag{48}$$

Considering that reasonable initial conditions for Σ_P and Σ_y are readily available, the size of the parameter set to be estimated is dramatically reduced.

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Tables and figures

Table 1: RMSEs for different maturities

maturity (years)	**RMSE (basis points)**
0.25	0.0028
1	9.2313
2	3.63122
3	0.0118797
4	0.885371
5	5.24329e-05
7	3.33382
10	8.67598
1	9.94581
2	2.09054e-05
3	5.16343
5	12.2225
7	18.3568
10	24.8387
average	6.8786

Table 2: determinants of the third factor.

$S_{3t} = c + \phi_1 S_{3t-1} + \phi_2 \Delta CDS_t + \phi_3 \Delta XL_t + \phi_4 VSTOXX_t + \phi_5 D_t + \varepsilon_t$				
	EFSF	**EFSF**	**France**	**Germany**
c	-0.00037**	-0.00036**	-0.00058***	-0.000295***
S_{3t-1}	0.9450***	0.9482***	0.9857***	0.9771***
$\Delta CDS_t\ (FR)$	-0.9191*	-	-0.2603	-
$\Delta CDS_t\ (DE)$	-	-1.0008	-	-1.4242*
ΔXL_t	-0.0093***	-0.0093***	-0.0074**	-0.0055*
$VSTOXX_t$	1.0246	1.5406**	2.5333**	-0.5445
D_t (2007 : 8)	-0.00142***	-0.00143***	-0.000692***	-0.00038***
D_t (2011 : 11)	0.00163***	0.00158***	-0.004286***	-0.000151
R^2 (adj)	0.941	0.885	0.881	0.955

Note: here c is an intercept, ΔCDS_t is the change in credit default swaps rates, ΔXL_t is the change in a measure of excess liquidity, $VSTOXX_t$ is the Euro STOXX 50 area volatility index by DB and Goldman Price, D_t are dummy variables picking up extreme events in the dates August 2007 and November 2011. Sample size: 213.

Table 3: determinants of the third factor, sample starting 2011:6

$S_{3t} = c + \phi_1 S_{3t-1} + \phi_2 \Delta CDS_t + \phi_3 \Delta XL_t + \phi_4 VSTOXX_t + \phi_5 D_t + \phi_6 BA_t + \varepsilon_t$				
	EFSF	**EFSF**	**France**	**Germany**
c	-0.000374	-0.000809*	-0.000958*	0.000277
S_{3t-1}	0.865928***	0.877338***	0.879943***	0.970804***
$\Delta CDS_t\ (FR)$	-1.243307	-	-0.378832	-
$\Delta CDS_t\ (DE)$	-	-1.405896	-	-1.182595
ΔXL_t	-0.008857**	-0.010634**	-0.007429	0.001790
$VSTOXX_t$	0.697189	0.522964	1.979787	-0.569060
D_t (2011 : 11)	0.001354**	0.001394**	-0.003785***	-0.000147
$BA_t\ (FR)$	-9.77E-06	-	2.56E-05	-
$BA_t\ (DE)$	-	3.24E-05	-	-2.14E-05
R^2	0.814	0.812	0.675	0.930

Note: here c is an intercept, ΔCDS_t is the change in credit default swaps rates, ΔXL_t is the change in a measure of excess liquidity, $VSTOXX_t$ is the Euro STOXX 50 area volatility index by DB and Goldman Price, D_t a dummy variable picking up extreme event in November 2011, and BA_t is the bid-ask spread. Sample size: 115.

Table 4: timeline of events

Sep-01	U.S. terrorist attacks
Jan-04	Committee of European Banking Supervisors
Mar-08	Collapse of Bear Stearns
Sep-08	Lehman Brothers bankruptcy
Apr-10	Greece requests financial assistance
May-10	First programme approved for Greece
May-10	Start of the SMP
June-10	EFSF created
Nov-10	Ireland financial assistance
May-11	Portugal financial assistance
Oct-11	Dexia resolution
Dec-11	3Y- LTROS announced
Feb-12	EFSF programme for Greece
Mar-12	ECB suspends eligibility of Greek bonds used as collateral in repo operations
Apr-12	Bankia resolution
Jul-12	Mario Draghi's "Whatever it takes" speech
Aug-12	Outright Monetary Transactions (OMT) annoucement
Oct-12	ESM operating
Dec-12	ESM assistance to Spain
Apr-13	ESM financial assistance to Cyprus
Jul-13	ECB forward guidance
Dec-13	Spain and Ireland: End of financial assistance
Jun-14	GovC decision TLTROS
Sep-14	GovC decision ABS, covered bonds
Jun-14	Portugal: End of financial assistance
Jan-15	GovC decision, EAPP
Jun-15	Greece fails to repay IMF loan
Aug-15	ESM Board of Governors approves ESM programme for Greece
Dec-15	Extension of QE
Jan-16	EMIR regulation on CCPs
Mar-16	Increase pace of APP
Mar-16	Cyprus: End of financial assistance
Dec-16	ECB decreases pace of APP
Jan-17	Short-term debt relief measures for Greece
Jun-18	Medium-term measures of Greece
Sep-18	ECB resumes Cyprus asset purchases
Aug-18	Greece: end of ESM financial assistance programme
Mar-20	ECB announces more QE for pandemic

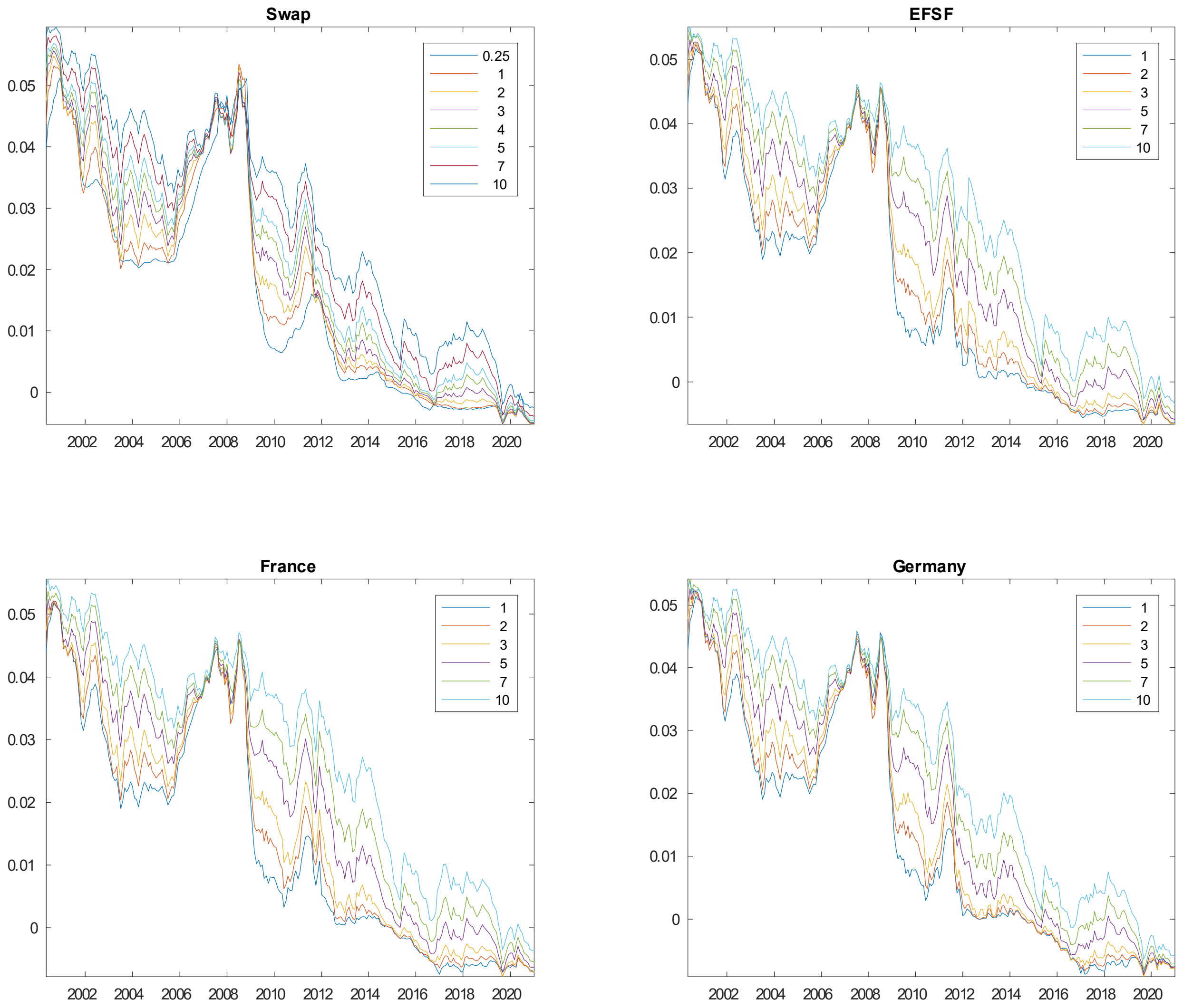

Figure 1: Data. Swap curve and spot curves for EFSF, France, and Germany. Units are expressed in levels, so for example $0.06 = 6\%$. Source: Data obtained from Bloomberg Data Services.

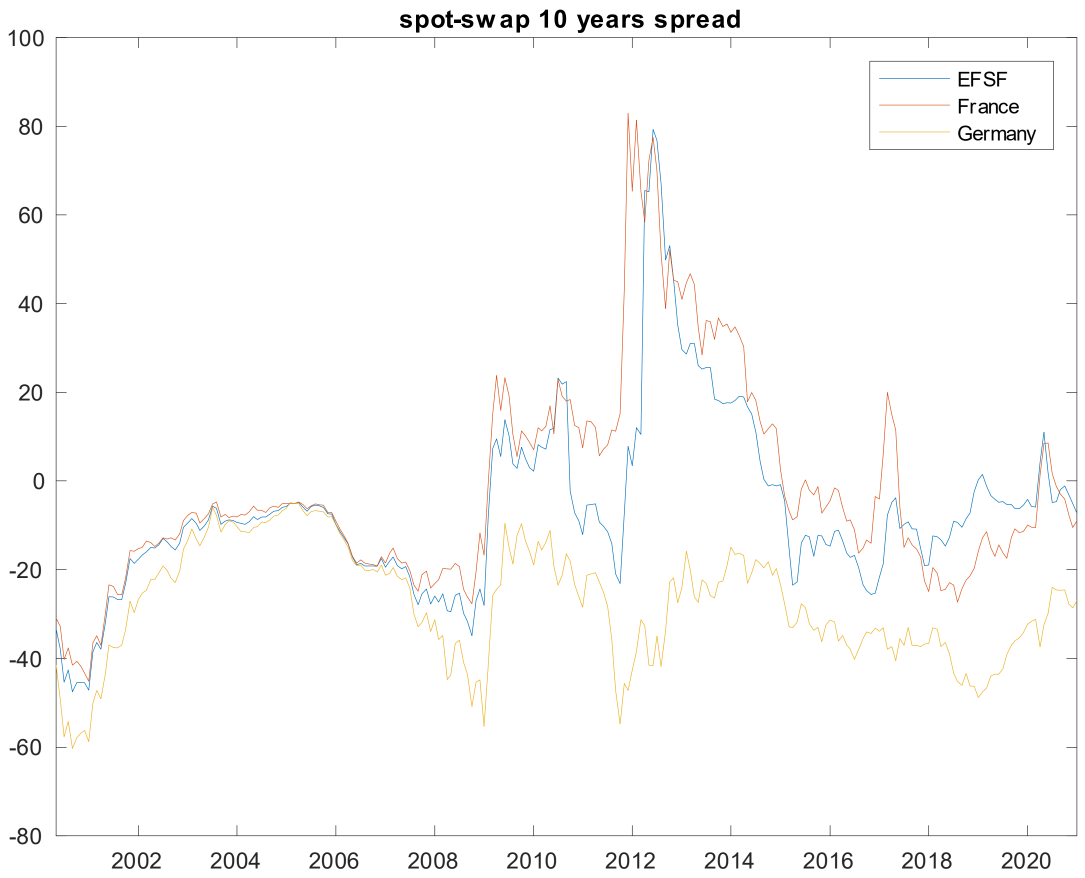

Figure 2: Spreads between swap and spot rates. Units are basis points. Source: Authors' calculation using data obtained from Bloomberg Data Services.

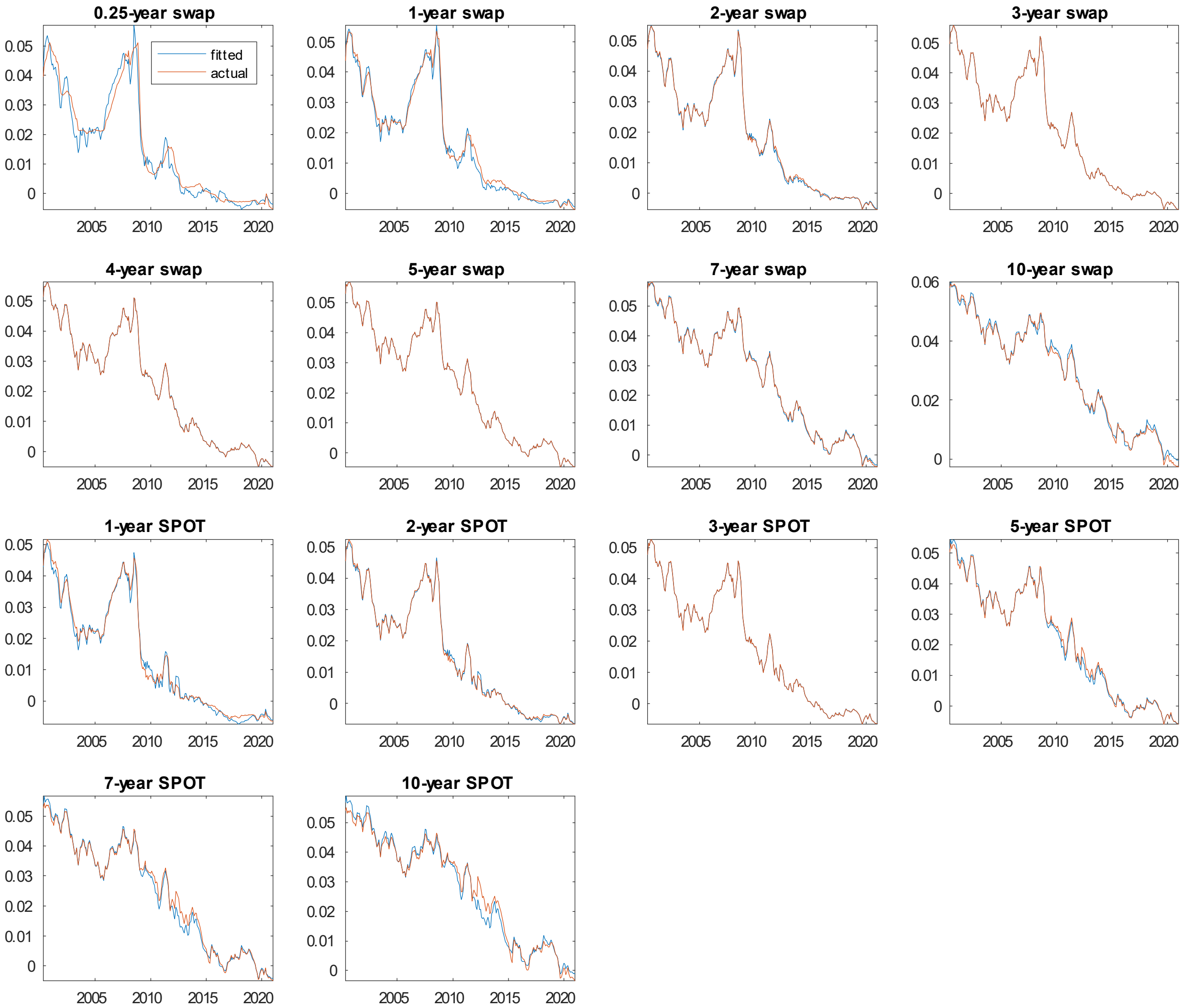

Figure 3: Actual and fitted yields, swap-EFSF curve. Units are expressed in levels, so for example 0.06 = 6%. Authors' calculation using data obtained from Bloomberg Data Services.

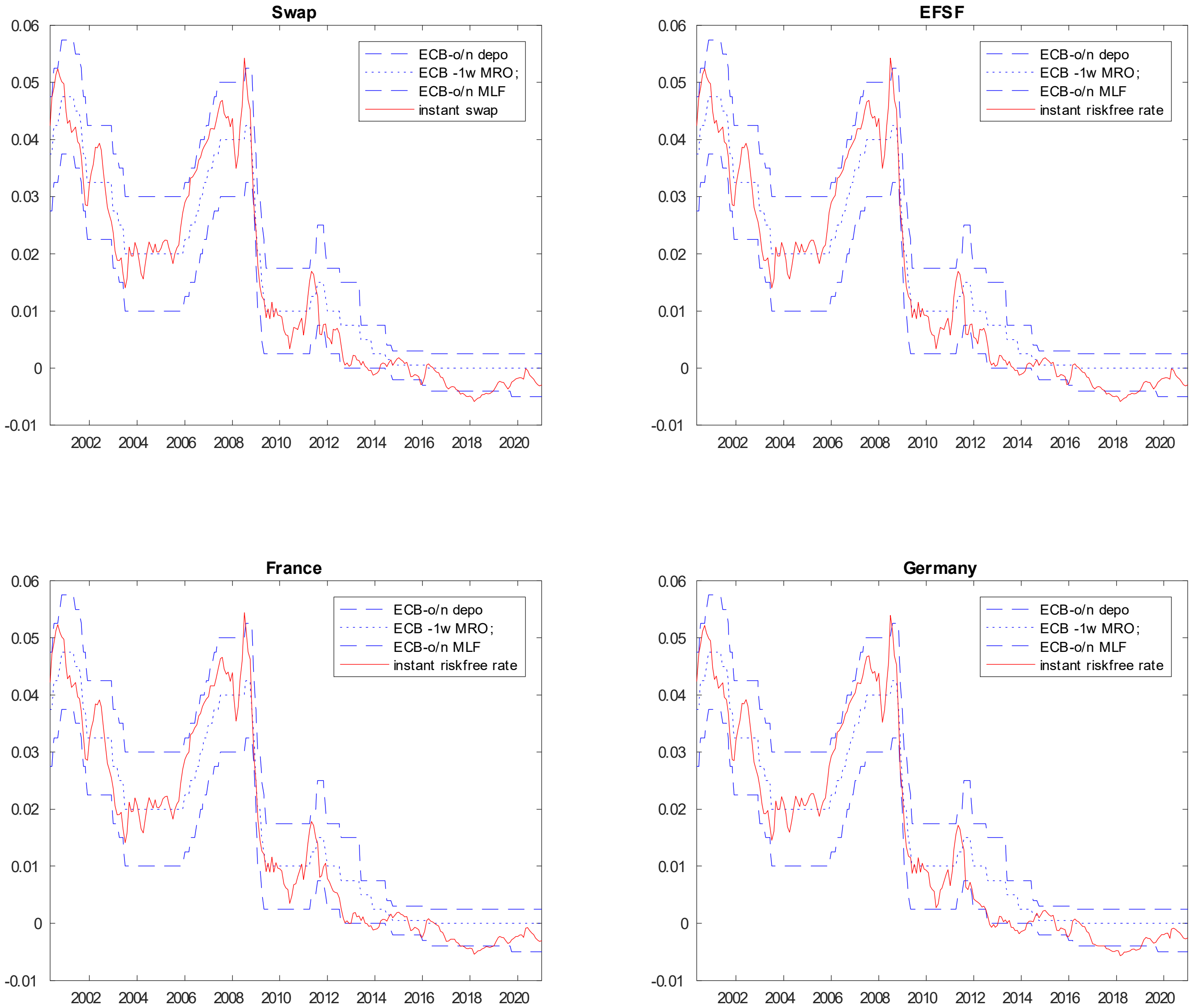

Figure 4: Instantaneous risk-free rates for alternative curves. Units are expressed in levels, so for example $0.06 = 6\%$. Source: Authors' calculation using data obtained from Bloomberg Data Services.

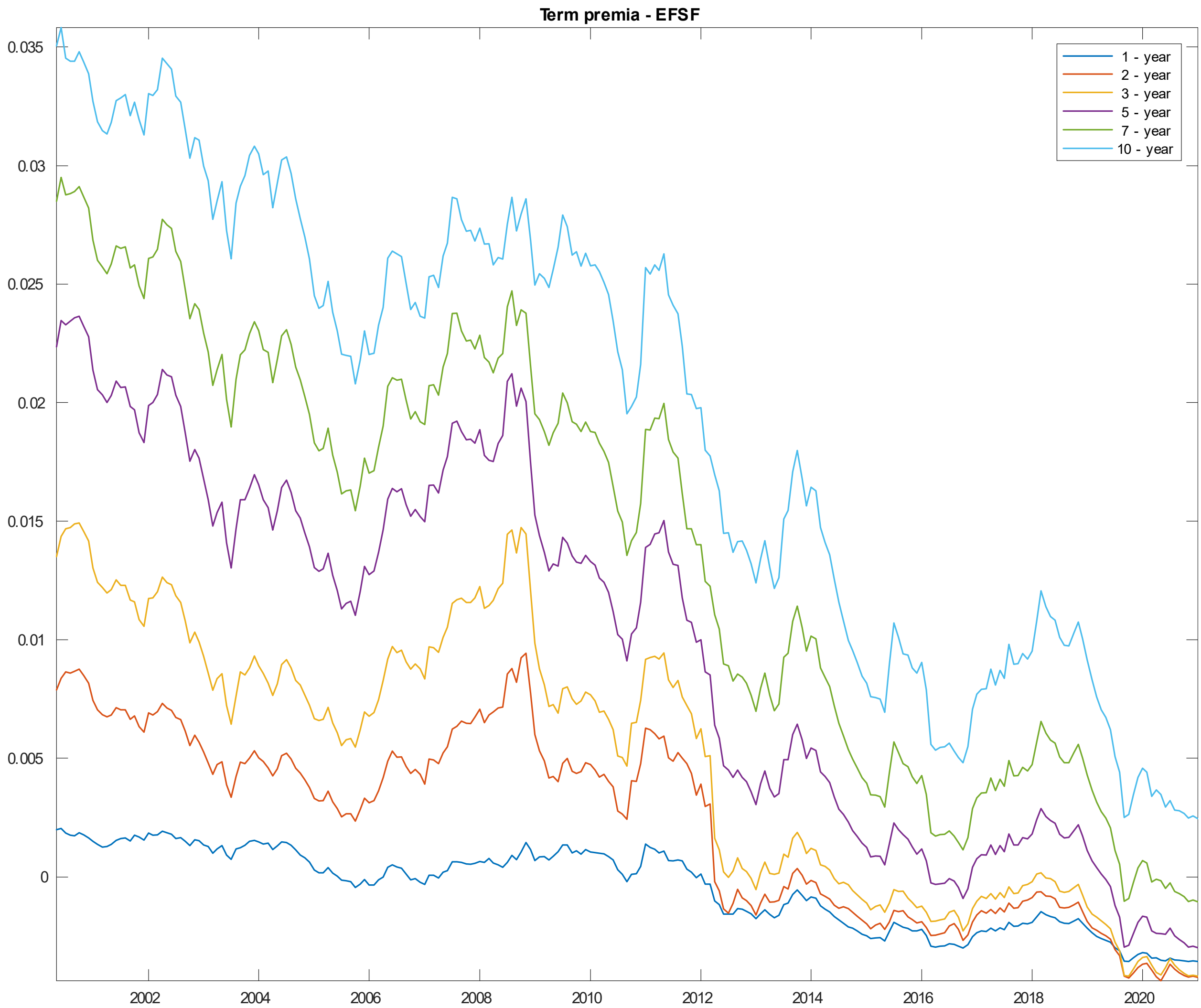

Figure 5: Term premia - EFSF curve. The term premium is the one shown in (19). Units are expressed in levels, so for example 0.03 = 3%. Authors' calculation using data obtained from Bloomberg Data Services.

Figure 6: Term premia on the 10-year yield. The term premium is the one shown in (19). Units are expressed in levels, so for example 0.03 = 3%. Source: Authors' calculation using data obtained from Bloomberg Data Services.

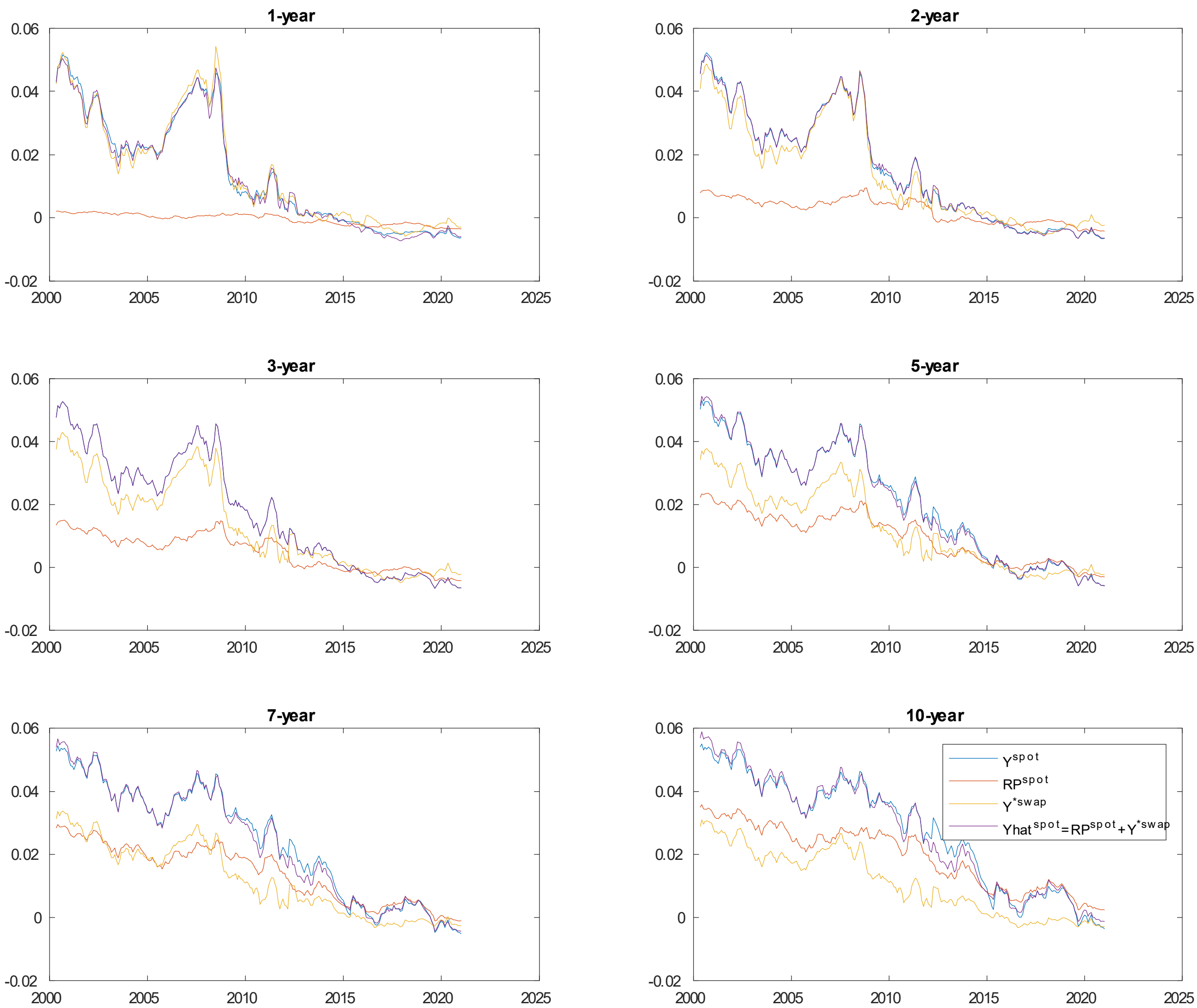

Figure 7: Decomposition of EFSF yields. The figure illustrates the decomposition shown in (20). The term premium is the one shown in (19). Units are expressed in levels, so for example 0.06 = 6%. Source: Authors' calculation using data obtained from Bloomberg Data Services.

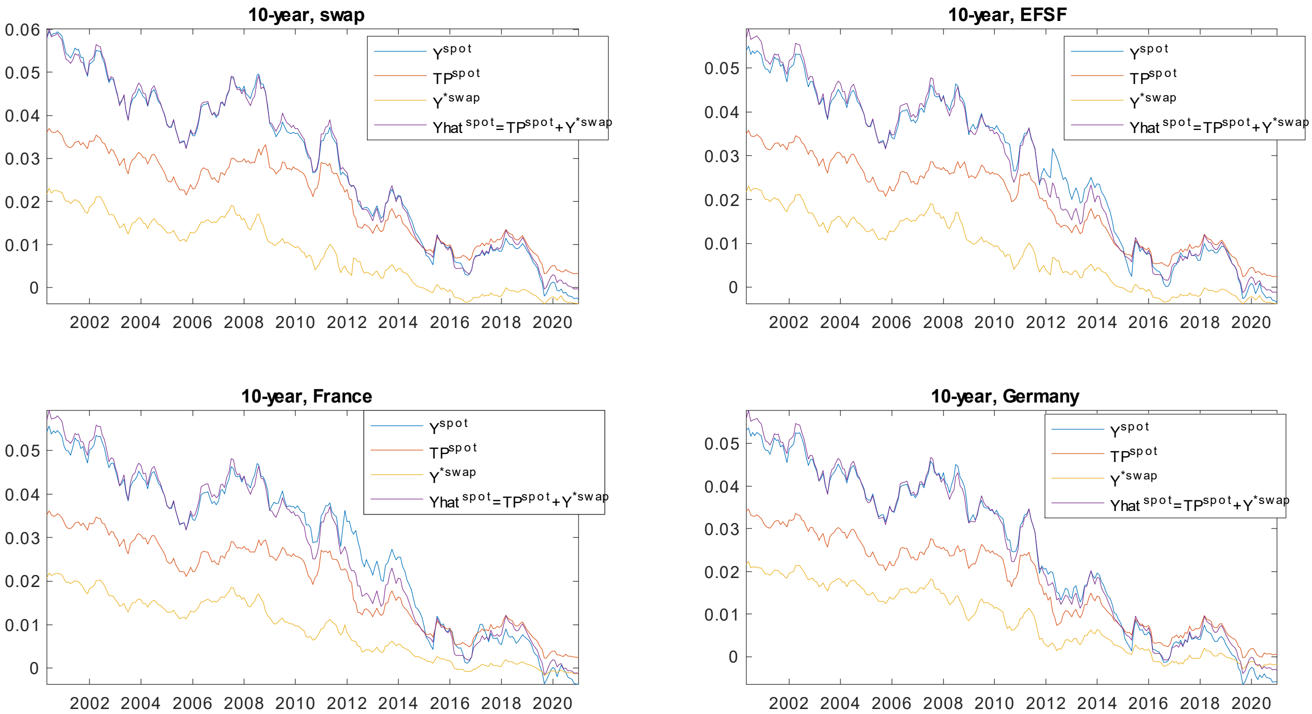

Figure 8: Decompositions for different curves. The figure illustrates the decomposition shown in (20). The term premium is the one shown in (19). Units are expressed in levels, so for example $0.06 = 6\%$. Source: Authors' calculation using data obtained from Bloomberg Data Services.

Figure 9: Estimated S_t latent factors, swap-EFSF curve. Units are expressed in levels, so for example $0.06 = 6\%$. The data-based level is defined as the 10-year yield. The data-based slope is defined as the difference between the 10-year and 1-year yield. The data-based third factor is defined by the difference between the 3 month swap rate and the 1-year EFSF yield. Source: Authors' calculation using data obtained from Bloomberg Data Services.

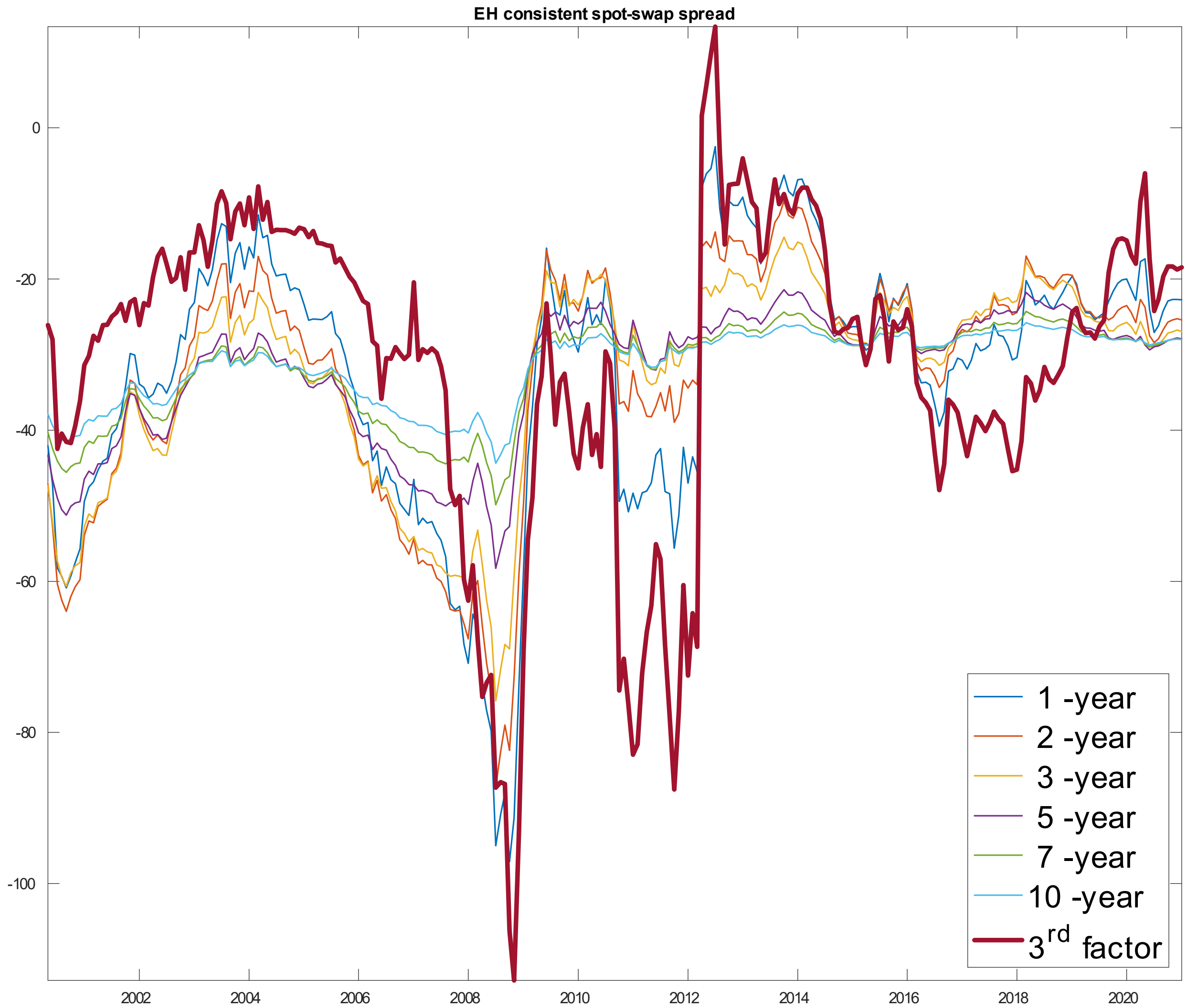

Figure 10: Spreads between EFSF and swap term premia. The bold line is the third pricing factor. Units are in basis points. Source: Authors' calculation using data obtained from Bloomberg Data Services.

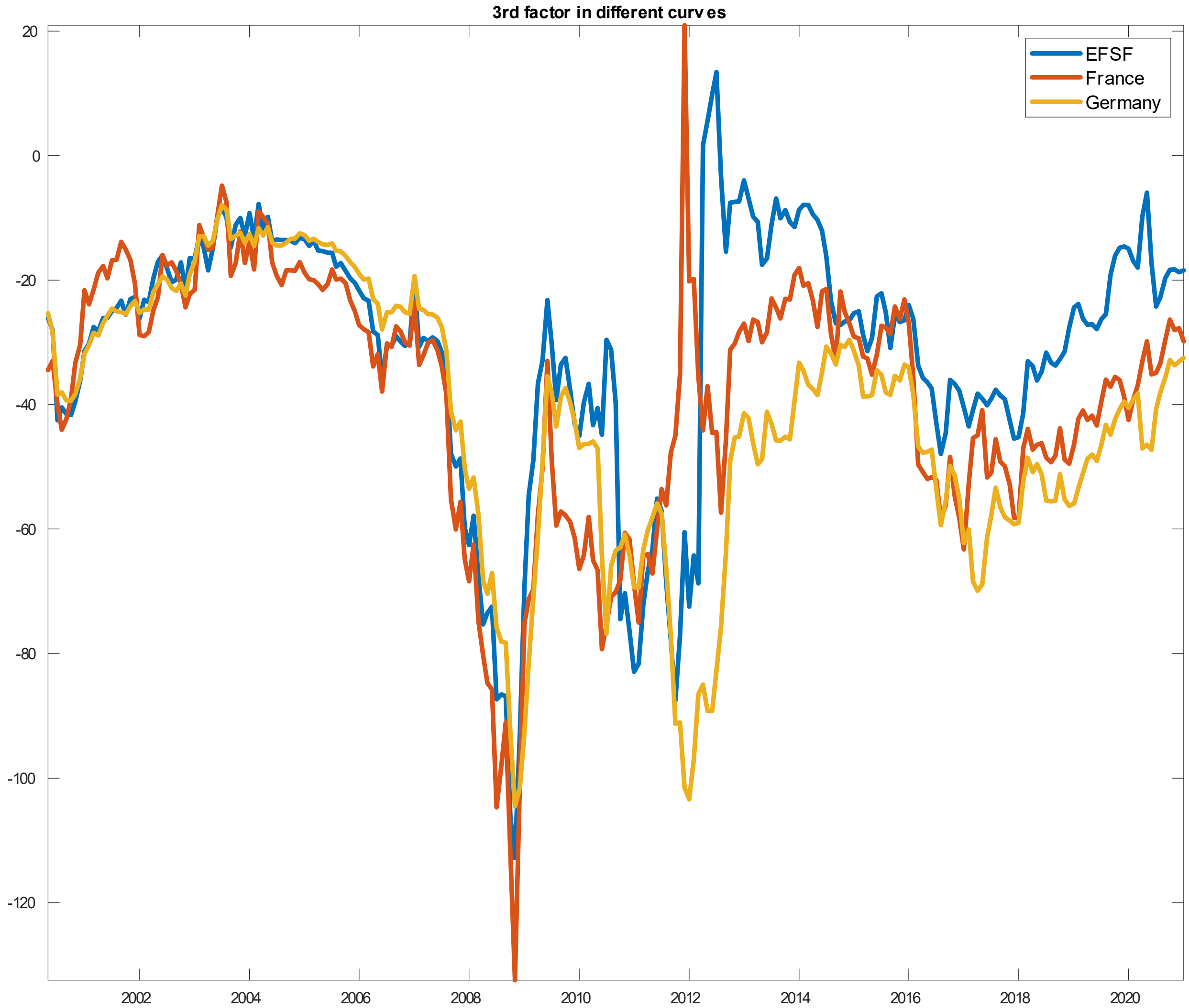

Figure 11: Third factor for EFSF, France, and Germany. Units are in basis points. Source: Authors' calculation using data obtained from Bloomberg Data Services.

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