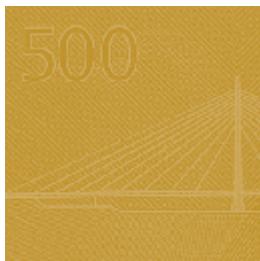




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### LIQUIDITY AND CREDIT RISK PREMIA IN GOVERNMENT BOND YIELDS

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NOTE: This Working Paper should not be reported as representing the views of the European Central Bank (ECB). The views expressed are those of the authors and do not necessarily reflect those of the ECB.

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## **Abstract**

This paper quantifies liquidity and credit premia in German and French government bond yields. For this purpose, we estimate term structures of government-guaranteed agency bonds and exploit the fact that any difference in their yields vis-à-vis government bonds can be attributed to differences in liquidity premia. Adding the information on risk-free rates, we obtain model-free and model-based gauges of sovereign credit premia, which are an important alternative to the information based on CDS markets. The results allow us to quantify the price impact of so-called “safe haven flows”, which strongly affected bond markets in late 2008/early 2009 and again during some phases of the sovereign debt crisis. Thus, we show to what extent these effects disguised the increase of sovereign credit premia in the government yields of core euro area countries.

Keywords: liquidity premium; sovereign credit risk;  
yield curve modeling; bond markets;  
state space models;

JEL classification: E44; G12; G01

## Non-technical summary

This paper quantifies liquidity and credit premia in German and French government bond yields during the financial crisis of 2008/2009 and the subsequent sovereign debt crisis of 2010/2011. In contrast to most existing studies on sovereign yield spreads, we rely neither on liquidity proxies (such as transaction-based measures of liquidity) nor on credit proxies (such as CDS premia or fiscal projections) to decompose yields. Instead, we estimate term structures of government-guaranteed agency bonds and exploit the fact that any difference in their yields vis-à-vis government bonds can be attributed to differences in liquidity premia. Thus, pricing information from the agency market allows us controlling directly for credit risk. Using the information on expected future monetary policy rates embedded in overnight-indexed swap (OIS) rates we obtain also gauges of sovereign credit premia in (i) a model-free and (ii) a model-based framework.

Our results allow us to quantify the impact of so-called safe haven flows on government yields. These effects were very pronounced in late 2008/early 2009 and again during some phases of the sovereign debt crisis, partly disguising the increase of sovereign credit premia in the analysed countries. While the market perception of higher sovereign credit risk pushed up German and French sovereign yields to a broadly similar extent until the second half of 2011, afterwards the differences between France and Germany in terms of credit premia increased, yet not nearly as much as suggested by the CDS market pricing.

Overall, our measures of sovereign credit risk for the two largest euro area countries are far less volatile and less subject to temporary over- and undershooting effects as the CDS premia. Our alternative gauge of sovereign credit risk is very valuable in the light of considerable scepticism about the reliability of sovereign CDS premia for large countries, where counterparty risks in case of sovereign default could become substantial. Regarding our measures of liquidity premia in sovereign bonds yields, the analysis suggests that yield spreads between government-guaranteed agency bonds and government bonds can be used as a reliable and very informative real-time indicator. In

contrast to the trading-based measures of liquidity, it is (i) easy to obtain and compute and (ii) easy to interpret in terms of a direct price impact across the term structure. Therefore, our estimated term structures of liquidity premia constitute a step forward in the monitoring of liquidity effects in the two large euro area sovereign debt markets.

# 1 Introduction

The term structure of government bond yields is a key source of information regarding investors' outlook for inflation and economic growth. However, the recent financial crisis has demonstrated that other factors can also be reflected in government yields. In the past few years periods of significant shifts in demand for highly rated and liquid assets have been observed in the bond markets, often referred to as safe haven flows. Moreover, as governments have taken on more and more liabilities in the course of the crisis, the very premise that highly-rated government bonds are default-free has been questioned. Thus, the notion of credit premia in bond yields has become relevant even for the largest sovereign issuers.

This paper quantifies liquidity and credit premia in German and French government bond yields for various maturities. Our analysis is based on the fact that any difference in the yields of government-guaranteed agency bonds vis-à-vis government bonds can be attributed to differences in liquidity premia. Using the information on expected future monetary policy rates embedded in overnight-indexed swap (OIS) rates we obtain also gauges of sovereign credit premia in (i) a model-free and (ii) a model-based framework. The results are important for assessing the impact of safe haven flows on the nominal sovereign yield curve, as well as for assessing sovereign credit risk in a way alternative to the information based on CDS markets.

Liquidity premium is understood in this paper as a higher price of an asset due to the fact that it is more liquid than other assets, i.e. it can be traded in large volumes at lower costs. In this sense, we consider liquidity from the asset pricing perspective, focusing on its price incorporated in the overall asset value. Credit premium is understood as a price discount on an asset due to its potentially uncertain payoff in the future. Although the importance of liquidity and credit effects in analysing sovereign bond yield movements have gained wide acceptance in the light of recent financial and sovereign debt crises, it still poses problems for the quantification of these effects for very liquid and highly rated markets, like those of German or French sovereign bonds. Regarding liquidity, its

increase may not be fully reflected in the traditional trading-based measures like bid-ask spread, as for highly liquid markets these variables are anyway very low. Rather, additional liquidity effect may be better reflected in the pricing of the respective asset, which we focus on. Regarding credit, the information from CDS markets, usually used for corporate bonds or sovereigns, is often criticised as prone to substantial distortions. In particular, the informativeness of CDS spreads for measuring sovereign credit premia of large countries may be impaired because, in the case of the default of a large AAA sovereign, some of the counterparties who sold the credit protection are likely to be also insolvent by this time.

In this paper, we estimate the term structures of government-guaranteed agency curves for Germany and France, which allow us to obtain real-time gauges of bond market liquidity premia for all maturities.<sup>1</sup> In a model-free approach, we construct upper and lower bounds for the size of sovereign credit premia for these two sovereigns. Finally, in a model-based approach we relax the assumption commonly made in the related literature, that agency bond yields are not influenced by any noticeable liquidity effects, allowing for the possibility that the spread between government and agency yields may, to some extent, also reflect agency *illiquidity* premia. We use a state space model, which delivers a more precise quantification of liquidity and credit premia components of sovereign yields.

Our results allow us to quantify the impact of so-called safe haven flows, which strongly affected bond markets in late 2008/early 2009 and again during some phases of the sovereign debt crisis, on government yields. We show to what extent these effects disguised the increase of sovereign credit premia in Germany and France. In terms of comparing those sovereigns, we show that while the spread between French and German bonds in late 2008/early 2009 was very high entirely due to the differences in liquidity premia, a spread increase of similar magnitude in late 2011 was also partly reflecting the divergence of credit premia. In absolute terms, the results show that the credit premia increased during late 2008 and, after a brief overshooting, remained stable at around

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<sup>1</sup> Time series of agency yields or liquidity premia are available upon request.

20-40 basis points for Germany and around 50 basis points for France since mid-2009.

Only in September 2011, French credit premium increased somewhat, but far less than was suggested by the CDS market pricing.

Overall, our results facilitate a real-time assessment of liquidity and credit premia in two major euro area bond markets. Such timely indicators are particularly useful in the post-2007 environment of rapidly increasing public debt in major industrialised economies and repeating periods of investor uncertainty facilitating safe haven flows. The ability to better disentangle the impact of credit and liquidity effects on government yields is also important for policy recommendations. For example, the implications of wider sovereign yield spreads in the euro area depend on whether this widening is mainly ascribed to credit or to liquidity premia. If spread widening is caused mainly by concerns about liquidity risk, measures to improve secondary market liquidity could be considered. On the other hand, if wider spreads reflect mainly concerns about the sustainability of fiscal positions, this would call for corrective fiscal policy measures. Another example is the extraction of inflation expectations from yield curve data: so-called break-even inflation rates are essentially computed as the difference between nominal and real government yields. Since liquidity effects impinge differently on nominal and inflation-linked bond yields, the derived inflation expectations can be contaminated by such non-fundamental influences. Credit risk premia, however, affect nominal and real zero-coupon yield curves to the same extent and would thus not affect the extracted measures of inflation expectations.

The remainder of the paper is organised as follows. Section 2 presents an overview of the literature on sovereign bond market liquidity and credit premia. Section 3 discusses the estimation of agency yield curves for Germany and France. Section 4 uses a model-free approach to disentangle liquidity and credit effects in sovereign yields with the estimated curves. Section 5 presents a state space model which allows extracting liquidity and credit premia in German and French yields using Kalman filter techniques. Section 6 concludes.

## 2 Related studies

The literature on decomposing sovereign bond yields into fundamental and liquidity components can be divided into two strands.<sup>2</sup> The first strand has used proxies for credit quality and liquidity to explain the movements in yield spreads vis-à-vis the risk-free rate. For example, Beber, Brandt, and Kavajecz (2009) explain spreads between long-term bond yields of ten euro area countries and euro area swap rate using CDS spreads as a proxy for credit quality and trading-based liquidity measures like bid-ask spreads or market depth.<sup>3</sup> More recently, Schwarz (2011) models sovereign yield spreads over German bonds with CDS spreads (for credit) and a spread between German agency and government bonds as a liquidity measure, while Favero, Pagano, and von Thadden (2008) use the US Treasury-swap spread as a global credit risk factor and bid-ask spreads for liquidity. For corporate bond markets, Bongaerts, de Jong, and Driessen (2011) analyse trading-based liquidity measures and default probability estimates for single assets, while Dick-Nielsen, Feldhütter, and Lando (2009) use information on CDS spreads and ratings to extract rating-dependent liquidity components before and during the crisis.<sup>4</sup> However, the problem with using proxies for sovereign credit and liquidity is that in many markets they are either not reliable or not available at all. With respect to sovereign credit premia, the informativeness of CDS spreads of large and highly rated countries is likely to be impaired because, in the case of the default of a large AAA sovereign, some of the counterparties who sold the credit protection are likely to also be insolvent by this time. This means that the CDS premia of large AAA sovereigns

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<sup>2</sup> In this paper, we understand sovereign credit premium as one of fundamental components of yields. Referring to credit premium, we refer to risk-neutral credit premium.

<sup>3</sup> For a comprehensive overview of liquidity proxies used for sovereign bonds, see e.g. Fleming (2003) or Elton and Green (1998).

<sup>4</sup> Similar studies for this market include Covitz and Downing (2007) who use trading volume and maturity as proxies for bond's liquidity and credit rating, as well as issuer's equity return volatility as proxies for credit quality. A similar analysis employing bid-ask spreads for liquidity of corporate bonds for various rating classes is provided by Chen, Lesmond, and Wei (2007). Ericsson and Renault (2006) use on- and off-the-run Treasury spread as a proxy for liquidity and a difference between Moody's Baa- and Aaa-rated corporate bond yield indices for credit quality. Longstaff, Mithal, and Neis (2005) show that the majority of corporate yield spreads is due to default risk, as measured by CDS spreads.

may be substantially influenced by the counterparty risk.<sup>5</sup> Regarding trading-based liquidity measures for sovereign bonds, there are problems with both availability and quality since these bonds are mostly traded on an OTC basis. For example, trading on the largest European electronic platform, MTS, is not only a small fraction of all transactions (around 2% for German bonds) but its share also decreased during the crisis due to the shift towards the OTC market.

The second strand of literature seeks to disentangle fundamental and liquidity effects by directly controlling for one of them. For example, some studies focus on bonds with the same credit quality but with different liquidity. Perhaps the best known example of a liquidity measure constructed using this logic is the so-called “on-the-run premium”, i.e. the yield spread between off- and on-the-run U.S. Treasury securities, as documented by Warga (1992) and others. Amihud and Mendelson (1991) confirm the liquidity effects for Treasury bills and notes, relating their magnitude to the residual maturity, while Goldreich, Hanke, and Nath (2005) relate the observed on-the-run premium to both, current and future expected liquidity. Using data from other markets, Longstaff (2004) proposed a so-called “flight-to-liquidity premium”, measured as the yield spread between the Treasury and Refcorp bonds, the latter being guaranteed by the U.S. government and thus having the same credit quality as Treasury securities. This measure is based on an assumption that agency bond yields are not influenced by any strong liquidity effects. Using a similar approach for a broader set of assets, Reinhart and Sack (2002) decompose swap, corporate and Treasury yields into several components, including a risk-free rate, liquidity and credit premia.<sup>6</sup> Recently, some studies have modelled yields in a state space framework with latent factors driving liquidity and credit risk components. For example, sovereign credit risk has been modeled by Duffie, Pedersen, and Singleton (2003), who account only for latent term-structure factors, but not for liquidity premia.

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<sup>5</sup> Additionally, CDS contracts are denominated in the USD or EUR, meaning that the nominal payoff may lose value in case of the respective sovereign default. Furthermore, some studies show that CDS pricing is also influenced by liquidity effects in these markets (e.g. see Trapp (2009))

<sup>6</sup> In a related study, Krishnamurthy and Vissing-Jorgensen (2010) isolate the impact of net supply of Treasuries on the price of risk and liquidity. Risk in this study, as in Reinhart and Sack (2002), regards the corporate risk and not the sovereign risk.

Fontaine and Garcia (2009) introduce liquidity as an additional factor in a dynamic term structure model and identify it by estimating the model for a panel of on- and off-the-run Treasury yields.<sup>7</sup> Still, none of these papers obtain both credit and liquidity components of bond yields of large and highly rated sovereigns.

Our paper belongs to the second strand of the literature. We decompose French and German sovereign spreads into credit and liquidity premia based on the idea that, while credit quality is issuer-specific, liquidity is bond-specific. In the identification of both components we thus use the idea that changes in perceived credit quality should, everything else equal, influence all bonds of the same issuer in the same way (for a given maturity), whereas changes in liquidity can move the prices of single bonds. To control directly for sovereign credit risk we use estimated agency yield curves. In the first part of our analysis, we construct model-free indicators of liquidity and credit premia for the two analysed euro area government bond markets across their term structures. Liquidity indicators constructed in this part closely follow Longstaff (2004). In the second part of the paper, we employ a state-space model, which allows us to relax an assumption made in the previous literature (e.g. in Longstaff (2004) or in Schwarz (2011)) that liquidity effects are only reflected in sovereign yields and not in agency yields. In this way, we allow for the possibility of upward pressures on agency yields given their relative illiquidity. Overall, our paper contributes to the literature by facilitating a real-time assessment of liquidity and credit premia in two major euro area bond markets using a method alternative to difficult to obtain and imprecise trading-based liquidity proxies and to volatile and potentially disrupted CDS markets. Comparing our results with the dynamics of other liquidity and credit proxies, shows, however, that our method enables to capture the important developments visible in other measures, with fewer overshooting effects.

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<sup>7</sup> Liu, Longstaff, and Mandell (2006) use a similar framework to jointly model the Treasury, repo and swap term structures, identifying the liquidity component as the difference between general collateral government repo rates and on-the-run Treasury yields and the default component as the difference between swap and repo rates. A similar approach is followed by Feldhütter and Lando (2008) who model Treasury bonds, corporate bonds and swap rates and decompose the latter into convenience yield, credit risk and swap-specific factors.

### 3 Yield curve estimation

#### 3.1 Bond data

We estimate four yield curves, using bonds issued by two agencies: the German *Kreditanstalt für Wiederaufbau* (KfW) and the French *Caisse d'Amortissement de la Dette Sociale* (CADES), as well as the German and French governments. KfW is a German development bank involved in supporting public policies like lending to small and medium enterprises, housing, infrastructure and environment projects.<sup>8</sup> KfW bonds have an explicit guarantee from the Federal Republic of Germany, written in a special law on the KfW.<sup>9</sup> CADES is a French public entity created to refinance and amortise the accumulated debt of the French social security system.<sup>10</sup> It is fully owned by the French state, which guarantees its obligations in case of insolvency and offers liquidity support if needed.<sup>11</sup> While the objectives and the core businesses of these two institutions are different, both of them have explicit and full debt guarantees from their sponsoring states. Thus the bonds issued by them could default only if the corresponding state itself defaults, which means that the credit risk of KfW (CADES) equals the credit risk of Germany (France).

We use daily ‘dirty prices’<sup>12</sup> obtained from Bloomberg on individual bonds issued by KfW, CADES, Germany and France, covering the period from 1 January 2006 to 14 October 2011. Since KfW and CADES are the largest euro area agency issuers, the number of outstanding bonds is sufficiently large to estimate reliable yield curves.<sup>13</sup> We include bonds with the minimum issue size of EUR 1 bn. All included bonds are

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<sup>8</sup> KfW is owned by the German Federal Republic (80%) and Länder (20%). For more details see Barclays Capital (2009, p. 340).

<sup>9</sup> See ‘Gesetz über die KfW’, available at [www.kfw.de](http://www.kfw.de).

<sup>10</sup> For this purpose, it uses the proceeds of a dedicated tax to amortise the debt. See Barclays Capital (2009, p. 320).

<sup>11</sup> Pursuant to Article 2 of the January, 25th 1985 Act governing corporate receivership and liquidation, if public-sector organisations wound up, their debts would be transferred to the government authority that established them (in case of CADES it is the French government). See also further supporting acts available at: <http://www.cades.fr/en/node/415>.

<sup>12</sup> Dirty price means the full price of the bond, i.e. including accrued interest between the coupon dates.

<sup>13</sup> For all other euro area agencies, a reliable estimation of the whole term structure cannot be conducted for all days in the analysed period, since the number of issued bonds is not sufficient to span the whole yield curve (given the bonds’ maturity structure).

traditional nominal bullet bonds. For each day, we have between 10 and 21 agency bonds, spanning well the entire maturity spectrum, with issuance volumes of between EUR 1 and 6 bn per bond.<sup>14</sup> For sovereign bonds, we have between 36 and 42 bonds with volumes of EUR 8.75 to 28 bn EUR. Although the agency markets are relatively small, these bonds are actively traded. Also, these markets are actively monitored by investors, for example in the context of commenting the developments in the local covered bond markets.

For each daily yield curve, we include bonds with between 1 and 35 years of remaining maturity, which in all cases leaves us with well-spanned yield curves. We exclude all securities with less than 1 year to maturity to avoid volatile yield movements closer to maturity. By excluding very long-term bonds, we avoid special clientele effects which may influence the pricing of these bonds, e.g. demand effects driven by pension fund regulation. Figure 1 shows the ranges of maturities available for estimation over our sample for agency issuers at each point in time.

### 3.2 Estimation methodology

We estimate zero-coupon yield curves for the four issuers using so-called exponential basis functions, as proposed by Vasicek and Fong (1982).<sup>15</sup> Specifically, we model the price of a coupon bond ( $P$ ) as the sum of its  $c$  cash-flows ( $P_{j,\tau_j}$ ), i.e. zero-coupon bonds:

$$P = \sum_{j=1}^c P_{j,\tau_j}, \quad (1)$$

The price of each zero-coupon bond ( $P_{j,\tau_j}$ ) with remaining maturity  $\tau_j$  is modeled as the following sum of exponential functions:

$$P_{j,\tau_j} = \sum_{i=1}^m \beta_i e^{-i\alpha\tau_j}, \quad (2)$$

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<sup>14</sup> This is broadly comparable to the per-bond issuance volumes of smaller euro area governments.

<sup>15</sup> For details of this method, see also Bolder and Gusba (2002) where the method is referred to as MLES Exponential. We use 6 basis functions and fix the parameter  $\alpha$  (in the notation of the mentioned paper) to 0.05. Estimated yield curves are fairly insensitive to precise choice of  $\alpha$ .

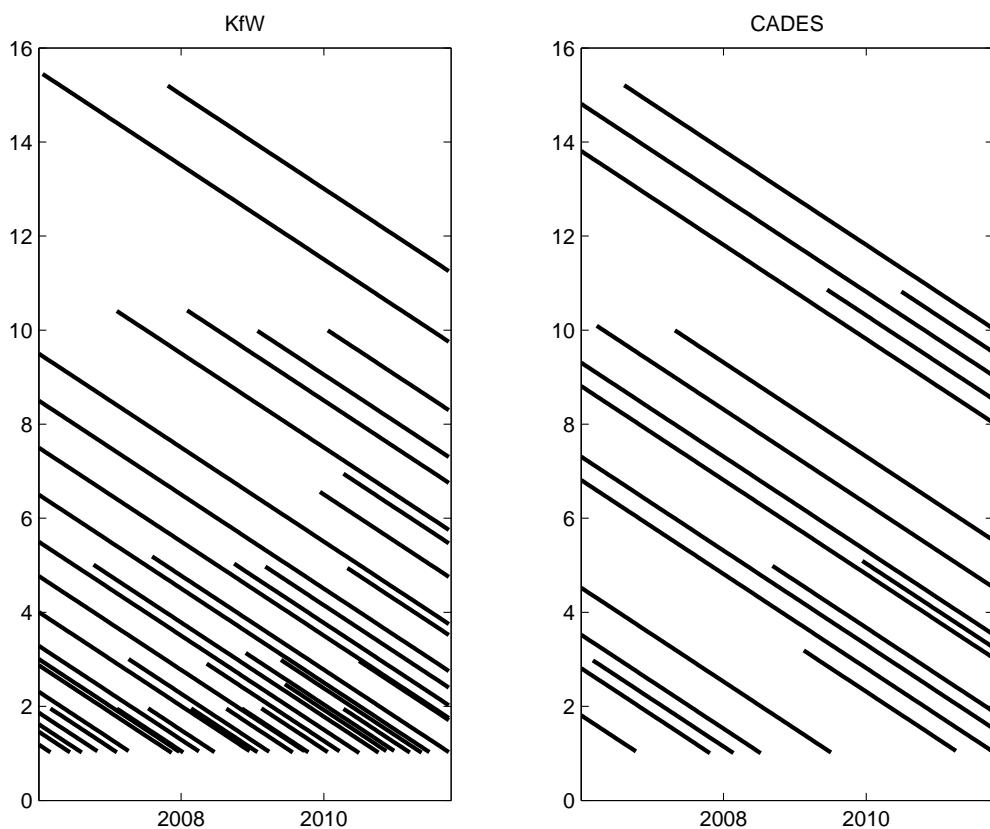


Figure 1: Remaining time to maturity (in years) of included agency bonds

NOTE: The figure shows time to maturity in years for each bond used for the estimation of the KfW (left panel) and CADES (right panel) agency curves at each point in time. The sample period is 1 January 2006 to 14 October 2011.

where  $m$  is the number of base functions used in the estimation,  $\beta$  is a coefficient and  $\alpha$  is a constant.

A key advantage of this method is that it involves no numerical optimisation as the parameters can be conveniently estimated by linear regression. Therefore, the method is also extremely fast and circumvents the problem of sensitivity to starting values of e.g. the Nelson-Siegel-Svensson (see Nelson and Siegel (1987), and the extension by Svensson (1994)). Moreover, Bolder and Gusba (2002) found this yield-curve estimation approach to be at least as accurate as the more frequently used methods such as the Nelson-Siegel-Svensson method in fitting the empirically observed features of the term structure.

## 4 Model-free framework for measuring liquidity and credit premia

### 4.1 Liquidity premia in euro area sovereign bond yields

For a given maturity, yields of bonds denominated in the same currency can differ mainly because of differences in credit and liquidity risk. Distinguishing between these two sources of variation is important, for example from the policy perspective. For example, in late 2008/early 2009 the sovereign yield spread between the two largest euro area countries, France and Germany, increased sharply. Notably, both countries have a very high credit rating and very liquid markets for their government bonds. The five-year French-German government yield spread increased from a level of around 3 basis points (bps) in July 2007 to a maximum of around 50 bps in January 2009, see Figure 2. Another example would be an even higher increase in the French-German sovereign spread to over 70 basis points during the sovereign debt crisis, especially in September 2011. Were these developments due to changes in relative credit quality of the French and German governments or did they reflect changes in relative liquidity premia, and to what extent?

If the French-German yield spread reflects a relative increase in the credit risk premium

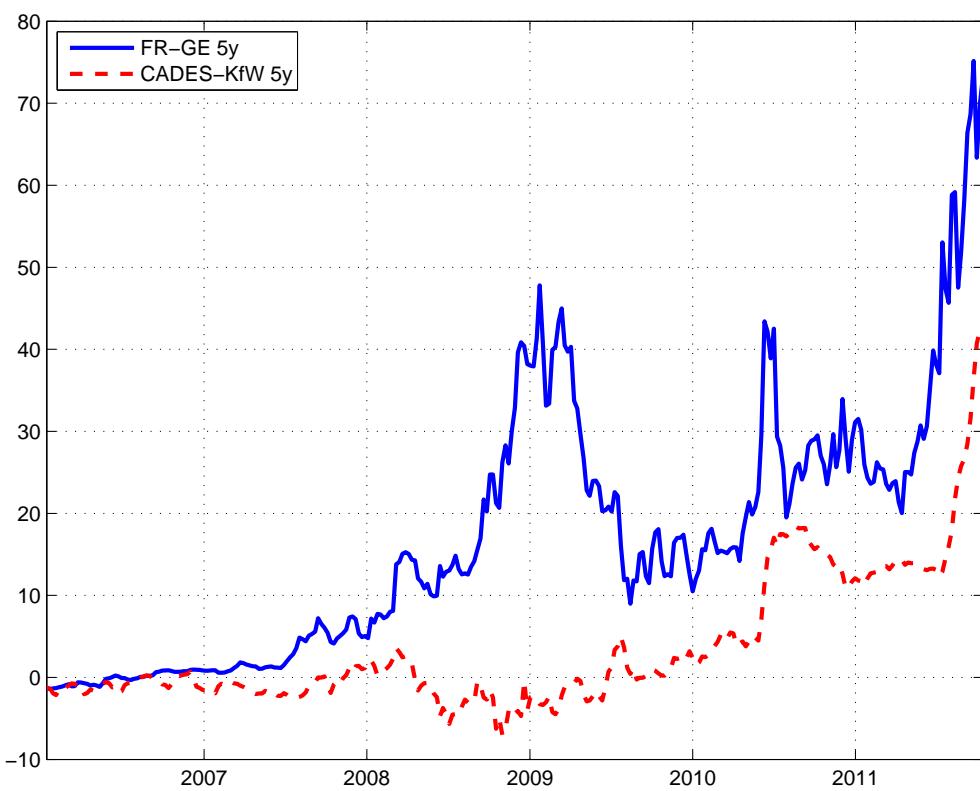


Figure 2: French-German sovereign and agency spreads

NOTE: The figure shows the spreads (in basis points) between French and German sovereign bonds as well as the spreads between French and German agency bonds (labeled CADES for the French agency and KfW for the German agency). All spreads are computed as weekly averages, for 5-year maturity. The sample period is 1 January 2006 to 14 October 2011.

of France, a similar wedge should open up between the yields on the two government-guaranteed agencies' bonds. In late 2008/early 2009 this was not the case. Figure 2 shows the French-German sovereign spread as well as the spread between CADES and KfW. In fact, during the entire period of 2008/2009 financial turmoil, the agency spread remained at a level very close to zero. This pattern of a wide sovereign spread along with a tight agency spread suggests that the German and French sovereign markets experienced changes in relative liquidity during the 2008/2009 financial turmoil and not changes in relative credit quality.<sup>16</sup> However, during the sovereign crisis of 2010 and especially in the second half of 2011, the French agency bonds started to trade at a higher premium than bonds of the German agency, which also suggests a relative difference in the priced credit risk of French and German sovereigns. All described results also hold for other maturities and are shown in Figure A-1 in the Appendix.

Figure 3 shows the configuration of the four yield curves on the following dates: (i) 2 July 2007, just before the onset of the money-market turmoil, (ii) 9 March 2009, when the 10-year French-German sovereign spread peaked (at 54 basis points), (iii) 26 April 2010, just before the confidence crisis in May 2010, and (iv) most recently, i.e. 14 October 2011. For all four charts, the scaling of the y-axis is comparable. Before the onset of the turmoil in mid-2007, all yield curves essentially overlapped. During the 2008/2009 financial crisis, even on those days where the wedge between the French and German sovereign curves was very wide, the agency curves still almost overlapped.<sup>17</sup> This finding is consistent during the time of the financial crisis and can be observed for all maturities. Later on during the sovereign debt crisis, as presented by the most recent configuration of the curves, the wedge between sovereign yields was still non-negligible but the agency curves no longer overlapped. This pattern is especially evident in the second half of 2011.

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<sup>16</sup> Theoretically, the close overlap between KfW and CADES yields may have resulted from diverging credit risk premia being almost perfectly off-set by opposite movements in relative liquidity premium. This, however, seems extremely implausible in particular because one would not expect that a deterioration in the perceived credit quality of France vis-à-vis Germany, would boost liquidity of CADES relative to KfW bonds.

<sup>17</sup> The inverse humps on the German government curve seen in Figure 3 (b) are effects related to the German bond futures market. For a detailed discussion, see Ejsing and Sihvonen (2009).

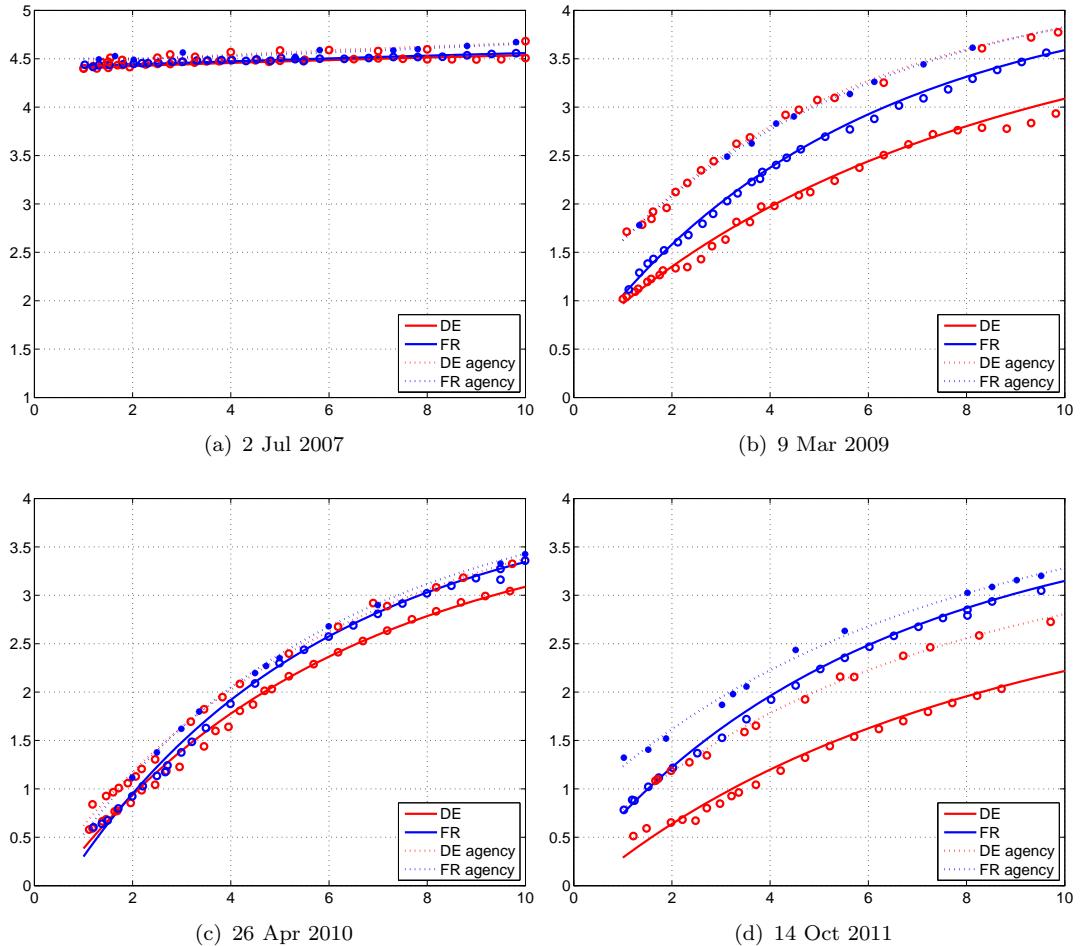
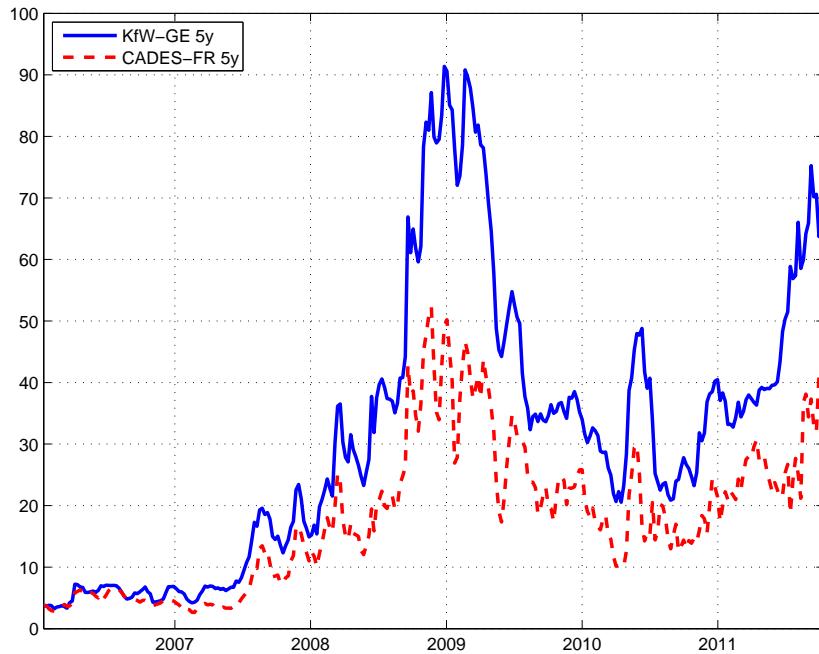
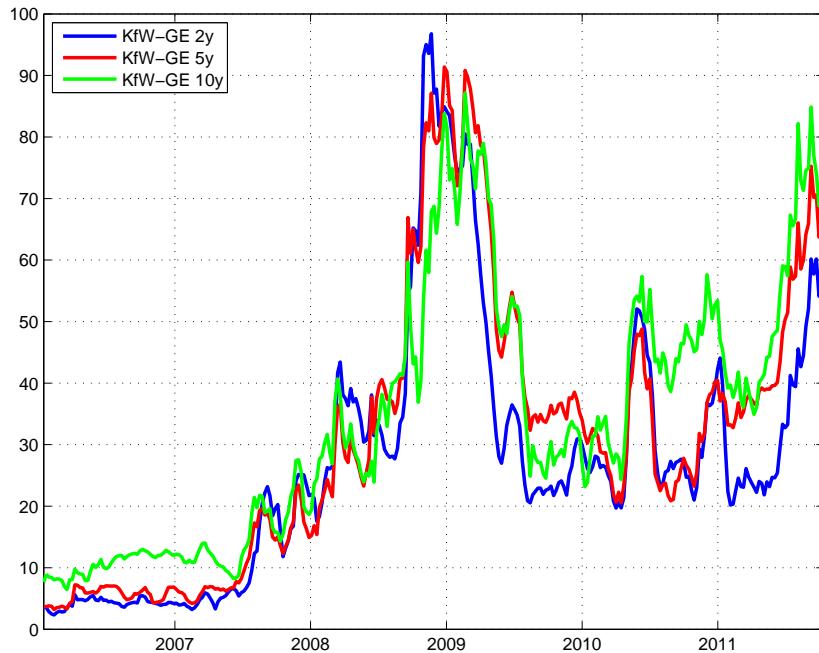


Figure 3: Par yield curves and yields-to-maturity

NOTE: The figure shows the par yield curves (in percent p.a.) of agency and sovereign bonds for Germany and France on four dates: (a) 2 July 2007, just before the onset of the liquidity turmoil, (b) 9 March 2009, when the 10-year French-German sovereign spread peaked (at 54 basis points), (c) 26 April 2010, just before the confidence crisis in May 2010, and (d) most recently, i.e. 14 October 2011. The distances between the curves are presented comparably throughout the figures. The circles refer to the yield-to-maturity on the individual bonds used in the estimation of the curves.



(a) Country comparison



(b) Maturity comparison

Figure 4: Agency-sovereign spreads for Germany and France

NOTE: The figure shows the spreads (in basis points) between agency and sovereign bonds. Subfigure (a) compares the agency-sovereign spread for 5-year maturity for Germany and France (labeled KfW-GE and CADES-FR, respectively). Subfigure (b) compares the agency-sovereign spread for Germany for different maturities. All spreads are computed as weekly averages. The sample period is 1 January 2006 to 14 October 2011.

Quantifying the developments of liquidity premia, Figure 4 compares the spreads between agency and sovereign bonds, i.e. the liquidity measure proposed by Longstaff (2004), for analysed countries and maturities. Panel (a) shows the spreads between five-year agency and sovereign bonds for both countries. Indeed, there is a large increase in the liquidity premium in the German sovereign bond market reflected in the high KfW-Germany spread during 2008/2009 crisis. Moreover, the premium paid for French government bonds relative to comparable agency bonds increased as well, albeit to a smaller extent than that of Germany (the KfW vs. Germany spread peaked at around 95 bps while the CADES vs. France spread peaked at 55 bps). During the sovereign debt crisis, the liquidity premium increased as well - first very briefly during May 2010, and then more significantly during the second half of 2011. Comparing the developments across maturities, panel (b) shows that the dynamics is quite similar, although maturity segments preferred by investors in various phases of the crisis vary to some extent. For example, while during the Lehman crisis, pressure on the shorter end of the curve was somewhat larger than on the longer end, the sovereign crisis was characterised by a higher preference for longer-term bonds. Importantly, Longstaff (2004) interpreted the spread between agency and Treasury yields exclusively as a liquidity effect in Treasury yields. In principle, however, both sovereign and agency bonds could be affected by the liquidity effects, and in that case, the spreads reported in Figure 4 show the sum of those effects. We address this issue in Section 5.

## 4.2 Sovereign credit risk

To quantify sovereign credit premia, we need a good estimate of the risk-free rate to control for the changes in expectations about future monetary policy rates and in related term premia. Moreover, the measure of the risk-free rate should also - to the greatest extent possible - be unaffected by credit and liquidity risk. The overnight-indexed swap rate (OIS) is arguably the best directly observable gauge of the risk-free rate, especially throughout the recent financial crisis, because the counterparty credit risk component

is very small as compared to usual interest rate swaps.<sup>18</sup> Using OIS rates as the risk-free benchmark, we compute the spreads of sovereign and agency yields. If agency yields are broadly unaffected by liquidity premia (the most likely interpretation), the agency vs. OIS would be a good measure of the German sovereign credit risk premium. If, on the other hand, increases in liquidity premia are mainly due to upward pressures on agency yields (much less likely), the government spread vs. OIS would be a good measure of the sovereign credit premium. Therefore, we interpret the two spreads as a lower and an upper bound for the ‘true’ sovereign credit premium.

Using these bounds, instead of a point estimate, allows us to have a gauge for sovereign credit risk without taking a stand on whether and to what extent an increase in the agency-sovereign spread (Figure 4) reflects a downward pressure on sovereign yields or an upward pressure on agency yields. We compare the credit bounds with a measure from an alternative market, the sovereign CDS. In frictionless markets, there is an arbitrage between the CDS and corresponding bond markets. Therefore, accounting for liquidity effects in bond markets, sovereign CDS should stay within the agency/sovereign credit bounds. However, as mentioned before, there are several effects that can influence CDS pricing substantially, making it a very volatile and potentially disrupted measure of sovereign credit risk. In the case of the default of a large AAA sovereign, in particular, some of the counterparties who sold the credit protection are likely to also be insolvent by this time. This is why sovereign CDS for large AAA sovereigns may include a substantial premium for the counterparty risk. Additionally, as shown for example in Trapp (2009), supply-demand effect in the CDS market may also influence market pricing substantially. For these reasons, the information on sovereign credit risk of Germany and France from CDS markets should be less precise than our bounds for credit risk based on the agency and sovereign bond markets.

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<sup>18</sup> The floating rate of the OIS is based on a specified published index of the daily overnight rate for the OIS currency. At maturity, the parties determine the net payment by calculating the difference between the accrued interest of the fixed rate and the geometric averaging of the floating index rate on the notional swap principal. Because there is no exchange of principal and only the net difference in interest rates is paid at maturity, OIS contracts have little credit risk exposure and are unaffected by the 3- or 6-month credit risk premia which contaminate standard interest swap rates (via the floating Libor-based leg of the swap).

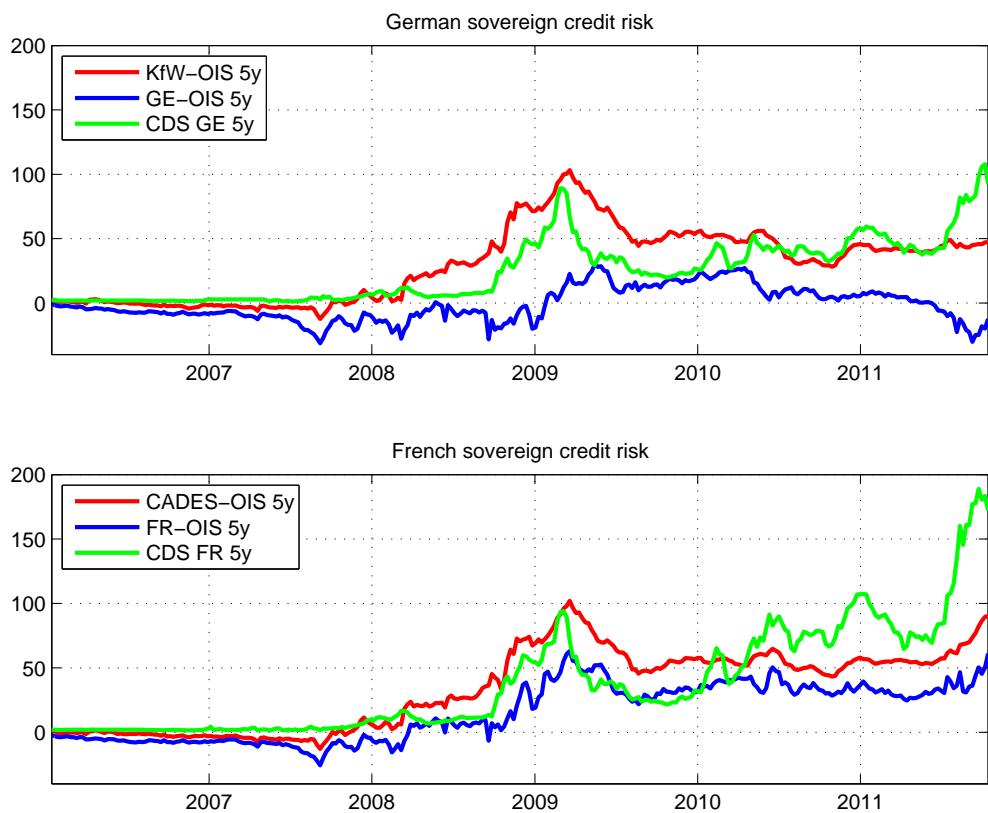


Figure 5: Sovereign credit risk for France and Germany

NOTE: The figure shows the spreads (in basis points) (1) between agency yields and OIS, (2) between sovereign yields and OIS, as well as (3) sovereign CDS premia for Germany and France. All spreads are computed as weekly averages for 5-year maturity. The sample period is 1 January 2006 to 14 October 2011.

Figure 5 shows the results for the 5-year maturity, while Figure A-2 in the appendix shows the additional results for 10-year and 2-year maturities. During the 2008/2009 crisis, the market-implied credit risk premium increased substantially for both sovereign issuers, presumably reflecting the impact of the banking crisis on the public finances (see Ejsing and Lemke (2011) for evidence of the pricing of the risk transfer from the banking sector to the sovereign balance sheet). After stabilising at around 10-50 basis points for Germany and around 30-60 basis points for France in the second half of 2009, sovereign credit risk of these countries remained broadly stable throughout most of the sovereign debt crisis in 2010/2011, until it started to increase for France in the second half of 2011. The CDS premia for both countries tended to stay within the bond market bounds for the sovereign credit risk until the later stage of the sovereign debt crisis, when the CDS pricing of sovereign credit was above the agency market pricing, especially for France. Apart from the above mentioned caveats of sovereign CDS markets, a plausible explanation for misaligning CDS and agency market pricing in 2011 can be the reluctance to offer CDS contracts, e.g. due to balance sheet adjustments and deleveraging conducted by banks. Also, generally increasing risk aversion during this period is reflected in the offered price of CDS contracts on large sovereigns more than in agency yields. Alternatively, one could bring up an argument that the agency market does not reflect the sovereign credit risk correctly, due to, for example, its poor liquidity or small investor base. However, despite the relatively small size of the market as compared to sovereign bonds, agency bonds are very well known and frequently traded products. For example, they are commonly commented upon by investment banks and used as benchmark curves to monitor developments in many markets, e.g. the local covered bond markets. Therefore, a much more plausible explanation of misaligning CDS and agency market pricing is provided by special effects in the CDS market, which make the price for credit protection for large sovereigns higher than the sovereign credit risk as perceived by investors.

## 5 Model-based framework for measuring liquidity and credit premia

In this section we apply a state-space model to extract two latent factors, ‘credit’ and ‘liquidity’, which affect the sovereign and agency spreads. In this model-based approach, we allow for the possibility that agency yields can also be affected by the changes in investor demand for liquid assets or by the pricing of liquidity. To identify credit- and liquidity-related spread components, we impose a restriction that the credit factor should affect sovereign and agency yields identically. This assumption is based on the above mentioned feature of KfW and CADES bonds, namely that the credit risk of a guaranteed agency bond is the same as that of the guaranteeing sovereign.

### 5.1 Model

We follow Reinhart and Sack (2002) in positing that an individual yield,  $y_{i,t}$  can be interpreted as the sum of the risk-free rate, credit and liquidity premia:

$$y_{i,t} = r_f t + CreditPremium_{i,t} + LiquidityPremium_{i,t} + u_{i,t}. \quad (3)$$

We assume that within a given country, credit and liquidity premia for the sovereign and agency issuers are governed by unobservable common factors. These assumptions allow for the formulation of a linear state-space model, which we use to extract latent credit and liquidity factors.

We estimate the model independently for both countries and formulate it in terms of yield spreads over the risk-free rate. Owing to their AAA rating and large market liquidity, both German and French government bonds are likely destinations for safe haven flows. Therefore, we would expect that stress in financial markets would, everything else equal, exert *downward* pressure on the sovereign yields of these countries, i.e. we would expect the liquidity factor in equation (3) to be negative for the sovereign issuers. On the contrary, an increase in the credit risk should lead to an identical increase in sovereign and agency yields, i.e., we expect a positive credit factor.

Our model for long-term yield *spreads* can be summarised in state space representation as follows:

$$Y_t = \begin{bmatrix} 1 & 1 \\ 1 & \psi \end{bmatrix} X_t + \varepsilon_t \quad (4)$$

$$X_{t+1} = \begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix} X_t + \begin{bmatrix} \sigma_1 & 0 \\ 0 & \sigma_2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \rho & \sqrt{1-\rho^2} \end{bmatrix} \nu_t \quad (5)$$

where  $Y_t = (y_{sov,t} - y_{OIS,t}, y_{agency,t} - y_{OIS,t})'$  is a vector of observables including either the German or French 5-year sovereign and agency yield spreads over the 5-year OIS.  $X_t = (x_{c,t}, x_{l,t})'$  is a vector containing the two latent factors governing credit and liquidity premia. For the credit factor, we impose a common loading on the observations normalised to 1. For the liquidity factor, we allow for different loadings for sovereign and agency yields. We normalise the loading of sovereign yields on the liquidity factor to 1. In the second equation, the state equation,  $\nu_t = \begin{bmatrix} \nu_{1,t} \\ \nu_{2,t} \end{bmatrix}$  with  $\nu_{j,t} \stackrel{iid}{\sim} N(0, 1)$  for  $j = 1, 2$  and  $t = 1 \dots T$  generate the innovation terms of the latent processes. The parameters  $\sigma_1, \sigma_2, \rho$  correspond to the standard deviations and correlations of the innovations. In the first equation, the observation equation,  $\varepsilon_t$  are i.i.d. observation errors with diagonal covariance matrix and variances  $\sigma_{\varepsilon_1}^2$  and  $\sigma_{\varepsilon_2}^2$ , i.e., we allow for different variances of the measurement errors but restrict their covariance to zero.<sup>19</sup>

## 5.2 Identification

We have to ensure that the state space representation (4) of the latent liquidity factor and credit factor is actually unique, i.e., that its parameters are identifiable. For fixed observation equation, i.e., known value of parameter  $\psi$ , the model is uniquely defined since then  $X_t$  is a unique mapping of  $Y_t$ . If  $\psi$  is unknown and have to be estimated as in our case, however, the model is only uniquely defined if different values of  $\psi$  lead to a dynamic of  $X_t$  which is not captured by the structure of the state equation (5), i.e., only, if the structure of the state equation determines  $\psi$  for given observations.

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<sup>19</sup> Note that we could also, equivalently, model the yields in levels rather than in spreads, including a third (observed) factor, i.e. the OIS rate. However, the estimation results would be unaffected. It also does not change the results materially when we impose a random walk-restriction on the dynamics of factors ( $\Phi$ ), or when we allow for two variance regimes for their innovations.

In the following, we therefore analyze the structure of the state equation if we change the parameter values of  $\psi$  to  $\psi^*$ . We insert

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & \frac{\psi - \psi^*}{\psi - 1} \\ 0 & \frac{\psi^* - 1}{\psi - 1} \end{bmatrix} \begin{bmatrix} 1 & \frac{\psi^* - \psi}{\psi^* - 1} \\ 0 & \frac{\psi - 1}{\psi^* - 1} \end{bmatrix}$$

into the observation equation and get an observation equation with the same structure but a different value  $\psi^*$  of parameter  $\psi$  and different state variables:

$$\begin{aligned} Y_t &= \begin{bmatrix} 1 & 1 \\ 1 & \psi \end{bmatrix} X_t + \varepsilon_t \\ &= \underbrace{\begin{bmatrix} 1 & 1 \\ 1 & \psi \end{bmatrix}}_{= \begin{bmatrix} 1 & 1 \\ 1 & \psi^* \end{bmatrix}} \underbrace{\begin{bmatrix} 1 & \frac{\psi - \psi^*}{\psi - 1} \\ 0 & \frac{\psi^* - 1}{\psi - 1} \end{bmatrix} \begin{bmatrix} 1 & \frac{\psi^* - \psi}{\psi^* - 1} \\ 0 & \frac{\psi - 1}{\psi^* - 1} \end{bmatrix}}_{:= X_t^*} X_t + \varepsilon_t \\ &= \begin{bmatrix} 1 & 1 \\ 1 & \psi^* \end{bmatrix} X_t^* + \varepsilon_t. \end{aligned}$$

The model is identifiable for unknown  $\psi$  if the dynamics of the resulting process  $X_t^*$  is not captured by the structure of the state equation in model (5) for  $\psi^* \neq \psi$ .

A closer look at the dynamic of  $X_{t+1}^*$  yields

$$\begin{aligned} X_{t+1}^* &= \begin{bmatrix} 1 & \frac{\psi^* - \psi}{\psi^* - 1} \\ 0 & \frac{\psi - 1}{\psi^* - 1} \end{bmatrix} X_{t+1} \\ &= \begin{bmatrix} 1 & \frac{\psi^* - \psi}{\psi^* - 1} \\ 0 & \frac{\psi - 1}{\psi^* - 1} \end{bmatrix} \begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix} \underbrace{\begin{bmatrix} 1 & \frac{\psi - \psi^*}{\psi - 1} \\ 0 & \frac{\psi^* - 1}{\psi - 1} \end{bmatrix} X_t}_{X_t} \\ &\quad + \begin{bmatrix} 1 & \frac{\psi^* - \psi}{\psi^* - 1} \\ 0 & \frac{\psi - 1}{\psi^* - 1} \end{bmatrix} \begin{bmatrix} \sigma_1 & 0 \\ 0 & \sigma_2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \rho & \sqrt{1 - \rho^2} \end{bmatrix} \nu_t \\ &:= \begin{bmatrix} \alpha_1 & (\alpha_1 - \alpha_2) \frac{(\psi - \psi^*)}{\psi - 1} \\ 0 & \alpha_2 \end{bmatrix} X_t^* \\ &\quad + \begin{bmatrix} \sigma_1^* & 0 \\ 0 & \sigma_2^* \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \rho^* & \sqrt{1 - \rho^{*2}} \end{bmatrix} \nu_t \end{aligned}$$

with

$$\begin{aligned} \rho^* &= -\frac{(\psi \sigma_1 \rho - \psi \sigma_1 \psi^* \rho + \sigma_2 \psi^2 - \psi \sigma_2 \psi^* - \sigma_1 \rho + \sigma_1 \psi^* \rho - \sigma_2 \psi + \sigma_2 \psi^*) \dots}{[(\sigma_1^2 - 2 \sigma_1^2 \psi^* + 2 \sigma_1 \psi \sigma_2 \rho - 2 \sigma_1 \psi^* \sigma_2 \rho + \sigma_1^2 \psi^{*2} - 2 \sigma_1 \psi \sigma_2 \rho \psi^* \dots} \\ &\quad \dots + 2 \sigma_1 \psi^{*2} \sigma_2 \rho + \sigma_2^2 \psi^2 - 2 \sigma_2^2 \psi \psi^* + \sigma_2^2 \psi^{*2})(\psi - 1)^2]^{1/2}. \end{aligned}$$

First, consider the structure of the matrix containing the autoregressive parameters  $\alpha_1$  and  $\alpha_2$ . In the dynamics of the latent states  $X^*$ , this matrix is of diagonal form, i.e., of the form of equation (5), only if either  $\alpha_1 = \alpha_2$  or if  $\psi = \psi^*$ . Thus, different values of  $\alpha_1$  and  $\alpha_2$  would ensure identifiability of the model. However, in our case, we cannot ensure different values of  $\alpha_1$  and  $\alpha_2$ , since for both latent processes a random walk ( $\alpha_1 = \alpha_2 = 1$ ) is highly plausible.

Second, consider the correlation  $\rho^*$  of the innovations of process  $X^*$ . Setting  $\psi^* = \psi$  gives  $\rho^* = \rho$ . Since the equation for  $\rho^*$  is transcendental, it is hard to state that no other choices of  $\psi^*$  lead to this result for general values of the other parameters. For the special case of  $\rho = 0$ , however, we get

$$\rho^* = -\frac{\sigma_2 (\psi^2 - \psi \psi^* - \psi + \psi^*)}{\sqrt{(\sigma_1^2 - 2\sigma_1^2\psi^* + \sigma_1^2\psi^{*2} + \sigma_2^2\psi^2 - 2\sigma_2^2\psi\psi^* + \sigma_2^2\psi^{*2})(\psi - 1)^2}},$$

which equals zero only for  $\psi^* = \psi$ . Therefore, for latent states with uncorrelated innovations ( $\rho = 0$ ), our state space model (4) is uniquely defined.

We therefore assume the innovations of the factors to be uncorrelated in the following analysis. From the economic point of view, credit quality and liquidity should not be generally correlated, especially for highly liquid and highly rated markets.<sup>20</sup> Historically, there were several instances of rating downgrades for large and liquid markets, which had hardly any impact on trading and liquidity (for example a downgrade of U.S. sovereign debt by S&P in August 2011). The orthogonality of credit and liquidity factors is commonly used in the previous literature, for example, in Beber, Brandt, and Kavajecz (2009), or in Schwarz (2011). Also empirically the assumption seems realistic. Computing the empirical correlation between the first differences of the KfW-Germany yield spread and CDS spreads for Germany (and the analogous for France) yields values around zero for most subsamples. Hereby, the difference between KfW and German yields is proportional only to the liquidity factor. Assuming that the changes in CDS are proportional to the changes of our credit factor, the correlation should be a rough proxy of the correlation between the factor innovations in our framework.

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<sup>20</sup> An exception can rather regard the markets of issuers of rather poor quality, closer to a default event.

### 5.3 Estimation results

We estimate the model by maximum likelihood using a standard linear Kalman filter applied to weekly averages of yield spreads. To assess the precision of the estimated parameters, asymptotic variances based on numerical approximation of the Hessian at the solution are calculated. Since our sample size  $T = 301$  is of moderate size given the model, it is unsure whether these asymptotical results are representative for the finite sample variances. We therefore conduct a nonparametric bootstrap procedure to estimate the finite sample variances directly. The applicability of the procedure used in the state space context has been shown by Stoffer and Wall (1991).

Let, for convenience,  $\hat{\theta}$  be the vector of all estimated parameters. The bootstrap procedure applied consists of four steps. [1.] By running the Kalman filter with parameter vector  $\hat{\theta}$ , we get estimates of the realizations of the normalized innovation,  $(\hat{\nu}_t)_{t=1\dots T}$ . [2.] We then sample with replacement  $T$  times from  $\{\nu_t, t = 5 \dots T\}$  to obtain  $\{\nu_t^*, t = 5 \dots T\}$ , a bootstrap sample of innovations. We start at  $t = 5$  because Stoffer and Wall (1991) recommend to preserve the first innovations due to the transient behavior of the Kalman filter during the first steps. [3.] Using the state space model (4), the parameter vector  $\hat{\theta}$  and the bootstrap sample of innovations, a bootstrap data set  $\{Y_t^*, t = 1 \dots T\}$  is calculated by recursively applying the model. [4.] Steps [2.] and [3.] are repeated for  $b = 1 \dots B$  times. In each step we estimate the model parameters denoted by  $\hat{\theta}^{*b}$  based on bootstrap data set  $b$ . The bootstrap estimator for the variance of the initial estimates  $\hat{\theta}$  is the variance of  $B$  bootstrap estimates  $\hat{\theta}^{*b}$ .

Table 1 presents the estimation results.<sup>21</sup> For convenience we suppress the results regarding the observations errors. Their standard deviations are estimated to be about  $\exp(-20)$  and this negligible small. As was to be expected, the bootstrap estimates of

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<sup>21</sup> In our baseline model (the results reported), we use constant variances  $\sigma_{\nu_1}^2$  and  $\sigma_{\nu_2}^2$  of factor innovations. However, to account for the fact that the innovations of factors driving the yields is most likely not constant throughout our sample, we introduced an additional variance regime, specifying a ‘financial crisis period’. This regime is dated from 19 Sep 2008 (the first Friday after the collapse of Lehman Brothers) to 10 Jul 2009 (the last Friday before the implied volatility of the euro area bond market returned to the pre-Lehman level). Since the introduction of two variance regimes does not change our results materially, we present here only the more parsimonious constant-variance version of the model.

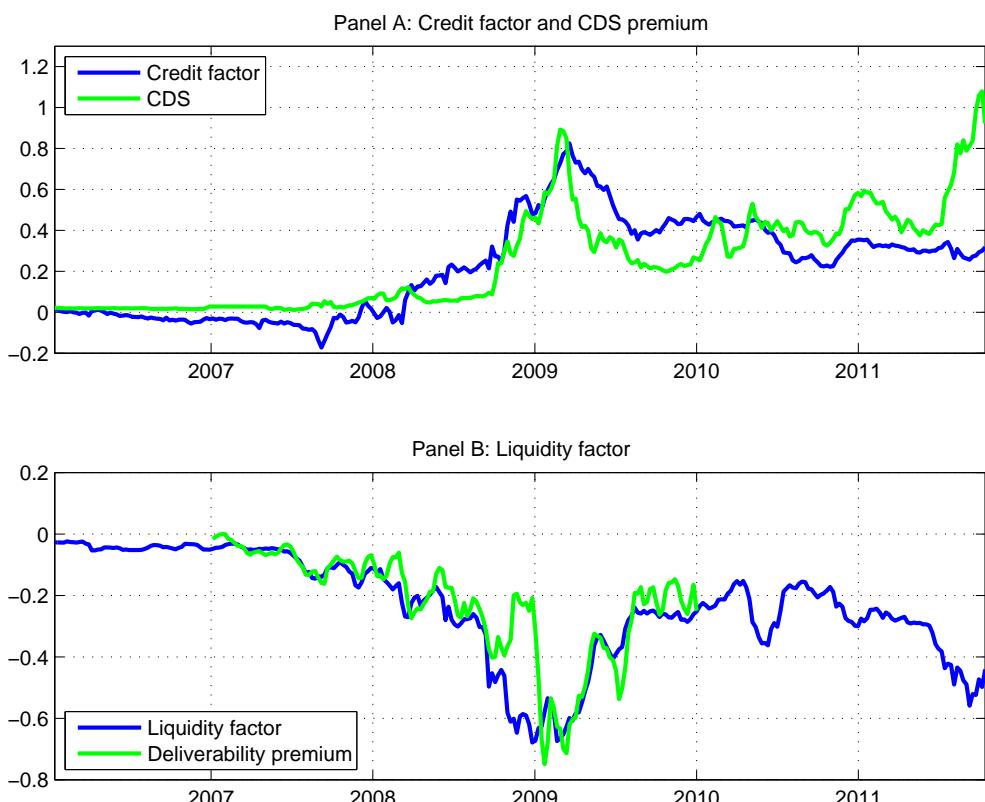
the standard deviations lie above the asymptotic standard deviations. The loading of the agency yield on the liquidity factor is in all cases negative, and rather small in absolute terms. In particular, the loading of agency yields on the liquidity factor,  $\psi$ , is estimated to -0.35 and -0.19 for German 5-year and 10-year yields, and -0.15 and -0.08 for corresponding French yields. This compares with the normalised value of 1.00 for the sovereign yields. Taking the estimated standard deviations in account, at least the values regarding Germany are satisfactorily different from zero. This suggests that at least for Germany the liquidity premium in agency yields accounts for up to 30% of the whole agency-government spread. In this respect the model-based approach allows for a more precise quantification of liquidity effects on the sovereign yield curve, as compared to the model-free measure discussed in Section 4.1. The dynamics of both measures is, however, the same.<sup>22</sup>

Two latent factors obtained from the estimation using 5-year yield spreads are shown in Figures 6 and 7. The results for the 10-year maturity are shown in the appendix (Figures A-3 and A-4). The estimated parameters of our model are reported in table 1. In late 2008/early 2009, the credit risk of Germany and France increased substantially (upper panels) as the result of the banking crisis and its impact on public finances. At the same time, however, German (and to a smaller extent French) yields were subject to a substantial downward pressure (lower panels) due to the increased demand of highly liquid and highly rated assets, the so-called safe haven flows. While this downward pressure abated from mid-2009 onwards before spiking again in the spring of 2010 and further during the second half of 2011, perceived credit risk varied less after mid-2009 and remained quite elevated throughout. For France, credit risk component started to increase further with the intensification of the sovereign debt crisis in late 2011.

The estimated latent factors can be compared with exogenous proxies for credit quality and liquidity premia of government bonds. We compare our credit factors with the German and French sovereign CDS premia for the same maturity. For the liquidity

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<sup>22</sup> As a heuristic robustness check for the identification of the system, we report in Figure A-5 in the Appendix the log likelihood values of models computed for varying values of the loading of agency yields on the liquidity factor ( $\psi$ ), keeping all other parameters constant.



**Figure 6: Estimated factors vis-à-vis credit and liquidity proxies, Germany 5y**  
 NOTE: The figure shows model-implied credit and liquidity factors for Germany (blue lines) for the 5-year maturity plotted against the CDS and the deliverability premia (green lines).

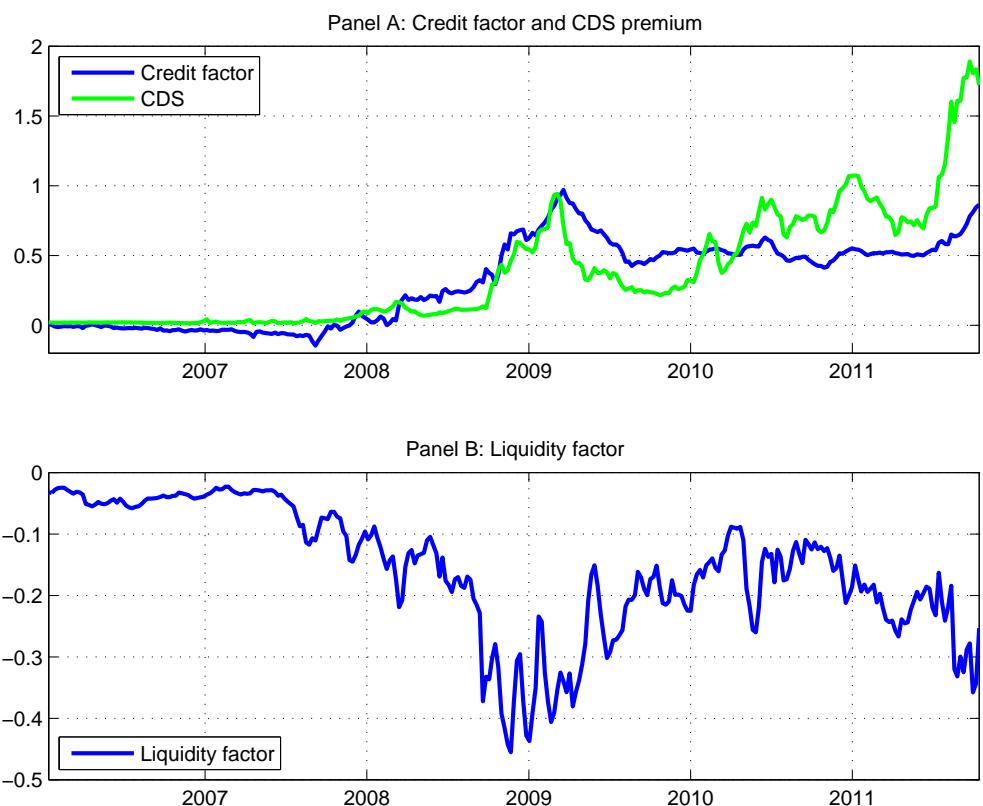


Figure 7: Estimated factors vis-à-vis credit and liquidity proxies, France 5y  
 NOTE: The figure shows model-implied credit and liquidity factors for France (blue lines) for the 5-year maturity.  
 The credit factor is plotted against the French sovereign CDS premium (green line).

Country	Mat.		Param.	As. Std.	Bts. Std.	p-As.	p-Bts.
Germany	5y	$\alpha_1$	1.00	.0044	.0116	.00	.00
		$\alpha_2$	1.00	.0050	.0101	.00	.00
		$\log(\sigma_1)$	-7.44	.0816	.1751	.00	.00
		$\log(\sigma_2)$	-7.39	.1398	.3154	.00	.00
		$\psi$	-0.35	.0762	.1830	.00	.06
	10y	$\alpha_1$	1.00	.0030	.0098	.00	.00
		$\alpha_2$	1.00	.0054	.0090	.00	.00
		$\log(\sigma_1)$	-7.37	.0822	.1341	.00	.00
		$\log(\sigma_2)$	-6.91	.1255	.1873	.00	.00
		$\psi$	-0.19	.0555	.0853	.00	.03
France	5y	$\alpha_1$	1.00	.0034	.0099	.00	.00
		$\alpha_2$	.99	.0084	.0110	.00	.00
		$\log(\sigma_1)$	-7.34	.0816	.1593	.00	.00
		$\log(\sigma_2)$	-7.20	.1347	.2564	.00	.00
		$\psi$	-0.15	.0614	.0978	.02	.13
	10y	$\alpha_1$	1.00	.0026	.0087	.00	.00
		$\alpha_2$	.99	.0100	.0114	.00	.00
		$\log(\sigma_1)$	-7.30	.0825	.1386	.00	.00
		$\log(\sigma_2)$	-6.82	.1257	.2212	.00	.00
		$\psi$	-0.08	.0500	.0849	.11	.35

Table 1: Estimated parameters of the state space model and their significance

NOTE: The columns refer to the estimated values of the parameters (“Param.”) as well as to the asymptotic standard deviations and standard deviations estimated by nonparametric bootstrap (“As. Std.” and “Bts. Std.”, respectively). The last two columns refer to the p-values for a two-sided test against zero based on the respective estimate of the standard deviation.

factor, we use a measure based on the results in Ejsing and Sihvonen (2009), who show that due to the existence of highly liquid bond futures markets, bonds in certain maturity buckets benefit from an additional liquidity premium due to their eligibility to be delivered for futures contracts. This measure can only be applied to the German market and is available only for a portion of our sample period.<sup>23</sup> Figures 6a and 7a show that the latent credit factors are indeed closely related to the CDS premium. In fact, the 2008/2009 crisis peak level of the estimated credit premium equals that of the CDS premium. However, as discussed in Section 4, during the sovereign debt crisis, CDS

<sup>23</sup> Ejsing and Sihvonen (2009) examine liquidity and bond pricing in the German government market and find that the existence of the highly liquid German futures market leads to significant liquidity spill-overs into the German cash market. Specifically, they find that bonds which are deliverable into the futures contracts are trading more liquidly and are commanding a price premium. Inspired by these findings, we use the daily yield spread between the estimated 10-year German sovereign yield and the average yield of the bonds included in the delivery basket for the 10-year Bund future contract as an alternative measure of the liquidity premium.

markets tend to price higher credit risk than suggested by our credit factors. Turning to the liquidity factor, Figure 6b shows that the dynamics of the deliverability spread (Ejsing and Sihvonen (2009)) is very similar to our model-based estimates.

## 6 Conclusion

We disentangle credit and liquidity premia in German and French sovereign bond yields during the financial crisis of 2008/2009 and the subsequent sovereign debt crisis of 2010/2011. In contrast to most existing studies on intra-euro area yield spreads, we rely neither on liquidity proxies (such as transaction-based measures of liquidity) nor on credit proxies (such as CDS premia or fiscal projections) to decompose yields. Instead, we control directly for credit risk by using government-guaranteed agency bond yields across their estimated term structures. To control for the changes in the risk-free rate, we use long-term OIS rates.

Our results show that since the onset of the financial crisis in 2007, the market-implied credit risk premium has increased substantially for both analysed sovereign issuers. This increase in sovereign credit risk has been partly disguised by the strong decline in expected future monetary policy rates as well as by the significant downward pressure on the core-country yields resulting from repeated safe haven flows. While the market perception of higher sovereign credit risk pushed up German and French sovereign yields to a broadly similar extent (of around 40-50 basis points) - until the second half of 2011, the downward pressures on yields due to the changes in the liquidity premia were much more pronounced for Germany. In the second half of 2011, the differences between France and Germany in terms of credit premia increased, yet not nearly as much as suggested by the CDS market pricing.

Our measures of sovereign credit risk for the two largest euro area countries are far less volatile and less subject to temporary over- and undershooting effects as the CDS premia. Our alternative gauge of sovereign credit risk is very valuable in the light of considerable scepticism about the reliability of sovereign CDS premia for large countries,

where counterparty risks in case of sovereign default could become substantial. Furthermore, the current regulatory headwinds faced by the sovereign CDS market additionally increase the usefulness of an alternative measure of sovereign credit risk.

Regarding our measures of liquidity premia in sovereign bonds yields, the analysis suggests that yield spreads between government-guaranteed agency bonds and government bonds can be used as a reliable and very informative real-time indicator. In contrast to the trading-based measures of liquidity, it is (i) easy to compute and (ii) easy to interpret in terms of a direct price impact across the term structure. Moreover, timely high-quality transaction-based liquidity measures are not publicly available for the euro area markets and if based on electronic trading platform, are prone to the changes of trading behavior of investors, like e.g. shifts to the OTC markets during the crisis. Therefore, our estimated term structures of liquidity premia constitute a step forward in the monitoring of liquidity effects in the two large euro area sovereign debt markets. Time series of our estimates are available upon request.

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## Appendix

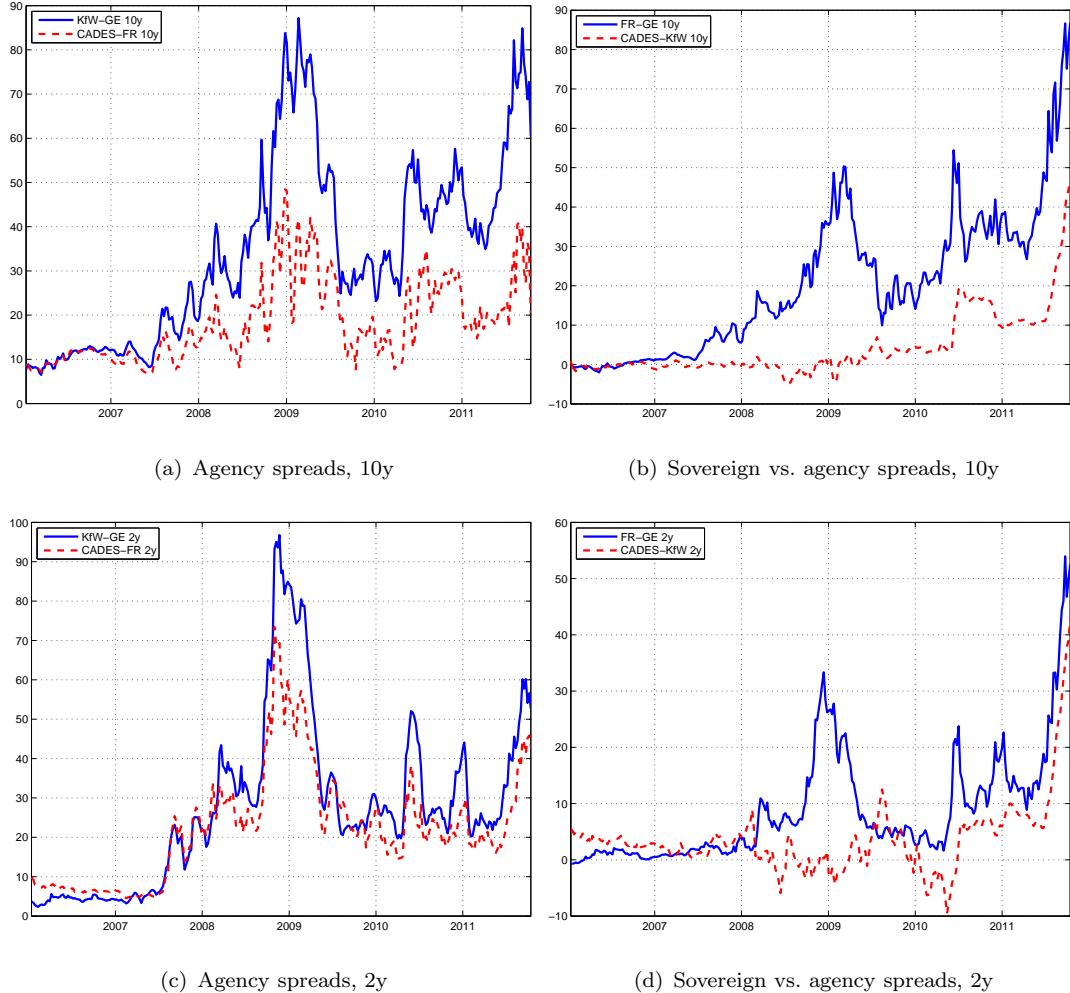
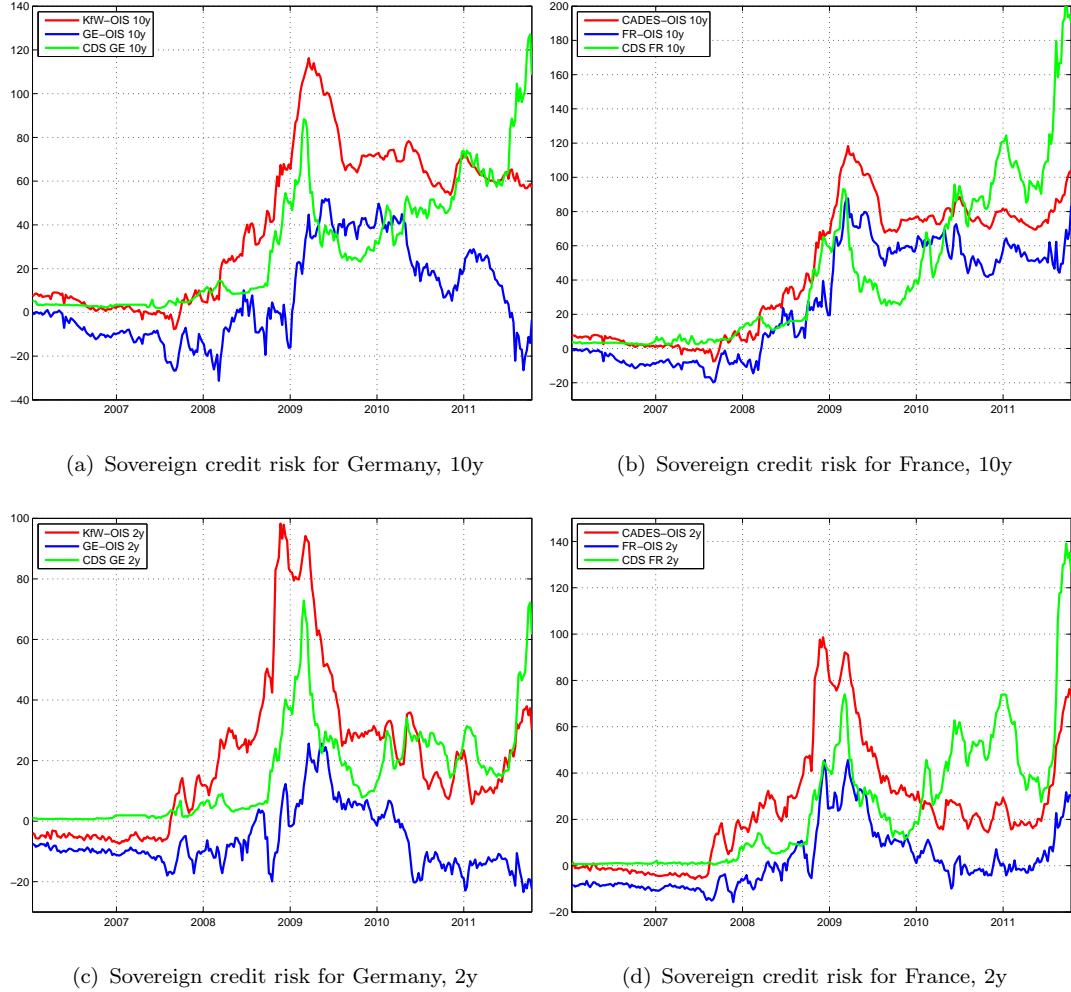


Figure A-1: Agency and sovereign spreads for Germany and France, 10- and 2-year maturities

NOTE: The figures labeled "Agency spreads" show the spreads (in basis points) between agency and sovereign bonds for Germany and France (labeled KfW-GE and CADES-FR, respectively). The figures labeled "Sovereign vs. agency spreads" show the spreads (in basis points) between French and German sovereign bonds as well as the spreads between French and German agency bonds (labeled CADES for the French agency and KfW for the German agency). The spreads are computed for the 10-year maturity (subfigures (a) and (b)) and 2-year maturity (subfigures (c) and (d)). Weekly averages are reported. The sample period is 1 January 2006 to 14 October 2011.



**Figure A-2: Sovereign credit risk for France and Germany, 10- and 2-year maturities**  
 NOTE: The figures show the spreads (in basis points) (1) between agency yields and OIS, (2) between sovereign yields and OIS, as well as (3) sovereign CDS premia for Germany (subfigures (a) and (c)) and France (subfigures (b) and (d)). The spreads are computed for the 10-year maturity (subfigures (a) and (b)) and 2-year maturity (subfigures (c) and (d)). Weekly averages are reported. The sample period is 1 January 2006 to 14 October 2011.

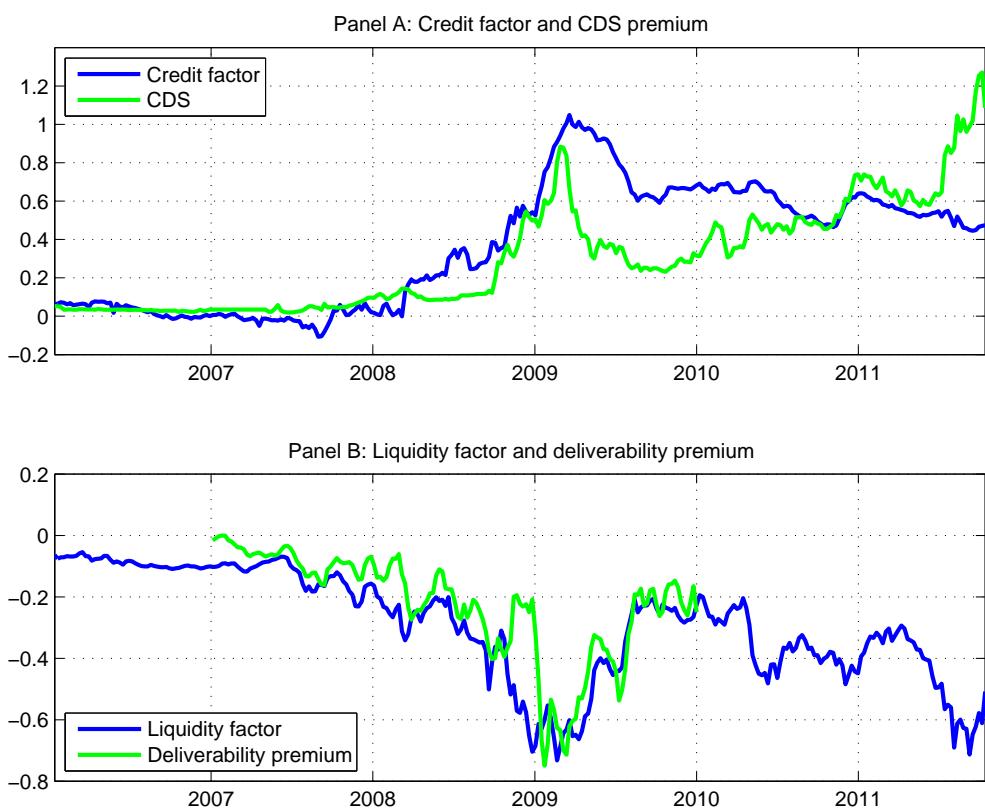


Figure A-3: Estimated factors vis-à-vis credit and liquidity proxies, Germany 10-year maturity

NOTE: The figure shows model-implied credit and liquidity factors for Germany (blue lines) for the 10-year maturity plotted against the CDS and the deliverability premia (green lines).

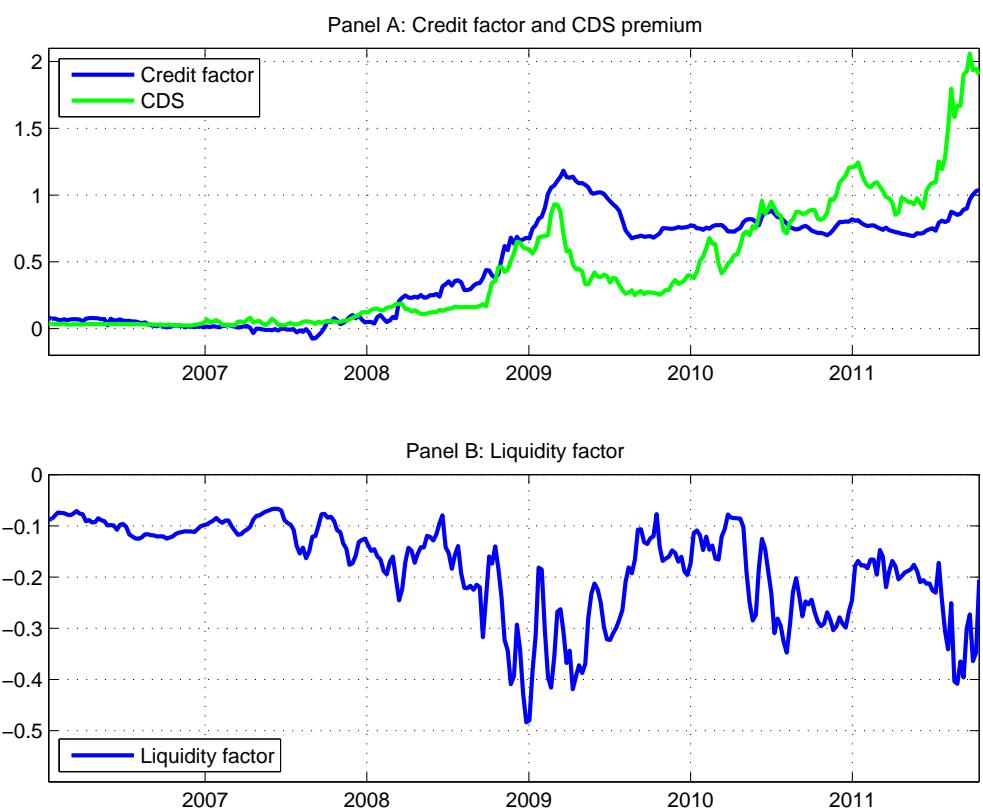


Figure A-4: Estimated factors vis-à-vis credit and liquidity proxies, France 10-year maturity

NOTE: The figure shows model-implied credit and liquidity factors for France (blue lines) for the 10-year maturity. The credit factor is plotted against the French sovereign CDS premium (green line).

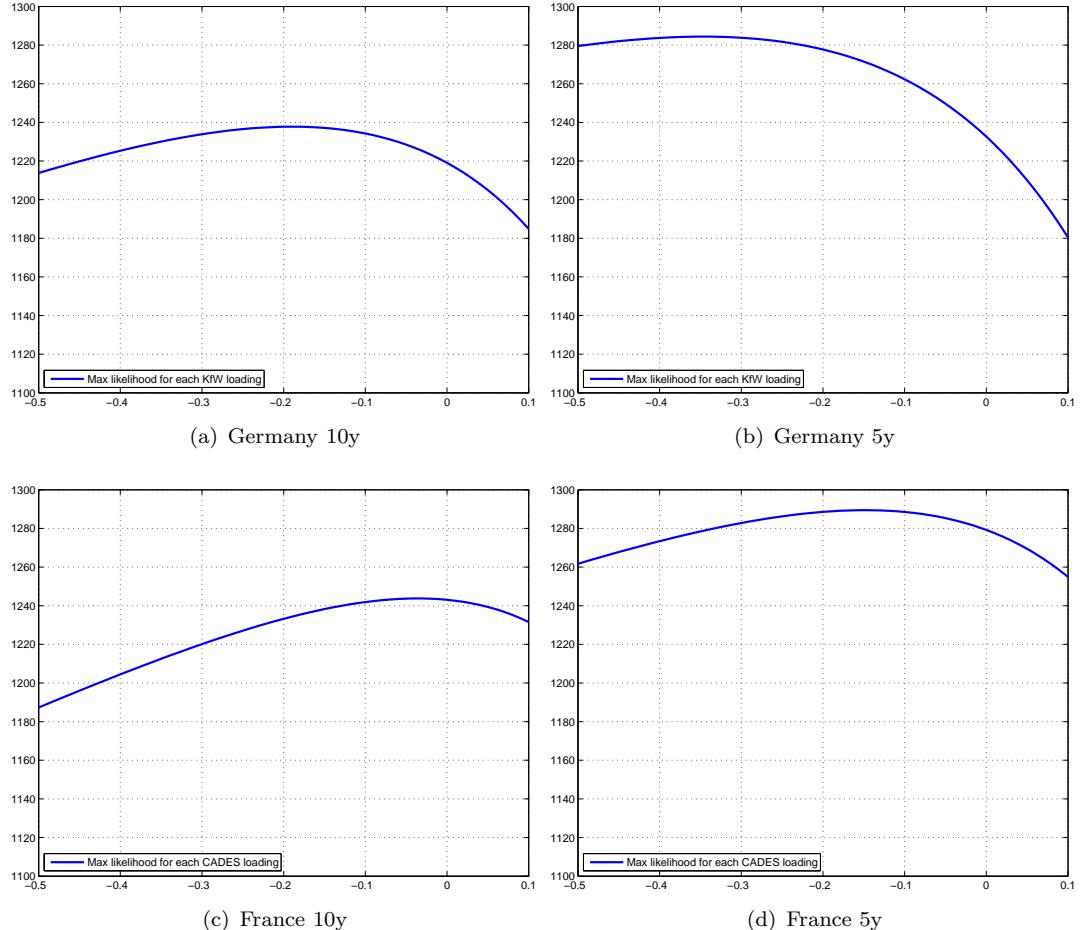


Figure A-5: Log-likelihood for different values of  $\psi$

NOTE: The figure shows the log likelihood computed for different values of loading of the agency yields on the liquidity factor,  $\psi$  in the estimations for (i) 10-year German yields, (ii) 5-year German yields, (iii) 10-year French yields, and (iv) 5-year French yields. All other parameters are kept constant at the optimal values estimated by the model.  $\psi$  is varied in the interval (-1.5, 1.5). The maximum is achieved for the values corresponding to the optimal parameter vector obtained by the estimation.