ARTICLES

EURO AREA RISK-FREE INTEREST RATES: MEASUREMENT ISSUES, RECENT DEVELOPMENTS AND RELEVANCE TO MONETARY POLICY

This article discusses the concept of the risk-free rate, as well as its relevance to the economy in general and to monetary policy in particular. It presents the challenges involved in measuring euro area risk-free rates, both conceptually and quantitatively. The article argues that these challenges have been exacerbated since the start of the global financial crisis, as different measures of risk-free rates have tended to diverge more than in the past, and it offers explanations as to why these discrepancies have arisen. Finally, the article shows how interest rates derived from overnight index swap (OIS) contracts can be a useful complement to AAA-rated bond yields when reporting on euro area risk-free rates.

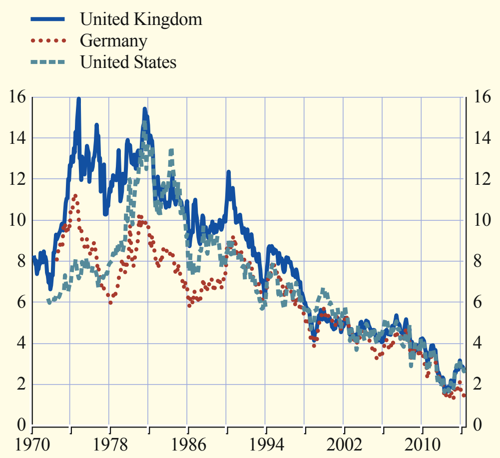
1 INTRODUCTION

The concept of the "risk-free interest rate" – namely the return on an ideal, perfectly liquid bond carrying no credit risk – plays an important role in financial markets and for monetary policy analysis. Risk-free rates most notably serve as a key benchmark for pricing other, risky assets. In particular, measures of the risk-free rate are used as a discount rate to calculate the present value of investment projects or the value of future financial payments. Risk-free yields are also important for monetary policy-makers both because the pass-through of policy rates across the risk-free term structure is a key part of the monetary policy transmission mechanism and because risk-free interest rates can provide information about market expectations of key economic variables, including the evolution of the key ECB interest rates.

The theoretical notion of the risk-free rate is typically measured by the yield on high-rated sovereign bonds. Using this measure, over the last three to four decades there has been a trend decline in risk-free yields across major industrialised economies, and long-term yields have reached historically low levels over the last couple of years (see Chart 1). Part of this decline undoubtedly reflects a stabilisation in inflation expectations and a compression of inflation risk premia,[1] but over the recent period other factors have also been at work.[2] After the start of the global financial crisis in late 2008, the increased demand for liquid and risk-free assets probably spurred the further decline in yields on assets that are considered close to risk-free. Additionally, more structural factors like strong demand from "real money investors" (comprising institutions such as pension funds and insurance companies) – in the context of an ageing society and regulatory and accounting changes – have also continued to exert downward pressure on yields. On the supply side, in recent years there has also been a decline in the size of some categories of risk-free asset.

Chart 1 A longer-term perspective on ten-year government bond yields

(percentages per annum)



Sources: Deutsche Bundesbank, Bank of England and Federal Reserve Board.

1 Long-term nominal bond yields can be understood as long-term real yields, average long-term inflation expectations over the maturity of the bond and inflation risk premia, i.e. a generalisation of the Fisher equation.

2 For a discussion of some of the driving forces of long-term bond yields, see P. Turner, "Is the long-term interest rate a policy victim, a policy variable or a policy lodestar?", in J.S. Chadha, A.C.J. Durré, M.A.S. Joyce and L. Sarno (eds.), *Developments in Macro-Finance Yield Curve Modelling*, Cambridge University Press, 2014.

For instance, certain high-rated securitisation instruments have disappeared and the volume of AAA-rated sovereign debt has shrunk owing to a deterioration in the creditworthiness (and credit rating) of several sovereign issuers. Moreover, in some jurisdictions, large-scale purchases of high-rated fixed income securities by central banks have contributed further to the decline in the supply of risk-free assets available to private sector investors and hence to the reduction in yields.

In Chart 1, German bond yields have been used to represent euro area risk-free rates over a long period, including the time before and after the introduction of the euro. For the period back to September 2004, the ECB publishes a yield curve (i.e. interest rates at various maturities) based on AAA-rated euro area government bonds and this could, in principle, be seen as a good proxy for the risk-free yield curve of the currency area. However, during the financial crisis the pool of AAA-rated issuers shrank and the yields of issuers remaining in the pool sometimes diverged, affected to varying degrees by credit risk premia, liquidity premia and other factors. This has reduced the representativeness of the AAA yield curve as a risk-free curve for the euro area as a whole.

Against this background, this article considers in detail the recent challenges involved in measuring risk-free rates for the euro area. As well as highlighting some of the reasons for the divergence across various common measures of risk-free rates during the financial crisis, the article also suggests that interest rates derived from OIS can provide a useful complement to AAA-rated yields in reporting on risk-free rates.

The article is structured as follows. Section 2 explains the concept of the risk-free rate, as well as its relevance to the economy in general and to monetary policy in particular. Section 3 then discusses the challenges involved in measuring the euro area risk-free rates, both conceptually and quantitatively. Section 4 describes developments in euro area risk-free rates during the crisis and highlights the differences that have emerged between yields based on AAA-rated government bonds and OIS contracts. Finally, Section 5 concludes.

2 RISK-FREE RATES: CONCEPT AND RELEVANCE TO MONETARY POLICY

The notions of a "risk-free asset" and a "risk-free rate of return" play a central role in economic analysis and are frequently referred to by financial market commentators. At an abstract level, a risk-free asset can be defined as a security that pays a specified unit of account at a certain date in the future in any possible state of the world. A specific example could be a zero coupon bond that pays out €100 in three years' time with absolute certainty.[3] The price at which this bond is purchased today determines its return, which is then referred to as the "three-year risk-free rate". In this example, the certainty of getting €100 at maturity is equivalent to saying that the issuer of the bond will honour its obligations in all states of the world. Accordingly, the risk-free property of the bond can be characterised as the absence of default or credit risk.

In practice, the assumption of absolute certainty regarding a bond's promised payoff seems unrealistic. While there have always been sound public and corporate bond issuers that have never defaulted on their debt, for any newly issued bond there is always some residual uncertainty as to whether default can be completely ruled out over the time until the bond matures. Hence, investors and commentators usually seem to employ some relative notion of safety when referring

3 A zero coupon bond pays the so-called principal amount at maturity but no coupons before; it is also called a pure discount bond, as discussed in Box 1.

to a risk-free rate. One common practice is to rely simply on the label awarded by credit rating agencies to judge a bond's riskiness, so that a AAA rating would constitute the dividing line separating (approximately) risk-free assets from their riskier counterparts. However, it must be borne in mind that a rating is usually a relative (rather than an absolute) statement of credit risk. Thus, broadly speaking, a higher-rated bond would be expected to default less often than its lower rated counterpart, although the actual expected default frequency of each rating category may well change over time and across the business cycle.[4]

Besides default or credit risk, however, there are several other sources of risk that are of relevance to the price or return of an asset. A bond can, for instance, be subject to liquidity risk, when investors face the possibility of future adverse market conditions if selling the bond before maturity. This risk of deteriorating liquidity would lead to a lower bond price (and a higher yield) on account of liquidity premia. Conversely, for bonds that exhibit particularly high standards in terms of safety and liquidity, investors will, in general, be willing to pay a higher price (i.e. accept a lower yield), especially if these bonds are more readily accepted as collateral in financial transactions. The negative liquidity premium on these bonds would rise in absolute terms were the pool of high-quality bonds to shrink, as this would lead to an increase in the relative scarcity of such much-prized assets (a "scarcity premium"). A nominal bond is also typically subject to inflation risk. Taking the example used above, the assumed absence of credit risk implies that the bond pays back €100 after three years, which makes it risk-free "in nominal terms". However, it is not risk-free "in real terms" because how much of a (euro area) consumption basket the bond's payoff could buy in three years will still be uncertain.[5]

Notwithstanding these further facets of the concept of risk-freeness, the remainder of this article will consider "risk-free" assets as those that have a very low perceived credit risk and – relatedly – carry the highest rating.

The risk-free rate has important functions in financial markets and in the economy more generally. Most importantly, estimates of risk-free rates serve as a benchmark in the pricing of other assets. To take the simplest example, risk-free rates over various terms to maturity (the term structure of interest rates – see Box 1) are required to compute the net present value of a sequence of future risk-free financial payments. The benchmark function also subsumes a communication and coordination aspect, as risk-free yields often serve as a yardstick for the comparison of risky assets – the common practice of quoting euro area sovereign bond yields as spreads vis-à-vis their German counterpart or a swap rate is a case in point.[6]

For monetary policy, the term structure of risk-free yields is important for at least two reasons: (i) it is an important element in the transmission of monetary policy and (ii) it contains useful information about market expectations of key economic variables.

4 The IMF's April 2012 Global Financial Stability Report states that a AAA rating in 2007 was associated, on average, with a default probability (as derived from credit default swap spreads) of about 0.1%, but this figure had increased more than ten-fold to about 1.3% in 2011. One major caveat is that credit default swap spreads typically also incorporate risk premia that go beyond pure compensation for expected losses, so that part of the reported increase in spreads might be attributable to the rise in these premia.

5 "Exchange rate risk" is another aspect underlining the fact that the risk-free property is linked to a specific unit of account. For instance, for investors wishing to receive their payoffs in US dollars, the payoff of €100 is certain (by assumption) but the EUR/USD exchange rate prevailing in three years' time is not, and hence the dollar payoff is risky. Finally, if sold before maturity, the three-year bond in this example is subject to "interest rate risk". For instance, if the investor sells the bond after one year, the price that he receives will depend on the two-year interest rate prevailing at that time, which is uncertain today.

6 See, for example, the article entitled "The determinants of euro area sovereign bond yield spreads during the crisis", *Monthly Bulletin*, ECB, May 2014.

Regarding the role of risk-free rates in monetary policy transmission, the first step in this process normally consists of steering very short-term interbank interest rates by means of monetary policy instruments. Moreover, through its monetary policy strategy and communications, the central bank also affects expectations of how it will steer short-term risk-free rates in the future.[7] Current and expected future short-term risk-free rates are, in turn, a major determinant of the whole term structure of short and longer-term risk-free interest rates. This term structure of risk-free interest rates is therefore a key input into the pricing of other assets that are relevant to the financing conditions of households and corporations, their consumption, production and investment decisions and, finally, price-setting and inflation. For instance, for a given default risk and credit spread of a corporate issuer, a decrease in the risk-free rate of relevant maturity would reduce the firm's market financing costs, improving its ability to finance production and investment, and so on. The term structure of risk-free rates can therefore be seen as the backbone of the wider transmission of the monetary policy stance to a broader range of asset prices and, ultimately, the real economy.

Concerning the information function, the yield curve is a useful tool for the central bank to extract market participants' expectations of future levels of interest rates, inflation and real activity. One example in this respect is the calculation of market-based inflation expectations and inflation risk premia at various horizons from the difference between the term structure of nominal and inflation-linked bond yields.[8] Another example is the inference of market expectations of future monetary policy. This is possible because, as mentioned above, long-term rates reflect expectations of future short-term rates, which in turn reflect expectations of the central bank's key policy rates and its use of other monetary policy instruments. However, besides future rate expectations, longer maturity yields typically contain term premia of unknown and possibly time-varying extent, so that the extraction of interest rate expectations from the yield curve poses some analytical challenges.[9]

7 See, for example, the article entitled "The ECB's forward guidance", *Monthly Bulletin*, ECB, April 2014.

8 See, for example, P. Hördahl and O. Tristani, "Inflation Risk Premia In The Term Structure Of Interest Rates", *Journal of the European Economic Association*, Vol. 10(3), pp. 634-657, 2012; and J.A. Garcia and T. Werner, "Inflation compensation and inflation risk premia in the euro area term structure of interest rates", in J.S. Chadha, A.C.J. Durré, M.A.S. Joyce and L. Sarno (eds.), *Developments in Macro-Finance Yield Curve Modelling*, Cambridge University Press, 2014.

9 For a review of the literature analysing the term structure of interest rates, see, for example, R.S. Gurkaynak and J. Wright, "Macroeconomics and the Term Structure", *Journal of Economic Literature*, Vol. L (June 2012), pp. 331-367, 2012.

Box 1

BOND YIELDS: BASIC CONCEPTS AND ESTIMATION OF A ZERO COUPON YIELD CURVE

A coupon bond is a security that entitles the holder to a pre-specified stream of (coupon) payments over its life (maturity) and, at its maturity date, a final coupon payment and the bond's redemption value (the principal). A zero coupon (or pure discount) bond is the simplest type of fixed income security, providing a single payoff at maturity, i.e. no coupons are paid out beforehand. A coupon bond can therefore be thought of as a collection of zero coupon bonds.

The yield to maturity is defined as the yield that equates the present value of the bond's cash flows with its price. For a bond with a maturity of m years that pays out coupons of C each year over m years and has a final principal payment of X, the yield to maturity (y_m) therefore solves the following equation:

$$P_m = C/(1 + y_m) + C/(1 + y_m)^2 + ... + (C + X)/(1 + y_m)^m \quad (1)$$

where P_m is the bond's price and the right-hand side of the expression represents the present value of the bond's cash flows discounted by the yield to maturity.

In this article, the spot rate for a given maturity, m, is defined as the current yield to maturity on a zero coupon bond with maturity m. By contrast, an m-year implied forward rate h years ahead is defined as the m-year spot rate prevailing from year h to year h+m that can be obtained today [1]. Such a forward rate can be derived from prevailing spot rates and vice versa. For example, if S_2 denotes the two-year spot rate and F_1 denotes the one-year forward rate one year ahead (i.e. the one-year spot rate prevailing in one year that can be obtained today), then:

$$(1 + S_2)^2 = (1 + S_1)(1 + F_1) \qquad (2)$$

The yield curve or term structure of interest rates is defined as the relationship between maturity and the corresponding spot rate (zero coupon yield). The forward curve is the relationship between the future horizon h and the corresponding m-period forward rate h periods ahead.

Finally, for a given time to maturity m, and a given term structure of interest rates, the par yield of an m-year bond is the hypothetical fixed coupon rate that would make the bond's price equal its face value (e.g. €100), i.e. make it priced "at par".

As there are very few (sometimes no) zero coupon bonds traded at longer maturities, the term structure of zero coupon rates is not readily available from market data. It has therefore to be estimated based on a set of several coupon-bearing bonds using mathematical techniques. The underlying idea is that the price of each coupon-bearing bond can be understood as the sum of all coupon (and redemption) payments, discounted by the respective zero coupon yield, i.e. the respective point on the term structure of zero coupon rates.

The ECB regularly constructs and publishes two zero coupon yield curves for euro area government bonds (all bonds and AAA-rated bonds). In a first step, those bonds which are sufficiently liquid to enter the curve estimation are identified. The ECB selects bonds with a minimum trading volume of €1 million per day and a maximum bid-ask spread of 3 basis points.

The zero coupon yield curve is assumed to have a specific functional form called the Nelson-Siegel-Svensson model.[2] The estimation of the curve is done by means of an algorithm that minimises the sum (over all selected bonds) of the quadratic differences between the observed bond prices and those implied by the fitted zero coupon curve.

1 In some cases the forward rate on an instrument may be traded directly, but it will still be related to the term structure of spot rates through the process of arbitrage. This is because the payoff structure of such a forward contract can, in principle, be replicated by trading between bonds of different maturities.

2 The Nelson-Siegel-Svensson model's functional form for the zero coupon rate z(TTM) is:

$$z(TTM) = \beta_0 + \beta_1 \left[\frac{1-e^{\left(\frac{-TTM}{\tau_1}\right)}}{TTM/\tau_1}\right] + \beta_2 \left[\frac{1-e^{\left(\frac{-TTM}{\tau_1}\right)}}{TTM/\tau_1} - e^{\left(\frac{-TTM}{\tau_1}\right)}\right] + \beta_3 \left[\frac{1-e^{\left(\frac{-TTM}{\tau_2}\right)}}{TTM/\tau_2} - e^{\left(\frac{-TTM}{\tau_2}\right)}\right]$$

where TTM is the term to maturity and β_i, τ_i are the parameters to be estimated. See L.E.O. Svensson, "Estimating and Interpreting Forward Interest Rates: Sweden 1992-1994", NBER Working Paper No 4871, 1994.

As a final step, the term structure of forward rates can be derived mathematically using the model's functional form and the estimated parameters.[3]

3 The concepts described in this box are explained in more detail in many finance textbooks. See, for example, J.Y. Campbell, A.W. Lo and A.C. MacKinley, *The Econometrics of Financial Markets*, Chapter 10, Princeton University Press, 1997.

3 MEASURES OF THE EURO AREA RISK-FREE YIELD CURVE

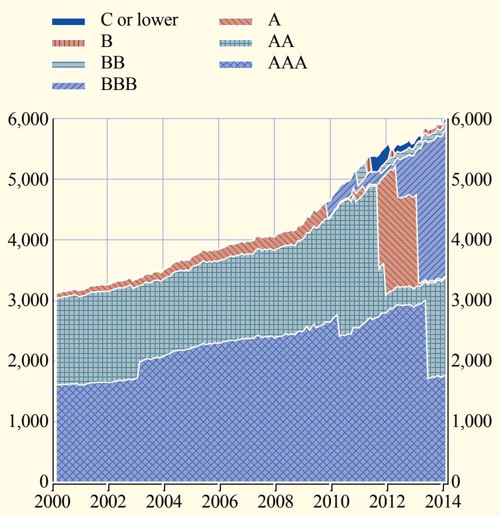
The ECB publishes daily estimates of two euro area yield curves, both derived from government bonds.[10] One yield curve is based on bonds issued by all euro area central governments. This yield curve provides a broad representation of the euro area but is not considered a good proxy for risk-free rates owing to fundamental differences between the countries, as also reflected in rating differences. The other yield curve is based on central government bonds given a AAA rating by Fitch Ratings.

The fact that the AAA curve is linked to the rating provided by a credit rating agency poses two challenges when the curve is used as a candidate measure for the term structure of risk-free rates. First, while market participants required a similar yield across AAA-rated euro area sovereign issuers until 2007, the risk assessment across issuers within this rating class has become more diverse as a result of the financial and sovereign debt crises, which is reflected in quite heterogeneous yield levels. Second, owing to rating downgrades, the sample of bonds underlying the estimation of the curve has changed over time. The estimated yields can therefore be affected by such composition changes, as discussed in Section 4. Moreover, the volume of outstanding euro area government bonds classified as AAA shrank significantly during the crisis, from around two-thirds to currently only around one-third of all euro area central government bonds (see Chart 2), raising questions about the representativeness of the AAA yield curve as a benchmark for the euro area.

Given the intricacies associated with constructing the yield curve based on AAA-rated sovereign issuers, it makes sense to look for alternative representations of the risk-free term structure.[11] One alternative is to use interest rate derivatives. These are typically swap contracts, where two counterparties exchange the difference between a fixed interest payment (the swap rate) and a variable interest payment, which is based on

Chart 2 Outstanding amounts of euro area central government bonds by ratings

(EUR billions)



Sources: Fitch Ratings and ECB.
Notes: The ratings are those assigned by Fitch Ratings. Only long-term debt securities are included.

10 These data series begin in September 2004. For more background information, see the ECB's website and the article entitled "The new euro area yield curves", *Monthly Bulletin*, ECB, February 2008.

11 Using different yield curves for different purposes is in line with the recommendations of a report published in March 2013 by a working group established by the BIS Economic Consultative Committee, entitled "Towards better reference rate practices: a central bank perspective".

future short-term rates. When the variable rate is linked to a reference rate that is considered close to risk-free and expected to remain that way for the duration of the swap contract, the quoted fixed rate of the swap rate itself can also be thought of as close to credit risk-free. Any potential counterparty risk does not distort quoted swap rates, as it is priced "separately".[12]

Before the financial crisis it was common among market participants to benchmark risk-free rates using interest rate swaps, in which the variable rate was based on EURIBOR rates. However, with marked increases in credit risk priced into EURIBOR rates, the yield curve based on EURIBOR-linked swaps was clearly no longer a good proxy of the risk-free yield curve.[13] With the development and deepening of the OIS market (see Box 2), however, it has become feasible to derive a yield curve that is related to future overnight interest rates (the EONIA). The credit risk of overnight lending is naturally much smaller than the credit risk of lending at longer maturities, so the fact that the EONIA has such a short maturity means that the credit risk of OIS rates is normally very small.

12 "Credit value adjustments" are negotiated bilaterally between the counterparties to compensate for counterparty risk and subsequently added to or subtracted from the observed quotes to obtain the final transaction price. For more on credit value adjustments, see, for example, J. Hull and A. White, "LIBOR vs. OIS: The Derivatives Discounting Dilemma", *Journal of Investment Management*, Vol. 11, No. 3, pp. 14-27, 2013.

13 The ECB used EURIBOR-based swaps to extract the instantaneous forward curve until the beginning of 2008, when it changed to using the AAA-rated government bond yield curve (see the February 2008 issue of the Monthly Bulletin). In addition to credit risk, another reason for reconsidering the reference rate function of EURIBOR was the evidence of manipulation within the panel of institutions contributing to the computation of EURIBOR (see the article entitled "Reference interest rates: role, challenges and outlook" in the October 2013 issue of the Monthly Bulletin).

Box 2

THE OVERNIGHT INDEX SWAP MARKET

An overnight index swap (OIS) is a financial contract between two counterparties to exchange a fixed interest rate against a geometric average of overnight interest rates (in the euro area, the EONIA) over the contractual life of the swap. The instrument belongs to the derivative class called "interest rate swaps".

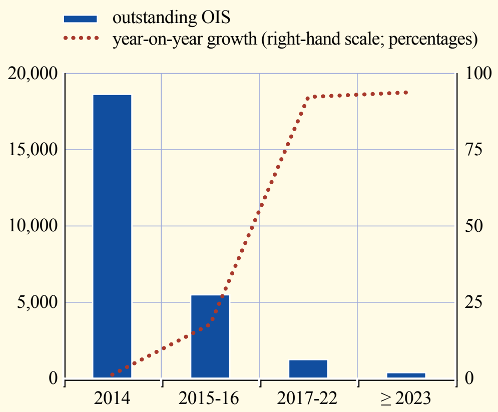
Today there are two main types of euro-denominated interest rate swap, the main distinguishing feature of which is the exposure of the variable rate: (i) OIS, with a variable rate which is the average of the EONIA rates, and (ii) EURIBOR-based swaps, with a variable rate of one of the EURIBOR rates (e.g. the three-month or six-month EURIBOR). Interest rates swaps are used intensively by both financial and non-financial companies. The appeal of interest rate swaps is that the user can easily manage interest rate risk. As an example, a company can issue long-dated, fixed rate bonds and enter into an interest rate swap whereby it agrees to pay a variable interest rate in exchange for receiving a fixed interest rate. In doing so, it changes the interest rate exposure of its debt from fixed to variable.

An important distinction from bonds is that with swaps there is no initial payment and no exchange of principal. Therefore, swaps are non-investible, i.e. they do not serve as a store of value.

The market for interest rate swaps is over the counter (OTC), but many maturities up to 30 years are quoted on various trading platforms. OIS are considered the market standard for swaps with maturities of up to around one year, as also documented by annual ECB money market surveys. Swaps with the variable leg linked to EURIBOR remain the market standard beyond the two-year maturity, but the use of longer-dated OIS has increased (see the chart) so much that quoted OIS rates at these maturities are thought likely to provide a reliable signal about market expectations of future EONIA rates (and associated term premia). As an illustration of the perceived reliability of quoted OIS rates, the financial industry has adopted the OIS curve for the discounting of collateralised derivatives.[1]

Outstanding amounts of OIS contracts by maturity

(EUR billions; percentages)



Source: Depository Trust & Clearing Corporation (DTCC).
Note: Outstanding amounts as at 14 March 2014 of euro-denominated OIS contracts cleared through the DTCC.

1 In derivatives transactions, counterparties mostly post collateral when the market value of the derivative changes. Therefore, credit risk premia in derivatives transactions can be regarded as negligible, so market participants need a reference yield curve that is close to risk-free to value such a collateralised derivative correctly. As an example, one of the big clearing houses, LCH.Clearnet, adopted OIS discounting for interest rate swaps in June 2010.

One potential concern in using OIS rates as a measure of risk-free rates is that the market for OIS contracts is still developing, notably for maturities beyond one year (see Box 2). Nevertheless, the yield curve based on OIS is currently assessed to be a useful additional tool for assessing risk-free rates. Thus, even at long maturities, the resulting forward curve (see Box 3) is a valuable device for assessing market participants' expectations of future levels of overnight interest rates, subject to the potential impact of term premia.

Box 3

CONSTRUCTING A YIELD CURVE FROM OVERNIGHT INDEX SWAP RATES

Quoted overnight index swap (OIS) rates can be interpreted in a similar way to par bond yields, i.e. the hypothetical fixed coupon rate that would make the bond price equal the bond's face value. The derivation of the OIS zero curve consists of the following two steps:

(i) zero spot rates are calculated from quoted OIS rates using a bootstrapping method,[1]

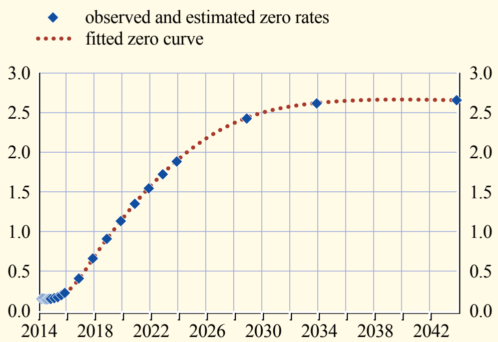
1 Bootstrapping is a method for calculating zero rates from the prices of a set of coupon-bearing rates or quoted swap rates. Starting from an observed or given zero rate, the bootstrapping method can be applied to generate a zero rate for a coupon-bearing rate with longer maturity by applying a no-arbitrage implied forward rate equation. By forward substitution, for example the three-year zero rate can be derived once the one-year and two-year zero rates are known, and the three-year par rate is observed. This can be iterated to generate zero rates for all maturities of observed coupon-bearing rates. See, for example, R.W. McEnally and J.V. Jordan, "The Term Structure of Interest Rates", in Chapter 37 of F.J. Fabozzi and T.D. Fabozzi (eds.), *The Handbook of Fixed Income Securities*, 4th edition, New York, Irwin Professional Publishing, 1995.

(ii) based on these zero rates, a zero curve is estimated with a smoothing spline.[2] The specification of the smoothing spline allows the estimation of a smooth curve, which at the same time fits the zero rates at observed maturities well (see the chart). By comparison with estimating the whole curve in one step by using a numerical optimisation, such as the Nelson-Siegel-Svensson model used for deriving the bond yield curves (see Box 1), the smoothing spline allows the observed data to be matched relatively well for short and long maturities, independently.

Finally, the zero curve obtained can be used to construct OIS-based forward curves.

Examples of constructing OIS zero rates using a smoothing spline

(annual percentages; 2 January 2014)



Sources: Thomson Reuters and ECB calculations.
Notes: Blue points denote zero rates based on observed quotes; the red dotted line is the zero curve on a daily interval.

2 A smoothing spline is a method for fitting a smooth function (yield curve) to potentially noisy individual observations (zero yields for specific maturities). One example of a smoothing spline is a function s(x) that minimises $p\sum_i w_i (y_i - s(x_i))^2 + (1-p)\int \left(\frac{d^2 s}{dx^2}\right)^2 dx$ where p is a specified smoothing parameter, x_i is a specific maturity, y_i is the corresponding zero rate and w_i are weights that sum to 1. The smoothing parameter p determines the relative weight placed on the conflicting goals of s being smooth and having s closely fitting the data.

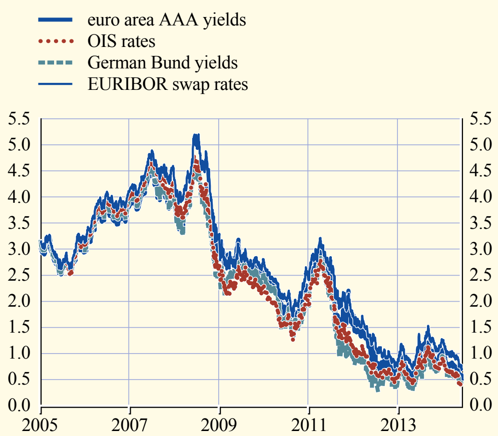
4 RECENT DEVELOPMENTS IN EURO AREA AAA BOND RATES AND OIS RATES

Before the onset of money market tensions in the summer of 2007 risk-free rates derived from different euro area instruments moved together quite closely. Chart 3 illustrates this point by plotting four different measures of five-year rates that might have been viewed as proxies for the risk-free rate from the perspective of the start of 2007: yields from the AAA-rated euro area curve, yields from the euro area OIS curve, yields from the German Bund curve[14] and EURIBOR swap rates. All these rates were seen as incorporating little credit risk and they used to display very similar levels and move together closely.

Starting in the second half of 2007, however, these measures started to show significant divergences from each other at various times, as described in Sections 4.1 and 4.2 below. (For example, the largest spread between all four measures in Chart 3 reached over 100 basis points in September 2008 after Lehman Brothers collapsed, and it reached similar levels in November 2011 during the sovereign debt crisis.) This raised the issue of which measures should be considered the most reliable proxies for the euro area risk-free rate, which is discussed in Section 4.3.

Chart 3 Measures of five-year risk-free rates

(percentages per annum)



Sources: ECB, Thomson Reuters and Deutsche Bundesbank.

14 "German Bund curve" refers to the term structure of German government bond yields. This is estimated from coupon-bearing German government bonds on a daily basis by the Deutsche Bundesbank using the Nelson-Siegel-Svensson approach.

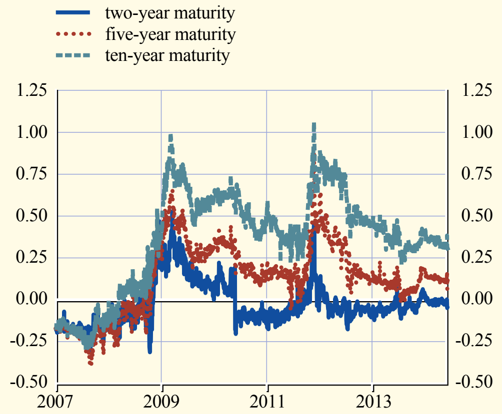
4.1 THE GLOBAL FINANCIAL CRISIS

In the period preceding the start of the global financial crisis in September 2008 there was a small negative spread both between AAA-rated euro area sovereign bond yields and OIS rates and between German Bund yields and OIS rates (see Charts 4 and 5). For example, the forward curves in the top left-hand panel of Chart 6 show that in June 2007 forward rates from OIS exceeded those from AAA-rated bonds and German Bunds at all but very short horizons. The spreads between OIS, Bund and AAA bond rates during this period may have reflected the extreme aversion to bank credit risk at the time, which may also have affected expected future EONIA rates. Moreover, the spread between KfW bond[15] and German Bund yields, a common measure of the liquidity premium, rose gradually over this period. This could indicate flight-to-liquidity flows into high-rated and liquid assets, which could also help explain the low level of German Bund yields and other AAA-rated bond yields (relative to OIS).

After the bankruptcy of Lehman Brothers on 15 September 2008 the relationship between OIS rates on one hand and AAA-rated bond yields and German Bund yields on the other hand changed and a positive spread opened up. (The top right-hand panel of Chart 6 provides a snapshot of the forward curves at the end of November 2008 and illustrates that the AAA curve lay above the others at that time.) One reason for the positive spread was probably an increase in perceived euro area sovereign credit risk, which also affected AAA-rated sovereign issuers after they took on many of the burdens and risks originating in their respective national financial sectors.[16] This is also reflected in the credit default swap (CDS) premia on AAA-rated sovereign issuers, which increased to unprecedented levels during the period, including for Germany (where five-year CDS premia increased to around 90 basis points in February 2009).

Chart 4 Spreads between AAA-rated bond yields and OIS rates at two, five and ten-year maturities

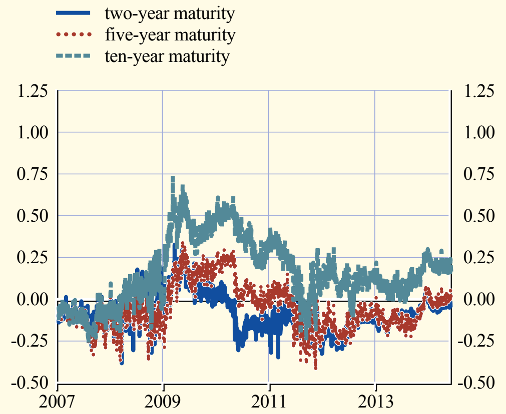
(percentage points)



Sources: ECB and Thomson Reuters.

Chart 5 Spreads between Bund yields and OIS rates at two, five and ten-year maturities

(percentage points)



Sources: Deutsche Bundesbank and Thomson Reuters.

15 The Kreditanstalt für Wiederaufbau (KfW) is a German development bank. Bonds issued by KfW and the German Bund are both guaranteed by the German state and, therefore, carry the same credit risk. See also the box entitled "New evidence on credit and liquidity premia in selected euro area sovereign yields", *Monthly Bulletin*, ECB, September 2009.

16 See, for example, the article entitled "The determinants of euro area sovereign bond yield spreads during the crisis", *Monthly Bulletin*, ECB, May 2014.

At the same time there was also an increasing divergence between the yields on sovereign bonds within the AAA basket. For example, as shown in Chart 7, in the months after the collapse of Lehman Brothers German five-year bond yields were as much as 275 basis points lower than Irish five-year bond yields.[17] Part of that phenomenon is explained by investors pricing in the increased credit risk for Ireland – even though the rating downgrade had not yet taken place – in light of the expected burden entailed in government support for the national financial system. But part is also probably explained by a flight to liquidity, consistent with the sharp increase in the spread between yields on KfW bonds and German government debt during this period (see Chart 8). This may also partly explain why the increase in AAA-OIS spreads was much larger than the corresponding increase in Bund-OIS spreads.

4.2 THE SOVEREIGN DEBT CRISIS

During the sovereign debt crisis, which originated in late 2009, yields based on the pool of all AAA-rated euro area sovereign bonds continued to exceed yields on German Bunds and OIS rates. In Chart 6, the middle panel on the right-hand side and the bottom panel on the left-hand side show the forward curves at two key points in the sovereign debt crisis. For comparison, the middle panel on the left-hand side shows the curves just before the sharp escalation of the sovereign debt crisis.

Spreads between AAA bond, Bund and OIS rates reached new highs in November 2011, as financial market tensions intensified and concerns about the sovereign debt crisis led to large increases in credit premia on most euro area sovereign bonds, including those of some AAA-rated countries. This resulted in another large divergence between yields on euro area AAA-rated sovereign bonds (as shown in Chart 7). Since the exclusion of countries from the AAA pool requires a downgrade from Fitch Ratings, and this can lag behind a rise in credit concerns about a country, this timing effect will have partly contributed to the overall rise in AAA-rated bond yields.

Around the same time the spread between German bond yields and OIS rates also fell to negative levels, suggesting that German yields were being driven down by flight-to-liquidity flows (see Chart 5). This is consistent with the increase in KfW-Bund spreads during this period, indicating a sharp increase in liquidity preference. The negative spread between German bond yields and OIS rates was particularly persistent at short to medium maturities, suggesting that flows into Bunds were concentrated at these maturities.

At the end of November 2011 AAA-OIS spreads started to narrow again as market sentiment improved, against a background of coordinated action by the ECB and other central banks to ease money market tensions, as well as unconventional liquidity measures introduced by the ECB in early December.[18] Subsequently AAA-OIS spreads declined further, although they remained just above 10 and 30 basis points at five and ten-year maturities respectively up to the end of May 2014. Short and medium-term Bund-OIS spreads returned from negative values to close to zero over the same period, while the spread at longer maturities remained positive.

4.3 IMPLICATIONS OF THE CRISIS FOR MEASURING RISK-FREE RATES

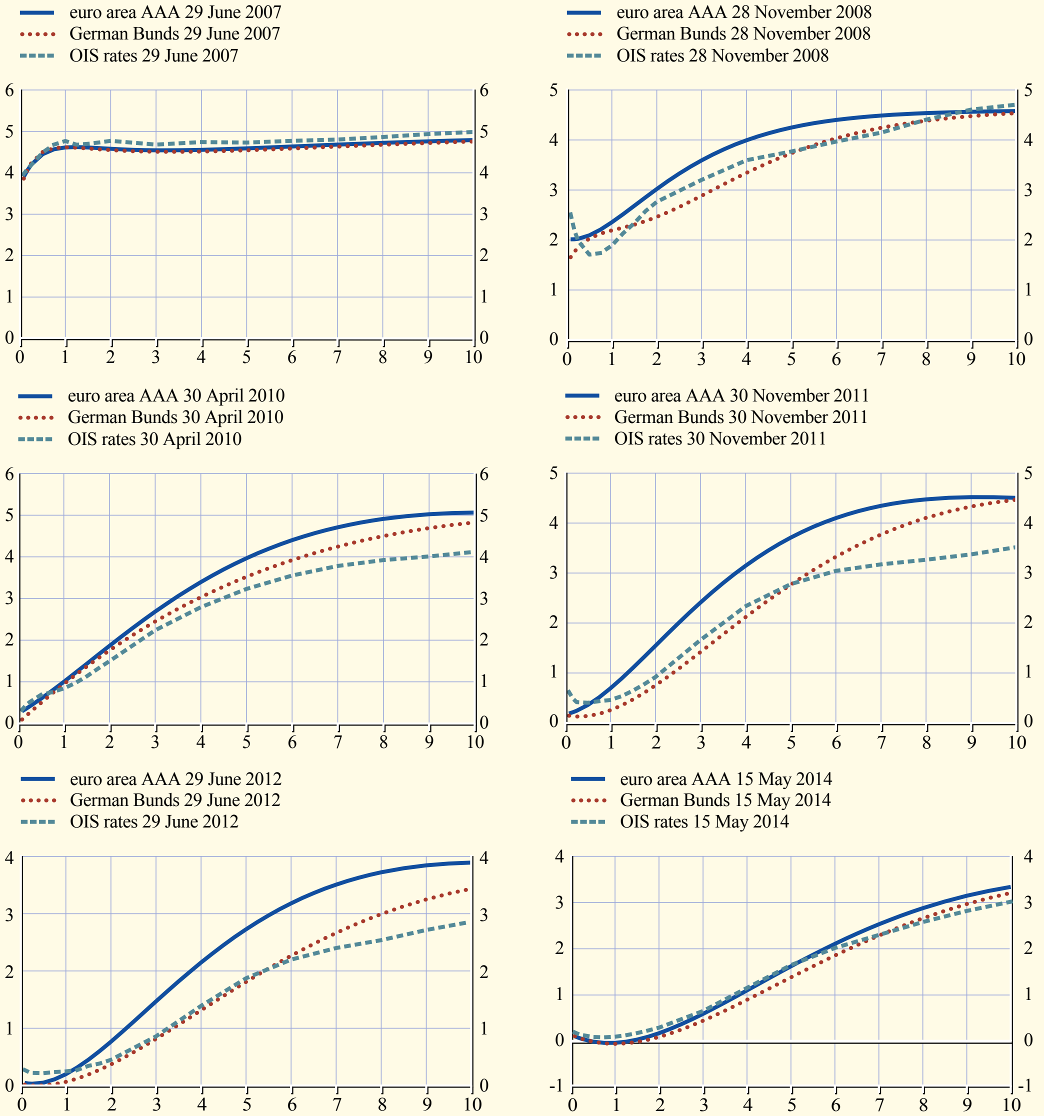
Experience during the crisis shows that there is no unique measure of the euro area risk-free rate. Rising credit risk premia, ratings downgrades and flight-to-liquidity flows have all had different

17 In Chart 7, the discontinuity in the line for Irish five-year sovereign bond yields reflects the fact that in April 2009 Ireland was downgraded by Fitch Ratings and consequently removed from the AAA yield curve.

18 In particular, the ECB announced on 8 December 2011 that it would carry out two three-year longer-term refinancing operations in December 2011 and February 2012. For more details, see Box 3, entitled "Impact of the two three-year longer-term refinancing operations", *Monthly Bulletin*, ECB, March 2012.

Chart 6 Instantaneous forward curves derived from AAA-rated bonds, German Bunds and OIS

(percentages per annum)



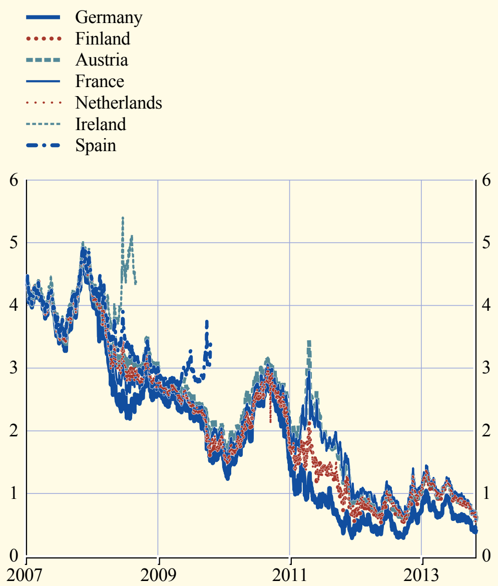
Sources: ECB, Deutsche Bundesbank and Thomson Reuters.

and sizeable effects on traditional bond-based measures of euro-area risk-free rates. Though not entirely insulated from these influences, the yield curve based on OIS contracts potentially offers a more robust measure of risk-free rates and seems to have been less affected by the aforementioned special factors during the crisis, as confirmed by the statistical analysis reported in Box 4.

As regards the specific comparison between the OIS curve and yields based on German Bunds, the empirical evidence reviewed in this article generally suggests that the difference is likely to be more pronounced during periods of financial market stress. As illustrated by the middle panel on the right-hand side of Chart 6, at the end of 2011 the forward curve based on German Bunds was significantly lower for shorter-term maturities than its counterpart based on OIS rates. Lower values

Chart 7 Five-year AAA-rated sovereign bond yields

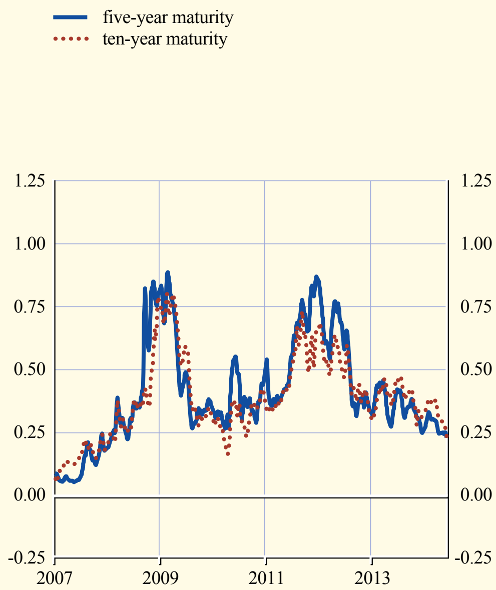
(percentages per annum)



Sources: Thomson Reuters and Deutsche Bundesbank.

Chart 8 KfW-Bund spreads at five and ten-year maturities

(percentage points)



Sources: ECB and Thomson Reuters.

for yields based on German Bunds during the period of financial stress experienced in November 2011 are consistent with the impact of flight-to-liquidity effects uncovered by the formal econometric analysis performed in Box 4. As demonstrated by the results illustrated in the chart in Box 4, flight-to-liquidity effects are likely to increase the price of securities that are considered most liquid, such as German Bunds. In contrast, since the OIS curve is less sensitive to flight-to-liquidity effects, risk-free rate measures based on OIS contracts are less likely to suffer from biases owing to liquidity or scarcity risk premia.

There are therefore good reasons to consider OIS rates as a complement to established measures of risk-free rates, while not replacing them completely. As mentioned earlier, however, the OIS market itself is quite young and liquidity is concentrated at short and medium-term maturities, which would caution against relying on it exclusively.

Box 4

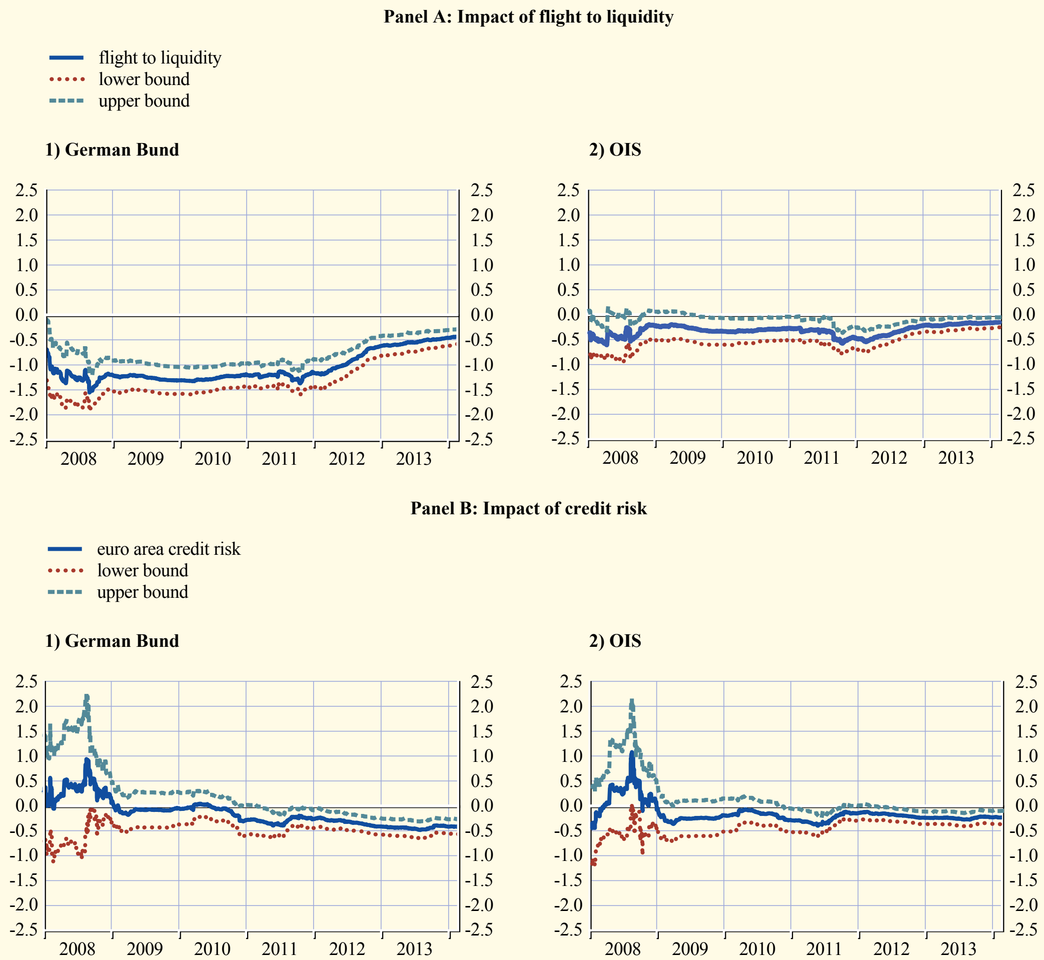
THE RELEVANCE OF CREDIT AND LIQUIDITY RISK TO AAA-RATED BOND YIELDS, BUND YIELDS AND OIS RATES

The aim of this box is to assess the role that euro area credit risk and "flight to liquidity" (meaning preference for highly liquid assets) play in developments in yields at the five-year maturity derived from the yield curves of euro area AAA-rated bonds, German Bunds and overnight index swaps (OIS) using regression methods. Euro area credit risk is measured by the first principle component of euro area sovereign credit default swap (CDS) spreads vis-à-vis the German sovereign CDS. Flight to liquidity is measured by the KfW-Bund spread referred to in the main text.[1]

Three separate three-year rolling-window regressions were run with the same set of regressors, which, in addition to the three measures of interest, include an intercept, the one-period lagged dependent variable, the three-month OIS rate, the three-month EURIBOR-OIS spread, the German sovereign CDS, the German sovereign bid-ask spread, the EUR/USD exchange rate, the implied volatility of the EUR/USD exchange rate, a euro area inflation swap rate, a euro area corporate bond spread, the one-period lagged US stock price index, one-period lagged

Impact of euro area flight to liquidity and credit risk on the German Bund yield and OIS rate at a five-year maturity

(percentage points; February 2008-April 2014)



Source: ECB calculations.
Notes: The lower and upper bounds provide the 95% confidence interval. Time variation is obtained by using three-year rolling regressions.

1 See also R.A. De Santis, "The euro area sovereign debt crisis: identifying flight-to-liquidity and the spillover mechanism", *Journal of Empirical Finance*, Vol. 26, pp. 150-170, 2014; and A. Monfort and J.-P. Renne, "Credit and liquidity risks in euro-area sovereign yield curves", *Banque de France Working Paper Series*, No 352, 2011.

US stock market implied volatility and the one-period lagged US OIS rate. All variables are in first differences and the fixed income variables used as dependent variables all have a five-year maturity.

The results summarised in the chart (for German Bunds and OIS rates only, for reasons of conciseness) suggest that daily changes in OIS rates were generally less sensitive (than either AAA or Bund yields) to movements in flight-to-safety flows over the crisis period. Specifically, the chart plots the pass-through from euro area credit risk and the flight-to-liquidity measure to those yields, together with the respective 95% confidence intervals. During the period 2008-11, as expected, the pass-through from flight to liquidity was negative and on average amounted to about -1.2 percentage points for the German Bund yield, -1 percentage point for the euro area AAA bond yield and -0.3 percentage point for the OIS rate (see Panel A of the chart). This effect has steadily declined in 2013 and 2014 proportionally across the three asset classes. Euro area credit risk negatively affected the German Bund yield and, to a smaller extent, the OIS rate during the euro area sovereign debt crisis (see Panel B of the chart). Credit risk only had a small effect on AAA bond yields, which probably reflects the offsetting effects of credit risk on the German Bund (suggested in Panel B of the chart) and on other high-rated sovereign yields.

5 CONCLUSIONS

The onset of the global financial crisis has posed a number of challenges for measuring risk-free rates in the euro area, with different measures tending to diverge more than they previously did. The euro area yield curve based on AAA-rated government bonds, which is regularly produced by the ECB, was subject to both upward and downward pressures from developments during the crisis. For instance, flight-to-quality flows acted to depress the yields on some AAA-rated government bonds to different extents at various times, while rising credit premia acted to push yields of some AAA issuers higher than others. Moreover, credit rating downgrades have mechanically shrunk the pool of AAA government bonds, in turn making the AAA curve less representative of the euro area as a whole.

The development of the OIS market provides an alternative way of measuring euro area risk-free rates. This market has grown rapidly over recent years, with market participants increasingly using OIS rates as a benchmark, and the fact that OIS are based on the EONIA – the key overnight money market rate – makes them particularly informative from a monetary policy perspective. In this respect, a combined analysis of OIS and AAA rates may be warranted when reporting on risk-free rate developments or when gauging market expectations of future interest rates or macroeconomic variables.