

■ Term structures in economic analysis

The path of interest rates of different maturities provides a wide range of information on how monetary policy, business cycle developments and the inflation outlook interact. When analysing interest rate developments, central banks pay particular attention to the impact of monetary policy measures on different maturity segments of the yield curve. Using term structure models, it is possible to look at the determinants of interest rates in detail. In particular, the models allow us to identify different interest rate components that cannot be observed directly. These include, above all, “pure” interest rate expectations and different risk premia.

In principle, a yield curve can be derived from various instruments of interest-bearing securities. For monetary policymakers, the €STR yield curve is of interest in the first instance, as the euro short-term rate (€STR) is closely linked to the policy rates. The yield curve of Federal securities also provides important information on bond-specific aspects, such as safety, scarcity and liquidity, which are likewise important for the transmission of monetary policy.

In the current setting, the path of the €STR yield curve indicates further rising policy rates until autumn 2023. However, the curve currently overstates “pure” expectations about the further hike in policy rates. This is because the continued high degree of uncertainty about how inflation will develop entails interest rate risk for market participants. To compensate for this, they demand risk premia in the form of higher term premia. Long-term interest rates have also risen significantly since the beginning of 2022. In this case, too, longer-term term premia increased alongside “pure” interest rate expectations.

Higher inflation expectations and inflation risk premia were the initial economic drivers of the increase in longer-term yields since the start of 2022. Investors demand the latter to compensate for unexpectedly high future inflation. Owing to the inflation dynamics, the Eurosystem subsequently introduced monetary policy tightening measures. This also led to significantly rising (inflation-adjusted) real interest rates in the second half of 2022. In addition, the yield-lowering effect of the Eurosystem’s monetary policy purchase programmes on term premia gradually declined. This was initially driven by the end of net purchases and later by the ECB Governing Council’s anticipated announcement that the full reinvestment of asset holdings would come to an end.

Term premia have risen lately, but are still at a historically low level. Experience gained over the past few decades with supply shocks such as those in the 1970s has shown that, after a prolonged period of strong inflationary pressures, term premia have remained at an elevated level. This was due to a high degree of perceived inflation uncertainty. Even after inflation was successfully tamed in the 1980s, this uncertainty initially persisted. In terms of the current setting, combating inflation in the Eurosystem is the highest priority in order to prevent any doubts arising as to monetary policy’s pursuit of stability.

■ Introduction

Yield curve contains important monetary policy and economic information

The yield curve describes the relationship between the maturity of bonds and their interest rates. For central banks, studying interest rate movements along the yield curve provides valuable insights for monetary policy analysis. To put it simply, monetary policymakers change the monetary policy stance by adjusting policy rates or – as introduced in the low interest rate environment – by purchasing assets. They thus influence the interest rates of different maturities, which help shape the macroeconomic environment and inflation developments through changed general financing conditions. This typically gives rise to a close relationship between the use of monetary policy instruments and general financing conditions. Movements in the yield curve therefore give monetary policymakers information about the transmission of monetary policy measures. At the same time, they provide valuable indications of market participants' expectations and risks relating to the macroeconomic situation and the inflation outlook. This is why the Bundesbank has traditionally paid great attention to developments in the yield curve.¹

Term structure models disentangle risk premia from expectations

Identifying the drivers of interest rate movements can give us a greater understanding of them. Term structure models decompose interest rate movements into expected short-term interest rates that cannot be directly observed – “pure” interest rate expectations – and into risk premia that cannot be directly observed. Conceptually, pure interest rate expectations can be determined using the historical dynamics of interest rates, supplemented, where applicable, by macroeconomic data or surveys that are not affected by risk aspects. The term premium is then the difference between the observed interest rates and the interest rate expectations derived from the model. This decomposition can be used as a basis for analysing the impact of policy rate changes and non-standard monetary policy measures, amongst other things. The main issue to be explored is the extent to which the observed interest rates

reflect “pure” interest rate expectations of market participants and what portion of the interest rates constitutes compensation for the assumption of various risks (see the upper chart on p. 55).

Depending on the type of asset, risk-averse market participants require risk premia for different types of risk. These include, in particular, the risk of an unexpected change in future interest rates (interest rate risk) and the risk of default on a payment or loan (credit risk). In addition, market participants wish to be compensated for the risk that, in an environment of shrinking market liquidity, securities can only be sold off quickly at a discount (liquidity risk). Finally, investors may be willing to accept a lower yield (i.e. higher price) if, for example, they are seeking a specific asset for regulatory reasons that is, however, difficult to obtain (scarcity premium). Generally speaking, investors demand a positive risk premium for investments with high payouts when the economy is faring well and low payouts when it is doing badly. Securities with high payouts in bad times have an insurance element. Investors are willing to pay a premium for such assets or to forego a yield. As with insurance, the risk premium is negative in this case.

Components of risk premia

The first section of this article discusses how the yield curve of overnight index swaps (OISs) of different maturities can be decomposed into the components mentioned above. OIS rates are based on swap agreements in which two parties swap an agreed fixed interest rate against a series of overnight floating interest rates over a set term. The overnight floating rate is pegged to the movement of the €STR.² OIS rates for short and medium-term maturities are therefore

Article discusses policy rate expectations, ...

¹ The first Bundesbank Monthly Report with an article on yield curves was published in 1971; see Deutsche Bundesbank (1971). More recently, the specificities of estimating yield curves during the financial crisis were discussed in Deutsche Bundesbank (2013) and the zero lower bound on interest rates in Deutsche Bundesbank (2017a).

² The €STR is an overnight interest rate calculated by the ECB on the basis of individual transactions between banks and financial counterparties. Before the €STR was introduced, OIS agreements were based on the EONIA.

closely tied to the Eurosystem’s monetary policy toolkit (see the lower chart on this page). The OIS rates provide information on the priced-in “pure” expectations of future monetary policy measures and the associated interest rate uncertainty as assessed by market participants.

... the special role of Federal securities ...

The second section of this article focuses on yields of Federal securities. Owing to their excellent credit quality, Federal securities are considered to be default-free and provide the benchmark in the euro area for euro-denominated debt securities overall. For example, they form the basis against which corporate bonds or government debt instruments issued by other jurisdictions are priced.³ Federal securities yields follow a similar path to OIS rates of matching maturity. However, they are also subject to bond market-specific influences, which result in an interest rate spread between the OIS rate and the Federal bond (Bund) yield (see the adjacent chart). The analysis focuses on additional premia for particular safety, high scarcity and high liquidity. These have become more important in recent years with the use of non-standard monetary policy measures.

... and the economic drivers of interest rate movements

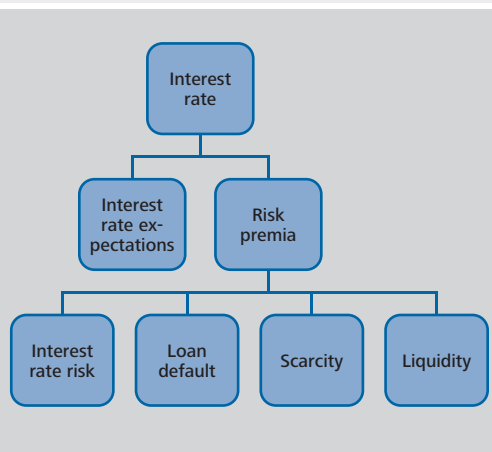
Finally, the third section of this article deals with the relationship between interest rates, inflation and the real economy. By analysing inflation-related and real components of the yield curve, we can gain a deeper understanding of the impact of inflation expectations, the growth outlook and the associated uncertainties on the yield curve. This section also addresses the questions of how well a recession can be predicted on the basis of yield curves and how monetary policy should respond to the current high price increases given the experience gained from earlier periods of high inflation.

Policy rate expectations and interest rate risk

Short-term swap rates dominated by policy rate expectations

By varying their policy rates, monetary policymakers influence the slope, curvature and level of the yield curve. Based on an OIS term struc-

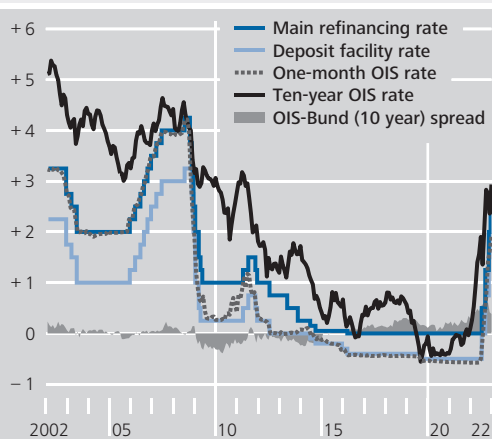
Determinants of interest rate movements



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Interest rates in the euro area

%, month-end data



Sources: Bloomberg, ECB and Bundesbank calculations.
 Deutsche Bundesbank

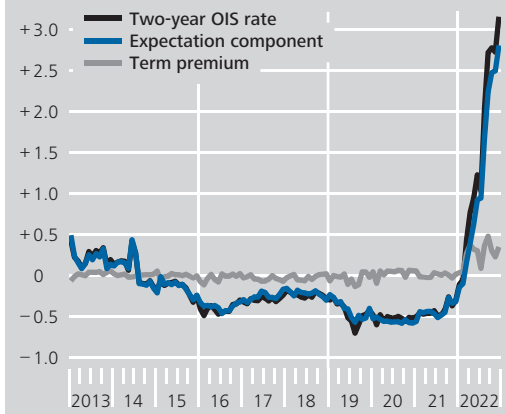
ture model, the upper chart on the next page shows the decomposition of the two-year OIS rate into the average expected €STR path (expectation component) and the term premium since 2013.⁴ A large part of the variation in this

³ See Deutsche Bundesbank (2017b).

⁴ See Geiger and Schupp (2018). A key aspect of this model is the explicit inclusion of a binding lower bound. The specification of the lower bound takes into account both current and expected future changes in the effective lower bound. This means that the model is capable of mapping how policy rates have gradually moved into negative territory. As regards model estimation, the approach also considers short and long-term interest rate surveys to ensure that expectations derived from the yield curve about the future path of short rates are as consistent as possible with the survey results.

Decomposition of the two-year OIS rate

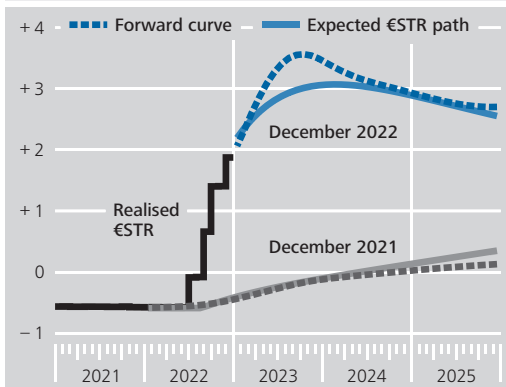
%, month-end data



Sources: Bloomberg, ECB and Bundesbank calculations based on Geiger and Schupp (2018).
 Deutsche Bundesbank

OIS forward curve and expected €STR path

%, month-end data



Sources: Bloomberg, ECB and Bundesbank calculations based on Geiger and Schupp (2018).
 Deutsche Bundesbank

maturity segment is driven by the expectation component.

Communication of monetary policy influences policy rate expectations ...

The degree of monetary policy accommodation hinges not only on the actual level of the policy rate but also on the expected future path of policy rates. This is because policy rate expectations have a major impact on general financing conditions. Through its monetary policy communication, the central bank can seek to influence the expectations market participants have about the future development of policy rates.

The central bank can indirectly influence policy rate expectations by communicating its assessment of the economic and inflation outlook. This gives market participants the opportunity to readjust their expectations about the perceived future path of policy rates accordingly.⁵

... indirectly via central bank assessments of economic outlook ...

The central bank can also directly influence market participants' policy rate expectations, however. It does so by explicitly describing the path it intends policy rates to take. In doing this, it also aims to reduce uncertainty about the medium and longer-term path of interest rates and thereby to lower term premia. One such form of explicit communication about future policy rates, known as forward guidance, started to become more prominent in the Eurosystem from July 2013. At that time, the scope for policy rate cuts was increasingly limited by the perceived lower bound. The result of this communication, targeting interest rate expectations and the term premium, was that OIS rates with medium-term maturities continuously converged with the deposit facility rate (see the upper chart on this page). The forward guidance increased the downward pressure on medium-term interest rates because the Governing Council of the ECB explicitly communicated that policy rates could fall further below the previously perceived lower bound ("easing bias"). It thus signalled even greater downside risks for the future path of interest rates, which was reflected in temporarily negative term premia in these maturity segments.

... and directly via forward guidance

This pattern underwent a significant change at the beginning of last year. Since then, inflation in the euro area has accelerated further amidst Russia's attack on Ukraine. The Governing Council of the ECB subsequently adjusted its forward guidance by first removing the easing bias in March 2022 and, since July 2022, emphasising that future policy rate developments will be data-dependent. From July to Decem-

Markets expecting further policy rate hikes in 2023

⁵ This "information effect" of monetary policy communication has received academic attention recently. See Jarociński and Karadi (2020) or Kerßenfischer (2022).

ber, the Governing Council decided on several large interest rate hikes totalling 250 basis points. As at the end of December 2022, market participants consider a maximum €STR of 3.0% to be the most likely level (see the lower chart on p. 56). Market participants therefore expect further interest rate changes in view of the persistently high inflationary pressures. The expected €STR is up to 50 basis points lower than the observed €STR forward rates. This positive term premium suggests that market participants mainly see a risk of interest rate hikes in the context of high inflation uncertainty.



Duration risk an important element of OIS term premium

The relative importance of the term premium on the OIS rate increases as the maturity lengthens. The longer the capital of a fixed-income security is tied up, the greater the effect of interest rate changes on the value of the swap (duration). Higher uncertainty about the path of interest rates is thus “automatically” translated into higher premia as the maturity increases. At present, the term premium for the ten-year OIS rate is 75 basis points, compared with 40 basis points for the two-year OIS rate.

Purchase programmes reduce term premia

Of particular importance to monetary policy is the fact that the estimated term premium has declined significantly since 2014 and was in negative territory until the start of 2022. This was largely due to forward guidance as well as the Eurosystem’s broad-based purchase programmes. These include the asset purchase programme (APP) announced in January 2015 and, from March 2020, the pandemic emergency purchase programme (PEPP). Both were subsequently increased and expanded.⁶ The programmes primarily took effect through a mechanism referred to in the literature as duration extraction. The Eurosystem added duration risk to central bank balance sheets by purchasing debt securities held by other investors using central bank money that is not exposed to interest rate risk. This reduced the aggregate duration risk to which non-Eurosystem balance sheets were exposed. Investors were

thus prepared to accept a lower yield by way of lower to negative term premia.⁷

With regard to monetary policy transmission, it is important to be able to gauge the functional relationship between purchase programmes, duration extraction and the level of the term premium. To do so, an expanded OIS term structure model can be used which explicitly takes into account the aggregate duration risk of non-Eurosystem investors and quantifies the effect on the term premium.⁸

The upper chart on p. 58 shows the effect of the APP and PEPP on the OIS term premium. The estimations indicate that the ten-year OIS rate was around 100 basis points lower by the end of 2020 than in the counterfactual scenario in which the Eurosystem had not bought bonds. The end of net purchases under the PEPP (March 2022) and the APP (July 2022) and adjusted market expectations of a shorter re-investment period saw the aggregate duration

Eurosystem’s duration extraction lowers term premium ...

... and dissipates only gradually in subsequent years

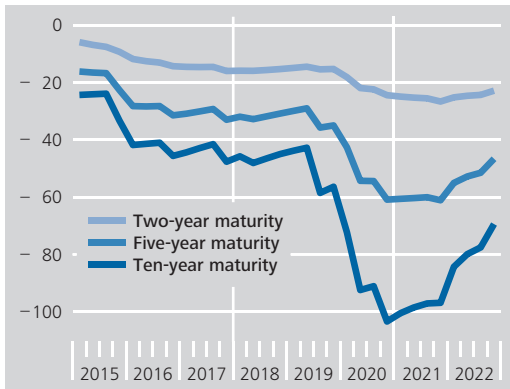
⁶ See Rostagno et al. (2021) and <https://www.ecb.europa.eu/mopo/implementation/app/html/index.en.html> for an overview of the evolution of the Eurosystem’s purchase programmes.

⁷ See Li and Wei (2018) as well as Eser et al. (2019).

⁸ For details, see Deutsche Bundesbank (2019). For an analysis of the effects on Bund yields in the run-up to the announcement of the purchase programmes, see also Lemke and Werner (2020).

Estimated contribution of bond purchases* to OIS rates

Basis points, end-of-quarter data

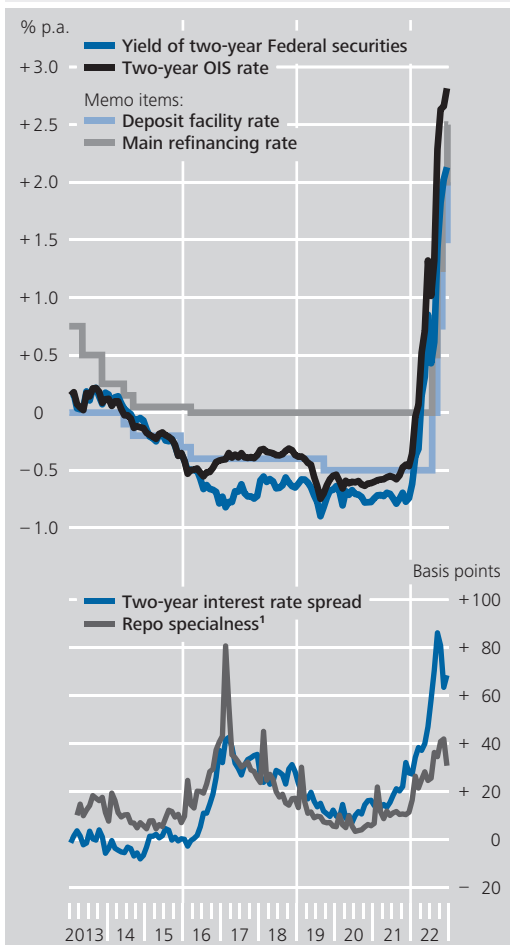


Sources: Bloomberg, ECB and Bundesbank calculations. * Under the APP and PEPP.

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OIS rate and Bund yield as well as their interest rate spread

Monthly averages



Sources: Bloomberg, NEX, EUREX and Bundesbank calculations. ¹ Interest rate premium when certain German Federal securities are pledged as collateral for a secured overnight money market loan (repo transaction) rather than unspecified general collateral.

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risk in the market rise again. In line with this, the yield-lowering effect of the purchase programmes decreased in 2022. In order to ensure consistency with the monetary policy stance, the Governing Council of the ECB decided at its December 2022 meeting to reduce monetary policy asset holdings at a measured and predictable pace from March 2023 onwards. The portfolios will be reduced by €15 billion per month on average until the end of the second quarter of 2023, in order to reduce the yield-lowering effects on the term premium. The subsequent pace of the decline will be determined over time. According to the estimations, however, the decrease in term premia induced by the asset purchases persists for years – in fact, for as long as the Eurosystem’s balance sheet contains duration risk.

The special role of Bunds: benchmark status and scarcity

Yields on Federal securities have been lower than OIS rates for some years now. For example, the two-year OIS rate was close to the deposit facility rate between 2017 and 2021 given the effect of the forward guidance described above. OIS rates are largely constrained downwards by the Eurosystem’s deposit facility rate and the perceived lower bound. Two-year Federal securities yields, however, were significantly lower than the deposit facility rate for a time. During the purchase programmes, Bund yields fell more sharply than OIS rates of the same maturity (see the adjacent lower chart). However, this cannot be due to credit quality, as both instruments are considered virtually default-free by market participants. The special role of Federal securities is also shown by the fact that, in the secured short-term money market, interest rate reductions are granted if German Federal securities are provided as collateral.⁹ This

Yields on Federal securities lower than OIS rates

⁹ For a general overview of the repo market, see Deutsche Bundesbank (2022a). For more on the impact of the asset purchase programmes on the repo market with German collateral, see Baltzer et al. (2022).

interest rate reduction is referred to as repo specialness and was at an all-time high in the autumn of 2022.¹⁰

Federal securities: benchmark for valuation

There are many reasons for the size of the two interest rate spreads mentioned above. Federal securities are the benchmark in the euro area. The Federal securities market is a reference market for numerous euro-denominated financial products. For example, the prices of Federal securities are the benchmark for all government bond prices in the euro area as a whole.

High level of safety, liquidity and scarcity of Federal securities

Owing to the combination of good credit quality and high issue volumes, Federal securities are very liquid across all the typical dimensions, such as “breadth” (trading costs at a given volume), “depth” (tradable volume at a given price) and “resilience” (the half-life of random price fluctuations). The high level of liquidity can also be seen, for example, in the fact that the bond futures with the highest turnover in the euro area are based on Federal securities.

Federal securities a safe haven in times of crisis

Federal securities are a good default-free way to put away liquid funds even in times of crisis – unlike swaps. Liquidity and scarcity premia therefore rise in times of crisis (safe haven effects). Market participants are willing to pay a higher price (convenience premium) for the advantage of access to a Bund which is scarce in such market situations as well. This can be readily seen in the OIS rate-Bund yield spread at the start of the COVID-19 crisis, for example.¹¹

Demand caused by regulation: scarcity premia ...

Institutional investors also hold Federal securities for reasons relating to monetary policy and regulation. This primarily concerns banks (Basel rules, collateral for derivatives), insurers (solvency rules) and central banks (exchange rate management, reserve maintenance, monetary policy objectives).¹² This is the reason for what is known as a scarcity premium. This premium cannot be explained by traditional interest rate risk or counterparty credit risk. The monetary policy purchase programmes increase this scar-

city premium, as they reduce the freely tradable Federal securities in free float.¹³

The special factors listed here, which have time-varying effects of different magnitudes on Bund prices, impair the quality of the economic indicators derived from them. This should be taken into account when making statements on expected policy rate changes, inflation expectations and the economic outlook, which will be discussed in the next section.

... influence indicators derived from interest rates

The yield curve: statements about the economy and inflation

Economic developments and inflation dynamics are fundamental drivers of the yield curve. First, monetary policy responds to a changed inflation outlook, which is reflected in the path of interest rates. Second, the yield curve reflects market participants’ expectations about future inflation and economic developments. The following section examines the impact of inflation expectations and the growth outlook on the yield curve.

Yield curve’s relationship to economy and inflation

Real and inflation-related components of the nominal yield curve

Inflation-linked bonds provide a direct and forward-looking market assessment of the expected real interest rate and thus an indirect as-

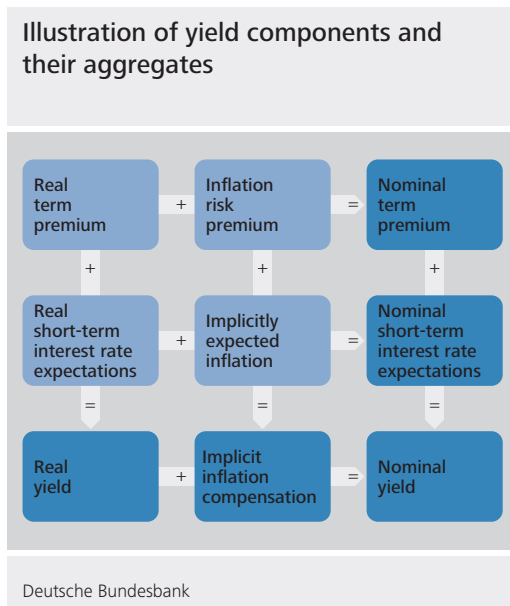
Real yields on inflation-linked bonds

¹⁰ The particularly high repo rates at the end of the year are not due to the scarcity of securities, but rather to specific reporting dates under banking regulation; see Munyan (2015).

¹¹ For a comparison among euro area countries, see Jiang et al. (2021). Bletzinger et al. (2022) and Carriero et al. (2022) find such a premium compared with bonds issued by the EU or EFSF as well.

¹² See, for example, Cohen et al. (2018) and Domanski et al. (2017).

¹³ For information on changes in the holder structure and the free float of Federal securities, see Deutsche Bundesbank (2018) and Deutsche Bundesbank (2022b). Deutsche Bundesbank (2022c) looks at their implications for the state of the market for Federal securities.



flationary scenarios in their calculations given very low inflation expectations.

When it comes to monetary policy analysis, it is important to take account of the inflation risk premium. First, as stated above, the calculated bond-based compensation for inflation only corresponds to “pure” inflation expectations if it is adjusted for the inflation risk premium. Second, it affects monetary policy transmission from short-term to long-term yields. This is because changes in inflation risk premia in long-term yields can, for example, strengthen or weaken the monetary policy steering intended via the policy rate. Given a low and relatively stable inflation risk premium, monetary policy impulses can also be transmitted more directly to financing conditions. At the same time, a low inflation risk premium reflects market participants’ high confidence in the determination and ability of monetary policymakers to achieve the inflation target.

Relevance of inflation risk premium to monetary policy

assessment of economic developments. For inflation-linked bonds, the coupon and principal increase with the inflation rate, meaning that a real yield can be calculated. Like yields on nominal bonds, real yields on inflation-linked bonds can also be decomposed into a “pure” expectation component and a term premium.

The real rate of interest on financial assets is closely tied to expected real economic developments. In particular, it is based on the return on investments along the path of economic development and is influenced in the longer term by potential output growth.¹⁴ One result of this is that deteriorating real interest rate expectations could be seen as an indication that market participants are revising their real growth expectations downwards.

Link between interest rates and long-term growth

Market-based inflation outlook from real and nominal bond yields

Based on the difference between nominal and real yield curves, it is possible to draw conclusions about the implicit inflation compensation in bond markets at different maturities. For example, implicitly expected inflation can be calculated as the difference between nominal and real short-term interest rate expectations (see the chart above). These data thus give the Eurosystem useful, real-time information about market participants’ inflation outlook. The difference between the nominal term premium and the real term premium also yields the inflation risk premium. Inflation-linked bonds in fact not only protect investors against expected inflation. This type of bond also safeguards the purchasing power of the invested euros against an unexpected increase in inflation. In most cases, risk-averse investors are willing to pay a positive inflation risk premium for this additional security. In recent years, however, the inflation risk premium has also been negative at times. At that time, investors also included de-

From a conceptual point of view, real term premia can be positive or negative. In other words, investors can either demand a higher yield on a long-term investment or be willing to accept a lower yield by way of these premia. For risk-averse investors, the option of being able to hedge their consumption even in bad times is crucial.¹⁵

Cyclical properties of real term premia

¹⁴ This view closely corresponds to the question as to the fundamental drivers of real interest rate developments. The equilibrium real interest rate can be described as the real short-term interest rate that closes the gap between realised growth and growth potential and stabilises the inflation rate. For more information, see Brand et al. (2018), Deutsche Bundesbank (2001) or Bliss (1999).

¹⁵ The macroeconomic literature derives general properties of (real) term premia; see Chien and Lee (2019) and Campbell (1986).

Negative real term premium

If, say, the yield on real bonds were to decrease in an environment of weakening growth expectations, real long-term bonds would provide a hedging opportunity for investors' desired consumption level. This is because a declining yield means that the value of the bond increases and that a real gain is achieved in the event of a sale. Investors are then willing to accept a lower yield. This is reflected in a negative real term premium. The bond will then have an insurance element. This is usually the case when growth expectations weaken, inflation falls and monetary policymakers subsequently loosen the monetary policy stance.

Positive real term premium

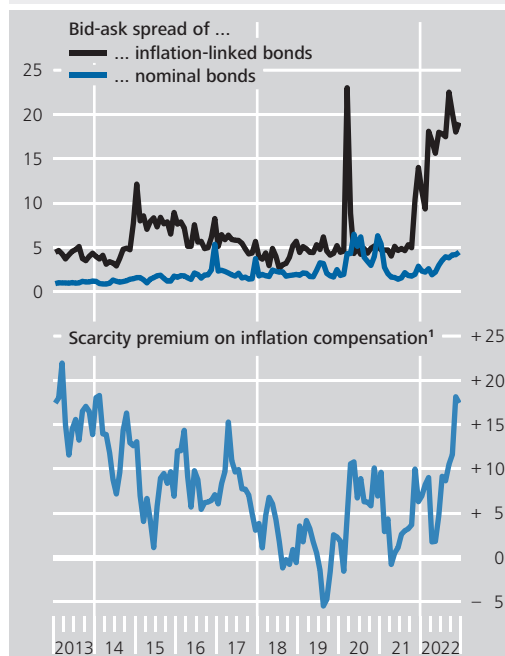
If, conversely, in an imminent recessionary phase, real bond yields rise and the market values of real bonds fall, investors typically demand compensation. This is then a positive real term premium. This could happen if the economic outlook deteriorates whilst inflation expectations rise. In such an environment, possibly driven by supply shocks, monetary policymakers tighten the monetary policy stance in order to stabilise inflation expectations, despite the looming economic downturn. The bond does not have an insurance element in this situation.

Empirical characteristics of inflation risk premia and real term premia

Studies have shown that real term premia tend to be countercyclical and increase during recessions.¹⁶ Empirical and more heavily model-based studies also reveal the factors that have played an important role in the historical evolution of real term premia and inflation risk premia.¹⁷ Market participants demand a higher inflation risk premium if the inflation outlook appears uncertain. The inflation risk premium is also higher if (nominal) short-term interest rates are more volatile. This could be the case, for example, if the monetary policy stance changes rapidly and market participants are uncertain about the intended monetary policy stance. A countercyclical relationship can be discerned in relation to economic activity: higher unemployment or low consumer confidence are usually associated with high inflation risk premia. In the past, periods of recession have often been

Relative liquidity and scarcity of inflation-linked Federal securities*

Basis points, monthly averages



Sources: Bloomberg, MTS and Bundesbank calculations. * Median of all inflation-linked bonds and equivalent nominal bonds. ¹ Difference between the asset swap rates of linked and nominal bonds.

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associated with high inflation. This is another reason why, in such times, investors have demanded greater compensation for assuming inflation risk. Monetary policy also influences the size of the inflation risk premium. Focusing heavily on the price stability objective, monetary policy is able to contribute to lower inflation risk premia, especially in the medium term. The sooner monetary policymakers are able to credibly commit to the inflation target, the greater the impact on inflation risk premia.¹⁸ One major way in which this can be achieved is if monetary policymakers provide credible, forward-looking communication on the interest rate path they intend to take to ensure that the inflation target is met.

In times of crisis, in particular, liquidity differences between inflation-linked and nominal

Liquidity premia

¹⁶ See Christensen and Rudebusch (2019).

¹⁷ See Abrahams et al. (2016).

¹⁸ See Kliem and Meyer-Gohde (2022).

Decomposition of nominal yields into real and inflation-related components using short time series

Together with the yields on inflation-linked Federal securities, the yields on nominal Federal securities can be broken down into real and inflation-related sub-components in the model. This type of combined estimation then allows all components of nominal yields to be calculated as shown in the chart on p. 64. A detailed decomposition of this kind provides deeper insights into nominal interest rate developments.

The Bundesbank has calculated yield curve parameters for inflation-linked Federal securities since 2011 – prior to this, insufficient data points were available along the maturity spectrum to ensure stable estimates.¹ This period is relatively short, which may pose a problem as the estimation parameters of the yield curve can be biased when using fairly short time series. The bias is signalled by the fact that the estimation results for the long-term expectation component are excessively stable, whereas the term premia component is excessively volatile. Therefore, a model approach that takes into account the challenge of a short data history works well for analysing the yield curve of inflation-linked Federal securities.

The sub-components in the chart on p. 64 are estimated in two steps.² The first step is to estimate a term structure model using data on the nominal interest rate structure for Germany starting from 1999.³ This produces nominal expectations about the future short-term interest rate and term premia. Based on this estimation, a restriction is imposed on the real estimation. To this end, the variance of changes in the nominal expectation component from 2011 to the present day is calculated. The second step consists of estimating the model for real

yields whilst imposing a restriction. The restriction is that the variance of changes in the real expectation component matches the variance of changes in the nominal expectation component from the first step. The estimation is thus based on the hypothesis that the statistical properties of real and nominal short-term interest rate expectations are similar. For the expectation component of long-term bond yields, this requires anchored long-term inflation expectations. This estimation results in a relatively stable decomposition of real yields into real term premia and the real expectation component. Inflation expectations and the inflation risk premium are derived from the difference between the nominal and real equivalents.

In this approach, the scope for interpretation is limited in two regards. First, the real and the nominal term structure models are estimated separately. Other models estimate the nominal and real term structures together in a joint model approach.⁴ Unlike modelling performed in a joint model, the separate estimation does not allow for any statements about the statistical relation-

¹ The Federal Government issued the first inflation-linked bond in 2006. It had an original maturity of ten years. Further bonds and other residual maturities followed later.

² For a more detailed discussion of the restriction concept and how it relates to the literature, see Halberstadt (2021). The discussion paper restricts the variance of changes in average expected future short rates, whereas the analysis presented here restricts the variance of changes in average short-term interest rate expectations over ten years. The alternative calibration used in the discussion paper aims at binding the model-implied variance of short-term interest rate expectations to that of short rate expectations from surveys.

³ Using the model developed by Adrian et al. (2013).

⁴ See Pericoli (2019), D'Amico et al. (2018) or Abrahams et al. (2016).

ships between the real and nominal model parameters. Moreover, comparing the statistical properties of separate model estimations for real and nominal yields with those of an estimation in a closed model approach shows that a joint estimation of both yield curves allows a smaller model framework with fewer factors and parameters to be used with no significant deterioration in estimation quality.⁵

Second, the impact of liquidity differences in the real and nominal bond markets cannot be estimated in the analysis presented here. However, models that do take these liquidity differences into account are only able to determine the associated premia with high levels of imprecision (see margin heading “Liquidity premia” beginning on p. 61).

⁵ See Christensen et al. (2008).

Federal securities play a major role and make it more difficult to interpret changes in interest rates.¹⁹ Specifically, inflation-linked bonds have lower market liquidity than their nominal equivalents, which is reflected in considerably wider trading ranges than those for nominal bonds (see the chart on p. 61). However, separately identifying liquidity premia in a model with nominal and real yields is a highly imprecise exercise.²⁰

In addition, the scarcity premia mentioned above also play a role in determining market-based inflation compensation – the difference between nominal and real bonds. The scarcity premia on nominal bonds are higher than those of real bonds. Inflation compensation therefore tends to be underestimated, currently by around 20 basis points (see the chart on p. 61).²¹ This is another aspect that makes economic interpretation more difficult. This is especially true in times of crisis, when fluctuations in the scarcity premium are particularly pronounced.

The large number of influencing and disruptive factors suggests that there may be methods with different focal points for modelling and quantifying yield curve components. The box on pp. 62 f. outlines a specific method for decomposing nominal yield movements into their real components and the impact of inflation since the outbreak of the coronavirus pandemic in the chart on p. 64. This method allows for, above all, the challenge posed by the short historical availability of inflation-linked German bonds. It should be noted, though, that liquidity and scarcity premia were not taken into account. The decomposition of the ten-year Bund yield calculated in this manner illustrates the change in the significance of inflation-related

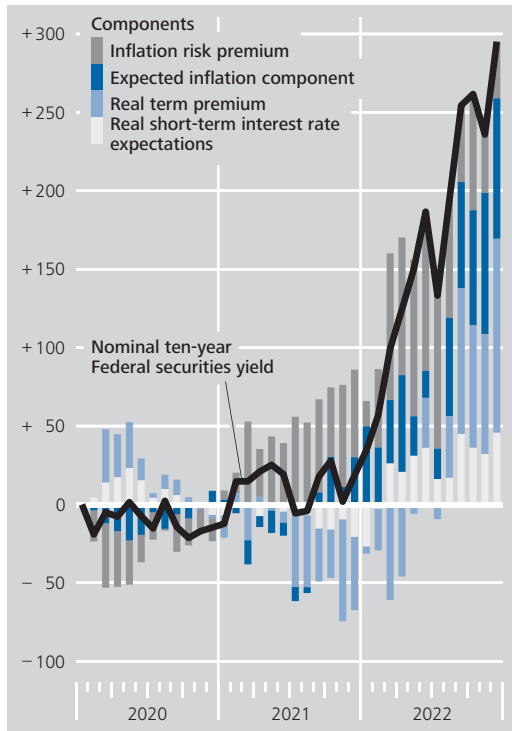
Development of sub-components since coronavirus pandemic outbreak

Scarcity premium understates inflation compensation

¹⁹ European Central Bank (2021) addresses this issue for the euro area. Abrahams et al. (2016) and D’Amico et al. (2018) tackle the subject matter for US government bonds. ²⁰ In addition to the other references in this paragraph, see also Andreasen et al. (2021) and Christensen (2022). ²¹ Fleckenstein et al. (2014) find a comparable premium on inflation-linked US government bonds.

Development of Federal securities yield: nominal and real components

Basis points, month-end data, change since start of 2020



Deutsche Bundesbank

components over the past few years.²² While they were still lowering yields at the start of the coronavirus pandemic, the inflation risk premium was already contributing to higher yields over the course of 2021. This indicates that market participants already saw unexpectedly high inflation developments as a possibility at this stage. They demanded higher risk compensation for this increased uncertainty. From the second half of 2021 onwards, the increase in yields then also increasingly reflected higher inflation expectations. The monetary policy tightening measures subsequently introduced by the Eurosystem also contributed to higher real yields last year. In particular, investors increasingly demanded a higher real term premium for investing in long-term inflation-linked bonds. In view of the massive supply shocks, this may have reflected greater uncertainty about economic developments and a diminishing risk appetite in the context of rising policy rates. This development is therefore consistent with the above-mentioned findings of a stronger coun-

tercyclical development of the real term premium. Based on the model estimates, the real short-term interest rate expectations in the summer of 2022 reflected a gloomy economic outlook. For example, the contribution of real short-term interest rate expectations was lower in July and August 2022, when gas prices in spot markets peaked.

Yield curve components by historical standards

What can be learned from the historical evolution of yield curve components and applied to the current situation, in which the economic outlook is deteriorating and high inflation rates are being observed? The following section focuses on two aspects. It looks, first, at how well a recession can be predicted on the basis of yield curves and, second, how monetary policy should respond to the current high inflation rate. To this end, the nominal yield on ten-year Bunds is decomposed on the basis of a term structure model into a nominal expectation component and a nominal term premium, starting from 1967 (see the chart on p. 69).²³ A further breakdown into real components, as in the previous section, is not possible for this long period, as inflation-linked bonds are a fairly new financial instrument.

Yield curve and business cycle since 1967

In the past, before recessions, the short-term expectation component has risen so sharply

²² The chart illustrates the components' contributions to the change in nominal yield. The model employed here using bond data provides trading-day results. Owing to the specified influencing and disruptive factors, the level of inflation-related yield components can be determined more reliably on the basis of survey-based long-term inflation expectations.

²³ The decomposition of interest rate developments follows the approach of Speck (2023). This makes it possible to estimate a term structure model with simple linear regressions, even if there is no observable short-term interest rate of one-month maturity as for Federal securities. As an extension of existing linear regression approaches such as Adrian et al. (2013), the approach avoids a numerical optimisation as in Joslin et al. (2010). The estimated model is a classic, exponential-affine term structure model with a homogeneous error variance term excluding macroeconomic variables.

Current drivers of market-based probabilities of recession based on the yield curve

The shape of the yield curve is a closely watched economic indicator of short-term economic growth among financial market participants, with particular attention being paid to a flat, or even falling, yield curve. A rule of thumb of sorts has been established in financial markets: long-term rates falling below short-term rates, known as inversion, can be interpreted as a recessionary signal.

Persistent global price pressures and the accompanying decline in private consumption and investment have been casting a shadow over the economic outlook since late 2021. In Europe, high energy prices and the uncertainty they have brought about are also dimming economic prospects. In this context, a flattening of the yield curve observed since the summer of 2022 – not only in Germany but also in other countries inside and outside the euro area – raises the question as to whether this is currently indicative of a looming recession.

On a long-term historical average, the yield curve is sloping upwards. A flattening yield curve may reflect reduced compensation for interest rate risk, but also decreased short-term interest rate expectations.

There can be various reasons for the statistical relationship between the yield curve inverting and a recession occurring. Amongst other things, the prospect of rising inflation may prompt the central bank to raise its policy rates. If, for example, this causes market participants to expect lower inflationary pressures in the medium to long term and an economic slowdown, yields at the short end of the yield curve will see stronger growth than at the long end. However, a flattening of the curve may also

be the result of market participants anticipating a more accommodative monetary policy in the future if, looking ahead, they believe that the central bank could lower policy rates in response to an economic slowdown.¹

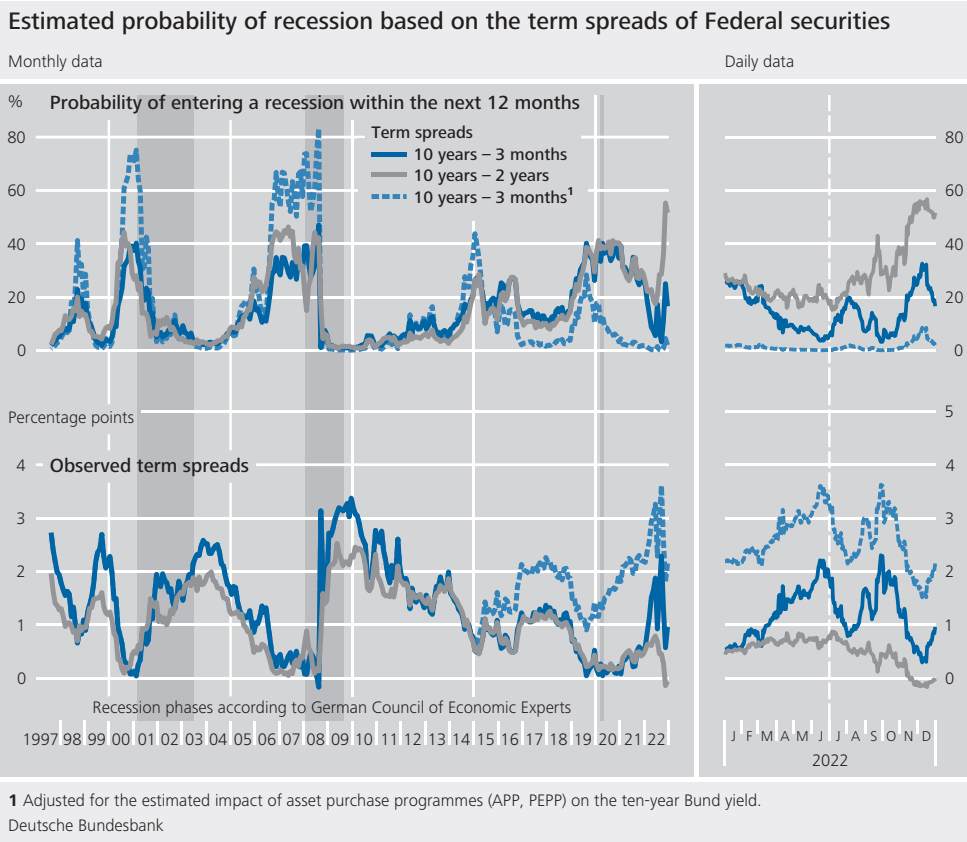
Historically, this relationship between a flattening of the yield curve and an increase in recession risk is clear to see. When short-term yields have risen above long-term yields in the past, a recession has often followed. This pattern has been studied empirically for both Germany and the United States.² In the latter's case, an inversion of the US Treasury yield curve has preceded each of the last eight recessions. A false positive, when an inversion of this yield curve was not followed by a recession in about a year, last occurred in 1966.³

Econometric methods can be used to estimate the probability of a flattening or inversion of the yield curve preceding an economic downturn: specifically, using logistic regression, the slope of the yield curve is assigned a level of probability with which a recession will occur within one year. The slope is measured by the term spread between ten-year and three-month government bond yields (10Y-3M) and the spread between ten-year and two-year yields (10Y-

¹ For a discussion of possible scenarios involving an inversion of the yield curve and practical aspects of estimating probabilities of recession from term spreads, see Estrella and Trubin (2006).

² For references to literature and an earlier study using German data, see Deutsche Bundesbank (2013). Estrella and Mishkin (1998) analyse the performance of the term spread and other financial variables as predictors of US recessions.

³ See Federal Reserve Bank of Cleveland (2022). The website also provides up-to-date estimates of the probability of a US recession.



2Y). In estimates using US data, recessions are usually dated as defined by the NBER. The German Council of Economic Experts uses a similar method to define recession phases for Germany.⁴

In the above chart, these German recession phases are each assigned a probability of recession based on various term spreads. The three recessions that have occurred in Germany since 1997 were each preceded by periods in which the yield curve inverted. The estimate shows recession probabilities of over 40% for these periods, indicating that an inversion is not a sure sign of a looming recession. Instead, an inversion signals a significantly above-average probability of recession compared with periods of larger term spreads.⁵ The probability of recession steadily increases as the term spread decreases. Given the distribution function in the chart on p. 67, a term spread of zero is therefore an arbitrary value that is

assigned a relatively high probability of a future recession.

While, prior to 2022, the recessionary signals from the two measures employed to calculate the slope were similarly clear, their strength has diverged since the start of 2022 due to the maturities the measures use. Based on the 10Y-2Y spread, the probability of recession stood at 52% as at the end of December 2022. This is thus far stronger than the signal from the 10Y-3M spread, which, for that point in time, indicated an only 17% probability of a looming

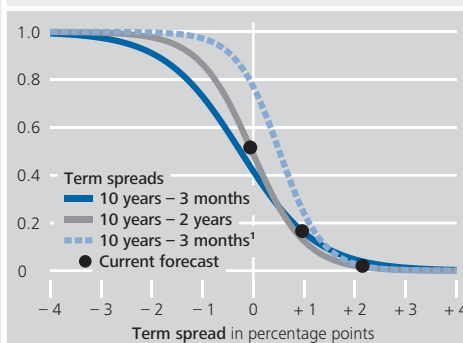
⁴ While the main term spread found in the literature is the 10Y-3M spread, some market participants also make use of the 10Y-2Y spread. For information on dating business cycles, see Breuer et al. (2022). The German Council of Economic Experts publishes and keeps these data up to date on its website.

⁵ Haubrich (2006) reports similar findings for the United States. For a discussion of models used to forecast economic downturns, see Deutsche Bundesbank (2020).

recession.⁶ The technical reason for this discrepancy is the exceptional shape of the yield curve. The slope is very steep, especially in the maturity range of up to two years, before flattening off somewhat in the subsequent medium to long-term maturity range. This maturity-specific difference reflects two things. First, market participants have been expecting the Eurosystem to continue to rapidly normalise monetary policy in view of the medium-term inflation outlook – that is to say, market participants and the Eurosystem have been anticipating inflation rates above the inflation target of 2% over the medium-term forecast horizon. Second, the flat yield curve for medium to longer-term maturities reflects recessionary concerns. As current inflationary pressures are very pronounced, market participants do not currently expect the central bank to react to a deterioration in the economic outlook by cutting policy rates. Monetary policy needs to be tightened to achieve its aim of 2% inflation over the medium term, even if a recession could occur. At the current end, this market view is captured more by the 10Y-2Y spread than by the 10Y-3M spread.⁷ The volatile term spreads of recent months have translated into volatile recession probabilities via the estimated relationship.

Non-standard monetary policy measures have also influenced the steepness of the yield curve in recent years. The asset purchase programme (APP) and the pandemic emergency purchase programme (PEPP) were aimed, in particular, at reducing long-term yields in the capital market. As a result, the term premium fell to historically low and, at times, negative levels.⁸ When term premia are low, even expectations of small interest rate cuts can bring about inversions. From this, the model then tends to derive higher probabilities of recession. The impact of non-standard monetary policy

Distribution of recession probabilities as a function of term spreads



Sources: German Council of Economic Experts and Bundesbank calculations. ¹ Adjusted for the estimated impact of asset purchase programmes (APP, PEPP) on the ten-year Bund yield. Deutsche Bundesbank

measures of this kind on long-term yields is not directly measurable. However, it can be estimated using structural models. The first step is to determine the impact of the two purchase programmes, which have been running since 2015, on the ten-year Bund yield. The various term spreads that are

⁶ Bauer and Mertens (2022) discuss a similar pattern for the US yield curve.

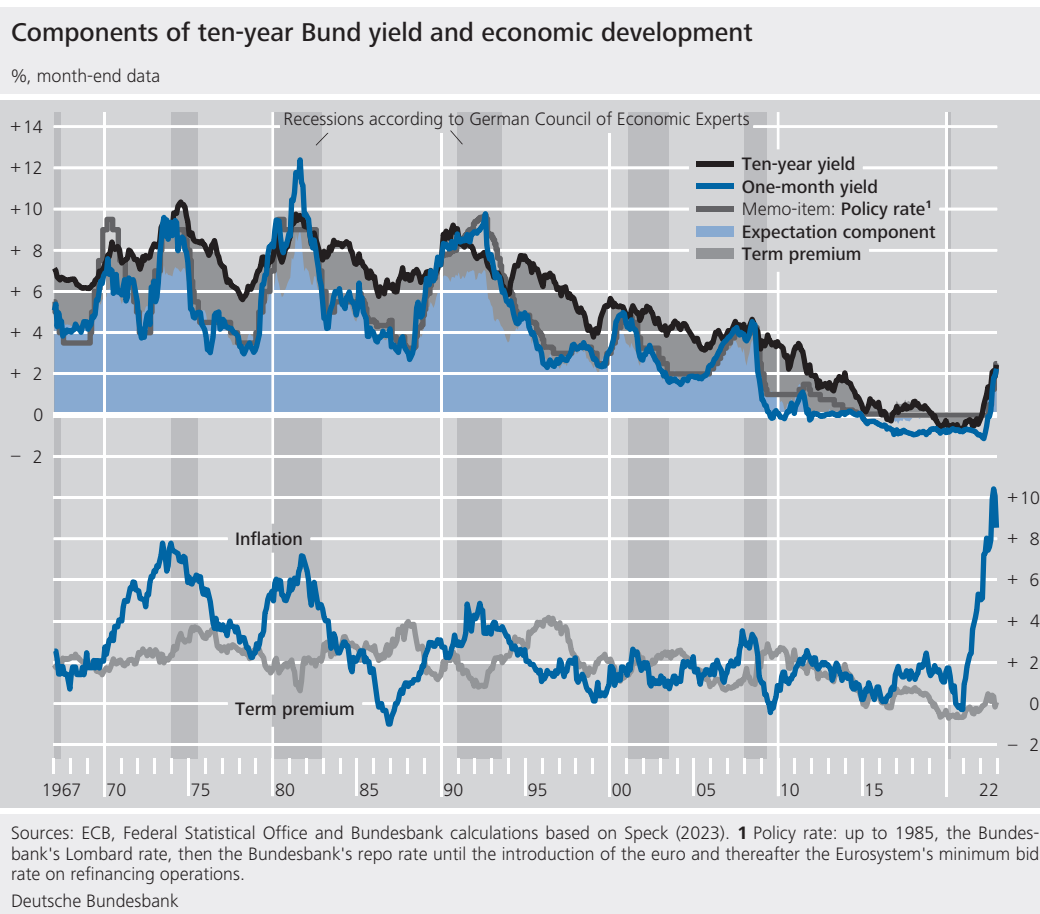
⁷ In recent months, the gap between the two term spreads has revealed the market developments to which investors have been paying particular attention. In the summer of 2022, recessionary concerns prevailed. Markets were expecting monetary policy to move away from its original tightening path. As a result, the short end of the yield curve flattened significantly between June and August, bringing the two term spreads back closer together. The probability of recession calculated from the 10Y-3M term spread therefore also increased significantly for a time during these months.

⁸ The purchase programmes have contributed to lower long-term yields via the expectations component, but above all via the term premium; see Deutsche Bundesbank (2016).

then used in the recession estimates are adjusted for this effect.⁹

The impact of this adjustment on the probability of recession is particularly evident for 2020 and 2021, the years shaped by the pandemic. While the unadjusted term spreads foresaw a significantly higher risk of recession for the entire period, the probability of a recession fell rapidly after the outbreak of the pandemic in the spring of 2020 in the case of the adjusted 10Y-3M term spread. Since the Eurosystem had a major impact on long-term government bond yields through its purchases under the PEPP (and the continuation of the APP at the same time), the probability of recession is significantly higher over this period based on the unadjusted term spreads. Adjustment eliminates any potential “false signals”, though it does come with its own specific limitations. For example, this approach cannot account for whether market participants expect adjustments to the purchase programmes. This becomes evident in the second half of 2014, when expectations about the upcoming launch of the APP led to a significant drop in longer-term yields even before any actual decision was made regarding the programme. As these effects are not captured, the adjusted term spread also assesses the risk of recession in 2014 as high. A similar effect could also materialise at present. Changes in market participants’ expectations about an earlier reduction in the Eurosystem’s securities holdings from 2023 are already reducing the dampening effect of the securities holdings on long-term interest rates. At the current end, therefore, probabilities of recession based on the adjusted term spread tend to be deemed as lower.

⁹ Specifically, the Eurosystem’s bond purchases under the APP and PEPP are modelled in the DSGE model of Kühl (2018). With the announcement of each purchase programme, agents internalise the future course of those programmes, but adjust their expectations with each calibration of the programmes. The model allows for the calculation of what are known as duration extraction effects, which are regarded as one of the main channels for the impact of bond purchases on yields (see, for example, Krishnamurthy and Vissing-Jorgensen (2012)). Expectations about possible adjustments to the purchase programmes or other possible effects of such programmes (such as signalling effects) are not taken into account. Only the term spread between the ten-year and three-month yields is adjusted for the effect of the purchase programmes. The reason for this is that the three-month yield is influenced more by the policy rate than by purchase programmes, and an adjustment of the ten-year yield is therefore sufficient. For the term spread between the ten-year and two-year yields, both maturities would have had to be adjusted, which is not possible using the Kühl (2018) model.



Development of yield curve before recessions

that short-term yields have sometimes exceeded long-term yields. The slope of the yield curve was thus a summary of expectations regarding the degree of monetary policy restriction and, with that in mind, cyclical risk (for information on the indicator function of the yield curve for future recessions, see the box on pp. 65 ff.). At the current end, it signals a fairly high probability of recession by historical standards. However, it should be noted when interpreting the situation that the level of the derived probability does not necessarily provide an indication of the severity or duration of a possible recession.

Term premia up after oil crises

Another historical pattern is the evolution of the term premium over the business cycle. The nominal term premium, which includes the inflation risk premium, increased worldwide with a time lag in the 1970s as a result of the oil price shocks. The reason for this was that the degree by which the monetary policy stance was restricted in the major currency areas was

not sufficient at that time to quickly stabilise the inflation process. While central banks did also raise policy rates in the 1970s – in some cases significantly – in view of soaring inflation rates,²⁴ inflation and interest rate volatility were strong. The associated uncertainty was accompanied by rising inflation risk premia globally. Only a few central banks, such as the Bundesbank and the Swiss National Bank, were able – with greater emphasis on rules-based conduct geared towards price stability – to curb inflation and the inflation risk premium somewhat more strongly. On the whole, however, this inflation uncertainty, and thus the nominal term premium, remained comparatively high – even after inflation was successfully reined in in the 1980s.

At present, the term premium and the inflation risk premium are at a rising, but historically still

²⁴ See Lubik and Schorheide (2004), Pflueger (2022) and Enders et al. (2022).

Currently, term premia are still historically low

very low, level. For example, the nominal term premium on ten-year Bunds since 1967 has averaged around 190 basis points, whereas it stood at just under 10 basis points as at the end of December 2022. The Eurosystem's duration extraction via the monetary policy purchase programmes described in the previous sections as well as the incipient securities scarcity were the two main factors to push the term premium to this low level. This has caused potential for setbacks to build up.

Stability-oriented monetary policy guarantees low term premia

The historical co-movement of inflation and the term premium is a warning sign for European monetary policy. Experience gained over the past few decades with supply shocks has shown that, even after successful disinflation, as in the 1980s, the term premium – once it has risen – initially remains at a high level.²⁵ The fight against inflation must therefore be made top priority in order to ensure that the credibility of monetary policy remains intact.²⁶ Otherwise, there is a risk of market participants' uncertainty about inflation developments translating into a de-anchoring of inflation expectations in the medium and long term.

■ Summary

Yield curve as a valuable source of information for monetary policy

The yield curve contains valuable and up-to-date information for monetary policy. It reflects economic developments and the impact of monetary policy measures. This article discusses how the Bundesbank uses this information with the aid of numerous term structure models. In the current environment of persistently high inflation, the analyses show that

market participants expect further policy rate hikes. In addition, since the end of active net asset purchases and the reduction of the monetary policy securities portfolio announced in December 2022, the impact of asset purchase programmes on interest rates has been gradually declining. This was recently reflected in rising nominal term premia, which came under additional upward pressure in the context of very high inflation and cyclical risk.

However, yields on Federal securities also include liquidity premia, which make it more difficult to interpret changes in interest rates as a mirror of expectations surrounding economic developments. In practice, regulatory and institutional factors also influence the level and course of yields on Federal securities and their components.

In the past, nominal term premia have risen in particular when, faced with a supply-driven rise in inflation, market participants doubted the central bank's determination to combat inflation. A monetary policy that is consistently geared to the inflation target can ensure that inflation expectations do not become de-anchored in view of the current high level of inflation uncertainty. This also reduces the risk of higher interest rates resulting from permanently increased risk premia.

Market-specific influences on bond yields

Inflation risk premia can only be kept low by means of credible monetary policy

²⁵ Deutsche Bundesbank (2022d) suggests that the latest energy price hikes are even more supply-driven than in the 1970s.

²⁶ Palomino (2012) shows that a credible, time-consistent monetary policy can reduce the inflation risk premium more strongly than a discretionary monetary policy strategy with a lower emphasis on the inflation rate over the business cycle.

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