Monetary policy indicators at the lower bound based on term structure models

Making appropriate monetary policy decisions is predicated on reliable information about the monetary policy stance. To this end, monetary policy indicators measure the extent to which monetary policy is expansionary or restrictive and form the basis for analyses examining the effect of monetary policy on the real economy and inflation. A short-term interest rate is typically used here as it serves as the starting point for policy rates.

However, in response to the financial and sovereign debt crisis, the Eurosystem set out to preserve price stability not only by cutting policy rates but also by adopting a set of expansionary non-standard measures. As increasing use was made of these unconventional measures, the informative value of the short-term interest rate as a monetary policy indicator diminished over time and led to a growing need for alternative indicators. This applies to the monetary policy asset purchase programmes, in particular, as they are aiming to lower longer-term interest rates now that the lower bound on short-term interest rates has been reached.

Monetary policy indicators that take into account such measures can, in principle, be calculated using term structure data in conjunction with appropriate theoretical models. Examples from the latest research are the "shadow short rate", the "crossing time" and the "effective monetary stimulus". They are presented in this article and discussed with respect to their information content and benefit to monetary policymakers. All in all, it is clear that deriving and estimating these indicators is fraught with a high degree of uncertainty. Nevertheless, all individual indicators suggest that the measures undertaken by the Eurosystem have enabled it to achieve an even more accommodative monetary policy stance.

Although monetary policy indicators are used to evaluate the monetary policy stance, it is impossible to establish by means of these indicators alone whether this monetary policy stance is appropriate. In view of this, the Eurosystem's monetary policy strategy takes into account a number of economic, price, credit and financial indicators that can be interpreted in terms of their implications for the medium-term inflation outlook and that ultimately make it possible to gauge the appropriateness of the monetary policy stance.

Introduction

Eurosystem responses to the financial and sovereign debt crisis

In response to the financial and sovereign debt crisis, the Eurosystem has, since 2007, set out to preserve price stability not only by cutting policy rates but also by adopting a set of non-standard measures designed to counteract the negative impact on the financial system and macroeconomic developments. Prior to June 2014, the primary objective of these measures was to safeguard the functioning of the monetary policy transmission process; however, given the subdued medium-term inflation outlook and with market-based inflation expectations falling, the Eurosystem subsequently made further cuts to monetary policy rates and undertook a series of further non-standard measures with the explicit aim of achieving an even more accommodative monetary policy stance.[1]

Targeted longer-term refinancing operations and asset purchase programmes since June 2014

These measures included the launch of two series of targeted longer-term refinancing operations (TLTROs), the asset-backed securities purchase programme (ABSPP) and the third covered bond purchase programme (CBPP3), as well as the launch of the expanded asset purchase programme (APP) in January 2015. The last of these includes not only the pre-existing ABSPP and CBPP3 but also the subsequently launched corporate sector purchase programme (CSPP) and the public sector purchase programme (PSPP), the most significant programme in terms of purchase volume. In December 2016, the ECB Governing Council decided to continue conducting asset purchases under the APP until December 2017, or beyond, if necessary, and in any case until the Governing Council saw a sustained adjustment in the path of inflation consistent with its inflation target. In doing so, its aim is to achieve inflation rates below, but close to, 2% over the medium term.

Measuring monetary policy stance challenging in view of large number of non-standard measures

It is crucial for monetary policymakers to be able to assess the impact of their measures on an ongoing basis and thus gauge the appropriateness of the monetary policy stance. For this purpose, they need to be able to measure the monetary policy stance in as close to real time as possible. Prior to the financial crisis, this was reflected fairly well in short-term interest rates. Furthermore, in order to assess appropriateness, changes in short-term interest rates were interpreted together with additional economic, price, credit and financial indicators with respect to their implications for the medium-term inflation outlook. However, a landscape in which non-standard monetary policy measures feature heavily makes measuring the monetary policy stance a far more challenging task. This is especially true if monetary policymakers find themselves at the lower bound and therefore move away from changing policy rates, focusing instead on employing unconventional measures in an attempt to shift the monetary policy stance.

This article presents a selection of alternative indicators for measuring the monetary policy stance and discusses their respective strengths and weaknesses. Given the key role played by long-term interest rates in monetary policy transmission and the focus of significant non-standard monetary policy measures on longer-term interest rates, the indicators presented here are based on term structure information – in other words, on interest data at differing maturity dates. Building on this, this article reveals the extent to which, in the context of the measures adopted by the Eurosystem in the low-interest-rate environment, these indicators signal a change in the monetary policy stance over time.

Measuring the monetary policy stance at the lower bound

First, central banks with mandates to preserve price stability need indicators that provide in-

1 See Deutsche Bundesbank, The macroeconomic impact of quantitative easing in the euro area, Monthly Report, June 2016, pp 29-53.

Eurosystem's monetary policy strategy based on broad analyses assessing medium-term inflation outlook

formation on the future path of the inflation rate if they are to assess the current monetary policy situation. Given the long and varying time lags in monetary policy and incomplete knowledge of potential changes in structural relationships in an economy, this information (and what it means for price developments) is particularly uncertain. The Eurosystem's monetary policy strategy therefore focuses on broad-based analyses of the inflation outlook and incorporates a number of economic, price, credit and financial indicators that can be interpreted in terms of their implications for the medium-term inflation outlook.

Short-term interest rate was a highly informative indicator before crisis erupted, …

Second, central banks need indicators that enable them to directly assess the impact of their policies. It is typically assumed that there is a close link between the use of monetary policy instruments and general financing conditions, as well as a link between the latter and economic developments.[2] In simplified terms, monetary policymakers signal a change in the monetary policy stance by revising policy rates. In doing so, they steer current short-term interest rates and shape expectations about how they will move in future. This, in turn, has an impact on long-term interest rate developments and, as a result of changes in general financing conditions, the macroeconomic environment and loan dynamics, too. As a result, the short-term interest rate is usually considered a sufficiently informative indicator for measuring the monetary policy stance and therefore typically has broad theoretical and empirical applications in the analysis of monetary policy effects.[3]

… but informative content has diminished over time due to increasing use of non-standard measures

Against the backdrop of the financial and sovereign debt crisis, the informative value of the short-term interest rate as a monetary policy indicator has diminished. This was caused, in particular, by using non-standard monetary policy measures in an environment in which the scope for further policy rate cuts became increasingly constrained by the lower bound. For instance, some of the unconventional measures aim to shape the expected path of short-term interest rates, reduce the maturity, credit risk or liquidity risk premiums priced into longer-term interest rates or even improve banks' financing situation by means of targeted long-term refinancing operations, thereby raising the credit supply.

Need for alternative monetary policy indicators

The PSPP's specific objective is to reduce yields on long-term bonds by lowering the term premiums demanded by market participants for assuming interest rate risk ("duration channel").[4] Going beyond that, the Eurosystem is announcing and conducting asset purchases with the expectation that market participants will regard these moves as an indication – in addition to forward guidance regarding the future policy rate path – that the Eurosystem plans to maintain its accommodative monetary policy stance and, in particular, low short-term interest rates for a prolonged period ("signalling channel").

2 For a comprehensive overview of monetary policy transmission, particularly via the exchange rate channel, see Deutsche Bundesbank (2016), op cit, p 35; Deutsche Bundesbank, The role of banks, non-banks and the central bank in the money creation process, Monthly Report, April 2017, p 24; and Deutsche Bundesbank, The Eurosystem's bond purchases and the exchange rate of the euro, Monthly Report, January 2017, pp 13-39.

3 See M Woodford (2003), Interest and prices, New York: Princeton University Press; F Smets and R Wouters (2003), An estimated dynamic stochastic general equilibrium model of the euro area, Journal of the European Economic Association 1, pp 1123-1175; L J Christiano, M Eichenbaum and C L Evans (2005), Nominal rigidities and the dynamic effects of a shock to monetary policy, Journal of Political Economy 113, pp 1-45. In addition, the short-term interest rate is often compared in its capacity as a monetary policy indicator to selected reference values in order to roughly assess the appropriateness of the monetary policy stance. See J Taylor (1993), Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy 39, pp 195-214; Deutsche Bundesbank, Taylor interest rate and Monetary Conditions Index, Monthly Report, April 1999, pp 47-63; T Laubach and J Williams (2003), Measuring the natural rate of interest, Review of Economics and Statistics 85, pp 1063-1070; and A A Weber, W Lemke and A Worms (2008), How useful is the concept of the natural real rate of interest for monetary policy?, Cambridge Journal of Economics 32, pp 49-63.

4 For a detailed discussion on the impact of quantitative easing and for further reading, see Deutsche Bundesbank (2016), op cit.

Term structure modelling at the lower bound

Analysing impact of monetary policy measures along entire yield curve …

Analysing interest rate movements along the yield curve provides valuable information on the impact of monetary policy measures. Using term structure models, it is possible to investigate how policy rate changes and unconventional measures targeting the entire yield curve affect interest rates for different maturities. The models can provide information on the extent to which observed interest rates are shaped by market participants' actual interest rate expectations and what proportion of interest constitutes compensation for taking risk.[5] In particular, it is possible to use term structure models to measure the monetary policy stance by condensing information derived from interest movements into individual indicators, thereby consolidating it.

… using term structure models

Even prior to moving into this phase of low interest rates, affine – ie linear – term structure models had been widely established as a standard model for yield curve analysis at many central banks.[6] These models describe the dynamics of the yield curve under the condition of no arbitrage[7] using several factors that, in principle, cannot be observed. These "latent factors" are not precisely set out in economic terms; in other words, it is not possible to exactly determine the economic context in which they are linked to the term structure. However, they must possess certain statistical properties (and it is often possible to draw conclusions about economic relationships in retrospect based on the pattern they follow over time).[8] Using these latent factors, it is possible to describe the yield curve very precisely, with two to three such factors usually proving sufficient for this purpose. The variation of interest rates for different maturities is consolidated into several factors by means of statistical procedures and put to use in term structure model estimates. In this context, interest rates are affine functions of these factors – that is to say, they are assumed to be in a linear relationship with them. Interest rate expectations can be generated by forecasting factors.

Affine term structure models can only describe course of short-term interest rate to a limited extent in a low-interest-rate environment

Given the assumption of linearity, affine term structure models implicitly assume that interest rates and interest rate expectations can, in principle, be negative to any possible extent. The lower bound therefore constitutes a problem for this type of term structure modelling since the actual course of interest rates calls this linearity assumption into question. In addition, due to the fact that interest expectations can adopt values below the lower bound, this has implications for the modelling of expectations regarding future interest rate movements. Furthermore, it is assumed in affine models that interest rate volatility is constant over time. At the lower bound, however, short-term interest rates, in particular, are likely to remain at that level and thus be less variable than in phases in which the interest rates are clearly above the lower bound.[9]

Explicit consideration of an effective lower bound

Against this background, the use of lower bound models to analyse interest rate dynamics along the maturity spectrum has become increasingly widespread in recent years. This model class takes account of the behaviour of

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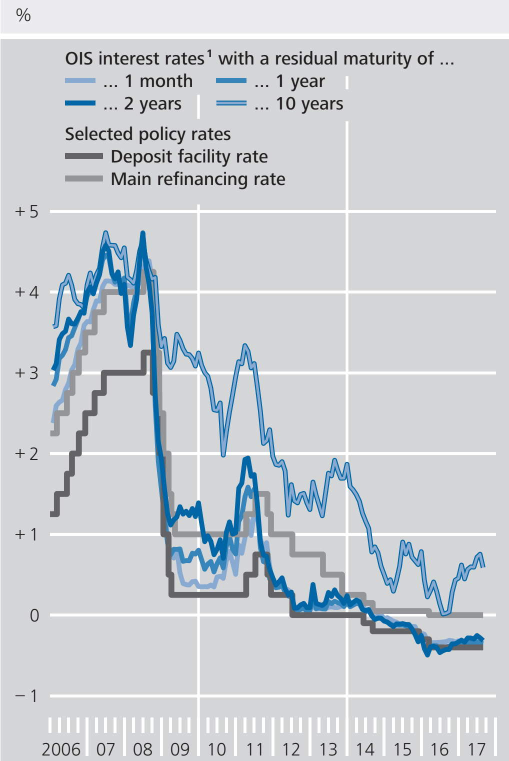
5 Depending on the type of security, risk premiums are demanded to cover, in particular, the risk of an unexpected change in future short-term interest rates and unexpected inflation developments, but also the risk of a payment default or inability to sell quickly in the event of declining market liquidity.
6 See Deutsche Bundesbank, Determinants of the term structure of interest rates – approaches to combining arbitrage-free models and monetary macroeconomics, Monthly Report, April 2006, pp 15-28; DH Kim and JH Wright (2005), An arbitrage-free three-factor term structure model and the recent behavior of long-term yields and distant-horizon forward rates, Federal Reserve System Finance and Economics Discussion Series 2005-33; and T Adrian, RK Crump and E Moench (2013), Pricing the term structure with linear regressions, Journal of Financial Economics 110, pp 110-138.
7 The condition of no arbitrage means that holding portfolios with identical cash outflows but different bond positions allows no room for risk-free profits.
8 From a statistical point of view, these factors can be interpreted as level, steepness and curvature factors. See R Litterman and J Scheinkman (1991), Common factors affecting bond returns, Journal of Fixed Income, 1, pp 54-61.
9 See L Krippner (2015), Zero lower bound term structure modeling: a practitioner's guide, New York: Palgrave Macmillan US.

short-term interest rates in a low-interest-rate environment outlined above by introducing a shadow short rate and a lower bound (see the box on pages 18 to 22 and further information on page 24 ff).[10] It is assumed that the shadow short rate corresponds to the short-term interest rate that is actually observed, provided the latter is above the lower bound.[11] If the short-term interest rate remains at the lower bound, the shadow short rate falls below it as per its linear relationship with the statistical factors. The expected path of short-term interest rates therefore also depends on the probability of the expected shadow rate lying above or below the lower bound. Accordingly, the distribution of possible realisations of the expected short-term interest rate is restricted to values above the lower bound, which is key to the plausible modelling of interest rate expectations at the lower bound. As a result, the lower bound affects the distribution of future potential interest rate realisations well before the lower bound is actually reached. This effect is amplified as interest rate expectations converge towards this lower bound.

Selected euro area interest rates



Sources: Bloomberg and Bundesbank calculations. **1** Month-end figures.
Deutsche Bundesbank

OIS interest rates as risk-free benchmark rates in the euro area

The adjacent chart shows recent interest rate movements in the euro area based on the overnight index swap (OIS) yield curve.[12] OIS interest rates are based on swap contracts in which two parties agree to exchange a fixed interest rate for a series of floating rates. These floating rates are indexed to the EONIA rate.[13] As only the interest payments linked to a nominal amount that is to be determined are exchanged at the end of the contract, OIS contracts usually bear very little or no counterparty risk. Due to this characteristic, the contracts are not used as a store of value, which means that their prices cannot even be driven by flight to quality in favour of very safe and liquid forms of investment in times of crisis – a move that can, for instance, be observed in the prices of government bonds, which are considered safe havens. Above all, however, one side of the contract, namely the variable interest rate, is closely linked to the Eurosystem's policy rates, as the EONIA closely tracks the main refinancing rate in normal times and the deposit facility in times of high levels of excess liquidity.[14] This means that the OIS yield curve contains largely unbiased information about expectations priced in along the term structure regarding future monetary policy measures.

10 The concept of the shadow rate dates back to F Black (1995), Interest rates as options, Journal of Finance 50, pp 1371-1376. To see how this concept is transposed into a term structure model, see D H Kim and K J Singleton (2012), Term structure models and the zero bound, Journal of Econometrics 170, pp 32-49; J H Christensen and G D Rudebusch (2015), Estimating shadow-rate term structure models with near-zero yields, Journal of Financial Econometrics 13, pp 226-259; and L Krippner (2015), op cit.
11 The (shadow) short rate considered here has a maturity of one month. Shadow rates can be derived for all maturities.
12 Due to OIS rates not being available prior to July 2005, EURIBOR swap rates are used for the period from January 1999 to June 2005.
13 The EONIA is a reference rate for the euro interbank overnight market calculated on the basis of actual transactions.
14 See European Central Bank, Euro area risk-free interest rates: measurement issues, recent developments and relevance to monetary policy, Monthly Bulletin, July 2014, pp 63-77.

A lower bound model for the euro area including survey data

In order to model the term structure in an environment of remarkably low interest rates close to zero, lower bound models have become established as extensions of Gaussian affine multifactor models.[1] Lower bound models make it possible to model the path of the short-term interest rate in such a way that it does not fall below a prescribed lower bound.

Similarly to the various Gaussian models, lower bound models assume that, on condition of no arbitrage, the dynamics of the term structure can be described using several influencing variables (unobservable or observable), which are stacked as "factors" in the vector X_t and follow a linear vector autoregressive law of motion. Two different probability measures are assumed for this law of motion in the model: the risk-neutral probability measure Q and its counterpart, the historical probability measure P, which generates the actual variation in interest rates.[2]

When using the risk-neutral probability measure,

$$X_t = \mu^Q + \phi^Q X_{t-1} + \Sigma\epsilon_t, \quad (1)$$

applies, where ϵ_t is a standard normal distributed (Gaussian) error term, μ is a constant, ϕ is a matrix that describes the correlation of the factors with their own past values, and Σ is a parameter matrix which determines the dispersion of the error terms. Under the historical probability measure, the factors follow the law of motion

$$X_t = \mu^P + \phi^P X_{t-1} + \Sigma\epsilon_t. \quad (2)$$

The short-term one-period shadow short rate, si_t, is an affine – ie linear – function of these very factors, for which

$$si_t = \delta_0 + \delta_1' X_t. \quad (3)$$

applies. The observable short-term interest rate $i_{1,t}$ corresponds to this shadow interest rate, as long as the shadow short rate lies above the (potentially time-varying) lower bound lb_t. If it falls below this bound, the observable short-term interest rate is equal to the lower bound:

$$i_{1,t} = max(si_t, lb_t). \quad (4)$$

The non-linear link between the short-term interest rate and the shadow short rate in equation (4) is used to ensure that the short-term interest rate is not able to fall below the lower bound. At the same time, the expected path of the short-term interest rate can be shown to remain at this lower bound for an extended period of time, provided that the shadow interest rate is expected to fall below this bound over a longer period of time (see the chart of the estimation results on page 21). The expected path of the observable short-term interest

1 See DH Kim und KJ Singleton (2012), Term structure models and the zero bound, Journal of Econometrics 170, pp 32-49; L Krippner (2015), Zero lower bound term structure modeling: A practitioner's guide, New York: Palgrave Macmillan US; JHE Christensen and GD Rudebusch (2015), Estimating shadow-rate term structure models with near-zero yields, Journal of Financial Econometrics 13, pp 226-259. For an overview of the class of Gaussian multifactor models, see the box in Deutsche Bundesbank, Gaussian affine multifactor term structure models, Monthly Report, July 2013, pp 43-44.
2 When pricing securities, investors under or overweight certain future scenarios depending on their attitude towards risk, meaning that different dynamics of factors are assumed when determining securities prices (Q measure). The difference between the dynamics of the Q and P measures thus describes the dynamic of the forward premiums.

rates therefore depends on the probability of the expected shadow interest rate lying above or below the lower bound. The expected short-term interest rates follow a truncated distribution accordingly, restricted by the lower bound.[3] Spot rates with maturity n result from a non-linear function depending on the factors X_t together with the function terms of the equations (1), (3) and (4)

$$i_{n,t} = g_n(X_t; \mu^Q, \phi^Q, \Sigma, \delta_0, \delta_1, lb_t). \qquad (5)$$

Although this function does not have an analytical solution, interest rates can be determined using an approximation of the implied one-period forward rates.[4] They then represent the average of the implied forward rates

$$i_{n,t} \approx \frac{1}{n} \sum_{h=0}^{n} f_{h,t}. \qquad (6)$$

Term and forward premiums are the difference between the spot interest rates or forward rates derived from the model, calculated in each case using the coefficients estimated under the risk-neutral and historical probability measures.

This box presents the estimated results of such a lower bound model for the euro area.[5] The model is specified using three latent factors and uses monthly OIS rates based on the EONIA rate, with a residual maturity of between one month and ten years, for the period from January 1999 to August 2017. The path of the lower bound is directly prescribed for the model in the form of the path of the Eurosystem's deposit facility rate.[6]

To be able to identify more precisely the model parameters under the historical probability measure used to determine the model-implied interest rate expectations and the long-term interest rate level, additional survey-based interest rate forecasts are taken into account in this specification.[7] For this purpose, the model-implied interest rate forecasts are matched with survey data of concurring maturities and augmented with a measurement error between the two variables, which means that, although a certain convergence of interest rate forecasts from the model and the surveys is

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3 The conditional expected value of the short-term interest rate in $t+n$ periods is defined as
$E_t^P[i_{1,t+n}] = lb_t + \sigma_n^P d\left((E_t^P[si_{t+n}] - lb_t)/\sigma_n^P\right)$,
for which $d(x) = x\emptyset(x) + \Phi(x)$, $\emptyset(x)$ is the functional value of the distribution function of the standard normal distribution, and $\Phi(x)$ represents the functional value of the density function of the standard normal distribution. Here, $E_t^P[si_{t+n}]$ is the conditional expected value of the shadow interest rate and σ_n^P is the corresponding standard deviation.

4 The one-period forward rate in h periods can be approximated as $f_{h,t} \approx lb_t + \sigma_n^Q d\left((sf_{h,t} - lb_t)/\sigma_n^Q\right)$. The notations correspond to the remarks in footnote 3. $sf_{h.t}$ is the shadow forward rate, while σ_n^Q represents the corresponding standard deviation. See CJ Wu and FDN Xia (2016), Measuring the macroeconomic impact of monetary policy at the zero lower bound, Journal of Money, Credit and Banking 48, pp 253-291, and L Krippner (2015), op cit.

5 For detailed information, see F Geiger and F Schupp (2017), Euro area term structure decompositions and expected short rate paths – robustness and economic plausibility, mimeo. To this end, the model is converted to a non-linear state space model and estimated using the extended Kalman filter under a maximum likelihood approach.

6 For more information, see also W Lemke and AL Vladu (2016), Below the zero lower bound – a shadow-rate term structure model for the euro area, Deutsche Bundesbank Discussion Paper, No 32/2016. For alternative lower bound specifications for the euro area, see also T Kortela (2016), A shadow rate model with time-varying lower bound of interest rates, Bank of Finland Research Discussion Paper 19, and CJ Wu and FDN Xia (2017), Time-varying lower bound of interest rates in Europe, Chicago Booth Research Paper 17-06.

7 See DH Kim and A Orphanides (2012), Term structure estimation with survey data on interest rate forecasts, Journal of Financial Quantitative Analysis, 47, pp 241-272, and M Priebsch (2013), Computing arbitrage-free yields in multi-factor Gaussian shadow-rate term structure models, Finance and Economic Discussion Series, Board of Governors of the Federal Reserve System 2013-63.

guaranteed, this does not have to be complete:[8]

$$E_t^P[i_{n,t+j}] = i_{n,t+j}^{Survey} + v_t. \qquad (7)$$

The motivation for incorporating survey data is the finding from the literature that the models are often estimated with data sets that cover too narrow an observation period to sufficiently determine the actual variation of interest rates, measured against the very high persistence of interest rates with few interest rate cycles. This can sometimes produce the estimated results for the medium and long maturities, according to which the change in interest rates can be almost exclusively attributed to changes in the term premiums, while the long-term interest rate expectations move only marginally.[9] At the same time, very little information about the long-term level of the expected short-term interest rate is provided for a model estimated using a data set characterised by a persisting period of low interest rates close to the lower bound as well as low volatility, as is the case in the euro area.[10] If, on the other hand, interest rate expectations are linked to the survey data, the model is able to use this additional information to describe the expected interest rate changes more precisely. With this in mind, the estimates incorporate both short and long-term survey-based interest rate forecasts.[11]

The chart on page 21 depicts the model-generated path of the short-term interest rate in March 2016 and in August 2017. For the first of the two dates, it can be seen that the expected shadow short rate was markedly negative until July 2019 due to the (expected) persistence of factors, but the short-term interest rate path remained constrained by the lower bound due to the truncated distribution characteristic. Therefore the asymmetry of the distribution of the short-term interest rate also becomes apparent, as its most likely path (modal path) has remained significantly below its expected path. As a result, market participants consider the most likely outcome to be that the short-term interest rate will remain at the lower bound for over 2.5 years before gradually increasing. The path of the short-term interest rate in August 2017 is compatible with an interest rate path scenario in which the December 2016 decision of the Governing Council of the ECB will be fully implemented, followed by a subsequent tapering phase, and in which, in line with forward guidance, the deposit facility rate will only subsequently be raised. The model estimations imply that the short-term interest rate will remain at the lower bound for just over another 1.7 years before experiencing a gradual increase.

8 Survey-based expectations are only an approximate reflection of market price expectations. On the one hand, this may be due to the low number of survey participants; on the other hand, though, it may be explained by the potential variations in the information available to participants and the point in time at which they submit their answers. Alternatively, therefore, it can be assumed that the subjective expectations of survey participants deviate from the objective statistical expectations held under the historical probability measure P. For more information, see also M Piazzesi, J Salamao and M Schneider (2015), Trend and cycles in bond premia, mimeo, and M Chernov and P Mueller (2012), The term structure of inflation expectations, Journal of Financial Economics, 106, pp 367-394.
9 See M D Bauer, G D Rudebusch and C J Wu (2012), Correcting estimation bias in dynamic term structure models, Journal of Business and Economic Statistics 30, pp 454-467, and G R Duffee and R H Stanton (2012), Estimation of dynamic term structure models, Quarterly Journal of Finance 2, pp 1-51.
10 Monte Carlo analyses of simulated data sets show that the unconditional expected value of the short-term interest rate is estimated to be too low in the very data sets which are characterised by a protracted period of low interest rates, resulting in long-term interest rate expectations falling short and excessively high risk premiums. See also F Geiger and F Schupp (2017), op cit.
11 The data pool comprises interest rate forecasts by Consensus Economics. Survey-based interest rate forecasts for term structure models applied to the euro area are used by J-P Renne (2017), A model of the euro area yield curve with discrete policy rates, Studies in Nonlinear Dynamics & Econometrics, 21, pp 99-116, and P Hördahl and O Tristani (2014), Inflation risk premia in the US and the euro area, International Journal of Central Banking, 10, pp 1-47.

With regard to the longer-term maturity segment, the chart on page 22 shows the model-generated decomposition of the five-year, five-year forward rate into the average path of the expected short-term interest rates and forward premium components. A high degree of the variability of the forward rate can be explained by the change in the forward premium,[12] which can be seen in particular to have declined markedly in the wake of the "Greenspan conundrum"[13] between June 2004 and June 2006 and again in anticipation of widespread asset purchases since the beginning of 2014, and to have remained negative since then.

However, the longer-term model-implied interest rate expectations have also proven to be time-varying, and have tended to be lower since the height of the financial and economic crisis in 2008. In order to be able to pass judgment on the economic plausibility of the level and the variability of the expected short-term interest rates in the longer-term forward rates (and therefore also on the forward premiums, indirectly), it may be advisable to perform a comparison of the expectations component with an equilibrium nominal short-term interest rate in the medium to long term derived from a macroeconomic model. The interest rate expectations contained in the financial market prices at the long end of the term structure should position themselves at this level if it is assumed that the term structure reflects macroeconomic information, particularly with regard to long-term inflation expectations and the equilibrium real interest rate. The latter is determined by estimating a natural rate of interest which is consistent in the longer term with a permanently closed output gap and a stable inflation rate following the easing of all cyclical fluctuations.[14]

Model-implied paths of short-term interest rates

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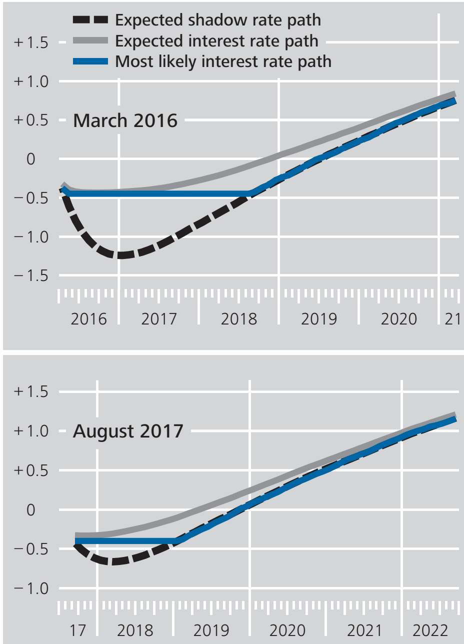
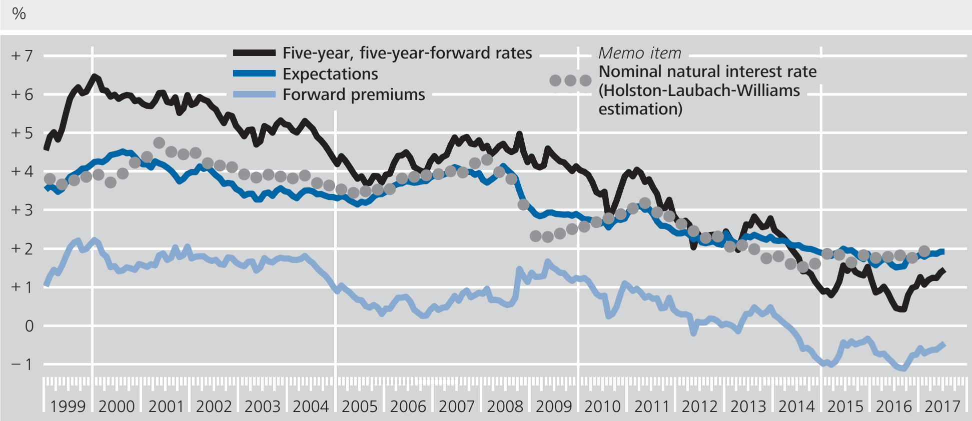


Sources: Bloomberg, Consensus Economics and Bundesbank calculations based on F Geiger and F Schupp (2017).
Deutsche Bundesbank

12 See also R K Crump, S Eusepi and E Moench (2017), The term structure of expectations and bond yields, Federal Reserve Bank of New York Staff Reports, No 775. The authors use all available survey data for interest, inflation and economic developments in the United States, and come to the conclusion that most of the variation in interest rates is driven by changes in the term premiums. Macroeconomic demand shocks, in particular, may explain the development of term premiums.
13 This "conundrum" was referred to in a speech by former US Fed chairman Alan Greenspan, in order to illustrate the apparent breakdown of the conventional relationship between short-term and long-term interest rates in the United States during the period of increasing interest rates between 2004 and 2006. The increases in the federal funds rate were not initially transmitted to the long-term interest rates, which even declined slightly. For an account of this phenomenon, see Deutsche Bundesbank, Globalisation and monetary policy, Monthly Report, October 2007, p 29.
14 See K Holston, T Laubach and J Williams (2017), Measuring the natural rate of interest: International trends and determinants, Journal of International Economics, 108, Supplement 1, pp 59-75. The maturity perspective of the derived natural rate of interest in this model estimation is not explicitly defined, but refers to a longer-term perspective due to the modelling strategy and the definition of the latent variable and shock processes: "Our definition takes a 'longer-run' perspective, in that it refers to the level of real interest rates expected to prevail, say, five to 10 years in the future, after the economy has emerged from any cyclical fluctuations and is expanding at its trend rate". See T Laubach and J C Williams (2016), Measuring the natural rate of interest redux, Business Economics, 41, pp 57-67.

Decomposition of five-year, five-year-forward rates



Sources: Bloomberg, Consensus Economics and Bundesbank calculations based on F Geiger and F Schupp (2017) and K Holston, T Laubach and J Williams (2017).
Deutsche Bundesbank

Indeed, the longer-term interest rate expectations derived from the lower bound model capture the level and path of the nominal natural interest rate rather well, the latter in the period under review being primarily driven by the real natural interest rate path amid simultaneously stable long-term inflation expectations. This observation is interesting in that the two models have no information directly in common in the estimates. While the term structure model solely contains term structure information, the macroeconomic model only takes the inflation rate, the level of gross domestic product and the *ex-ante* short-term real interest rate into consideration in its estimates.[15] Long-term forward rates thus appear to reflect trends in key macroeconomic variables in both real and nominal terms, which play an important role in the formation of longer-term interest rate expectations.[16]

15 For more detailed information on the estimation of the natural interest rate in the euro area, see Holston et al (2017), op cit. As the natural rate of interest is estimated in real terms, this rate is extended in the chart to include long-term inflation expectations (Consensus Economics' average inflation expectations stand at six to ten years), making it possible to directly compare it with the nominal interest rate expectations of the term structure model.
16 For more on this topic, see also R K Crump, S Eusepi and E Moench (2017), op cit; M D Bauer and G D Rudebusch (2017), Interest rates under falling stars, Federal Reserve Bank of San Francisco Working Paper Series, No 2017-16; A Cieslak and P Povala (2015), Expected returns in Treasury bonds, Review of Financial Studies, 28, pp 2859-2901, and P van Dijk, S J Koopman, van der Wel, M and J H Wright (2014), Forecasting interest rates with shifting endpoints, Journal of Applied Econometrics, 29, pp 693-712.

Yield curves of government bonds can also be used to derive monetary policy indicators

Yield curves in the government bond markets are less closely linked to the deposit facility rate, as the market participants active in these markets – most notably large institutional investors – do not have access to the Eurosystem's deposit facility. This is especially true of large institutional investors that are non-banks. As a result, some safe haven government bonds with short and medium-term maturities have, in recent years, generated yields well below the OIS curve at times. This has been observed in periods of high risk aversion resulting from safe haven investment strategies and, in particular, since, in a move that was partly anticipated, the deposit facility was abandoned as the lower bound for PSPP purchases.[15] The disparity between interest rates at the short end has led to the yield curve of safe haven bonds sometimes containing information that differs from the OIS curve. The indicators presented here are therefore also dependent on the choice of yield curve. For reasons of consistency, all indicators are estimated on the basis of the OIS yield curve in the following paragraphs, even though it would also be reasonable to estimate some of them based on government bonds considered safe.

Effective lower bound in the euro area time-varying and clearly negative

In the light of the lessons learned from interest rate developments in the United States and the widespread view that nominal short-term interest rates cannot fall far below zero due to the possibility of holding cash, a large number of model variants assume a fixed lower bound of (close) to zero.[16] In actual fact, however, it has been shown not least by developments in the euro area that it was also possible for short-term money market rates to fall below zero in line with the gradual lowering of the deposit facility rate to -0.40%. Even more pronounced was the move into negative territory for short-term Bunds when, in February 2017, the yields on Bunds with a maturity of one year hit a low of -0.95%. These securities are obviously attractive despite negative interest rates. This is probably driven not only by the cost of holding cash (eg storage costs, insurance etc) but also by regulatory and institutional aspects.

If the deposit facility rate for the OIS market constitutes a *de facto* binding lower bound, this means that the central bank's perceived willingness to further cut policy rates also plays a role. Consequently, the effective lower bound could then be reached as soon as the central bank – in the eyes of market participants – takes the view that it would not be expedient to make further interest rate cuts due to the undesirable side effects of such a move running counter to the actual expansionary intention of the policy rate cuts.[17]

Overall, it is evident that the effective lower bound perceived by market participants is influenced by a variety of factors and also may change with these over time.[18] This does not call the existence of a *de facto* binding lower bound in question, however, as it is still assumed that this is reached either when the cost of holding cash is exceeded or there is an expectation that the central bank will consider the positive net effects of further interest rate cuts to have been exhausted.

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15 In addition, regulatory requirements, eg in the insurance sector, as well as the investment behaviour of international, public sector entities, eg in the context of currency management, ensure that there is high structural demand for government bonds with a high credit rating.
16 See, for example, J H Christensen and G D Rudebusch (2015), op cit; J C Wu and F D Xia (2016), Measuring the macroeconomic impact of monetary policy at the zero lower bound, Journal of Money, Credit and Banking 48, pp 253-291; and M Bauer and G D Rudebusch (2016), Monetary policy expectations at the zero lower bound, Journal of Money, Credit and Banking 48, pp 1439-1465.
17 See B Cœuré, How binding is the zero lower bound?, speech held at the "Removing the zero lower bound on interest rates" conference, London, 18 May 2015.
18 See W Lemke and A Vladu (2016), Below the zero lower bound – a shadow-rate term structure model for the euro area, Deutsche Bundesbank Discussion Paper, No 32/2016; and T Kortela (2016), A shadow rate model with time-varying lower bound of interest rates, Bank of Finland Research Discussion Paper 19. For an estimation of the lower bound in the United States, see J Christensen and G Rudebusch (2016), Modelling yields at the zero lower bound: are shadow rates the solution? Advances in Econometrics 35, pp 75-125; for Japan, see H Ichiue and Y Ueno (2013), Estimating term premia at the zero bound: an analysis of Japanese, US, and UK yields, Bank of Japan Working Paper Series E-8.

Monetary policy indicators for the euro area derived from the yield curve

Lower bound models make it possible to derive plausible interest rate expectations in a low-interest-rate environment. In addition, various indicators that are especially suited to measuring the monetary policy stance in a low-interest-rate environment can be derived from these models. The following part of the article presents the "shadow short rate", the "crossing time" and the "effective monetary stimulus" (EMS). They are all determined using information derived from the entire yield curve. As a result, each of these indicators incorporates not only term premiums but also expectations regarding the future path of short-term interest rates. In terms of the suitability of these indicators for measuring the monetary policy stance, however, one caveat to be noted is that yield curve developments can only be steered to a certain extent, and indirectly, through monetary policy – in other words, changes in the indicators do not only show changes in the monetary policy stance. Other major determinants are, in particular, real economic developments and international interest rate linkages.[19]

The shadow short rate

Shadow short rate is the interest rate which would materialise without a lower bound, …

From an economic perspective, the shadow short rate can be interpreted as the short-term interest rate that would materialise in the market without a lower bound. Such an interpretation seems intuitive, especially as the shadow short rate corresponds to the short-term interest rate for as long as it is above the lower bound. This concept is based on the assumption that investors can, in principle, also store their funds in cash to avoid significantly negative interest rates (cash option). As it is not possible to borrow or invest at this rate, it cannot be observed and does not have a direct impact on the financing conditions of the private sector. The shadow short rate is, therefore, a hypothetical interest rate resulting from an estimation of the yield curve, taking into account the value of the cash option. The cash option is, likewise, a theoretical concept which can only be estimated on the basis of theoretical assumptions. For this purpose, option pricing theory is used and combined with information from the yield curve.[20]

… its path depends heavily on model specifications

As a rule, it is possible to estimate the shadow rate in lower bound models on this basis. In order to ensure that the shadow rate is plausible in economic terms and can be used as an indicator of the monetary policy stance at the lower bound on interest rates, an appropriate bar has to be set for the specification of the lower bound model. Choosing the specification involves a trade-off of sorts between two objectives. The first objective is for the estimation to provide a good explanation for the observed interest rate developments and to obtain plausible interest rate expectations. The second objective is to generate an – unobservable – shadow short rate derived from the model (in other words, one that truly cannot be explained by the empirical model) as an indicator of the monetary policy stance at the lower bound.[21] The number of latent factors used in the model and the determination of the lower bound, in particular, affect the level and the dynamics of the shadow short rate.

The chart on page 26 illustrates this by comparing shadow short rates derived from different

19 See P Hördahl, J Sobrun and P Turner (2016), Low long-term interest rates as a global phenomenon, BIS Working Paper, No 574; M Abbritti, S Dell-Erba, A Moreno and S Sola (2013), Global factors in the term structure of interest rates, IMF Working Paper, No 13/233; and FX Diebold, C Li and Z Yue (2008), Global yield curve dynamics and interactions: a dynamic Nelson-Siegel approach, Journal of Econometrics, 146, pp 351-363.
20 See F Black (1995), op cit. An option is a contract ensuring the buyer's right to buy or sell an underlying asset, which is to be determined, up to an agreed date and strike price. In this sense, the cash option guarantees the buyer's right to invest his financial resources in cash at an interest rate of 0%, thus circumventing negative interest rates. The cash option is a purely hypothetical contract.
21 See L Krippner (2016), Documentation for measures of monetary policy, available at: http://www.rbnz.govt.nz/-/media/ReserveBank/Files/Publications/Research/Additional%20research/Leo%20Krippner/5892888.pdf?la=en

model specifications. One of the model variants is based on a less flexible specification with only two factors. The derived shadow rates are determined both for a lower bound of -0.4% and one of 0%, which is relatively high compared with the actual movement of short-term interest rates. This, in turn, means that the part of the yield curve which runs below this lower bound does not need to be described by the model and the few factors in this lower bound mainly depict the long end of the yield curve. This means that the shadow short rate primarily reflects the dynamics of long-term interest rates in the form of a linear combination of factors. In other words, the more strongly the shadow short rate reflected observable short-term interest rates, the more difficult it would be to deviate downwards from the lower bound. The changes in the shadow rate are therefore linked to the points in time when non-standard measures were announced, and a change in the shadow rate indicates a change in the monetary policy stance.[22] On the other hand, information on actual movements in the short and medium-term segments is not taken into account in some cases, especially when the short and medium-term interest rates derived from the model run along a comparatively high lower bound. Consequently, monetary policy measures, such as lowering the deposit facility rate, which mainly has an effect up until the medium-term segment, are only partially captured by the shadow short rate.

Lower bound models preferred class for modelling interest rate expectations at lower bound

By comparison, opting for a model with three factors and a lower (and more plausible) lower bound on interest rates of -40 basis points better describes the yield curve as a whole.[23] The high estimation quality ensures that the interest rates running above the assumed lower bound can be adequately described and the estimated interest rates do not fall below the lower bound. However, the model no longer allows the shadow rate to be noticeably below the lower bound. On the contrary, this has eliminated the sharp deviation of the shadow rate from the observed short-term interest rate (see the chart on page 26). As a result, the option of interpreting the shadow short rate as an information variable for non-standard monetary policy measures geared towards the long end of the curve is largely lost. As with the analysis of the short-term interest rate, this would effectively not show any changes in the monetary policy stance since mid-2011 and the non-standard measures would, accordingly, not be adequately reflected in the shadow rate. In the context of a specification with only two factors, the shadow rate thus provides a better picture of the impact non-standard measures have on the capital market as the shadow rate is more closely interlinked with the path of long-term interest rates. In addition, the shadow rate in these model classes is a great deal more robust to the choice of lower bound.[24]

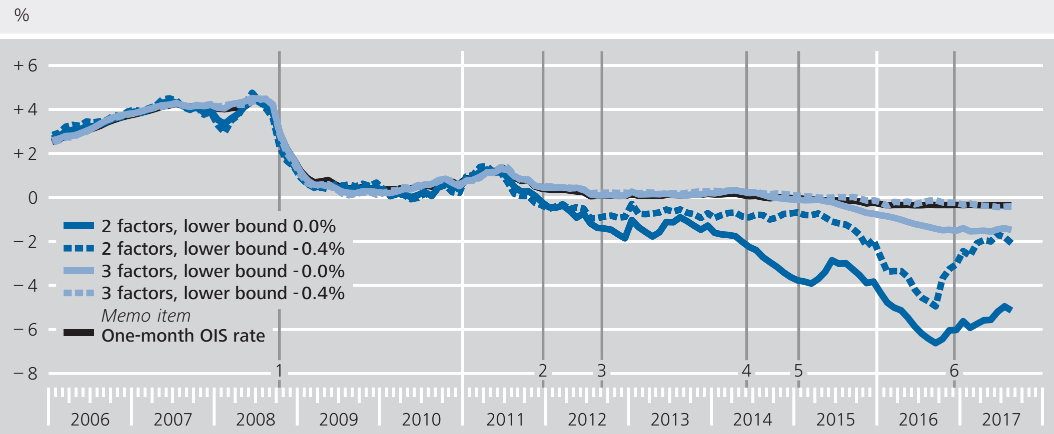
The higher estimation quality of a three-factor model is imperative, however, if plausible expectations regarding the path of short-term interest rates and certain characteristics of interest rate movements at the lower bound are to be determined. To be applied in this way, the greater ability to forecast interest rates of the model with three factors is more important, whereas the dependence of the actual shadow short rate on the specification and parameterization of the model used is less important.

Shadow short rate very hard to interpret

Overall, it is evident that the level and path of the shadow short rate react very sensitively to the respective model specifications. Against this background, the shadow short rate should ultimately only be interpreted as a qualitative indicator since its estimated level is difficult to

22 See J Wu and F Xia (2016), op cit. The authors estimate a monetary policy VAR by replacing the federal funds rate with the shadow short rate as a monetary policy variable for the years during which the zero lower bound was binding in the United States.
23 The lower bound is based here on the lowest level of the Eurosystem's deposit facility rate, which in the euro area is regarded as the floor for the unsecured interbank money market rate. For a more detailed explanation, see p 23 f.
24 See L Krippner (2015b), A comment on Wu and Xia (2015), and the case for two-factor shadow short rates, CAMA Working Paper No 48/2015, Centre for Applied Macroeconomic Analysis.

Short-term shadow rates based on different model specifications*



Sources: Bloomberg and Bundesbank calculations based on L Krippner (2015). ***** Calculated with differing assumptions concerning the lower bound in models with two or three factors. **1** Full allotment. **2** Decision to introduce LTRO. **3** Draghi speech in London. **4** Decision to introduce TLTRO I and announcement of ABSPP. **5** Decision to introduce APP. **6** Extension of APP.

Deutsche Bundesbank

interpret due to the high sensitivity of the model.

Crossing time and expected interest rate path

Crossing time indicates expected path of short-term interest rates

The non-standard monetary policy measures, including the asset purchase programmes, as well as the communication on future policy rate developments, which the Governing Council of the ECB has linked to the duration of the APP, aim, amongst other things, at lowering the long-term interest rate by tweaking the expected course of short-term interest rates.[25] Correspondingly, the monetary policy stance is also reflected in market expectations regarding the path of short-term interest rates. The duration for which the observable short-term interest rate remains at the lower bound and the point in time when it goes back above a certain threshold (crossing time), can, therefore, potentially also be used as a measure of the monetary policy stance. Taken in isolation, the further down the line crossing time occurs, the more accommodative the monetary policy stance becomes as it indicates the expectation that policy rates will remain at a lower level for an extended period of time.

The crossing time can be defined as the median of a large number of short-term interest rate paths simulated on the basis of a term structure model, ie the time when the short-term interest rate goes back above the 0% threshold, indicating that short-term interest rates are returning to normal.[26] The chart on page 27 shows the evolution of the distribution of the crossing time since January 2015 based on a

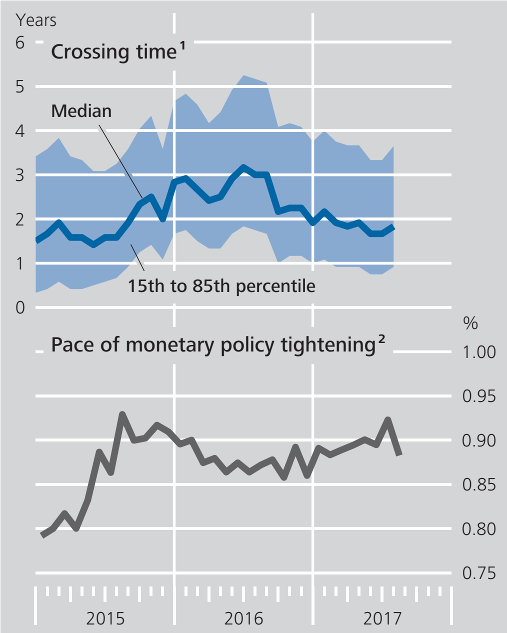
25 According to its forward guidance, the Governing Council expects the key ECB interest rates to remain at their present levels for an extended period of time, and well past the horizon of the net asset purchases (see M Draghi, introductory statement to the ECB's press conference on 20 July 2017 in Frankfurt am Main). Regarding the effects of monetary policy communication in the context of non-standard measures, see also G Coenen, M Ehrmann, G Gaballo, P Hoffmann, A Nakov, S Nardelli, E Persson and G Strasser (2017), Communication of monetary policy in unconventional times, ECB Working Paper No 2080.
26 The crossing time is determined by means of a Monte Carlo simulation by simulating several thousand paths of the expected short-term interest rate based on an estimated term structure model. For each path, the point in time when it exceeds a specific pre-defined level (in this case 0%) is recorded. Often, the path is required to remain above this level for a certain amount of time (eg 12 months) before the time is recorded. The median of the distribution of crossing times (lift-off distribution) determined in this way corresponds to the optimal forecast, assuming that market participants wish to minimise their absolute forecast error. In the vast majority of cases, the median corresponds to the date when the modal path, ie the most likely path of the shadow rate, too, exceeds the determined threshold. Deviations are possible, but should be limited in each case. Alternatively, the crossing time presented here could therefore also be calculated in connection with determining the modal path. See M Bauer and G Rudebusch (2016), op cit, as well as W Lemke and A Vladu (2016), op cit.

lower bound model, which, due to its specifications, is capable of describing with the greatest possible precision the term structure and the associated interest rate expectations (details on the model specifications can be found on pages 18 to 22). After the markets, at the beginning of 2015, had expected interest rates to return to positive territory within a median period of two years, this period continuously grew larger as time passed following the decision to introduce the APP in January 2015 and to further cut the deposit facility rate. Evidently, the Eurosystem was able to credibly communicate a prolonged period of low short-term interest rates. At its peak in July 2016, the indicator showed an expected return of the interest rate to above 0% by July 2019, ie within a space of just over three years. As time progressed and against the backdrop of the yield curve steepening in the autumn of 2016, the crossing time moved closer again and is currently envisaged for mid-2019.

However, indicator only meaningful at lower bound …

In contrast to the hypothetical concept of the shadow short rate, the crossing time, in its function as a monetary policy indicator, measures expectations about future observable developments. The crossing time can, therefore, also be verified empirically in retrospect. At the same time, however, the crossing time is defined only at the lower bound and becomes uninformative as soon as the short-term interest rate rises above the selected threshold value. Neither does it give any indication as to whether market participants expect a gradual or rapid increase in the short-term interest rate. It therefore makes sense to introduce an additional indicator to the analysis in order to measure the expected pace of monetary policy tightening.[27] The lower graph of the above chart thus shows the path of the short-term interest rate deemed the most likely by market participants over a period of two years once it has gone back above the 0% threshold. Since 2015, this figure has remained stable between 0.8 and 1.0 percentage point. This implies, *ceteris paribus,* that the rise in short-term interest rates expected by market participants has

Crossing time and pace of monetary policy tightening



Sources: Bloomberg, Consensus Economics and Bundesbank calculations based on F Geiger and F Schupp (2017). **1** Time until the short-term interest rate goes back above zero. **2** Change in the modal path of short-term interest rates over a period of two years from when the 0% threshold was crossed.
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been more subdued than, for example, between October 1999 and October 2000 or between December 2005 and June 2007, when the Governing Council of the ECB increased its policy rates by 2.25 and 2 percentage points respectively.

… and does not take into account the impact of monetary policy measures on forward premiums

A further weakness of the crossing time defined here as an indicator of the expansiveness of monetary policy is that it is not able to show the impact of monetary policy measures which, besides the expected path of short-term interest rates, also have an effect through term premiums. However, these effects can be captured, amongst other things, by the conditional distribution of short-term interest rates, con-

27 See M Bauer and G Rudebusch (2016), op cit.

taining not only pure interest expectations but also an extra term premium.[28]

Distribution information on interest rate path expands scope of analysis

The chart on page 29 shows this distribution at different points in time between May 2014 and January 2015, when the Governing Council adopted its first TLTRO series and asset purchase programmes, as well as in August 2017. The individual sub-graphs illustrate how the term premiums initially decreased steadily, which is reflected by narrowing distribution and a flattening OIS forward rate for one-month contracts (see also pages 18 to 22). In August 2017, distribution significantly expanded again, which went hand in hand with the forward rate becoming steeper and could be regarded as an indication of monetary policy rates being expected to normalise. Overall, it appears that, by introducing the APP and forward guidance, the Eurosystem has managed to reduce the uncertainty about future interest rate developments and the associated risk premiums. In particular, these measures have temporarily caused forward rates to drop considerably.[29]

The effective monetary stimulus

Effective monetary stimulus derived from current yield curve and "neutral" interest rate

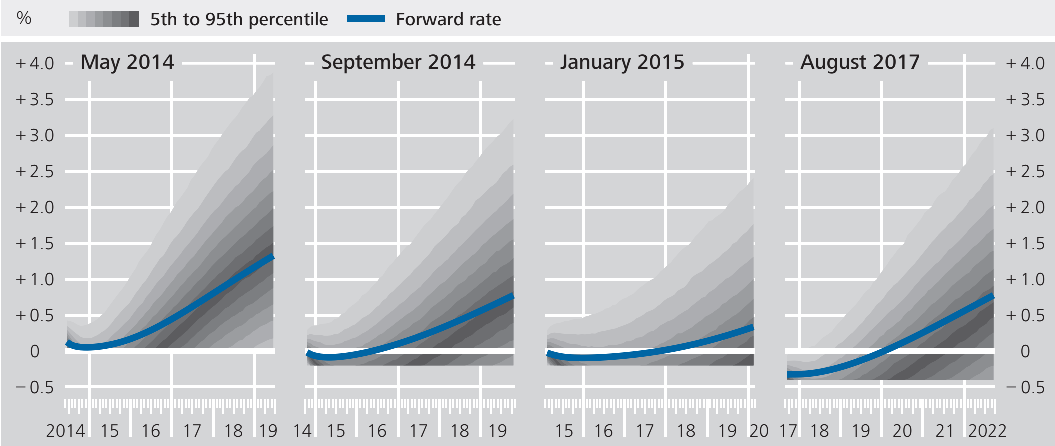
The effective monetary stimulus (EMS) aims to provide summarised information on the development of forward rates, bundled in the form of a single indicator for measuring the monetary policy stance. To this end, the EMS uses the "neutral" interest rate, which evens out in the long term, as a benchmark to put the path of the forward rate into perspective. The EMS is defined as the negative value of the integral between this neutral interest rate and the forward rate curve.[30] In other words, it compares two interest rate concepts, one of which aims to capture the current financing conditions on the capital markets and the other the long-term equilibrium level of interest rates for the economy as a whole. The farther the forward rate curve lies below the neutral interest rate, thus pushing down the EMS, the higher the measured degree of monetary policy accommodation. This means that the EMS's direction of impact is defined in the same way as short-term interest rates. The EMS is defined both for normal times and for periods in which interest rates move along the lower bound.

Indicator value depends on assumption regarding neutral interest rate

Accordingly, the volume of the EMS depends largely on the level of the neutral interest rate, which can, in principle, be estimated using different modelling approaches as follows. The neutral interest rate could, say, be approximated directly from an estimated lower bound model as the interest rate towards which the forward rate (or the expected short-term interest rate) converges in the very long term.[31] Alternatively, it could be derived from an estimated macroeconomic model as an equilibrium interest rate which is compatible with a permanently closed output gap and a stable inflation rate.[32] Besides the associated model uncertainty, the neutral interest rate is difficult to determine from an empirical perspective, too, not least because it is necessary to define the output gap as precisely as possible to obtain an exact estimation. Accordingly, determining the EMS is, in many respects, contingent on estimation quality and the ability to identify unobserved indicators; it is, therefore, particularly fraught with uncertainty.

28 This short-term interest rate is calculated as the expected value of the short-term interest rate below the probability measure that, in addition to actual expectations, also incorporates a yield spread relating to the uncertainty regarding the future interest rate path (term premium). If Jensen's inequality term is taken into account as well, the future average of this interest rate corresponds to the forward rate with the same maturity.
29 For results based on US data, see also M D Bauer and G D Rudebusch (2014), The signaling channel for Federal Reserve bond purchases, International Journal of Central Banking 10(3), pp 233-289.
30 See L Krippner (2015), op cit.
31 See L Krippner (2014), Measuring the stance of monetary policy in conventional and unconventional environments, CAMA Working Paper 6/2014, Centre for Applied Macroeconomic Analysis.
32 See T Laubach and J Williams (2003), op cit, or R A Barsky, A Justiniano and L Melosi (2014), The natural rate of interest and its usefulness for monetary policy, American Economic Review, Vol 104, No 5, pp 37-43.

Conditional distribution of the future one-month OIS rate, taking account of the forward premium



Sources: Bloomberg, Consensus Economics and Bundesbank calculations based on F Geiger and F Schupp (2017).
Deutsche Bundesbank

Another approach is to use survey data. According to simple growth theory models, real interest rates are essentially determined by the rate of real economic growth.[33] What follows from this is that nominal growth expectations stemming from surveys could be used as a directly observable variable in determining a nominal EMS.[34] Although growth expectations from surveys, too, contain an element of forecasting uncertainty, they do not depend on the assumptions made as part of a specific lower bound or macroeconomic model and are, therefore, likely to be more robust to model variations.

EMS can either be estimated in term structure model or determined through model-free calculation

In such a model-free variant, the EMS is defined as the difference between a long-term interest rate and long-term nominal growth expectations from surveys and can thus be determined based on observable indicators without using a term structure model.[35] In the model-based variant, the EMS is the integral of the difference between a model-implied forward rate and long-term nominal growth expectations.[36]

The model-based estimation of the EMS allows the indicator to be decomposed into its individual parts. Assuming the expectations hypothesis of the term structure, the EMS component which is attributable to expectations of risk-neutral market participants can be determined.[37] Similarly, the EMS component resulting from the existence of term premiums, which risk-averse market participants demand for taking on maturity risks relating to long-dated bonds, can be determined as well.

Model-based calculation allows decomposition of indicator into expectation and forward components

33 See, for example, R Barro and X Sala-i-Martin (2004), Economic growth, Second Edition, MIT Press. For information on how interest rates are determined in relation to the natural interest rate, see also K Wicksell (1898, translation published in 1936), Interest and prices: a study of the causes regulating the value of money, Macmillan and Co, Ltd, London
34 See A Halberstadt and L Krippner (2016), The effect of conventional and unconventional euro area monetary policy on macroeconomic variables, Deutsche Bundesbank Discussion Paper, No 49/2016.
35 The 30-year rate of return was used to compute the EMS here. The choice of maturity is not of critical importance when using the EMS as a monetary policy indicator in empirical analyses. In standardised values, the EMS is similar for yields of differing maturities; see A Halberstadt and L Krippner (2016), op cit.
36 Given the high estimation quality of the term structure model, the interest rates and forward rates derived from the estimated model are almost identical with the observed interest rates and forward rates. Based on the same neutral interest rate, the model-free variant of the EMS is equivalent to the model-based variant, with the exception of the extent of the measurement bias regarding interest rates.
37 In line with the expectations hypothesis of the yield curve, a risk-neutral investor assumes that the long-term interest rate corresponds with the average of short-term interest rates; he expects this if his funds are to be continuously reinvested for the investment horizon in question.

Analysis of the impact of monetary policy shocks on macroeconomic variables using the effective monetary stimulus indicator

Empirical studies on the impact of monetary policy measures conventionally use a short-term interest rate as a benchmark for the monetary policy stance as this forms the link with monetary policy rates. Such studies are often carried out using vector autoregressive models.

For instance, in a vector autoregressive model, the impact of monetary policy is generally estimated by analysing the response (eg in the form of impulse response functions) of variables that are of interest, such as the output gap and inflation, to a monetary policy shock (ie an unanticipated change in the monetary policy stance). The use of an exogenous shock makes it possible to separate the impact of the monetary policy measure from the endogenous effects caused by other factors.[1]

Such model estimates can generally be used to demonstrate that an increase in short-term interest rates causes output and inflation to fall. In a period of persistently low interest rates close to the lower bound where unconventional measures are used, such estimates are no longer sufficient and more detailed monetary policy indicators, such as the effective monetary stimulus (EMS), are required.

The EMS is defined as the negative value of the integral between a neutral interest rate and the forward curve. It uses two interest rate concepts – one to capture the current financing conditions on the capital markets and the other to capture a long-term equilibrium level for the economy.[2] In this analysis of the impact of monetary policy on German industrial production and price developments[3] using the framework of a small vector autoregressive model with time-varying parameters, we have thus opted to use the EMS as an indicator for the monetary policy stance as this reflects both conventional and unconventional monetary policy measures.[4] A further major advantage of using the EMS as opposed to alternative indicators, eg a shadow interest rate, is that it can be determined based on observable indicators without having to use a term structure model.[5] An unobservable indicator such as a shadow short rate would imply additional uncertainty for the analysis

1 See, for example, C Sims (1992), Interpreting the macroeconomic time series facts: the effects of monetary policy, European Economic Review 36 (5), pp 975-1000; L Christiano, M Eichenbaum and C Evans (1999), Monetary policy shocks: what have we learned and to what end?, Handbook of Macroeconomics 1A, pp 65-148, Amsterdam: North-Holland; J Stock and M Watson (2001), Vector autoregressions, Journal of Economic Perspectives 15 (4), pp 101-115; as well as B Bernanke, J Boivin and P Eliasz (2005), Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach, Quarterly Journal of Economics 120 (1), pp 387-422.
2 See L Krippner (2015), Zero lower bound term structure modeling: a practitioner's guide, New York: Palgrave Macmillan US.
3 The log level deviation of industrial production from its time-varying trend is used for industrial production, and the annualised growth rate of the producer price index is used for price developments. In addition, commodity price developments are included in the analysis as a control variable.
4 See A Halberstadt and L Krippner, The effect of conventional and unconventional euro area monetary policy on macroeconomic variables, Deutsche Bundesbank Discussion Paper, No 49/2016.
5 For more information on determining the EMS in a lower bound model or on the basis of observed indicators, see p 28f.

as it is already estimated with uncertainty itself.[6]

The observation period spans the years from 1999 to 2015 – and thus both a period of purely conventional monetary policy (1999-2008) as well as the subsequent period in which unconventional measures were taken. In a vector autoregressive model, the statistical properties of a monetary policy shock change if the EMS is used as the monetary policy variable instead of the short-term interest rate. If the short-term interest rate is used, shocks are much smaller in the unconventional phase because it remains at the lower bound, and the low volatility, too, yields only small non-deterministic movements. However, in the case of the EMS, the statistical properties of the derived shocks are very similar throughout the observation period. This applies to both the size of the shocks and their persistence. In recent years, when an EMS shock has occurred, the impact thereof has lasted for a similar length of time as at the beginning of the monetary union (see also the chart on page 32).

But a key criterion for the quality of a monetary indicator is, above all, whether it captures all the information needed. The EMS indicator includes, *inter alia,* information on term premiums and the market participants' expectations about the future development of short-term interest rates. The central bank can only control these two elements indirectly and to a limited extent. Thus, a change in the indicator value or in the monetary policy shock under analysis can, generally speaking, be attributable to factors other than just the central bank's intention to change the monetary policy stance.

However, the conventional practice of using a short-term interest rate as a monetary policy indicator in the application of a small vector autoregressive model also has disadvantages. For instance, even in the case of conventional policy rate management, the long end of the yield curve and thus the long-term financing conditions that generally drive investment decisions within the economy are influenced not only by monetary policy but also, to a certain degree, by other factors, such as the national real economic setting or the international environment. Therefore, the more closely the short-term interest rate is linked to the development of long-term interest rates, the more complete a picture of monetary policy transmission it is likely to paint. Thus, it is not only the EMS but also the short-term interest rate that are merely proxies for a monetary policy indicator that must be examined in each case to determine whether it is fit for use in practice.

With the EMS as a monetary policy indicator, the model results for both the period before the financial crisis – when short-term yields were still well above zero – and the period of low interest rates are more plausible than when a short-term interest rate is used. This is particularly evident in the impulse responses of the macroeconomic variables to a monetary policy shock. If the EMS is used as a monetary policy indicator, prices and industrial production in Germany fall as expected in the medium term in response to an increase in the EMS (see the chart on page 34); however, if the short-term interest rate is used, this is not the case.[7]

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6 The shadow short rate is an unobserved, hypothetical interest rate. The estimate thereof also hinges heavily on the modelling assumptions. The EMS indicator is more robust but is also dependent on the natural interest rate selected (see p 28f); see L Krippner (2015), op cit; as well as L Krippner (2015b), A comment on Wu and Xia (2015), and the case for two-factor shadow short rates, CAMA Working Paper No 48/ 2015, Centre for Applied Macroeconomic Analysis.
7 The EMS is defined in such a way that, as with the short-term interest rate, an increase can be interpreted as monetary policy tightening.

Impulse responses of macroeconomic variables to an unanticipated change* in the effective monetary stimulus (EMS)

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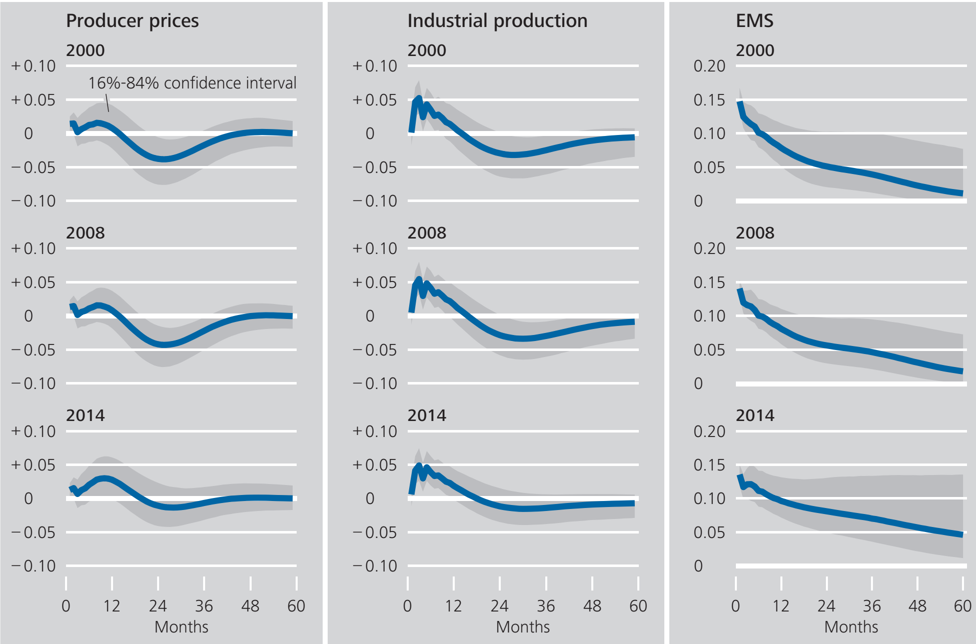


Source: Bloomberg, Federal Statistical Office, Consensus Economics, IMF and Bundesbank calculations based on A Halberstadt and L Krippner (2016). * Amounting to one standard deviation.
Deutsche Bundesbank

For large stretches of the observation period, these falls are also statistically significant, but not for the period of low interest rates. In the latter's case, the estimated declines in both industrial production and prices are weaker and statistically insignificant.

The estimate shows, moreover, that the macroeconomic variables are significantly influenced only if unanticipated changes in the EMS indicator are considered as a whole – ie including the expectations and term premium components into which the model-based EMS indicator can be decomposed.[8] In this aggregated view, both channels are required for the transmission of unconventional monetary policy measures to the overall economy.

The results of the analysis are similar for both the estimate with German macroeconomic data and that with corresponding euro area aggregates. If alternative indicators for macroeconomic activity and inflation are used for the estimate, the model results are by and large similar, thus indicating that they are robust.

8 See A Halberstadt and L Krippner (2016), op cit.

EMS is a consistent indicator in phases of standard and non-standard monetary policy

The volatility of the EMS has changed only slightly since 1999 (see the chart on page 34).[38] The decline in the EMS since 2008 reflects an easing of the monetary policy stance through non-standard measures. These measures are not always announced exactly at the same time as changes in the indicator value occur. If the measures had previously been expected in the market, this would have already become evident through the development of the indicator value in the run-up to the announcement. Consequently, the significant decline in the EMS in the course of 2014 can also be explained by increased market expectations concerning a broad-based government bond purchase programme.

Not even EMS can provide information on adequacy of monetary policy stance

Similar to the other indicators discussed here, the EMS is not able to provide information on the adequacy of the monetary policy stance either, not least because the neutral interest rate used here does not take account of determinants which are key to economic developments and thus also to achieving the monetary policy objective of price stability. These determinants and, by extension, also the concept of the neutral interest rate are, however, hard to identify empirically.[39] The information content of the absolute level of the EMS and thus the difference between current and neutral interest rates is, therefore, at best, as reliable as an estimation of the neutral interest rate.

On the assumption that any potential estimation error in the neutral interest rate is largely constant over time, the change in the EMS can, however, serve as an indicator for measuring changes in the monetary policy stance and may be useful for monetary policy analysis (see the box on pages 30 to 32).

Concluding remarks

Data on term structure valuable for monetary policy analysis …

On the basis of term structure data and models, it is possible to obtain meaningful indicators for measuring the monetary policy stance, even at the lower bound and when non-standard monetary policy measures are deployed. However, conclusions regarding the expansiveness of monetary policy based on individual indicators are subject to a high degree of uncertainty. Furthermore, any interpretation of the development of the indicators must take into account that they are based on changes in financial market prices, which not only reflect monetary policy, but are also influenced by other factors.

However, the indicator dynamics provide a good description of the changes in the monetary policy stance in terms of its direction of impact. The estimations of such indicators presented in this article consistently suggest that the Eurosystem's non-standard measures have, in fact, increased the expansiveness of the monetary policy stance overall.

… even in an environment of normalising interest rates

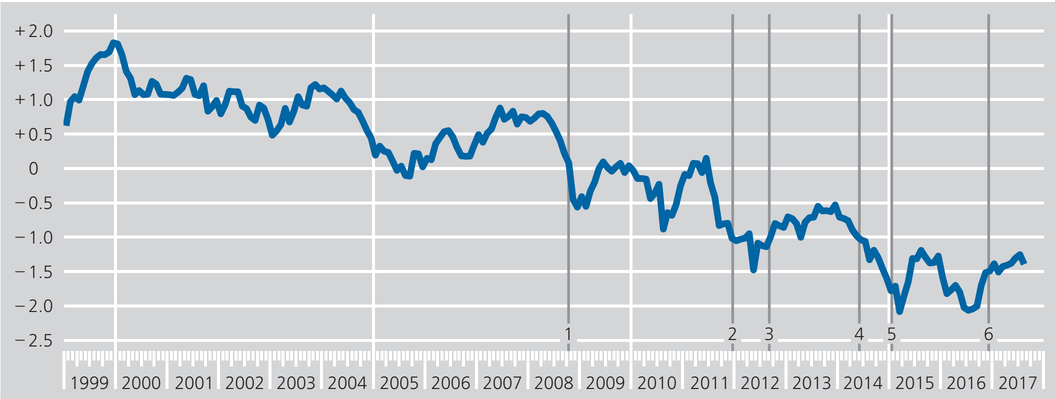
Even in a normalising interest rate environment where the short-term interest rates are becoming uncoupled from the negative lower bound, an analysis of the yield curve and its information content, bundled into the indicators presented here, provide important additional information for monetary policy analysis. For instance, the impact of policy rate changes and

38 As 30-year OIS rates are not available for the period prior to 2006, the EMS is calculated using government bond yields.

39 While the EMS is similar to the common monetary models for analysing monetary policy in that it is based on an interest rate spread concept, the underlying neutral interest rate concept does not take into account the typically modelled shocks affecting the course of the natural rate, which a central bank in an environment of nominal rigidities responds to via its interest policy. In this model class, the output gap, which monetary policy makers use to influence inflation developments through interest policy, is determined by the difference between the expected path of short-term (forward) interest rates and the time-varying path of the natural (forward) interest rate. See Barsky et al (2014), op cit; M Del Negro, M Giannoni, M Cocci, S Shahanaghi and M Smith (2015), Safety, liquidity, and the natural rate of interest, Staff Report, No 812, Federal Reserve Bank of New York, May 2015; and J Gali and M Gertler (2007), Macroeconomic modeling for monetary policy evaluation, Journal of Economic Perspectives, American Economic Association, Vol 21 (4), pp 25-46. For the transfer of this theoretical interest rate spread concept to a semi-structural macro-econometric model for deriving a natural yield curve, see M Brzoza-Brzezina and J Kotlowski (2014), Measuring the natural yield curve, Applied Economics, Vol 46 (17), pp 2052-2065; and K Imakubo, H Kojima and J Nakajima (2017), The natural yield curve: its concept and measurement, Empirical Economics, forthcoming.

Effective monetary stimulus*

Indicator-specific scaling



Sources: Bloomberg, Consensus Economics and Bundesbank calculations. * Model-free version. **1** Full allotment. **2** Decision to introduce LTRO. **3** Draghi speech in London. **4** Decision to introduce TLTRO I and announcement of ABSPP. **5** Decision to introduce APP. **6** Extension of APP.

Deutsche Bundesbank

the associated monetary policy communication on the expected path of short-term interest rates and on term premiums can be shown.

Continuous adjustment to changing monetary policy environment required

Finally, it should be borne in mind that, although monetary policy indicators are used to measure the monetary policy stance, they do not *per se* provide information as to whether this monetary policy stance is adequate. In view of this, the Eurosystem's monetary policy strategy takes into account a number of economic, price, credit and financial indicators that can be interpreted in terms of their implications for the medium-term inflation outlook and that ultimately make it possible to reliably gauge the adequacy of the monetary policy stance, which is something indicators derived from the term structure are not capable of. However, methodological developments in the area of term structure modelling are advancing rapidly at present. It would, therefore, appear to make sense for central banks to follow these developments and to critically examine the ensuing monetary policy indicators in terms of their suitability for monetary policy analysis.