Inflation expectations: newer instruments, current developments and key determinants

Expectations about future inflation developments are a key indicator with which to assess the effectiveness and credibility of monetary policy. Inflation expectations can be derived from survey data or from financial market instruments, such as inflation-indexed bonds or inflation swaps. Expectations derived in this way are, however, generally point forecasts. Inflation options – a relatively new type of financial market instrument – enable market participants to go one step further and to derive risk-neutral or preference-weighted probability distributions. These distributions yield information regarding the range of dispersion used by market participants for the point forecasts, whether they symmetrically estimate the risk of missing the mean and how they rate the likelihood of exceptionally high or low inflation rates occurring.

An event study which looks at the period between 2009 and 2014 shows that the probabilities of occurrence of future inflation rates responded heterogeneously to macroeconomic data and monetary policy announcements over time. It can also be observed against the backdrop of the intensification of the sovereign debt crisis that market players' uncertainty regarding future inflation developments in the euro area has increased.

Last year saw a marked decline in, above all, long-term market-based inflation expectations; however, they rebounded somewhat after the turn of the year, not just in the euro area but also in the United States and in the United Kingdom. The stronger influence of oil prices is often cited in this context. However, it is still too early to say with any degree of certainty whether this will continue to have an impact over the longer term. Given the major importance of firmly anchored inflation expectations for the economies, the lower expected value, especially in the financial market data, and the wider fluctuation margin of inflation expectations should, at any rate, be analysed meticulously and interpreted with caution.

The significance of inflation expectations and how they are derived

Inflation expectations influence inflation rates and are a measure of a central bank's credibility

Expectations regarding future developments in inflation play a significant role in the pricing policy of enterprises and in wage negotiations. They therefore impact not only on current inflation but also on future realised inflation rates. For a monetary policy that is geared towards price stability, inflation expectations and, in particular, how they change over time provide important information about the central bank's credibility and the effectiveness of monetary policy.

Advantages and disadvantages of inflation expectations derived from survey data and financial instruments

As inflation expectations – unlike realised rates of price change – cannot be observed directly, they have to be derived from either survey data or from the prices of inflation-indexed financial market products.[1] There are advantages and disadvantages to both approaches. In surveys conducted among experts or households, respondents can be asked directly about their inflation expectations, but the quality of the answers depends on the choice of respondents. As for financial market prices, the level of the inflation expectations often has to be separated from other factors that influence prices, such as uncertainty or liquidity premiums. These factors generally vary over time and are therefore not always easy to filter out of the expectations component, which also changes over time. In the case of investments in inflation-linked financial market instruments, an inaccurate assessment of the future rate of inflation results in losses, whereas an inaccurate assessment by survey participants does not generally have any direct financial impact. The prices of financial instruments should therefore not reflect any strategic overestimations or underestimations of market participants' expectations. The continuous price formation also ensures that reassessments of inflation expectations occur on a very frequent basis. Financial market prices are widely available via electronic data providers. Financial market derivatives which use inflation as a reference variable are now widely used.

Inflation expectations derived from bonds …

For those financial market instruments which are directly linked to inflation, inflation-indexed bonds can be distinguished from derivatives, such as inflation swaps or inflation options. The remuneration paid on an inflation-indexed bond comprises a coupon payment and an explicit adjustment for realised inflation rates, which no longer appears in the return on the bonds. If the return on an inflation-indexed bond is deducted from the return on a (maturity-matched) nominal bond, this gives the break-even inflation rate (BEIR). If the *ex post* inflation rate realised during the term of the financial instruments is equal to the BEIR, an investor would generate equally high returns on both bonds. The expected rate of inflation over the term of the bond therefore plays a decisive role for investors. However, in addition to the actual inflation expectations, the BEIR also contains the premiums for the uncertainty regarding the occurrence of the expected inflation rates (inflation risk premiums) as well as for the liquidity differences between both types of bonds (liquidity premiums). It is therefore not possible to draw any direct conclusions from the BEIR about future inflation rates.

… and inflation swaps

In contrast to bonds, only net cash flows are paid in the case of inflation swaps, but not the underlying nominal amounts. At the time of concluding the contract, the trading partners agree to exchange a fixed cash flow (a fixed interest rate) for the realised inflation rate (ie the variable cash flow), which is unknown at the start of the term. The fixed interest rate on an inflation swap therefore reflects the inflation expectations as well as an inflation risk premium that may be contained in the swap. In the case of inflation swaps, the investor therefore also has to consider how certain he be-

1 For information on the problems encountered in measuring inflation expectations, see also Deutsche Bundesbank, Some approaches to explaining the behaviour of inflation since the last financial and economic crisis, Monthly Report, April 2014, with a particular focus on pp 66-72.

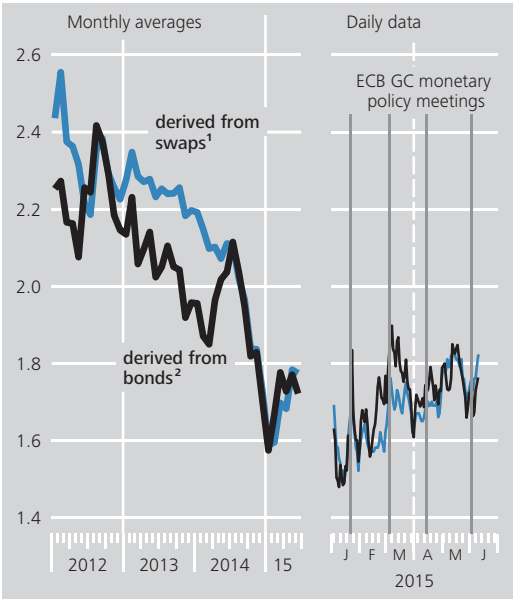
lieves the expected inflation rates will be over the term of the inflation swap. Liquidity premiums, should, however, play a lesser role in this connection, as only interest rate differentials are exchanged and not nominal amounts. On the other hand, default risks could arise for those instruments traded on the interbank market. These risks are often reduced by collateralising the payment obligations, but they cannot be ruled out completely.

Development of long-term inflation expectations

The BEIR and the fixed interest rate of the inflation swap, both of which with different maturities, can be used to derive spot and forward inflation rates, which provide information about the development of current and future inflation expectations over various time horizons. The forward inflation rates considered here are implicit, which means that they are derived from traded spot products. Unlike in the case of forward rate agreements (FRAs) for interest rates, for instance, there is no dedicated market for futures. Technically speaking, the long-term (spot) expectations – adjusted for short-term (spot) expectations and the maturity difference – are used to derive the forward inflation rates.[2] In perfect markets, an arbitrage equilibrium would exist between the prices for bonds and swaps. This means that it would not be possible to realise any arbitrage profits – ie risk-free profits – from different instruments with the same cash flow. Under certain assumptions, such as the absence of transaction costs and unrestricted access to funds at the risk-free interest rate, the BEIR would be equivalent to the fixed interest rate of the inflation swap. In actual fact, however, these two figures may occasionally differ. These deviations can largely be explained on the basis of liquidity differences, which can be triggered by safe haven inflows into nominal bonds, for example. In the last five years, the forward inflation rates derived from bonds and swaps have been moving mainly sideways, albeit amid some fluctuations. They declined uniformly in mid-2014 before going back up at the beginning of 2015.

Five-year forward inflation rate* in the euro area

% pa



Sources: Thomson Reuters, EuroMTS and Bundesbank calculations. * Excluding tobacco. **1** Derived from the fixed payout of inflation swaps, which is substituted by the annual realised inflation rates five or ten years ahead. **2** Derived from separately estimated yield curves of German and French inflation-indexed and maturity-matched nominal bonds which are subsequently aggregated using GDP weights.

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Inflation options

Inflation options allow probability distributions to be calculated

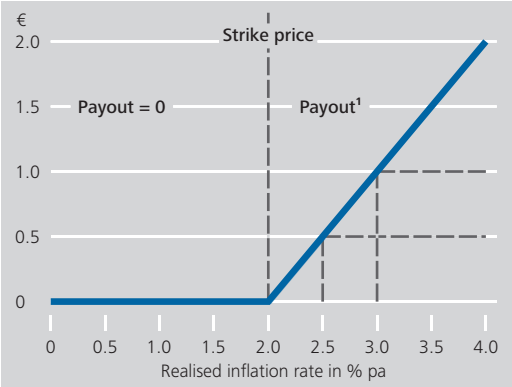
Inflation-indexed bonds and inflation swaps yield information on the general direction of market participants' inflation expectations. Using inflation options, the uncertainty regarding the occurrence of expected inflation rates, asymmetrical expectations or the probabilities of extreme events can also be determined. This means, for example, that the dispersion of the expectations for inflation rates can also be calculated, as well as the likelihood of inflation rates falling below zero over a specific time horizon.

2 Example for an expected five-year forward inflation rate five years ahead:

$$FwdInflRate_{5,10} = \left(\frac{(1+r_{10})^{10}}{(1+r_5)^5}\right)^{\frac{1}{10-5}} - 1,$$

where $r =$ inflation expectations ten or five years ahead. If the five-year spot BEIR has a value of 2% and the ten-year spot BEIR is 2.1%, the implied five-year forward rate five years ahead has a value of 2.2%.

Payouts of an inflation cap with a one-year maturity



1 Realised inflation rate less the strike price multiplied by the nominal value of the contract.

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Definition and payout structure of inflation options

An inflation option gives the bearer the right to a compensation payment if, at a pre-determined point in time, ie the maturity date, the realised rate of inflation is above (inflation cap) or below (inflation floor) a previously agreed inflation rate threshold – the strike price of the option. The adjustment payments increase in proportion to the deviations of the realised inflation rate from the threshold value, with a rising realised inflation rate in the case of caps and a declining rate in the case of floors. For example, the bearer of an inflation cap with a nominal value of €100, a strike price of 2% and a maturity of one year would receive a payout of €1 if the realised annual inflation rate stood at 3% on the maturity date. No payouts would be made prior to the maturity date.

Market for inflation options

The market for inflation options is a young market, which, however, has recorded strong growth of late according to market reports.[3] Inflation options are traded solely "over the counter" (OTC), ie between financial intermediaries and not via stock exchanges or trading platforms. This is why the market is dominated by trade between banks, which, however, often operate on behalf of investment funds and insurance companies. The latter aim, to a certain extent, to secure their real incoming and outgoing payments, such as by increasing their payouts in the event of a sharp rise in the rate of inflation and inflation-linked annuities. In this context, the option buyers are the collateral takers, whereas the option sellers are the collateral providers. Furthermore, inflation options can be used to contain the risk stemming from the unsecured payments of the variable cash flows from inflation swaps and the inflation adjustment payment for issuers of inflation-indexed bonds. By doing so, the issuer of an inflation-indexed bond could, for example, protect himself against payments that may become due in the event of particularly high inflation rates. Conversely, however, the inflation option, which is a financial derivative, could also be used to build up a leveraged position which relies on future inflation rates going up or down. While the coupons of inflation-indexed bonds have to be serviced, and the difference between fixed and variable interest rates generally has to be offset on a daily basis for inflation swaps, only an option premium is paid in the case of options and no further payments are due until maturity.

Data quality

The quality of the options data can only be assessed indirectly. Information on aggregate liquidity measures, such as trading volumes or bid/ask spreads, is not very readily available in the OTC markets. There is a fundamental risk that the market for inflation options is not very liquid.[4] Illiquid financial instruments could, however, contain distorted or outdated information about the market participants' expectations (stale quotes). For example, events such as the sovereign debt crisis in Greece or the developments in Ukraine led, at least temporarily, to liquidity distortions between nominal bonds and inflation-indexed bonds. Even though they did not directly affect the markets

3 For further information, see, for example, the market report on the following website: http://www.ifre.com/derivatives-inflation-options-market-booms/21004568. article

4 Liquidity distortions can, in principle, also occur on the markets for other inflation-indexed instruments and generally make it more difficult to derive undistorted inflation expectations. Nevertheless, given that inflation-indexed bonds and inflation swaps have been around for longer and are also more widespread, they provide a more concrete basis for identifying liquidity distortions.

for inflation swaps and, in particular, for inflation options, a knock-on effect through the arbitrage relationship cannot be ruled out completely. One way of indirectly evaluating the quality of the data is to check whether the put-call parity of options has been met.[5] Furthermore, the development of the means of the inflation expectations derived from options can be compared with those from inflation swaps. Neither of these two methods provides any evidence to suggest that the various measures for assessing inflation expectations for the euro area take a systematically different course.

Prices as a starting point for probabilities of occurrence

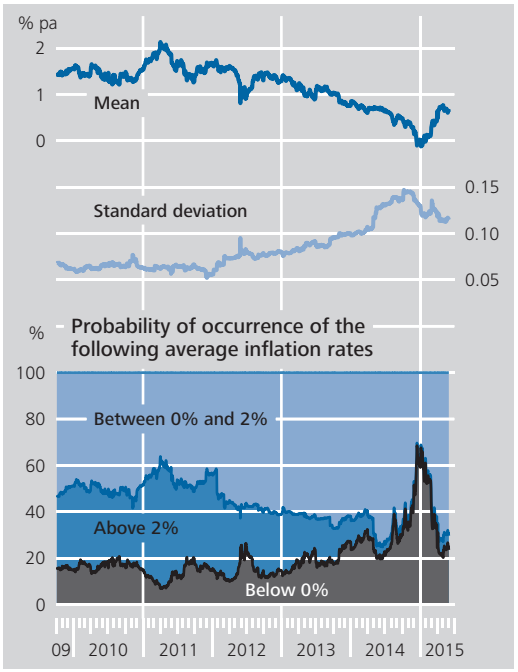
The prices of inflation options generally contain useful information, which, however, is initially only available for individual, discrete strike prices (inflation rates, in this case). They are bundled together by calculating "preference-weighted" or risk-neutral density functions, which yield information on the probability that market participants assign to specific inflation rates occurring (see the box on pages 50 and 51 for further information on deriving density functions). If, for example, owing to a change in the data situation, market participants anticipate higher future inflation rates, the value – and thus the price – of hedging against higher inflation rates increases. Conversely, it can therefore be derived from a higher option price that a higher probability of occurrence is attributed to the "higher inflation" event. This is, however, based on the assumption that the average investor is "risk-neutral", ie the higher price does not contain a risk premium. Only then does the derived "risk-neutral" density correspond exactly to the objective density, which can be used to derive mathematically accurate probabilities of occurrence.

Impact of uncertainty and premiums on expectation indicators

In actual fact, however, it is likely that variable risk premiums play a role in some cases, which means that care must be taken when interpreting the indicators derived from them. It is apparent that uncertainty grew among market participants concerning future inflation rate developments, irrespective of horizon, as the sovereign debt crisis deepened in 2012 (see above chart). This increased dispersion of the expected inflation rate derived from options is not limited to the euro area but rather extends, for example, to the United Kingdom.[6] Uncertainty also rose with respect to expectations derived from surveys.[7] Furthermore, a shift in the distribution symmetry was noted, with real-

Inflation expectations derived from inflation options over a three-year horizon

Daily data



Sources: BGC Partners, Bloomberg and Bundesbank calculations.
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5 The put-call parity is based on the assumption of two no-arbitrage portfolios which replicate the same cash flow. The first portfolio contains a call option and a sum of money equal to the discounted strike price. The second portfolio contains a put option with the same strike price as the call option and the underlying base value of the option. Irrespective of whether the price of the base value is achieved, both portfolios always have the same payouts, which is why the prices for call and put options must be the same for a given price of the base value and the discount factor. Otherwise, risk-free profits resulting from long and short positions on both portfolios are possible. See, for example, J Hull (2006), Options, futures and other derivatives, 6th edition, Prentice Hall, New Jersey, USA.
6 For more information, see T Smith, Option-implied probability distributions for future inflation, Bank of England, Quarterly Bulletin 2012 Q3, pp 224-233.
7 For more information, see Deutsche Bundesbank, Some approaches to explaining the behaviour of inflation since the last financial and economic crisis, Monthly Report, April 2014, with a particular focus on pp 66-72.

Estimating risk-neutral density functions from inflation options[1]

An option is a derivative financial instrument; its price is derived from the development of the value of an underlying asset (or underlying instrument). It grants the right but not the obligation to purchase (call option) or sell (put option) a certain amount of the underlying asset at a previously defined price (strike price). With a European option – unlike with an American option – the contract can only be exercised upon maturity, ie on a previously agreed expiry date.

The inflation options discussed in this article are European over-the-counter options with a residual maturity of one, three, five or ten years.[2] Their underlying instrument is the euro-area Harmonised Index of Consumer Prices excluding tobacco (HICPxT).[3] One special feature is that the spot price of the underlying asset – the change in the HICP that has arisen since the last publication – is not available every day as opposed to options on stock price indices, say, where the price of the underlying asset is calculated on the market every day. When calculating the option price, it is possible to use the forward price instead of the spot price of the underlying asset. For inflation options, the forward price is equivalent to the price of the corresponding maturity-matched inflation swap. This price is the fixed payment of an inflation swap – also known as the fixed interest rate on the inflation swap.

An inflation call option is known as a cap; an inflation put option is known as a floor. It is standard market practice with options to quote strike prices for the future inflation rate at intervals of half a percentage point.[4] Upon maturity, the holder of a cap receives the average inflation rate realised over the option's term less the strike price, ie the inflation rate specified in the contract. For inflation floors, the opposite is true. Option premiums for inflation options are quoted in basis points of the nominal value. For zero coupon options, the time series are available as of October 2009.[5]

There are a number of different procedures to derive risk-neutral density functions from option prices and thus to assess the uncertainty of market participants with regard to the probability of future inflation rates occurring. The simplest way is to create discrete probability distributions – ie histograms. This calculation first takes the difference between the option price and the "neighbouring" option prices – ie those options that are next to each other in terms of the strike price – and multiplies this by two. This difference is then discounted at the risk-free interest rate[6] to arrive at precisely the risk-neutral probability that the realised inflation rate will be in the range between the strike prices. This procedure was introduced in the literature by Breeden and Litzenberger (1978) and is based on the fact that – after adjustment using the discount factor – the second derivation of a continuous call price function after the strike price corresponds to the risk-neutral

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1 For more information, see the explanations and references in M Scharnagl and J Stapf, Inflation, deflation and uncertainty: What drives euro area option-implied inflation expectations and are they still anchored in the sovereign debt crisis? Deutsche Bundesbank, Discussion Paper No 24/2014.
2 Options can have maturities of 1, 3, 5, 7, 10, 12, 15, 20 or 30 years. As the liquidity of the very long maturities is questionable, in general only the timeframe up to 10 years is used.
3 There are historical reasons for using the price index excluding tobacco. The first inflation-indexed bonds in continental Europe were bonds on the French consumer price index excluding tobacco. Since then all inflation-related euro financial contracts have been indexed on the HICPxT.
4 In concrete terms, end-of-day balances of indicative quotations of option premiums for caps with strike prices of 1%, 2%, 3%, 4%, 5% and 6% and floors with strike prices of -2%, -1%, 0%, 1% and 2% (plus the half percentage point quotations between all of these prices) are available to calculate the probability distributions of inflation expectations.
5 The data are from BGC Partners Market Data.
6 EONIA swap rates are used to approximate "risk-free" interest rates in that fixed interest rates for a contractually stipulated range of maturities are swapped for variable, daily EONIA interest rates. The EONIA swap reflects expected European interest rates. Counterparty credit risks are mitigated, in part, by collateralisation but cannot be ruled out completely.

Payoff matrix for a butterfly spread with centre K = 2%

Status quo = realised inflation rate in %	Long cap with strike price = 1%	Two short caps with strike price = 2%	Long cap with strike price = 3%	Total payoff of butterfly spread
– 1	0	0	0	0
0	0	0	0	0
1	0	0	0	0
2	1	0	0	1
3	2	– 2	0	0
4	3	– 4	1	0

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density. It also assumes that short sales are possible, that there are no transaction costs and that funds can be borrowed at the risk-free interest rate.[7]

A simplified presentation of the following combined transactions comprising various options renders the results more intuitive. In a transaction known as a "butterfly spread", a market participant sells two caps at a strike price of, say, 2% (a short position) and in their place buys two caps at a strike price of, say, 1% and 3% (see table above). The participant receives a payoff of exactly one unit of money if the inflation rate actually amounts to 2% on the expiry date. In the literature, this is also referred to as an Arrow-Debreu portfolio. This type of portfolio pays exactly one unit of money if uncertain events assume a specific form. Due to the normalised payoff, the combined price for the butterfly spread can be used to derive the probability with which market participants expect the realisation of an inflation rate of 2%. Once all these discrete strike prices are at hand, they can be used to calculate histograms for the probability of these strike prices occurring.

Calculating the continuous density functions is more complex. For instance, such functions can be derived from certain interpolation procedures for continuous option price functions.[8] As an alternative, several probability densities (with a parametrical, functional form) can be mixed or "folded".[9] Such a procedure is used in the following calculations. First, two log-normal densities are combined on a linear basis. Second, the compound parameter and the two structural parameters "Mean" and "Standard deviation" have to be determined. In total, therefore, only five parameters are required to determine the mixed density. The parameters are then determined in such a way that the deviation of the "estimated" option prices that are implicitly given by the densities from the option prices actually observed is minimal. The resultant densities are, in part, asymmetrical and show – measured in terms of normal distribution – greater probabilities of extreme events.[10]

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7 See D Breeden and R Litzenberger (1978), Prices of state-contingent claims implicit in option prices, Journal of Business, Vol 51, pp 621-651. The price of a European call option c is $c = e^{-rT} \int_{S_T=K}^{\infty} (S_T - K) \mathrm{g}(S_T) \, dS_T$, with r representing the risk-free interest rate, K the strike price, T the maturity, S_T the underlying asset price upon maturity (here the realised inflation rate) and $\mathrm{g}(S_T)$ the risk-neutral density function of S_T. The second derivation after the strike price is

$$\frac{\partial^2 c}{\partial K^2} = e^{-rT} g(K).$$

In marginal cases of very small intervals between the strike prices δ, the risk-neutral density function can be derived from an Arrow-Debreu portfolio

$$g(K) = e^{rT} \frac{c_{(K-\delta)} + c_{(K+\delta)} - 2c_{(K)}}{\delta^2}.$$

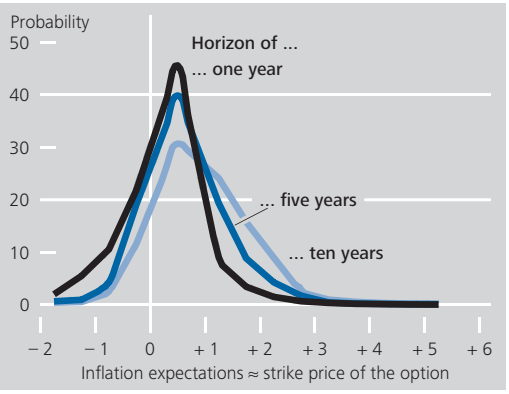
8 The Bank of England, for one, uses this approach: T Smith, Option-implied probability distributions for future inflation, Quarterly Bulletin 2012 Q3, pp 224 et seq.

9 This approach is followed by, for example, Y Kitsul and J Wright (2013), The economics of option-implied probability density functions, Journal of Financial Economics, Vol 110, pp 696-711.

10 For more information, see, for example, W Melick and C Thomas (1997), Recovering an asset's implicit pdf from option prices: an application to crude oil during the Gulf crisis, Journal of Financial and Quantitative Analysis, Vol 32, pp 91-115.

Risk-neutral density functions for inflation expectations

%; calculated on 31 March 2015



Sources: BGC Partners, Bloomberg and Bundesbank calculations.
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isations below the mean subsequently being weighted more heavily. As a result, the probabilities of inflation rates falling below zero spiked not only as the sovereign debt crisis intensified in 2012 but also, in particular, when extremely low inflation rates were realised in the latter half of 2014. Although the weights of tail risks are enhanced by assuming risk neutrality, such asymmetrical distribution reflects market participants' fears of negative future inflation rates.

Correlation between option maturity and probability distribution

A major formative structural component of risk-neutral densities is the (residual) maturity of the underlying options. As the maturity date approaches, the probability mass becomes more concentrated around the mean value of the density, which is also close to the current realised inflation rate. This is because the closer an option is to maturing, the lower the uncertainty surrounding the future inflation rate. This pattern can be seen, for example, in risk-neutral densities based on options with residual maturities of ten, five and one year(s) as at 31 March 2015. The realised inflation rate for the European Harmonised Index of Consumer Prices excluding tobacco (HICPxT) stood at -¼% in March 2015 (compared with an average of 1¾% since 1999). This shows that density functions become narrower and focus more on the realm of lower inflation rates when option maturities are shorter. However, it should be noted when interpreting the density function that assuming risk neutrality, which was mentioned previously, causes the probabilities of occurrence to be systematically overestimated at the upper and lower distribution ends and underestimated for the mean value.

Determinants of inflation expectations and changes in the sovereign debt crisis

Determinants of inflation expectations

It is essential for monetary policymakers to influence future inflation expectations in the desired manner to the best of their ability and to respond appropriately to changes in inflation expectations. In this context, a distinction must be made between short and longer-term inflation expectations. Longer-term expectations should be firmly anchored – that is to say, they should fluctuate only slightly over time and be below, but close to, 2% for the euro area. A key anchor of stability in this regard is the credibility of the Eurosystem. By contrast, given the long-term and time-varying lags in the monetary policy transmission process, it is impossible to perfectly stabilise short-term expectations. Consequently, short-term inflation expectations may change in response to unexpected turns of events, cyclical fluctuations and monetary policy measures. Over the longer-term horizon, however, such influences are diluted, meaning that responses to unfolding events – oil prices being one example – should lessen as inflation expectation horizons increase.

Using event studies to identify determinants

The high observation frequency of option prices makes it possible to identify changes in inflation expectations at short intervals. This is often done using event studies, in which monetary policy measure announcements or macroeconomic surprises are viewed in relation to changes in the inflation expectations derived from them. As the price formation process on the capital markets is characterised by continuous information processing, behaviour in response to the surprise or news of the macro-

economic or monetary policy event must first be identified. A method frequently used for financial market data is to deduct the current realisation of a macro variable from the expectations previously expressed by market participants in a survey. The difference between the published variable and the survey variable is then the actual news. Only this should lead to same-day changes in financial market prices and, thus, the inflation expectations derived from them. Therefore, taken in isolation, "positive" figures could contain a negative surprise component. Such survey results are supplied by commercial data providers and are available for important macroeconomic data such as the expected growth of gross domestic product (GDP).[8] It must be taken into account when studying the data, however, that they are only available for a short period (this is generally so in the case of inflation-indexed financial market instruments for the euro area and especially so in the case of inflation options). It is therefore unclear whether the findings of empirical studies also hold in the long term.

Yield changes as an indicator of monetary policy announcements

There are no surveys for monetary policy measures, as exist for macroeconomic variables, that systematically include all monetary policy measures that were in some way unconventional (asset purchase programmes, long-term tenders, changes to the collateral framework etc). Consequently, the intraday change in the yields of long-term government bonds is used as an indicator of behaviour in response to news. Events such as the announcement of an expansionary measure may well have an interest-enhancing effect using this indicator, too – for example, if a further-reaching or higher-volume measure had been expected by market participants. Such a way of identifying news has not escaped criticism with respect to effect incidence.[9] All the same, government bond yields (as an indicator) and inflation expectations derived from inflation options in the euro area were shown to be significantly more volatile on days on which monetary policy decisions were announced than on those on which they were not during the observation period between 2009 and 2014.

How inflation expectations are affected by macroeconomic news …

As macroeconomic variables from individual countries are generally made available before euro-area aggregates, surprise developments in the larger countries of Germany, France and Italy are used to assess the effects of news. The time series of macroeconomic surprises are normalised with their respective standard deviation. As expected, standardised macro surprises with a larger coefficient have an effect on shorter-term inflation expectations (see also box on pages 54 and 55). These correlations generally exhibit the anticipated signs. For instance, "negative" announcements such as surprisingly high unemployment rates, which indicate a lower-than-expected capacity utilisation of the economy, cause inflation expectations to fall. By contrast, "positive" cyclical surprises lead to increased inflation expectations. The number of significant coefficients for Italy increased as the sovereign debt crisis intensified, presumably because the country's high level of debt sparked greater interest in its economic development and was paid more attention by market participants. Overall, however, macroeconomic surprises go significantly less than 10% of the way to explaining the variance of inflation expectations. The manner in which macroeconomic surprises affect inflation expectations derived from inflation swap data has been analysed in a complementary event study, in which conclusions have also been drawn on the anchoring of inflation expectations. In particular, surprises in terms

8 This article uses the median of Bloomberg survey data listed under "World Economic Releases".

9 For one example of a discussion, see D Thornton (2014), The identification of the response of interest rates to monetary policy actions using market-based measures of monetary policy shocks, Oxford Economic Papers, Vol 67, pp 67-87. The main criticism levelled here is that interest responses are overestimated due to regressing yield changes on monetary policy news alone, whereas interest rates respond to all other news at the same time. Such overestimations can be mitigated using a variety of approaches, such as high-frequency data, identification through heteroscedasticity, or evaluating news by means of a latent factor or by adjusting for the average response on days on which monetary policy events did not occur.

Time-varying responses of inflation expectations derived from inflation options to macroeconomic surprises and monetary policy announcements[1]

Within a specified period of time, financial market variables are shown to respond significantly to surprises in macroeconomic variables.[2] This is also the case for inflation expectations derived from inflation options. The underlying estimate measures the daily changes in inflation expectations in response to all same-day macroeconomic surprises and monetary policy announcements.[3] This means the impact of each individual announcement is controlled by the impact of all other same-day news, as long as the announcement time series are not multicollinear.[4] As macroeconomic variables for individual countries are usually available earlier than the euro-area aggregates, the surprise developments in the larger countries of Germany, France and Italy are used to estimate the effects of news. The time series of macroeconomic surprises are each normalised with their standard deviation. In terms of macroeconomic surprises, indicators such as business climate, rates of price change, purchasing managers' indices, as well as the French unemployment rate are significantly correlated with the inflation expectations. The focus on Italian macro data rises in 2014 in particular (see the table on page 55).

In contrast to macroeconomic variables, there are no surveys for monetary policy measures that systematically cover all measures, including the unconventional measures. Hence, for monetary policy surprises, the same-day change in yields on long-term government bonds is used as an indicator of the news content. The monetary policy announcements are also divided by their standard deviation and "normalised" using the mean value of the daily changes over the entire period. The results show that

1 Results up to the end of 2013 can be found in M Scharnagl and J Stapf, Inflation, deflation and uncertainty: What drives euro area option-implied inflation expectations and are they still anchored in the sovereign debt crisis?, Deutsche Bundesbank Discussion Paper, No 24/2014.
2 See, for example, T Andersen, T Bollerslev, F Diebold and C Vega (2003), Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange, American Economic Review 93, pp 38-62.
3 The estimating equation is: $\Delta p_{\pi^e,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \gamma m_t + \varepsilon_t$, with $\Delta p_{\pi^e,t}$ representing the change in the probability of inflation on day t, β_j as the coefficient of the surprise $s_{j,t}$ of the macro variable j, and γ as the coefficient of the monetary policy announcement m_t measured by a change in the GDP-weighted yield on euro-area government bonds. ε_t is the error term.
4 Low pairwise correlation coefficients, and variance extrapolation factors slightly greater than one, indicate no multicollinearity.

Inflation and deflation probabilities and monetary policy announcements*

Period	October 2009 to July 2011	August 2011 to December 2013	2014
Dependent variables:	Independent variable: daily changes in GDP-weighted ten-year yields on euro-area bonds		
Probability of inflation over …			
… 1 year	– 0.82**/0.16		
… 3 years	– 0.75***/0.08		
… 5 years	– 0.72***/0.07		– 0.13**/0.01
… 10 years	– 0.69***/0.06		– 0.27**/0.01
Probability of deflation over …			
… 1 year	0.32**/0.04	– 0.25*/0.07	1.6**/0.01
… 3 years	0.25**/0.07		0.59*/0.01
… 5 years	0.33***/0.09		0.52**/0.01
… 10 years	0.25***/0.11		0.33*/0.01

Sources: BGC Partners, Bloomberg, Reuters and Bundesbank calculations. * Controlled using 23 time series of macroeconomic surprises. Blank fields indicate coefficients are not significant. *, **, *** 10%, 5%, 1% significance level (heteroscedasticity and autocorrelation consistent t-statistic) / adjusted r^2.

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Inflation and deflation probabilities and macroeconomic surprises*

Dependent variables	October 2009 to July 2011		August 2011 to December 2013		2014	
	Independent variable					
	Probability of inflation 5 years	Probability of deflation 5 years	Probability of inflation 5 years	Probability of deflation 5 years	Probability of inflation 5 years	Probability of deflation 5 years
Germany						
Current account balance						
Harmonised Index of Consumer Prices						
Ifo business climate			– 0.05*		– 0.05***	
Industrial output						
Producer price index						
Unemployment rate						
Purchasing Managers' Index (manufacturing)						
Purchasing Managers' Index (services)	– 0.09***	0.06***				
France						
Business climate						
Consumer price index	0.06**					
Gross domestic product						0.09**
Industrial output						
Producer price index	– 0.13**	0.12**				
Unemployment rate	– 0.07*	0.02*				
Purchasing Managers' Index (manufacturing)					0.09***	
Purchasing Managers' Index (services)						
Italy						
Business climate	0.05***	– 0.02***				
Harmonised Index of Consumer Prices						
Industrial output			0.05**			
Producer price index					0.04***	– 0.11**
Real gross domestic product	0.04**				– 0.01***	0.05**
Purchasing Managers' Index (manufacturing)						
Purchasing Managers' Index (services)						– 0.15*
Adjusted r^2	0.07	0.09	0.02	0.01	0.01	0.01

Sources: BGC Partners, Bloomberg, Reuters and Bundesbank calculations. * Controlled using monetary policy announcements. Blank fields indicate coefficients are not significant. *, **, *** 10%, 5%, 1% level of significance (heteroscedasticity and autocorrelation consistent *t*-statistic).

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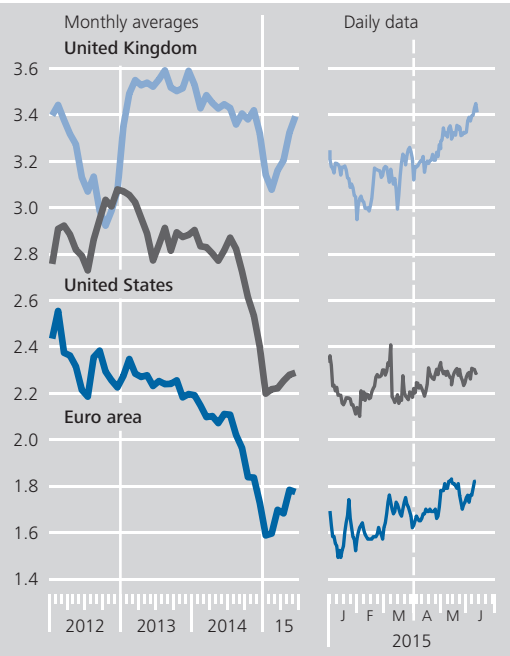
monetary policy announcements have a greater impact on inflation expectations over the shorter time horizon of one to three years and become less significant in the years from mid-2011 to 2013 (see the table on page 54). In 2014, the number of significant coefficients picks up, particularly in connection with deflation expectations (deflation is defined here as an inflation rate of less than zero). In this respect, the monetary policy announcements have, at least in part, contributed to reducing the expectation of negative inflation rates in future.

However, subdividing the observation period does not allow for the continuous observation of changes in the coefficients. Time-varying coefficients were therefore also estimated using the flexible least squares method, which involves minimising both the "normal" static measurement error and a dynamic measurement error that reflects changes over time.[5] Here, too, it is clear that the impact of monetary policy announcements on inflation expectations initially decreased before increasing again (see also the chart on page 59).

5 Specifically, the coefficient is estimated as the minimisation of the incompatibility cost function $C(\beta,\mu) + (1-\mu)r_M^2(\beta) + \mu r_D^2(\beta)$. With the given weighting μ, this minimises the estimation errors: $r_M^2(\beta) = \sum_{t=1}^{T} u_t^2$ and $r_D^2(\beta) = \sum_{t=2}^{T}(\beta_t - \beta_{t-1})'(\beta_t - \beta_{t-1})$.

Five-year forward inflation rates five years ahead*

% pa



Sources: Thomson Reuters, Bloomberg and Bundesbank calculations. * Derived from the fixed payout of inflation swaps, which is substituted by annual realised inflation rates five or ten years ahead.

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of realised inflation rates are shown to have no significant impact on long-term inflation expectations (see box on pages 57 to 59).

… and other variables

Other variables had a greater impact on inflation expectations derived from options. For example, changes in equity prices proved to be significant. The fact that changes in company valuations reflect higher or lower growth prospects for the companies of a country and, hence, of its overall economy, may be a contributing factor here. Another major determinant is the price of oil. Here, however, it must be noted that – much in much the same way as the price of financial instruments – the daily oil price is determined by expectations regarding matters such as the future capacity utilisation ratio of the global economy. Both variables could therefore be determined by a common factor. While it is difficult to identify a cause in this case, a major change in the correlation between oil prices and long-term inflation expectations has been present in empirical estimates since mid-2014; corresponding structural break tests are significant. It is too early to say whether this stronger correlation is based on fundamentals and whether it will persist.

Long-term inflation expectations driven by global factor?

Market-based inflation expectations in various currency areas have been remarkably synchronised over the past year (see adjacent chart). In particular, the decline in long-term inflation expectations in the latter half of 2014 and the rebound at the start of 2015 followed a very similar pattern in the United States, the United Kingdom and the euro area. While the monetary policy environment in the United States was characterised by debates surrounding the "tapering" of its unconventional monetary policy measures, expectations in the euro area regarding the establishment of an asset purchase programme grew. In this respect, it seems likely that long-term inflation expectations were determined by global factors. Both the oil price and the inflation risk premiums derived from financial market models are moving in tandem with long-term inflation expectations, although the reason for this has yet to be determined.[10] Significant negative demand shocks need to be identified as drivers of both variables in order to account for the observed correlation with the forward inflation rate. One example of such a driver would be an ongoing global dearth of demand that led to a drop in long-term inflation expectations amid falling oil prices in oil-importing countries. However, such an explanation is potentially inadequate. The past year's oil price developments are therefore also frequently discussed in connection with the growing supply attributable, *inter alia,* to US oil production.

10 For more information, see, for example, FOMC Minutes, published on 7 January 2015 on http://www.federalreserve.gov/monetarypolicy/fomcminutes20141217.htm; and J Haubrich, G Pennacchi and P Ritchken (2011), Inflation Expectations, Real Rates, and Risk Premia: Evidence from Inflation Swaps, Working Paper 11/07 of the Federal Reserve Bank of Cleveland, for which an updated dataset is available. For a more basic explanation, see J Campbell, R Shiller and L Viceira, Understanding inflation-indexed bond markets, Brookings Papers on Economic Activity Spring 2009, pp 79-120.

Anchoring of long-term inflation expectations in the euro area

One possible definition of the anchoring of long-term inflation expectations involves the idea that they react only to a very small extent to changes in the currently realised inflation rates. The background to this is that, given a minor reaction of the long-term expectations, the deviations of the realised inflation rates are not seen as permanent, and a return to the target value of below, but close to, 2% is expected. An event study therefore investigates changes in the long-term, market-based inflation expectations as a reaction to surprises about the economic situation. The first releases of inflation rates for the large countries – Germany, France and Spain – as well as for the euro area as a whole by the respective statistical offices are used as events. In addition, the real economic situation is represented by the releases of confidence indices for the corporate sector of individual countries and the monetary union as a whole.[1] The information known in the market prior to the publication of inflation or real economic indicators is recorded by surveys carried out until shortly before release. Only the surprise of the event – the difference between realised data and the survey expectation – should have an impact on the change in the market-based inflation expectations.

In contrast to inflation options, data for inflation swaps have been available since 2004, allowing a comparison with the pre-crisis period. In order to model changes over time, a time-variable, non-linear regression is estimated:

$$\Delta ILS_t^n = \alpha_t^n + \delta_t^n(\beta S_t) + \varepsilon_t^n,$$

ΔILS_t^n are the changes in the inflation swap rates with maturity n at the point in time t and S_t is the surprise of the macroeconomic data release. The vector β captures the structurally different reaction to the eight surprises – eg the difference between the impact of the German inflation rate and French industrial confidence – and is identical for all points in time and maturities. The scalar δ_t^n models the variation over the time t and maturities n for the news.[2] It is advantageous that several announcements are available in every month. As a result, the sample, with which the time-variable effect δ_t^n is estimated, increases. The estimation is carried out in two steps. First, the structural reaction β is determined using daily inflation swap rates with maturities of two to ten years, with the time variability in the financial crisis being represented by nine-month time dummies for the period from 2008. The dummies are normalised so that a value of one corresponds to the reaction of a two-year inflation swap prior to the financial crisis in the period from 2004 to 2007.

The estimates of the structural reaction coefficients β in the following table show that published inflation releases have a significantly positive impact on the changes in inflation expectations gained from inflation swaps. German data, in particular, show

1 Germany, France, Italy, Spain and the aggregate euro area were taken into consideration in the selection of the indicators. No surprise data on industrial confidence exist for Spain. Italian inflation is excluded owing to multicollinearity to inflation in the euro area. The selected indicators are the quickest to provide information about the macroeconomic situation. Other key indicators such as industrial production, GDP growth and producer prices are available only with a major time lag.

2 This method was developed in connection with the zero lower bound of interest rates by E Swanson und J Williams (2014), Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates, American Economic Review, Vol 104, pp 3,154-3,185.

Estimation of the structural reaction coefficient β of news on inflation swaps

Item	β
Inflation in Germany	3.397***
Inflation in euro area	1.177*
Inflation in Spain	1.481***
Inflation in France	2.587***
Ifo business climate in Germany	4.477***
Industrial confidence in euro area	– 2.200***
Industrial confidence in France	1.280***
Business climate in Italy	0.952***

Sources: Bloomberg, Reuters and Bundesbank calculations. *, **, *** indicate significant deviation from 0 at a significance level of 10%, 5% and 1% based on standard errors adjusted for heteroscedasticity.

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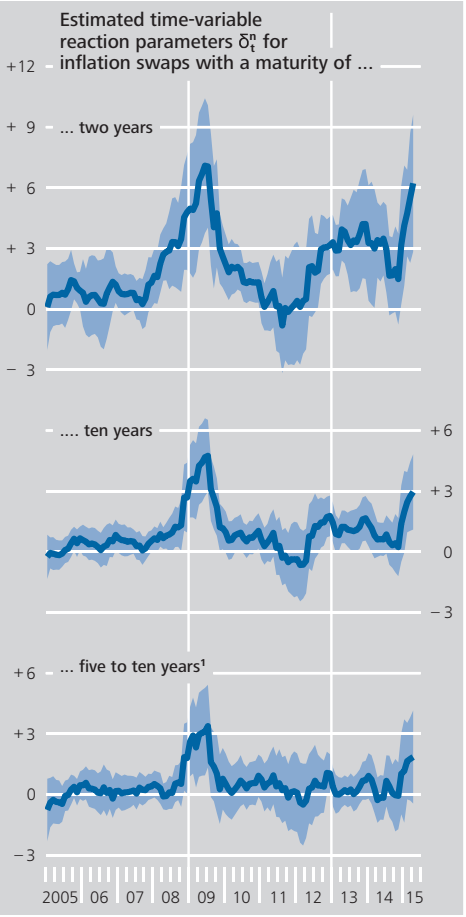
Reactions of inflation swaps to macroeconomic news*

Monthly



* Point estimators and 95% confidence interval adjusted for heteroscedasticity. **1** Reaction of the five-year forward inflation rate starting in five years.

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high coefficients, which may reflect the size of the economy, but also the speed with which data are published.

In a second step, the product of the estimated coefficient and the surprise (βS_t) is used in a time-shifting (rolling) regression in order to determine the time-variable effect as a reaction parameter δ_t^n at monthly intervals.

For a maturity of two years, the inflation swap rates react significantly positively (see adjacent chart). The value of the reaction of the two-year swap rates δ_t^{2Y} increases during the financial market turmoil in 2008 and 2009, before falling back and then rising again from the end of 2011, and in April 2015, it was more than five times higher than before the financial crisis. However, the longer the maturity of the inflation swap rates used, the smaller the time-variable effect is, as is shown by the reaction parameter of the ten-year maturity δ_t^{10Y}. In addition, the reactions for the long-term horizons between 2010 and 2015 are predominantly at a low level insignificantly different from zero.

If the five-year forward inflation rate starting in five years derived from inflation swap rates is used as a dependent variable, a reaction parameter of zero ($\delta_t^{5Y \to 10Y} = 0$) denotes an insignificant impact of the surprises on long-term inflation expectations. The adjacent chart shows no significant reaction of the long-term inflation expectations and, hence, their firm anchoring during most of the period under study. One exception is the first half of 2009, a closer look at which shows that the reaction was caused by real economic shocks. Market participants evidently expected that it would take an extended period of time for the economy to recover from the setback due to the financial and economic crisis and

that it would therefore not be possible to increase prices until later. News about inflation rates had no significant impact on inflation expectations in this period. Furthermore, since the end of January 2015, there has been a marked rise in the reaction of the five-year forward inflation rate starting in five years; owing to greater estimation uncertainty, however, this is not significantly greater than zero. In addition, the publication of inflation rates for February 2015 contained a number of positive surprises, which were accompanied by increases in inflation swap rates. The increase in the reaction parameter therefore partially reflects a (desired) convergence towards the inflation target.

In summary, no robust evidence can be derived from the event study to show that the financial market players are calling into question the anchoring of long-term inflation expectations in the light of recently low inflation rates and negative inflation surprises.

Effect of monetary policy announcements on inflation expectations

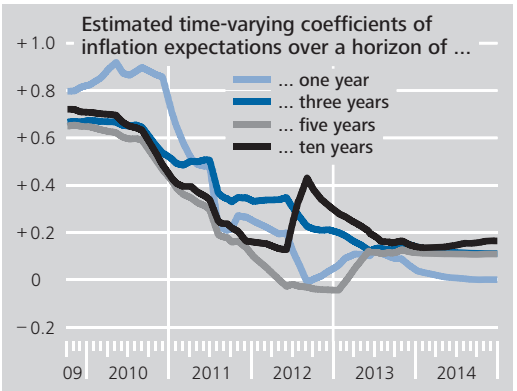
Monetary policy announcements had a time-varying impact on inflation expectations in the euro area during the period under observation (see the adjacent chart and box on pages 54 and 55). Initially, they had a greater impact over a horizon of up to three years. A major contributing factor here is that the transmission of monetary policy to the real economy takes time. The regressions also demonstrate that the effect of monetary policy announcements showed a downward trend between 2010 and 2012 before moving back up in 2013 and 2014. These estimates are subject to a considerable degree of uncertainty and, in some cases, are not significant; thus, they should only be interpreted with great caution. However, a possible explanation for this phenomenon could be that, at the height of the sovereign debt crisis, it was difficult for market participants to assess the impact of the monetary policy measures taken on the euro-area inflation rate.

Crisis-period inflation expectations more volatile, but not unmoored

A study of inflation expectations derived from inflation options reveals that expectations have

How inflation expectations respond to monetary policy announcements

Daily data



Sources: BGC Partners, Bloomberg and Bundesbank calculations.

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Inflation expectations more volatile, but not unmoored

recently become more mixed. In some cases, the way in which expectations respond to unfolding events is also changing. This phenomenon transcends euro-area borders, affecting large industrial countries such as the United States and the United Kingdom as well. Overall, however, it cannot be concluded from the increased volatility of inflation expectations and the stronger response to factors such as oil price developments that inflation expectations have become unmoored. Instead, the discernible fall in long-term inflation expectations since the 2009 recession against a backdrop of low realised inflation rates could be pointing to a slower adjustment of values to around the target of below, but close to, 2%. Although a slight rebound in inflation expectations has been observed in recent months, it would nevertheless seem advisable to monitor developments closely. In this context, use should be made of insights into probability distributions derived from inflation options in addition to established expectations derived from surveys, inflation-indexed bonds and inflation swaps. These make it possible to not only capture market participants' uncertainty but also identify asymmetrical distribution and quantify the likelihood of tail risks.