Analysis

Have market inflation expectations strengthened?

Monetary policy | 30 March 2017 | Tomi Kortela

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Estimated on the basis of inflation swaps, euro area inflation expectations have increased. Interpretation of inflation swaps is not, however, a straightforward matter, as the price of an inflation swap can be affected by, for example, its risk level.

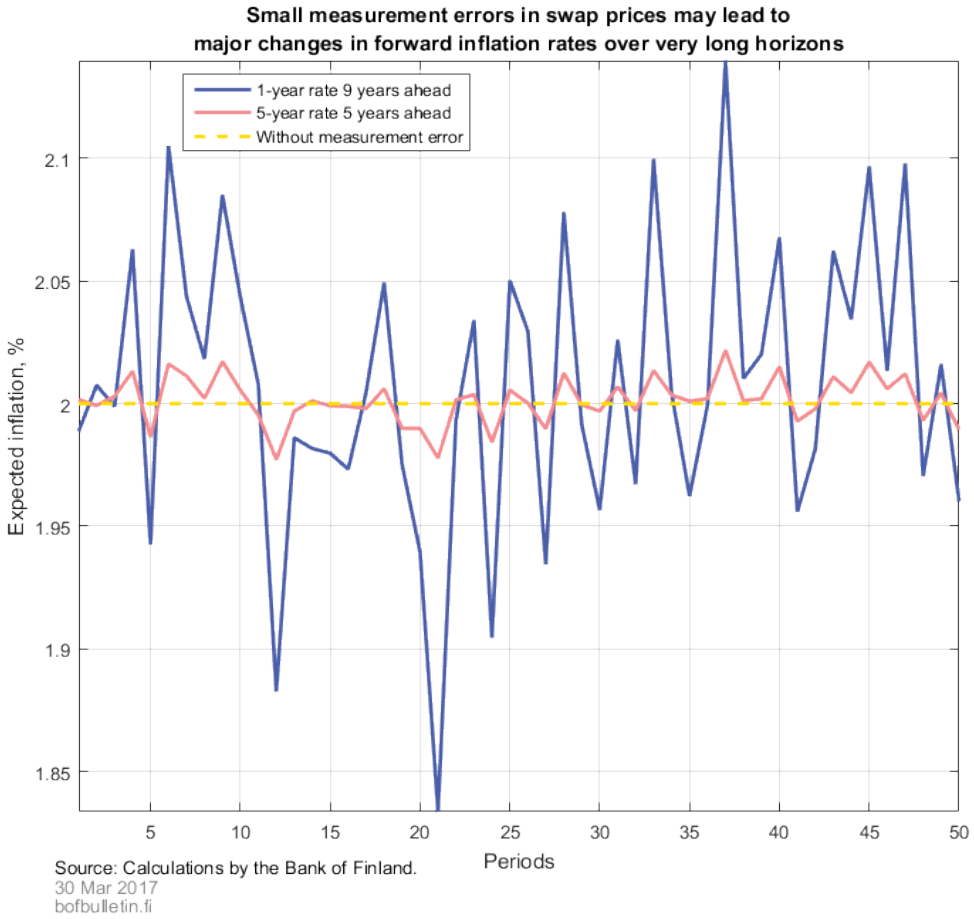


Risks involved in straightforward interpretation of inflation swaps

Inflation expectations play a key role in determining inflation, as expectations of future inflation are reflected in current prices.[1] For this reason, central banks monitor closely the evolution of inflation expectations. Inflation expectations can be measured in many different ways: via surveys, by examining inflation forecasts or by measuring inflation expectations on the basis of financial instruments. If financial market prices are used for measuring, we refer to market-based inflation expectations. Inflation expectations on the euro area markets are often measured by inflation swaps.[2]

The development of expected inflation inferred from (inflation) swaps is typically surveyed by monitoring different forward inflation rates (Chart 1). Forward inflation describes average inflation derived from swap prices over a given future horizon. For example, the 'two-year one year ahead' forward inflation rate illustrates average two-year inflation when the calculation of average inflation begins one year from today.

Chart 1.



Expected inflation inferred from swaps has accelerated since autumn 2016 (Chart 1). As swaps are, however, relatively complex securities, the information extracted from them must be interpreted with caution. Upon examination of recent developments in euro area inflation expectations, at least three factors need to be taken into consideration.

Firstly, short-term forward inflation rates over very long horizons (e.g. one-year inflation nine years ahead) are sensitive to small changes in long-term swap prices. For example, pricing or measurement errors may lead to considerable changes in these types of forward inflation rates.

Secondly, it is difficult to observe the path of expected inflation on the basis of forward inflation curves over different horizons, as the inflation rates indicated by the curves are, in part, overlapping or fail to cover all periods. Moreover, when the markets expect a pick-up in inflation, forward inflation will also accelerate over time. In such a case, a change in forward inflation does not necessarily mean a change in inflation expected by the markets.

Thirdly, swap prices reflect the compensation required by investors for bearing the risk related to inflation. As the riskiness of a swap is also affected by factors other than expected inflation over

the life of the swap, the swap price may differ from the rate of inflation expected by the markets. Such components having an impact on the price of a security are called premia. Changes in inflation expectations derived directly from swap prices may, in fact, mirror changes in premia, rather than changes in inflation expected by the markets.

Interpretation of expectations can be improved by modelling the term structure of swaps

The above examples demonstrate that forward inflation inferred from swap prices needs to be interpreted with caution. Such interpretation-related risks can be assessed by modelling the term structure of inflation swaps. This means the reciprocal relationship of prices of swaps with different maturities. If we take this term structure into account, we can obtain more information on inflation expected by the markets than by only monitoring individual swap prices. This approach has many advantages.

The term structure model enables calculation of inflation expected by the markets, based on a large array of swap prices. This path of expected inflation is affected by a number of swap prices, and in the calculation there is no need to choose which swap prices are to be used for capturing market expectations. As a consequence, measurement errors related to individual swaps have only a limited effect on the results.

Another key advantage is that the model enables assessment of the size of premia related to swap prices. Even if estimates from such models are only indicative, they help perceive the significance of premia in inflation expectations.

In other words, the results given by the term structure model of inflation swaps allow the assessment of risks related to the interpretation of expectations derived directly from swap prices. The question as to whether market inflation expectations have increased can thus be answered with greater certainty.

The modelling of swap prices can mainly be approached in the same manner as the modelling of interest rates. In this analysis, the model chosen is a typical term structure model of interest rates, which is known as an arbitrage-free dynamic Nelson-Siegel model.[3] On the basis of three time-varying factors, the model seeks to account for prices of swaps with different maturities in such a way that swap pricing at one point in time imposes absence of arbitrage – i.e. there is no possibility of gaining risk-free profit.

The modelling of the term structure of inflation swaps differs in two respects from the modelling of the term structure of interest rates. Firstly, in practice, only swaps with full-year maturities can

be used in the modelling. This is because seasonal variation in inflation would lead to considerable price volatility in swaps with maturities other than full years, which would hamper the modelling exercise. Secondly, in the modelling, forward inflation rates must be used, as swap prices are subject to so-called calendar effects.[4]

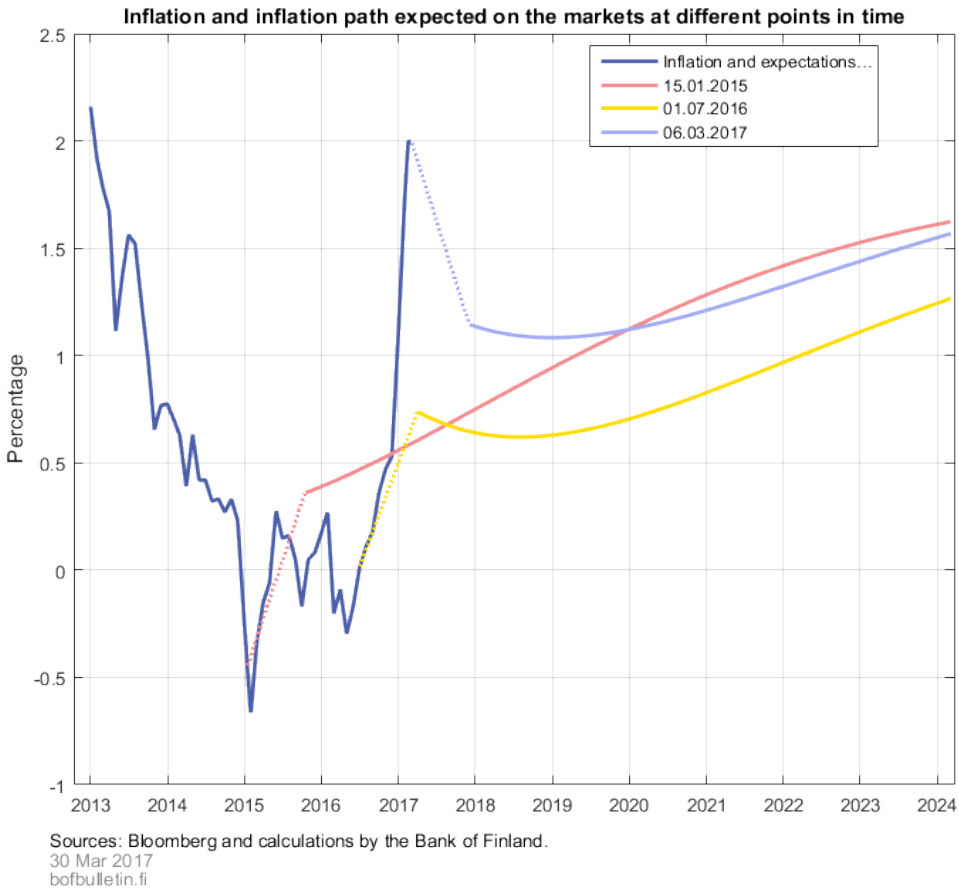
Term structure model makes it possible to obtain a consistent picture of inflation expectations

Trading in inflation swaps takes place off exchange on an over-the-counter basis, directly between the parties involved. Firms providing financial market information collect price data on the basis of transactions made. The prices so obtained can, however, include measurement errors; in other words, they do not necessarily correspond to real market prices, but are estimates thereof.[5]

Inflation swap markets are highly sophisticated, with significant market turnover, meaning that measurement errors related to prices are in most cases small. The problem is that short-term forward inflation rates over very long horizons are sensitive to even minor measurement errors.

Next, we examine a situation (Chart 2), in which all swap prices are without measurement error 2%, whereby forward inflation rates over the various horizons are likewise 2% (the yellow broken line in the chart). The chart also presents two forward inflation rates over different horizons (1-year rate 9 years ahead and 5-year rate 5 years ahead), on the assumption that measurement errors related to prices are identically and independently normally distributed and the standard deviation of the measurement errors is one basis point, i.e. 0.01 of a percentage point.[6]

Chart 2.

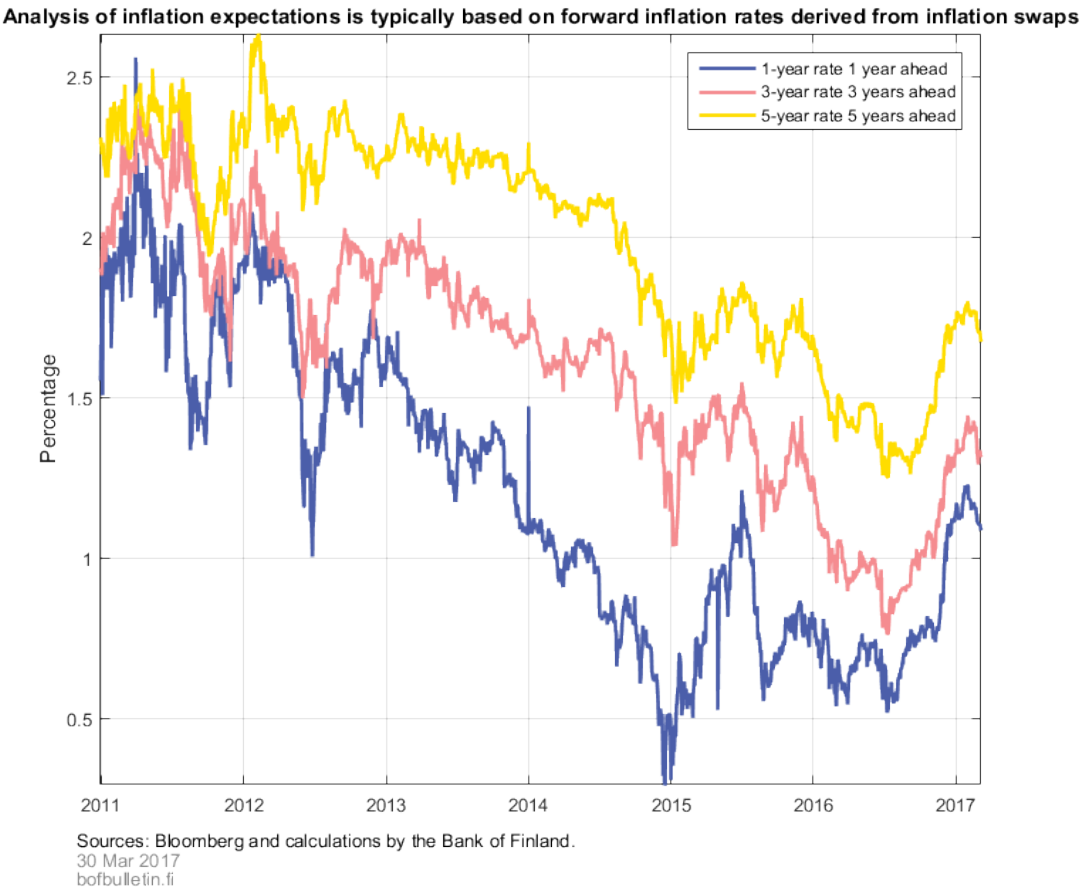


Our examination shows that the value of short-term (one-year) forward inflation over a very long horizon (9 years ahead) is highly sensitive to relatively small measurement errors (Chart 2). Even small measurement errors result in errors of more than 0.10 of a percentage point in forward inflation. Errors of this size can be deemed significant, as measurement errors may in certain situations lead to misinterpretation of changes in inflation expectations.

This characteristic, however, applies only to very short-term forward inflation over a very long horizon. In fact, the typically used '5-year 5 years ahead' forward inflation rate gives almost unbiased results. For example, typical values of forward inflation – as in Chart 1 – are not sensitive to minor measurement errors; the problem only concerns less frequently used forward inflation rates over very long horizons.

The impact of potential measurement errors on longer-term forward inflation rates can be removed by using information extracted from all swaps, i.e. the information provided by the term structure of forward inflation rates, for the modelling of inflation expectations (Chart 3).

Chart 3.



In the left-hand panel (Chart 3), the circled values of forward inflation on 6 March 2017 can, in the current environment, be considered as representing a typical term structure of inflation expectations. The chart depicts 1-year inflation 1–9 years ahead: for example, the observation at 5 years is roughly speaking 1-year inflation 5 years ahead as expected by the markets, i.e. inflation in 2022. In addition, the fitted value of the model (the line in the chart) has been set as close to the observations as possible on condition that the prices based on the fitted value incorporate no opportunity for risk-free profit.

Short-term forward inflation rates are highly consistent with efficient pricing – i.e. the difference between the observations and the fitted value is small (Chart 3). This supports the idea of efficient markets, but longer-term forward inflation rates appear to deviate from the fitted value. The difference may be due to a number of factors – such as the poor fit of the chosen model for the data – but the most likely cause is a small measurement bias in the data. This conclusion is underpinned by the fact that the difference is significant expressly in forward inflation rates over very long, i.e. 9-year horizons, which are exposed to measurement errors, as discussed above.

The fitted value of the model also enables examination of long-term forward inflation rates. The fitted value calculated with the model is not based on the prices of two swaps (as the observations in the chart are), but on the entire term structure of swaps. Accordingly, the model's fitted value can be deemed as giving a consistent picture of market inflation expectations, also in respect of long-term forward inflation, as the fitted value is based on information from several observations. This prevents any measurement errors in the data from leading to wrong interpretations of the inflation expected by the markets.

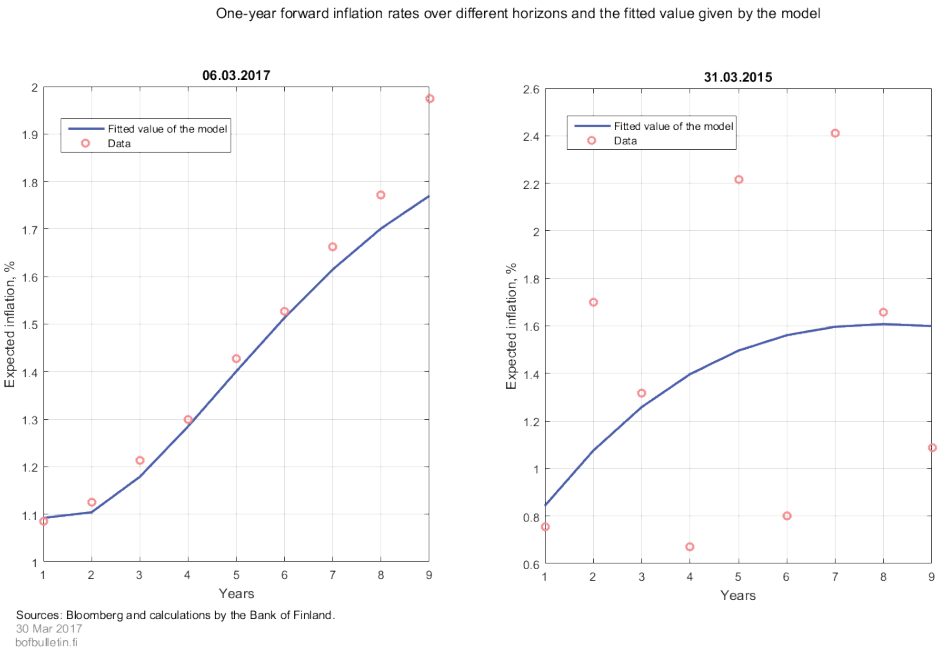
In some contexts, the fitted value of a model is the only way of examining market inflation expectations. This is the case, for example, when swap prices observed on the markets fail to provide a credible path for inflation (the right-hand panel in Chart 3).[7] It is a situation in which the markets are unable to form a picture of future inflation. The reason for this may be that the markets need some time to process new information received. In such cases, the fitted value is still able to produce a credible picture of market inflation expectations. These exceptions are relatively rare, but show that the use of a model's fitted value in exploring inflation expectations gives a consistent picture of market expectations in different situations.

Term structure model enables calculation of inflation path expected by the markets

A typical way of analysing market-based inflation expectations is to monitor cross-temporal developments in forward inflation rates over different horizons (see Chart 1). In such analyses, inflation expectations are often overlapping in part or fail to incorporate all periods, rendering it hard to capture the inflation path expected by the markets. Furthermore, as forward inflation rates measured at different points in time naturally illustrate expected inflation over different periods of time, comparison of forward inflation values over different horizons is not straightforward.

Using the term structure model of inflation swaps, we can calculate the path of expected inflation inferred from swap prices. As this path gives one value of expected inflation for each point in time, such paths are mutually comparable (Chart 4).[8]

Chart 4.



In early March 2017, the markets based their pricing on inflation of about 1.1% at the beginning of 2019, from which inflation was expected to accelerate steadily to slightly over 1.5% by the end of 2024 (Chart 4). Inflation expectations have risen significantly since July 2016, when they were 0.6% and 1.3%, respectively. Upon examination of inflation paths (Chart 4), we thus arrive at the same interpretation as in connection with monitoring individual forward inflation values (Chart 1): inflation expectations have strengthened recently. However, in analysing inflation expectations with the help of the path of inflation expected by the markets (Chart 4), we can more easily consider market expectations in relation to, for example, current inflation and other inflation forecasts than in the case of a review based on individual forward inflation rates (Chart 1).

Our examination based on inflation paths explicitly shows that the markets continue to expect relatively subdued inflation far into the future (Chart 4). Three years ahead, market pricing for inflation is still below 1.5%. Consequently, despite higher inflation expectations, the markets do not expect any significant increase in inflation in the immediate years ahead. This becomes clearly visible if we explore the expected inflation path as a whole (Chart 4) rather than individual forward inflation rates (Chart 1).

We can also see that in mid-January 2015 the long-term inflation expectation was nearly the same as in March 2017: the inflation path expected by the markets for 2021–2024 is almost the same at these two points in time (Chart 4). If the same analysis is conducted using 3-year forward inflation 3 years ahead, the result is not the same: forward inflation was 1.0% on 15 January 2015 and

correspondingly 1.3% on 6 March 2017 (Chart 1). Thus, if an individual forward inflation rate is used for comparing longer-term inflation expectations, the expectations appear to have strengthened by 0.3 of a percentage point, although in reality long-term inflation expectations appear to be practically the same (Chart 4).

The difference in the results stems from the fact that forward inflation for January 2015 measures average inflation in 2018–2021, but the corresponding forward inflation for 2017 measures average inflation over the period 2020–2023. Accordingly, longer-term comparison of forward inflation rates is not straightforward, as they describe different periods of time. Straightforward analyses may arrive at wrong conclusions of the behaviour of long-term inflation expectations. Therefore, besides examinations based on forward inflation rates, it is advisable to also look at the path of expected inflation on the markets. It is particularly useful to conduct such an analysis if comparisons are to be made between longer horizons.

Volatility in premium size changes inflation expectations derived from swap prices

Inflation swap prices reflect compensation required by investors for bearing the risk related to inflation. As the riskiness of a swap can also be affected by factors other than expected inflation over the life of the swap, the swap price may differ from the rate of inflation expected by the markets. Such components having an impact on the price of a security are called premia.

Premia are a reflection of the risks inherent in swaps, which may be a consequence of the liquidity or maturity of a swap, for instance. The size of premia fluctuates over time, and they are of different size for swaps with different maturities; hence, swap price movements are due, in part, to changes in these premia rather than changes in the inflation expected by the markets.

In the above discussion, the significance of premia in swap prices was disregarded, and prices were considered to merely reflect expected inflation. This can be justified in two ways.

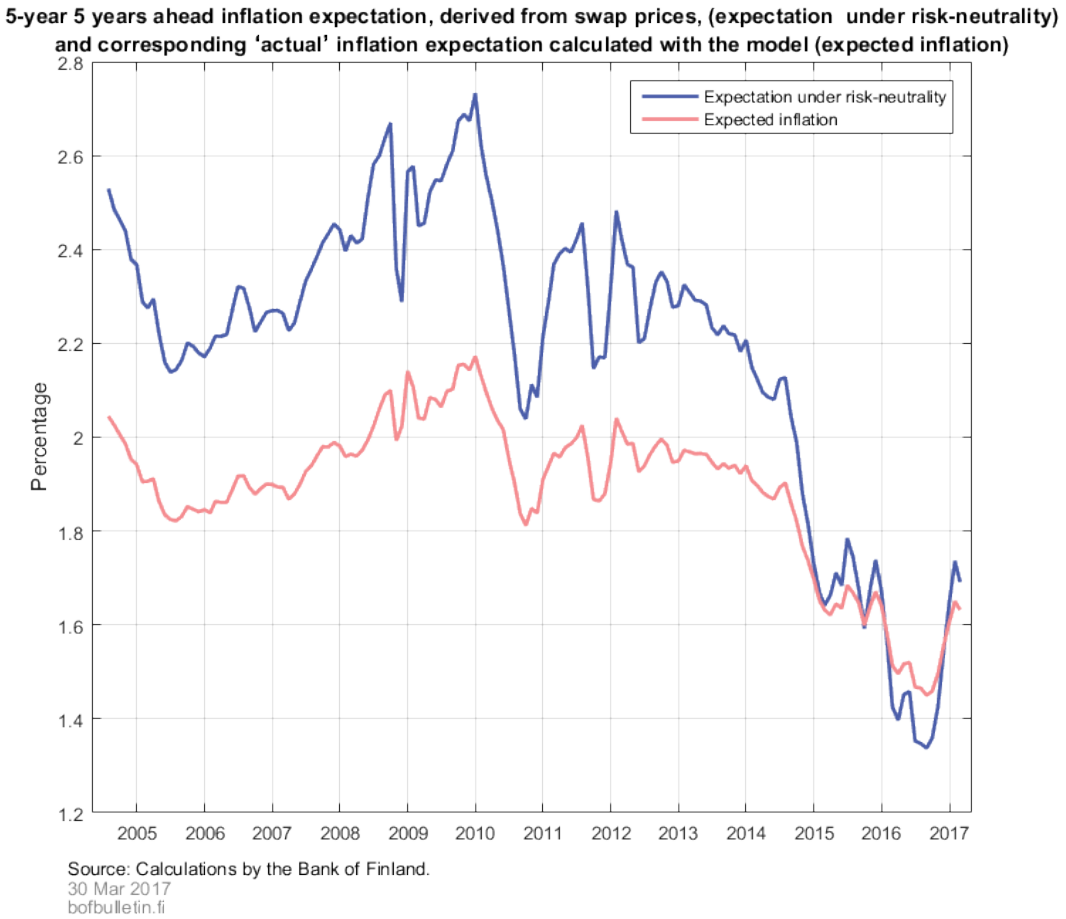
Firstly, if market participants are assumed to be risk-neutral and the markets to be efficient, no premia exist on the markets. As risk-neutral market participants require no compensation for bearing risks, swap prices can be directly interpreted as representing market inflation expectations. For this reason, expectations derived directly from swap prices are understood to mean expectations under risk-neutrality. As a rule, market participants' behaviour does not support the assumption of risk-neutrality. In practice, premia do have some impact on swap prices.

Secondly, if the premia are small, the price of a swap can be thought to directly mirror the inflation expected on the markets. In general, however, premia are assumed to fluctuate significantly over

time on the financial markets.

The size of premia cannot be directly observed from market prices, and instead a model needs to be employed for their calculation. The term structure model of inflation swaps can be used in an effort to estimate the size of premia in swap prices. By deducting the size of a premium from the market price of a swap, we can obtain the 'actual' inflation expectation shown by the inflation swap price – thus, no longer the inflation expectation under risk-neutrality. Given that the size of a premium is dependent on the model used for its estimation, the results across different models differ and the differences may be even considerable. Therefore, a high degree of uncertainty is related to such estimates. In Chart 5 we analyse the results obtained by the model used here in respect of monthly observations for 5-year forward inflation 5 years ahead.

Chart 5.



The inflation expectation under risk-neutrality in Chart 5 is the same as the 5-year inflation expectation 5 years ahead derived directly from market prices. By contrast, expected inflation in the same chart illustrates corresponding actual inflation expectation on the markets, after deduction from market prices of the premium calculated using the model. The difference between

the curves in the chart thus depicts the size of the premium.

The analysis shows that expectations calculated directly from swap prices prior to 2013 – i.e. under risk-neutrality – pointed to the markets anticipating long-term inflation of around 2.3%. With the impact of a premium (on average, about 0.4 of a percentage point) taken into account, market inflation expectations were well aligned with the ECB's inflation target of holding inflation below, but close to, 2% over the medium term. A positive premium indicates that the markets require compensation for their readiness to bear the risk of high inflation. This was seen in the swap price being higher than expected inflation. Consequently, high inflation swap prices at that time did not mean that market expectations deviated from the ECB's inflation target.

Expectations derived from inflation swap prices fell significantly during the course of 2013. This is in part accounted for by weakening inflation expectations, but is largely explained by smaller premia. The premium appears, in fact, to enter negative territory at the beginning of 2016, when market participants can be considered as paying for bearing the risk of high inflation. One interpretation for this pricing is that the markets expected inflation to remain muted for an extended period of time and inflation swaps were perceived as providing good insurance against risks of low inflation.

The recent elevation of inflation expectations is, in turn, accounted for by a change in both factors: the 'actual' market inflation expectation has strengthened and the premium has grown. The bulk of the rise in risk-neutral expectations appears to be explained by the removal of negative premia, but inflation expected by the markets has also begun to accelerate. However, higher inflation expectations shown by market prices cannot be entirely interpreted as a strengthening of market inflation expectations.

If expectations derived directly from swap prices cannot be interpreted as market inflation expectations, should their use be abandoned altogether? There is no reason to do so.

Firstly, changes in risk-neutral expectations – i.e. derived directly from market prices – incorporate information on both the probability of an event and its riskiness. For example, if premia on inflation swaps decline, the markets can be assumed to be ready to pay even more for protection against negative inflation risks. This provides additional information for monetary policy decision-making, as it can be seen that the negative implications of protracted low inflation have increased.

Secondly, estimates of the size of premia depend on the choice of the model used and are generally very sensitive to different model assumptions. Considering the challenge of making an accurate estimate of premium size, no far-reaching conclusions based on models should be made about market inflation expectations. For this reason, risk-neutral inflation expectations still provide a

reliable basis for analysing market inflation expectations. In this connection, however, we should bear in mind that the pricing of inflation swaps is also affected by factors other than the inflation expected on the markets.

Expectations have risen by less than a straightforward analysis indicates

Market inflation expectations have strengthened significantly since autumn 2016. Even so, higher market inflation expectations need to be interpreted with caution, as the interpretation of information embedded in different securities is not always straightforward.

One way of adding certainty to interpretations is to use models as an aid for analysing changes. The above results showed that in many cases an analysis directly based on forward inflation is sufficient, but estimation with the help of a term structure model adds a broader dimension to the analysis. Overall, it can be noted that inflation expectations have increased on the markets since last autumn, albeit by less than a straightforward scrutiny of prices would indicate.

Notes

1. Expectations affect inflation, as prices in the economy are typically changed at long intervals, owing to costs involved in price modifications. Expectations of future price developments must therefore be taken into account when setting current prices. In addition, wages and salaries are normally agreed for a longer period at a time, and expected inflation will then be reflected in the wage level, as households want to safeguard their purchasing power. Wages and salaries constitute a key cost factor for firms, whereby changes in wages and salaries are reflected in prices and actual inflation. ↑
2. An inflation swap is a derivative subject to trading on the financial markets and can be used to provide protection against uncertainty about future inflation. One of the parties to a swap agreement pays a pre-determined amount on the due date, whereas the other party's payment depends on inflation developments during the life of the swap. The structure and characteristics of inflation swaps are illustrated more closely in the Bank of Finland Bulletin 4/2016. ↑
3. Insights into models of this type are offered by Diebold and Rudebusch in Yield curve modelling and forecasting (2013). Princeton University Press. ↑
4. For more information on calendar effects, see Bank of Finland Bulletin 4/2016. ↑
5. Measurement errors can emerge, due, for example, to the nature of trading and liquidity differentials in swaps. ↑
6. The actual swap price is thus 2%, but with an error of the size of the standard deviation of the measurement error it would be 2.01%. ↑
7. Forward inflation rates indicate the markets expected inflation to be about 0.7%, 2.2% and ↑

0.8% in 2019, 2020 and 2021, respectively. This is not a credible path.

8. Inflation swaps are linked to an index with a lag of three months; hence, for example, a 1-year swap predicts inflation over a period of 9 months. This 9-month period is illustrated by the broken line in Chart 4. ↑

Keywords

inflation, inflation expectations, inflation swap, premium