Bond prices and market expectations of inflation

By Francis Breedon.[1]

Last November, a new method was introduced for deriving the inflation expectations that appear regularly in the Inflation Report *from UK government bond prices. This article gives a description of the new method and assesses how well the expectations derived using it would have predicted inflation in the past. The data used are now available to researchers—details of how to obtain them are given in a box on page 164.*

Market expectations of future inflation are important indicators for monetary policy. Not only can they give useful forecasts of inflation, but they provide a measure of financial markets' perceptions of the current monetary stance.

The expectations derived from financial asset prices have a number of advantages over other measures of private-sector expectations, such as surveys. They are available almost continuously, whereas surveys are produced intermittently and take some time to compile. The prices from which they are derived combine the information of a large number of sophisticated investors. The fact that the expectations are derived from prices in financial markets where actual investments are made means that they are likely to reflect more careful consideration than survey responses. And asset prices allow expectations to be derived over a much longer time-horizon than can be provided by surveys.

An article in last August's 1994 *Quarterly Bulletin* gave an assessment of a number of methods used to derive market expectations.[2] This article describes in more detail the method the Bank has chosen to adopt, gives the reasons for that choice and assesses the forecasting power of the derived expectations.

Deriving inflation expectations from government bond yields

To derive market expectations of inflation from government bond yields, two economic relationships are used—the expectations theory of the yield curve and the Fisher equation.

The expectations theory of the yield curve suggests that the yield on a long-term bond contains expectations of future short-term interest rates. The theory is based on the idea that an investor choosing between investing in a long or short-term bond will base the choice on an expectation of future interest rates. If, for example, he or she expects

interest rates to rise next year, the investor will demand a higher yield on a two-year bond than on a one-year one, because of the expectation that in a year's time the return on a one-year bond will be higher. As a result, expectations become embodied in the relative prices of the two bonds.

In practice, for a number of reasons (described below), it is unlikely that the expectations theory holds exactly: long-term interest rates are unlikely to be *simply* the average of actual and expected future short-term rates. But expectations are probably the most important single factor affecting the relationship between short and long-term rates.

The second relationship used to derive market expectations of inflation is the Fisher equation: this states in essence that the nominal interest rate is the sum of expected inflation and real interest rates.

Since index-linked bonds compensate investors for inflation, the return on an index-linked bond is related to current and expected future short-term real interest rates. So using the Fisher equation, market expectations of inflation can be calculated by subtracting the real interest rates derived from the yields on index-linked bonds from the nominal yields on conventional bonds.[3] But since different bonds carry different coupons, it is not correct simply to use the yields on bonds trading in the market in this calculation; the yields must be converted so that they are on a comparable basis. This is done by creating a *zero-coupon yield*—the yield on a hypothetical bond that bears no coupon. By looking at zero-coupon yields at various maturities, a series of average inflation expectations over a number of years ahead can be built up. These expectations (for example, of average inflation *over* the next 20 years) can then be converted to implied forward rates (for example, the annual rate of inflation *in* 20 years' time) to give a profile of expected inflation.

The critical step in deriving the implied forward inflation rates is arriving at market expectations of average nominal

and real interest rates at all maturities. This is done by fitting nominal and real (zero-coupon) yield curves. By fitting a yield curve through observed bond yields, it is possible to derive a market expectation for every possible maturity (since the curve interpolates between the maturities for which bonds exist). The choice of the technique used to estimate the yield curve can, however, have a marked effect on the implied forward inflation rates, so the choice of fitting technique is an important one.[1]

Estimating the nominal yield curve

There is no one 'correct' method for fitting a yield curve; different methods have different advantages and disadvantages. The choice of method depends on the purpose for which the curve is being fitted.

To fit curves to be used to derive inflation expectations, the Bank judged that the following criteria were the most important:

● the technique should aim to fit implied forward rates (rather than, for example, yields), since the final objective is to derive implied forward inflation rates;

● it should give relatively smooth forward curves, rather than trying to fit every data point, since the aim is to supply a market expectation for monetary policy purposes, rather than a precise pricing of all bonds in the market; and

● it should allow as many economic restrictions as possible to be imposed.

In practice, the last criterion favoured a method based on the discount function which imposes the desirable condition that cash flows received on the same date are discounted at the same rate. A further restriction imposed was that expectations of short-term interest rates a long time in the future should not vary; that is, an investor's expectation of the one-year interest rate likely to prevail in, say, 50 years' time should be the same as the expectation of rates in 51 years' time (the implied forward curve should be flat at the long end).

On the basis of the three criteria, the Bank decided to adopt the estimation method proposed by Svensson,[2] which is itself an extension of a method developed by Nelson and Siegel.[3] The Svensson method is based on the discount function and explicitly fits the implied forward curve with a relatively small number of parameters; details are given in the annex on page 165.

The estimation of the curve then involves finding values for the parameters to minimise the deviations of observed bond yields from the fitted curve. In practice, the equation used has to be extended to include additional parameters to allow

for tax effects.[4] Chart 1 illustrates the nominal par yield curve on 10 March estimated using the Svensson method and its relationship with bond yields on that day.[5] As it shows, some bond yields may lie a long way from the fitted curve. This is mainly because the different coupons paid by bonds in the market change their payment profile and tax properties.

Chart 1
Par yield curve
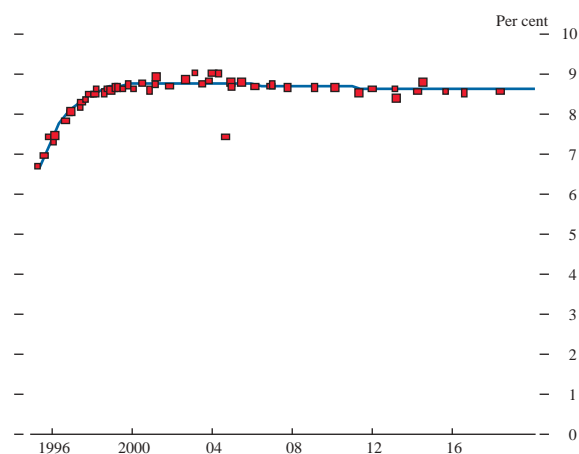
(a) Estimated using the Svensson method based on prices on 10 March.

Estimating the real yield curve

The same criteria used to choose an estimation method for the nominal curve were also applied to the real curve. There are, however, two additional complications when fitting the real curve:

● the limited number of index-linked bonds: there are currently 14 index-linked bonds in issue (compared with 58 nominal bonds); in 1982, there were only four; and

● the lag in indexation: to allow investors to know in advance the value of the next coupon, index-linked bonds are up-rated using the level of the retail prices index eight months before the coupon date. Because of this lag in indexation, there is still a small element of inflation risk in index-linked bonds, which needs to be removed if a real yield curve is to be estimated.

Given that the number of index-linked bonds sets a limit on the number of parameters that can be estimated, if real yield curves are to be estimated from 1982 no more than three parameters can be used. This restriction—and the fact that, on examination, the real yield curve proved to be very stable—led the Bank to adopt a simple, three-parameter estimation method for the real curve (see the annex for further details).

To overcome the problem of the indexation lag, an assumption has to be made about investors' expectations of inflation over the eight months for which they are not

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(1) A description of different fitting techniques was given in the August 1994 *Quarterly Bulletin* article.
(2) See Svensson, L E O, 'Estimating and interpreting forward interest rates: Sweden 1992–4', *CEPR Discussion Paper,* 1,051.
(3) Nelson, C R and Siegel, A F, 'Parsimonious modelling of yield curves', *Journal of Business,* 1987.
(4) The additional parameters are described in Deacon, M and Derry, A, 'Estimating the term structure of interest rates', *Bank of England Working Paper No 24.* Parameters to reflect ex-dividend and FOTRA (free of tax to residents abroad) effects are also included.
(5) The par yield curve is constructed by assuming all bonds in the market pay a coupon equal to their yield.

covered by the bond. Since market expectations of inflation can be derived using the real and nominal forward curve, it is possible to ensure internal consistency in the estimation process by iterating so as to equate the assumed level of inflation and the level derived from the fitted curves.

Another problem resulting from the limited number of index-linked bonds is that it is not possible to fit the extra tax parameters into the real curve estimation. For most index-linked bonds this is not a problem, since the assumption that they are held by zero-rate taxpayers—such as pension funds—seems realistic. However, for the shortest-maturity index-linked bonds, anecdotal evidence suggests that there is some tax effect (because short-maturity index-linked bonds appear to be particularly attractive to high-rate taxpayers); the Bank has yet to find an estimation method that can allow for this effect. Because of this and the eight-month indexation lag, the real yield curve may not be very reliable at maturities shorter than two years.

Chart 2 traces the changes in ten-year zero-coupon real rates since 1982; it shows that, like nominal rates, real rates have risen over the last year or so. But it is notable also that real interest rates are not significantly higher currently than the average over the period.

Chart 2
Ten-year zero-coupon real rates

The derived inflation expectations

Chart 3 shows the paths of the implied forward inflation rates two and ten years ahead derived using the new Bank method—that is, it gives for each date the rate of inflation expected to prevail in two and ten years' time. It shows how these rates generally fell during the 1980s, apart from in the last year or so. The brief increase in ten-year rates in 1992, following the suspension of sterling's membership of the ERM, is also evident. And it is also notable that, although two-year implied forward inflation rates have risen since the end of 1993, longer-term forward inflation rates have remained relatively low.

Chart 3
Implied forward inflation rates
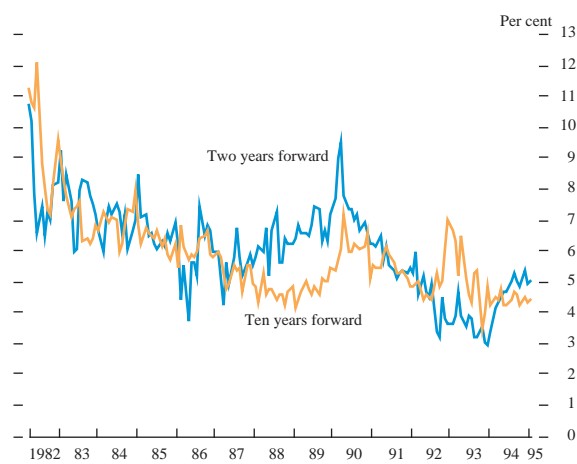
As noted above, however, the implied forward curves fitted to bond yields may not represent true market expectations. There are two main factors that may cause the implied forward rates to differ from pure expectations.

The first is the existence of risk or liquidity premia. Some bonds may have particular characteristics, such as price volatility or a lack of liquidity, that may make them unattractive to investors. The Svensson estimation method reduces the sensitivity of the estimated yield curves to bond-specific effects; but if there are some premia applying to a class of bonds (for example, long bonds generally exhibit greater price volatility), this may cause the fitted curves to deviate from the true expectations.

The second is the result of *Jensen's inequality* (also called convexity). This mathematical result applies to any non-linear function; for a convex function, such as that between bond prices and implied forward rates, it means that the implied forward rates may be a downward biased estimate of the true market expectation.[1] The extent of the bias is related to the expected volatility of bond yields and the particular properties of each bond. The reason for it is that certain bonds give better insurance against unexpected outcomes than others, so that investors will be prepared to pay something for that insurance over and above the expected value of the bond.

There is no simple way of establishing either the direction or the magnitude of the combined impact of these two effects. But to the extent that the impact is relatively constant over time, it is reasonable to interpret changes in implied forward rates as being primarily the result of changes in expectations.

The accuracy of implied forward rates in predicting future inflation

So far, this article has explained how implied forward inflations can be derived as a measure of market expectations of inflation. A separate—though related—issue is that of the predictive power of the derived rates. The

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(1) Jensen's inequality states that for a strictly convex function, the expectation of the function of a random variable will be greater than the function of the expectation of that variable (ie E [f(x)] > f [E(x)]).

issues are related because one reason why implied forward rates may give poor predictions—if they do—is that they do not measure expectations correctly. The other main reason is that the market's expectations may themselves actually predict future inflation poorly. However, as noted in the introduction, financial markets aggregate the information of a large number of people, and predictions made in financial markets are backed by investment; because of this, they might be expected to predict inflation better than most other forecasts.

Since index-linked bonds have been issued for a relatively short time, it is not yet possible to construct a very rigorous test of the forecasting power of implied forward inflation rates; any test over such a small sample can only be indicative. Bearing this in mind, the Bank has looked in recent research at the predictive power of changes in average inflation expectations over various periods, to evaluate the extent to which the slope of the *inflation curve* (the zero-coupon yield curve derived by subtracting the real from the nominal curves) predicts future changes in inflation.

As well as overcoming some statistical problems, this approach has two advantages. First, since changes in implied forward inflation rates are likely to be more reliable than the level (for the reasons discussed above), a test based on changes in expectations is more appropriate. And second, although the implied forward inflation curve is less reliable at maturities below two years (because of the problems with the real curve), the average inflation curve over two or more years should be more reliable and contains an expectation of average inflation over the first two years.

Charts 4–6 show the paths of the expected change in inflation over the following two, three and four years respectively, and compares them with what actually occurred. In general, the inflation curve appears to predict future changes in inflation quite well, with changes in expected inflation being associated with changes in actual

Chart 4
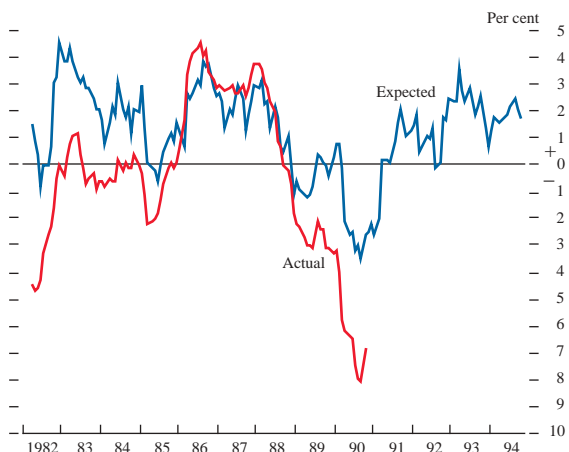
Expected and actual changes in inflation: over two years(a)
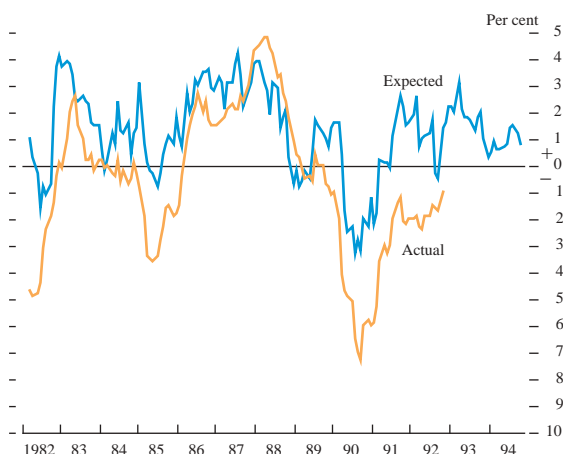
(a) The change in inflation is defined as the difference between the prevailing level and average inflation over the following two years.

Chart 5

Expected and actual changes in inflation: over three years(a)
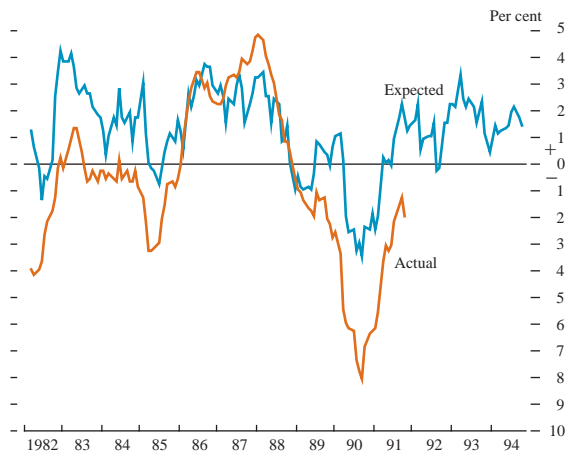
(a) The change in inflation is defined as the difference between the prevailing level and average inflation over the following three years.

Chart 6

Expected and actual changes in inflation: over four years(a)

(a) The change in inflation is defined as the difference between the prevailing level and average inflation over the following four years.

inflation over the following years. There seems, however, to be some bias in the prediction over the period, with the inflation curve consistently overpredicting future inflation. Tests confirm that there is a statistically-significant tendency for the slope of the inflation curve to overpredict future inflation, with the average overprediction being about 1.7% for forecasts two, three and four years ahead.

Why does the inflation curve overpredict future levels of inflation? There are three possible explanations:

● The overpredictions are an effect of the small sample period. It is conceivable that, over the relatively short sample of data available, the market persistently overpredicted inflation. After the experience of the 1970s when, for example, inflation rose from 9.4% to 17.2% between January and December 1979, it is plausible that the market might have allowed for the possibility of a similar event in the 1980s.

● The inflation curve overestimates true expectations. It is possible that the difference in returns between conventional and index-linked bonds overestimates

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Data available for researchers

A full set of the curves fitted using the approach outlined in this article are now available to outside researchers. These comprise:

● Zero-coupon nominal curves.
● Implied forward nominal rates.
● Zero-coupon real curves.
● Implied forward real rates.
● Zero-coupon inflation curves.
● Implied forward inflation rates.

The data are available as compressed tab-delimited ASCII files on 3.5″ high-density diskettes. They are in the form of fitted values at semi-annual maturities from half a year to 25 years. The curves are available at monthly (end-month) and daily frequencies between end-March 1982 and April 1995. There is a charge of £50 for daily data; the monthly data are available free of charge. Those wishing to obtain the data should mark their request 'yield curve data' and send a cheque payable to the Bank of England to the Bank's Monetary Instruments and Markets Division.

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inflation expectations. The most likely cause of such an overestimate is an inflation risk premium, which makes index-linked bonds more attractive to investors than conventional bonds (because index-linked bonds protect investors against inflation). In such circumstances, the yields on conventional bonds would have to be persistently higher (or those on index-linked bonds persistently lower) than true market expectations to compensate investors for inflation risk.

● There are problems with the technique for fitting the curve. Because of factors such as tax, the estimated yield curve may not be a good measure of the actual returns that investors derive from bonds. This is particularly likely to be the case over fairly short forecasting horizons.

Conclusions

Although there are a number of relatively minor improvements that could be made, the approach to estimating implied forward inflation rates described in this article gives a fair summary measure of the information contained in government bond prices. Analysis of the inflation predictions contained in these prices indicates that implied forward inflation rates do have predictive power, but that they have a tendency to overpredict future inflation. But since that overprediction has remained relatively stable over time, changes in implied forward inflation rates have contained information about future changes in inflation.

Annex

Estimation of yield curves

The Bank has adopted a method for estimating yield curves proposed by Svensson; the method involves estimating the following equation:

$$f(m) = \beta_0 + \beta_1 \exp(-m/\tau_1) + \beta_2[(m/\tau_1)\exp(-m/\tau_1)] + \beta_3[(m/\tau_2)\exp(-m/\tau_2)]$$

where $f(m)$ is the forward rate at a given maturity m, and the βs and the τs are the parameters to be estimated.

One of the advantages of the Svensson approach is that it is relatively easy to understand. Each parameter has a simple interpretation; and they determine how smooth the slope of the curve is and the points at which humps appear. β_0 represents the long-run level of interest rates, the β_1 term represents the slope of the curve, and the β_2 and β_3 terms represent humps in the fitted curve. By combining the elements, it is possible to create a large range of possible curves, as suggested in the chart.

Components of the forward rate curve
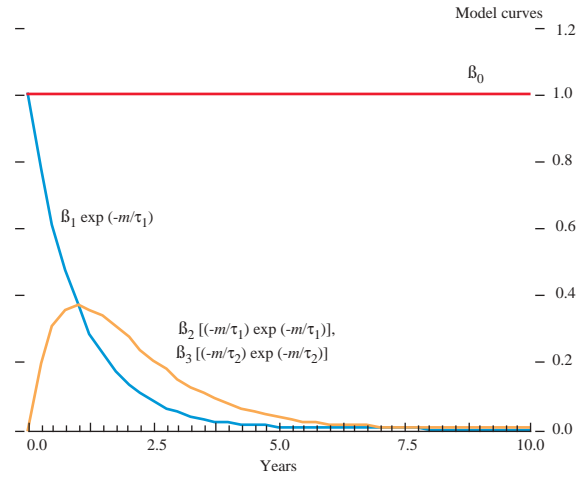
To estimate the real yield curve, the Bank uses a simplified version of the Svensson curve, in which only β_0, β_1 and τ_1 are estimated.