What accounts for the fall in UK ten-year government bond yields?

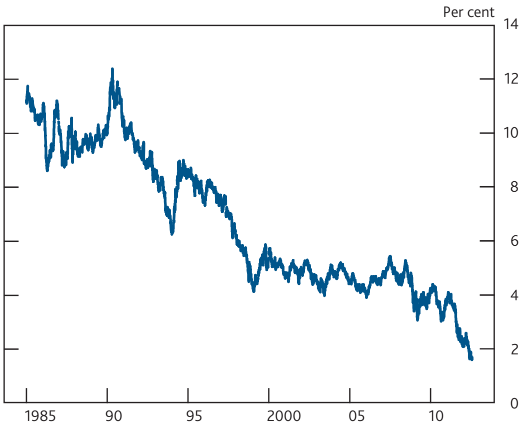
By Rodrigo Guimarães of the Bank's Macro Financial Analysis Division.[1]

Financial market measures of future interest rates and inflation rates can provide useful and timely information for policymakers. Recent advances in yield curve modelling have improved the Bank's capacity to extract policy-relevant information from these market measures. Such models suggest that the fall in the yield on UK ten-year nominal government bonds since the onset of the financial crisis largely reflects lower expectations of real interest rates at shorter horizons, consistent with an expectation that policy rates will remain low for some time. The model estimates also indicate that inflation expectations have been relatively stable, and suggest that there are no signs that they have become less well anchored.

Market interest rates play a crucial role in the transmission mechanism of monetary policy.[2] They also contain timely information on financial market participants' expectations of future policy rates, which will be related to their perceptions of current and expected future economic developments. Market participants' perceptions of risk are also reflected in these interest rates.

One measure of market interest rates is the yield on government bonds. UK government ten-year nominal spot yields[3] **(Chart 1)** — a key benchmark for government borrowing costs — have recently been at a historical low, at less than half their average rate between 1997 and 2007. The low level of government bond yields in the United Kingdom and in several other major economies[4] has received extensive coverage.

Chart 1 UK ten-year nominal spot rates



Sources: Bloomberg and Bank calculations.

In order to extract policy-relevant information from yields, it is important to understand what has driven these rates lower. Decompositions can be carried out along a number of dimensions to shed light on the drivers. First, movements in ten-year spot rates can be split into movements at different points within the ten-year maturity to assess whether the changes are mainly at shorter or longer horizons. Second, movements in nominal rates can be decomposed into changes in real interest rates and changes in implied inflation rates. And third, movements in nominal rates can be divided into the part that reflects changes in market participants' expectations and the part associated with changes in their required compensation for risk ('risk premia').

Policymakers care about these decompositions because influencing the expected path of the policy rate plays an important role in the transmission mechanism of monetary policy. Because monetary policy controls short-term rates, but has much less discretion in affecting longer-term rates, the maturity profile matters. In addition, beliefs about future inflation play a role in determining the rate of inflation, so it is important for the Monetary Policy Committee (MPC) to monitor indicators of inflation expectations, such as those derived from financial markets. And estimating risk premia can give policymakers an indication of market participants' assessments of risks.

(1) The author would like to thank David Latto for his help in producing this article.
(2) See Bank of England (1999) for a discussion of the transmission mechanism.
(3) All yields in this article are zero-coupon, continuously compounded, government bond yields. UK data and further information are available at www.bankofengland.co.uk/statistics/Pages/yieldcurve/default.aspx.
(4) Government bond yields in the United States and Germany have behaved similarly, although they have risen for some other countries. For details of recent moves in government bond yields, see the 'Markets and operations' article on pages 186–201 in this *Bulletin*. Here the focus is on UK yields.

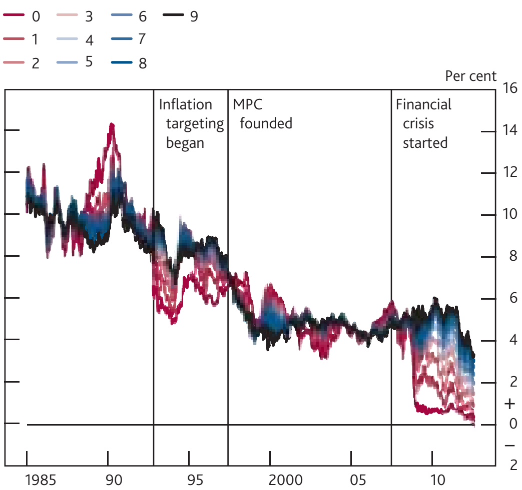
This article carries out these decompositions and assesses which of the components can account for the fall in ten-year nominal spot rates since the start of the financial crisis. The first section decomposes movements in UK ten-year nominal spot rates into changes at different maturities. It also splits nominal yields into real and implied inflation rates. The second section explains what risk premia are and how they can be disentangled from expectations of future interest rates and inflation. The third section uses recent work undertaken at the Bank of England to decompose yields into the components reflecting expectations of future rates and the risk premium. A final section concludes.

Decomposing nominal rates by maturity and into real and inflation rates

The ten-year spot rates shown in **Chart 1** are the average rates that apply over a ten-year period. But there can be substantial variation in shorter-term rates within that ten-year maturity. The ten-year spot interest rate can be decomposed into a series of short-term forward interest rates using yields at different horizons (the yield curve).(1) Forward interest rates are the rates that apply today to borrowing between some specified future periods; for example, the one-year forward rate four years ahead is the current rate at which it is possible to borrow for a one-year period starting in four years' time.

Chart 2 shows a decomposition of the ten-year nominal spot rate into the ten successive one-year forward rates that cover that period. For example, the line labelled '4' shows the one-year forward rate four years ahead. On each date, the average of the ten one-year forward rates is equal to the ten-year nominal spot rate shown in **Chart 1**.

Chart 2 UK nominal one-year forward interest rates up to nine years ahead



Sources: Bloomberg and Bank calculations.

This decomposition shows that the fall in the ten-year spot rate since 2008 reflects the impact of one-year forward rates at different horizons falling at different times rather than a gradual but simultaneous decline of rates at all maturities. In 2008–09, shorter-horizon forward rates fell markedly as monetary policy was loosened. This largely reflects the Bank's response to the deterioration in the UK economic outlook — Bank Rate was cut from 5% in October 2008 to 0.5% in March 2009, and the asset purchase programme was announced.(2) By July 2011, one-year forward rates out to three years ahead were less than half their 1997–2007 averages. They have continued to fall since then, and are currently close to zero. That is consistent with an expectation that policy rates will remain low for some time.

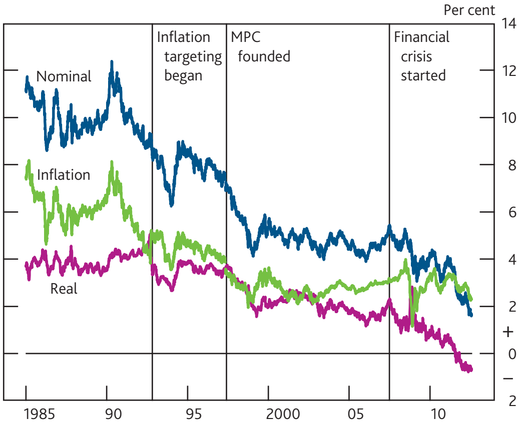
In contrast, longer-horizon forward rates remained closer to their averages over the decade to 2007 until recently. And despite the falls in longer-horizon forward rates over the past year, the short end of the yield curve still accounts for most of the fall in ten-year spot rates since 2008. While this is perhaps not surprising given the amount of policy easing, it shows that the fall in ten-year spot rates should not be taken to necessarily imply a decline in longer-term forward rates. Looking at even longer horizon forwards beyond ten years confirms this picture: the further ahead the horizon, the smaller are the observed falls in interest rates relative to their average level in the decade prior to the financial crisis.

Nominal spot rates can also be decomposed into real rates and implied inflation rates. UK real spot rates are extracted from retail prices index (RPI) index-linked government bonds. And the implied RPI inflation rate is calculated as the difference between the nominal and real rates. In this article, all inflation measures shown are based on the RPI, unless otherwise stated. **Chart 3** shows the UK government ten-year nominal spot rates along with the real and implied inflation rate components. It is clear from **Chart 3** that the ten-year spot implied inflation rate was the main driver of the fall in the nominal rate between the late 1980s and the 2000s, but since 2008 almost all of the fall in nominal rates is explained by decreasing real rates.

The difference in the main drivers of the fall in ten-year spot rates over these two periods is summarised in **Table A**, which presents data on the nominal interest rate, and its real interest rate and implied inflation rate components in more detail. The table presents average rates covering the eight-year period before the start of inflation targeting (1985–92 column) and the period between the creation of the MPC and the beginning of the financial crisis (1997–2007 column) to illustrate the

(1) For a review of interest rate concepts and the relation between spot and forward rates see Joyce, Sorensen and Weeken (2008), page 165. For a description of the methodology used to construct spot and forward yields used in this article see Anderson and Sleath (1999).
(2) See Joyce, Tong and Woods (2011) for evidence of quantitative easing announcement effects on bond yields.

Chart 3 UK ten-year spot rates



Sources: Bloomberg and Bank calculations.

change in the average levels seen in the 1980s relative to those seen in the 2000s.[1] It also shows the changes in rates in each of the past three years relative to their 1997–2007 pre-crisis averages. Alongside data on the ten-year spot rate, data covering the first five years (five-year spot) and the second five years (five-year, five-year forward) of that ten-year period are shown for nominal, real and implied inflation rates.

Table A UK government rates since 1985

Percentage points

	Averages		Changes relative to pre-crisis[a]		
	1985–92[b]	1997–2007[c]	July 2010	July 2011	July 2012
Nominal					
Ten-year spot	10.0	4.9	-1.4	-1.8	-3.3
Five-year spot	10.1	5.0	-2.8	-3.3	-4.5
Five-year, five-year forward	9.9	4.8	0.1	-0.2	-2.2
Real					
Ten-year spot	3.9	2.2	-1.3	-2.2	-2.9
Five-year spot	3.6	2.3	-2.4	-3.5	-3.7
Five-year, five-year forward	4.2	2.0	-0.3	-0.9	-2.0
Inflation					
Ten-year spot	6.1	2.8	-0.1	0.4	-0.5
Five-year spot	6.5	2.8	-0.5	0.2	-0.7
Five-year, five-year forward	5.6	2.8	0.3	0.7	-0.2

Sources: Bloomberg and Bank calculations.

(a) End-of-month values minus average from June 1997 to June 2007.
(b) Average from January 1985 to October 1992.
(c) Average from June 1997 to June 2007.

The table shows that ten-year nominal spot rates fell from an average of 10% in the pre-inflation targeting period to an average of 4.9% in the 1997–2007 period, with implied inflation rates accounting for two thirds of that fall. The recent fall in nominal ten-year rates relative to 1997–2007 has been almost entirely due to a decline in real rates, while implied inflation rates have remained more stable.[2] The table also shows that the fall in nominal ten-year rates in the 1990s was evenly distributed across the different horizons: the five-year spot and the five-year, five-year forward rates both fell by similar amounts. The fall since 2007 has been more concentrated in shorter maturities.

Extracting information from asset prices and accounting for risk premia

Typically, investors dislike uncertainty about future income and require additional compensation for holding assets that have uncertain returns. That additional compensation is called a risk premium. In general terms, a risk premium is the difference between the expected return from a risky asset and the expected risk-free rate. Risk premia will be related to how uncertain people are about asset returns and how much they care about exposure to risk. For example, the more investors care about risk, the larger risk premia will be in absolute terms. But risk premia also depend on the economic outlook more generally, since this will influence the impact that risks have on investors. If returns on risky assets tend to be particularly low during bad times — when investors would value some additional income most highly — they will require extra compensation to hold the asset (relative to a risk-free asset). But if returns on risky assets tend to be high during bad times, 'risky' assets actually help to insure investors. Investors will therefore be willing to pay a premium to hold the asset. In the first scenario risk premia will be positive, and in the second scenario risk premia will be negative.

Index-linked bonds pay out a pre-specified real rate, so the only risk is what real risk-free rates will be in the future. The risk premium part of real rates derived from index-linked bonds is referred to as the real risk premium. The cash flows on conventional bonds (nominal bonds) are specified in terms of a fixed amount of money. This means that investors are also exposed to uncertainty over future inflation rates, which erodes the real value of the cash flows. That additional risk premium part of the nominal bond rate is referred to as the inflation risk premium. **Figure 1** shows how nominal rates can be decomposed into expected and risk premium components for both their real and inflation parts.

If risk premia were negligible or constant, then changes in expectations about the future could be inferred in a straightforward way from changes in asset prices. But there is considerable evidence that risk premia in all markets are significant and time varying.[3] That means that, in order to extract expectations from asset prices correctly, risk premia have to be estimated. In addition, risk premia themselves can

(1) See Benati (2005) for a discussion of the evolution of the implementation of the inflation-targeting regime in the United Kingdom and King (2007) for a discussion of the operational independence of the Bank of England and creation of the MPC.
(2) This result also holds for the United States and a composite of German and French yields for the past five years. But the data are not available for the entire sample considered here.
(3) See Cochrane (2011) for a recent comprehensive survey.

contain useful information for policy, for example on investors' perceptions about the balance of risks around the outlook for inflation.

Figure 1 Decomposing nominal yields

			Nominal rate			
			=			
Real rate			+	Inflation rate		
	=				=	
Expected real rate	+	Real risk premium		Expected inflation rate	+	Inflation risk premium

In order to disentangle the expected and the risk premia components of an observed change in market rates, economic models or survey information (or a combination of both) can be used. Surveys of private forecasters can be used to infer expectations directly, but they tend to be published only monthly or quarterly, are generally available for only a subset of time horizons, and typically have a shorter span of historical data than yield curves. In contrast, economic models allow decompositions for any period and maturities for which yields are available. Some models can incorporate information from both surveys and yield curves and thus capture the advantages of both.

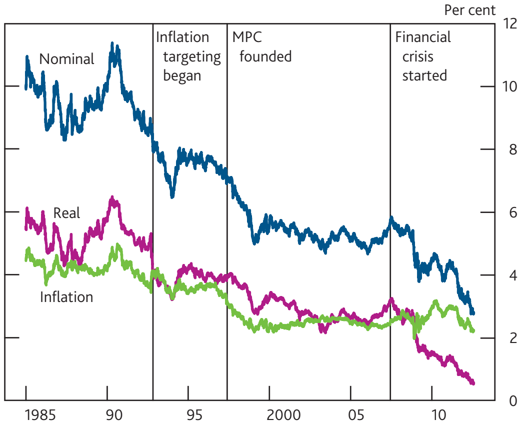
That approach of using information from both yield curves and survey expectations is the one taken in this article, building on previous Bank research. Joyce, Lildholdt and Sorensen (2009) used a Gaussian affine dynamic term structure model (G-ADTSM) — a standard method of modelling interest rates — to extract risk premia from UK nominal and real yields. In that model, one-month risk-free nominal interest rates, inflation rates and bond yields are modelled as a standard vector autoregression (VAR) — a system of equations where each variable depends on the past values of all the variables in the model. The model then allows the decomposition into separate risk premia and expectation components; the VAR allows us to calculate expected future rates, and the risk premia is then the difference between the model-implied bond yields and the expected future rate. Surveys give additional information on the expected nominal interest and inflation rates and so can be included in the model. The box on page 217 discusses these models in more detail.

Recent work undertaken in the Bank extends the model of Joyce, Lildholdt and Sorensen (2009) to, among other things, better fit the short end of the yield curve, which, as discussed in the previous section, has accounted for the majority of the change in yields over the past five years. In part, that is done by incorporating survey information on short-term interest and inflation rate forecasts in the model estimation. The box on page 217 also has more details on the model used in this article. In the next section the decomposition of the ten-year spot rate into its different components, as illustrated in **Figure 1**, is shown based on this new model.

Historical model decomposition of UK yield curves

The model decomposition suggests that both inflation and real rate expectations contributed to the fall in nominal expected rates during the 1990s, but that since the beginning of the crisis, expected real rates have accounted for most of the fall in expected nominal yields (**Chart 4**). This is not surprising given the breakdown shown in **Chart 3** and **Table A**, which showed that real rates accounted for most of the recent fall in nominal rates.

Chart 4 Model estimates of ten-year spot expected rates



Source: Bank calculations.

The model decomposition also suggests that risk premia have varied over time (**Chart 5**). There were particularly large falls in inflation risk premia during the 1990s. In part, that might be related to the adoption of the UK inflation-targeting regime in 1992 and the operational independence of the Bank of England in 1997.(1) Between 1997 and 2007, real and inflation risk premia moved within a relatively narrow range. Over the past five years, however, there has been more substantial variation in risk premia, which accounted for a large part of the variation in the implied inflation rate and the temporary spike in real rates seen just after the bankruptcy of Lehman Brothers (**Chart 3**). But despite the volatility within the past five years, the recent levels of risk premia have been little different from their pre-crisis averages. **Table B** shows that the nominal risk premium was only 0.7 percentage points below its pre-2007 average in July 2012 (compared to a fall of 2.7 percentage points in the expected component) and it accounted for less than a quarter of the fall in the level of yields relative to their 1997–2007 average.

(1) This is consistent with the international evidence in Gürkaynak, Levin and Swanson (2010) and Wright (2011).

G-ADTSMs and the role of surveys

Gaussian affine dynamic term structure models (G-ADTSMs) are, and have been for a long time, a widely used approach to interest rate modelling. They owe their popularity to their simplicity: the risk-free rate and the price of risk are modelled as linear functions of a few latent state variables, which proxy for the fundamental shocks driving the economy. These latent variables evolve according to a standard vector autoregression (VAR). Yet despite their simplicity these models can fit historical yield curves very well.

Estimation

In G-ADTSMs, model-implied yields will be linear functions of the latent state variables. The coefficients will be a function of the underlying VAR dynamics and prices of risk, and will vary with the maturity of the yield in a way that precludes arbitrage opportunities. Estimation for G-ADTSMs can be done using the Kalman filter (KF), which is designed to deal with linear models with latent variables. The KF is also a good method for dealing with missing data, so it can easily accommodate the use of survey forecasts of interest rates and inflation, which are typically observed at different frequencies than the yield and implied inflation data. Since the expectation of rates is a linear function of state variables, all that is needed is to add additional observation equations matching the model-implied expectations to the corresponding survey forecasts (see Kim and Orphanides (2005) or Joyce, Lildholdt and Sorensen (2009) for details).

Use of surveys

Kim and Orphanides (2005 and 2007) have argued that including survey forecasts is a good way to avoid instability in ADTSM estimates. And Carroll (2003) shows evidence that professional market forecasters' expectations lead households' and businesses' expectations, and so can serve as leading indicators of general expectations of policy and inflation. In addition, Chernov and Mueller (2011) — in a model in which they explicitly allow for the possibility that survey expectations differ from those priced in bond yields — find no evidence that expectations from professional forecasters are not the same as those implicit in yield curves. For these reasons recent internal Bank research has attempted to include more survey forecasts.

Recent Bank work

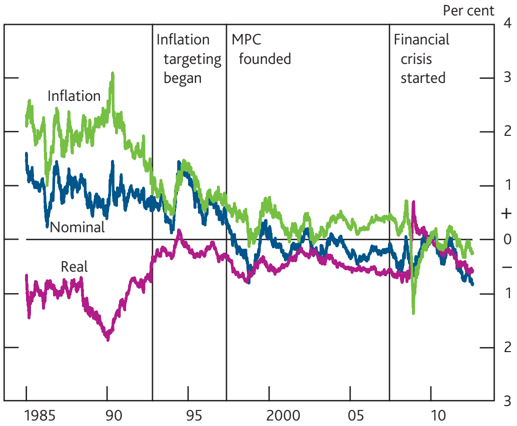
The model of Joyce, Lildholdt and Sorensen (2009) had four factors driving the nominal yield curve: the observed RPI inflation rate, and three latent factors. Only two of the latent factors were allowed to explain the real yield curve. In their model inflation and the real yield curve were driven by separate factors. In the model used in this article these assumptions have been relaxed, allowing all of the factors that determine nominal yields to affect both real and inflation rates. This is in line with most fully specified general equilibrium models, in which all factors determining the equilibrium will typically affect both inflation and real yields. For more information, see the discussion in Andreasen (2011) and Chernov and Mueller (2011). The preferred model specification has four factors without the restrictions imposed by Joyce, Lildholdt and Sorensen (2009).

Joyce, Lildholdt and Sorensen (2009) included Consensus survey forecasts for the five-year average of inflation, five years ahead in the estimation of their model. The model used in this article includes inflation forecasts from Consensus for each of the next five years, as well as the five-year average five years ahead forecasts. In addition, the model used in this article includes forecasts from the Bank's survey of external forecasters. This survey is conducted by the Bank each quarter, and has forecasts for Bank Rate at one, two and three years ahead, which are available since 1999. The combination of fewer restrictions in the real curve dynamics and the use of the short-term survey forecasts leads to a better fit at short maturities, particularly for the real yield curve. The added flexibility in the model is required to be able to match the yield curve data and surveys at all maturities.

Differences between models

The big difference between the models in the G-ADTSM class and more structural models, such as dynamic stochastic general equilibrium (DSGE) models, is that G-ADTSMs are agnostic about what the underlying drivers of movements in interest rates are. Even in a DSGE model, the risk-free rate and risk premia may be linear functions of underlying latent state variables (as in Andreasen (2011)). But in those DSGE models, a full set of assumptions on preferences, production and other constraints will be imposed that give a structural interpretation to the underlying state variables. The coefficients linking risk-free rates and risk premia to the state variables will also be functions of all the assumptions. Whereas in a G-ADTSM, the only restrictions imposed are those that guarantee bonds do not offer arbitrage opportunities.

Chart 5 Model estimates of ten-year spot risk premia



Source: Bank calculations.

Table B Model decomposition of UK ten-year spot yields

Percentage points

	Averages		Changes relative to pre-crisis[a]		
	1985–92[b]	1997–2007[c]	July 2010	July 2011	July 2012
Nominal					
Fitted rate[d]	10.0	4.9	-1.4	-1.8	-3.3
Expected rate	9.5	5.4	-1.3	-1.6	-2.7
Risk premium	0.9	-0.2	-0.1	-0.2	-0.7
Real					
Fitted rate[d]	3.9	2.1	-1.3	-1.9	-2.5
Expected rate	5.3	2.9	-1.6	-1.9	-2.4
Risk premium	-1.1	-0.5	0.3	0.1	-0.1
Inflation					
Fitted rate[d]	6.2	2.8	-0.1	0.1	-0.8
Expected rate	4.2	2.5	0.4	0.4	-0.3
Risk premium	1.9	0.3	-0.4	-0.2	-0.6

Sources: Bloomberg and Bank calculations.

(a) End-of-month values minus average from June 1997 to June 2007.
(b) Average from January 1985 to October 1992.
(c) Average from June 1997 to June 2007.
(d) The fitted rate is the model-implied rate. The differences between rates shown here and those in **Table A** are the model residuals.

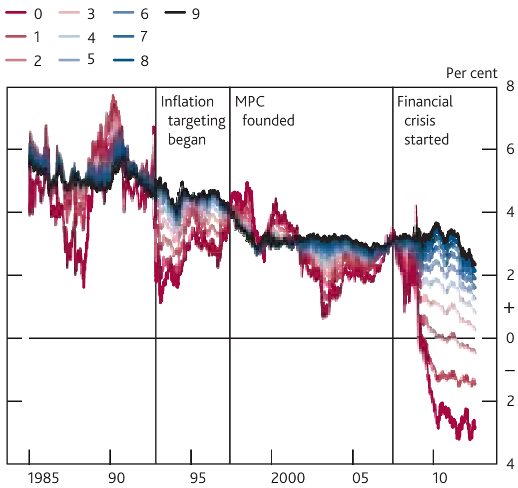
The changes in the levels of expected inflation and inflation risk premia over the past few years relative to their 1997–2007 averages have been relatively small, although they accounted for a large fraction of the fall in ten-year nominal yields over the past year (**Table B**).

The next two subsections take each of the real and inflation expected rate and risk premium parts shown above, and decomposes them further by maturity.

Model decomposition of the real yield curve

As discussed above, the change in the level of the ten-year nominal spot rate relative to its pre-crisis average was due in large part to developments in the ten-year real rate (**Table A**), mainly reflecting changes in the expectations component of real rates (**Table B**). The model decomposition of the real yield curve (**Chart 6**) shows that, since the start of the financial crisis, expected real rates at shorter horizons fell by more, and earlier, than longer-term expected real rates. The fall in expected real rates at maturities up to three years accounted for more than half of the fall in the ten-year average expected real rate from 1997–2007 to July 2012. And the fall in rates at maturities up to five years accounted for three quarters of the fall. Expected real rates at shorter horizons tend to move procyclically with monetary policy: they tend to increase as the policy rate rises and fall as the policy rate falls. So the pattern during the current crisis is not particularly unusual. For example, when Bank Rate was cut in September 1992, shorter-term expected real forward rates also fell much more than longer-term forwards. But in the current crisis period, those moves have been larger and are expected to persist for longer than in previous monetary policy cycles.

Chart 6 Model estimates of one-year forward expected real rates up to nine years ahead

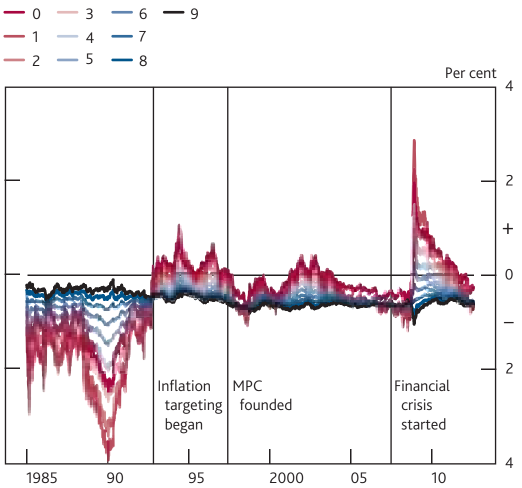


Source: Bank calculations.

Changes in real risk premia since 2008 also largely reflect movements at shorter horizons (**Chart 7**). On average, real risk premia have been negative, suggesting that real bonds offer investors insurance.[1] Following the adoption of inflation targeting, real risk premia were more stable and less negative. This could reflect greater monetary policy credibility, which reduces the short-term hedging value of real bonds as real rate uncertainty falls. But real risk premia moved sharply higher during the height of the crisis. In part, the spike in 2008 is likely to reflect market disruptions around the time of Lehman Brothers' bankruptcy that might have affected real yields.

(1) In return for inflation indexation, investors are willing to accept a smaller return. See Campbell, Shiller and Viceira (2009).

Chart 7 Model estimates of one-year forward real risk premia up to nine years ahead

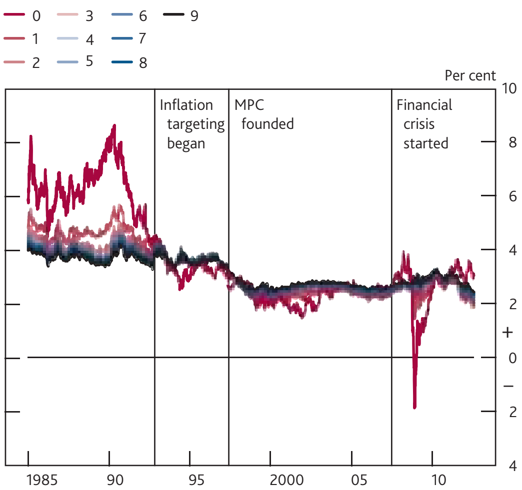


Source: Bank calculations.

Model decomposition of the implied inflation curve

Shorter-term inflation expectations fell sharply in late 2008 as the outlook for the United Kingdom, and the world economy, weakened markedly (**Chart 8**). That fall unwound quite quickly. It also did not feed through to inflation expectations at longer horizons, which is why the ten-year average expected rate fell only slightly (**Chart 4**). Expected inflation appears to have been less cyclical than the expected real rate. The model estimates suggest that there are no signs that inflation expectations have become less well anchored.

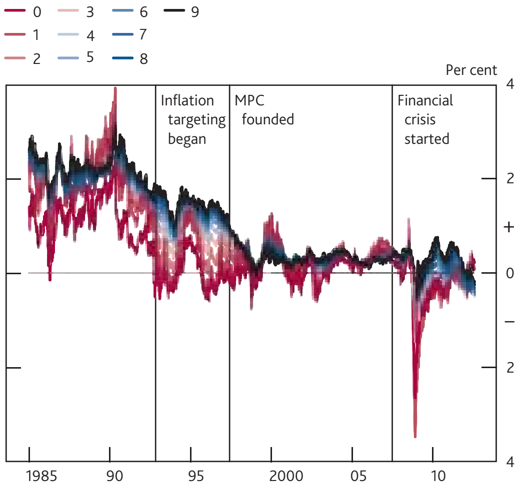
Chart 8 Model estimates of one-year forward expected inflation up to nine years ahead



Source: Bank calculations.

Inflation risk premia also fell sharply during 2008 (**Chart 9**). The fall was much more persistent than the fall in expected inflation rates: it both stayed for longer and affected longer forward maturities. This is likely to be associated with the nature of the concerns about the economic outlook: if the occurrence of deflation is seen to coincide with a bad state of the world, then nominal assets become a good hedge for investors and hence should command a negative risk premium for the insurance they provide.(1) More generally, inflation risk premia remain much lower than they were in the 1980s. Particularly for long-horizon inflation risk premia, that is likely to have been associated, at least in part, with the introduction of the inflation-targeting regime and Bank of England operational independence.

Chart 9 Model estimates of one-year forward inflation risk premia up to nine years ahead



Source: Bank calculations.

While the downward spikes in the components of implied inflation might also have been affected by market disruption following the collapse of Lehman Brothers, the magnitude of the fall in the model estimates of expected inflation is consistent with survey forecasts. For example, the forecast of the RPI inflation rate for 2009 from independent private forecasters, compiled by HM Treasury (HMT),(2) fell from 2.3% in August 2008 to -1.9% in February 2009. Inflation swap rates also fell sharply during this period, as did the option-implied measures discussed in the article by Smith on pages 224–33 in this *Bulletin* and financial market measures of expected inflation in other countries.

The decomposition of the sharp fall in implied inflation rates during the financial crisis illustrates the importance of disentangling expectations of future inflation and inflation risk premia in market-implied inflation rates. If policymakers had taken the market-implied inflation rate as a direct measure of expectations, they might have thought that inflation was expected by financial market participants to be much lower than surveys implied was the case. Furthermore, they might have concluded that the fall in inflation expectations would be

(1) See Campbell, Sunderam and Viceira (2012). If the deflationary scenario is associated with a bad macroeconomic environment, and weak growth of consumption, then nominal bonds are a good hedge and investors will be willing to pay for the deflation insurance they provide.
(2) Available at www.hm-treasury.gov.uk/data_forecasts_index.htm.

very persistent. The decomposition from the model, which uses short-term survey forecasts of nominal rates and inflation, implies a smaller and less persistent fall in implied inflation expectations. This is consistent with survey forecasts of inflation. And the large negative inflation risk premium estimated by the model is consistent with some of the evidence from option prices, shown in the article by Smith on pages 224–33 in this *Bulletin*, as discussed in the next section.

Assessing the robustness of the model decompositions

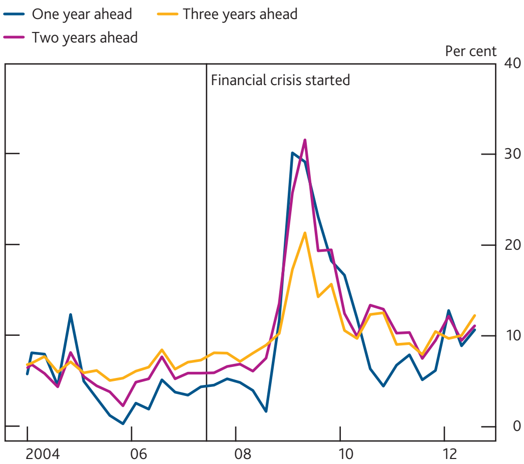
For policymaking purposes, it is important to assess the robustness of any particular model decomposition of yield curves. One way to do that is to estimate a large variety of models to investigate whether changes in model specification can make big changes to the results. Recent work undertaken at the Bank suggests that a range of different model specifications provides a similar qualitative message and estimate for the decomposition, and that the inclusion of surveys in the estimation of the model delivers robust estimates. That evidence is summarised in the box on page 221.

An alternative cross-check is to look at independent evidence. This includes evidence from other data sources for the United Kingdom that were not used in the model, as well as evidence for other countries that have experienced similar yield curve moves.

One possible independent cross-check is provided by the information contained in the article by Smith on pages 224–33. That article focuses on the distribution of future UK inflation around forward RPI inflation rates that can be extracted from option prices. The option-implied probability distributions of future RPI inflation also point to significant deflation concerns at the height of the crisis. For example, the measure of the balance of risks to inflation three years ahead fell sharply in late 2008, rose during 2009 and has remained stable since then (see **Chart 11** on page 231 of that article).

Another independent check (also discussed in the article by Smith) can be provided by using information from surveys not used in the analysis presented here. One such measure is the probability of low inflation from the Bank's survey of external forecasters (SEF). The SEF asks respondents to assign probabilities to inflation falling within pre-specified ranges for its three forecasting horizons.[1] **Chart 10** shows that the perceived likelihood of low consumer prices index (CPI) inflation increased sharply during 2008. Although the probability of higher inflation also increased, the balance of risks[2] around the inflation target fell sharply. That balance of risks was negative at the height of the crisis, but rose through 2009 and has remained broadly stable since then (see **Chart 11** on page 231 of the article by Smith). This evidence on

Chart 10 Probability of low CPI inflation[a] from survey of probability forecasts



Source: Bank calculations.

(a) Probability of annual CPI inflation being less than 1% at one, two and three-year horizons.

the perceived direction of risks to future inflation is consistent with the movements — and the negative sign — of the model-implied inflation risk premia (**Chart 9**).

In addition, the average central forecasts for inflation of respondents to a number of other surveys not used in the model presented here also show that the fall in expectations was temporary and not expected to persist for long, similar to the estimates for inflation expectations suggested by the model. And central forecasts for the path of expected real rates implied by forecasts from the HMT survey mentioned earlier are consistent with the model-implied expected real yield curve.

Ten-year nominal yields in the United States and some euro-area countries have moved in similar ways to those for the United Kingdom. Studies focusing on bond yields for these countries during the recent crisis period have reached similar conclusions to this article. For example, Garcia and Werner (2011) find that developments in inflation risk premia in the euro area were also consistent with euro-area survey measures of the balance of risks around inflation expectations. And Christensen, Lopez and Rudebusch (2012) find similar evidence of a significant deflation probability implied by US inflation-linked bond markets at the height of the crisis. Although not shown in Smith's article on pages 224–33, option-implied distributions for inflation in the euro area and the United States also behaved similarly to those in the United Kingdom.

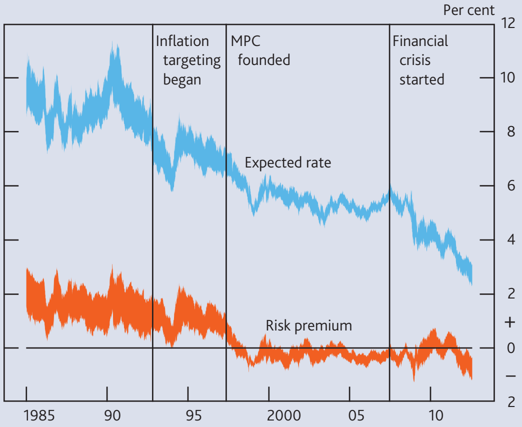
(1) This information was not used in deriving the model decompositions.
(2) Defined as probability inflation will overshoot the target rate by more than 1% minus the probability it will undershoot the target by more than 1%.

Assessing robustness of G-ADTSMs

Recent research by Joslin, Singleton and Zhu (2011) has led to a drastic reduction in the computational time required for estimating Gaussian affine dynamic term structure models (G-ADTSMs). This has made it feasible to estimate several models with different specifications, sample periods and combinations of surveys and restrictions on risk premia. This in turn allows inference about the features that are robust and those that are sensitive to particular modelling choices. Recent work undertaken in the Bank has done just that, estimating a large range of models.

Chart A shows the swathe of model estimates from six different models. The models vary according to the number of latent factors allowed and the survey forecasts used. All the models shown in this article have been estimated using monthly nominal yields since 1972 and real yields since 1985.

Chart A Range of model decompositions of ten-year nominal spot yields



Source: Bank calculations.

The model sizes vary from three factors, which is considered to be the minimum number of factors to explain the variation in yield curves (see Duffee (2002) and references therein), to five factors, which is the number used in some more recent studies (see Chernov and Mueller (2011) and Joslin, Singleton and Zhu (2011)).

For each model size two sets of survey forecasts were used. In both, the Bank Rate forecasts for one, two and three years ahead from the Bank's survey of external forecasters (SEF) (see the box on page 217) were used (available quarterly since 1999). For one set, the SEF forecasts for inflation one, two and three years ahead (available quarterly since 1996) were also used. Since these refer to CPI inflation rates since 2004, a 0.8 percentage point wedge (as an approximation to account for the RPI-CPI inflation wedge) was added to the forecasts from this date. The other set used forecasts for RPI inflation from Consensus for the next five years and the five-year average five years ahead in the estimation of the model (available half-yearly since 1990).

Chart A shows the range of estimates for all the models for the ten-year spot nominal risk premia and expected rates. **Chart A** shows that there is greater uncertainty about the decomposition for the first half of the sample, through to the late 1990s. But that does not affect the qualitative results discussed in this article.

The uncertainty is more pronounced for the real decomposition (not shown here). The swathe of model estimates is particularly wide (relative to the magnitude) for real term premia estimates, which might reflect the lack of availability of survey forecasts for interest rates before the 1990s. Survey data for Bank Rate, which come from the Bank's quarterly SEF, are only available since 1999, while the longest-running survey data for inflation (available from Consensus) start in the early 1990s. This highlights the importance of survey data in stabilising the model estimates. However, the qualitative message is not affected, particularly concerning the recent crisis period for which the swathes are narrower.

Conclusion

This article has shown that the drivers of the recent fall in UK ten-year nominal spot rates to historically low levels have been very different to those that drove the fall that occurred between the 1980s and the 2000s, both in terms of the horizon at which forward rates fell and the breakdown into real rates and implied inflation rates. Whereas the fall between the 1980s and the 2000s was evenly split along the maturity spectrum, the recent fall in nominal ten-year spot interest rates has been concentrated in shorter-term forward rates. And the data show that the vast majority of the recent fall of nominal yields was accounted for by a decrease in real interest rates, while the fall between the 1980s and the 2000s largely reflected a decline in implied inflation rates.

To understand what might lie behind the recent movements in the data, a model can be used to decompose real and inflation rates into expected rates and compensation for risk. The model estimates presented in this article imply that recent low ten-year nominal spot rates largely reflect low expected real rates, which have fallen most at shorter horizons. Expected real rates tend to move with the monetary policy cycle, particularly at shorter horizons. So given that the MPC cut Bank Rate sharply during 2008 and 2009, to its lowest level in history, and subsequently embarked on a programme of asset purchases to loosen policy further,(1) it is perhaps not surprising that expected real rates have fallen by more and for longer in recent years than in previous cycles.

Short-term market-implied inflation rates fell markedly at the height of the crisis, reflecting sharp declines in both inflation expectations and inflation risk premia. Inflation risk premia subsequently rose, but they remain a little lower than their pre-crisis average. The model-implied measure of inflation expectations also rose, and has since been relatively stable at close to its 1997–2007 average level, suggesting that inflation expectations have not become less well anchored.

Overall, the analysis in this article suggests that the low level of long-term nominal yields does not reflect low long-term risk premia. That is clear both from the maturity analysis of the data, and the model decomposition of yields, which suggests that less than a quarter of the fall in the ten-year spot rate is due to the compression of nominal risk premia.

(1) See the letter from the Governor to the Chancellor, available at www.bankofengland.co.uk/monetarypolicy/Documents/pdf/govletter090305.pdf.

References

Anderson, N and Sleath, J (1999), 'New estimates of the UK real and nominal yield curves', *Bank of England Quarterly Bulletin*, November, pages 384–92.

Andreasen, M M (2011), 'An estimated DSGE model: explaining variation in term premia', *Bank of England Working Paper No. 441*.

Bank of England (1999), 'The transmission mechanism of monetary policy', paper by the Monetary Policy Committee, April.

Benati, L (2005), 'The inflation-targeting framework from an historical perspective', *Bank of England Quarterly Bulletin*, Summer, pages 160–68.

Campbell, J Y, Shiller, R J and Viceira, L M (2009), 'Understanding inflation-indexed bond markets', *Brooking Papers on Economic Activity*, Spring.

Campbell, J Y, Sunderam, A and Viceira, L M (2012), 'Inflation bets or deflation hedges? The changing risks of nominal bonds', *Harvard Business School Working Paper No. 09–088*.

Carroll, C D (2003), 'Macroeconomic expectations of households and professional forecasters', *The Quarterly Journal of Economics*, Vol. 118, No. 1, pages 269–98.

Chernov, M and Mueller, P (2011), 'The term structure of inflation expectations', *Journal of Financial Economics*, forthcoming.

Christensen, J H E, Lopez, J A and Rudebusch, G D (2012), 'Pricing deflation risk with US Treasury yields', *Federal Reserve Bank of San Francisco Working Paper No. 2012–07*.

Cochrane, J (2011), 'Discount rates', *Journal of Finance*, Vol. 66, pages 1,047–108.

Duffee, G R (2002), 'Term premia and interest rate forecasts in affine models', *Journal of Finance*, Vol. 57, pages 405–43.

Garcia, J A and Werner, T (2011), 'Inflation risks and inflation risk premia', *European Central Bank Working Paper No. 1,162*.

Gürkaynak, R S, Levin, A and Swanson, L (2010), 'Does inflation targeting anchor long-run inflation expectations? Evidence from long-term bond yields in the US, UK and Sweden', *Journal of the European Economic Association*, Vol. 8, No. 6, pages 1,208–42.

Joslin, S, Singleton, K J and Zhu, H (2011), 'A new perspective on Gaussian Dynamic Term Structure models', *Review of Financial Studies*, March.

Joyce, M, Lildholdt, P and Sorensen, S (2009), 'Extracting inflation expectations and inflation risk premia from the term structure: a joint model of the UK nominal and real yield curves', *Bank of England Working Paper No. 360*.

Joyce, M, Sorensen, S and Weeken, O (2008), 'Recent advances in extracting policy-relevant information from market interest rates', *Bank of England Quarterly Bulletin*, Vol. 48, No. 2, pages 157–66.

Joyce, M, Tong, M and Woods, R (2011), 'The United Kingdom's quantitative easing policy: design, operation and impact', *Bank of England Quarterly Bulletin*, Vol. 51, No. 3, pages 200–12.

Kim, D H and Orphanides, A (2005), 'Term structure estimation with survey data on interest rate forecasts', *Federal Reserve Board Finance and Economics Discussion Series*, No. 2005–48.

Kim, D H and Orphanides, A (2007), 'The bond market term premium: what is it, and how can we measure it?', *BIS Quarterly Review*, June.

King, M A (2007), 'The Monetary Policy Committee of the Bank of England: ten years on', *Bank of England Quarterly Bulletin*, Vol. 47, No. 1, pages 24–38.

Smith, T (2012), 'Option-implied probability distributions for future inflation', *Bank of England Quarterly Bulletin*, Vol. 52, No. 3, pages 224–33.

Wright, J H (2011), 'Term premia and inflation uncertainty: empirical evidence from an international panel dataset', *American Economic Review*, Vol. 101, No. 4, pages 1,514–34.