New information from inflation swaps and index-linked bonds

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Prices of index-linked financial instruments can be used to obtain market-based measures of inflation expectations and real interest rates. These measures are regularly used by the Bank's Monetary Policy Committee to inform its assessment of economic conditions. In the United Kingdom, the index-linked gilt market is long established and has been used to infer such measures for many years. More recently, international index-linked markets have developed further, with increased issuance of index-linked bonds and greater use of index-linked derivatives. This article outlines how new market data provide useful additional information. We show that inflation swap rates can be used to estimate market expectations of inflation, and how the larger range of information from index-linked markets facilitates analysis of market-based expectations for inflation and real interest rates across countries.

Introduction

Index-linked financial instruments can be used to infer market-based measures of inflation expectations and real interest rates. These measures have the advantage of being forward looking, timely and frequently updated for a range of maturities. They are regularly presented to the Bank's Monetary Policy Committee to inform its assessments of economic conditions.

For some time the Bank has used the prices of index-linked and conventional bonds to derive real and nominal yield curves for the United Kingdom.(1) And these curves are used to infer a market-based measure of inflation expectations.(2) Recent developments in international index-linked markets have provided a larger set of market data. We can use this to derive a greater range of market-based measures, both for the United Kingdom and abroad. This facilitates analysis of implied inflation expectations and real interest rates across countries.

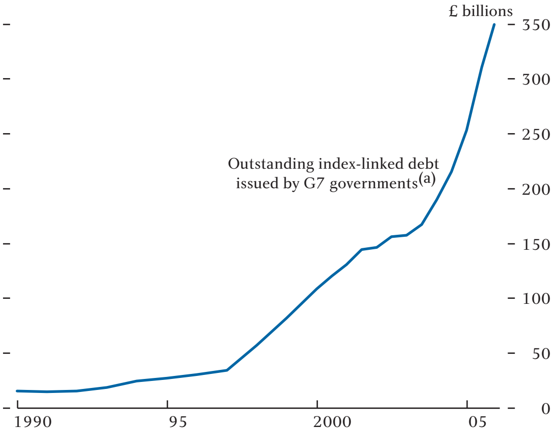
The structure of the article is as follows. First, we describe developments in index-linked financial markets. Second, we outline how these developments provide additional information. In particular, we show that inflation swap rates can be used to infer market-based measures of inflation expectations, and look at how increased issuance of foreign index-linked bonds has provided additional information. The third section discusses the consistency between measures derived from inflation swaps and index-linked bonds, both in theory and in practice. And the fourth section considers what the derived measures imply about expectations for economic prospects. Of particular interest to central banks are measures of markets' long-term inflation expectations, reflecting their confidence in the ability and determination of monetary authorities to control inflation. The final section summarises and concludes.

Developments in index-linked markets

The inflation indexation of financial instruments dates back hundreds of years. But the development of large international markets in government-issued index-linked debt started in the early 1980s, when the United Kingdom began issuing index-linked gilts. Governments of other industrialised countries also began to issue index-linked bonds during the 1980s and 1990s. In global terms index-linked markets remained relatively small with a reputation for poor liquidity. But the market has grown significantly in recent years: the value of issued index-linked debt has more than doubled since 2002 (Chart 1). This change reflects increased issuance by the US Treasury, as well as governments of some other major countries starting to issue index-linked bonds (notably Italy from 2003 and Japan from 2004).

(1) For a full description of the Bank of England's yield curve fitting techniques, see Anderson and Sleath (2001). Estimates of UK yield curves are published at www.bankofengland.co.uk/statistics/yieldcurve.
(2) The derivation and interpretation of breakeven inflation from index-linked gilts is outlined in Scholtes (2002).

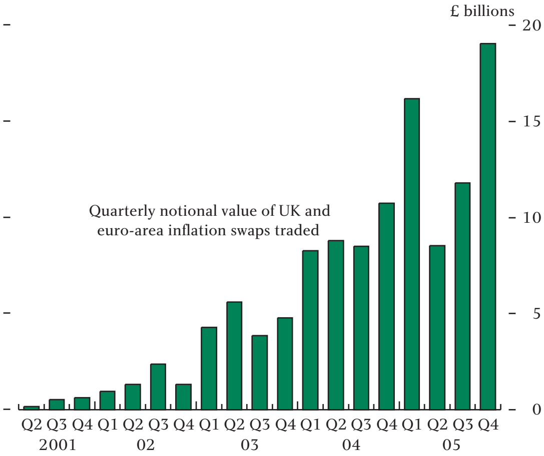
Chart 1
The size of index-linked bond markets



Source: Reuters.

(a) Excluding Germany.

Chart 2
Notional value of inflation swaps traded



Source: ICAP estimates.

During recent years, markets for inflation-linked derivatives have also grown quickly. The largest is the market for inflation swaps, which allow counterparties to exchange a fixed interest rate for payments linked to inflation.(1) (The structure of an inflation swap contract is outlined below.) The inflation swap market is transacted over-the-counter (OTC), rather than via an exchange, so comprehensive data on market activity are not available. However, data from a large broker give an indication of how quickly trading activity has increased (Chart 2).(2) The growth of this market resembles that of the interest rate swap market in the early 1980s. And like that market, the size of the inflation swap market is not constrained by the supply of cash bonds, so the potential for further growth is unlimited.

The euro area has the most active inflation swap market. An initial driver of this was Italian demand for products designed to protect investors from high inflation. The providers of these products could use index-linked bonds or inflation swaps to hedge their resulting inflation exposure. And as demand for the products grew, the inflation swap market was increasingly used for this purpose. UK and US inflation swap markets have seen increased activity during the past year or so. UK demand is dominated by pension funds which have long-term liabilities linked to inflation that they would like to hedge.

Estimating market-based expectations — new possibilities

These developments mean there now exists an increasingly liquid global market in index-linked bonds and derivatives.(3) The greater range of index-linked instruments and increased market activity provide additional market data. We can use this to derive a larger set of market-based measures of expectations of inflation and real interest rates than was previously the case.

It is important to mention that our derived measures are likely to encapsulate more than just market participants' expectations. Market-based measures of inflation expectations are also likely to incorporate inflation risk premia, which investors demand as compensation for uncertainty about future inflation, and possibly other premia related to institutional factors.(4) Likewise, derived real yields may contain risk premia and be affected by institutional factors.(5) These caveats are important when using the curves to infer market expectations, as we do in the final section of this article.

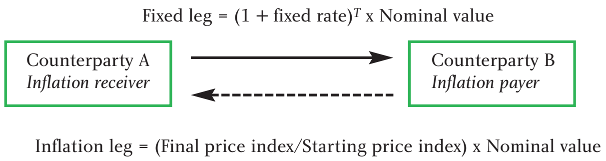
Using market rates on inflation swaps

An inflation swap is a bilateral contractual agreement. It requires one party (the 'inflation payer') to make periodic floating-rate payments linked to inflation, in exchange for predetermined fixed-rate payments from a

(1) Transactions in other index-linked derivatives, such as options and futures, are becoming more common and these markets are likely to expand significantly over time.
(2) Data are only for UK and euro-area contracts and do not include trades between banks and clients. ICAP's market share is subject to variation.
(3) Trading volumes are much lower than those for conventional government bonds or nominal interest rate swaps but those markets are the most deep and liquid in the world.
(4) See Scholtes (2002) for a detailed description.
(5) See 'Interpreting long-term forward rates', *Bank of England Quarterly Bulletin*, Winter 2005, page 418.

second party (the 'inflation receiver'). Inflation swap contracts are arranged OTC so the pay-off structure can be matched to the needs of the counterparty. Hence a variety of contracts are traded, incorporating different cash-flow structures and/or added characteristics such as floors and caps.(1) However, the most common is the zero-coupon inflation swap. This has the most basic structure with payments exchanged only on maturity.

Cash-flow structure of zero-coupon inflation swap of maturity *T* years



The zero-coupon inflation swap has become the standard contract for which rates are quoted in the wholesale market by brokers, and is the data source we use here.(2) The rates observed represent the fixed rate paid by the inflation receiver — that is, the fixed rate agents are willing to pay (receive) in order to receive (pay) the cumulative rate of inflation during the life of the swap. Hence the quoted rate, termed the breakeven inflation rate, will depend on expected inflation over the life of the swap (as well as any risk premia). Thus we can use the quoted rate to derive market-based measures of expectations for inflation.

The box outlines how we can then estimate an inflation forward curve from zero-coupon inflation swap rates. Having estimated an inflation curve we can also derive a real interest rate curve, on the basis that a nominal yield can be decomposed into a real yield and an inflation component. Hence we deduct the inflation forward curve from a separately estimated nominal forward curve to obtain a real forward curve.

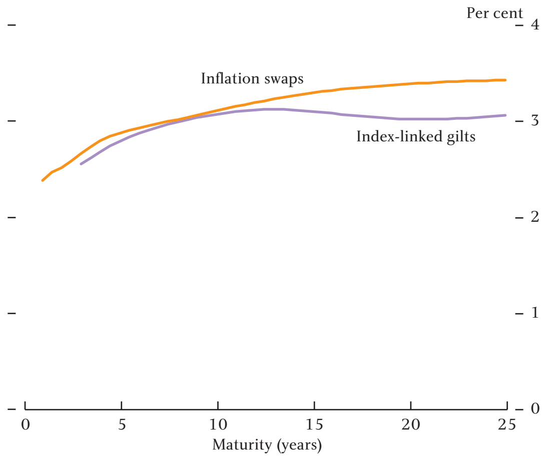
UK inflation forward curves

Potentially inflation swaps offer information beyond that provided by index-linked bond markets, even for the United Kingdom which has a long-established index-linked bond market. This is because our ability to estimate curves using bonds depends on the number of bonds available and the range and dispersal of their maturities. Both will change over time. However, for inflation swaps we observe daily quoted rates for contracts with a wide range of maturities that are evenly spread. For the United Kingdom, maturities range from one to 25 years.(3) And there are contracts for each year up to ten years and subsequently for maturities of 12, 15, 20 and 25 years.

The additional information allows us to derive UK inflation and real curves that begin at short horizons, as UK inflation swaps offer a measure which starts at about ten months.(4) In contrast, the shortest index-linked gilt included in our curve estimation matures in October 2009, more than three years hence.(5) One caveat here is that short-dated contracts are the least traded UK inflation swaps (market factors are discussed later).

Chart 3 compares UK curves derived from inflation swaps and from index-linked and nominal bonds. Between three and ten years the curves are virtually identical. At the longest horizons the curves diverge somewhat with the curve derived from inflation swaps being slightly higher than the curve derived from index-linked bonds. (The consistency of the two measures is discussed below.)

Chart 3
UK inflation forward curve for 21 February 2006



Sources: Bank of England and Bloomberg.

International breakeven inflation curves

We are also able to derive a range of international curves. This follows recent issuance of US and euro-area index-linked bonds, together with the development of international inflation swap markets.

(1) For explanations of some common inflation swap structures see 'Inflation-protected bonds and swaps', *Quarterly Bulletin*, Summer 2004, pages 124–25. Greater detail and other examples can be found in Deacon *et al* (2004).
(2) Our data are composite series from Bloomberg that incorporate rates available across a selection of brokers.
(3) A few brokers quote longer maturities, up to 50 years.
(4) The one-year contract less the two-month indexation lag.
(5) The curve is evaluated at the bond maturity minus the lag length.

Estimating an inflation forward curve from inflation swap rates

This box outlines how we can use inflation swap rates to estimate an inflation forward curve. This involves adjusting the observed swap rates to account for the imperfect indexation of the contracts, before using our standard curve estimation technique.

In practice, inflation swap contracts have indexation lags. This means a contract is referenced to inflation for a period that begins before the date on which the contract is priced and ends before the contract matures. We can say that a contract of maturity T years traded at time t will be referenced to inflation over a period $t - L$ to $t + T - L$, where L is the indexation lag expressed as a fraction of a year. The (annually compounded) swap rate can therefore be expressed as:

$$\left(1+swap\ \ rate_t\right)^T = \left(1+\tilde{\pi}_{t-L,t+T-L}\right)^T \qquad \textbf{(1)}$$

where $\tilde{\pi}_{i,j}$ represents the inflation compensation required by investors for the period between i and j, expressed as an annual rate.(1)

Our aim, however, is to derive an estimate for expected inflation from today, time t, whereas the swap rate depends on expected inflation from $t - L$ to $t + T - L$. We would like to be able to strip out inflation that has already accrued, $\hat{\pi}_{t-L,t}$. Essentially to be able to decompose the swap rate into:

$$\left(1+\tilde{\pi}_{t-L,t+T-L}\right)^T = \left(1+\hat{\pi}_{t-L,t}\right)^L \left(1+\tilde{\pi}_{t,t+T-L}\right)^{T-L} \qquad \textbf{(2)}$$

Expressions **(1)** and **(2)** enable us to derive an estimate of inflation compensation from today:

$$\left(1+\tilde{\pi}_{t,t+T-L}\right)^{T-L} = \frac{\left(1+swap\ \ rate_t\right)^T}{\left(1+\hat{\pi}_{t-L,t}\right)^L} \qquad \textbf{(3)}$$

Unfortunately, the denominator is not directly observable. This is because price indices are compiled monthly and published with a lag, so we are never in possession of a price index for today.

We encounter this 'publication lag' problem when deriving real interest rate forward curves from index-linked bond prices. To get round it we assume that today's price level, P_t, can be extrapolated using the latest available annual inflation rate, π_{t1}, and the latest available price level value, P_{t1}, which refer to time t_1:

$$P_t = \left[1+\left(t-t_1\right)\pi_{t1}\right]P_{t1}, \text{where } \pi_{t1} = \frac{P_{t1}-P_{t1-1year}}{P_{t1-1year}}$$

This assumption is rather simplistic. But it has the advantage of being consistent with the technique already in use to estimate real interest rate curves from index-linked bonds, as set out by Anderson and Sleath (2001).(2)

We then calculate an estimate of the inflation that has already accrued, $\hat{\pi}_{t-L,t}$, using this estimate for today's price level and the swap's reference price index level (specified according to market conventions set out in the appendix). Hence we can use **(3)** to estimate rates for inflation compensation from today. Once we have these rates we use our standard yield curve estimation technique to fit a forward curve.(3)

(1) As discussed in the main text, inflation compensation may differ from expected inflation.
(2) In future, we may be able to obtain a less 'naïve' estimate of today's price level from inflation futures. Futures based on near-term outturns for US and euro-area inflation have recently started trading on the Chicago Mercantile Exchange.
(3) We use the 'Variable Roughness Penalty' technique, which we also employ for curves based on bonds. The methodology is outlined in Anderson and Sleath (1999) and explained in more detail in Anderson and Sleath (2001).

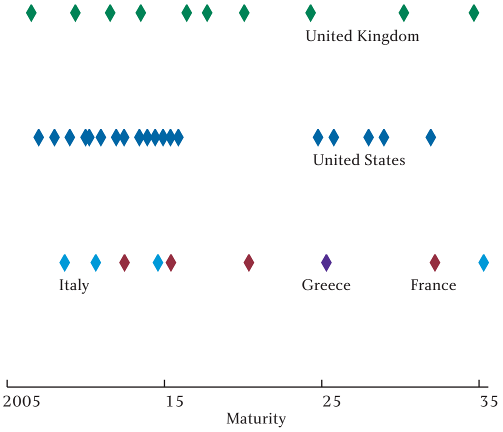
To estimate US and euro-area real interest rate curves from index-linked bonds we employ the same methodology used to derive UK real curves.(1) However, we have to adjust the way we treat the price data to reflect differences in the bond conventions and specifications used in different markets (these are set out in the appendix). Before presenting these curves it is important to highlight a couple of issues related to the index-linked bonds used to estimate the curves.

There are now a relatively large number of bonds indexed to US CPI inflation issued by the US Treasury — commonly referred to as Treasury Inflation Protected Securities (TIPS). However, at longer horizons there is a range of maturities for which no bonds are available. Maturities are evenly spread out to ten years, but after that the next bond's maturity is 20 years ahead (Chart 4). So our curve estimation is based on a detailed set of data points out to ten years, but relies

(1) Described by Anderson and Sleath (2001).

heavily on our yield curve modelling technique between ten and 20 years. Hence inferences about real rates and inflation expectations near this range of maturities are more limited. In contrast, inflation swap contracts linked to US CPI inflation provide an even spread of maturities.

Chart 4
Distribution by maturity of index-linked bonds(a)



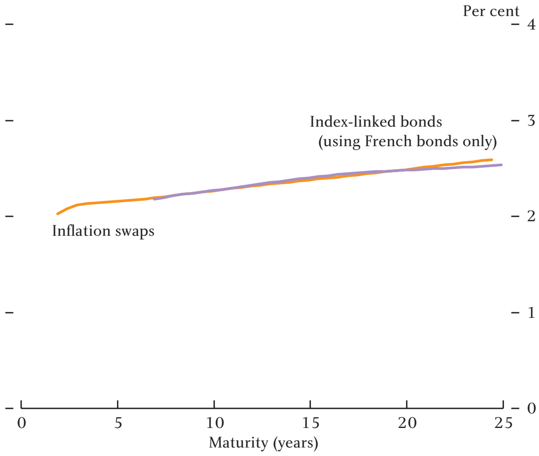
Source: Reuters.

(a) This summarises the current situation, which will change through time as bonds mature and others are issued. The chart does not include the 2055 UK index-linked gilt.

Chart 4 also shows government bonds linked to the euro-area HICP inflation index, which can be used to estimate a euro-area curve. Although there are fewer bonds, the spread of maturities is relatively even. However, an additional complicating factor is that the bonds were issued by three different governments — those of France, Greece and Italy. This could be a problem if investors view each government differently in terms of default risk. If so, the prices of different governments' debt may trade with different credit premia. This problem does not occur for zero-coupon inflation swap contracts since these euro-area contracts are standardised and homogeneous.

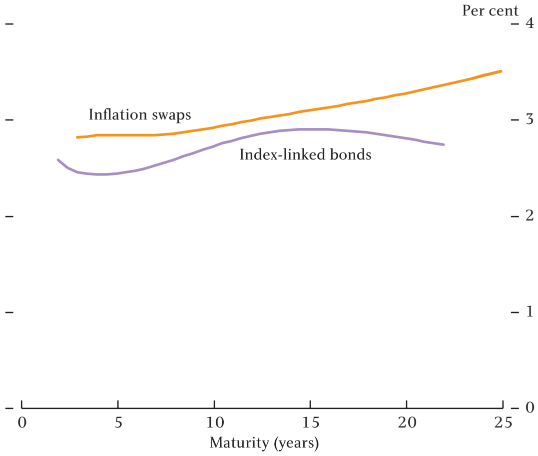
Charts 5 and 6 compare curves derived from index-linked bonds and inflation swaps for the euro area and United States respectively. For the euro area, which has the most developed inflation swaps market, the curve derived from inflation swaps extends to shorter maturities — the shortest-horizon contract being the two-year inflation swap. Where comparable, the two curves are virtually identical. For the United States, the shortest inflation swap contract we observe rates for is the three-year contract. Here there are differences between the two curves at all maturities.

Chart 5
Euro-area inflation forward curves for 21 February 2006



Sources: Bank of England and Bloomberg.

Chart 6
US inflation forward curves for 21 February 2006



Sources: Bank of England and Bloomberg.

Why might there be differences between curves derived from the two sources?

The inflation curves shown are for a specific date, but are fairly typical of the period for which we have comparable data. UK curves derived from the two sources are very similar at shorter horizons but diverge a little at the longest horizons. Curves for the euro area are almost identical, although small gaps are sometimes observed at the longest horizons. For the United States, there are persistent differences, with curves derived from inflation swaps being slightly higher than curves derived from index-linked bonds. Gaps between the US curves have tended to be about 10 to 30 basis points, across the maturity spectrum.

Theoretical consistency

In theory, the inflation compensation implicit in the prices of nominal bonds relative to index-linked bonds should be the same as that embodied in inflation swap rates. The two should be consistent due to arbitrage. That is because the pay-offs of index-linked bonds can be replicated using inflation swap contracts. And two portfolios with identical future pay-offs should have the same price via arbitrage. Hence, with perfect markets we would expect perfect substitution between breakeven rates available in the inflation swap and bond markets.(1)

Practical differences

In theory, inflation curves derived from inflation swaps and index-linked bonds should be identical, but in practice there can be differences. The primary cause is likely to be that market factors inhibit investors from arbitraging or hedging fully between inflation swap and index-linked bond markets.(2) This might occur because of barriers to arbitrage caused by incomplete markets. The ability to arbitrage or hedge across markets is dictated by the availability of assets for that purpose, so a lack of suitable assets would hinder these transactions. Another possibility is that trading costs create barriers to arbitrage. In broad terms, trading costs are likely to be inversely related to levels of market activity and competition.

If barriers to arbitrage are relevant here, this might partly be a symptom of some of the markets being relatively young. Hence these factors might recede over time as markets mature and activity increases. Also, these barriers may affect certain maturities more than others. For example, at maturities where a range of index-linked instruments are available, relative pricing may be better than at 'missing' points on the curve, where there is a lack of instruments. Similarly, trading costs may be lower at maturities where there is more market activity, and *vice versa*.(3)

If barriers to arbitrage do exist, prices in the two markets would be set more independently. In this case, relative supply and demand in each market would determine pricing and might cause breakeven rates to be different in one market versus the other. For example, if index-linked bonds are considered illiquid they will be less attractive to investors and so prices may be lower than otherwise. And an often cited feature of inflation swap markets is an excess of those wishing to receive inflation relative to those wishing to pay inflation. Other things being equal, this would raise breakeven rates — the price of receiving inflation — compared to otherwise. A further factor is that any distortions to the relevant nominal yield curve would affect inflation curves derived from index-linked bonds, but not those derived from inflation swaps.(4)

It is perhaps worth noting that we would not expect differences to be caused by counterparty risk premia in the inflation swap rates we use. That is because transactions make use of standard agreements, which require collateral to be posted and provide some legal protection in the event of counterparty default.(5) And even in cases where there is a significant credit differential between counterparties, any premia would be built into transactions on a bilateral basis rather than affecting the data we observe (which are rates quoted by brokers in the wholesale markets). Neither would we expect any differences to be caused by systemic banking sector risk. This contrasts with the nominal interest rate swap curve, which generally lies above the relevant nominal government bond curve because interest rate swaps are referenced to future interbank market rates — usually six-month Libor — which contain premia that reflect systemic banking sector risk.(6)

So, in summary, inflation curves derived from inflation swaps are theoretically consistent with those from index-linked bonds. However, if assumptions underlying this theory are not met, curves derived from the two sources may differ in practice. The curves we derive generally provide a very similar read on expectations. In some cases there are differences and hence the practical caveats mentioned in this section should be borne in mind when interpreting the curves.

(1) Perfect markets describe theoretical ideal conditions for markets to function. This involves numerous assumptions, including no trading costs; no barriers to entering or leaving the market; complete access to information by all parties; and the rationality of all parties.
(2) For a description of how arbitrage/hedging transactions work in practice see Chapter 5 of Benaben (2005).
(3) At the time of writing, inflation swap market activity is concentrated at different maturities in different markets. Most trading in UK contracts is in maturities over 15 years. For the euro-area and US markets, most activity is in contracts with maturities under ten years.
(4) When using index-linked bonds we first estimate a real curve and then subtract this from the relevant nominal curve to obtain an inflation curve. In contrast, inflation curves are derived directly from inflation swap rates.
(5) Typically agreements developed by the International Swaps and Derivatives Association are used. These are also used for nominal interest rate swaps and mitigate bilateral counterparty risk to the extent that credit premia on observed swap rates are typically considered negligible.
(6) In practice, a number of other factors may also influence nominal swap spreads. A discussion of observed swap spreads can be found in Cortes (2003).

What do our curves tell us?

Inflation and real interest rate curves are regularly used by the Monetary Policy Committee to inform its assessments of the prospects for inflation and economic conditions. This section outlines how they might be employed. As mentioned earlier, when using the curves it is important to remember they are likely to encapsulate more than just market participants' expectations. They are likely to incorporate risk premia and may also be affected by institutional factors. So in conducting our analysis we accept the curves may provide an imperfect proxy of market expectations.

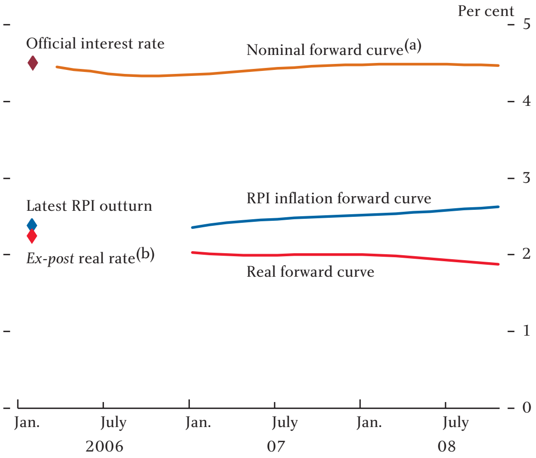
Prospects for the current economic cycle

Chart 7 compares recent UK interest rates and inflation with forward curves at short horizons. These imply that, on 21 February, RPI inflation was expected to remain fairly close to its level for the year to end-January 2006 (which was then the latest available outturn). The real interest rate forward curve can be used to indicate market expectations for prevailing monetary conditions in the future. It indicates that UK real rates were expected to fall slightly over subsequent years. It is worth noting that the real and inflation curves presented here relate to RPI inflation, rather than CPI inflation which is now targeted by the MPC. It is possible to derive expectations for CPI inflation, although this requires making assumptions about the future difference between CPI and RPI inflation and hence ceases to be a purely market-based measure.

Charts 8 and 9 show inflation and real interest rate forward curves for the euro area and the United States, also on 21 February. These imply that markets expected inflation to be about 2% and 2.5% respectively over the medium term. This seems fairly consistent with the inflation objectives of the ECB and the Federal Reserve.[1] And this also seems to suggest that any inflation risk premia were relatively small. Over the medium term, real forward rates are expected to rise in both the euro area and the United States. The euro-area real forward curve has a steeper gradient, possibly reflecting their position in the economic cycle relative to the United States.

Overall, it is apparent that despite the increase in oil prices over the past two years, medium-term market implied inflation expectations in the euro area, the United Kingdom and the United States appear to have remained broadly consistent with the objectives of the respective central banks.

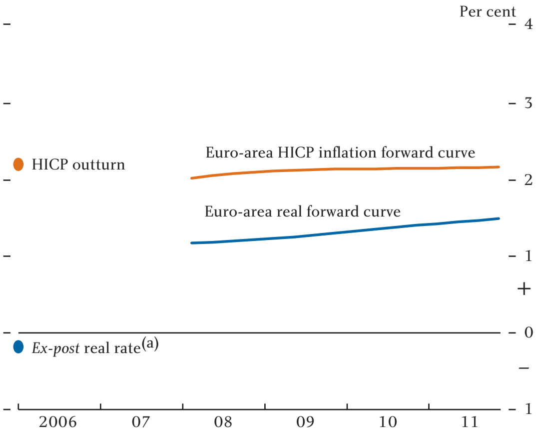
Chart 7
UK forward curves for 21 February 2006



Sources: Bank of England and Bloomberg.

(a) Curve derived from instruments that settle on Libor, and then adjusted for credit risk.
(b) Calculated as the average official interest rate during the year to end-January 2006 less RPI inflation over the same period.

Chart 8
Euro-area forward curves for 21 February 2006



Sources: Bank of England and Bloomberg.

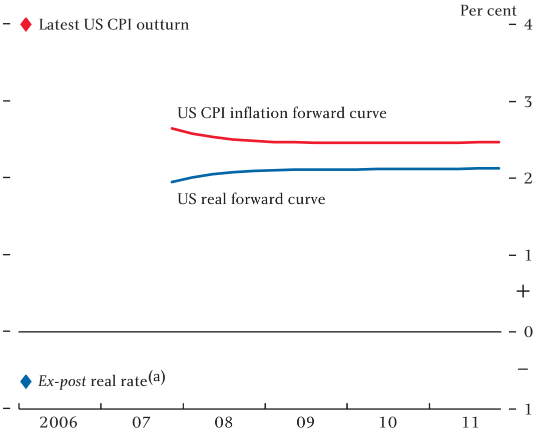
(a) Calculated as the average official interest rate during the year to end-December 2005 less HICP inflation over the same period.

Long-term real interest rates

Chart 10 shows time series of long-term real interest rates. This highlights a recent trend for falls in the level of long-term real interest rates, as discussed in two boxes in recent Bank publications.[2] These noted that the trend might be due to increases in world saving rates, particularly in emerging Asian economies, and possibly

(1) The ECB aims at inflation rates of below, but close to 2% over the medium term; the Federal Reserve does not explicitly aim for a specific rate of inflation.
(2) See 'The economics of low long-term bond yields', *Bank of England Inflation Report*, May 2005, page 6; and 'The fall in global long-term real interest rates', *Bank of England Quarterly Bulletin*, Spring 2005, page 12.

Chart 9
US forward curves for 21 February 2006

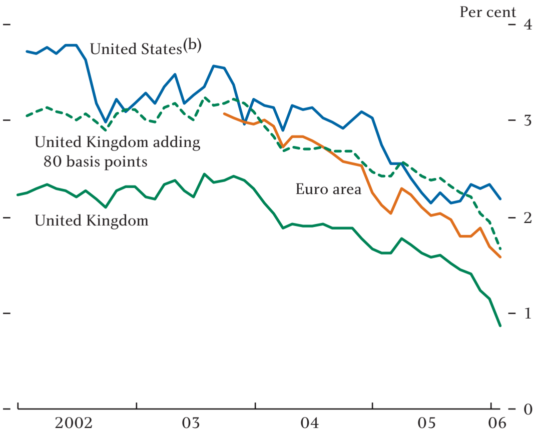


Sources: Bank of England and Bloomberg.

(a) Calculated as the average official interest rate during the year to end-January 2006 less CPI inflation over the same period.

lower levels of planned investment in developed economies. The boxes also highlighted the possibility that changes in risk premia or market factors, such as increased institutional demand for certain government bonds, may have affected the market rates we observe. It is also possible that the continuing development of index-linked markets may have made index-linked instruments more attractive to investors and hence reduced any liquidity premia they demand. This would increase the price of index-linked bonds and hence reduce real rates, but this factor would not explain the magnitude of the fall in real rates we observe.

Chart 10
International real ten-year forward curves[a]



Sources: Bank of England and Bloomberg.

(a) Data are monthly average rates.
(b) US data are nine-year forward rates.

Chart 10 also allows us to compare the level of international ten-year real rates. Theory predicts that at long horizons real rates of return (on similar assets) should be the same internationally.[1] Hence we might expect our derived real rates to converge toward a 'world real interest rate' at long maturities.

For this comparison, UK rates have been adjusted upwards by 80 basis points to reflect the long-run average difference between RPI and CPI inflation and hence crudely make them more comparable with US and euro-area rates.[2] To the extent that this is the correct adjustment, the chart shows that UK and US rates have been relatively close since mid-2002.[3] The euro-area series covers a shorter period. Initially euro-area rates were at a very similar level, but during the past year have been consistently at a slightly lower level. So there appears to be some evidence for ten-year real rates being at similar levels internationally, although we do not observe total convergence. However, it is less clear whether there is any evidence of convergence at maturities much longer than ten years.

There are several potential explanations for the absence of full convergence. First, if international markets were in practice segmented, real interest rates would be influenced by domestic economic prospects. Second, differences in regulatory requirements and tax regimes could affect the demand schedule of the marginal investor for each country. Third, it is possible that investors demand risk premia for investing in bonds, and that the size of these premia might be different for bonds issued by different countries. Finally, the inflation indices on which the real rates are based are not fully comparable. The different composition of the index used for UK index-linked instruments has only been crudely accounted for. Furthermore, the CPI indices vary in their precise construction and potentially their ability to proxy the 'true' deflator facing individuals in each country.

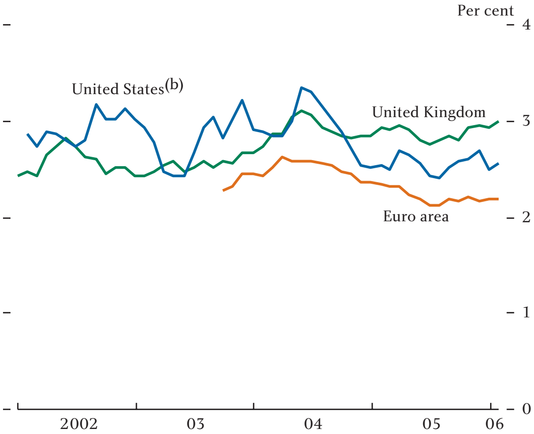
The longer-term outlook for inflation

A primary driver of investors' long-term inflation expectations is their confidence in the ability and determination of the monetary authorities to control

(1) This result is based on a world with perfect capital mobility, freely floating exchange rates and where uncovered interest rate parity holds. For a fuller discussion see Jenkinson (1996) or Brooke *et al* (2000).
(2) UK index-linked instruments are linked to RPI inflation whereas US and euro-area instruments are linked to CPI and HICP indices respectively, which have a more similar construction. Hence the UK time series has been adjusted upwards by the average difference between UK RPI and UK CPI since 1989 when CPI data are first available. This is not necessarily an accurate guide to future differences between RPI and CPI inflation. For further details see 'The wedge between RPI and CPI inflation', *Inflation Report*, November 2005, pages 29–30.
(3) Mid-2002 is around the time the US TIPS market became more liquid.

inflation. As explained above, our inflation forward curves will encapsulate market participants' expectations for inflation and also inflation risk premia that reflect uncertainty about future inflation. Although it is difficult to decompose forward rates into these components, both are likely to be (inversely) related to the perceived credibility of the monetary authority in controlling inflation.

Chart 11
International inflation ten-year forward rates[(a)]



Sources: Bank of England and Bloomberg.

(a) Data are monthly average rates.
(b) US data are nine-year forward rates.

Chart 11 shows long-horizon inflation forward rates for the United Kingdom, the United States and the euro area. In each case the level of the forward rates appears broadly consistent with the central bank's inflation objective of price stability. This appears to indicate that investors believe central banks are likely to meet their inflation objectives of broad price stability over the long term, and that any inflation risk premia are relatively small. US inflation forward rates have been slightly more volatile than those for the United Kingdom and the euro area. This might reflect more variation in investors' long-term expectations for US inflation and inflation risk premia, or institutional factors such as liquidity in the TIPS market.

Summary and conclusions

Recent developments in international index-linked markets have provided new market data. We can now estimate a greater range of international inflation and real interest rate forward curves using either inflation swaps or index-linked bonds. These curves facilitate analysis of inflation expectations and real rates across countries, and are regularly used by the Monetary Policy Committee to inform its assessments of economic conditions. At short to medium-term horizons the curves are a useful guide to market expectations about the evolution of the current economic cycle. At long horizons, inflation forward rates can be used to gauge financial markets' confidence in the ability and determination of monetary authorities to control inflation. In the United Kingdom, the United States and the euro area these currently appear broadly consistent with each central bank's inflation objective of broad price stability.

Appendix
Details of inflation swaps and index-linked bonds across countries

There are variations in the design of index-linked bonds and inflation swap contracts across countries. The tables in this appendix outline the design features of the index-linked bonds and inflation swaps whose prices are used in this article. In particular, the price index to which each instrument is referenced; the indexation lag, which identifies which month the contract is referenced to; the method used to calculate the reference price level (described in more detail below); and whether the contract has a floor, which protects investors from deflation.

Table A
Index-linked bonds

	Reference index	Lag length (months)	Calculation of reference price level	Floor[(a)]
United Kingdom	UK RPI	8 [(b)]	End of month[(b)]	No
United States	US CPI (urban consumers NSA)	3	Interpolated	Yes
France	Euro-area HICP excluding tobacco	3	Interpolated	Yes
Greece	Euro-area HICP excluding tobacco	3	Interpolated	Yes
Italy	Euro-area HICP excluding tobacco	3	Interpolated	Yes

(a) When deriving curves using index-linked bonds with an inflation floor (to protect investors against deflation) we assume the floor has a negligible impact on the bond prices.
(b) All new UK bonds issued since September 2005 have used a three-month indexation lag and the interpolated reference price level method.

Table B
Standard zero-coupon inflation swaps

	Reference index	Lag length (months)	Calculation of reference price level	Floor
United Kingdom	UK RPI	2	End of month	No
United States	US CPI (urban consumers NSA)	3	Interpolated	No
Euro area	Euro-area HICP excluding tobacco	3	End of month	No

Calculation of the reference price level[(1)]

The reference price level is important for both index-linked bonds and inflation swaps. For index-linked bonds it determines the scaling applied to each coupon and the redemption payment. For inflation swaps it determines the calculation of payments on the floating leg of the contract.

The reference price level is either an end-of-month value or a value interpolated between levels for two consecutive months. For the end-of-month method, the price level is just the published index value for the month specified by the indexation lag. For example, euro-area inflation swaps traded in April are based on the index value for January. Under the interpolated method, a new value is calculated each day. For the first day of any month the reference value is the same as for the end-of-month method. But for subsequent days the value is calculated by interpolating between that index value and the following month's index value. For example, US inflation swaps traded in mid-April will be referenced to a value interpolated between the index values for January and February. This is calculated as follows:

$$CPI_{ref} = CPI_{M-L} + \left(\frac{d-1}{D}\right).[CPI_{M-L+1} - CPI_{M-L}]$$

where M is the current month (in which the contract is traded), L is the indexation lag (in months), d is the day of the current month, and D is the number of days in the current month.

(1) For more detail see Deacon *et al* (2004).

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