EUROPEAN CENTRAL BANK

EUROSYSTEM

ECB WORKSHOP
ON THE ANALYSIS OF
THE MONEY MARKET

WORKING PAPER SERIES
NO 978 / DECEMBER 2008

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In 2008 all ECB publications feature a motif taken from the €10 banknote.

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ECB WORKSHOP ON THE ANALYSIS OF THE MONEY MARKET

On 14 and 15 November 2007, Alain Durré, Huw Pill and Diego Rodriguez-Palenzuela of the ECB's Monetary Policy Stance Division organised a central bank workshop titled "The Analysis of the Money Market: Role, Challenges and Implications from the Monetary Policy Perspective". This workshop provided an opportunity for participating central bank experts to exchange views and foster debate, also in interaction with international organizations and academic institutions. The first day of the workshop addressed issues related to the macro-perspective of the money market, drawing on the experiences of a large number of countries. The second day adopted a micro-perspective on the money market, looking in particular at trading behaviour in the overnight money market and its implications for the evolution of spreads.

A first version of this paper was presented at this workshop. The papers presented at the time of the workshop did not consider the potential implications of the financial turmoil for the results of the paper, given that the tensions in money markets emerged in August 2007. The published version of these papers represents an update of the original paper, which incorporates the discussion which took place at the workshop and in most cases a discussion on the developments in the money markets since August 2007.

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Abstract

This paper reviews the main instruments and associated yield curves that can be used to measure financial market participants' expectations of future UK monetary policy rates. We attempt to evaluate these instruments and curves in terms of their ability to forecast policy rates over the period from October 1992, when the United Kingdom first adopted an explicit inflation target, to March 2007. We also investigate several model-based methods of estimating forward term premia, in order to calculate risk-adjusted forward interest rates. On the basis of both in and out-of-sample test results, we conclude that, given the uncertainties involved, it is unwise to rely on any one technique to measure policy rate expectations and that the best approach is to take an inclusive approach, using a variety of methods and information.

JEL Classification: E43, E44, E52

Keywords: Interest rates, forecasting, term premia.

Non-technical summary

The Bank of England's Monetary Policy Committee (MPC) is interested in financial market participants' expectations of future monetary policy rates for a variety of reasons. Most obviously, the market's interest rate expectations affect the lending and borrowing rates facing firms and consumers and so play an important role in the transmission mechanism of monetary policy to the real economy. Monetary policy makers therefore want to know how their decisions and communications are affecting these expectations. In addition, these expectations may themselves contain useful information about the market's perceptions of current and future economic developments, which policymakers might also want to incorporate into their own view of the outlook.

There are a variety of possible financial market instruments that can be examined for the purpose of measuring the market's policy rate expectations. But none are self-evidently suited for the task, in that none are directly linked to the UK policy rate, Bank Rate. Moreover, different instruments vary in terms of their credit quality (default risk) and liquidity (the extent to which there is an active market for the particular instrument), which may be reflected in their associated interest rates, driving them away from genuine Bank Rate expectations. In addition, interest rates, particularly those relating to more distant future periods, may also reflect term premia (the compensation investors require for the risk of future interest rate changes), which will complicate their relationship with policy rate expectations.

Market expectations cannot, of course, be directly observed, making it difficult to assess which financial market instruments measure them best. In order to evaluate different financial market instruments, the paper makes the underlying assumption that more reliance should be placed on those instruments that have more accurately predicted Bank Rate in the past since, other things being equal, instruments that have predicted relatively well are less likely to have been affected by other factors.

The first part of the paper attempts to evaluate the interest rates derived from various financial instruments in terms of their ability to forecast UK policy rates over the period from October 1992 to March 2007. The sample therefore covers a period during which the United Kingdom followed an explicit inflation target, but excludes the period of turbulence in international money and credit markets that began in Summer 2007.

The main finding is that interest rates derived from instruments or yield curves that are less likely to embody material credit or liquidity risk premia have done better in forecasting Bank Rate. But beyond this finding, it proves difficult to discriminate. This may not be that surprising if financial markets work efficiently, so that expectations are consistently reflected in different instruments. We do, however, find some evidence that is consistent with term premia being important at horizons of a year and beyond, which potentially obscures the information in market interest rates about future policy rate expectations.

The paper then examines several ways of estimating term premia, in order to calculate term premia-adjusted market interest rates. One method of doing this suggested by other work is to regress the difference between Bank Rate outturns and implied interest rates onto macroeconomic and financial information. Under certain conditions, the fitted values from these sorts of regression provide a measure of term premia. We construct such measures but in general find them to be sensitive to the precise specification, forward horizon and sample period being examined. We also compare these regression-based term premia estimates with other common ways of measuring term premia using survey expectations and interest rate models. Different approaches are sometimes found to provide quite different term premia estimates.

Finally, we examine how important it is to adjust for term premia in inferring interest rate expectations from market rates. When we compare various methods of forecasting Bank Rate out of sample (that is, using no information that would not have been available to forecasters in real time), we find no consistent pattern. Sometimes, using a regression-based method to adjust market rates for term premia produces Bank Rate forecasts inferior to those generated by unadjusted market interest rates, or by simply assuming that Bank Rate will remain constant.

The main message of this paper is that it does not seem prudent to rely on any one particular method for measuring monetary policy rate expectations from financial market instruments. The best approach seems to be to take an inclusive approach, using a variety of methods and information. This provides some support for the convention of conditioning the Bank of England *Inflation Report* forecast projections on a profile of market interest rates that has not been explicitly adjusted for term premia. But this remains an active area of research at the Bank and elsewhere and it is conceivable that further research may change this conclusion.

1 Introduction

The Bank of England's Monetary Policy Committee (MPC) is interested in financial market participants' expectations of future monetary policy rates for a variety of reasons. Most obviously, the market's interest rate expectations affect the lending and borrowing rates facing firms and consumers and so play an important role in the transmission mechanism of monetary policy to the real economy. Monetary policy makers therefore want to know how their decisions and communications are affecting these expectations. In addition, these expectations may themselves contain useful information about the market's perceptions of current and future economic developments, which policymakers might also want to incorporate into their own view of the outlook.

There are a variety of possible instruments that can be examined for the purpose of generating a measure of the market's policy rate expectations. But the existence of term premia and differences in credit quality, maturity, liquidity and contract specifications of alternative instruments mean that it is not straightforward to infer what market interest rates imply for market expectations about Bank Rate, the current UK policy rate. For the past couple of years the Bank has constructed its main *Inflation Report* projections for output growth and inflation on the basis of a profile for future Bank Rate implied by market yields.[1] The precise method of constructing this profile is not set in stone and the instruments used have changed over time.[2] But the aim has always been either to use financial instruments that can be regarded as being close to default risk free (eg government bonds), or to make simple adjustments to interest rates on instruments that might incorporate credit or liquidity premia (eg unsecured interbank lending rates). The convention, however, has not been to adjust these profiles for term premia.

In the first part of this paper, we attempt to assess which financial instruments or curves provide the best measure of short-term market expectations of UK policy rates, by examining how well their implied forward rates have predicted subsequent policy rate outturns up to two years ahead.[3] Our sample covers the period from October 1992, when the United Kingdom first adopted an explicit

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[1] The Bank continues to publish forecasts based on constant interest rates, but puts more emphasis on the projections based on the market path (see Lomax (2005)). Goodhart (2005) criticises this approach, partly on the grounds that market forward rates are poor predictors of future policy rates, something we will examine in some detail in this paper.
[2] As the *Inflation Report* (Bank of England (2007)) puts it: 'The MPC may change the way it estimates these [market] expectations from time to time, as shifting market conditions can alter the relative advantages of using different methods'. Further information on the methods used to construct the market interest profile is provided on the Bank of England website, www.bankofengland.co.uk/publications/inflationreport/conditioning_path.htm.
[3] The choice of two years ahead was largely dictated by the availability of actively traded financial instruments, but over longer horizons it is also less likely that market participants will have well-defined views of the path of monetary policy.

inflation target, to March 2007. So it does not include the period of turbulence in international money and credit markets that began in Summer 2007. Our results are therefore not affected by the large increases in liquidity and credit premia on some financial market instruments that subsequently occurred. The assumption underlying the analysis is that more reliance should be placed on those instruments that have had the best predictive content since, other things being equal, instruments that have predicted Bank Rate outturns more accurately are less likely to have been affected by other factors. Unlike in the United States (see similar analysis for the United States by Gurkaynak, Sack and Swanson (2007)), and akin to the situation in the euro area (see eg Durre, Evjen and Pilegaard (2003)), there are no sterling instruments that settle directly on the domestic policy rate. So policy rate forecast errors can come from technical differences to do with the instrument being used, as well as genuine monetary policy surprises. Most of these technical factors might under normal circumstances be expected to be relatively constant over time, making them less likely to be important when we look at changes in rates. However, there is a large literature suggesting that term premia may vary over time, though it is an open question how important they are at the relatively short horizons we consider. (For a textbook review of the literature on time variation in term premia, see Cuthberton and Nitzsche (2005), and for some recent evidence for the United Kingdom see, for instance, Lildholdt, Panigirtzoglou and Peacock (2007).)

We then turn to examine whether it is possible to make some prior adjustments to market forward rates to remove the influence of term premia. To the extent that the difference between forward rates and policy rate outturns — realised forward premia — are predictable *ex ante* using available macro and financial indicators, this may provide a means of quantifying the implied term premia embodied in forward rates. This regression-based approach has been used for the United States by Piazzesi and Swanson (2008), who find that term premia on futures are countercyclical and predictable. We also find some evidence that forecast errors can be predicted by economic and financial variables, although the results are sensitive to the precise specification, forward horizon and sample period examined. One possible reason for this may be that the predictable element of realised forward premia is a poor proxy for term premia. So we also supplement our analysis by examining term premia estimates based on survey expectations of future interest rates and estimates from an affine dynamic term structure model (see Joyce, Lildholdt and Sorensen (2008)). The association between the various measures examined is weak at short maturities, but increases with the forecast horizon. Nevertheless, these different methods can sometimes produce very different quantitative estimates. We compare unadjusted market forward rates with various alternative measures of term premia-adjusted forward rates using several of our term premia estimates. Finally, we carry out a separate exercise that updates our estimates in real time and suggests that *ex-post* analysis understates the uncertainties that exist. The sensitivity of the resulting paths of implied monetary policy expectations to the method used to produce them suggests it is prudent not to rely on any one technique to adjust for term premia and instead to draw on a variety of methods and information.

The structure of the paper is as follows. Section 2 provides an overview of the available financial market instruments and fitted yield curves that can be used to infer expected future policy rates for the United Kingdom. In Section 3 we examine the predictive power of each of the instruments and curves for future changes in policy rates. Section 4 considers the extent to which policy rate prediction errors are explicable *ex ante* in terms of macroeconomic and financial indicators and contrasts the resulting regression-based term premia estimates with estimates from surveys and an affine term structure model. Section 5 uses our estimation results and other methods to evaluate measures of risk-adjusted interest rate expectations out of sample. Section 6 concludes.

2 A review of available financial market instruments and yield curves

Short-term interest rate expectations can be inferred from a range of financial market instruments. However, there are no sterling market instruments for which settlement is directly linked to the realised level of Bank Rate (the United Kingdom's official policy rate, as set by its Monetary Policy Committee). So we must consider instruments and interest rates that are influenced by additional factors, such as liquidity and credit risk, and try to take these into account in order to infer market participants' expectations of the future level of Bank Rate. In addition, some instruments will not provide information about expectations for *overnight* interest rates at a certain date in the future, which is what we would ideally like to derive, but rather about expected future *term* interest rates. We can think of these as providing information on expectations for the average overnight rate during the period of the term rate.

2.1 Individual instruments

General collateral sale and repurchase agreements

The gilt sale and repurchase ('gilt repo') market began in January 1996. Gilt repo transactions involve the temporary exchange of cash and gilts between two parties and are a means of short-term borrowing using gilts as collateral. Since the lender of funds holds government bonds as collateral he/she is protected in the event of default by the borrower; hence this is a form of *secured* lending. General collateral (GC) repo rates refer to the rates for repurchase agreements in which any gilt stock may be used as collateral and should, in principle, reflect only minimal credit risk. Repo contracts are traded for a range of maturities, from overnight to one year.

Gilts/government bonds

A conventional UK government bond, or 'gilt', is a promise by the government to pay the holder a fixed cash payment (coupon) every six months until the maturity date, at which point the holder receives the final coupon payment and the principal. Since gilts are issued by the UK government, they can be regarded as free of credit risk, and therefore might be thought of as an obvious instrument to use for inferring future policy rate expectations. However, one difficulty of using them for this purpose is that there are generally few government bonds with short maturities. Rather than examining the informational content of government bonds on their own, we examine forward rates from the Bank of England's government liability yield curve, which combines them with GC repo rates to fit the short maturities we are interested in (see Section 2.2 below for more details).

Treasury bills

Treasury bills (T-bills) are short-term government securities that are issued at a discount to their face value, rather than paying interest directly. One reason we might expect Treasury bill rates to contain less reliable information about future interest rates than other instruments is that their secondary market has tended to be relatively illiquid, with their quoted prices often being indicative rather than representing true market prices. Moreover, over various periods in the past they have been in high demand from banks to satisfy their regulatory requirements, which may have affected their prices, though this may be less of an issue over the period we consider. The UK government issues T-bills at both one-month, three-month and six-month maturities, but for reasons discussed below we shall only use three-month Treasury bills in our analysis.

Unsecured sterling interbank loans (Libor rates)

An unsecured interbank loan is a cash loan where the borrower receives an agreed amount of money at an agreed interest rate. The loan is *unsecured*, as the lender does not receive collateral as protection against default by the borrower.

The London interbank offered rate (Libor) provides a measure of the interest rate at which banks can raise unsecured funds from other financial institutions in reasonable market size. The British Bankers' Association (BBA) calculates Libor fixings by taking an average of the offer rates collected at 11 am each day from a panel of financial institutions operating in London in the sterling interbank market. The BBA publishes sterling Libor for maturities ranging from overnight to one year. The financial institutions that are part of the Libor panel are long-established creditworthy institutions, but the loans are unsecured and so carry some possibility of default. The interest rates required by the lender will reflect this repayment risk, which adds a premium to Libor compared with true default risk-free rates. In addition to credit premia, Libor rates will also be affected by liquidity conditions in money markets and so may contain liquidity premia. Although it has increased significantly since the financial turmoil began in Summer 2007, the spread between Libor and secured rates tended to be quite small over the period we examine (from October 1992 to March 2007).

Short sterling futures

A short sterling interest rate futures contract settles on the three-month BBA Libor rate prevailing on the contract's delivery date. Contracts are standardised and traded between members of Euronext.liffe (LIFFE). The most liquid and widely used contracts trade on a quarterly cycle with maturities in March, June, September and December. Short sterling contracts are available for settlement in up to six years' time, but the most active trading takes place in contracts with less than two years' maturity. Interest rate futures are predominantly used to speculate on, and to hedge against, future interest rate movements. Counterparty credit risk is close to negligible due to daily marking-to-market and collateral requirements imposed by LIFFE.

Forward rate agreements

A forward rate agreement (FRA) is a bilateral or 'over-the-counter' (OTC) interest rate contract in which two counterparties agree to exchange the difference between a fixed interest rate and an as yet unknown Libor rate of specified maturity that will prevail at an agreed date in the future. Payments are calculated against a pre-agreed notional principal. Like short sterling contracts, FRAs allow institutions to lock in future interbank borrowing rates. Unlike futures contracts, which are exchange traded, FRAs are bilateral agreements with no secondary market. FRAs have the advantage of being more flexible, however, since many more maturities are readily available. Non-marketability means that FRAs are typically not the instrument of first choice for taking speculative positions, but the additional flexibility does make FRAs a good vehicle for hedging, as they can be formulated to match the cash flows on outright positions. In this paper we do not directly test the information content of FRAs, but these are one of the instruments used to construct the bank liability curves we test. (The estimation of bank liability curves is discussed in Section 2.2 below.)

Interest rate swaps (SONIA and Libor)

An interest rate swap contract is an agreement between two counterparties to exchange fixed interest rate payments for floating interest rate payments, based on a pre-determined notional principal, at the start of each of a number of successive periods. Swap contracts can, therefore, be thought of as equivalent to a series of FRAs with each FRA beginning when the previous one matures. The floating interest rate chosen to settle against the pre-agreed fixed swap rate is determined by the counterparties in advance. There are two such floating rates used in the sterling swap markets: the sterling overnight index average (SONIA) and six-month Libor rates.

SONIA is the average interest rate, weighted by volume, of unsecured overnight sterling deposit trades transacted prior to 3.30 pm on a given day brokered by members of the Wholesale Money Brokers' Association. As SONIA is an overnight rate, and credit risk in overnight transactions is generally small compared with longer-maturity deals, it is usually close to Bank Rate. A SONIA overnight index swap is a contract that exchanges at maturity a fixed interest rate against the compounded SONIA rates that have prevailed over the life of the contract. As these swap contracts are structured so that they involve minimal counterparty risk, the expected path of SONIA they embody should also not reflect material credit risk premia. SONIA swaps are typically used to speculate on or to hedge against interest rate movements at short maturities. The SONIA swap market has expanded rapidly recently, but over our sample period the volume of trading was typically relatively limited at maturities beyond six months.

Libor swaps settle against six-month Libor rates (see above for an explanation of Libor). They are typically used by financial institutions to help reduce their funding costs, to improve the match between their liabilities and their assets, and to hedge long positions in the cash markets. Traded swap contract maturities range from 2 years to 30 years. Because they are not available below two years, we do not directly test their information content for future policy rates, but they are included as one of the instruments used to construct the bank liability yield curves we test.

2.2 Yield curves

The Bank of England estimates zero-coupon yield curves for the United Kingdom on a daily basis.[4] They are of essentially two kinds. One — called the government liability curve (GLC) — is based on UK government bonds and includes GC repo rates at horizons out to a year. The other — called the bank liability curve (BLC) — is based on Libor interest rates and market rates on instruments linked to Libor; specifically short sterling futures, FRAs and Libor-based interest rate swaps. The method used to produce both these curves is based on a cubic spline technique, with a penalty function which results in greater smoothness at longer horizons. This so-called variable roughness penalty or VRP method is explained in more detail in Anderson and Sleath (1999, 2001) and its application to bank liability instruments is described in Brooke *et al* (2000). Because the technique is non-parametric the shortest (and longest) maturity available depends on the shortest (and longest)

[4] These are published on the Bank's website at www.bankofengland.co.uk/statistics/yieldcurves.

maturity instrument that is included in the curve. So, in the case of the GLC, maturities below two years are only available consistently since the beginning of 1996 when the GC repo market began. The BLC is available at very short horizons over a longer period, since it includes Libor rates which are available at three-month maturities.

A variety of methods have been used to generate a conditioning path of market interest rates for the *Inflation Report* forecast. Before the onset of the financial market turmoil that began in Summer 2007,[5] the market path was based on an adjusted version of the BLC that subtracted an estimate of credit risk premia from the unadjusted BLC. This adjustment was based on recent spreads between Libor rates and those on GC repo rates (as the latter were assumed to be similar to risk-free rates). The adjustment varied up to the twelve-month horizon, after which it was held constant (given that the longest maturity traded in the GC repo market is twelve months). A further adjustment was also applied to account for the average spread of the short-horizon GC repo rate relative to Bank Rate and this second adjustment was held constant across all horizons. We shall examine the predictive ability of the GLC, BLC and this adjusted BLC in our empirical analysis.[6]

2.3 Constructing comparable forward rates

In order to assess the predictive content of the various financial market instruments and yield curves discussed above for future policy rates, we first need to construct their implied forward rates.

In the case of our yield curve estimates, we can compute forward rates for any future horizon that we have prices for, covering virtually any period (or tenor). This is not possible for the individual instruments without making strong assumptions about interpolation, which would render such comparisons less meaningful. So the forward rates used for our analysis are calculated for tenors and horizons for which we can construct comparable rates.

Throughout the paper we therefore use rates with tenors of three months, as this is the only maturity for which we can construct comparable rates across the full range of instruments. For each instrument there is a range of forward horizons at which the implied three-month rates begin, the shortest being zero days forward (equivalent to a three-month spot rate) and the longest being two

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[5] Starting with the November 2007 *Inflation Report* slightly different methods have been used by the Bank to derive the interest rate conditioning paths because the disruption in international money and credit markets meant that the normal method was no longer deemed appropriate (information on the method used is provided in the relevant *Inflation Report* and more details are contained on the Bank of England website, www.bankofengland.co.uk/publications/inflationreport/conditioning_path.htm).

[6] The market interest rate profile used to condition the *Inflation Report* forecast is based on a moving average (usually fifteen days) of forward interest rates with an overnight tenor. Our analysis does not use averaged rates.

years. The range of forward horizons varies across instruments depending on the maturities actively traded in each market. For all monthly frequency data, we use forward rates calculated for the last business day of each calendar month. However, short sterling futures have maturities that are denominated in quarters rather than months and mature mid-month. So to incorporate futures into our analysis we also consider forward rates at the same quarterly frequency.

To ensure consistency across our various instruments/curves, all forward rates have been converted to annualised daily compounded rates. Chart 1 shows these forward rates for the individual instruments and curves that we examine plotted against Bank Rate, where 0 month indicates the implied rate over the next three months (the three-month spot rate), 3 month indicates the implied three-month rate three months ahead, 6 month indicates the implied three-month rate six months ahead, etc. (More details on the construction of the forward rates from each instrument are contained in Appendix C.)

3 Forecasting policy rates

In this section we test how well the different instruments and curves have predicted Bank Rate.

3.1 Method

An obvious starting point for testing the predictive content of these forward rates is simply to regress policy rate outturns onto them and then to examine the goodness of fit of the estimated equations. This means running the following regression for each curve/instrument being considered:

$$y_{t+h,t+h+k} = \alpha_h + \beta_h f_{t,t+h,t+h+k} + \varepsilon_t^h \qquad \textbf{(1)}$$

where $y_{t+h,t+h+k}$ denotes the policy interest rate observed over k periods h periods ahead;[7] $f_{t,t+h,t+h+k}$ denotes the implied k-period forward rate h periods ahead observed at date t; ε_t is an error term; and

[7] It is important to match policy rate outturns to the period covered by the forward rates. To calculate corresponding policy rate outturns, the policy rate prevailing on each day is compounded up over the relevant three-month period and then annualised to make it comparable. So if there are k days in the relevant three-month period and we denote the policy rate prevailing in period t by y_t, the annualised policy rate outturn over the three-month period h periods ahead is denoted $y_{t+h,t+h+k}$ such that: $y_{t+h,t+h+k} = \left(\prod_{i=0}^{k} \left(\frac{y_{t+h+i}}{100} + 1 \right)^{1/365} \right)^{365/k}$.

α_h and β_h are constant parameters. This predictive equation is of course often used to test the expectations hypothesis of the term structure. Under the pure expectations hypothesis, where forward rates are unbiased estimates of future policy rates then we expect $\alpha_h = 0$ and $\beta_h = 1$ and the errors from the equation to be well behaved. Under the more general expectations hypothesis, forward rates may embody a constant premium (in the context of some of our regressions this may reflect credit or liquidity premia, as well as term premia), which we would expect to pick up in the value of the α_h intercept parameter. If, on the other hand, premia are time-varying, we might expect to find the slope coefficient β_h significantly different from unity (assuming premia covary with interest rates). Other things being equal, the latter might be taken as a rejection of the expectations hypothesis, though it is perhaps worth recalling that this need not be the case, eg if agents are not rational and/or they make persistent forecast errors.

Since interest rates are close to having a unit root and our focus is on short-term predictive content, we adopt the standard practice of deducting the current policy rate, y_t, from both sides of the equation (see eg Gurkaynak, Sack and Swanson (2007)). So the regression we actually estimate is the following equation in changes form:

$$y_{t+h,t+h+k} - y_t = \alpha_h + \beta_h (f_{t,t+h,t+h+k} - y_t) + \varepsilon_t^h \qquad \textbf{(2)}$$

We then compare the fit of this equation across financial instruments/yield curves and with a benchmark random walk model (where we predict $y_{t+h,t+h+k}$ with the level of the current policy rate, y_t).

3.2 Monthly frequency results

Other research (eg Lildholdt and Vila Wetherilt (2004)) suggests that the predictability of UK policy rates improved notably after the introduction of inflation targeting in the United Kingdom, so this makes the post-October 1992 sample a natural period to examine. We ran the policy rate forecasting regressions over several sample periods: the period from October 1992, when the United Kingdom authorities first adopted an explicit inflation target; the period since May 1997, when the Bank of England was granted operational independence for setting interest rates; and a shorter common sample period, dictated by the availability of data for all of our instruments over each forecast horizon. The forward rate data we used in our analysis ran up until the end of December 2006 and the policy rate outturns up to March 2007 so, as already mentioned, our analysis does not cover the period of disruption and volatility in credit and money markets that began in the Summer of 2007.

Depending on the availability of data, results are presented for forecast horizons of 0, 3, 6, 12, 18, 21 and 24 months ahead using both monthly and quarterly data.

Tables A to C set out the results from the forecast regressions for those instruments/curves for which we can derive implied forward rates on a monthly frequency. The tables report the parameter estimates and associated measures of statistical significance calculated using standard errors corrected for heteroscedasticity and autocorrelation using the Newey-West procedure. As measures of how well the equations fit, we also report the adjusted R-squared and the root mean squared error (RMSE) of the equations relative to the RMSE from a benchmark random-walk model. Chart 2 plots the adjusted R-squared, alpha and beta coefficients by horizon for each of the instruments/curves over the longest sample period available back to October 1992 and over shorter common sample periods over each forecasting horizon.

Perhaps the most striking result to emerge is how well some of the instruments and curves do in forecasting future interest changes, particularly at shorter horizons. For example, when we use all the available data back to October 1992, as shown in Table A, the adjusted R-squared values for the three-month ahead regressions range from 37% (T-bill and Libor rates) to 65% (government liability curve). And, in big picture terms, these results are little changed when the sample is truncated to cover the shorter sample period since Bank of England independence (Table B), nor when we use common sample periods across each forecast horizon (Table C). It is also noteworthy that the RMSEs from all the instruments/curves beat the benchmark random-walk specification over all horizons, though as we might expect, the explanatory power of the instruments/curves tends to fall in absolute and relative terms as the forecasting horizon lengthens. Nevertheless, even looking 24 to 27 months ahead the GLC is able to explain about 25% of the variation in policy rates over the full sample, though its explanatory power is slightly lower since May 1997.

No instrument/curve clearly dominates all the others consistently across all maturities.[8] At shorter horizons, GC repo rates tend to do best overall at forecasting policy rates. Between the curves, the GLC and the adjusted BLC outperform the unadjusted BLC at both short and long horizons. The clearest finding is that Treasury bills and Libor-related instruments as embodied in the BLC do less well in the forecasting regressions.

Turning to the parameter estimates, in all the forecasting regressions it is striking that the constant term (though not always statistically significant) takes a negative sign, which increases in absolute

[8] This conclusion is confirmed when we run encompassing regressions including forward rates from all the instruments/curves.

size with maturity. This is consistent with a positive forward term premium, as it suggests that unadjusted forward rates tend to overpredict policy rate outturns.[9] The beta coefficient is positive throughout and often statistically significant, though less than unity and decreasing in maturity (though the size of the estimates appears to stabilise at the longest horizons we consider). Though the pattern varies slightly according to the instrument/curve and sample period, on the whole formal tests cannot reject beta being unity at short horizons out to a year, but at longer horizons this hypothesis tends to be rejected, which might indicate the presence of time-varying term premia.

3.3 Quarterly frequency results

The results reported in Tables D to F repeat the same analysis using quarterly data, allowing us to include forecasts from sterling futures contracts into our comparison. Chart 3 plots the adjusted R-squared, alpha and beta coefficients by horizon for each of the instruments/curves over the longest sample available back to October 1992 and over shorter common sample periods.

Not surprisingly, the results at the quarterly frequency are similar to those using monthly data in qualitative terms. Most of the market instruments and curves do a reasonable job at predicting future policy rates at shorter horizons, dominating the random-walk model in terms of relative RMSE, and explaining up to 60% (GLC) of the variation in policy rates at the shortest horizon examined over the full sample. Predictability tends to fall as the horizon lengthens, but even at two years the curves dominate the random walk.

In terms of comparisons across instruments, at the short end, Treasury bills and futures tend to be dominated by GC repo, SONIA swaps, the GLC and the adjusted BLC. Further out, the GLC and the adjusted BLC dominate the unadjusted BLC. Overall, futures rates have about the same amount of predictive content as the BLC, which is not surprising since they are one of the instruments used to construct it.

As with the monthly regressions, we see that the constant term is negative and increases (in absolute size) with maturity, while the beta coefficient is less than unity and decreasing with maturity (though stabilising and possibly even increasing slightly at the longest horizons we examine). If anything, the hypothesis that beta is unity tends to be rejected at more horizons, according to the quarterly results, but there is a clear pattern of rejection at longer horizons.

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[9] It is possible that this might partly reflect the fact that the level of policy rates has been persistently lower than expected over the period since 1992. To examine this further, we ran the same regressions on a shorter sample period limited to

4 Term premia estimates

In Section 3 we demonstrated that, although some financial instruments and associated yield curves seem to do a good job in predicting future movements in policy rates, the restrictions of the expectations hypothesis were often rejected, at least beyond horizons of a year ahead.[10] These results are consistent with time-varying term premia.

The object of this section is to examine several ways of estimating term premia, in order to correct market forward rates for risk. One method of doing this is to regress the *ex-post* forecast errors, or their negative which can be thought of as a measure of the realised or *ex-post* forward premium, onto macroeconomic and financial market information available *ex ante* to see whether some part of the return is predictable (for a recent discussion of this regression-based method see eg Kim and Orphanides (2007)). To the extent that these realised premia are predictable, and investors are rational, the fitted values from these regressions can be interpreted as term premia estimates. These forward premia estimates can then be used to adjust market forward rates *ex ante* to form risk-adjusted forward rates.

Of course, this method of estimating forward term premia is entirely reduced-form and subject to the risk of 'data mining'.[11] Moreover, the underlying assumptions on which it is based may not hold (*eg* uncorrelated expectational errors). We therefore compare our regression-based estimates with estimates based on survey expectations of interest rates (derived from Consensus Economics data on expected Libor rates (see also Peacock (2004)) and from forward premia derived from an affine term structure model (taken from Joyce, Lildholdt and Sorensen (2008)). The affine model we use is explained in more detail in Annex D.

4.1 Regression-based term premia estimates

The regression-based method of estimating forward term premia involves estimating the following equation:

$$f_{t+h,t+h+k} - y_{t,t+h,t+h+k} = \alpha_h + \beta_h X_t + \varepsilon_t^h \qquad \textbf{(3)}$$

data after 2000. Our main findings also held over this shorter sample, at least in qualitative terms.

[10] It needs to be borne in mind that since none of the instruments or curves we examine settle directly on Bank Rate itself, the rejection of these restrictions does not strictly provide a rejection of the expectations hypothesis as normally defined. Our focus is more on the issue of whether the relevant instrument or curve provides an unbiased estimate of future policy rates, which requires the same restrictions to hold.

[11] Clearly there are a large number of data releases and market measures that might potentially explain term premia. We have focused on a relatively small number of indicators that have been found to be important in previous work. In the case of our macro indicators, we chose two measures that have a relatively clear relationship with the business cycle.

where the negative of the *ex-post* errors – the *ex-post* or realised forward premium – is regressed onto a vector, X_t, of financial and macro variables available to market participants in period *t*. Using this approach, Piazzesi and Swanson (2008) find that excess returns on US interest rate futures can be predicted *ex ante* by cyclical macro and financial indicators. Piazzesi and Swanson suggest a number of possible reasons why cyclical indicators may be important, including the fact that investors' risk aversion may vary with the business cycle.

We repeated the same basic approach for our data set. Following Piazzesi and Swanson, who find that non-farm payrolls do particularly well in predicting excess returns, we began by looking at the association between realised forward premia and employment growth, which should be negatively related to realised premia if they are countercyclical. Although we take care to adjust for the publication lags in the data, the UK Labour Force Survey series of employment growth we use (see Chart 4) has been subject to revision over the past and we were unable to construct a real-time series going back over our sample. However, using GDP data, where a richer data set is available, we were able instead to construct a real-time measure of the output gap. Although the GDP data are quarterly, they are sometimes revised significantly in subsequent months, and we had access to the backrun of GDP monthly vintages going back to 1993.[12] For each monthly vintage of quarterly GDP, we ran a Hodrick-Prescott filter to detrend the data and then constructed an output gap series based on the last observation of each series, which refers to the real-time estimate of the previous quarter's output gap. The resulting time series is shown in Chart 4. If term premia are countercyclical, we would expect the sign on the output gap coefficient to be negative.[13]

We also examined the relationship between realised forward premia and several financial indicators, which have been found to be linked to term premia in previous work. So we considered the relationship between forward premia and implied volatility on three-month sterling futures, which we expect to have a positive association, as higher implied volatilities are likely to be associated with greater interest rate uncertainty. We also considered the relationship between realised forward premia and the slope of the yield curve, measured here by the spread between the two-year instantaneous forward rate from the GLC and the current policy rate. A lot of previous literature suggests that the slope of the yield curve is positively related to term premia (see eg Fama and Bliss

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[12] Given the publication cycle of the United Kingdom's Office for National Statistics, the first estimate of quarterly GDP becomes available in the first month of the following quarter.
[13] We also tried including the squared output gap as an additional regressor to allow forward premia to be more/less sensitive to the output gap at larger absolute values. The squared terms were sometimes statistically significant but there was no consistent pattern in the results, so we do not report them here.

(1987)). One possible rationalisation for this could be that risk aversion is countercyclical, which would be consistent with the yield curve being upward/downward sloping in downturns/upturns, other things being equal.

Results

Results for the regressions are shown in Tables G and H. For conciseness, given the high correlation between the different instruments/curves, we only present results for the GLC for the full sample and the adjusted BLC over the Bank of England independence sample (these results are very similar to the results using the GLC over the same period) using monthly frequency data for four different forecast horizons (6, 12, 18 and 24 months ahead).

Table G shows results for regressions that include a constant term and each of our macro/financial indicators as regressors. The first set of results shows the results from a simple regression on a constant, which provides a measure of the average forward term premium (assuming that expectations are rational and forecasting errors average out to zero). As we might have expected, these premia estimates increase with horizon and are statistically significant for the most part. What is at first sight surprising is the relatively large size of these forward premia (eg over 90 basis points for two–year forward rates) and the fact that they do not appear to have fallen after the Bank of England gained independence in May 1997. However, it needs to be remembered that realised forward premia will reflect policy rate forecasting errors, as well as genuine term premia. And to the extent that agents made either persistent negative or positive forecast errors over the period, this will be reflected in the average estimates we get. If, as seems possible, policy rates over the more recent sample period turned out to be systematically lower on average than agents were expecting then this will be reflected in higher measured average *ex-post* forward premia.

The results from including employment growth (EMP) as a regressor are shown in the second regression. These results are rather inconclusive, in contrast to Piazzesi and Swanson's findings for the United States. The sign on employment growth is only negative at shorter horizons and statistically insignificant. Moreover, the explanatory power of the equation is negligible. Truncating the sample does not change these results. As already stated, however, our data on employment growth were not available to investors in real time, so the third regression shows the impact of regressing our realised forward premia measures onto our real-time output gap measure (YGAP). Although it is often statistically significant over the full sample (but not over the shorter post-1997 sample), the results are again rather disappointing in that the output gap has a positive rather than a negative sign (suggesting counterintuitively that forward premia are procyclical rather than countercyclical).

The fourth and fifth set of regressions show the relationship with our financial indicators: implied volatility (Imp Vol) and the yield curve slope (Yld Slope). Over the full sample, the sign on implied volatility is positive across all horizons, as we would expect, and statistically significant at most horizons. Moreover, the explanatory power of the regressions reaches 20% at some horizons. But over the shorter sample back to May 1997, the coefficient on implied volatility becomes statistically insignificant though remaining positive and the explanatory power of the regression is negligible. The regressions showing the relationship with the slope of the yield curve are perhaps the most successful. The sign on the yield curve slope is positive in almost all cases, as expected, and the coefficients are statistically significant at the longer horizons. The explanatory power of this regression peaks at 40% at the two-year horizon over the full sample, but this falls to less than 20% over the post-May 1997 period.

Table H repeats the same regressions when the own forward rate is also included as an additional regressor, as Piazzesi and Swanson do. As the first regression shows, the forward rate has a positive statistically significant coefficient across almost all horizons, and appears to have a lot of explanatory power for realised forward premia. At longer horizons, the equation can explain 50% or more of the variation in the *ex-post* forward premium over both sample periods.

If we now add employment growth to the specification, it remains statistically insignificant over the full sample period back to October 1992. But over the sample since May 1997, employment growth now has a statistically significant negative coefficient over all horizons and an adjusted R squared of over 60% at the two-year horizon. If instead we combine the own forward rate with the output gap, the latter now has the correct negative sign over both samples, although it tends to be statistically insignificant. The fourth set of regressions shows that implied volatilities are statistically insignificant and often wrongly signed in the regression with forward rates. Again perhaps the most successful regressions are those including the slope of the yield curve, which remains positively signed for the most part and statistically significant at the longer horizons. Over the longer sample, the regression with the yield curve slope and forward rate explains over 50% of the variation in the realised forward premium 24 months ahead, and this increases to over 70% over the shorter sample.

Assessment

Of course, all these estimates are reduced-form and based on a relatively short sample of data and, possibly as a direct consequence, most of the results seem very sensitive to the precise specification, forward horizon and sample period we examine. Indeed, CUSUM tests (unreported) reveal instability in almost all the regression equations over the sample period back to 1992. On the face of it, we do not find strong evidence that our regression model estimates of forward premia are countercyclical. The macro business cycle measures we include are only statistically significant and negatively signed when forward rates are included in the regressions and we restrict the sample to post-1997. It is possible, of course, that this reflects a small sample problem rather than a lack of cyclicality. Put another way, it may just be that the United Kingdom has not seen enough business cycle variation over the sample we examine.

The most remarkable feature of the results is the importance of the current forward rate in the regressions. This might indicate that forward premia are related to the level of expected interest rates or it might indicate that at longer horizons most of the variation observed in forward rates comes from variations in forward premia. However, the high persistence of the forward rate itself may caution us against taking the statistical results and particularly the estimated standard errors at face value. Nevertheless, these results are interesting and seem in spirit with the findings of both Cochrane and Piazzesi (2005) and Piazzesi and Swanson (2008).

Another interesting finding is the explanatory power of the slope of the yield curve, which has a positive statistically significant coefficient in almost all the sets of regressions we have estimated, with or without the inclusion of the own forward rate. This result is in line with many other previous studies, where the yield curve slope has been found to predict bond and other asset returns.

By way of summary, Chart 5 plots the resulting forward premia estimates for 12 and 24-month horizons estimated over the inflation targeting sample period as a whole and over the sample of Bank independence for all the models (with the exception of the employment growth regression since the latter is not strictly a real-time measure). The predicted values from these regressions show considerable differences for a given sample/forecast horizon when the forward rate is excluded (which otherwise dominates the macro and financial indicators) and are clearly sensitive to the choice of sample period and forecast horizon, suggesting model instability.

4.2 Survey and affine model term premia estimates

We now turn to a comparison of the implied forward term premia from our preferred regression models (the yield curve slope model and the yield curve slope/forward rate model both estimated over the full sample) with premia calculated from surveys and from an affine term structure model. Both have advantages and disadvantages relative to the regression method.

Survey-based measures of term premia have the advantage that they are not affected by expectational errors, nor do they assume rationality. Of course, if the survey data completely captured the policy rate expectations of those setting market prices, we would not have any reason to question the resulting term premia estimates, but this is unlikely to be the case. The survey-based measure of forward term premia we use is constructed using survey data from Consensus Economics,[14] who ask around 20 financial market economists every month for their expectations of three-month Libor rates three and twelve months ahead (see Peacock (2004)).[15] To construct survey-based forward premia, we have deducted these survey expectations from the corresponding Libor forward rate. Since the survey asks about Libor, which contains credit risk, it needs to be borne in mind that the survey responses are not strictly comparable with policy rate expectations, and of course it is not clear how representative this poll is of those setting market interest rates.[16]

The affine term structure model estimates we use are based on a joint model of the UK nominal and real yield curves. The model uses a no-arbitrage essentially affine framework (after Duffee (2002)), incorporating latent factors, inflation and inflation survey information (further details are set out in Appendix D) and is estimated by maximum likelihood using the Kalman filter. The main advantage of using term premia estimates from an affine model is that they are constructed in a theoretically consistent way, which ensures that it is not possible to make risk-free profits. One disadvantage of the approach is that the resulting term premia estimates are not truly *ex-ante* measures, since the estimation method uses full sample information (although since we use the *ex-ante* filter, the estimates do have a recursive element); another is that these models have a large number of free parameters and are typically estimated over relatively short samples, which can lead to overfitting.

A comparison

Chart 6 shows the forward premia estimates from our preferred regression models with survey and affine term structure model-based estimates for three and twelve months ahead and with the affine model estimates only for 24 months ahead.[17] Examining the chart shows that the longer horizon premia measures fell quite closely together at around the time the Bank of England was granted operational independence in setting interest rates in May 1997. But after 1997 the measures move less closely together. In particular, the affine model premia estimates are much less volatile.[18] Interestingly, the survey-based measure moves quite closely with the regression-based model

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[14] Reuters carry out a survey of City economists on their policy rate expectations, but this survey is only available on a consistent basis back to the late 1990s, which has led to us excluding it from our empirical analysis. However, it is regularly reported in briefing to the Bank of England's Monetary Policy Committee.
[15] Peacock (2004) finds that he cannot reject the hypothesis that the Consensus interest rate expectations are rational.
[16] It also needs to be borne in mind that the surveys are necessarily compiled over several days rather than at a particular point in time and that there is always an issue about how much incentive respondents have to give their true expectations.
[17] We have tried to match the time period and tenor as closely as possible, but since the survey dates are usually in the beginning to the middle of the month, it is not possible to match them precisely.
[18] It may be relevant that the affine term structure model was constructed with the aim of fitting medium to long-term maturities and that the shortest maturity spot rate used to estimate the model was a one-year rate.

estimates over this period. One clear feature of the results is that the correlation of these different forward premia estimates increases with the length of the forward horizon. For example, for three months ahead the affine model measure has a correlation of 0.064 with the survey-based measure, -0.38 with the yield curve slope model and 0.20 with the yield curve slope/forward rate model, but at 12 months these correlations rise to 0.73, 0.71 and 0.41 respectively. At 24 months ahead, the correlation between the affine model and the regression model measures increases to 0.71 and 0.87.

It is also interesting to ask to what extent these alternative term premia measures are themselves predictable using macro and financial information available *ex ante*. Tables I and J therefore report regressions of the survey and affine model-based premia onto the same macro and financial indicators used earlier to explain the realised forward premia. The results for the survey-based term premia throw up several interesting results. The first is that the average size of the survey-based premia estimates is much smaller than the average for *ex-post* premia. Not surprisingly, they increase moving from the three to twelve-month horizon and they are also much lower over the post Bank independence sample, so the twelve-month forward premium according to our results was on average 11 basis points over the sample since May 1997. Another interesting finding is that these estimates tend to be more consistently countercyclical than those using realised forward premia over the period since May 1997, in that the coefficients on the real-time measure of the output gap are negative and statistically significant for most of the model specifications. Turning to the two financial indicators, the relationship between the survey-based forward premia measures and implied interest rate volatility tends to be statistically insignificant, and again it remains striking that it is the regressions containing the slope of the yield curve that have the highest explanatory power. Over the sample since October 1992, the yield curve slope on its own explains as much as 50% of the variation in the survey-based twelve-month forward term premium.

The results from the regressions on a constant in Table J show that the affine model term premia estimates are larger than the survey-based measures, but share the same property of increasing with horizon and being lower after May 1997. The employment growth regressions suggest the affine measures are countercyclical over the full sample period, but not in the period since May 1997. But the output gap regressions provide no evidence of countercyclical premia; indeed overall the results suggest the opposite (though the coefficients tend to be statistically insignificant). Turning to the financial indicators, the affine model measures are positively related to both interest rate implied volatility and to the slope of the yield curve. Again the regressions on the yield curve slope are the most successful, in terms of explanatory power. Over the full sample, the 12 and 24-month term premia regressions containing the yield curve slope on its own have adjusted R squared statistics of a little under 50%, though the relationship with the yield curve slope is weaker over the more recent sample since May 1997.

Assessment

The different term premia measures we have looked at all behave in slightly different ways, though it is reassuring that the correlation between them tends to increase with the length of the forward horizon. The extent to which these measures correlate with macro and financial indicators also varies significantly. There is some evidence that the survey-based premia estimates are more consistently countercyclical than the other measures, at least on the post-May 1997 sample (the relationships are unstable back to 1992). This may reflect the fact that the survey-based measures are not distorted by forecast errors, although another potential factor may be the fact that since they relate to Libor rate expectations they may also embody credit premia, which we might expect to be countercyclical.

It is difficult to infer from this analysis which measures should be preferred. The survey-based measures have the advantage of being *ex-ante* measures, but it remains unclear how representative they are of expectations of market participants and, regardless of the virtues of using a measure which is unaffected by forecast errors, the limited availability of survey expectations in terms of frequency and forecast horizons, means that we need to consider other measures.

5 Term premia-adjusted measures of expected monetary policy

In this section we turn to consider how unadjusted forward rates compare with various risk-adjusted measures calculated using the forward premia estimates discussed in Section 4. To do this, we first consider a couple of recent episodes (September 1999 and August 2004) where our risk-adjusted measures give different implications for monetary policy expectations. We then ask how our risk-adjusted measures would have performed in real time. Although our regression-based models of forward premia run off real-time data, the regressions themselves were estimated using data over the full sample period. To make a truly real-time comparison, we re-estimate the models sequentially using only data available in each period and then compare the resulting forecasts with policy rate outturns, in order to evaluate which methods would have provided the most reliable predictions.

5.1 How important is it to adjust for term premia?

The left-hand-side chart in the first panel of Chart 7 shows several market forward rates (GC repo, adjusted BLC and GLC) at the end of September 1999. All the unadjusted curves show a sharp rise in forward rates out to two years, reaching nearly 7% on the adjusted BLC measure. The left-hand-side chart on the second row shows market forward rates at the end of August 2004, when rates (we now know) had peaked at 4.75% and forward curves were only very slightly upward sloping, with most market forward rates (SONIA swaps, GC repo and adjusted BLC) rising from just below to just over 5% two years ahead. Interestingly, the GLC in this period lay below the other forward curves by a small but persistent wedge, which partly explains the switch to using the adjusted BLC for the Bank's *Inflation Report* forecast around this time.

The charts in the right-hand-side panel show corresponding risk-adjusted forward rates derived from the regression model containing the yield curve slope and own forward rate and from the affine term structure model. We also show the actual outturn of policy rates. On both occasions it is evident that the adjusted measures would have implied a much lower profile for monetary policy expectations and, moreover, a profile which was more closely in line with subsequent policy rate outturns.

In Chart 8 we extend this analysis by plotting the same term premia-adjusted measures for horizons of 3, 12 and 24 months ahead against subsequent policy rate outturns. There are often sizable differences between the risk-adjusted measures and the unadjusted forward rates (from the adjusted BLC), but it is also evident that there can at times be significant differences between the risk-adjusted measures themselves.

5.2 Real-time measures of policy rate expectations

An important issue for policy-makers is how reliable these risk-adjusted measures of market rates are in real time. Although the regression-based model is derived by regressing realised forward premia onto information available in real time, the coefficient estimates themselves are based on full sample information. Similarly, although there is a recursive element to the estimation method we use,[19] our affine model is estimated using yields and inflation data over the full sample period and so its forecasts for future policy rates are not strictly out-of-sample forecasts.

To judge the importance of this, we estimated the yield curve slope and the yield curve slope/forward rate regression models both recursively and using a rolling window method. The recursive estimates were derived starting with three years of data and then extending the sample one month at a time. The rolling window estimates involved estimating the same models using a 36-month window, which was then rolled forward one month at a time. The sequential term premia estimates derived from each set of estimates was then used to calculate corresponding risk-adjusted forward rates. We then calculated the RMSE statistics from these models and compared them with results using unadjusted forward rate predictions, survey predictions, risk-adjusted forward rates using a constant

[19] We use the filtered estimates of the state vector rather than the smoothed estimates.

risk premium model, and a simple random walk. The results are shown in Table K for various common sample periods.

We first note that there is no consistent picture across maturities as to which measure gives the best out-of-sample forecast of policy rates. The yield curve slope regression model (with no forward rate and estimated recursively) provided the best policy rate predictions out of sample over a couple of sample periods, but on some occasions the unadjusted forward rate or a simple random walk would have produced better forecasts than any of the model-based measures. Of course, these results are based on short samples and we are assuming that market expectations are more closely approximated by the method which produces predictions that lie closest to policy rate outturns, but nevertheless these results seem to suggest we should be cautious about using model-based methods in real time to forecast policy rate outturns. So while it obviously makes sense to examine different techniques that attempt to adjust market rates for term premia, the sensitivity of the resulting paths of implied monetary policy expectations to the method used to produce them suggests it is prudent not to rely exclusively on any one particular method. One interesting area for further research would be to examine the properties of different methods of combining the information in different term premia measures.

6 Conclusions

This paper reviews the main instruments and associated yield curves that can be used to measure financial market expectations of future UK policy rates. We evaluated these instruments and curves in terms of their ability to forecast Bank Rate over the period from October 1992, when the United Kingdom first adopted an explicit inflation, to March 2007. The main result was that forward interest rates derived from instruments or curves that were less likely to embody significant credit or liquidity premia, or that had been adjusted to take account of such premia, tended to provide more reliable forecasts of future Bank Rate. But beyond that finding, it proved difficult to discriminate between the various instruments and curves. This may not be that surprising if the forces of arbitrage work efficiently, so that expectations are consistently reflected in different financial market instruments. We did, however, find some evidence that the restrictions of the expectations hypothesis were not accepted at horizons of a year and beyond, which could be consistent with the existence of time-varying term premia.

We then examined several ways of estimating forward term premia, including regressing realised forward premia onto macroeconomic and financial information available to investors in real time. We found some evidence that these realised premia were predictable, but the results proved very sensitive to the precise specification, horizon and sample period being examined. We compared these regression-based term premia estimates with other common ways of measuring term premia using survey expectations and an affine dynamic term structure model. Different models were sometimes found to provide a quite different picture of the level of term premia. There was slightly stronger evidence that our survey-based premia estimates were countercyclical (possibly reflecting the role of forecasting errors in distorting the other measures), but this relationship was limited to the period since 1997 and did not hold in the full sample back to 1992. Finally, we examined how important it was to adjust for term premia in inferring interest rate expectations from market forward rates. Out-of-sample comparisons suggested no consistent pattern: sometimes either the unadjusted forward rates themselves or a random walk would have been superior to using a regression-based method to adjust market forward rates for term premia.

Given the uncertainties involved, it would not seem prudent to rely on any single method for measuring monetary policy expectations from financial market instruments. Rather the best approach seems to be to take an inclusive approach, using a variety of methods and information. This provides some support for the convention of conditioning the Bank of England *Inflation Report* forecast projections on a market profile of unadjusted forward interest rates, rather than using any one particular method to adjust mechanically for term premia. But this remains an active area of research at the Bank and elsewhere and it is conceivable that further research may change this conclusion.

Appendix A: Tables

Table A – Monthly frequency forecast regressions; sample from October 1992 to March 2007 (where available)

Forward rate measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No. of observations
T-bill	0	-0.052	(2.23)	0.608	(5.95)	0.365	0.795	0.000	171
GC repo	0	-0.044	(2.31)	0.877	(8.56)	0.641	0.596	0.233	118
	3	-0.079	(1.44)	1.009	(7.84)	0.599	0.630	0.947	115
	6	-0.131	(1.05)	0.739	(4.48)	0.390	0.777	0.117	90
	9	-0.186	(0.87)	0.620	(2.70)	0.248	0.862	0.101	87
Libor	0	-0.199	(6.18)	0.626	(7.24)	0.366	0.794	0.000	171
	3	-0.323	(5.08)	0.842	(8.91)	0.577	0.648	0.096	168
	6	-0.372	(3.57)	0.795	(6.74)	0.507	0.700	0.084	165
	9	-0.426	(2.66)	0.685	(5.20)	0.372	0.790	0.018	162
SONIA Swaps	0	-0.050	(2.53)	0.774	(7.85)	0.623	0.611	0.024	90
	3	-0.108	(1.94)	0.821	(7.29)	0.557	0.662	0.115	87
	6	-0.163	(1.23)	0.768	(3.78)	0.398	0.770	0.259	67
	9	-0.176	(0.87)	0.829	(2.67)	0.304	0.828	0.583	64
GLC	0	-0.019	(1.21)	0.805	(9.65)	0.650	0.589	0.021	115
	3	-0.023	(0.44)	0.939	(7.62)	0.548	0.669	0.620	112
	6	-0.139	(1.58)	0.862	(8.00)	0.529	0.684	0.202	152
	9	-0.262	(1.79)	0.695	(4.93)	0.398	0.774	0.032	161
	12	-0.329	(1.68)	0.562	(3.55)	0.274	0.849	0.007	159
	15	-0.371	(1.61)	0.473	(2.87)	0.213	0.884	0.002	156
	18	-0.399	(1.55)	0.415	(2.66)	0.185	0.900	0.000	153
	21	-0.433	(1.56)	0.394	(2.82)	0.193	0.895	0.000	150
	24	-0.491	(1.69)	0.409	(3.40)	0.244	0.867	0.000	147
BLC	0	-0.204	(6.15)	0.670	(7.42)	0.387	0.781	0.000	171
	3	-0.319	(5.08)	0.843	(8.87)	0.585	0.642	0.099	168
	6	-0.381	(3.66)	0.793	(6.81)	0.511	0.697	0.078	165
	9	-0.451	(2.78)	0.702	(5.06)	0.385	0.782	0.033	162
	12	-0.493	(2.21)	0.573	(3.72)	0.257	0.859	0.006	159
	15	-0.516	(1.90)	0.476	(2.87)	0.188	0.898	0.002	156
	18	-0.529	(1.70)	0.407	(2.49)	0.149	0.919	0.000	153
	21	-0.553	(1.64)	0.374	(2.56)	0.140	0.924	0.000	150
	24	-0.618	(1.78)	0.385	(3.28)	0.168	0.909	0.000	147
Adjusted BLC	0	-0.035	(1.83)	0.854	(8.48)	0.604	0.627	0.151	118
	3	-0.073	(1.38)	0.995	(8.58)	0.609	0.623	0.965	115
	6	-0.177	(1.65)	0.936	(7.24)	0.504	0.701	0.624	112
	9	-0.270	(1.63)	0.875	(5.31)	0.409	0.765	0.449	109
	12	-0.387	(1.72)	0.718	(3.75)	0.288	0.840	0.143	106
	15	-0.498	(1.83)	0.588	(3.14)	0.215	0.882	0.030	103
	18	-0.600	(1.97)	0.493	(3.33)	0.172	0.906	0.001	100
	21	-0.669	(2.06)	0.432	(3.23)	0.140	0.923	0.000	97
	24	-0.716	(2.15)	0.420	(2.48)	0.138	0.923	0.001	94

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table B – Monthly frequency forecast regressions; sample from May 1997 to March 2007 (where available)

Forward rate measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No. of observations
T-bill	0	-0.108	(3.09)	0.815	(6.21)	0.443	0.743	0.140	116
GC repo	0	-0.043	(2.28)	0.880	(8.29)	0.636	0.601	0.261	116
	3	-0.084	(1.55)	0.981	(7.57)	0.581	0.645	0.882	113
	6	-0.131	(1.05)	0.739	(4.48)	0.390	0.777	0.117	90
	9	-0.186	(0.87)	0.620	(2.70)	0.248	0.862	0.101	87
Libor	0	-0.185	(4.99)	0.665	(7.22)	0.425	0.755	0.000	116
	3	-0.321	(3.68)	0.919	(6.83)	0.521	0.689	0.550	113
	6	-0.416	(2.96)	0.942	(5.82)	0.444	0.742	0.718	110
	9	-0.488	(2.37)	0.776	(4.54)	0.326	0.817	0.194	107
SONIA Swaps	0	-0.050	(2.53)	0.774	(7.85)	0.623	0.611	0.024	90
	3	-0.108	(1.94)	0.821	(7.29)	0.557	0.662	0.115	87
	6	-0.163	(1.23)	0.768	(3.78)	0.398	0.770	0.259	67
	9	-0.176	(0.87)	0.829	(2.67)	0.304	0.828	0.583	64
GLC	0	-0.018	(1.20)	0.802	(9.47)	0.646	0.593	0.021	113
	3	-0.031	(0.60)	0.907	(7.40)	0.526	0.685	0.448	110
	6	-0.112	(1.04)	0.902	(5.89)	0.466	0.727	0.523	109
	9	-0.214	(1.26)	0.830	(4.66)	0.386	0.780	0.340	107
	12	-0.320	(1.43)	0.702	(3.68)	0.275	0.847	0.121	104
	15	-0.425	(1.57)	0.564	(3.25)	0.189	0.896	0.014	101
	18	-0.511	(1.67)	0.476	(3.26)	0.143	0.921	0.001	98
	21	-0.566	(1.74)	0.455	(2.77)	0.140	0.923	0.001	95
	24	-0.606	(1.80)	0.484	(2.28)	0.174	0.904	0.017	92
BLC	0	-0.188	(4.91)	0.699	(7.12)	0.443	0.743	0.003	116
	3	-0.320	(3.70)	0.929	(6.71)	0.528	0.684	0.607	113
	6	-0.416	(2.97)	0.907	(5.95)	0.443	0.743	0.545	110
	9	-0.511	(2.44)	0.815	(4.50)	0.340	0.809	0.306	107
	12	-0.582	(2.15)	0.648	(3.35)	0.223	0.877	0.071	104
	15	-0.652	(2.05)	0.508	(2.83)	0.152	0.916	0.007	101
	18	-0.720	(2.12)	0.428	(2.92)	0.116	0.935	0.000	98
	21	-0.764	(2.23)	0.388	(2.70)	0.098	0.945	0.000	95
	24	-0.803	(2.40)	0.381	(2.11)	0.098	0.944	0.001	92
Adjusted BLC	0	-0.035	(1.82)	0.852	(8.29)	0.597	0.632	0.152	116
	3	-0.079	(1.49)	0.968	(8.31)	0.590	0.638	0.787	113
	6	-0.185	(1.72)	0.909	(7.10)	0.483	0.715	0.479	110
	9	-0.279	(1.68)	0.849	(5.18)	0.388	0.778	0.357	107
	12	-0.398	(1.76)	0.685	(3.71)	0.266	0.853	0.091	104
	15	-0.512	(1.85)	0.551	(3.20)	0.193	0.894	0.011	101
	18	-0.607	(1.95)	0.476	(3.34)	0.158	0.913	0.000	98
	21	-0.666	(2.03)	0.440	(3.08)	0.141	0.922	0.000	95
	24	-0.709	(2.11)	0.438	(2.42)	0.147	0.919	0.003	92

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table C – Monthly frequency forecast regressions; common sample periods across forecast horizons

Forward rate measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No. of observations
T-bill	0	-0.079	(3.38)	0.767	(7.45)	0.552	0.666	0.026	90
GC repo	0	-0.025	(1.56)	0.821	(8.78)	0.668	0.573	0.059	90
	3	-0.073	(1.33)	0.842	(7.31)	0.527	0.684	0.174	87
	6	-0.149	(1.13)	0.815	(3.82)	0.412	0.761	0.388	67
	9	-0.202	(0.94)	0.696	(2.40)	0.286	0.838	0.300	64
Libor	0	-0.149	(4.93)	0.683	(7.28)	0.635	0.601	0.001	90
	3	-0.232	(3.25)	0.761	(7.24)	0.532	0.680	0.026	87
	6	-0.285	(1.85)	0.797	(3.67)	0.385	0.778	0.354	67
	9	-0.317	(1.30)	0.649	(2.28)	0.258	0.854	0.222	64
SONIA Swaps	0	-0.050	(2.53)	0.774	(7.85)	0.623	0.611	0.024	90
	3	-0.108	(1.94)	0.821	(7.29)	0.557	0.662	0.115	87
	6	-0.163	(1.23)	0.768	(3.78)	0.398	0.770	0.259	67
	9	-0.176	(0.87)	0.829	(2.67)	0.304	0.828	0.583	64
GLC	0	-0.006	(0.41)	0.757	(9.03)	0.676	0.566	0.005	89
	3	-0.027	(0.50)	0.788	(7.05)	0.497	0.705	0.062	86
	6	-0.069	(0.51)	0.747	(3.40)	0.363	0.792	0.254	67
	9	-0.121	(0.56)	0.639	(2.06)	0.234	0.868	0.249	64
	12	-0.308	(1.39)	0.733	(3.79)	0.301	0.832	0.171	106
	15	-0.409	(1.55)	0.607	(3.25)	0.217	0.880	0.037	103
	18	-0.504	(1.68)	0.494	(3.38)	0.160	0.912	0.001	100
	21	-0.573	(1.77)	0.439	(2.89)	0.137	0.924	0.000	97
	24	-0.619	(1.85)	0.454	(2.27)	0.160	0.911	0.008	94
BLC	0	-0.150	(4.91)	0.709	(7.50)	0.637	0.599	0.003	90
	3	-0.231	(3.25)	0.767	(7.04)	0.531	0.681	0.035	87
	6	-0.279	(1.83)	0.776	(3.63)	0.381	0.781	0.300	67
	9	-0.327	(1.30)	0.647	(2.20)	0.242	0.864	0.235	64
	12	-0.580	(2.15)	0.683	(3.41)	0.245	0.865	0.117	106
	15	-0.650	(2.06)	0.549	(2.81)	0.174	0.904	0.023	103
	18	-0.719	(2.12)	0.448	(2.91)	0.129	0.928	0.001	100
	21	-0.764	(2.23)	0.381	(2.85)	0.097	0.945	0.000	97
	24	-0.804	(2.40)	0.363	(2.20)	0.092	0.948	0.000	94
Adjusted BLC	0	-0.018	(1.05)	0.795	(8.45)	0.612	0.620	0.032	90
	3	-0.067	(1.25)	0.847	(7.63)	0.536	0.677	0.173	87
	6	-0.139	(1.07)	0.787	(3.83)	0.410	0.762	0.304	67
	9	-0.202	(0.94)	0.697	(2.41)	0.288	0.837	0.299	64
	12	-0.387	(1.72)	0.718	(3.75)	0.288	0.840	0.143	106
	15	-0.498	(1.83)	0.588	(3.14)	0.215	0.882	0.030	103
	18	-0.600	(1.97)	0.493	(3.33)	0.172	0.906	0.001	100
	21	-0.669	(2.06)	0.432	(3.23)	0.140	0.923	0.000	97
	24	-0.716	(2.15)	0.420	(2.48)	0.138	0.923	0.001	94

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table D – Quarterly frequency forecast regressions; sample from 1992 Q4 to 2007 Q1 (where available)

Forward rate Measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No. of observations
T-bill	0	-0.029	(1.11)	0.236	(2.37)	0.059	0.961	0.000	57
GC repo	0	-0.034	(1.72)	0.768	(6.71)	0.572	0.646	0.049	40
	3	-0.079	(1.51)	0.988	(7.41)	0.614	0.614	0.929	40
	6	-0.121	(0.85)	0.693	(3.52)	0.294	0.826	0.130	31
	9	-0.171	(0.76)	0.654	(2.43)	0.222	0.867	0.210	30
Libor	0	-0.112	(2.52)	0.348	(1.85)	0.105	0.938	0.001	57
	3	-0.274	(3.86)	0.726	(5.91)	0.439	0.743	0.030	57
	6	-0.337	(3.00)	0.735	(5.17)	0.424	0.752	0.068	56
	9	-0.380	(2.23)	0.638	(4.15)	0.304	0.826	0.022	55
SONIA swaps	0	-0.048	(2.15)	0.564	(3.86)	0.539	0.665	0.007	25
	3	-0.122	(2.06)	0.826	(7.09)	0.528	0.672	0.149	25
	6	-0.188	(1.37)	0.814	(3.79)	0.389	0.764	0.394	24
	9	-0.253	(1.01)	0.689	(2.07)	0.207	0.870	0.361	23
Futures	3	-0.284	(4.23)	0.785	(6.81)	0.486	0.710	0.068	57
	6	-0.336	(3.04)	0.720	(5.51)	0.410	0.761	0.036	56
	9	-0.396	(2.27)	0.631	(4.23)	0.297	0.831	0.017	55
	12	-0.435	(1.80)	0.520	(3.02)	0.188	0.893	0.007	54
	15	-0.450	(1.56)	0.432	(2.30)	0.136	0.921	0.004	53
	18	-0.456	(1.38)	0.368	(1.92)	0.106	0.936	0.002	52
	21	-0.487	(1.35)	0.344	(1.97)	0.104	0.937	0.000	51
	24	-0.573	(1.53)	0.372	(2.61)	0.140	0.918	0.000	50
GLC	0	-0.015	(0.87)	0.754	(7.36)	0.613	0.614	0.021	39
	3	-0.050	(0.91)	0.946	(6.08)	0.556	0.658	0.733	39
	6	-0.139	(1.45)	0.825	(5.68)	0.433	0.745	0.233	52
	9	-0.230	(1.50)	0.661	(4.09)	0.319	0.818	0.041	55
	12	-0.282	(1.40)	0.523	(2.96)	0.211	0.880	0.009	54
	15	-0.319	(1.36)	0.444	(2.38)	0.168	0.904	0.004	53
	18	-0.343	(1.31)	0.389	(2.18)	0.146	0.915	0.001	52
	21	-0.379	(1.32)	0.371	(2.35)	0.158	0.908	0.000	51
	24	-0.440	(1.45)	0.389	(2.89)	0.206	0.882	0.000	50
BLC	0	-0.114	(2.43)	0.359	(1.78)	0.104	0.938	0.002	57
	3	-0.282	(3.98)	0.760	(6.40)	0.462	0.727	0.048	57
	6	-0.339	(2.98)	0.729	(5.12)	0.417	0.756	0.063	56
	9	-0.395	(2.26)	0.636	(4.02)	0.300	0.829	0.025	55
	12	-0.427	(1.83)	0.517	(2.99)	0.193	0.890	0.007	54
	15	-0.457	(1.61)	0.445	(2.31)	0.148	0.914	0.006	53
	18	-0.467	(1.44)	0.382	(1.99)	0.117	0.930	0.002	52
	21	-0.490	(1.38)	0.350	(2.06)	0.111	0.934	0.000	51
	24	-0.561	(1.52)	0.366	(2.73)	0.140	0.918	0.000	50
Adjusted BLC	0	-0.026	(1.24)	0.721	(5.91)	0.495	0.702	0.028	40
	3	-0.065	(1.18)	0.978	(7.46)	0.567	0.650	0.864	40
	6	-0.150	(1.36)	0.915	(6.21)	0.449	0.732	0.566	39
	9	-0.234	(1.41)	0.864	(4.60)	0.357	0.791	0.472	38
	12	-0.335	(1.50)	0.705	(3.30)	0.238	0.861	0.176	37
	15	-0.435	(1.63)	0.599	(2.76)	0.184	0.890	0.073	36
	18	-0.523	(1.72)	0.492	(2.85)	0.138	0.915	0.006	35
	21	-0.599	(1.82)	0.410	(3.53)	0.103	0.933	0.000	34
	24	-0.659	(1.94)	0.411	(3.15)	0.107	0.930	0.000	33

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table E – Quarterly frequency forecast regressions; sample from 1997 Q2 to 2007 Q1 (where available)

Forward rate Measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No of observations
T-bill	0	-0.052	(1.13)	0.362	(1.48)	0.112	0.930	0.013	39
GC repo	0	-0.036	(1.86)	0.756	(6.66)	0.567	0.649	0.038	39
	3	-0.087	(1.68)	0.953	(7.19)	0.597	0.627	0.724	39
	6	-0.121	(0.85)	0.693	(3.52)	0.294	0.826	0.130	31
	9	-0.171	(0.76)	0.654	(2.43)	0.222	0.867	0.210	30
Libor	0	-0.153	(4.01)	0.566	(4.59)	0.360	0.789	0.001	39
	3	-0.310	(3.48)	0.915	(5.59)	0.514	0.688	0.605	39
	6	-0.397	(2.85)	0.931	(5.60)	0.398	0.766	0.681	38
	9	-0.464	(2.27)	0.805	(4.14)	0.294	0.828	0.324	37
SONIA Swaps	0	-0.048	(2.15)	0.564	(3.86)	0.539	0.665	0.007	25
	3	-0.122	(2.06)	0.826	(7.09)	0.528	0.672	0.149	25
	6	-0.188	(1.37)	0.814	(3.79)	0.389	0.764	0.394	24
	9	-0.253	(1.01)	0.689	(2.07)	0.207	0.870	0.361	23
Futures	3	-0.296	(3.47)	0.890	(6.13)	0.485	0.708	0.455	39
	6	-0.377	(2.72)	0.861	(5.58)	0.376	0.779	0.373	38
	9	-0.469	(2.20)	0.780	(4.17)	0.271	0.842	0.246	37
	12	-0.537	(1.87)	0.629	(2.80)	0.162	0.902	0.109	36
	15	-0.587	(1.76)	0.481	(2.30)	0.102	0.934	0.018	35
	18	-0.641	(1.78)	0.391	(2.20)	0.068	0.951	0.002	34
	21	-0.694	(1.91)	0.361	(2.47)	0.057	0.956	0.000	33
	24	-0.760	(2.16)	0.388	(2.45)	0.072	0.947	0.001	32
GLC	0	-0.017	(0.97)	0.758	(7.38)	0.618	0.610	0.024	38
	3	-0.057	(1.03)	0.964	(6.09)	0.564	0.651	0.822	38
	6	-0.119	(1.04)	0.905	(4.73)	0.410	0.758	0.623	37
	9	-0.193	(1.09)	0.838	(3.90)	0.323	0.811	0.455	37
	12	-0.275	(1.19)	0.692	(3.04)	0.209	0.877	0.186	36
	15	-0.370	(1.36)	0.564	(2.77)	0.141	0.913	0.040	35
	18	-0.453	(1.47)	0.462	(3.02)	0.096	0.936	0.001	34
	21	-0.512	(1.55)	0.448	(3.28)	0.100	0.934	0.000	33
	24	-0.557	(1.64)	0.504	(2.64)	0.146	0.909	0.015	32
BLC	0	-0.157	(4.05)	0.587	(4.70)	0.365	0.786	0.002	39
	3	-0.315	(3.46)	0.925	(5.84)	0.502	0.697	0.637	39
	6	-0.398	(2.82)	0.916	(5.35)	0.404	0.761	0.628	38
	9	-0.480	(2.28)	0.811	(4.03)	0.290	0.831	0.354	37
	12	-0.529	(1.91)	0.628	(2.92)	0.172	0.897	0.092	36
	15	-0.595	(1.82)	0.503	(2.42)	0.117	0.926	0.023	35
	18	-0.644	(1.80)	0.400	(2.31)	0.074	0.947	0.002	34
	21	-0.688	(1.91)	0.357	(2.58)	0.058	0.955	0.000	33
	24	-0.743	(2.13)	0.375	(2.53)	0.069	0.949	0.000	32
Adjusted BLC	0	-0.028	(1.38)	0.709	(5.89)	0.489	0.705	0.021	39
	3	-0.076	(1.41)	0.940	(7.41)	0.556	0.657	0.641	39
	6	-0.165	(1.49)	0.876	(6.18)	0.430	0.745	0.389	38
	9	-0.250	(1.50)	0.823	(4.48)	0.331	0.806	0.342	37
	12	-0.354	(1.56)	0.662	(3.28)	0.212	0.875	0.102	36
	15	-0.459	(1.66)	0.547	(2.88)	0.158	0.904	0.023	35
	18	-0.541	(1.72)	0.454	(2.97)	0.115	0.926	0.001	34
	21	-0.599	(1.79)	0.411	(3.34)	0.098	0.935	0.000	33
	24	-0.650	(1.89)	0.431	(2.97)	0.115	0.926	0.001	32

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table F – Quarterly frequency forecast regressions; common sample periods across forecast horizons

Forward rate Measure	Horizon (months)	α_k		β_k		R bar squared	Relative RMSE	Pvalue $H_o : \beta_k = 1$	No. of observations
T-bill	0	-0.084	(2.80)	0.667	(4.47)	0.436	0.735	0.036	25
GC repo	0	-0.044	(2.29)	0.741	(6.12)	0.600	0.619	0.043	25
	3	-0.090	(1.51)	0.844	(6.32)	0.516	0.681	0.255	25
	6	-0.161	(1.12)	0.790	(3.35)	0.343	0.793	0.382	24
	9	-0.207	(0.89)	0.727	(2.25)	0.254	0.844	0.408	23
Libor	0	-0.148	(4.03)	0.720	(5.53)	0.605	0.615	0.042	25
	3	-0.231	(3.06)	0.821	(5.74)	0.463	0.717	0.223	25
	6	-0.294	(1.76)	0.783	(3.29)	0.316	0.809	0.373	24
	9	-0.332	(1.22)	0.682	(2.08)	0.207	0.870	0.344	23
SONIA swaps	0	-0.048	(2.15)	0.564	(3.86)	0.539	0.665	0.007	25
	3	-0.122	(2.06)	0.826	(7.09)	0.528	0.672	0.149	25
	6	-0.188	(1.37)	0.814	(3.79)	0.389	0.764	0.394	24
	9	-0.253	(1.01)	0.689	(2.07)	0.207	0.870	0.361	23
Futures	3	-0.217	(3.42)	0.813	(6.26)	0.476	0.708	0.164	25
	6	-0.268	(1.84)	0.755	(3.44)	0.321	0.806	0.276	24
	9	-0.317	(1.20)	0.650	(2.04)	0.187	0.881	0.286	23
	12	-0.534	(1.87)	0.679	(2.88)	0.188	0.888	0.182	37
	15	-0.581	(1.76)	0.540	(2.31)	0.129	0.920	0.057	36
	18	-0.636	(1.79)	0.434	(2.19)	0.089	0.940	0.008	35
	21	-0.694	(1.92)	0.362	(2.56)	0.062	0.954	0.000	34
	24	-0.761	(2.15)	0.368	(2.61)	0.067	0.951	0.000	33
GLC	0	-0.024	(1.74)	0.740	(6.95)	0.729	0.509	0.023	25
	3	-0.042	(0.67)	0.790	(6.59)	0.476	0.709	0.093	25
	6	-0.079	(0.54)	0.722	(3.31)	0.304	0.816	0.215	24
	9	-0.119	(0.50)	0.650	(1.99)	0.192	0.878	0.298	23
	12	-0.256	(1.13)	0.740	(3.15)	0.242	0.858	0.276	37
	15	-0.343	(1.30)	0.630	(2.74)	0.180	0.893	0.117	36
	18	-0.432	(1.46)	0.511	(3.04)	0.127	0.920	0.006	35
	21	-0.517	(1.59)	0.438	(3.55)	0.103	0.933	0.000	34
	24	-0.575	(1.71)	0.464	(2.61)	0.131	0.918	0.005	33
BLC	0	-0.150	(4.09)	0.737	(5.75)	0.595	0.623	0.052	25
	3	-0.231	(3.09)	0.827	(5.85)	0.470	0.713	0.232	25
	6	-0.287	(1.73)	0.766	(3.25)	0.311	0.812	0.331	24
	9	-0.330	(1.17)	0.647	(1.95)	0.178	0.886	0.300	23
	12	-0.524	(1.91)	0.675	(2.96)	0.198	0.883	0.163	37
	15	-0.587	(1.83)	0.559	(2.38)	0.144	0.912	0.070	36
	18	-0.638	(1.82)	0.442	(2.27)	0.096	0.937	0.007	35
	21	-0.688	(1.92)	0.358	(2.68)	0.063	0.953	0.000	34
	24	-0.745	(2.13)	0.356	(2.73)	0.064	0.952	0.000	33
Adjusted BLC	0	-0.034	(1.86)	0.674	(6.05)	0.590	0.627	0.008	25
	3	-0.082	(1.39)	0.825	(6.63)	0.515	0.682	0.174	25
	6	-0.148	(1.05)	0.775	(3.48)	0.344	0.792	0.323	24
	9	-0.207	(0.88)	0.698	(2.17)	0.227	0.859	0.358	23
	12	-0.335	(1.50)	0.705	(3.30)	0.238	0.861	0.176	37
	15	-0.435	(1.63)	0.599	(2.76)	0.184	0.890	0.073	36
	18	-0.523	(1.72)	0.492	(2.85)	0.138	0.915	0.006	35
	21	-0.599	(1.82)	0.410	(3.53)	0.103	0.933	0.000	34
	24	-0.659	(1.94)	0.410	(3.15)	0.107	0.930	0.000	33

Relative RMSE = RMSE from prediction equation containing forward rate relative to RMSE from random walk.
T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table G – Realised forward (GLC) premia regressions, excluding forward rate

	October 1992 to March 2007				May 1997 to March 2007			
Horizon (months)	6	12	18	24	6	12	18	24
No. of Observations	150	157	151	145	108	102	96	90
C	0.145 (1.68)	0.496 (2.47)	0.756 (3.01)	0.946 (3.69)	0.191 (1.86)	0.448 (2.09)	0.769 (2.59)	0.934 (2.69)
C	0.163 (2.25)	0.569 (2.97)	0.739 (3.30)	0.888 (4.12)	0.414 (1.68)	0.576 (1.10)	0.122 (0.17)	0.194 (0.33)
EMP	-0.023 (0.48)	-0.090 (0.62)	0.021 (0.12)	0.073 (0.77)	-0.208 (1.09)	-0.116 (0.27)	0.589 (1.12)	0.672 (1.51)
R bar squared	-0.005	0.000	-0.006	-0.004	0.009	-0.008	0.025	0.032
C	0.115 (1.31)	0.369 (1.89)	0.568 (2.32)	0.779 (3.20)	0.188 (1.85)	0.447 (2.18)	0.775 (2.67)	0.963 (2.89)
YGAP	0.140 (1.49)	0.375 (1.70)	0.515 (2.09)	0.497 (2.54)	0.107 (0.53)	0.214 (0.70)	0.212 (0.89)	0.0319 (0.11)
R bar squared	0.051	0.131	0.165	0.157	0.005	0.012	0.005	-0.011
C	-0.166 (1.02)	-0.467 (1.26)	-0.409 (0.81)	-0.023 (0.04)	-0.140 (0.82)	0.214 (0.36)	0.485 (0.55)	0.384 (0.41)
Imp Vol	0.471 (2.22)	1.3920 (2.85)	0.649 (2.35)	1.342 (1.74)	0.594 (1.90)	0.399 (0.40)	0.495 (0.34)	0.982 (0.67)
R bar squared	0.080	0.196	0.173	0.110	0.033	-0.004	-0.004	0.007
C	0.137 (1.44)	0.358 (1.75)	0.492 (1.93)	0.593 (2.18)	0.181 (1.83)	0.438 (2.07)	0.765 (2.52)	0.944 (2.51)
Yld Slope	0.020 (0.28)	0.267 (1.96)	0.476 (3.03)	0.595 (4.91)	-0.078 (0.77)	0.079 (0.44)	0.378 (2.42)	0.502 (2.57)
R bar squared	-0.005	0.116	0.250	0.404	0.010	-0.002	0.111	0.185

T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table H – Realised forward (GLC) premia regressions, including forward rate

	October 1992 to March 2007				May 1997 to March 2007			
Horizon (months)	6	12	18	24	6	12	18	24
No. of Observations	150	157	151	145	108	102	96	90
C	-0.917	-2.145	-2.735	-2.526	-0.726	-2.031	-3.825	-4.661
	(2.51)	(3.39)	(3.67)	(3.52)	(1.55)	(2.76)	(7.35)	(5.66)
Fwd	0.202	0.464	0.587	0.565	0.181	0.476	0.852	1.015
	(2.82)	(4.23)	(5.06)	(5.56)	(1.87)	(3.45)	(7.99)	(5.77)
R bar squared	0.190	0.400	0.471	0.480	0.142	0.301	0.542	0.580
C	-0.898	-2.074	-2.859	-2.849	-0.671	-1.919	-3.859	-4.796
	(2.46)	(3.14)	(3.56)	(3.67)	(2.63)	(4.81)	(13.32)	(7.78)
Fwd	0.205	0.464	0.593	0.588	0.403	0.806	1.089	1.238
	(3.05)	(4.30)	(4.90)	(5.18)	(5.93)	(13.02)	(9.71)	(8.98)
EMP	-0.047	-0.086	0.109	0.231	-1.099	-1.662	-1.135	-0.992
	(0.74)	(0.73)	(0.76)	(1.79)	(3.49)	(5.11)	(3.01)	(3.99)
R bar squared	0.191	0.399	0.474	0.506	0.419	0.539	0.625	0.642
C	-1.009	-2.479	-3.028	-2.989	-0.978	-2.391	-4.200	-5.474
	(2.94)	(4.97)	(4.98)	(3.12)	(2.10)	(3.77)	(9.98)	(18.00)
Fwd	0.220	0.528	0.641	0.651	0.228	0.543	0.918	1.155
	(3.02)	(5.52)	(6.03)	(3.89)	(2.31)	(4.04)	(9.08)	(19.42)
YGAP	-0.040	-0.144	-0.140	-0.180	-0.145	-0.227	-0.286	-0.588
	(0.38)	(0.84)	(0.92)	(0.62)	(0.52)	(0.56)	(0.94)	(3.19)
R bar squared	0.182	0.393	0.463	0.484	0.149	0.311	0.560	0.667
C	-0.926	-2.121	-2.729	-2.534	-0.880	-1.924	-3.550	-4.516
	(2.75)	(3.49)	(3.62)	(3.51)	(1.99)	(2.88)	(5.85)	(5.89)
Fwd	0.176	0.407	0.572	0.615	0.167	0.489	0.893	1.032
	(2.22)	(2.87)	(3.46)	(4.33)	(1.74)	(3.06)	(6.79)	(5.36)
Imp Vol	0.216	0.436	0.115	-0.405	0.415	-0.311	-0.866	-0.405
	(1.11)	(0.99)	(0.20)	(0.80)	(1.26)	(0.33)	(0.83)	(0.54)
R bar squared	0.200	0.407	0.468	0.484	0.154	0.300	0.554	0.579
C	-0.927	-2.105	-2.428	-1.651	-0.724	-2.078	-3.732	-4.483
	(2.37)	(3.06)	(3.59)	(2.69)	(1.63)	(2.82)	(7.21)	(6.52)
Fwd	0.204	0.456	0.525	0.395	0.180	0.486	0.836	0.982
	(2.59)	(3.71)	(4.79)	(4.13)	(1.94)	(3.42)	(8.27)	(6.68)
Yld Slope	-0.015	0.017	0.108	0.288	-0.002	0.145	0.363	0.425
	(0.24)	(0.18)	(0.85)	(2.64)	(0.02)	(1.00)	(2.93)	(2.88)
R bar squared	0.185	0.393	0.476	0.529	0.134	0.318	0.646	0.715

T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method.

Table I – Survey model term premia regressions

	October 1992 to March 2007			May 1997 to March 2007			
	Without fwd rate		With forward rate	Without fwd rate		With fwd rate	
Horizon (months)	3	12	12	3	12	3	12
C	0.0771 (1.79)	0.2145 (2.72)	-0.878 (2.60)	0.029 (0.81)	0.115 (1.80)	0.098 (0.81	-0.371 (0.93)
Fwd			0.196 (2.67)			-0.013 (0.57	0.096 (1.13)
R bar squared			0.265			-0.004	0.062
C	0.102 (2.00)	0.211 (1.95)	-0.846 (2.33)	0.154 (0.95)	0.053 (0.75)	0.097 (0.81)	-0.378 (1.13)
Fwd			0.200 (2.77)			-0.016 (0.35)	0.178 (2.49)
EMP	-0.027 (0.81)	0.004 (0.05)	-0.057 (0.46)	-0.037 (0.23)	-0.022 (0.24)	-0.050 (0.59)	-0.382 (2.40)
R bar squared	-0.002	-0.006	0.266	-0.007	-0.007	-0.014	0.127
C	0.056 (1.73)	0.165 (2.20)	-1.268 (3.25)	0.100 (1.85)	0.099 (1.84)	-0.210 (1.13	-0.984 (3.07)
Fwd			0.274 (3.76)			0.046 (1.28)	0.212 (3.64)
YGAP	0.069 (1.04)	0.165 (1.22)	-0.151 (1.54)	-0.227 (2.41)	-0.115 (2.60)	-0.174 (2.56)	-0.422 (4.51)
R bar squared	0.051	0.08	0.290	0.110	0.090	0.107	0.363
C	-0.131 (1.01)	-0.283 (1.45)	-0.860 (2.50)	0.029 (0.16)	0.106 (0.90)	0.135 (0.84)	-0.367 (0.87)
Fwd			0.164 (2.22)			-0.011 (0.48)	0.097 (1.16)
Imp Vol	0.331 (1.39)	0.792 (2.25)	0.256 (0.72)	0.164 (0.41)	-0.149 (0.57)	-0097 (0.37)	-0.017 (0.05
R bar squared	0.106	0.164	0.271	-0.003	0.008	-0.006	0.054
C	0.009 (0.37)	0.088 (1.53)	-0.339 (1.26)	0.118 (2.00)	0.035 (1.33)	-0.166 (1.31	-0.439 (1.15)
Fwd			0.080 (1.57)			0.041 (1.65)	0.110 (1.44)
Yld Slope	0.146 (6.03)	0.272 (4.93)	0.226 (4.28)	0 .186 (3.03)	0.141 (6.74)	0.165 (6.21)	0.195 (3.60)
R bar squared	0.465	0.502	0.494	0.180	0.369	0.381	0.280

T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method. For the sample October 1992 – March 2007 there are no results including the GLC forward rate, as no three-month forward GLC rates are available before 1997.

Table J – Affine model term premia regressions

	October 1992 to March 2007				May 1997 to March 2007					
	Without fwd rate		With fwd rate		Without fwd rate			With fwd rate		
Horizon (months)	12	24	12	24	3	12	24	3	12	24
C	0.572 (4.23)	0.842 (3.77)	-1.375 (5.91)	-2.326 (8.26)	0.191 (8.29)	0.234 (4.73)	0.276 (3.50)	0.010 (0.08)	-0.267 (0.94)	-0.864 (1.71)
Fwd			0.357 (7.86)	0.538 (11.01)				0.037 (1.45)	0.099 (1.68)	0.224 (2.18)
R bar squared			0.542	0.781				0.109	0.199	0.338
C	0.852 (8.61)	1.216 (7.22)	-1.116 (4.40)	-1.907 (6.69)	0.010 (0.13)	-0.081 (0.47)	-0.174 (0.63)	0.002 (0.02)	-0.264 (1.05)	-0.843 (1.80)
Fwd			0.357 (7.86)	0.509 (11.13)				0.003 (0.20)	0.061 (1.24)	0.195 (2.12)
EMP	-0.359 (5.28)	-0.464 (4.03)	-0.324 (7.63)	-0.309 (5.88)	0.172 (2.23)	0.298 (1.77)	0.425 (1.58)	0.165 (2.24)	0.178 (1.15)	0.122 (0.64)
R bar squared	0.248	0.175	0.722	0.857	0.234	0.198	0.185	0.227	0.236	0.342
C	0.495 (4.24)	0.678 (3.64)	-1.206 (2.24)	-2.465 (5.37)	0.197 (8.65)	0.244 (5.03)	0.290 (3.78)	0.108 (1.18)	-0.171 (0.75)	-0.755 (1.77)
Fwd			0.322 (2.89)	0.563 (6.19)				0.018 (0.95)	0.081 (1.76)	0.204 (2.36)
YGAP	0.330 (2.17)	0.538 (2.77)	0.050 (0.28)	-0.084 (0.52)	0.079 (1.44)	0.140 (1.22)	0.204 (1.15)	0.055 (1.03)	0.066 (0.80)	0.076 (0.70)
R bar squared	0.225	0.303	0.534	0.781	0.130	0.115	0.113	0.136	0.213	0.346
C	-0.293 (2.67)	-0.463 (2.54)	-1.267 (6.18)	-2.237 (7.86)	0.087 (1.56)	0.068 (0.55)	0.046 (0.24)	-0.051 (0.41)	-0.300 (1.10)	-0.876 (1.77)
Fwd			0.244 (4.17)	0.463 (7.07)				0.032 (1.28)	0.092 (1.44)	0.218 (1.95)
Imp Vol	1.336 (7.81)	1.968 (8.03)	0.790 (3.71)	0.532 (1.84)	0.199 (1.78)	0.316 (1.33)	0.435 (1.22)	0.161 (1.42)	0.136 (0.62)	0.080 (0.28)
R bar squared	0.483	0.473	0.644	0.799	0.076	0.057	0.051	0.155	0.204	0.334
C	0.443 (4.71)	0.597 (3.95)	-0.862 (4.20)	-1.994 (5.92)	0.192 (8.63)	0.239 (4.97)	0.281 (3.62)	-0.121 (0.96)	-0.296 (1.03)	-0.795 (1.49)
Fwd			0.247 (5.87)	0.472 (7.23)				0.064 (2.30)	0.106 (1.73)	0.211 (1.91)
Yld Slope	0.345 (6.30)	0.516 (6.78)	0.218 (6.20)	0.114 (1.87)	0.047 (2.60)	0.086 (2.59)	0.123 (2.56)	0.082 (4.16)	0.093 (3.46)	0.098 (2.35)
R bar squared	0.445	0.482	0.668	0.792	0.108	0.110	0.105	0.392	0.336	0.404

T-ratios shown in parentheses were calculated using standard errors corrected for heteroscedasticity and autocorrelation, using the Newey-West method. For the sample October 1992 – March 2007 there are no results including the GLC forward rate, as no three-month forward GLC rates are available before 1997.

Table K – Root mean square out-of-sample forecast error statistics

Horizon (months)	3	12		24	
Sample (data)	**2000:08-2006:09 (Adj BLC)**	**1996:10-2005:12 (GLC)**	**2001:03-2005:12 (Adj BLC)**	**1997:10-2004:12 (GLC)**	**2002:03-2004:12 (Adj BLC)**
Yield curve slope/ forward rate regression	0.256 [0.360]	1.082 [1.259]	0.796 [1.332]	1.472 [1.453]	1.172 [0.737]
Yield curve slope regression	0.618 [0.271]	0.626 [1.103]	0.856 [0.942]	1.200 [1.567]	1.883 [2.242]
Survey*	0.323	0.955	0.523	n.a.	n.a.
Forward Rate	0.228	0.893	0.653	1.206	0.667
Constant risk premia	0.227 [0.239]	0.938 [1.010]	0.861 [1.015]	1.229 [1.330]	1.243 [1.588]
Random Walk	0.360	1.085	0.220	1.253	0.603

n.a. = not available

* The Survey estimates of expected Libor rates were adjusted for credit premia using the gap between the BLC and adjusted BLC. Numbers in [] use a rolling regression window of 36 months rather than an accumulating window.

Appendix B: Charts

Chart 1 – Financial market instrument/yield curve forward rates against Bank rate

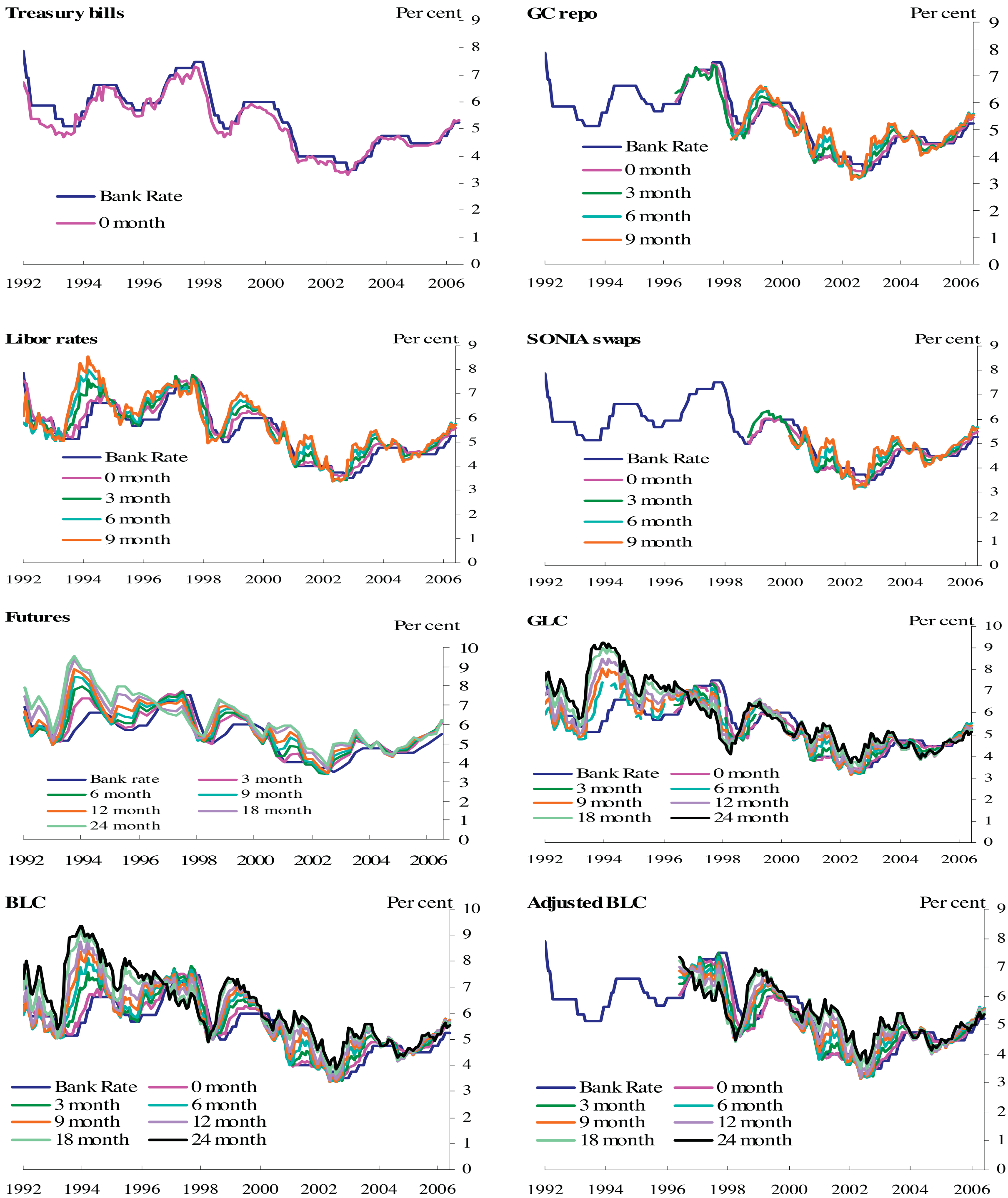
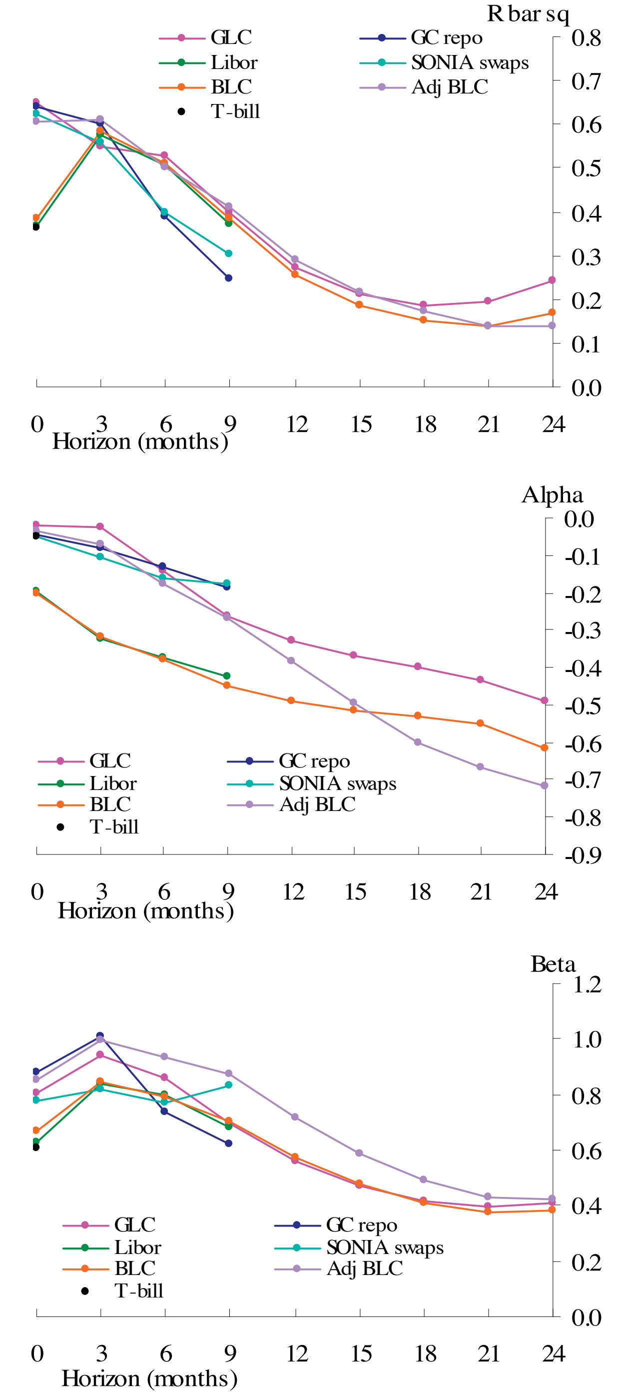


Chart 2 – Monthly frequency forecast regressions

Sample: October 1992 to March 2007 (where available)



Common samples for each horizon

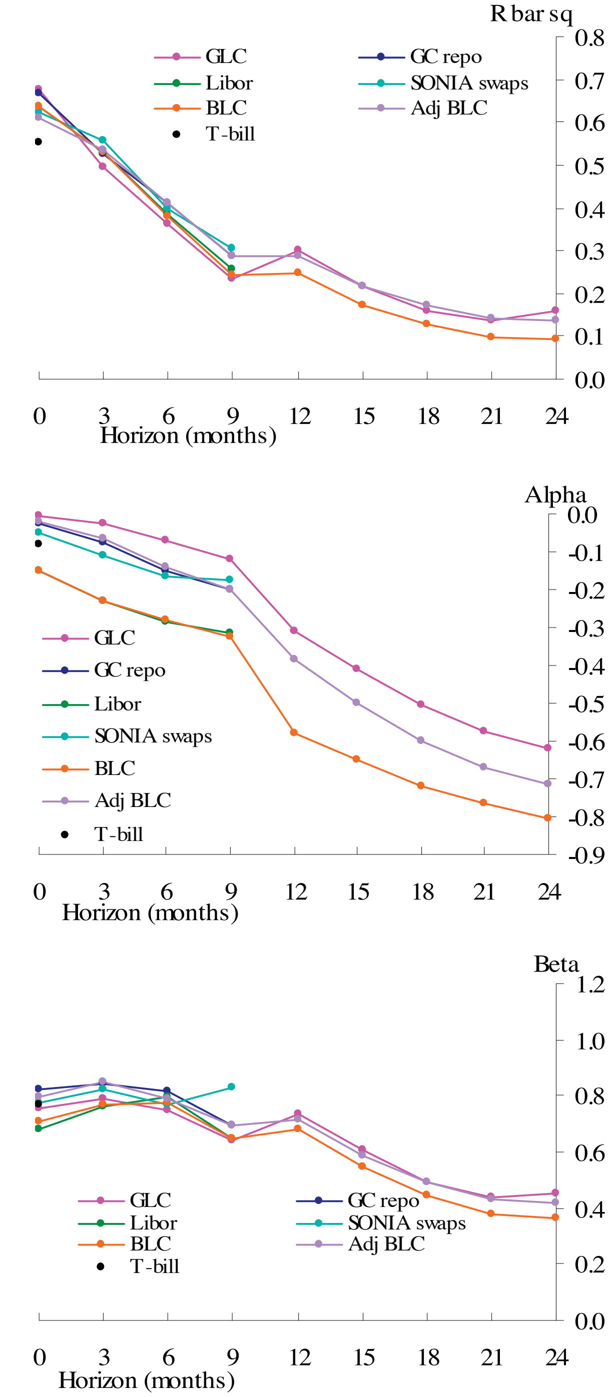
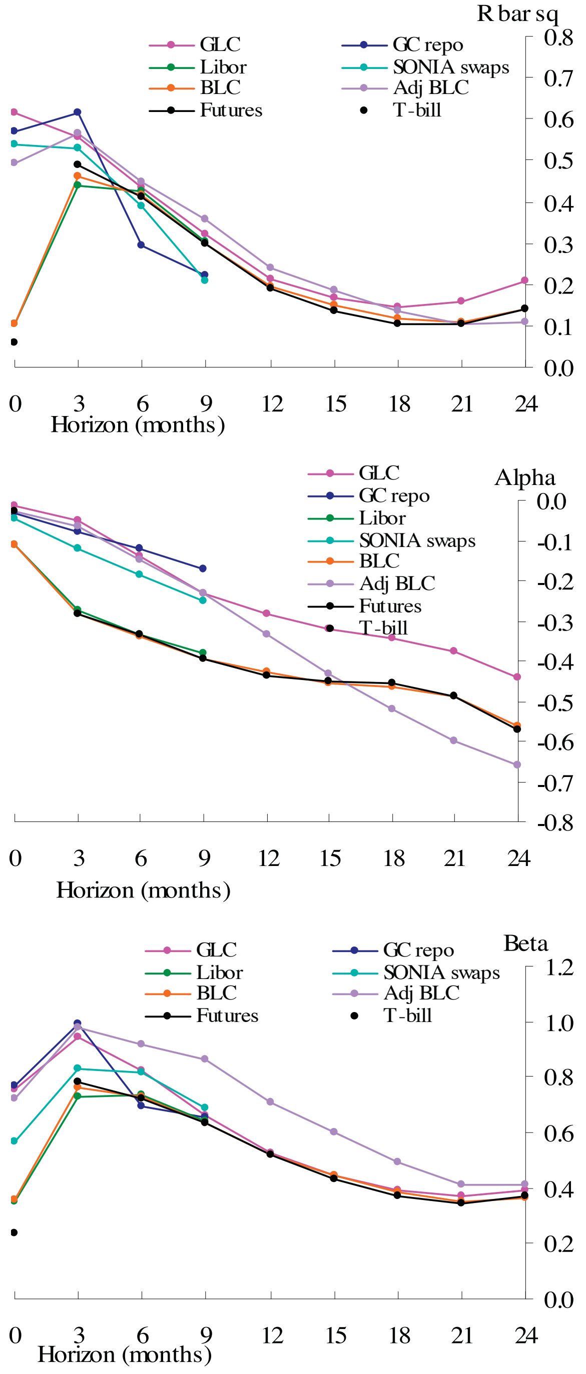


Chart 3 – Quarterly frequency forecast regressions

Sample: October 1992 to March 2007 (where available)



Common samples for each horizon

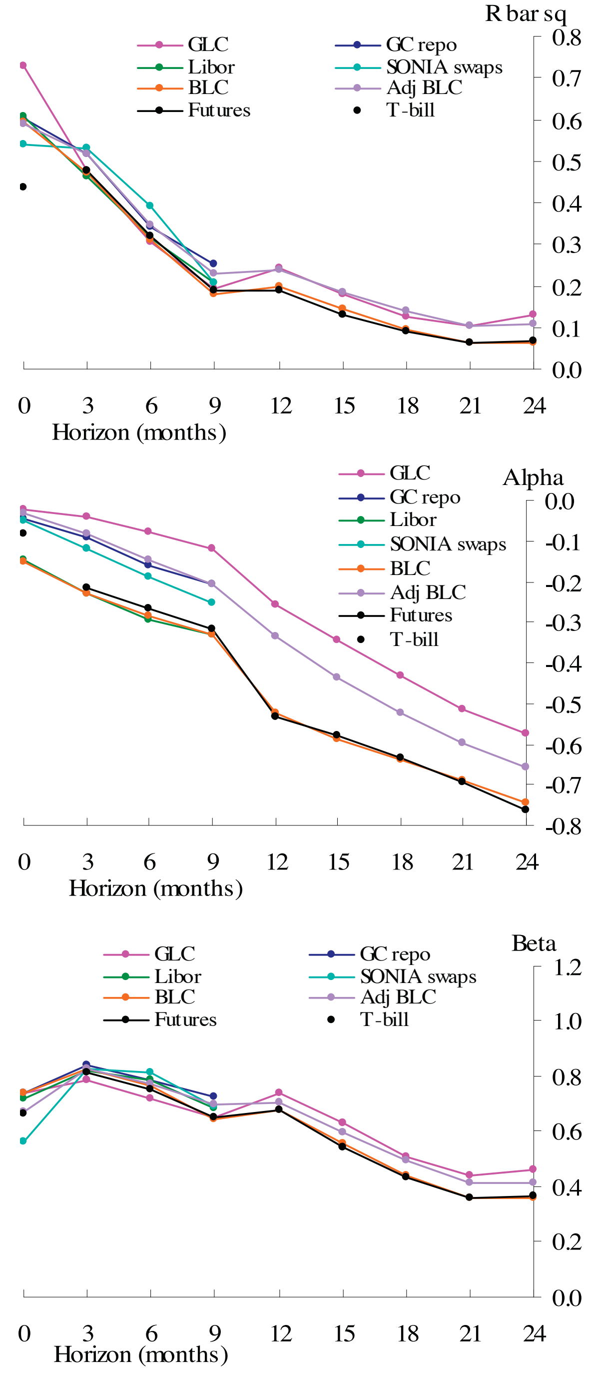


Chart 4 – Regressor variables included in realised forward premia regressions

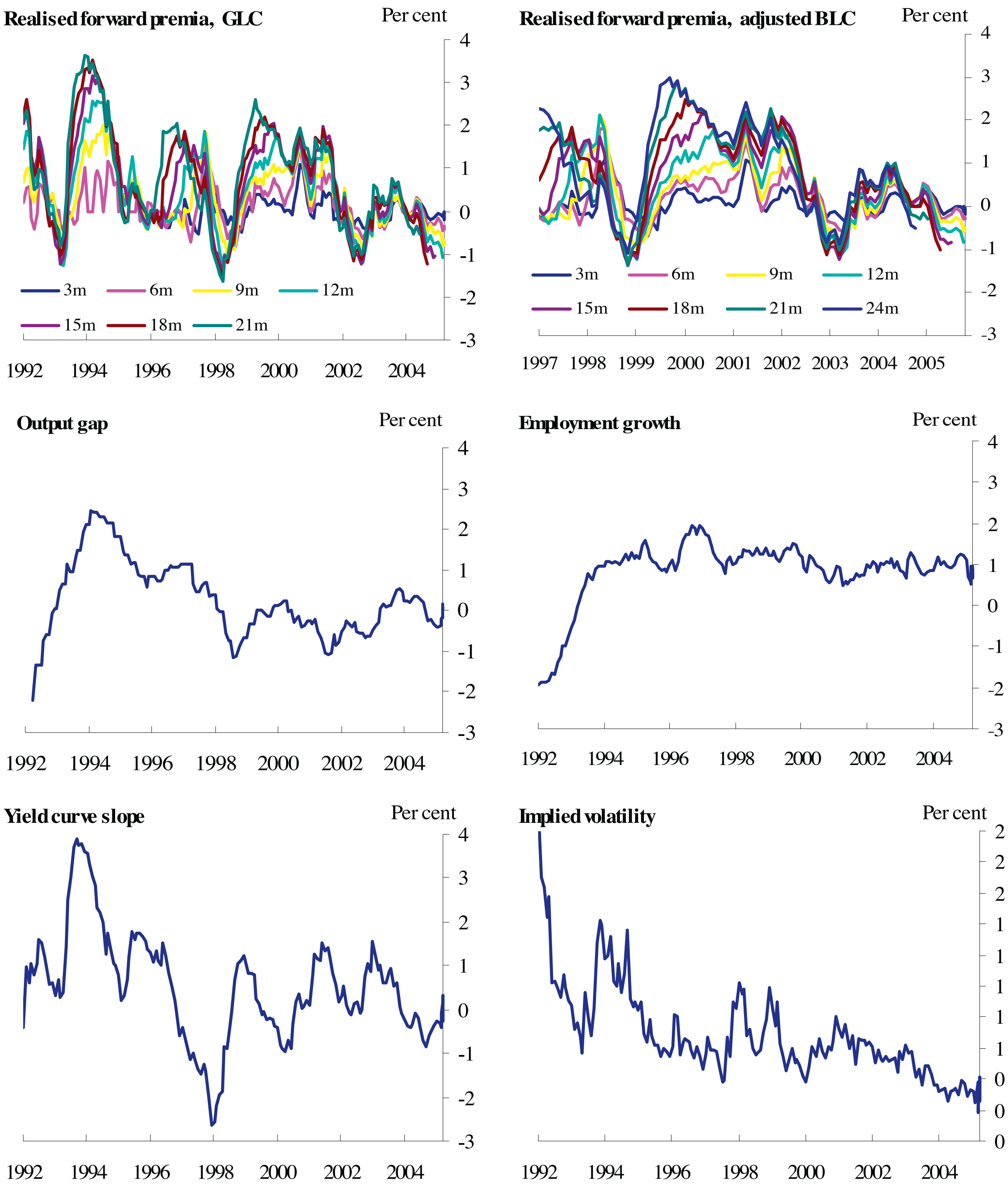


Chart 5 – Regression-based forward premia estimates

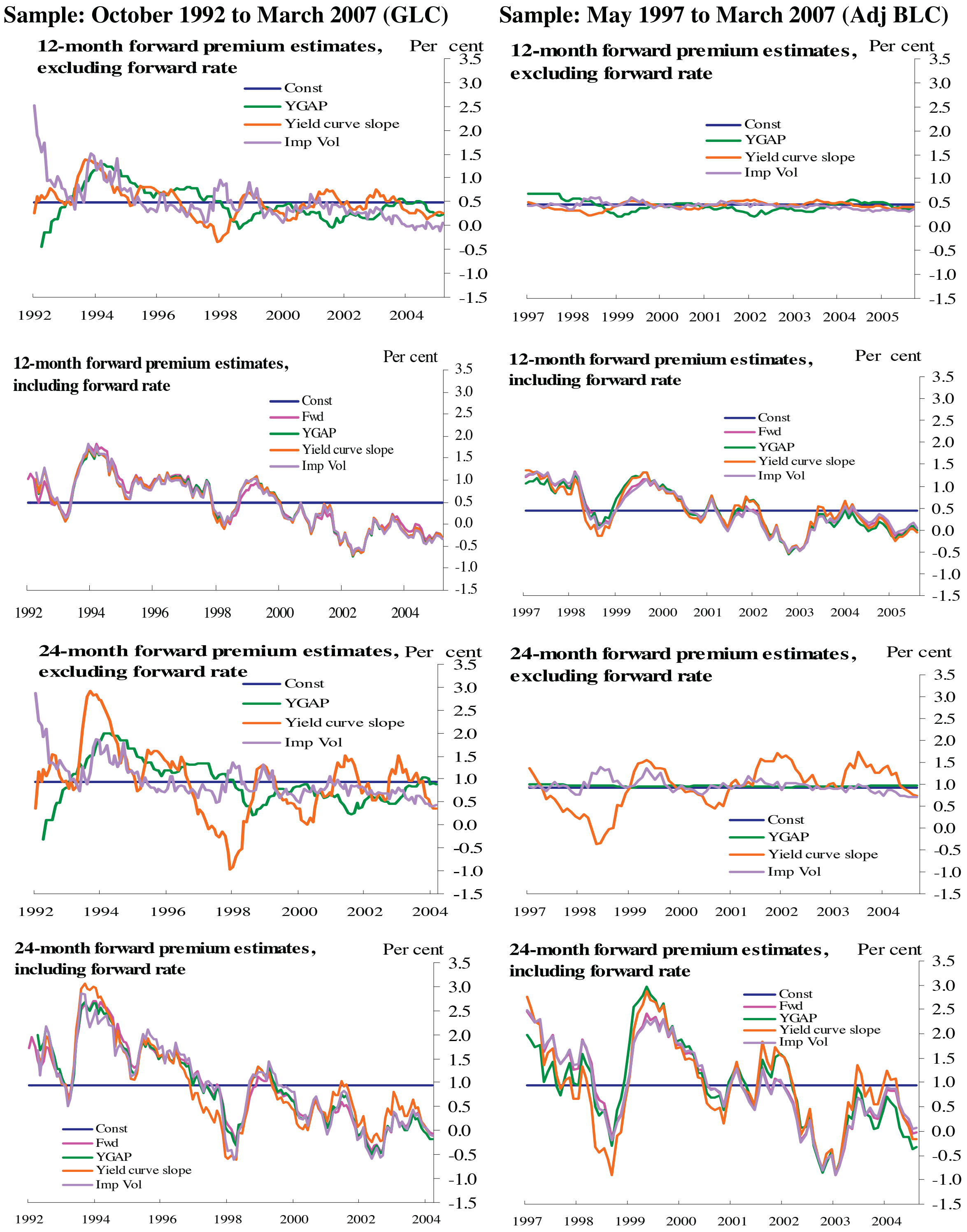


Chart 6 – Comparison of forward premia estimates based on regression, survey and affine models

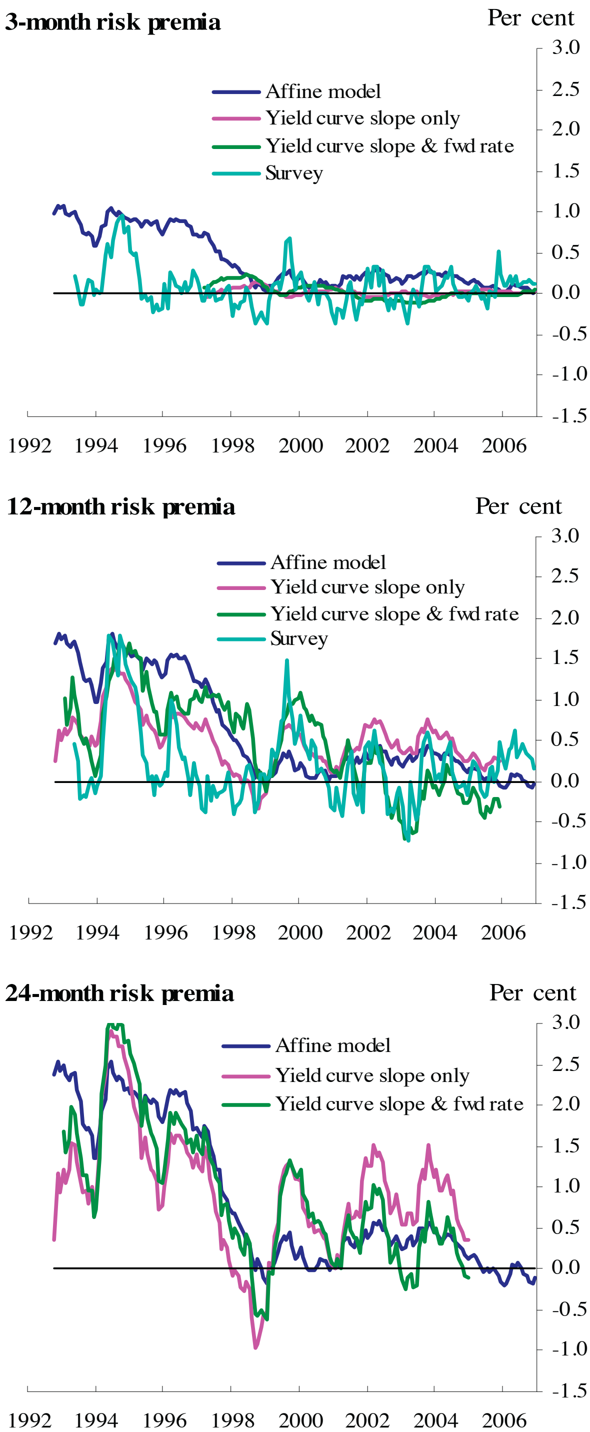


Chart 7 – Market forward curves and term premia-adjusted forward curves, September 1999 and August 2004

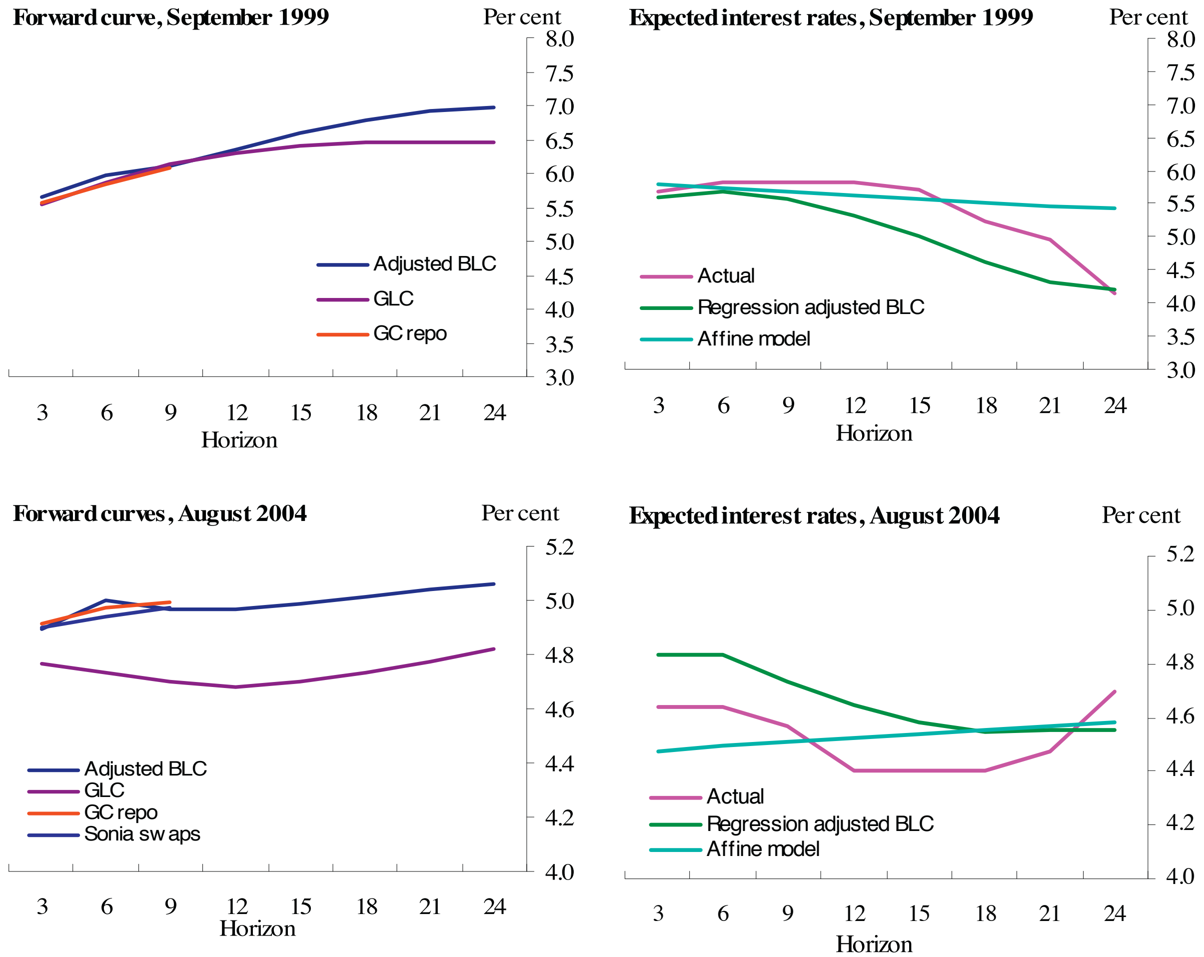
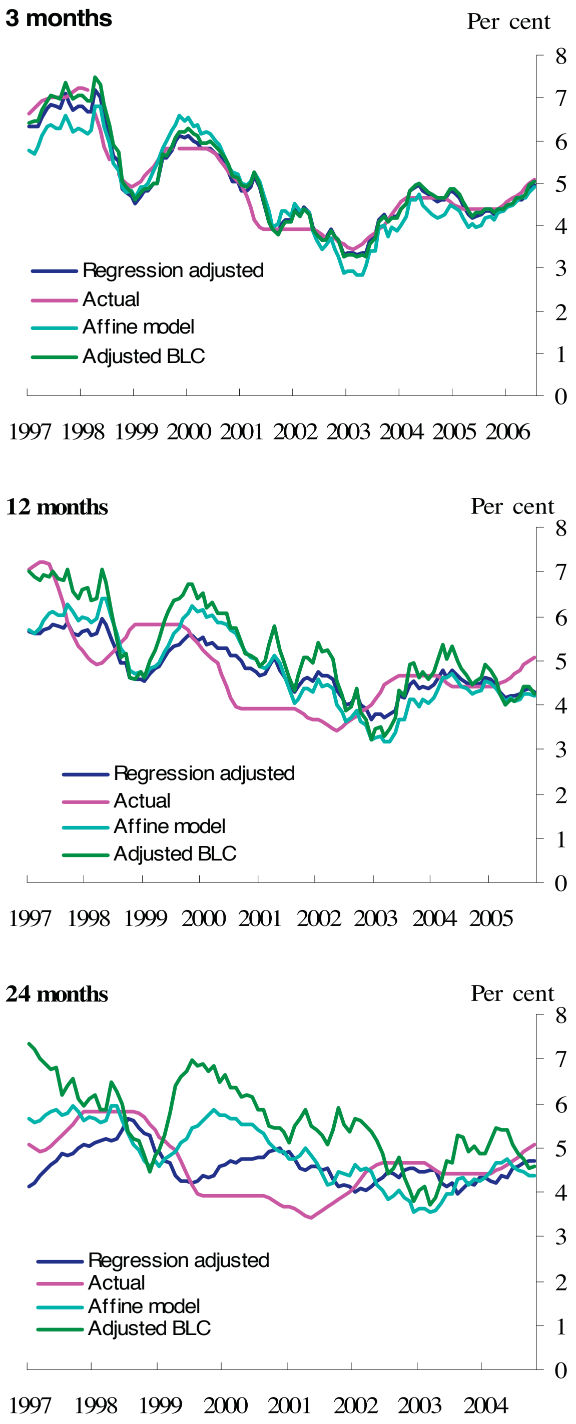


Chart 8 – Term premia-adjusted forward rates and Bank Rate outturns



Appendix C: Data description

The market instruments used differ in their quoting conventions, maturity and time to settlement.

Instrument	Compounding convention	Day count
Interbank loans	Investment (simple)	365
GC repo	Investment (simple)	365
SONIA swaps	Quoted as: investment (simple) Settle on: daily compounded	365
T-bills	Investment (simple)	365
Short sterling futures	Investment (simple)	365
Government liability curve	Continuous	365
Bank liability curve	Continuous	365
Adjusted bank liability curve	Continuous	365

To make the rates derived from the various market instruments comparable we convert all the rates to equivalent interest rates. These are expressed as 365-day daily compounded rates for comparison with policy rate outturns. The different compounding conventions can be expressed in equivalent terms as follows:

$$\frac{1}{1+\left(\frac{R_s}{100}\times\frac{T}{365}\right)}=\frac{1}{\left(1+\left(\frac{R_d}{100}\times\frac{1}{365}\right)\right)^{T}}=e^{\frac{-R_{cc}}{100}\times\frac{T}{365}}=DF_T$$

where R_s is a simple interest rate, R_d is a daily compounded rate and R_{cc} is continuously compounded; T represents the term or tenor of the rate in days; and DF_T is the discount factor, which is the present value of 1 unit in T days' time discounted by the relevant rate of interest.

Calculated discount factors for different maturities are then used to derive forward rates. The discount factor applying to period n is equal to the product of the discount factors for the preceding n-1 periods, ie. $DF_{T1}\times DF_{T2}=DF_{T3}$, where $T1 + T2 = T3$. So the forward discount factor $DF_{T2}=DF_{T3}\div DF_{T1}$.

As the table below shows, the available instruments trade at a range of maturities which dictates the horizons for which we can calculate forward rates.

Instrument	Forward horizon covered
Interbank loans	0-3 quarters
GC repo	0-3 quarters
SONIA swaps	0-3 quarters
T-bills	0 quarters
Short sterling futures	0-8 quarters
Government liability curve	0-8 quarters
Bank liability curve	0-8 quarters
Adjusted bank liability curve	0-8 quarters

A further complication arises from the differences in time to maturity of our various instruments depending on the day on which the rate is taken. For example, the term rates we use span a specific number of months (eg three, six, nine months), but the actual number of days can vary from 86 to 95 days. To account for this, we construct discount factors separately for each maturity and each instrument to exactly match the horizon spanned by that instrument.

Appendix D: Description of joint real-nominal affine term structure model

The joint real-nominal term structure model proposed by Joyce, Lildholdt and Sorensen (2008) belongs to the class of essentially affine models, where the market price of risk is linear in the factors. The theory behind the term structure model has two main elements. The first assumption is the absence of arbitrage, ie it is not possible to make a risk-free profit by combining real and nominal bonds. In the absence of arbitrage, the price of a real zero coupon bond with *n* periods to maturity is equal to the conditional expectation of the products of the future real stochastic discount factor (SDF).

$$P_t^{n,R} = E_t(M_{t+1}M_{t+2}..M_{t+n})$$

The price of a nominal zero-coupon bond with *n* periods to maturity is equal to the conditional expectation of the future nominal stochastic discount factor.

$$P_t^{n,N} = E_t\left(M_{t+1}M_{t+2}..M_{t+n}\frac{Q_t}{Q_{t+n}}\right) = E_t\left(\frac{Q_t M_{t+1}}{Q_{t+1}}\frac{Q_{t+1}M_{t+2}}{Q_{t+2}}..\frac{Q_{t+n-1}M_{t+n}}{Q_{t+n}}\right)$$

where Q_t is the current price level.

The second assumption is that the real SDF, which embodies attitudes towards risk, has a particular flexible form that allows for time-varying term premia, ie the conditional variance of the real SDF changes over time. The same (unique) real SDF prices both real and nominal bond yields. The log of the real SDF is given by

$$m_{t+1} = -(r^* + \gamma'(z_t - \mu)) - \frac{\Lambda_t' \Omega \Lambda_t}{2} - \Lambda_t' \Omega^{1/2}\varepsilon_{t+1}$$

Such a specification is standard in the essentially affine term structure literature: r^* is the long-run real interest rate; $(z_t - \mu)$ is an *(Nx1)* vector of factors driving the real SDF; ε_{t+1} is a vector of residuals to these factors; Ω is their covariance matrix; and Λ_t is an *(Nx1)* vector of risk prices. The market prices of risk are assumed to be linear in the *N* factors:

$$\Lambda_t = \begin{pmatrix}\lambda_1\\ \lambda_2\\ \lambda_3\\ \lambda_4\end{pmatrix} + \begin{pmatrix}\beta_{11} & \beta_{12} & \beta_{13} & \beta_{14}\\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24}\\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34}\\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44}\end{pmatrix}\begin{pmatrix}z_{1,t}-\mu_1\\ z_{2,t}-\mu_2\\ z_{3,t}-\mu_3\\ z_{4,t}-\mu_4\end{pmatrix}$$

The real SDF is equal to the deflated nominal SDF,

$$m_{t+1}^* = m_{t+1} - \pi_{t+1},$$

where $\pi_{t+1} = \ln(Q_{t+1}) - \ln(Q_t)$.

Combining the two assumptions, it is possible to obtain a recursive relationship between nominal and real bonds with different maturities. Yields on nominal and real yields become linear in the set of variables driving the real SDF and the model enables us to derive a theory-consistent breakdown of nominal forward interest rates into expected real rates, expected inflation and term premia.

Joyce *et al* (2008) assume that two (latent or unobservable) factors drive movements in expected risk-free real rates and that the same two factors and two additional ones (one RPI inflation, the other unobservable) drive real term premia and the nominal curve. There are just four factors driving the term structure of interest rates. Their model is estimated using real and nominal yields data from October 1992 when the United Kingdom adopted inflation targeting. To obtain a better identification of long-term inflation expectations and term premia, and to help alleviate small sample problems, they incorporate survey information on long-horizon inflation expectations.[20] The implicit assumption is that bond market expectations of inflation ten years ahead will be the same as those of professional economists on average over the sample.

[20] The motivation for including survey expectations in term structure models of this nature is explained in Kim and Orphanides (2005).

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