# Government bond market valuations in an era of dwindling supply

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## Abstract

This paper considers whether diminishing government bond supply has driven government bond prices above levels consistent with economic fundamentals. By assuming the swap market is unaffected by supply side considerations and by developing an expression for the fair value for the swap spread, we use swap spreads as a measure of the possible divergence between government yields and true risk-free rates. By investigating swap spreads across currencies and maturities, we find evidence that, in both the United Kingdom and the United States, government bond yields have been depressed below risk-free rates. Although this bias has corresponded with reductions in net issuance, it is difficult to identify a robust statistical relationship between issuance and the swap spread.

This paper also examines two specific issues which arise when government bonds cease to accurately reflect risk-free rates: (i) how policymakers should measure the risk-free term structure in the presence of distortions to the yield curve; and (ii) how bond market participants price non-government bonds in the absence of a risk-free benchmark.


## 1. Introduction

In the past two years there has been growing concern amongst market participants about the impact on government bond prices of the decreasing issuance of government securities by several of the G7 governments. This has been most pronounced in the United States, where the value of outstanding federal government debt held by the public has already declined from nearly 50% of GDP in the mid-1990s to 30.5% of GDP in 2001 and is forecast to fall to only 4.8% of GDP by 2011.[2] Reductions in the size of sovereign debt stocks are an important issue because government debt is central to the implementation of monetary policy and to fixed income markets more broadly. Government securities are the main asset class held by central banks, and are also used as benchmarks for monitoring risk-free interest rates and monetary conditions more generally, as well as providing pricing reference points and serving as hedging vehicles for other fixed income securities. Indeed, so widespread is the use of government securities and their derivatives that Friedman (1999) has claimed that "the entire risk management business as we know it today would have been impossible before the mid-1970s change in debt management policy [that re-enabled the US Treasury to issue long term debt]".[3]

Although the outstanding stock of government debt in the United Kingdom and the United States is still large, we will show that there is already some evidence that the falling net supply of government bonds in these countries has depressed their yields below "true" nominal risk-free rates and diminished their use as benchmarks. But while there has been a great deal of discussion of the impact on financial markets of reduced issuance and the corresponding depression of government bond yields, much of this has been in qualitative terms. This paper provides quantitative estimates of the size of these effects.

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[1] The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. The authors would like to thank Martin Brooke, Roger Clews, Mark Salmon and participants in the Study group on fixed income markets for helpful advice and comments. All errors are, of course, the authors'.

[2] See Congressional Budget Office (2001).

[3] In the mid-1970s the US Treasury was effectively banned from issuing long-term debt with coupons equal to current long-term interest rates by a legal prohibition on the issuance of Treasury securities with a coupon greater than 4.25%. As pointed out by Friedman, this meant that by the mid-1970s the mean maturity of US government debt was only 2.5 years.

In the United Kingdom there has been concern among the authorities for much of the postwar period that changes in the supply of government bonds affect gilt prices. Goodhart (1999) explains that the worry of the Bank of England was that an excessive supply of gilts would increase gilt market yields. Reflecting this concern, during the 1950s to 1970s the Bank acted in the gilt market to attempt to stabilise prices - it sold in a rising market and, until a change of policy in 1971, made net purchases to support the market when prices were falling. In particular, the Bank waited for environments in which yields were falling before undertaking sizeable gilt sales.

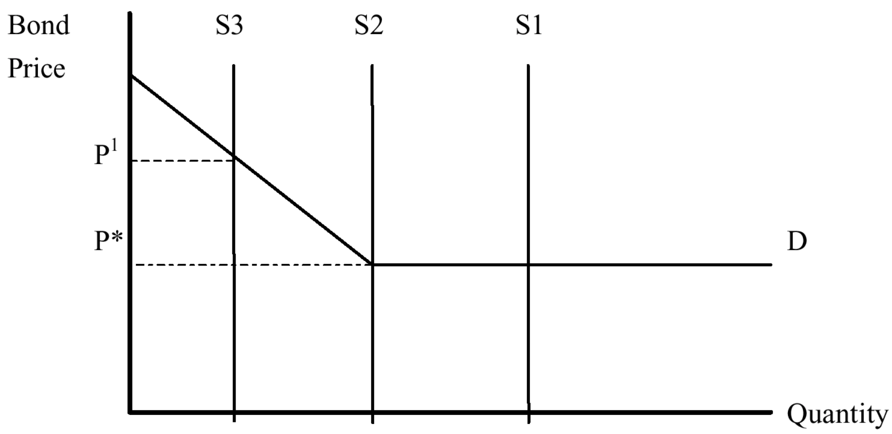
To test whether supply does matter in determining gilt prices, Goodhart and Gowland (1978) use monthly data on gilt sales from 1954 to 1972 and estimate cross autocorrelations between 20-year yields and net sales of long gilts. They find no support for the hypothesis that increased gilt sales push up gilt yields. Later work by Eggington and Hall (1993) examines the effect of gilt issuance on the slope of the yield curve. They first derive a measure of the slope of the yield curve by using principal component analysis (PCA). PCA enables movements in the yield curve to be decomposed into a limited number of underlying factors. In almost all applications of PCA to the yield curve, three factors are found: a parallel shift factor, a tilt factor (ie a change in the slope) and a twist factor (ie a change in curvature). Employing daily data on outstanding stocks of UK gilts, Eggington and Hall model the time series properties of the tilt factor and find that the supply of bonds has a significant impact on the shape of the yield curve. In particular, they find that an increase in the proportion of bonds with maturity greater than 10 years causes a steepening of the yield curve. This they take as evidence for a rejection of the expectations hypothesis in favour of a market segmentation view of the determination of the yield curve.

So previous central bank concern has been associated with the ill effects on the bond market of issuing too much debt too quickly. The current policy concern is effectively the opposite of this. It is that by repurchasing government debt the yields of government bonds will cease to act as a benchmark measure of the risk-free term structure of interest rates and that this will impose costs on the remainder of the economy. Of course, many mainstream financial economists would be uncomfortable with the idea that merely changing the supply of government bonds could have an impact on yields. In theory nominal yields on default risk-free bonds should depend on current and expected real risk-free interest rates, inflation expectations and appropriate risk premia. Just changing the supply of government bonds should not in theory cause a change in bond yields unless it changes one of these underlying drivers, such as a change in inflation expectations if investors perceived there to be a greater risk of the monetisation of government debt. And yet when market practitioners sought to explain much of the fall in UK and US long-term nominal bond yields during 1999 and early 2000, their explanations were generally in terms of the change in current and projected supply of government bonds, rather than these more theoretical considerations.

Under what conditions might we expect to see changes in the supply of government bonds result in their yields ceasing to be an accurate measure of the risk-free term structure of interest rates? There are two requirements: first, that there could exist a subset of investors with price-inelastic demand for government bonds; and, second, that the supply of bonds should fall sufficiently that these investors become the marginal and hence dominant investors that dictate the bond price. This is illustrated in Chart 1.

Chart 1

**The effect of diminishing supply on government bond prices**



In this highly simplified description of the world, there are two types of investor: the unconstrained marginal investor and the investor with a price-inelastic demand for government bonds. The unconstrained investor has a perfectly elastic demand for the bond at the equilibrium price P*. The constrained type would hold the bond even if its yield were lower (ie if its price were higher). Why would she do this? One reason is that she may be constrained (or strongly encouraged) by some form of regulation to hold a government bond even when its yield falls below the theoretical fair value. A second possibility is that the investor is an institutional fund manager whose performance may be closely measured against a government bond benchmark. Her incentives may be to hold government bonds even though they provide a poor total return so that the performance of the fund does not stray far from the performance benchmark. Price inelasticity of demand from constrained investors is the reason the demand curve slopes downwards at first. If the price falls to the risk-free yield, additional demand comes from the unconstrained investors. Chart 1 makes clear that we could observe a large reduction in supply of government bonds from S1 to S2 in the diagram without incurring any effect on price. This happens when there is sufficient supply, even after the debt buyback, to satisfy the demand of the constrained investors. As supply is cut further from S2 to S3, the bond price rises above P* to P1 as constrained investors bid up prices and yields drop below the risk-free curve. Bond prices become overvalued in the sense that their yields are no longer reflective of default risk-free interest rates.

Is this what we see in practice? In some markets, such as the UK index-linked gilts market, the observed yields do appear to be surprisingly low and the bonds are held almost exclusively by investors with strong incentives to hold them, notably pension funds and life assurance companies. For other markets, such as the UK conventional gilt and US Treasury markets, practitioners have also argued that negative net issuance of bonds has caused yields to fall below true risk-free rates. One problem with these arguments is that in practice we continue to observe a remaining subset of investors who hold these securities but who do not seem to be constrained in any way to do so. This observation leads Grinblatt (1995) to argue that either these investors are behaving irrationally or they may be holding these bonds for other reasons. Grinblatt suggests that because government bonds can be used as collateral to obtain cheap short-term funding (sometimes very cheap when a bond goes "special"), this liquidity "convenience yield" is reflected in prices, pushing yields below the risk-free curve.

The main purpose of this paper is to try and generate a measure of the extent to which government bond yields may have been pushed below true risk-free rates. We use interest rate swap spreads to measure the impact of the reduced supply on government bond yields. Financial market practitioners have regularly pointed to widening swap spreads in the US dollar and sterling fixed income markets as evidence that the corresponding government bonds are becoming overvalued as issuance declines. We develop the intuition behind these arguments by first developing a simple framework to measure the fair value of swap spreads and then use the excess of the observed swap spread over this fair value as our measure of the overvaluation of government bonds in alternative markets. This framework also allows us to consider how policymakers should adjust forward curves estimated from government bonds when trying to assess expectations of future short-term interest rates. Finally, we also examine whether the swap market is currently acting as the de facto benchmark for very high-quality bond issues.

The rest of this paper is organised as follows. In Section 2 we set out the main argument for using swap spreads as a measure of misvaluation in government bond markets. Section 3 examines empirically the behaviour of swap spreads, relating them in particular to net issuance of government debt. Section 4 examines two specific issues that arise if government bond markets cease to be an accurate measure of riskless interest rates: (i) how policymakers should measure the risk-free term structure in the presence of distortions to the yield curve; and (ii) how market practitioners price non-government debt in the absence of government bond market benchmarks. Section 5 concludes.

## 2. Using swap spreads as a measure of relative valuation

How can we measure whether government bond yields are artificially depressed? An obvious way would be to examine long bond yields or the slope of the yield curve. If long government bond yields are falling and/or the yield curve is inverting during a time of dwindling supply, then this might be taken as evidence that the bond market is becoming overvalued as a result. However, the obvious alternative to this explanation is that the bond market remains fair value but that the underlying fundamental economic drivers of long nominal bond yields - expected real interest rates, inflation and risk premia - have changed.

What we need is a way of disentangling movements in yields caused by reductions in supply from those that are caused by fundamental determinants. One way of doing this is to examine the movements in spreads between government bonds and other fixed income securities that are close comparators. If we assume that the latter securities remain fairly valued against the “true” (but unobservable) default risk-free yield curve, then we would expect the spreads between their yields and those of government bonds to widen as government bond yields become depressed. Here again, though, we are faced with the difficulty of disentangling changes in the spread due to changes in the fair value of credit spreads over risk-free rates and the movements due to government bond overvaluation. So to do this, we need to use a comparator instrument for which we have a very good idea of what the fair value of the spread between its yield and the true risk-free rate should be.

The instrument we use is the interest rate swap. An interest rate swap is an over-the-counter contractual agreement between two parties to exchange cash flow streams denominated in the same currency but calculated on different bases. The most common type of swap is the “plain vanilla” fixed-for-floating swap. This is an agreement that binds each party to make periodic interest payments to the other on a predetermined set of dates in the future, based on a notional principal amount denominated in the same currency. One party is the fixed rate payer - the fixed rate being agreed at the inception of the swap. The other party is the floating rate payer - the floating rate being determined during the lifetime of the swap by reference to a specific market rate.[4] Note that there is no exchange of principal at any time - there are only exchanges of (net) interest payments.

A par swap is a plain vanilla interest rate swap with zero initial premium (ie where the swap rate is set such that the fixed and floating “legs” of the swap have equal present value, so that it costs nothing to enter into the swap). One can think of the cash flows on a par swap as a combination of a fixed rate bond that pays a coupon equal to the agreed swap rate and a floating rate bond with coupon equal to the reference Libor rate. At initiation of the contract, it can be shown that the floating-rate bond is worth the notional principal. For the contract to have zero net present value, the fixed side must therefore also be worth the notional principal. In other words, the fixed side of the swap can be thought of as a fixed rate bond that trades at par and pays a coupon equal to the swap rate. It follows from this that the swap rate is a par yield.

The difference between the swap rate and a government bond par yield with the same maturity is called the swap spread. We use the swap spread as a measure of overvaluation by assuming that the swap market is fairly valued and by using a model for calculating the fair value of the swap spread. If the swap spread is greater than the level suggested by this model, then we attribute it to overvaluation in the corresponding government bond market. Clearly, the assumption that the swap market is fairly valued at all times, while the government bond market is not, is debatable. But we think there are stronger reasons to believe that the government bond markets may become overvalued than there are to suggest that swaps are mispriced: the swap market is now huge in terms of outstanding notional principal, there are no supply constraints as for the government bond market, it is easy to take long or short positions using swap contracts, and there are no obvious regulatory distortions affecting swap pricing.

### 2.1 A fair value for the swap spread

In the following section we outline a methodology to determine the fair value for the swap spread assuming the swap and the underlying government bond both pay their coupons semiannually. It is straightforward to rework this analysis for bonds and swaps with annual cash flows. We shall show that in theory the swap spread should be closely related to expectations of the future spread between six-month GC repo and six-month Libor. To see this, consider the following trade as an example:

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[4] For sterling fixed/floating rate swaps, the reference rate is by convention GBP six-month Libor with semiannual payment frequency on both legs. For euro fixed/floating swaps, the reference rate is generally EUR six-month Libor, with either *annual/semiannual* or *semiannual/semiannual* payment frequencies. US dollar swaps can commonly be referenced on an *annual/quarterly* basis on three-month USD Libor, or on an *annual/semiannual* basis on USD six-month Libor.

- short sell *$X* of 10-year government bonds trading at par and yielding *Y* (the fixed coupon rate);[5]
- invest the proceeds in six-month GC repo and roll over at each six-month interval over the 10-year life of the bond;
- simultaneously enter a 10-year swap contract (costing nothing) to receive fixed/pay six-month Libor at the current swap rate, R, on an $Xm notional principal.

This portfolio costs nothing to set up. Over the 10-year life of the bond, it pays a cash flow of:

$$(((R - Y)/2) - ((6M\ Libor - 6M\ GC\ repo)/2)) * \$X \tag{1}$$

every six months, where *R* and *Y* are the swap rate and the par yield on the bond at initiation of the trade. *(R–Y)* is the swap spread. The trader receives every six months *R/2* (half the initial swap rate) but has to pay out *Y/2* (half the coupon rate on the short bond position). He also has to pay out six-month Libor on the floating side of the swap, but receives the six-month GC repo rate on the invested proceeds from the short sold bond. The present value of this set of cash flows at initiation of the trade is given by:[6]

$$\sum_{i=1}^{20}\frac{(R-Y)X/2}{\left(1+\frac{r_i}{2}\right)^i}-E_0\sum_{i=1}^{20}\frac{(6MLIBOR_i-6MGCREPO_i)X/2}{\left(1+\frac{y_i}{2}\right)^i} \tag{2}$$

where $r_i$ is the appropriate maturity riskless nominal zero coupon yield used to discount the cash flows in the first summation term, since these are known at the start of the trade. The second term represents the present value of the expected spreads between six-month Libor and six-month GC repo multiplied by *X*, the underlying principal. These cash flows are uncertain and depend on the spread between these two six-month rates at each of the semiannual payment dates at which swap cash flows are exchanged and the repo trade is rolled over. Since they are uncertain, their expected values are discounted at rate $y_i = r_i + \gamma$, where $\gamma$ is a risk premium which reflects the anticipated risk of future movements in the Libor-repo spread. In equilibrium, under the CAPM, this spread will be determined by the covariance of innovations in the six-month Libor-repo spread with returns on the market portfolio.

If both the government bond and swap markets are fairly valued, then expression (2) should equal zero since the trade costs nothing to set up in the first place. Therefore:

$$\sum_{i=1}^{20}\frac{(R-Y)}{\left(1+\frac{r_i}{2}\right)^i}=E_0\sum_{i=1}^{20}\frac{(6MLIBOR_i-6MGCREPO_i)}{\left(1+\frac{y_i}{2}\right)^i} \tag{3}$$

Taking *(R-Y)* outside the summation term and rearranging provides an expression for the swap spread in terms of future expected spreads between six-month Libor and six-month GC repo:

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5 We are implicitly assuming it costs nothing to short the bond. But in practice it could go “special” in the repo market, so that the cost of reversing in the bond to sell could be non-negligible.

6 This formula ignores the impact of counterparty default risk on the swap. This risk is very low since there are no transfers of principal and each side of the swap is effectively collateralised by the value of the other side. Using simulations of a theoretical model of default risk, Duffie and Huang (1996) show that this risk contributes less than three basis points to the swap spread. In practice this risk is further minimised by the use of margining and the fact that banks often use AAA-rated special purpose vehicles to conduct swap business.

$$R - Y = \frac{E_0 \sum_{i=1}^{20} \left[ \left(6MLIBOR_i - 6MGCREPO_i\right) \Big/ \left(1 + \frac{y_i}{2}\right)^i \right]}{\sum_{i=1}^{20} \left[ 1 \Big/ \left(1 + \frac{r_i}{2}\right)^i \right]} \tag{4}$$

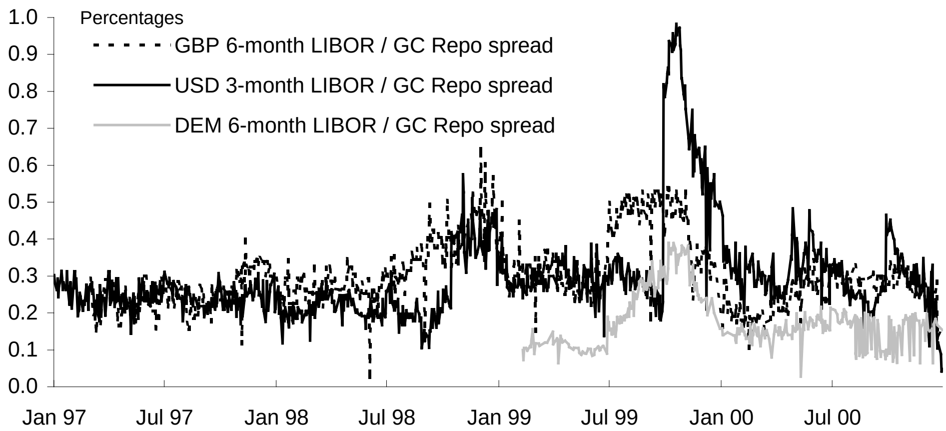
This equation demonstrates that the fair value of the swap spread is intimately related to expectations of the future spread between six-month Libor and six-month GC repo. If we assume the risk premium is zero, then the fair swap spread is simply a weighted average of future expectations of this spread over the life of the swap. By making assumptions about the expected future spreads between six-month Libor and GC repo and assumptions about the risk premium term, we can see what the swap spread ought in theory to be on the basis of equation (4).

Chart 2 shows time series for Libor-GC repo spreads for the US dollar, sterling and euro markets.[7] Although in the US dollar and sterling market these spreads have averaged around 30-40 basis points (bp), they have tended to widen during times of financial crisis such as the autumn of 1998. But they rarely move by more than 10-15 bp and appear to quickly revert back towards their mean levels. They were also much higher for the six months prior to the start of the year 2000. Given this behaviour, a simple rule for modelling expectations of the future spread is that they are flat at this historical average - we use 35 bp. In the euro markets the equivalent spread has historically been lower at 15-20 bp, so the appropriate rule should reflect this.

What is an appropriate level for the risk premium? We have done only a very limited amount of work on this. Using a simple CAPM framework, for the sterling market we regressed innovations in the Libor-repo spread against returns on the FTSE-100 as a proxy for the market portfolio. This yielded a beta estimate that was negative, but not statistically significantly different from zero. So our best guess at this stage is that the risk premium is small but negative. This makes sense since the spread is generally larger in times of financial crisis, when equity market returns tend to be negative. An asset which pays a higher return when the rest of the market is depressed should attract a negative risk premium. A zero risk premium, $\gamma$, gives a measure of the fair value of the swap spread of 35 bp using equation (4) and our simple expectation of the future Libor-repo spread. Using a –2% risk premium as an extreme case, we obtain an upper bound on the size of the fair value of the swap spread of 50-55 bp. All this suggests an estimate of the fair value for swap spreads in the sterling and US dollar markets of 40-50 bp, with perhaps 30 bp in the euro market.

Chart 2

**Libor-GC repo spreads for USD, GBP and EUR (DEM)**




[7] We only have data for the three-month GC repo-Libor spread for the United States.

## 2.2 Recent developments in swap spreads

How does this square with reality? Chart 3 plots 10-year swap spreads over government benchmark yields since 1987 for the dollar, sterling and euro (we use Deutsche mark swaps prior to 1999). What is clear is that for the middle part of the 1990s these swap spreads were close to what we would have expected given our simple model. Prior to this, swap spreads were wider, particularly in the United States and United Kingdom, though the swap markets were much less developed during the late 1980s than they are now. In mid-1997 swap spreads began to widen in the sterling and dollar markets. This continued through 1998 until in the autumn the spreads widened sharply in the dollar and in particular the sterling fixed income markets. Note, however, that the response was far more muted in the German swap market. This increase in spreads resulted from the flight to UK and US government bonds (particularly on-the-run issues) that followed the Russian debt crisis and subsequent near collapse of Long-Term Capital Management (LTCM). A further reason why swap spreads in the sterling market widened so much during this period was that LTCM and other leveraged institutions were forced to unwind positions in which they were short of UK gilts and receiving fixed on similar maturity swaps. In fact these trades were originally initiated to take advantage of swap spreads which looked too wide on the basis of the sort of argument we have described in Section 2. But as government bond prices were bid up, these positions began to rapidly lose money and were unwound in what were at the time illiquid markets. The effect was to cause a temporary widening in the swap spread.

Chart 3

**Ten-year swap spreads USD, GBP and EUR (DEM)**

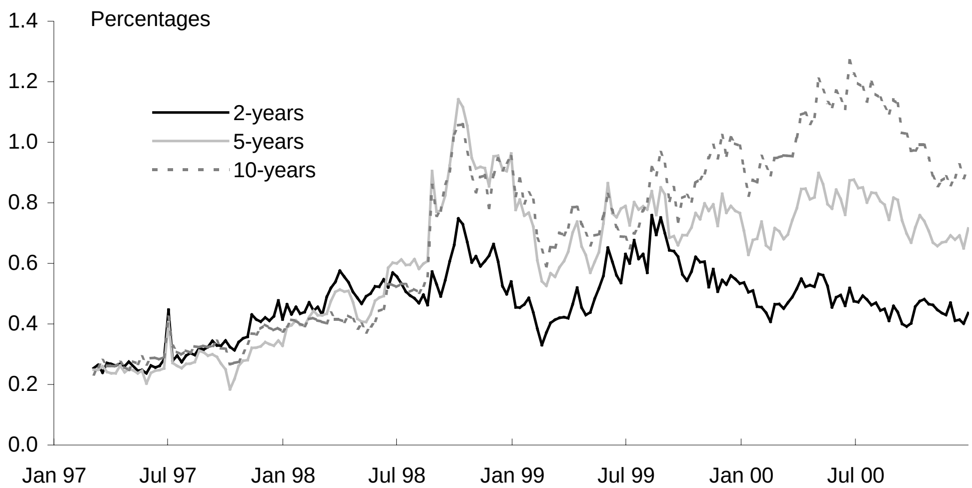



Chart 4

**Two, five and 10-year GBP swap spreads**

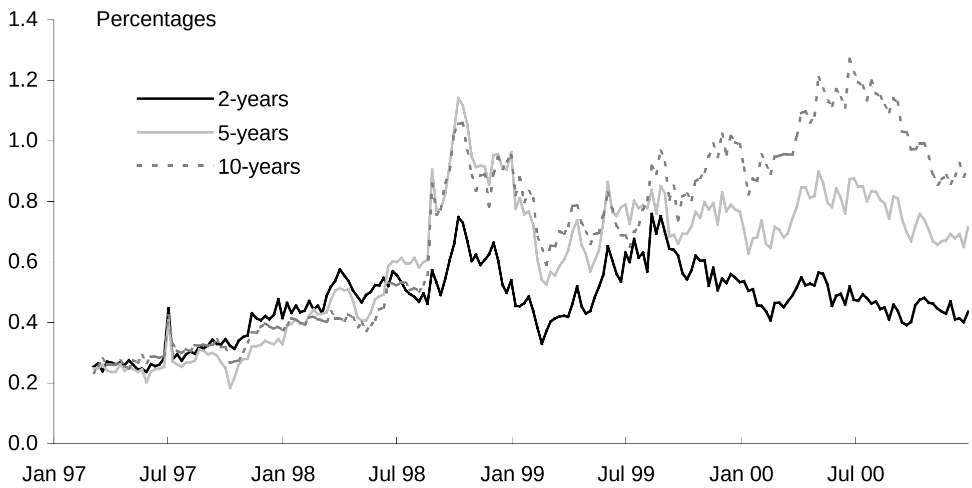


Chart 5

**Two, five and 10-year USD swap spreads**

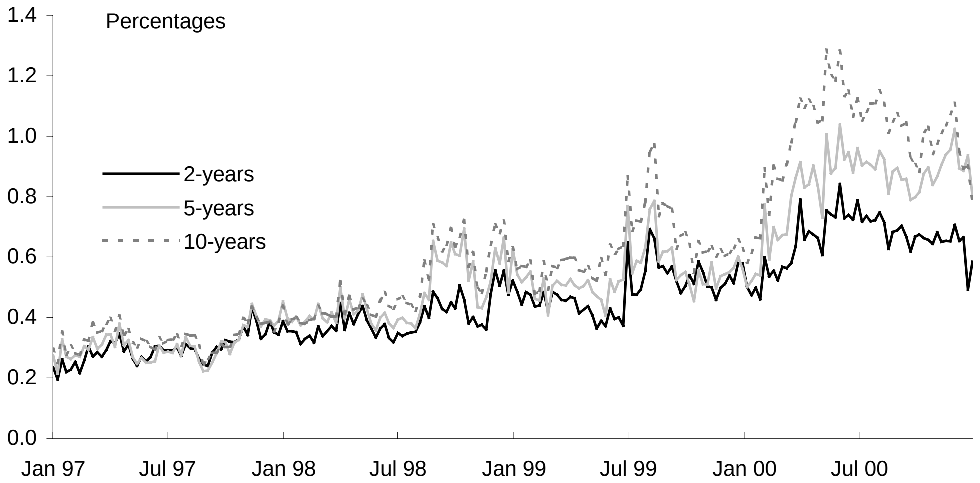
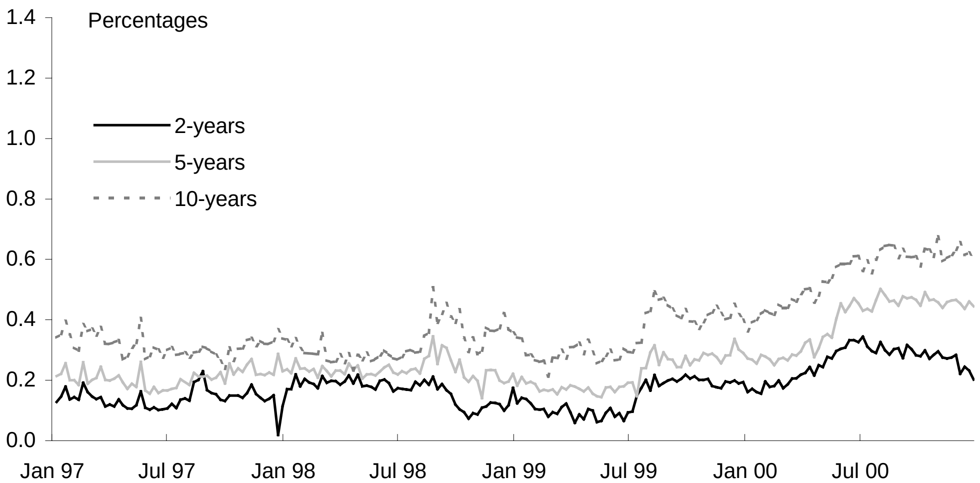



Chart 6

**Two, five and 10-year EUR (DEM) swap spreads**




Charts 4, 5 and 6 plot two, five and 10-year swap spreads for the sterling, dollar and Deutsche mark (euro after January 1999) markets. Two things are worth noting: (i) swap spreads widened far more for long-term swaps; and (ii) German swap spreads widened far less than sterling and dollar spreads. Had the events of autumn 1998 increased the perceived risk of interbank default over the short- to medium-term horizon, one would have expected to see increased forward spreads of Libor over collateralised debt over a short- to medium-term horizon. But this did not happen - 10-year swap spreads moved far more than two-year swap spreads. In addition, it should be recognised that the Libor bank pools for each currency have similar and overlapping memberships. Consequently, an increase in future expected interbank credit risk should have widened swap spreads in *all* currencies. But German swap spreads were far less affected than sterling and dollar spreads. All this suggests that movements in swap spreads during this period were not driven exclusively by credit risk considerations, but rather by the large flows to benchmark government bonds from interest rate swap positions receiving fixed in what had become illiquid markets.

In late 1998 swap spreads fell partially back to lower levels. But this development proved to be temporary, and the uptrend in swap spreads in the UK and US markets continued during 1999. This persistent widening in swap spreads was attributed by many to the reduction in the net supply of government bonds in both the UK and US markets. Indeed, dollar swap spreads widened dramatically in the first quarter of 2000 as the Treasury buyback schedule gathered momentum and projections started to indicate that the United States would be in a position to repay its national debt by the beginning of the next decade.[8] Our interpretation of the US and UK 10-year swap spread time series is that the Russian debt/LTCM crisis caused a spike in a series which was in any case on an upward trend as a result of a growing perception in the markets that the net supply of UK and US government bonds would be much lower looking forward. Fears of a worsening scarcity of UK and US sovereign debt caused yields on these bonds to decline relative to true risk-free rates.

So how overvalued is sterling and dollar sovereign debt? Recall that our estimate of the fair value of the swap spread in the United Kingdom and the United States was 40-50 bp. By comparison, during much of 2000, swap spreads in the sterling and dollar markets were around 110 and 100 bp respectively. If we make the crucial assumption that the swap market is fairly valued, then swap spreads at these levels suggest that yields on 10-year gilts and Treasuries were at the time depressed by around 60-70 bp. So it appears that even though the outstanding stock of debt in both countries remains large, the effect of currently negative net supply (and perhaps more importantly expectations that the stock of debt would continue to shrink) was to significantly depress bond yields in both countries.

## 3. Empirical behaviour of swap spreads

In this section we examine whether it is possible to identify an empirical relationship between swap spreads and the net supply of government bonds. A limited number of studies have already examined the empirical properties of swap rates and swap spreads. Early studies such as Sun et al (1993) and Minton (1997) sought to examine the equivalence between swap *rates* and the Libor yield curve using data on long-term Libor borrowing rates and eurodollar futures rates respectively. This was motivated by the recognition that the fixed side of a swap can be interpreted as a par yield. These studies found that, typically, the swap curve was close to, but not exactly the same as, the Libor par curve. Other studies such as Cooper and Mello (1991), Sorensen and Bollier (1994) and Duffie and Huang (1996) examined the value of the risk of counterparty default on an interest rate swap and how this was factored into the swap spread. As we pointed out in Section 2, Duffie and Huang showed via simulations that the value of counterparty default risk could not contribute more than a very small number of basis points to the swap spread. Furthermore, the collateralisation and margining practices between swap market participants that have become widespread since the mid-1990s now mean that counterparty default risk is not really a serious issue and so cannot explain swap spreads.

Grinblatt's (1995) work is closer to our own in that he attributes the size of the swap spread not to default risk but rather to the underlying government bond yield lying below risk-free rates. Grinblatt argues that this is because government bonds also yield a liquidity-based convenience yield, the present value of which is reflected within the bond price, pushing government bond yields below the risk-free equivalent. The origin of this convenience yield is not necessarily lower bid-ask spreads on government bonds, but rather, as explained in Duffie (1996), that holding government bonds can grant access to cheap short-term financing via the repo market if the bond goes "special". This is likely to be particularly relevant for newly issued *on-the-run* US Treasuries. Krishnamurthy (2001) has shown that much of the spread between the yield of *on-the-run* and "old" 30-year Treasury bonds can be explained by relative financing costs in the repo market - ie the present value of the cheap funding via specific repo offered by newly issued benchmark bonds. So part of the spread between a swap rate and an *on-the-run* government bond is likely to reflect this factor. But because "specialness" tends to be concentrated amongst the most recently issued bonds, it is difficult to explain much of the spread between swap rates and the yield on *off-the-run* bonds in this way.

Baz et al (1999) employ similar arguments to those in Section 2 to show that the swap spread is equal to a weighted average of forward Libor-Treasury spreads. They then model swap spreads econometrically, employing daily data with factors such as the slope of the yield curve, the level of interest rates, the GC repo-Libor spread, returns on the equity market and corporate bond spreads. They find that equity market returns, changes in credit spreads, and the slope of the yield curve have

[8] In January 2000, assuming unchanged taxation and spending plans, the Congressional Budget Office (CBO) projected that total federal surpluses would be sufficient to pay off all publicly held debt available for redemption by 2006 (source: US Congressional Budget Office, www.cbo.gov).

highly significant effects on UK and US swap spreads over the period 1994-99. The link between equity prices and swap spreads is attributed to changes in risk appetite amongst investors in response to sharp falls in equity prices. As risk appetite declines, investors find government bonds more attractive and so their prices are bid up, depressing yields and causing a widening in swap spreads. This phenomenon seems to have been particularly strong in the UK and US markets during the autumn of 1998. Such a phenomenon may also explain why there is a strong contemporaneous link between credit spreads and swap spreads: an isolated downward move in the government bond yield as a result of a “flight to quality” will cause all spreads over that yield to widen together. Finally, under the Baz et al model, a steepening of the yield curve causes a narrowing in the swap spread. They provide two potential explanations for this: first, that in a steep yield curve environment corporates issue long-term fixed rate debt but are keen to swap to floating rate debt with a lower current interest rate via receiving fixed on a swap; they argue this bias to receiving fixed in the swap market tends to narrow the swap spread; second, that the slope of the yield curve contains information on the future macroeconomic outlook and hence on credit conditions. So if the yield curve inverts and is indicative of a worsening of future credit conditions, then these authors suggest there should be a widening of the swap spread. We discuss the plausibility of this argument later.

It is worth stating at this stage that if supply considerations do impact on government bond yields, and thereby on swap spreads, one would expect the appropriate measure of supply to be the anticipated future profile of outstanding government stock. Unfortunately, we do not have a measure of the market’s expectations of the future outstanding stock. Perhaps the best we can do is measure how swap spreads react to concurrent supply shocks - namely current net debt issuance.

Charts 7 to 11 plot time series of the 10-year swap spread versus current net government issuance (as a proportion of GDP) for the UK, US, German, Japanese and Canadian markets respectively. In the German market net issuance has been low and stable,[9] whereas in Japan net issuance of government debt has been very substantial over the last few years.[10] The simple demand and supply analysis in Section 1 would suggest that bond market yields should lie on the default risk-free yield curve and swap spreads should remain close to their fair value. Charts 9 and 10 show that in Japan and Germany this has been the case. In the Canadian market, net issuance has become negative over the last three years, mirroring developments in the United States. But Canadian dollar swap spreads have remained close to our estimate of fair value at 30-40 bp. Nevertheless, our earlier analysis also suggested that reduced supply need not have an impact on bond yields either if there is no “constrained” subset of investors or if supply does not drop sufficiently. Perhaps these conditions have simply not been met in the Canadian markets. Given that there does not appear to be any obvious link between government bond supply and the swap spread in these three markets, we have not attempted to estimate any econometric link here.

In the United Kingdom and the United States there appears to be a stronger link. Chart 7 in particular suggests a negative correlation between net issuance of UK government debt and the level of 10-year sterling swap spreads. In the late 1980s/early 1990s the emergence of negative net issuance of UK government bonds was associated with widening of swap spreads and has been again since 1997. In the United States the reductions in outstanding government debt since 1997 have also been accompanied by widening 10-year swap spreads, although it is difficult to explain on these grounds why swap spreads were so wide in the early 1990s.

[9] We acknowledge that after 1999 one should look to euro area rather than German federal government net issuance as a driver of euro swap spreads.

[10] The Japanese government is now the world’s biggest debtor, with the dollar value of outstanding JGBs now greater than the stock of outstanding US Treasuries.

Chart 7

**UK government net issuance vs 10-year GBP swap spreads**

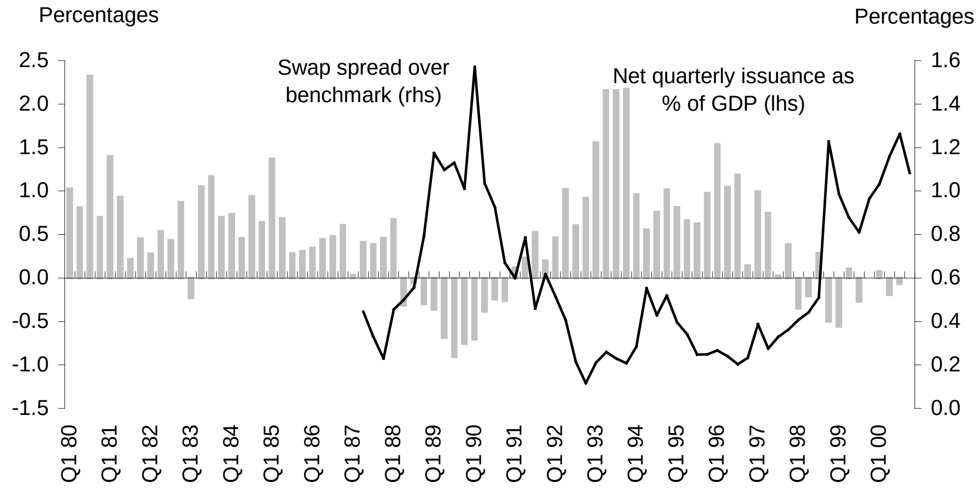



Chart 8

**US government net issuance vs 10-year USD swap spreads**

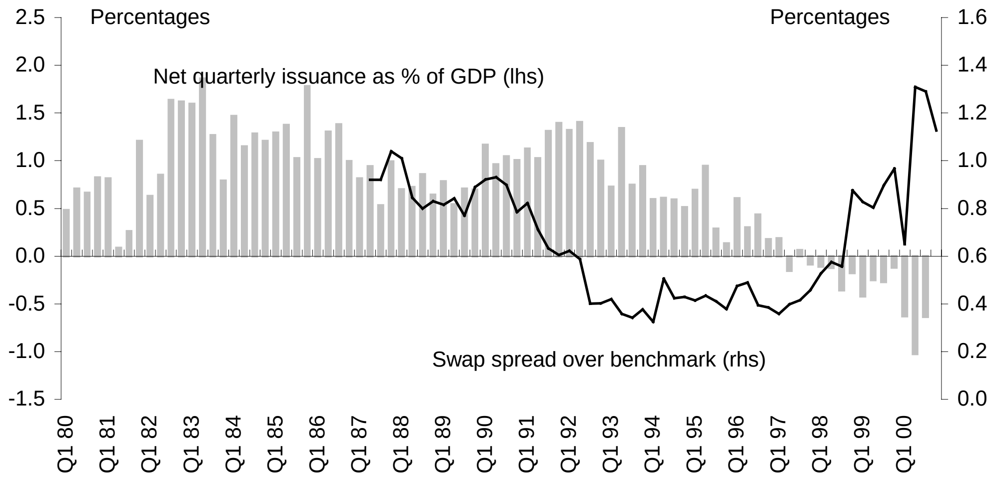



Chart 9

**German government net issuance vs 10-year EUR (DEM) swap spreads**

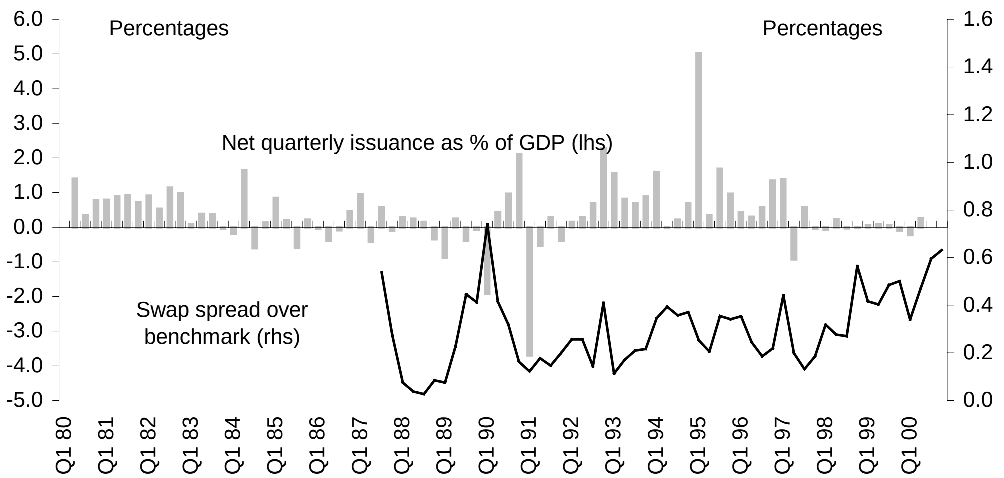


Chart 10

**Japanese government net issuance vs 10-year JPY swap spreads**

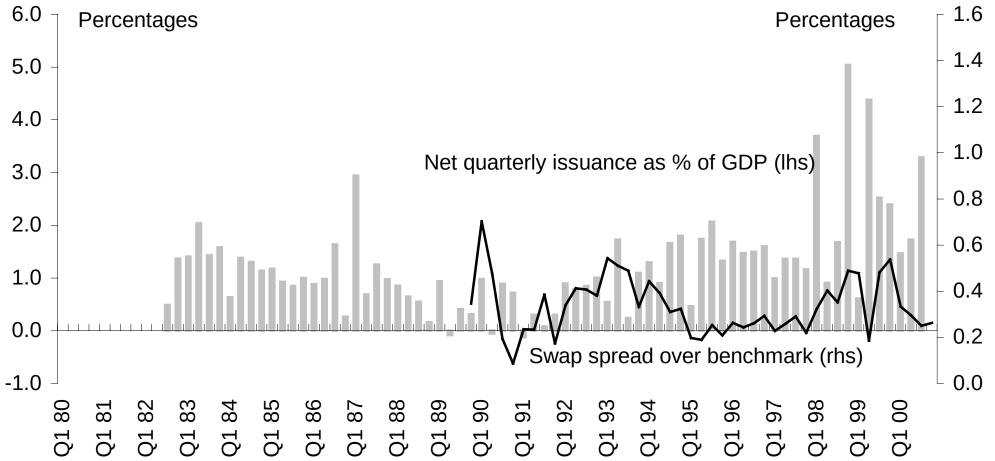
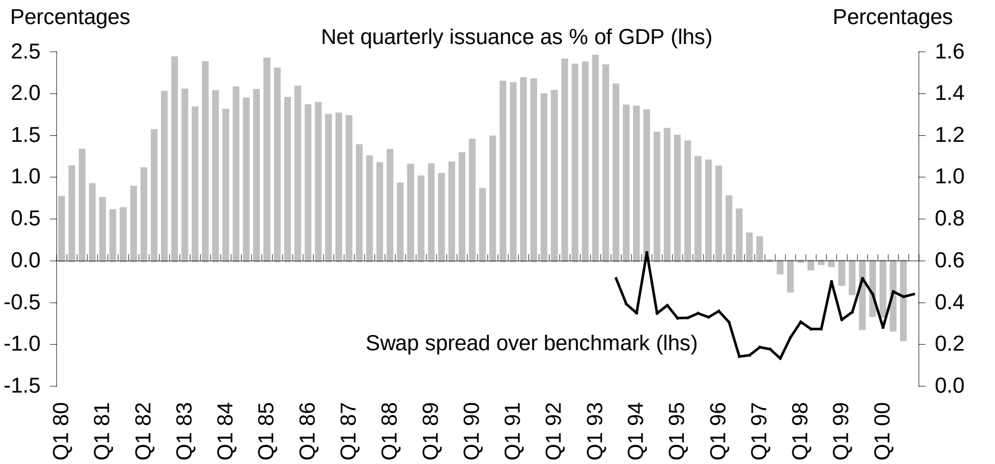



Chart 11

**Canadian government net issuance vs 10-year CAD**




To test for a statistical link between 10-year swap spreads and issuance in the UK and US markets, we regressed swap spreads, using quarterly data, against:

- **net issuance of government bonds as a proportion of GDP** - given by quarterly net issuance of government debt divided by GDP for the United Kingdom (not seasonally adjusted), and quarterly net federal government borrowing over GDP for the United States (seasonally adjusted because supply is seasonal);
- **the slope of the yield curve** - given by the difference between the appropriate 10-year government benchmark yield and the three or six-month T-bill rate;
- **short-term interest rates** - given by three-month sterling Libor and six-month US dollar Libor respectively;
- **the Libor-T-bill spread -** used as a proxy for the Libor-GC repo spread; and
- **quarterly equity returns** - given by the quarterly returns on the FTSE All-Share (UK) and S&P 500 (US) equity indices.

We estimated four different models for the United Kingdom and the United States covering the period 1989 Q3 to 2000 Q3. Results are provided in the statistical appendix. Model 1 simply regresses the swap spread against net issuance. In the United Kingdom the relationship is negative (as we expected) and highly statistically significant. In the United States the sign is negative and again significant. In model 2 we introduce other variables that have been found to have explanatory power in other empirical studies of swap spreads. The lagged swap spread term is highly significant in both cases, suggesting that these spreads are highly persistent. Unlike in Baz et al (1996), we find that the equity return is not significant. This is likely to be due to the fact that we use quarterly rather than daily data, so that a shock from the equity market may unwind too quickly to be picked up in our dataset. Neither do we find the Libor-T-bill spread to be significant. In both the United Kingdom and the United States net issuance now loses it statistical significance but the slope of the yield curve is significant.

In model 3, we omit the equity return and the Libor-T-bill spread. The net issuance remains statistically insignificant in this model. Note, however, that in both the United Kingdom and the United States the net issuance and the slope of the yield curve are co-linear. The sample correlation between the two series is 0.73 in the United Kingdom and 0.59 in the United States. And because the slope is a less volatile series, it has a smaller standard error and hence a higher t-statistic. Our interpretation is that if changes to supply impact on long-maturity bond yields as argued by Eggington and Hall (1993), then this will change the slope of the yield curve. So the slope is a symptom of the same cause - changed government bond supply - of bond yields as the swap spread, not an explanatory factor of the swap spread per se*.*

So on a priori grounds we omit the slope of the yield curve in the final model. In this model 4, net issuance re-emerges as a statistically significant factor to explain swap spreads - our measure of the depression of bond yields below the risk-free curve. The negative coefficient matches our expectation that reduced supply tends to increase the swap spread.

## 4. Implications for policymakers

We have seen the evidence for overvaluation within the UK and US government bond markets. This phenomenon clearly has wide implications for financial market participants and policymakers, but here we focus on two particular questions:

(i) how should central banks infer and interpret expectations of future nominal risk-free interest rates from fixed income markets in the presence of known distortions?

(ii) what will financial market practitioners use as a benchmark for pricing non-government fixed income securities in the absence of default risk-free debt?

### 4.1 Assessing market interest rate expectations in the presence of known distortions

In Section 2, we developed a measure of the fair value of par swap spreads. Using estimates based on historical norms for Libor-GC repo spreads, we calculated the likely bias in gilt and US Treasury par yields versus risk-free rates. When we wish to infer expectations of future short-term interest rates, however, we use forward rates rather than par yields. So we need to calculate the corresponding biases in forward rates. We show here how to calculate the appropriate adjustments to forward curves using the swap market as a benchmark.

To do this, we employ an argument very similar to the one we developed in Section 2. The steps are as follows:

(i) assume the swap market is fairly valued - ie swap rates reflect market expectations of future short interest rates, appropriate term and credit premia and convexity effects only;

(ii) form a simple trading rule which relates the spread of forward swap rates over government forward rates - the forward swap spread - to future expected spreads between six-month Libor and six-month GC repo;

(iii) calculate the fair value for that trading rule and hence the fair value for the forward swap spread;

(iv) it then follows that the difference between the forward swap spread observed in the market and this fair value is a measure of the degree to which the government forward is biased downwards versus its fair value.

We can use this measure of the bias to adjust up our government forward to obtain a measure of the "true" risk-free forward curve. Or equivalently we can use the forward swap curve adjusted for the fair value of the forward swap spread.

The trading strategy in this case is a short forward position with maturity *m* in *$X* worth of a six-month government bond and a long forward position of the same maturity in a six-month swap with notional principal of *$X*. The first part locks in the yield on short selling a six-month government bond in *m* years time at rate *FY*. The forward swap position locks in a six-month swap starting in *m* years' time that swaps a fixed rate *FR* in *m* years' and six-months for six-month Libor at that time. These forward contracts cost nothing today. In *m* years' time, the six-month government bond is sold short at the price locked in by the forward rate agreed now and the proceeds are invested in six-month GC repo. The payoff to this strategy comes in *m* years and six-months and equals:

$$[(FR - FY)/2 - (6MLIBOR_m - 6MGCREPO_m)/2]^* X \tag{5}$$

where $6MLIBOR_m$ and $6MGCREPO_m$ are the outturn values of six-month Libor and GC repo in *m* years' time. On the one hand, the trader receives the difference between the forward swap rate and the forward bond - the forward swap spread; on the other, he has to pay out the Libor-repo spread. The present value of this payoff is:

$$((FR - FY)X/2)e^{-r(m+0.5)} - E((6MLIBOR_m - 6MGCREPO_m)X/2)e^{-(r+\lambda)(m+0.5)} \tag{6}$$

where $r$ is the continuously compounded $m$+0.5 maturity zero coupon rate and $\lambda$ is the same risk premium as in equations (2) to (4) above. The first term is the present value of the forward swap spread payment received. Since this is known now, it is discounted at the risk-free rate. The second term is the present value of the expected payment made from the spread between six-month Libor and GC repo. Again, since this spread is unknown and uncertain until *m* years' time, its present value is its expectation discounted by $r$ plus the risk premium term $\lambda$.

Now note that when setting up this strategy, there was no cost at the start of the trade since neither of the forward contracts cost anything to initiate. Nor is there a net cash flow at year *m*: the proceeds of shorting the gilt are entirely invested in GC repo, and entering the swap via the forward costs nothing. So since it costs nothing to follow this trading strategy, the present value of its payoff in equilibrium and when both the gilt and swap markets are fairly valued must be zero:

$$((FR - FY)X/2)e^{-r(m+0.5)} - E((6MLIBOR_m - 6MGCREPO_m)X/2)e^{-(r+\lambda)(m+0.5)} = 0 \tag{7}$$

Rearranging this equation and dividing through by exp(-r(m+0.5))*X/2, we obtain an expression for the fair value of the forward swap spread at maturity m:

$$FR - FY = E(6MLIBOR_m - 6MGCREPO_m)e^{-\lambda(m+0.5)} \tag{8}$$

So the fair value of the forward swap spread for maturity *m* is given by the current expectation of the spread between six-month Libor and GC repo but adjusted by a risk premium term which reflects the risk of this spread. Assuming the swap market is fairly valued, the difference between this measure and the observed forward swap spread measures how biased the gilt market forwards are as a result of any regulatory distortions and lack of gilt supply. The fair value of the default risk-free forward rate (again assuming the swap market is fairly valued) is:

$$FY = FR - E(6MLIBOR_m - 6MGCREPO_m)e^{-\lambda(m+0.5))} \tag{9}$$

Equation (9) provides a formula for calculating estimates of (unobservable) risk-free forward rates from forward swap rates, *FR*, by adjusting downwards for the expected difference between future six-month Libor and GC repo rates. The difference between these estimated risk-free forward rates and the observed forward rates derived from government bonds is our measure of the bias in the government bond market. From this bias-adjusted, risk-free forward curve it is also straightforward to construct a zero coupon bias-adjusted curve.

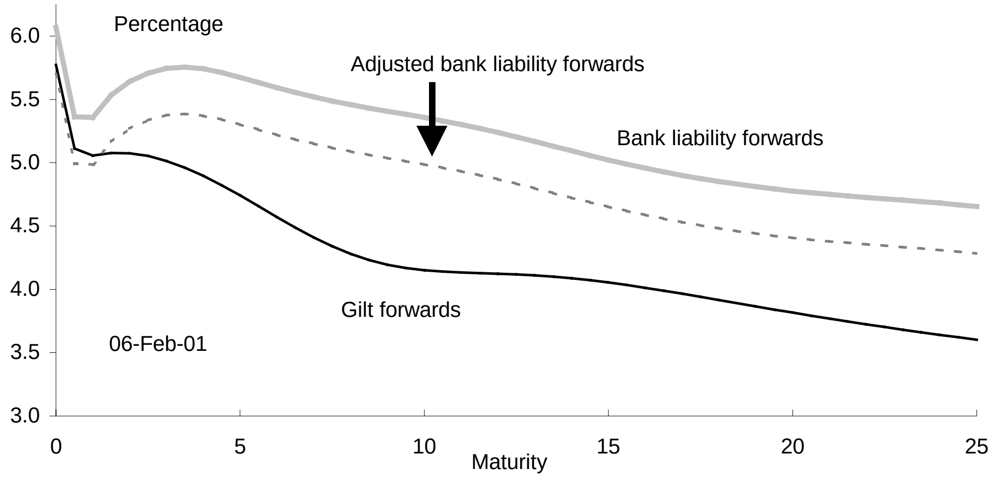
To estimate bias-adjusted, risk-free forward rates, we need estimates of the forward swap and government bond rates, the expectation of the future spread between six-month Libor and six-month GC repo, and $\lambda$, the risk premium attached to the risk of movement in the Libor-repo spread.

Government and swap forward rates are not directly observable, so we have to estimate them. This is done using the Bank of England's VRP yield curve estimation technique.[11] This method is applied to US Treasuries and dollar GC repo rates, and to gilts and sterling GC repo rates respectively to estimate government forward curves for both countries. A euro curve is generated using a combination of French and German government bonds. To estimate forward swap rates, we use fitted "bank liability" forward curves.[12] These employ the VRP technique to fit to Libor deposit rates, forward rate agreements (FRAs), three-month Libor futures and interest rate swaps. We do this by first transforming these rates into synthetic bond prices and then fitting forward curves to prices. From these forward curves we can calculate the forward swap rates that correspond to *FR* in equations (5) to (9).

In Charts 12-14 we plot government, bank liability and adjusted bank liability forward curves for the GBP, USD and EUR markets on 6 February 2001. The adjusted bank liability curve may be thought of either as the forward swap curve adjusted for the fair value of the spread between a forward swap rate and a risk-free forward rate or, equivalently, as the forward government rate adjusted for estimated biases caused by supply side and regulatory factors.

Chart 12

**GBP government and bank liability forward curves**




Note: GBP adjusted bank liability forward rates are calculated by subtracting 40 bp - the risk-adjusted estimate of the fair six-month GBP Libor-GC repo spread - from bank liability forward rates.

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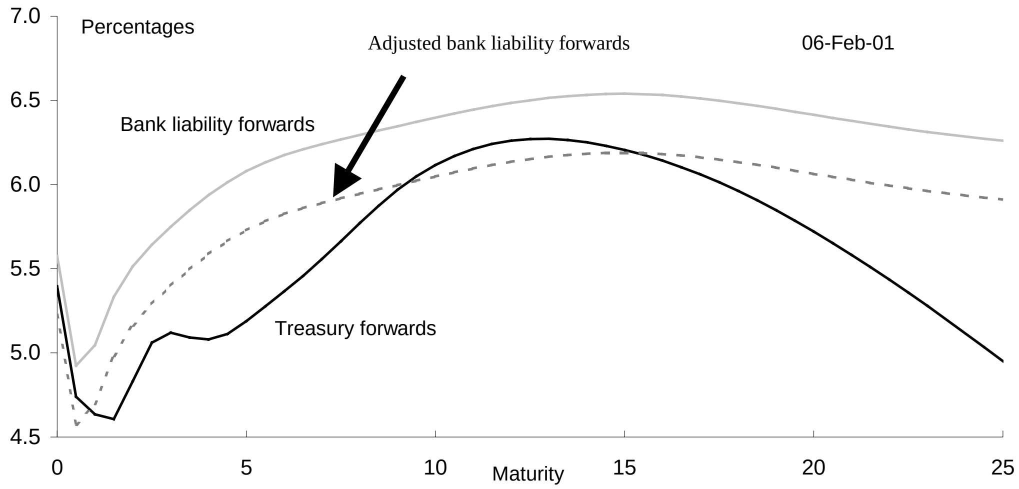
[11] See Anderson and Sleath (1999) for a description of the Bank of England's Variable Roughness Penalty (VRP) curve-fitting technique as applied to GC repo rates and conventional gilts.

[12] See Brooke et al (2000) for an outline of the Bank of England's Bank Liability VRP curve-fitting technique.

Chart 13

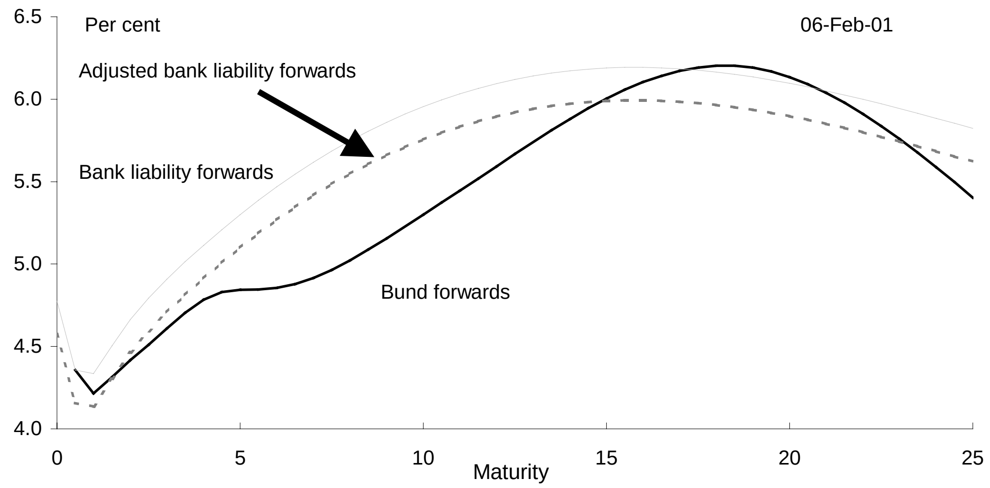
**USD government and bank liability forward curves**




Note: USD adjusted bank liability forward rates are calculated by subtracting 35 bp - the risk-adjusted estimate of the fair six-month USD Libor-GC repo spread - from bank liability forward rates.

Chart 14

**Euro government and bank liability forward curves**




Note: EUR adjusted bank liability forward rates are calculated by subtracting 20 bp - the risk-adjusted estimate of the fair six-month USD Libor-GC repo spread - from bank liability forward rates.

For the United Kingdom and the United States there is a clear difference between the solid forward curves estimated directly from government bonds and the dashed "valuation bias" adjusted forwards derived from swaps. This difference represents our estimate of the bias in government forward rates. For the United Kingdom, the bias grows with maturity until it reaches a maximum at around 10-15 years. In the United States the picture is complicated by the difficulties in fitting a sensibly shaped government yield curve when including both *on-the-run* and *off-the-run* bonds.[13] Nonetheless, it is

[13] "On-the-run" securities are the most recently issued securities of a given maturity. Older securities of a given maturity are called "off-the-run". The wide spread between *on-the-run* and *off-the-run* US Treasury yields creates oscillations in the forward curve corresponding to the maturities of the current benchmarks.

clear that on average there is a significant downward bias in the forwards estimated from US Treasuries (except in the 10- to 15-year range, where we think the curve is misestimated for the reasons given above). Beyond 15 years this bias increases with maturity, reflecting the well publicised bias in the 30-year T-bond yield - see McCulloch (2000) for a commentary on this phenomenon.

Finally, Chart 14 provides the equivalent forward curves for the euro market. What is slightly surprising is that although the differences between the government and the bias-adjusted curves is smaller than for the United States and United Kingdom, there is still a bias in the government curve. This estimated bias in the euro curve is a relatively new phenomenon, which can be attributed to the widening of euro swap spreads that occurred during mid-2000.[14]

### 4.2 New pricing benchmarks for fixed income securities

A major concern for policymakers in a world of diminishing issuance of government bonds is whether the efficiency of other fixed income markets would be affected by the absence of a highly liquid risk-free benchmark security. For the United States, Fleming (2000, 2001) considers whether other fixed income securities, such as interest rate swaps, supranational bonds and mortgage agency securities, could perform the benchmark role traditionally performed by US Treasuries. In this section we examine the extent to which the interest rate swap market has already become the de facto benchmark for high-quality issuers.

What do people mean when they attribute “benchmark” status to a fixed income security? In the case of government bonds it often refers to their use as a measure of the level of default risk-free interest rates. These are then used to reference and hedge other fixed income securities, and to monitor monetary and financial conditions more generally. It should be noted, however, that in our discussions with market contacts we found that market participants do not price bonds by adding an estimated spread to the benchmark government yield to calculate a yield for discounting the cash flows on a new bond. Rather they calculate yields by comparing them to similar comparator bonds. Even so, the yields on benchmark government bonds are widely monitored as measures of risk-free rates in the financial press, by financial market participants and by policymakers to assess monetary conditions and examine financial markets’ reactions to news on monetary policy and the macroeconomic outlook.

In what follows we show that the pattern of spreads of European Investment Bank (EIB) and World Bank (IBRD) bonds over swaps is more consistent than against government bonds across currencies. If by benchmark risk-free yields we mean a reliable measure of the nominal risk-free yield for that currency, then we ought to observe very similar spreads between the bonds of these institutions and the chosen benchmark instrument across different currencies. We can think of no compelling reason why spreads of supranationals’ bonds over the risk-free curve should be significantly wider in one currency than in another. So if, for example, we want to use government bonds as a benchmark for the risk-free rate in each currency, we should expect that the spreads of supranational bonds versus government bonds ought to be similar for different currencies.

Charts 15 and 17 plot credit spreads for EIB and World Bank bonds denominated in alternative currencies against the respective government bonds across maturities on 10 July 2000. To derive these spreads, we calculate for each bond a redemption yield on a synthetic government bond that has exactly the same cash flows and maturity characteristics using our estimated government zero coupon yield curves. We calculate the spread over this synthetic yield to avoid problems resulting from mismatching maturities or coupon rates between the two bond yields being compared.

If the government bonds are acting as a reliable measure of the risk-free rate, then we would expect these spreads to be consistent across currencies. Although spreads might be different across maturities - a term structure of spreads - we would want this pattern to be consistent across currencies also. What Charts 15 and 17 both show, however, is that the spreads between these supranational bonds’ yields and those on governments depend strongly on the currency in which they are calculated. It does not seem credible that the credit spread for 10-year EIB bonds over risk-free rates is 90 bp in

[14] One possible source for this widening of euro swap spreads is that market participants may have begun to anticipate a pay-down of government debt stocks even in Europe, aided at the time by strong GDP growth projections and higher than expected tax revenues from the government auctions of third-generation mobile telephone licences.

sterling or US dollars but only 30 bp for debt denominated in euros. Likewise, does it make sense that the World Bank pays a yield of only 30 bp over risk-free rates for five-year euro-denominated debt but 80 bp over risk-free rates for US dollar- and sterling-denominated? We think it does not and that the reason for the differences in spreads is due to the overvaluation of the US and UK government bond markets and the corresponding depression in government bond yields *below* the true nominal risk-free rates.

Charts 16 and 18 provide the equivalent spreads over swaps (although not adjusted for the fair value of the swap spread). Here again we construct synthetic coupon-and maturity-matched bond yields from our estimated zero coupon bank liability curves and compare these yields to the observed yields of individual bonds denominated in different currencies for the EIB and the World Bank. What Charts 16 and 18 show is that there is a much closer relationship between spreads across different currencies. For a given maturity, these spreads lie within a range of only around 20 bp. So the swap market seems to be providing a much more sensible measure of risk-free rates across currencies than government bond markets. In other words, the interest rate swap market acts as a far more consistent benchmark than the markets for government securities. Of course we know from Section 2 above that if we estimate a curve directly from swap rates, it will be biased versus the true nominal risk-free curve by the fair value of the swap spread. But Section 4.1 showed how we could adjust for this spread to obtain cleaner measures of risk-free forward or spot rates.

Chart 15

**EIB bond spreads against government bond curves**

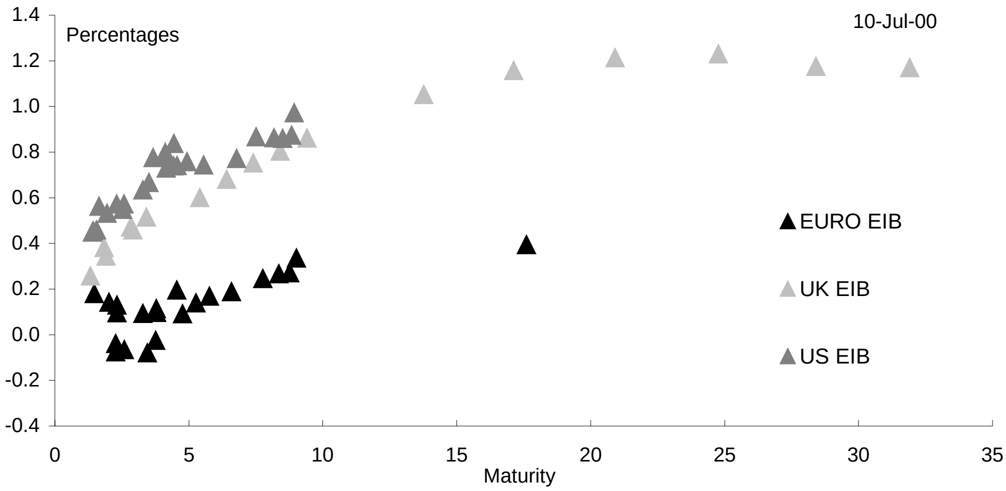



Chart 16

**EIB bond spreads against swaps**

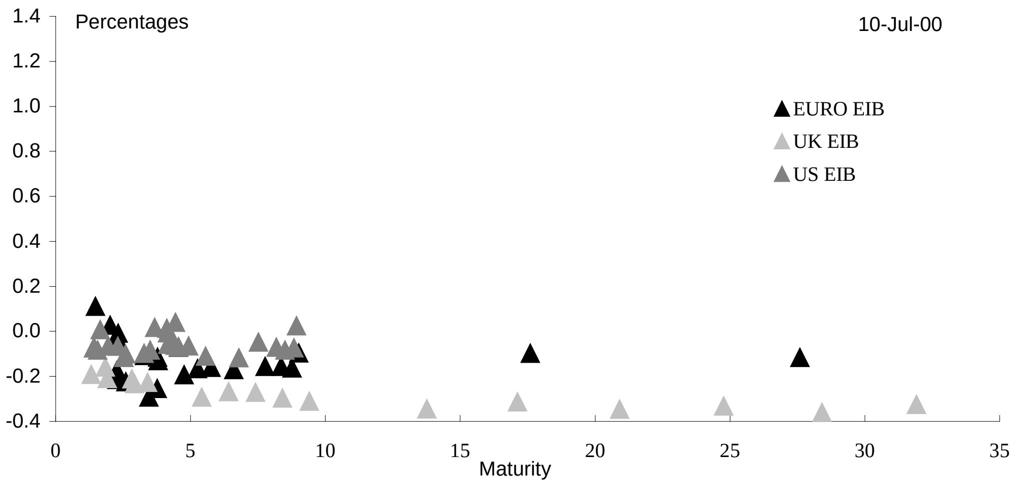


Chart 17

**World Bank spreads against government bond curves**

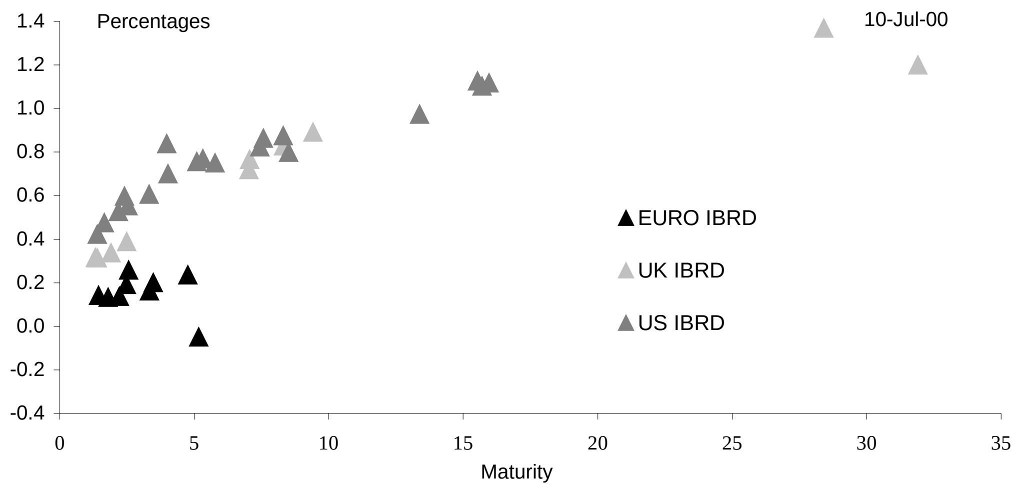
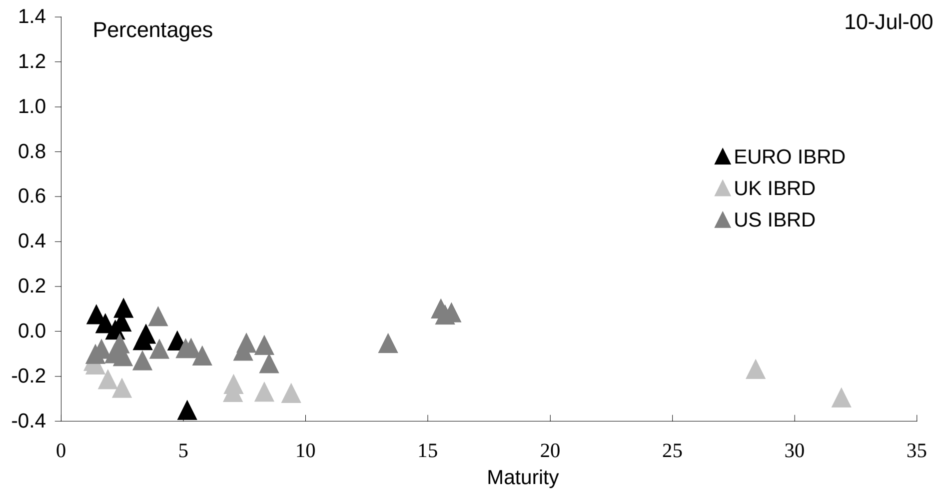



Chart 18

**World Bank spreads against swaps**




## 5. Conclusions

Over the last two years there has been widespread comment on the decline in government bond yields in the United Kingdom and the United States resulting from the reduced issuance of gilts and Treasuries. This paper provides a means for assessing the size of the bias between government bond yields and risk-free rates. We do this by assuming that the interest rate swap market is fairly valued. What we mean by this is that interest rate swap rates are priced off the true risk-free curve with an adjustment for the fair value of the swap spread. We show that this fair value swap spread is driven primarily by expectations of the future spread between Libor and the GC repo rate. Counterparty default risk is *not* a significant driver of swap spreads because swap market participants employ mark-to-market margining and collateralisation to mitigate this. Credit risk considerations should only impact on the fair value of the swap spread via expectations of future six-month Libor-repo spreads. By making further assumptions about these expectations based on the historical behaviour of the Libor-GC repo spread, we can make a simple estimate of the fair value of the swap spread. If these assumptions are correct and government bonds are priced consistently with the risk-free curve, then the observed swap spread will be equal to the fair value. Our measure of the divergence of government bond yields from the risk-free curve, is the excess of the observed swap spread over our measure of its fair value.

How have swap spreads behaved in practice? We have concentrated in this paper on developments in the US dollar, sterling and euro fixed income markets. We have shown that, for much of the 1990s, swap spreads were close to their fair values at maturities up to 10 years for all three currencies. This suggests that, on our measure, government bond yields were close to true default risk-free rates. But starting in 1997, longer maturity swap spreads in both the United Kingdom and the United States widened considerably. This was not just the result of the LTCM crisis (although market anecdote suggests that risk appetite for exploiting wide swap spreads has remained low since autumn 1998), but appears to reflect a longer-term structural change.

This evidence suggests that government bond yields have become depressed in the United Kingdom and the United States. It is another question, though, whether this is attributable to reductions in net supply. The timing of the widening of UK and US swap spreads, which coincides with the beginning of very low or negative net issuance of government bonds, suggests that reduced supply may have depressed long-dated bond yields below risk-free levels. We looked for an econometric link between swap spreads and the net supply of government bonds. The results were mixed. In the United Kingdom a very simple regression suggests a strong negative relationship. But when we incorporated other variables suggested by the literature, in particular the slope of the yield curve, net issuance ceased to be statistically significant. The probable reason for this is that the time series of net issuance of bonds and the slope of the yield curve are highly co-linear. So the change in the slope of the curve is a symptom of the same effect (long government bond yields driven lower by reduced supply).

In the United States the evidence for a link is weaker: the explanatory power of issuance for swap spreads is much lower. And, like in the United Kingdom, issuance appears to be co-linear with the slope of the yield curve, making it difficult to interpret the results. Nevertheless, there is a statistically significant link between net issuance and the swap spread for the two models that omit the slope of the yield curve. Judging from a chart of issuance versus the swap spread, our conclusion for the United States is that if supply has had an impact, it is only a recent phenomenon. But we know that market anecdote suggested that it was expectations of changes in *future* supply that caused much of the widening of swap spreads and our econometrics here could not pick up such a relationship since it was based on current supply.

This paper has also examined two additional issues: (i) how policymakers should measure the risk-free term structure in the presence of distortions to the yield curve; and (ii) whether interest rate swaps are becoming the alternative benchmark for fixed income markets.

Central banks often monitor movements in zero coupon and forward risk-free rates to assess changes in market perceptions of future monetary policy, changes to monetary conditions and the credibility of policy. We have shown how to adjust these curves to correct for biases. To address the second question: by examining spreads of bonds issued by supranationals, we have shown how the swap curve appears to act as a more consistent measure of the risk-free curve than the government curves across currencies. We take this as partial evidence that the swap curve is acting as the new price formation vehicle for movements in risk-free rates across currencies.

As a postscript, in late 2000 and early 2001 swap spreads narrowed somewhat in both the US and UK markets. In the United States, this was partly attributed to the macroeconomic slowdown and the large tax cut packages announced under the new US administration which led to expectations that the outstanding supply of government debt would not fall as quickly as previously thought. In the United Kingdom, the Minimum Funding Requirement legislation (that encouraged defined-benefit pension funds to hold long-dated gilts despite low yields) was, as had been widely anticipated, abolished in the March 2001 budget. So in both cases these moves in the swap spread can be understood as the partial unwinding of the previous demand/supply-driven depression of the respective government bond yields.

# Statistical appendix

Table A

**Econometric models of sterling 10-year swap spreads**

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Constant | 0.71<br>(18.23) | 0.51<br>(4.21) | 0.51<br>(4.27) | 0.29<br>(2.80) |
| Net issuance as a % of GDP | – 0.33<br>(– 7.22) | – 0.07<br>(– 1.33) | – 0.06<br>(– 1.25) | – 0.13<br>(– 2.87) |
| Slope of the yield curve | | – 0.08<br>(– 3.07) | – 0.08<br>(– 3.06) | |
| Three-month Libor-T-bill spread | | 0.11<br>(0.65) | | |
| Three-month Libor | | – 0.04<br>(– 2.37) | – 0.03<br>(– 2.52) | – 0.01<br>(– 0.65) |
| Quarterly return on FTSE | | – 0.08<br>(– 0.28) | | |
| Lagged 10-year swap spread | | 0.61<br>(6.05) | 0.62<br>(6.23) | 0.71<br>(6.86) |
| Adjusted R-squared | 0.50 | 0.76 | 0.77 | 0.74 |

t-statistics in brackets; sample 1987 Q3 to 2000 Q3.

Table B

**Econometric models of US dollar 10-year swap spreads**

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Constant | 0.65<br>(15.75) | 0.24<br>(3.00) | 0.24<br>(1.49) | 0.05<br>(0.66) |
| Net issuance as a % of GDP | – 0.10<br>(– 2.10) | – 0.02<br>(– 0.31) | –0.03<br>(– 0.57) | – 0.08<br>(– 2.60) |
| Slope of the yield curve | | – 0.05<br>(– 2.22) | – 0.05<br>(– 1.34) | |
| Six-month Libor-T-bill spread | | 0.11<br>(0.80) | | |
| Six-month Libor | | – 0.01<br>(– 0.50) | – 0.01<br>(– 0.31) | 0.02<br>(1.19) |
| Quarterly return on S&P 500 | | – 0.18<br>(– 0.43) | | |
| Lagged 10-year swap spread | | 0.77<br>(5.46) | 0.83<br>(7.93) | 0.81<br>(7.75) |
| Adjusted R-squared | 0.07 | 0.73 | 0.74 | 0.74 |

t-statistics in brackets; sample 1989 Q3 to 2000 Q3.

## Data appendix

| Description | | SA/NSA | Start | Source |
|---|---|---|---|---|
| UK BENCHMARK BOND 10-YEAR | RY | - | 1986 Q3 | Datastream |
| US TREAS BENCHMARK BOND 10-YEAR | RY | - | 1983 Q2 | Datastream |
| GERMANY BENCHMARK BOND 10-YEAR | RY | - | 1980 Q1 | Datastream |
| JAPAN BENCHMARK BOND 10-YEAR | RY | - | 1982 Q4 | Datastream |
| CANADA BENCHMARK BOND 10-YEAR | RY | - | 1986 Q3 | Datastream |
| UK (GBP) IR SWAP 10-YEAR | MR | - | 1987 Q2 | Datastream |
| US (USD) IR SWAP 10-YEAR | MR | - | 1987 Q2 | Datastream |
| GERMANY (DEM) IR SWAP 10-YEAR | MR | - | 1987 Q3 | Datastream |
| JAPAN (JPY) IR SWAP 10-YEAR | MR | - | 1989 Q4 | Datastream |
| CANADA (CAD) IR SWAP 10-YEAR | MR | - | 1993 Q3 | Datastream |
| UK INTERBANK 3-MONTH | OR | - | 1986 Q2 | British Bankers' Association |
| US INTERBANK 3-MONTH | OR | - | 1986 Q2 | British Bankers' Association |
| US INTERBANK 6-MONTH | OR | - | 1986 Q2 | British Bankers' Association |
| GERMANY INTERBANK 3-MONTH | OR | - | 1986 Q2 | British Bankers' Association |
| GERMANY INTERBANK 6-MONTH | OR | - | 1986 Q2 | British Bankers' Association |
| JAPAN INTERBANK 3-MONTH | OR | - | 1986 Q3 | British Bankers' Association |
| JAPAN INTERBANK 6-MONTH | OR | - | 1986 Q3 | British Bankers' Association |
| UK TREASURY BILL DISCOUNT 3-MONTH | MR | - | 1980 Q1 | Datastream |
| US TREASURY BILL 3-MONTH | MR | - | 1989 Q3 | Datastream |
| US TREASURY BILL 6-MONTH | MR | - | 1989 Q3 | Datastream |
| GERMANY GC REPO 3-MONTH | MR | - | 1999 Q1 | Deutsche Bank |
| GERMANY GC REPO 6-MONTH | MR | - | 1999 Q1 | Deutsche Bank |
| UK Net issuance of government debt, GBP | CUR | NSA | 1975 Q1 | Office for National Statistics |
| UK Nominal GDP, GBP | CUR | SA | | Office for National Statistics |
| US Govt net borrowing, USD | CUR | NSA | 1968 Jan | International Monetary Fund |
| US GDP, USD | CUR | SA | | International Monetary Fund |
| Canada Govt net lending, CAD | CUR | SA, AR | 1961 Q1 | Statistics Canada |
| Canada GDP, CAD | CUR | SA | 1975 Q1 | Statistics Canada/IMF |
| Germany Public sector debt as % of GDP | - | NSA | | Bundesbank |
| Japan National govt debt, JPY | CUR | NSA | 1980 Apr | Bank of Japan |

| | |
|---|---|
| CUR | current prices |
| NSA, SA | (not) seasonally adjusted |
| RY | redemption yield |
| OR | offer rate |
| MR | middle rate |

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