Credit spreads on sterling corporate bonds and the term structure of UK interest rates

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Abstract

This paper explores the relationship between credit spreads on sterling corporate bonds and the term structure of UK interest rates. In particular, it examines whether credit spreads are a reliable indicator of corporate bond default risk. Using daily price quotes from 1990 to 1998 the paper finds a small negative relationship between credit spreads on sterling investment-grade corporate bonds and the level and slope of the term structure of UK interest rates. The results are weaker than those found by Longstaff and Schwartz (1995) and Duffee (1996 and 1998) who both examine the relationship between US corporate bond credit spreads and the term structure of US interest rates. The weak relationship found suggests that credit spreads on sterling investment-grade corporate bonds have been driven by factors other than default risk. If so, we should be cautious in interpreting such credit spreads as measures of bond default risk. This result is important to both those in the field of financial stability interested in leading indicators of corporate defaults, and to monetary policy makers interested in the impact of interest rate changes on corporate bond default risk. Similar work should be repeated for sterling sub investment-grade corporate bonds once a sufficiently large data set can be assembled.

Summary

This paper explores the relationship between credit spreads on sterling corporate bonds and the term structure of UK interest rates. In doing so, it addresses the extent to which credit spreads are reliable indicators of default risk.

Finance theory has suggested that there is a relationship between interest rates and default risk, and hence a relationship between interest rates and credit spreads. However, the theoretical models conflict as to the nature of this relationship.

On the one hand, 'structural' models based on option pricing suggest that higher interest rates might be associated with lower credit spreads. Such models view equity as a call option on the value of the firm, with the strike price equal to the face value of the debt. For example, in such models, the firm defaults on debt repayment if the value of the firm is less than the face value of the debt on the debt repayment date. A higher risk-free rate in this static model corresponds to a higher expected growth rate in the value of the firm (other things equal) and so a lower level of default probability over any given horizon.

A second view can be derived from 'reduced-form' models. Such models do not attempt to model why firms default on their debt but instead assume that some bonds will default on the balance of probability. There are numerous types of reduced-form models; in the one used in this paper investors demand compensation for default risk by grossing up the coupon paid on a default-free bond by the expected default probability. If interest rates rise by 1 basis point, the gross-up effect increases the coupon by more than 1 basis point. Thus, the differential between the coupon on the corporate bond and the coupon on the risk-free bond increases in absolute terms with the size of the default-free coupon and credit spreads rise when the default-free interest rate rises.

This paper examines the empirical relationship between credit spreads on single-A and Aa-rated sterling corporate bonds and the level and slope of the UK yield curve for the period 1990 to 1998. The corporate bond price data are quotes rather than actual trades. Corporate bonds can be much less liquid than government bonds and it is possible for some corporate bonds not to trade for long periods of time. As a result, price quotes may not reflect all current information and so calculated credit spreads might reflect delays in the arrival of information rather than economic factors. Any such bias is likely to be exacerbated at times when information arrives frequently – for example, when government bond prices move sharply over short periods of time.

The credit spread series calculated exhibits particularly high volatility during the second and third quarters of 1994, a period when prices in the gilt market fell sharply. This volatility could have been due to uncertainty in the corporate bond market or could have been a result of non-synchronous gilt and corporate bond data. The paper finds that, though the occurrence of unchanged prices was high in the data set, they were not particularly prevalent during the period of high credit spread volatility in 1994.

Due to the possibility of stale prices throughout the data set the paper runs two sets of regressions: one set using daily data with an adjustment for non-synchronous prices and a second set using weekly data with no such adjustment. The results of the two sets of regressions are similar: in both there is a negative correlation between credit spreads and the slope and level of the yield curve. However, most of the coefficients in the regressions using daily data are statistically insignificant, while the coefficients in the regressions using weekly data are more negative, and most are

statistically significant. All results are economically small, in that a large change in the yield curve is required to produce measurable movements in spreads, suggesting the relationship is weak.
The weak relationship between interest rates and credit spreads in this study gives us cause to doubt whether such credit spreads are reliable indicators of corporate bond credit risk. One potential explanation is that factors other than interest rates are more important in driving credit risk. More likely is the possibility that the credit risk component of credit spreads on investment-grade corporate bonds is small relative to factors such as liquidity and risk aversion. Studies using US data suggest that this latter explanation is correct. So an interesting extension to this work would be to undertake a similar study on sub investment-grade sterling corporate bonds, where one would expect the credit risk component of credit spreads to be greater. However, we will probably need to wait for more sterling sub investment-grade corporate bonds to be available and for a sufficiently long history of data before conclusions can be drawn from that market.

1 Introduction

This paper examines whether credit spreads on sterling corporate bonds are reliable indicators of corporate default risk by looking at the relationship between credit spreads and the term structure of UK interest rates.[1] If the levels of current and expected future interest rates (the slope of the term structure) influence default risk and credit spreads reflect default risk then we would expect to find a correlation between interest rates and credit spreads on corporate bonds.

There are conflicting theories as to the relationship between credit spreads and interest rates. Section 2 of this paper explores some of these theoretical relationships by reviewing models developed in the literature for pricing default-risky debt. Structural models that link the cost of corporate debt to expected firm values and the volatility of firm values suggest that higher interest rates might be associated with lower credit spreads. This is because higher interest rates in those models correspond to a higher drift rate in the firm value process, and hence lower risk neutral default probabilities. In contrast, models that link directly the cost of corporate debt to default risk and recovery rates suggest that credit spreads should rise when short-term interest rates rise, even if the default probability remains constant. This is because investors will gross-up default-free yields by the probability of default in order to determine the yield on a default-risky bond. Thus, if the yield on a default-free bond rises by 1 basis point, investors will demand a rise of more than 1 basis point in yield on a default-risky bond. Moreover, if the probability of default rises when interest rates rise, for example because the firm faces liquidity constraints, then credit spreads would rise further in response to a rise in interest rates.

A number of authors have examined empirically the relationship between credit spreads and the term structure of interest rates. For example, Longstaff and Schwartz (1995) find that there is a strong negative relationship between credit spreads and both the level and slope of US Treasury yields using monthly US corporate bond yield indexes. However, since the yield indexes used by the authors include callable as well as non-callable bonds the results from their study may be overstated since the value of a bond call option tends to fall when interest rates rise. Duffee (1996 and 1998) found a weaker negative relationship between the level and slope of the Treasury yield curve and US corporate credit spreads using month-end data on non-callable US corporate bonds. He found that the responsiveness of credit spreads was weaker for high-rated bonds and stronger for low-rated bonds.

In this paper I examine the relationship between sterling investment-grade corporate credit spreads and the gilt term structure using daily and weekly data. Credit spreads are calculated using a gilt-matching methodology rather than from benchmark government bonds. The approach I use avoids duration mismatches that can arise from using benchmark bonds, although it can introduce estimation error problems instead. The paper also explores the impact of illiquidity in the sterling corporate bond market on credit spread calculations and its implications for the relationship between quoted bond prices and the gilt term structure.

The rest of the paper is set out as follows. Section 2 provides a literature review. Section 3 provides some descriptive statistics of the data used in this paper, the methodology for calculating the credit

(1) Where the credit spread is defined as the difference between the yield on a corporate bond and the yield of a government bond with identical promised cash flows. An alternative is to calculate spreads relative to swaps. Calculating spreads to government bonds has the advantage of avoiding any credit risk that might be embedded in swap rates, particularly since the practice of collateralising marked-to-market swap positions has been a relatively recent development; a disadvantage of calculating spreads to government bonds is that government bond yields may be sensitive to both corporate and government bond issuance.

spreads and investigates the problem of non-synchronous data. The regression model is presented in Section 4 and results are given in Section 5. Conclusions are set out in Section 6.

2 Review of the literature

This section reviews some models for pricing corporate bonds and discusses their implications for the relationship between corporate bond credit spreads and the term structure of interest rates. Corporate debt pricing models broadly fall into one of two classes: structural models and reduced-form models. The main characteristics of these model types are summarised in Sections 2.1 and 2.2 below. Section 2.3 reviews the results of some empirical work in the literature.

2.1 Intuition provided by structural models

Structural models follow the framework set out by Merton (1974) in using the principles of option pricing to price default-risky debt. Default is viewed as a call option held by equity holders which is exercised when the value of the firm falls below a given threshold. This option can be priced using techniques developed by Black and Scholes (1973) and Merton (1974). In these models, the price of a company's debt is a function of the firm's value, the default-free interest rate, the maturity of the debt, the company's gearing and the expected volatility of the firm's value.

Merton (1974) considers a firm whose capital structure comprises equity and a single zero-coupon bond. Default occurs if the firm's value at the maturity of the bond is below the value of the debt: the firm is unable to repay its debt even if it is able to liquidate all its assets. In Merton's model, the firm can default only on the maturity date of its zero-coupon bond since this is the first and only date when the firm makes a payment to bondholders. Repayment to bondholders in the event of default is the market value of the firm.

Merton assumes a flat term structure of default-free interest rates. Therefore, in his model, it is not possible to examine the relationship between credit spreads and changes in the slope of the yield curve. Since default can occur only on the maturity date of the zero-coupon bond, default risk depends on the value of the firm relative to the value of the debt at that time. A higher interest rate results in a higher drift rate for the firm value process and hence to lower risk-neutral probabilities of default at maturity.(2) This leads to the result that in Merton's model, a higher default-free interest rate is associated with lower credit spreads.

More recent structural models for valuing default-risky debt allow default to occur prior to the date on which the debt matures. In these models, the time of default is determined by the time the firm value first falls below a particular threshold.(3) As in Merton's model, Longstaff and Schwartz (1995) assume that the value of the firm follows a diffusion process with constant volatility. However, in the Longstaff and Schwartz paper, default-free interest rates are allowed to move randomly over time.(4) Such extensions to Merton do not alter the result that an increase in interest rates leads to a fall in default risk, and hence to a fall in the credit spread. This is because the probability of the bond

(2) This assumes that the current firm value remains unchanged after the increase in the interest rate. If the current value of the firm falls as a result of the rise in interest rates then the impact on the risk neutral probability of default is ambiguous and is related to the duration of the debt. Whether or not the value of the firm does change as a result of a change in interest rates is an empirical question.
(3) These models are termed 'First passage-time specifications'. The default threshold can be either constant or random.
(4) Interest rates are specified according to the Vasicek (1977) model.

defaulting continues to depend on the relative gap between the constant default threshold and the value of the firm.

2.2 Intuition provided by reduced-form models

'Reduced-form' models avoid using the firm's value to model default risk. In these models, default can occur for reasons other than a low firm value. For example, liquidity problems could be the trigger for default. Reduced-form models do not attempt to explain why default occurs but allow a hazard rate process (ie an evolving probability of default) to be specified. Since these models do not specify a firm value process, the payoff in the event of default is determined exogenously.

Jonkhart (1979) presents a simple model that links the probability of default directly to credit spreads without specifying a hazard rate process. The contracted rate of interest on par coupon bonds is calculated as a function of expected future default probabilities, recovery rates and default-free interest rates. In this framework, the credit spread demanded by investors rises when short rates rise. This is because investors gross up the default-free coupon by the probability of default to compensate for the possibility of default loss (in the same way that an investor calculates his required pre-tax return by grossing up his required post-tax return by his marginal tax rate). This grossing up means that a rise of 1 basis point in yield on a default-free bond leads to a rise of more than 1 basis point in yield on a default-risky bond.(5) Jonkhart's model further predicts that the rise in the credit spread resulting from a rise in short rates is greater for more default-risky bonds.

However, an increase in long forward rates can result in a fall in the credit spread. The intuition behind this can be explained by considering the contracted rate of interest on a ten-year annual par coupon bond that has a high probability of default in each future year. Most of the expected income from this bond will be received in the early years via high coupon payments; the investor may expect to receive little or none of the principle payment at maturity. A rise in the ten-year default-free forward rate by 1 percentage point would therefore have little impact on the calculated yield on this *default-risky bond*. In contrast, a rise in the ten-year default-free forward rate would increase the yield on a *default-free bond* through the discount effect on the principle repayment in the tenth year. Hence the credit spread between the default-risky bond and the default-free bond could tighten as long forward rates rise. Essentially, the duration of a coupon-paying default-risky bond is shorter than the duration of a default-free bond with the same promised cash flows.

While Jonkhart's pricing model for default-risky bonds implies that a rise in long forward rates could lead to a fall in credit spreads, an increase in the *slope* of the default-free yield curve could result in either a rise or a fall in credit spreads. That is because an increase in the slope of the default-free yield curve involves an increase in both short and long forward rates. One reduces the credit spread while the other increases the credit spread.

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(5) For example, suppose that the probability of default, D, on a one-year annual coupon bond is known and the recovery rate in the event of default is zero. If the one-year default-free interest rate is R, and the coupon on a bond is C, then a risk-neutral investor would price the bond as follows: $P = \frac{(1+C)(1-D)}{1+R}$. This can be re-arranged to determine the credit spread: $P = \frac{1+C}{1+R+\frac{D(1+R)}{1-D}}$. Differentiating the credit spread with respect to R gives $\frac{D}{1-D} \geq 0$. Note that this positive relationship between the credit spread and default-free interest rate exists even for risk-neutral investors.

Fons (1994) derives a simple bond pricing model to calculate the credit spread required by a risk-neutral investor on a default-risky bond issued at par, using historic default rates. He finds that his calculated credit spreads are always lower than credit spreads observed in the market, particularly for investment-grade bonds. He puts forward several reasons for this difference: lower liquidity in corporate bonds leads to a liquidity premium; tax effects that favour Treasuries over corporate bonds; risk-aversion of investors; and the risk of downgrade of bonds (event risk). Interestingly, he finds that the credit spreads estimated from his model are relatively insensitive to the yield on default-free bonds.

More recent reduced-form models have been built from models of stochastic interest rates, augmented with a hazard rate process. For example, Jarrow and Turnbull (1995) use the underlying interest rate model of Heath *et al* (1992) and specify a constant hazard rate. In the event of default the face value of the default-risky bond is assumed to fall to a constant fraction of its previous face value. Since the default process and the default-free interest rate process are assumed to be independent, interest rates do not drive credit spreads in this model.

Many reduced-form models allow the probability of default to vary over time, sometimes related with the level of interest rates. These models assume that defaults follow a Poisson process, with default occurring when the Poisson counter changes for the first time. The probability of default over a small time interval is specified by the intensity of the Poisson process. In all such models, the independence or dependence of interest rates and credit spreads is imposed on the model through the assumption about the independence or dependence of interest rates and default risk.

2.3 Empirical research

Nielsen and Ronn (1996) describe a two-factor model for default risk where interest rates (the first factor) and credit spreads (the second factor) are lognormally distributed and may be correlated. The recovery rate is assumed to be constant and so the implied hazard rate, following Duffie and Singleton (1997), is the default spread divided by one minus the recovery rate. The authors use data on US Treasury and corporate bonds to estimate the parameters of the model. They find that the estimated correlation between interest rates and the default spread is almost always positive, in contrast to the findings of Longstaff and Schwartz (1995) and Duffee (1996 and 1998) who find a negative correlation.

Fridson, Garman and Wu (1997) argue that default rates are linked to real interest rates rather than nominal interest rates. If nominal interest rates rise because inflation has risen, then a company’s income could be expected to rise in line with its interest payments. The authors use quarterly data from 1971 to 1995 and find a positive correlation between default rates and real interest rates. They argue that companies tend to default only after a delay, when they have exhausted their liquidity reserves and credit lines. When lags of the real interest rate are included in the model, Fridson *et al* find a maximum correlation of 0.5 between default rates and real interest rates.

3 Data methodology

The following Sections 3.1 and 3.2 describe the data set used here and the methodology by which credit spreads are calculated. Sections 3.3 to 3.4 examine the extent to which the bond prices in the data set are affected by non-synchronous data.

3.1 Description of the data set

The data used in this paper are daily bond price quotes from a data set of 340 sterling corporate bonds. The bonds are of varying credit qualities, ranging from Moody's Aaa to Ba, with the majority of bonds rated investment grade (rated Baa or higher). Data have been supplied by SBC Warburg (now UBS) for the period January 1990 to December 1996, and extended to December 1998 using price quotes from the Reuters 3000 database. In order to have a consistent extension of the data set from 1996, only bonds that existed in the SBC Warburg data set were taken from the Reuters 3000 database.(6) Bonds with call features or other embedded options were excluded from the data set, since the prices of such bonds are influenced by the value of the embedded option.

Another important feature of both data sets is that the prices are quotes and hence do not necessarily reflect actual trades. The secondary market for sterling corporate bonds is less liquid than the secondary markets for government bonds. Some bonds may not trade daily, leading to the possibility of stale price quotes and hence non-synchronous data. Section 3.3 examines the possibility of non-synchronous data and its implications for the calculated spread series.

3.2 Construction of the spread series

The bonds in the data set were categorised by credit rating and duration to create a total of twelve bond yield indices. The rating categories used were Moody's Aaa, Aa, A and sub-A; the duration categories were 0 to 4 years, 4 to 8 years and 8 to 12 years. The credit rating and duration composition of these indices was kept constant over time. Thus, as a bond was upgraded or downgraded it was moved from its existing index to the index of its new rating.(7) Likewise, a bond was re-categorised when its duration fell below the duration band for its index.

The subdivision by bond duration rather than maturity can be significant for the responsiveness of an index to a change in interest rates. This is because an increase in the level of the Treasury term structure shortens the duration of coupon-paying bonds. If the term structure of credit spreads is not flat, a rise in the default-free interest rate could, through duration effects, result in a change in the measured credit spread even if there was no change in the default risk of the bond. Ideally, credit spreads would be calculated from zero-coupon corporate bonds to avoid such effects. However, there are very few zero-coupon bonds in the UK corporate bond universe, so this approach is not possible. The method of categorising bonds by duration rather than maturity reduces the coupon bias in credit spread measurement.

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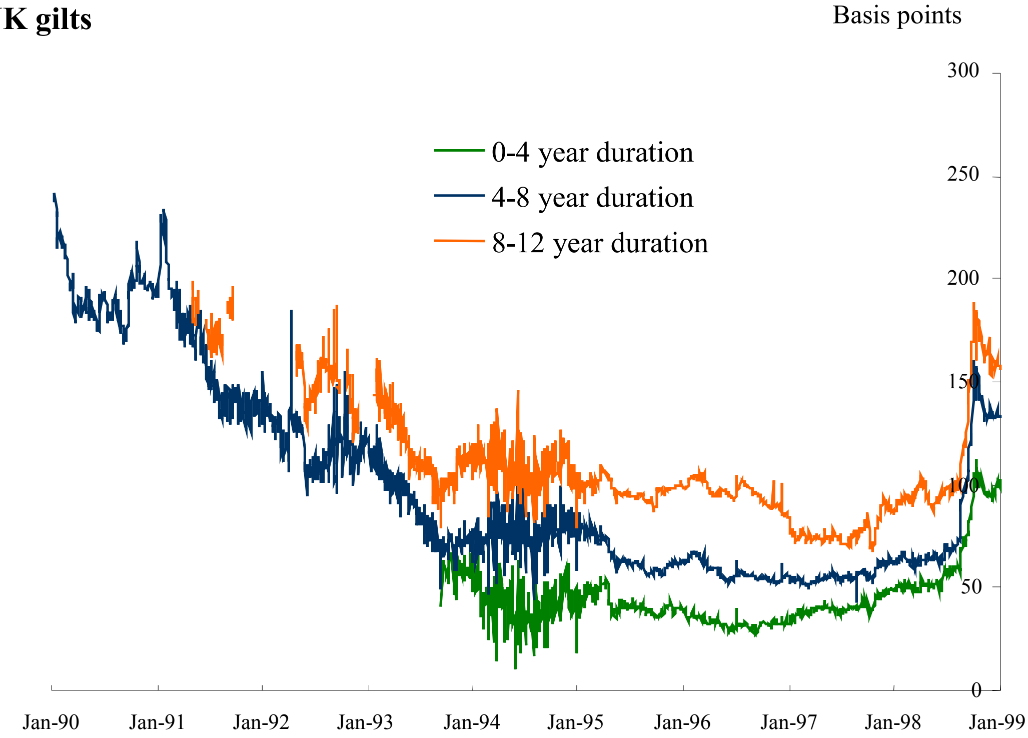
(6) While this has the advantage of consistency with the existing data set, it has the disadvantage of excluding new issues. It should also be noted that during the period 1990 to October 1998, both gilt and eurosterling bond prices were quoted in 32nds; after October 1998 prices in both markets were quoted in decimals.

(7) Duffee (1996) allows a bond to remain in its existing rating category for one period (a month) after its rating changes. This is so that the impact of a change in a bond's credit risk on its existing index is not lost when a bond is downgraded or upgraded. Duffee's procedure is not carried out in this paper, since I work with daily data and credit rating revisions are often priced into spreads before a rating agency announces the change in credit rating.

A-rated sterling yield spreads over duration-matched UK gilts

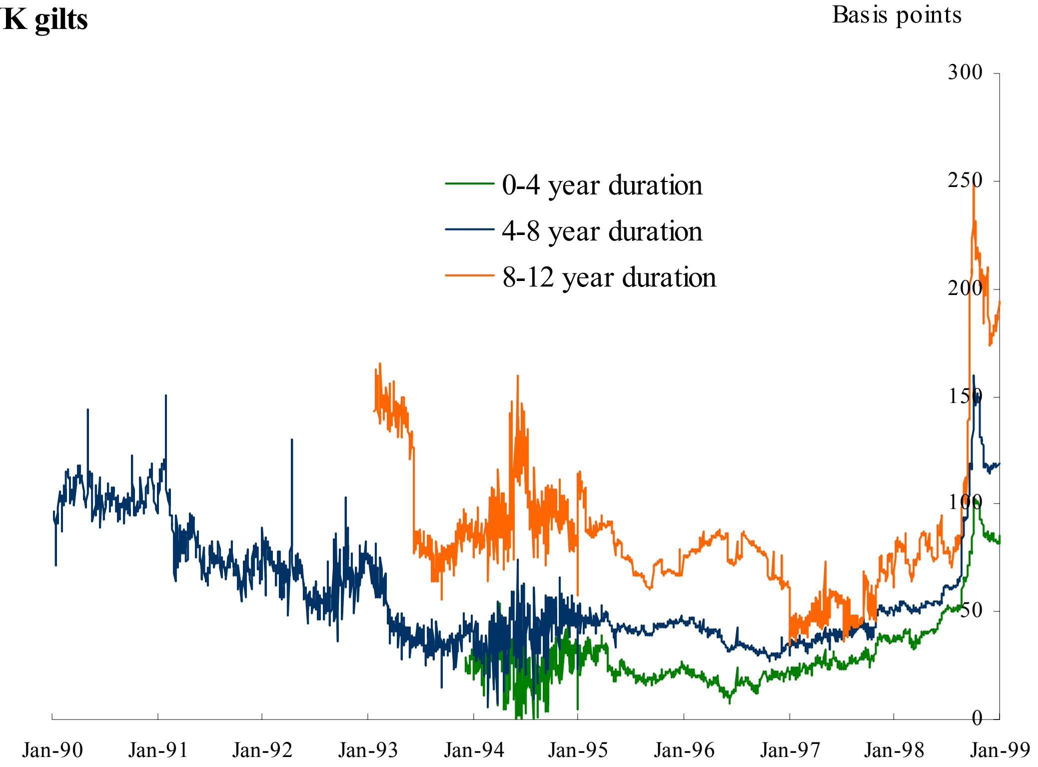


The SBC Warburg data set comprises a growing number of corporate bonds over time, with 7 corporate bonds rated A and Aa in 1990 and 130 corporate bonds rated A and Aa in 1996. The subdivision of the data set into 12 categories of credit rating and duration meant that some categories had few or no observations in 1990. There was an insufficient number of Aaa and sub-A rated bonds to create statistically meaningful aggregate indices for these categories over the sample period. Thus, it was decided to work with the two remaining rating categories: Aa and A.

The data set contains bonds issued by both UK and non-UK companies. Of the 100 Aa-rated bonds in the data set UK companies issued 47; companies based mainly in continental Europe and North America issued the other 53. In the A-rated category, UK companies issued 58 of the bonds and companies based mainly in North America and continental Europe issued 16. While ideally the data set would comprise only UK companies, it would not have been possible to create long-run data series without including non-UK companies.[8]

[8] One uncertainty is the extent to which each company is exposed to UK interest rates. One would expect a UK company to have a greater proportion of its debt denominated in sterling than a non-UK company. The precise exposure is difficult to gauge, however, not least because large corporations may use derivatives to hedge interest rate and currency risk.

Aa-rated sterling yield spreads over duration-matched UK gilts



The spread calculation methodology used in this paper differs from that employed by Duffee (1996) and others. There are a number of choices for the default-free benchmark from which credit spreads are calculated. Duffee (1996) takes as his benchmark an interpolated point between the closest constant maturity US Treasury yields on each side of the bond's remaining maturity. That method suffers from coupon bias, in that the duration of the benchmark Treasury can be different to the duration of the corporate bond. Thus the calculated credit spread can contain measurement error if the Treasury yield curve is not flat. Moreover, if the slope of the Treasury yield curve changes, this can result in a spurious change in the credit spread due to duration mismatching.[9]

In this paper, I calculate the credit spread on a corporate bond by subtracting the yield on a 'pseudo' government bond from the yield on the corporate bond. The pseudo government bond has identical promised cash flows to the corporate bond and is priced using data generated from the Bank of England's spline yield curve model.[10] This methodology minimises the measurement error when recalculating credit spreads following a change in the slope of the Treasury yield curve.[11] At times during the sample period used in this paper, the gilt term structure became very steep in the 0 to 5-year

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(9) Duffee (1996) found that coupon bias appeared to explain why credit spreads on long-maturity bonds were more sensitive to changes in the slope of the yield curve. In an earlier version of his 1996 paper, Duffee repeated his regressions for a small sample of zero-coupon bonds. He found that the relationship between credit spreads and the slope of the term structure was statistically insignificant while the relationship between credit spreads and the level of the term structure was only significant for short-maturity bonds.

(10) The spline data used here, going back to 1990, is published on the Bank's web site.

(11) In fact, the *expected* cash flows of a default-risky bond are lower than the *expected* cash flows of a default-free bond when the *promised* cash flows are the same on each bond. The resulting difference in duration is small except for those bonds with significant probabilities of default. In this study, I consider bonds rated single-A and higher, so this effect would be small.

maturity range. A mismatch of corporate bond and gilt maturities by 6 months could have resulted in a miscalculation of credit spreads, using the gilt benchmark method, of up to 50 basis points.

The duration-matched credit spread methodology used here also has disadvantages. Traders often price a corporate bond over a similar maturity liquid government bond, and so the credit spread might be correlated with idiosyncratic changes in certain government benchmark bonds. A methodology that calculates credit spreads from a default-free yield curve rather than a benchmark government bond will not take these movements into account. Furthermore, estimation errors in yield curve construction will transfer to calculated credit spreads. However, these disadvantages are likely to be outweighed by the advantage of accurately duration-matching the government benchmarks, since the primary concern of this paper is to examine the relationship between credit spreads and movements in the level and slope of the gilt yield curve.

Tables 2 and 3 in the annex provide summary statistics of the calculated credit spread series. The series exhibit the usual characteristics of investment-grade credit spreads in that credit spreads are wider for lower-rated bonds and longer-duration bonds. For example, the average credit spread for 8-12 year duration bonds rated single-A was around 100 basis points, compared to 80 basis points for bonds rated Aa of the same duration. In contrast, the average credit spread for 0-4 year duration bonds over the sample period was around 40 basis points and 25 basis points for single-A and Aa-rated bonds respectively.

The volatility of the credit spread series is variable throughout the sample period. The series exhibit high volatility in the period from February 1994 to October 1994, coinciding with a sharp bear market in gilts. Over this period, long gilt yields rose around 300 basis points from just over 6% to over 9%. Uncertainty would have played a part in the rise in volatility of the credit spread series, but the presence of non-synchronous data might have exaggerated volatility in this period. This latter possibility is explored in the following section.

3.3 Investigation into the presence of non-synchronous data

The six credit spread series calculated here indicate a period of high volatility during the second and third quarters of 1994. Given that the period of high spread volatility coincided with sharp falls in gilt prices during 1994 I investigated whether this volatility was exaggerated by the presence of non-synchronous data at that time.[12] During volatile market periods, liquidity in corporate bond markets can deteriorate if traders become reluctant to offer two-way prices. In addition, traders that mark-to-market their bond portfolios might not be able to price bonds accurately owing to lack of firm market prices. If stale prices (ie no reported price change) or non-synchronous prices are reported, then this could create a bias in the calculated credit spread between corporate bonds and government benchmark bonds. If changes in corporate bond prices lag changes in government bond prices when gilt prices are falling rapidly, it is possible that even negative credit spreads could be observed.

In testing whether stale or non-synchronous price data were responsible for the volatility in spreads during 1994 it was necessary to return to price data on individual bonds. Three sterling corporate bonds were taken from each of the rating categories Aa, and single-A. The bonds were chosen on the basis that they existed for as much of the 1990-96 period as possible, and they came from a variety of business sectors.[13]

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[12] The hypothesis is that changes in sterling bond yields lagged changes in gilt yields during that period, leading to a tightening and then widening in credit spreads.

[13] From 1996 to 1998, the price source changed to Reuters 3000, so the sample was restricted to the period 1990 to 1996.

3.4 *Tests for stale prices*

Two tests were carried out to see if stale prices had been more prevalent during the 1994 bear market (from February to October). The first test was to compare the number of days where the price remained unchanged across different sample periods. The 1990-96 price data for each bond was divided into three samples: (1) the period 1 January 1990 to 31 January 1994; (2) the period 1 February 1994 to 31 October 1994; and (3) the period 1 November 1994 to 31 December 1996. In each sample, the ratio of the number of times a price remained unchanged to the total number of price quotes in the sample period was calculated. Results are given in the table below.

Table 1: Proportion of days in each time period for which prices remained unchanged

	AA bonds			**A bonds**		
	McDonalds Corp	NatWest Bank	Thames Water	Pearson	British Airways	Severn Trent
Date issued	7/12/88	2/5/91	21/11/91	13/6/88	5/6/88	12/7/91
Pre-bear market	58.1%	29.0%	22.4%	11.4%	11.8%	28.0%
Bear market	17.1%	8.1%	6.6%	2.8%	4.3%	10.0%
Post-bear market	19.0%	9.3%	8.7%	7.5%	7.1%	13.9%

The figures in Table 1 indicate that the 1994 bear market period had the smallest proportion of days where prices remained unchanged, suggesting that there was not a prevalence of stale prices in this period – on the contrary prices changed more often in the 1994 bear market. However, the proportion of days where the price remained unchanged is relatively high throughout all the periods, which suggests that the presence of stale prices may be a more general problem when working with corporate bond data. The higher proportion of unchanged prices in the pre-bear market period than in the post bear market period suggests that the market became more liquid during the 1990s.

A second test was carried out to see if there was any correlation between stale prices and gilt market conditions. A dummy variable was set equal to 1 if the price of the bond remained unchanged from the previous day and 0 if the price changed. This time series was regressed on the change in the bond's corresponding duration-matched gilt yield. If stale prices had occurred more frequently during a period of rising gilt yields, the estimated coefficient on the change in the gilt yield would be positive (ie as gilt yields rose, non-trading occurred more frequently). The regression was carried out for the six bonds listed in the table above.

The results from the regression showed that there was no consistent relationship between changes in the gilt yield and stale prices.(14) It was concluded that the possible presence of stale prices could not account for the increase in credit spread volatility during the 1994 bear market. Instead, investor uncertainty during this period was the likely cause of the increase in credit spread volatility.

(14) The estimated slope coefficient varied between being positive and negative across the six bonds tested.

4 Model specifications and estimation

I use the same model specification as Duffee (1996) to examine the relationship between credit spreads and the gilt term structure. The gilt yield curve is parameterised through two factors, the three-month sterling Libor rate and a slope variable calculated as the difference between ten-year gilt yields and three-month sterling Libor.[15] This parameterisation of the yield curve captures much of the movement in the UK term structure, as shown by Steeley (1990 and 1992).[16]

The equation to be estimated is given by:

$$\Delta S_t = a + \sum_{j=-1}^{1} b_j \Delta Y_{t+j} + \sum_{j=-1}^{1} c_j \Delta SL_{t+j} + e_t$$

Where ΔS_t is the daily change in corporate spreads, ΔY_t is the daily change in the three-month sterling Libor rate and ΔSL_t is the daily change in the slope of the gilt yield curve. The error term e_t is assumed to have a normal distribution with zero mean. The equation was estimated using ordinary least squares (OLS) and the variance-covariance matrix of the estimated coefficients was adjusted for generalised heteroscedasticity using the Newey-West technique.[17]

The inclusion of lead and lagged term structure regressors is to correct for non-trading.[18] This approach is based on Scholes and Williams (1977), and further developed by Dimson (1979). The intuition behind Scholes and William's approach is that prices may only be reported at distinct, random intervals. This introduces errors-in-variables into econometric models that use only contemporaneous variables, leading to biased and inconsistent OLS estimators.[19] Aggregating lagged, current and lead coefficients (the 'AC method') helps to eliminate this bias when trading times are unknown.[20]

OLS regressions were carried out for Aa and A-rated sterling bond indices in the sample period 4 January 1990 to 31 December 1998. Separate regressions were run for short, medium and long-duration bonds, giving six sets of regression results. The results are reported in Table 4 in the annex. The 'short' duration credit spread series comprises corporate bonds with durations of between 0 and 4 years; 'medium' duration comprises bonds with durations of between 4 and 8 years; and 'long'

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(15) Duffee parameterises the US Treasury term structure through the three-month Treasury bill yield and a slope variable (the spread between 30-year Treasury yields and three-month Treasury yields). Three-month Libor is used here because of the lack of reliable data in the sterling Treasury bill market.

(16) Litterman and Scheinkman (1991) find a similar result for the US term structure.

(17) At a later stage, the squared change in the three-month rate was added to the equation as a proxy for volatility. However, in all regressions the coefficient was found to be statistically insignificant.

(18) The equation was tested with more than one lag, but it had little impact on the regression results.

(19) Scholes and Williams (1977) find that this problem is particularly severe when using daily data.

(20) Dimson (1979) proposed introducing the AC method in the context of measuring firm betas. He compared the characteristics of these estimated betas with the principal alternative techniques for dealing with infrequent trading – namely adjusted simple regression, simple regression with overlapping observations, trade-to-trade regression and the Scholes-Williams (1977) method. He found that the AC method compared favourably with the other methods and that it eliminated most of the bias in beta attributable to non-trading. Cornell and Green (1991) and Fama and French (1992) also adopt the AC method to measure betas. Fama and French (1992) note the result of Fowler and Rorke (1983) that shows that betas measured using the AC method are biased when the market return (the regressor) is autocorrelated. In that case the coefficients calculated using the AC method need to be adjusted by $1/(1+2\rho)$ where ρ is the autocorrelation coefficient of market returns. In the present study, I find that daily changes in the level and slope of the gilt term structure are only slightly negatively autocorrelated and thus the adjustment proposed by Fowler and Rorke does not affect the results. I therefore only report the simpler coefficients derived from the AC method.

duration comprises bonds with durations of between 8 and 12 years. The variance-covariance matrix of the estimated coefficients was adjusted for generalised heteroskedasticity using the Newey-West technique. T-statistics for the significance of coefficients at the 5% level are given in parenthesis and probability values of χ^2 tests for the significance of aggregated coefficients at the 5% level are in square brackets.

In addition to the above regressions using daily prices, a second set of regressions were undertaken using weekly prices. If prices were updated (or trades occurred) at least once a week then regressions using weekly data would mitigate any non-trading problems. Thus, the results of the regressions using daily prices could be benchmarked against the results derived using weekly prices.

The equation estimated for the weekly prices was:

$$\Delta S_t = a + b\Delta Y_t + c\Delta SL_t + e_t$$

where ΔS_t is the weekly change in corporate spreads, ΔY_t is the weekly change in the three-month sterling Libor rate and ΔSL_t is the weekly change in the slope of the gilt yield curve. The error term e_t is assumed to have a normal distribution with zero mean. The equation was estimated using ordinary least squares (OLS). There was evidence of heteroscedasticity in the error terms and the variance-covariance matrix of the estimated coefficients was therefore adjusted using the Newey-West technique.

5 Regression results

The regression results using daily data are presented in Table 4 in the annex. In all but two of the regressions that used daily data, there were no statistically significant relationships - at the 5% level - between credit spreads and the term structure of UK interest rates. There was a weak negative relationship between Aa-rated, short duration credit spreads and the *slope* of the term structure of interest rates and a weak negative relationship between Aa-rated, medium duration credit spreads and the *level* of the term structure of interest rates. In both regressions the negative relationship was economically small: credit spreads fell in both cases by 8 basis points for every percentage point rise in the slope (level) of the term structure of interest rates. The adjusted R-squared for each of the regressions ranged from 0.26 to 0.37.

Some additional regressions were run excluding the crisis period of August-December 1998, when credit spreads had widened by over 100 basis points in a few weeks. This was to test whether the relationship between credit spreads and the term structure of interest rates changed during the crisis period. However, the regression results were unchanged from those of the original regressions.

Duffee (1998) found that short-term US interest rates and credit spreads on non-callable US corporate bonds were negatively related: credit spreads on Aa and single-A rated corporate bonds fell by between 15 and 24 basis points for a 100 basis points increase in short-term US interest rates. Duffee found no consistent statistically significant relationship between the slope of the Treasury yield curve and bond spreads. The results found in this paper, using daily data, are more consistent with those found by Duffee (1996) in his regressions that adjust for coupon bias.

The regression results using weekly data are presented in Table 5 in the annex. In five out of these six regressions the coefficients on both the level and the slope were statistically significant and negative: credit spreads fell by 5 to 16 basis points for a 100 basis points increase in either the short-term default-free interest rate or in the slope of the yield curve. However, the adjusted R-squared for the regressions using weekly data were 0.13 or lower, possibly due to the drop in sample size when using weekly data. Thus, the regressions explained very little of the variation in sterling corporate credit spreads over the period.

The relatively weak relationship between credit spreads and the term structure of UK interest rates suggests that credit spreads are driven by factors other than default risk or that the link between interest rates and default risk is weak, which seems unlikely. Empirical work by Fridson *et al* (1997) on the US high-yield bond market indicates that default rates are positively correlated with lagged *real* interest rates. In the United Kingdom, trade credit insurer Euler reported that much of the increase in UK insolvencies during the first quarter of 1999 was due to the rise in UK interest rates in 1998. Thus, it appears that in both the United States and United Kingdom, there is a link between default risk and real or nominal interest rates. The absence of a significant positive relationship between interest rates and credit spreads in this paper therefore suggests that credit spreads on investment-grade bonds are driven by factors other than default risk.

6 Conclusions

The regression results using daily data showed that there was no consistent significant relationship between sterling corporate bond credit spreads and the level and slope of the term structure of UK interest rates. This result was unchanged when the crisis period of August to December 1998 was excluded from the regressions. In the regressions using weekly data there was a consistent statistically significant relationship between credit spreads and the level and slope of the gilt term structure, although the relationship was not strong. These indicated that credit spreads could fall by between 5 to 16 basis points for a 100 basis points rise in the level or slope of the gilt term structure over the period of one week.

The low sensitivity of credit spreads to changes in the term structure of interest rates suggests that credit spreads on investment-grade sterling corporate bonds have been driven by factors other than default risk. Recent studies on US corporate bond spreads by Elton *et al* (2001), Collin-Dufresne *et al* (2001) and Huang and Huang (2002) seem to support this conclusion. The results found here give us some cause to doubt the reliability of credit spreads on sterling investment grade corporate bonds as pure indicators of bond default risk. This finding is relevant to both financial stability, in terms of identifying leading indicators of corporate stress, and to monetary policy, where the concern is related more to the direct link between interest rates changes and corporate default risk.

A natural progression for future work is to investigate the extent to which liquidity drives credit spreads on corporate bonds. The obvious difficulty in conducting such work is deriving a model that can distinguish between liquidity and default risk. It would appear from the work carried out here that the default risk on investment-grade corporate bonds is small relative to other factors. This would point towards analysis on sub investment-grade bonds where default risk is more likely to drive credit spreads. However, researchers will have to wait until there are a greater number of sterling sub investment-grade corporate bonds before a robust analysis in this area can take place.

Annex – Statistical tables

Table 2 – Summary statistics of A-rated credit spread series

	0-4 year duration		4-8 year duration		8-12 year duration	
	Average spread (bps)	Average no. observations	Average spread (bps)	Average no. observations	Average spread (bps)	Average no. observations
1990	N/A	0	194	5	N/A	0
1991	N/A	0	163	9	178	1
1992	N/A	0	121	18	149	1
1993	75	1	87	25	117	4
1994	43	8	77	27	109	5
1995	42	4	65	19	97	2
1996	33	16	58	36	96	7
1997	41	16	56	36	77	7
1998	67	16	89	36	117	7

Table 3 – Summary statistics of Aa-rated credit spread series

	0-4 year duration		4-8 year duration		8-12 year duration	
	Average spread (bps)	Average no. observations	Average spread (bps)	Average no. observations	Average spread (bps)	Average no. observations
1990	N/A	0	103	2	N/A	0
1991	N/A	0	80	5	N/A	0
1992	N/A	0	66	11	N/A	0
1993	26	1	43	24	105	2
1994	25	9	41	33	97	2
1995	24	19	44	30	78	3
1996	18	33	36	35	77	3
1997	28	33	41	35	53	3
1998	58	33	79	35	116	3

Table 4 – Summary of regression results, using daily data

The following equation was estimated for six regressions using OLS on daily data:

$$\Delta S_t = a + \sum_{j=-1}^{1} b_j \Delta Y_{t+j} + \sum_{j=-1}^{1} c_j \Delta SL_{t+j} + e_t$$

ΔS_t is the change in corporate spreads, ΔY_t is the change in the three-month sterling Libor and ΔSL_t is the change in the slope of the government yield curve (given by the spread between the three-month Libor rate and the constant ten-year maturity gilt yield). The regressions were carried out on daily spreads in the sample period 4 January 1990 to 31 December 1998, using daily data. The variance-covariance matrix of the estimated coefficients was adjusted for generalised heteroscedasticity using the Newey-West technique. T-statistics indicating significance of coefficients from zero at the 95% level are given in parenthesis. Probability values of χ^2 tests are in square brackets, also indicating significance of coefficients from zero at the 95% level. The 'short' duration credit spread series comprises corporate bonds with durations of between 0 and 4 years; 'medium' duration comprises bonds with durations of between 4 and 8 years; and 'long' duration comprises bonds with durations of between 8 and 12 years.

Duration	**Rating**	**Obs.**	**$\Delta Y(t-1)$**	**$\Delta Y(t)$**	**$\Delta Y(t+1)$**	**$\Delta SL(t-1)$**	**$\Delta SL(t)$**	**$\Delta SL(t+1)$**	**$\sum \Delta Y$**	**$\sum \Delta SL$**	**Adj. R^2**
Short	A	1,327	0.3451 (5.42)	-0.3703 (6.03)	0.0087 (0.17)	0.3082 (7.18)	-0.4031 (7.31)	0.0260 (0.99)	-0.0165 [0.74]	-0.0685 [0.07]	0.34
Medium	A	2,257	0.4227 (8.31)	-0.3772 (7.22)	-0.0827 (2.90)	0.4027 (8.46)	-0.3868 (8.51)	-0.0074 (0.40)	-0.0372 [0.21]	0.0085 [0.75]	0.34
Long	A	1,491	0.3131 (3.47)	-0.4255 (6.90)	0.060 (0.88)	0.4056 (6.77)	-0.4292 (8.65)	-0.0041 (0.16)	-0.0524 [0.36]	-0.0277 [0.47]	0.26
Short	Aa	1,298	0.3276 (5.05)	-0.3716 (5.80)	0.0279 (0.54)	0.2945 (6.72)	-0.4027 (7.19)	0.0276 (1.03)	-0.0161 [0.76]	-0.0806 [0.04]	0.31
Medium	Aa	2,242	0.4193 (8.67)	-0.4267 (8.64)	-0.0764 (3.08)	0.4085 (9.01)	-0.4498 (10.43)	-0.0134 (0.73)	-0.0838 [0.00]	-0.0547 [0.05]	0.37
Long	Aa	1,475	0.4004 (5.40)	-0.4182 (6.56)	0.0160 (0.30)	0.4716 (7.38)	-0.4358 (8.29)	0.0322 (1.16)	-0.0018 [0.98]	0.0680 [0.19]	0.29

Table 5 – Summary of regression results, using weekly data

The following equation was estimated for six regressions using OLS on weekly data:

$$\Delta S_t = a + b\Delta Y_t + c\Delta SL_t + e_t$$

ΔS_t is the change in corporate spreads, ΔY_t is the change in the three-month sterling Libor and ΔSL_t is the change in the slope of the government yield curve (given by the spread between the three-month Libor rate and the constant ten-year maturity gilt yield). The regressions were carried out on daily spreads in the sample period 4 January 1990 to 31 December 1998 using weekly data. The variance-covariance matrix of the estimated coefficients was adjusted for generalised heteroscedasticity using the Newey-West technique. T-statistics indicating significance of coefficients from zero at the 95% level are given in parenthesis. The 'short' duration credit spread series comprises corporate bonds with durations of between 0 and 4 years; 'medium' duration comprises bonds with durations of between 4 and 8 years; and 'long' duration comprises bonds with durations of between 8 and 12 years.

Duration	**Rating**	**Obs.**	**$\Delta Y(t)$**	**$\Delta SL(t)$**	**Adj. R^2**
Short	A	276	-0.1567 (4.27)	-0.1284 (5.83)	0.13
Medium	A	470	-0.0927 (3.74)	-0.1102 (4.91)	0.05
Long	A	310	-0.1342 (3.73)	-0.1015 (4.20)	0.07
Short	Aa	262	-0.1365 (3.59)	-0.1326 (5.94)	0.12
Medium	Aa	467	-0.1382 (5.70)	-0.1584 (7.25)	0.11
Long	Aa	308	-0.0908 (1.40)	-0.0530 (1.23)	0.00

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