Decomposing corporate bond spreads

By Lewis Webber of the Bank's Systemic Risk Assessment Division and Rohan Churm of the Bank's Conjunctural Assessment and Projections Division.

Sterling, dollar and euro-denominated corporate bond spreads narrowed substantially between late 2002 and mid-2007, but widened abruptly during the recent financial market turmoil. This article uses a structural credit risk model to examine the extent to which movements in spreads over the past decade have been driven by credit and non-credit related factors. Compensation for bearing non-credit related illiquidity risk appears to have been a particularly important driver of high-yield spreads, including during the recent financial market turmoil, but the compensation required for credit risk has also increased recently.

Introduction

Corporate borrowers pay higher yields on the bonds they issue than governments pay on bonds of the same maturity. The difference between these yields is called the *corporate bond spread*.

Part of this spread compensates investors for the *expected default loss* associated with holding corporate debt — arising from the possibility that corporate bonds may not be repaid in full. Another component of the spread compensates risk-averse corporate bond investors for their exposure to *unexpected default losses* — arising from their aversion to uncertainty about whether that default risk will actually crystallise over the life of the bond. Together, these two components comprise the total part of corporate bond spreads that can be attributed to default-related *credit risks*.

In addition, corporate bond spreads may also contain compensation for a number of non-credit factors. In particular, the market for government bonds is usually more liquid than that for corporate bonds. Corporate bond spreads are therefore likely to contain a relative *illiquidity premium*. This reflects the additional compensation, compared to government debt, that investors in corporate bonds require for bearing the risk that they might not always be able to sell their claim immediately without incurring a substantial price discount.

There are a number of other non-credit related factors that might also influence corporate bond spreads. For example, corporate and government debt are often treated differently for tax and regulatory purposes; options for borrowers to redeem bonds early are more common for corporate debt than government debt; some corporate bonds are convertible into equity; and corporate bonds are less widely accepted as collateral than government debt, or only accepted on more stringent terms.

Understanding corporate bond spreads is important for the Bank's financial stability remit because these spreads reflect market participants' aggregate perceptions about the relative financial health of corporate issuers. Decomposing spreads into credit and non-credit related components can provide useful additional information. For example, an increase in corporate bond spreads that reflected a widespread pickup in expected default losses could be associated with a worsening macroeconomic outlook. This might have different implications for UK systemic stability than an increase in spreads that reflected an increase in compensation for uncertainty about future default losses, caused by a change in corporate bond investors' attitude towards risk. And changes in spreads that reflected compensation for bearing non-credit related illiquidity risk could help to infer information about prevailing financial market conditions.

Monitoring corporate bond spreads is also useful from a monetary policy perspective because these spreads are part of the cost of external debt financing for the corporate sector. Other things being equal, wider corporate spreads increase the cost of capital, which may lead firms to postpone or scale back investment projects, thereby reducing aggregate demand and muting inflationary pressure in the short run.

This article uses a so-called 'structural model' of credit risk to value the different claims on the assets of a corporate bond issuer. It describes a framework that can be used to model explicitly the compensation that corporate bond investors demand for bearing default-related credit risks, based on observed financial market data. Making different assumptions about investors' aggregate risk preferences allows this total credit-related compensation to be split into the two subcomponents described above: compensation for expected future default losses and compensation for uncertainty about future default losses. The non-credit related component of corporate bond spreads can then be inferred as a residual.

The model is used to investigate the extent to which movements in sterling, dollar and euro-denominated corporate bond spreads over the past decade can be attributed to credit and non-credit related factors. The model is also used to examine how credit and non-credit related risks were repriced in international corporate bond markets following the spillover of problems originating in the US securitised mortgage market to financial markets more broadly. This is described, for example, in the October 2007 *Financial Stability Report*.

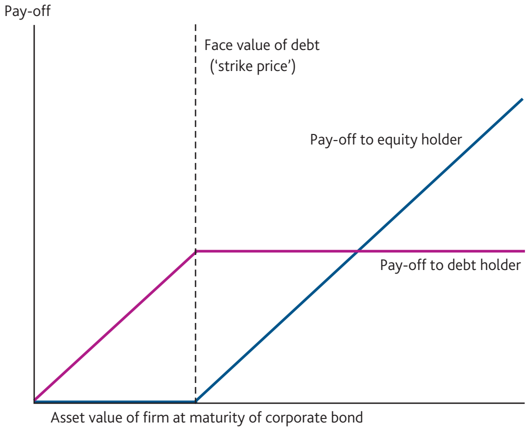
A structural model of credit risk

In the so-called 'structural approach' to credit risk modelling, the market value of a firm's equity can be used to infer the probability of corporate default by considering the positions of different claimants on the firm's (unobserved) asset value. In turn, this default probability determines the amount of compensation that investors require for bearing the credit risk associated with holding corporate bonds.

The simplest such approach, introduced by Merton (1974), is to consider a firm with a capital structure comprised of two basic elements: a fixed amount of non coupon-paying or 'zero-coupon' debt (the 'senior claim') and equity (the 'junior claim'). If the firm's asset value were insufficient to pay the face value of its debt when it fell due, the company would be in default. In this case, equity holders would receive nothing and bond holders, as senior creditors, would recover whatever the firm's assets were worth after paying any bankruptcy costs. If, on the other hand, the firm's assets were worth enough to repay the debt in full when it matured, the remainder would go to the equity holders.

Because equity investors are the residual claimants on the firm's asset value, they receive the same pay-off as a hypothetical investor who holds an option to buy the firm's assets at a 'strike price' equal to the face value of the firm's debts.(1) The equity value of a corporate borrower can therefore be described using option-pricing methods. If the underlying asset value of the firm were less than the strike price when the option was due to be exercised, the option would not be used and would expire worthless. But if the value of the firm were greater than the strike price, the pay-off to the option holder would be the difference between the two. So the pay-off to the equity holder would be zero if the value of the firm were less than the face value of the debt when it fell due, but would otherwise increase one-for-one with the firm's asset value. This is shown by the blue line in **Figure 1**.

Figure 1 Option-like pay-off to corporate bond and equity investors in the Merton model



Moreover, because the market value of debt is equal to the difference between the firm's asset value and its equity value, debt can also be valued using option-pricing methodology. This is shown by the magenta line in **Figure 1**.

This article uses a structural credit risk model that extends the simple Merton model in two key ways.(2) First, it is assumed that firms issue coupon-paying bonds rather than zero-coupon bonds, to match more closely the debt-financing behaviour that companies adopt in practice. Second, at every instant before the corporate bond matures, equity holders, as firm owners, choose whether to meet their debt obligations or to default.

In the model, equity holders will only service the company's debt if it is in their interests to do so. More precisely, they act to maximise the value of their residual claim on the firm's asset value, and will only continue to service the debt if the value of their claim will remain positive after the debt is paid. Equity holders are therefore assumed to set a critical threshold or *default boundary* for the value of the firm's assets at which the expected returns on equity from continued operation of the firm equal the cash flows required to keep the firm solvent. When the firm's asset value is above this default boundary, the firm is a going concern and equity holders choose to repay the debt. But when the firm's asset value falls to the default boundary, equity holders choose not to honour their debt obligations and the firm defaults.

Despite these extensions to the basic Merton framework, the fundamental insight that claims on the firm's assets can be

(1) An option gives the holder the right but not the obligation to buy (in the case of a 'call' option) or sell (in the case of a 'put' option) an asset at a pre-agreed 'strike' price at some point in the future. See also Black and Scholes (1973).
(2) Details of the model can be found in *Bank of England Working Paper no. 253* by Churm and Panigirtzoglou (2005).

valued using option-pricing methods still applies. Moreover, the broad intuition of the set-up remains the same: the closer the asset value of the firm is to the default boundary, the greater the probability that the firm will default on its debt in the future. This increases the corporate bond spread over the default-free government bond yield, other things being equal.

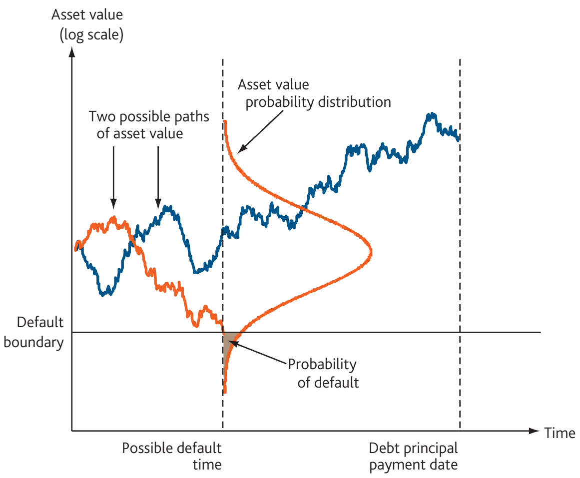
The model used in this article assumes that the return on the firm's assets is equal to its cost of finance, minus the cash flows that are paid out as dividends to equity holders and coupons to bond holders. This is an equilibrium condition. If, on average, the firm's asset value grew any more quickly, the firm would demand unlimited additional finance because the cost of doing so would be below the return on its assets. If, on average, the firm's asset value grew more slowly, the firm would be unviable in equilibrium.

A higher asset return raises the firm's asset value more quickly, reducing the probability of default, other things being equal. In contrast, higher payments to claimants on the firm will lead to slower asset value growth and a greater probability of default, other things being equal.

But there is also uncertainty about the asset value growth rate. The greater is this uncertainty, the higher the probability that the asset value of the firm will hit the default boundary over any given period. Uncertainty about the asset value growth rate means that the range of possible values for the firm's assets widens out over time. **Figure 2** illustrates two possible paths for the firm's asset value. It also shows the asset value probability distribution at some time prior to debt maturity, which reflects the range of possible asset values at that instant, with the most likely outcome at the peak of the 'hill'. If, at any point, the firm's asset value falls to the horizontal line, default occurs. This can happen before the debt principal is due to be paid.

The cumulative corporate default probability implicit in this set-up, up to the date on which the debt principal is due,

Figure 2 Evolution of a firm's asset value



determines the amount of compensation that corporate bond investors require for bearing the credit risk associated with holding the company's debt. As noted in the introduction, the total compensation for default-related risks that investors require in practice is likely to reflect their expected future default losses *and* their uncertainty about the size and timing of any such losses. As described in the Annex on pages 540–41, it is possible to separate out these two subcomponents. Intuitively, the model is used to calculate how much compensation investors would require for expected default losses if they were indifferent to uncertainty about their occurrence, by discounting the future cash flows they expect from the bond in practice at the default-free rate. Compensation for uncertainty about default losses is then obtained as the difference between total credit-related compensation and that required in this hypothetical case. In addition, there may be a residual part of observed corporate bond spreads that the model cannot explain. This contains compensation for all non-credit factors, including a premium for the relative illiquidity of the corporate bond market compared to the government bond market. This gives three contributions to observed corporate spreads: the compensation investors demand for expected default losses; compensation for uncertainty about default losses; and a non-credit related residual. The following sections go on to use the model to calculate these three components.

Implementing the structural model

For financial stability purposes, the Bank is often interested in understanding the behaviour of aggregate indices of corporate bond spreads as broad indicators of the financial health of similarly rated companies. Using the model described in the previous section, it is possible to decompose the Merrill Lynch investment-grade and high-yield indices of corporate bond spreads, for bonds denominated in sterling, dollars and euros.(1) These spreads are already adjusted for any option features in the corporate bonds. This helps to identify the unexplained non-credit related residual component of corporate bond spreads, since it excludes the possibility that the residual can be accounted for by, say, conversion or call options that are sometimes present in corporate debt.

Uncertainty about the representative corporate issuer's asset value cannot be observed directly. It is therefore estimated by looking at the representative issuer's equity return volatility and relating the value of the firm's equity to its asset value. Ideally, purely forward-looking measures of equity volatility implied from option prices(2) for each of the firms in the Merrill Lynch bond spread indices would be used, with the

(1) The Merrill Lynch Global Index System contains a number of indices of weighted-average corporate bond spreads, calculated over large samples of corporate debt issues. The indices are available by currency of issuance and credit rating, and are filtered to exclude small bond issues and issues with irregular coupon schedules.
(2) See also Clews *et al* (2000) for details about extracting forward-looking information from options prices.

same maturity as each firm's debt. But sufficiently long-dated equity options are not typically traded. Instead, an average of one-year option-implied equity volatility and ten-year historical equity volatility for a large proportion of firms in the indices is used. This helps to suppress the relatively large day-to-day movements in one-year implied equity volatility.(1)

The average growth rate of the firm's assets is calculated as a weighted average of the costs of debt and equity, using fixed long-run average leverage weights of 41.6% and 68.4% for investment-grade and high-yield corporate issuers respectively.(2) In turn, the cost of debt is proxied by the default-free government interest rate plus the observed corporate bond spread. The cost of equity is estimated as the default-free government interest rate plus an equity risk premium calculated using a one-stage dividend discount model (DDM) applied to UK, US and euro-area equity prices.(3)

In principle, the appropriate leverage ratio to use in the model is that expected over the maturity of the representative firm's debt, which can vary over time. However, since firms can adjust their payout ratios of dividends from earnings to ensure that leverage reverts towards a preferred level over the life of the debt, a fixed average of past leverage may be a reasonable proxy for expected leverage looking forward. Moreover, substantial changes in leverage that are not coupled with a change in credit rating might reasonably be assumed to be temporary.(4)

Accounting for recent bond spreads

Credit-related components of spreads

Charts 1–6 show decompositions of sterling, dollar and euro-denominated corporate bond spreads, for both investment-grade (left-hand column) and high-yield companies (right-hand column).(5) They suggest that compensation for bearing credit-related risks fell across the credit spectrum between the end of 2002 and mid-2007, but that credit risk compensation picked up during the recent financial market turmoil. The combined level of compensation for credit risk factors is greater for high-yield corporate debt (**Charts 2, 4** and **6**) than for investment-grade corporate debt (**Charts 1, 3** and **5**), since bonds at the lower end of the credit spectrum have a greater probability of defaulting over any given period, other things being equal. Furthermore, the *proportion* of the spread that can be accounted for by compensation for expected default losses and uncertainty about default losses is higher for high-yield corporate bonds than investment-grade bonds.

The component of sterling-denominated high-yield corporate bond spreads that can be attributed to expected future default losses has moved closely with the actual default experience of sub-investment grade companies globally since the start of our sample in 1998 (**Chart 7**). The recent increase in compensation for expected default losses, to above its average since 1998, suggests that market participants may already be projecting higher default rates going forward, consistent with Moody's October 2007 forecast.(6)

Between early 2003 and mid-2007, the compensation that investors required for exposure to uncertainty about future default losses associated with holding sterling-denominated investment-grade corporate bonds fell. The fall was proportionally greater than the decline in comparable compensation investors required for the uncertainty about future earnings streams associated with equities in the FTSE 100 index (**Chart 8**). Since the end of July 2007, however, the premium attached by investors to uncertainty about future default losses has increased sharply. This is consistent with the rapid transmission of the fundamental uncertainty surrounding the value of US sub-prime mortgage-backed securities to other structured products and to global interbank funding and bond markets, as described in the October 2007 *Financial Stability Report*. The model suggests that compensation for unexpected default losses is currently around twice its average level since 1997.

The estimates of credit-related risk premia shown in **Charts 1–8** are calculated using the market value of equity for the representative firm issuing in sterling, dollars and euros. They therefore rely on equity prices accurately reflecting aggregate expectations of corporate earnings prospects and uncertainty looking forward. If equity market investors were more optimistic about the outlook for corporate earnings than bond investors, for example, this could cause the model to underestimate compensation for credit-related default losses.

Non-credit related components of spreads

The non-credit related residual components of corporate bond spreads backed out from the model move reasonably closely with direct, market-based measures of corporate bond liquidity conditions. A number of studies have found that interest rate swap spreads are driven primarily by market liquidity conditions.(7) And **Chart 9** shows that the residual from the model-based decomposition of dollar-denominated investment-grade corporate spreads moves broadly with dollar interest rate swap spreads over default-free government bond

(1) It is possible that this may lead to an underestimation of long-dated equity volatility in times of extreme market stress.
(2) Leverage is defined as the ratio of debt principal to asset value.
(3) The DDM is described in Panigirtzoglou and Scammell (2002).
(4) A more complete description of the data, the calibration and the procedure can be found in Churm and Panigirtzoglou (2005). For example, the equity volatility index is rescaled for the high-yield spread decompositions. And there are other parameters that are not described here, including bankruptcy costs and the effective tax advantage of debt.
(5) The starting point for the decompositions is different but they all end in November 2007.
(6) Moody's Global Trailing 12-Month Issuer-Weighted Speculative-Grade Default Rates Forecast, October 2007.
(7) For example, see Liu *et al* (2002) and Huang and Neftci (2003).

Chart 1 Decomposition of sterling-denominated investment-grade corporate bond spreads

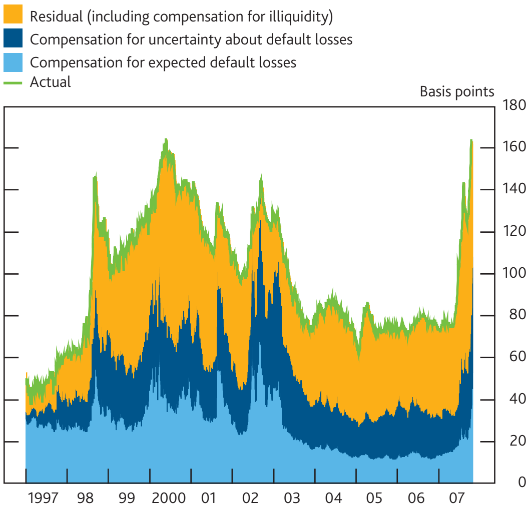


Chart 2 Decomposition of sterling-denominated high-yield corporate bond spreads

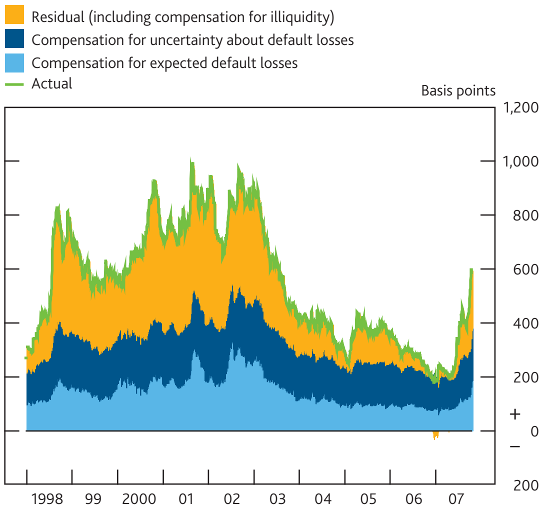


Chart 3 Decomposition of dollar-denominated investment-grade corporate bond spreads

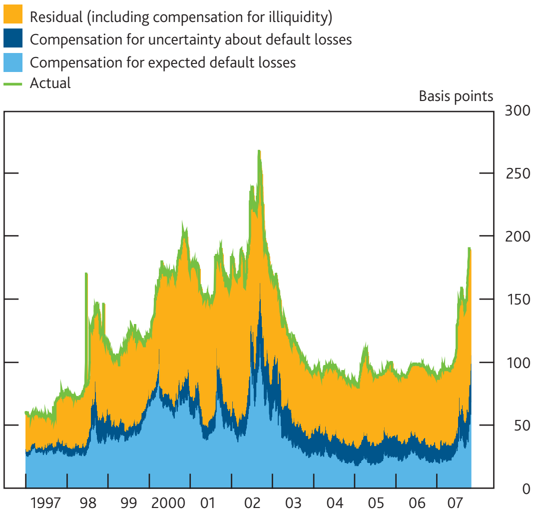


Chart 4 Decomposition of dollar-denominated high-yield corporate bond spreads

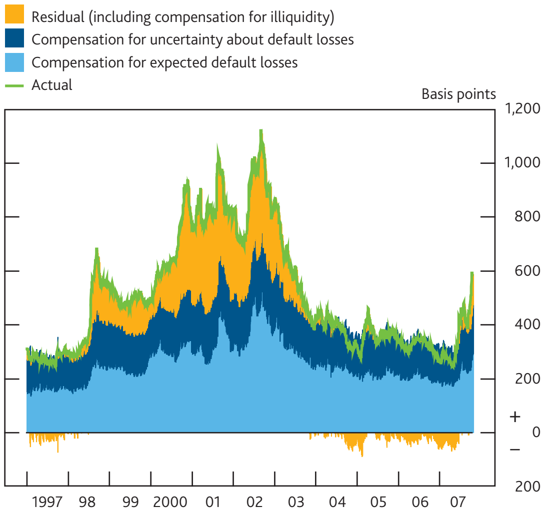


Chart 5 Decomposition of euro-denominated investment-grade corporate bond spreads

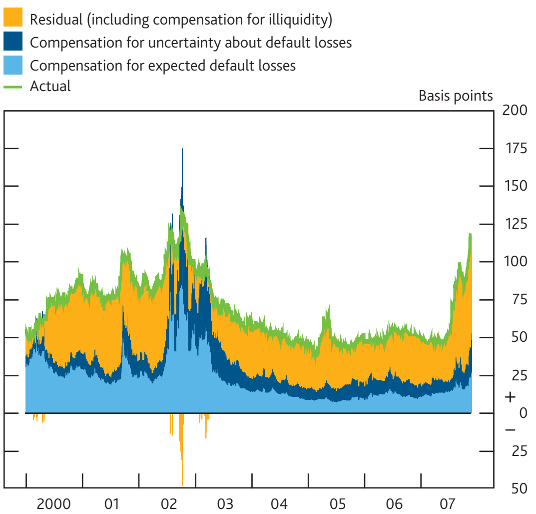


Chart 6 Decomposition of euro-denominated high-yield corporate bond spreads

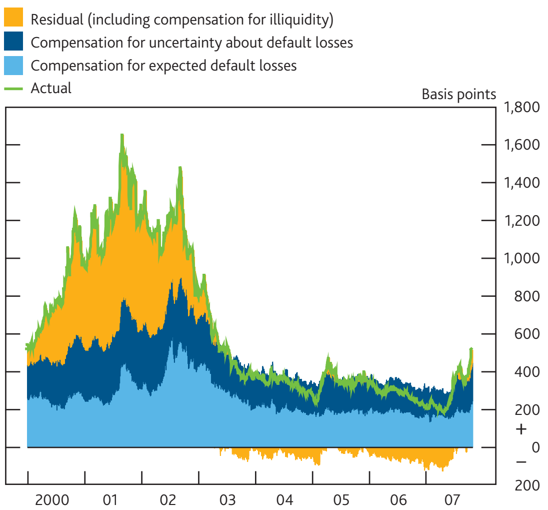
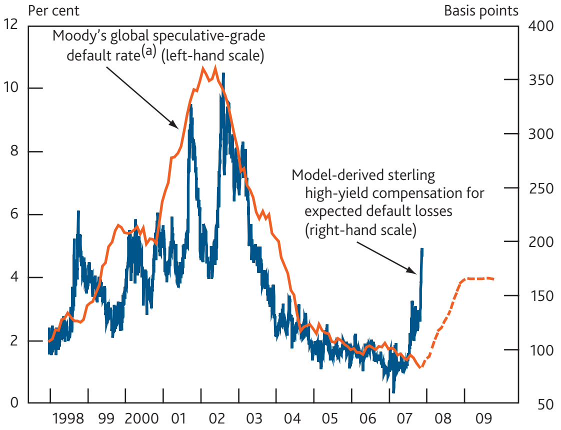
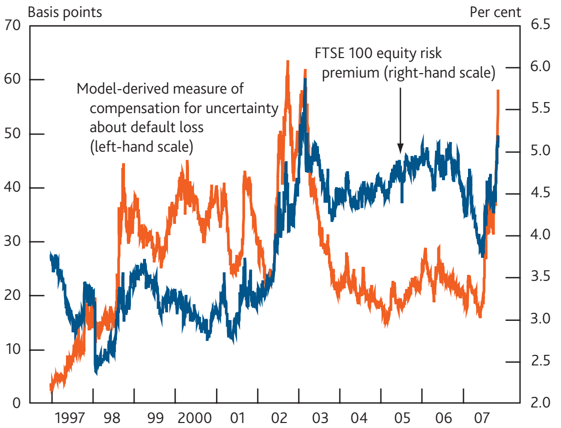


Chart 7 High-yield corporate default rate forecasts and compensation for expected default losses



(a) Solid line shows realised global speculative-grade default rate, dashed line shows Moody's October 2007 forecast.

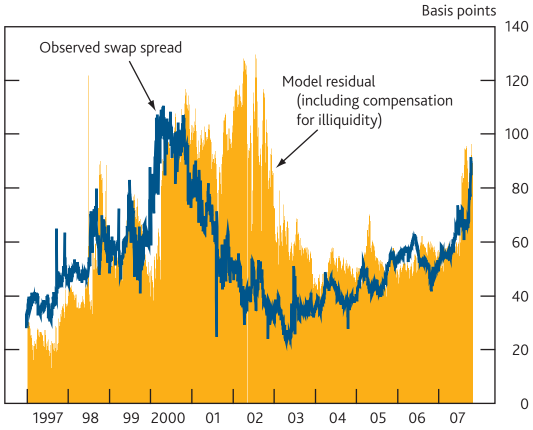
Chart 8 Compensation for pay-off uncertainty surrounding UK equities and corporate bonds



yields.[1] This suggests that they could be interpreted as compensation for bearing illiquidity risk.[2]

Chart 9 shows that the non-credit related residual component of dollar-denominated investment-grade spreads was generally high between mid-2000 and mid-2002, and widened by around 30 basis points between the end of 2001 and mid-2002. This broadly coincides with the episode of corporate accounting scandals in the United States, beginning when Enron filed for Chapter 11 bankruptcy protection in December 2001. The timing of the subsequent fall in the non-credit related residual broadly coincides with the introduction of the Sarbanes-Oxley Act, which became effective in August 2002 and set out stricter financial reporting standards for US-listed corporates. These observations are consistent with the interpretation of the model residual as a relative corporate bond illiquidity premium. Following the failure of a number of previously investment-grade corporates because of accounting fraud, investors may have become more uncertain about the reliability of corporate balance sheet information in general. This, in turn, may have led investors to feel less confident about their ability to trade rapidly out of

Chart 9 Dollar swap spread and implied dollar investment-grade illiquidity premium



their corporate bond positions, leading to a fall in demand for risky corporate assets and a widening of the illiquidity premium in corporate bond markets. But these fears subsequently subsided following the introduction of stricter rules on corporate disclosure in 2002. This legislation may have also helped to reduce credit risk premia.

Given the interpretation of the non-credit related residual as an illiquidity premium, it is notable from **Charts 2, 4** and **6** that there appears to have been a substantial compression in compensation for bearing illiquidity risk in high-yield corporate bond spreads between the end of 2002 and the start of the recent financial market turmoil. This would be consistent with investors having used increasingly risky strategies to maintain nominal returns over the period. Such return-seeking behaviour — or the so-called 'search for yield' — may have focused on high-yield corporate debt because those bonds offered higher spreads than their investment-grade counterparts. This could have helped promote activity in high-yield corporate bond markets, pushing spreads on high-yield bonds towards or even slightly below levels that offered sufficient compensation for default-related factors alone.[3]

In addition, illiquidity premia may have become compressed because of a shift in global investor demand from equities to fixed-income assets over the period — in particular, on the part of managers of official foreign exchange rate reserves in Asia and pension funds duration-matching their liabilities with holdings of bonds.[4] The behaviour of such investors may be

(1) Interest rate swaps were developed to allow the transfer of interest rate risk between two counterparties. Specifically, **Chart 9** shows 'plain vanilla fixed-for-floating' interest rate swap spreads, in which one investor receives floating interest rate payments (referenced to Libor) while making payments to another investor a pre-agreed fixed rate. See also Cortes (2003).
(2) The residuals from the model are one component of the financial market liquidity index described in Box 2 of the April 2007 *Financial Stability Report*.
(3) As discussed by Sir John Gieve in his 'Pricing for perfection' speech, given at the Bank of England on 14 December 2006. See also *Bank of England Quarterly Bulletin*, 2007 Q1, pages 112–17.
(4) As discussed by Paul Tucker in his Roy Bridge Memorial Lecture, 'Macro, asset price, and financial system uncertainties', on 11 December 2006. See also *Bank of England Quarterly Bulletin*, 2007 Q1, pages 122–30.

insensitive to the global business cycle and short-run financial market conditions. This could have increased the depth and hence liquidity of corporate bond markets, other things being equal.

For example, in the United Kingdom, the non-credit related residual component of sterling-denominated corporate bond spreads may have been influenced by regulation designed to alter the portfolio holdings of institutional investors directly. In particular, the Minimum Funding Requirement increased pension fund demand for UK government bonds in the late 1990s, putting downward pressure on UK government yields. Other things being equal, this would have widened corporate bond spreads for reasons unrelated to the possibility of corporate default. But it seems unlikely that this explanation could explain the high-frequency changes in the residual component of sterling-denominated corporate spreads over the period as a whole.

Recently, the compression in corporate bond illiquidity premia has unwound rapidly, particularly for high-yield debt. Between early August and the end of November 2007, the components of sterling, dollar and euro-denominated high-yield corporate spreads that can be attributed to compensation for bearing illiquidity risk increased by 121 basis points, 69 basis points and 57 basis points respectively. These increases coincided with the abrupt fall in demand for assets at risk of default that accompanied the drying up of liquidity in interbank money markets beginning in mid-2007.

Conclusion

The implications of the recent widening in corporate bond spreads depend on the driving factors. The model described in this article is one tool that can be used to separate out the compensation investors demand for bearing the risk of corporate default from compensation for non-credit related illiquidity risk.

The model used in this article suggests that compensation for bearing credit-related risks fell internationally and across the credit spectrum between the end of 2002 and mid-2007, corresponding to a period of generally falling realised corporate default rates. Illiquidity premia also fell over the period and appeared to become particularly compressed in high-yield corporate bond markets. This would be consistent with return-seeking behaviour among market participants that had focused on the highest-yielding assets, and a probable shift in global demand from equities to fixed-income assets.

However, credit and illiquidity risk premia both appeared to increase abruptly during the recent financial market turmoil. The model suggests that the compensation corporate bond investors require for bearing expected default losses has increased substantially since mid-2007 — consistent with expectations among market participants of higher corporate default rates looking forward. And the recent rise in fundamental uncertainty surrounding the value of some credit derivative instruments appears to have been reflected in corporate bond spreads as higher compensation for unexpected default losses. Alongside these increases, corporate bond illiquidity premia also appear to have risen — consistent with the recent drying up of liquidity in money markets.

Annex

Full technical details of the model used to decompose corporate bond spreads are described in Churm and Panigirtzoglou (2005). This annex provides an outline of the main calculations. The method is based on the Merton (1974) and Leland and Toft (1996) structural credit risk models.

Asset return volatility

Volatility in the return on a firm's underlying assets cannot be observed directly and so it is calculated as a transformation of observed equity return volatility using the Merton (1974) model. This is convenient because it is possible to derive a simple formula from which asset return volatility can be obtained directly, using observed market data.

In the Merton (1974) model, the underlying asset value of a firm evolves according to a so-called diffusion process:

$$\frac{dV_t}{V_t} = \mu dt + \sigma_V dW_t \qquad \textbf{(1)}$$

where V_t denotes the firm's asset value at time t.
μ denotes the asset value drift rate.
σ_V denotes the volatility of asset returns.
$dW_t \sim N(0,dt)$ denotes a normally distributed random fluctuation.

In turn, the equity value of the firm is a function of the underlying asset value, $E(V)$. Using Itô's lemma, the incremental change in equity value with asset value is:

$$dE_t = \frac{\partial E}{\partial V} dV_t + \frac{1}{2}\frac{\partial^2 E}{\partial V^2}(dV_t)^2 \qquad \textbf{(2)}$$

By substituting equation **(1)** into equation **(2)** and assuming that the value of equity follows a similar process to equation **(1)**, it is possible to relate σ_V (which is unobserved) to σ_E (which is observed):

$$\sigma_V = \left(\frac{V}{E}\frac{\partial E}{\partial V}\right)^{-1} \sigma_E \qquad \textbf{(3)}$$

Equity holders' optimal default barrier

The critical asset value, or default barrier, at which equity holders choose not to honour their debt obligations, V_B, is obtained using the Leland and Toft (1996) model. This assumes that equity holders, as owners of the firm, act to maximise the value of their claim on the firm's assets. At each instant, equity holders choose the default barrier such that there is no incremental change with asset value in the value of their claim from continued operation of the firm. Consequently, equity holders trigger default the first time that the asset value of the firm falls to the default barrier. This might occur before the corporate bond matures. The equity holders' choice of default barrier depends on, among other things, the value of the firm's asset return volatility. Equity holders therefore solve the equation:

$$\frac{\partial E\left(V_B\left(\sigma_V\right)\right)}{\partial V} = 0 \qquad \textbf{(4)}$$

Corporate bond pricing equation

The value of the debt issued by the firm is given by the present value of its expected coupon payments plus the present value of the principal due to be paid when the bond matures, adjusted for the present value of the expected loss given default. With semi-annual coupons, this can be written:

$$P_t = \sum_{t=1}^{2T-1} \frac{K}{2} e^{-r\frac{t}{2}}\left(1-\left(1-R\right)EDF_t\right) + \left(1+\frac{K}{2}\right)e^{-rT}\left(1-\left(1-R\right)EDF_t\right) \qquad \textbf{(5)}$$

where P_t denotes the price of the corporate bond.
K denotes the total coupon per annum.
r denotes the default-free rate of return.
R denotes the recovery rate.
T denotes the time until the bond matures.

EDF_t denotes the expected default frequency of the corporate issuer. This depends on, among other things, the level of the default barrier chosen by the firm's equity holders. Because equity holders choose to default the first time that the asset value of the firm falls to the default barrier, calculating the expected default frequency is analogous to pricing a so-called down-and-out barrier option (where the option holder loses the right to exercise the option if the price of the underlying asset falls below the strike price).

The two credit-related components of corporate bond spreads are calculated by solving equation **(5)** for the coupon payments that provide investors with sufficient compensation to ensure that the present value of the bond is equal to the principal payment expected when it matures, under different assumptions about their aggregate risk preferences.

Calculating compensation for bearing expected and unexpected default losses

It is assumed that, in practice, corporate bond investors demand compensation for bearing both expected and unexpected default losses. The sum of these two components is calculated using the model by assuming that investors recognise the uncertainty surrounding the firm's asset value growth rate. They therefore discount the future cash flows they expect in practice at a risky rate of return to reflect the possibility of default occurring looking forward. To isolate the compensation demanded for expected default losses, it is assumed that investors continue to expect risky rates of return, but instead discount expected cash flows at the default risk-free rate. Compensation for bearing the risk of unexpected default losses can then be obtained as the difference between these two values.(1)

(1) Equivalently, the total compensation investors demand for bearing expected and unexpected default losses is calculated in the model using *risk-neutral* valuation methods. This involves calculating the expected default frequency used in equation **(5)** under the risk-neutral probability measure. Compensation for expected default losses is isolated by calculating the expected default frequency used in equation **(5)** under the real-world probability measure.

References

Black, F and Scholes, M (1973), 'The pricing of options and corporate liabilities', *Journal of Political Economy*, Vol. 81, pages 637–59.

Churm, R and Panigirtzoglou, N (2005), 'Decomposing credit spreads', *Bank of England Working Paper no. 253*.

Clews, R, Panigirtzoglou, N and Proudman, J (2000), 'Recent developments in extracting information from options markets', *Bank of England Quarterly Bulletin*, Spring, pages 50–60.

Cortes, F (2003), 'Understanding and modelling swap spreads', *Bank of England Quarterly Bulletin*, Winter, pages 407–16.

Gieve, J (2007), 'Pricing for perfection', *Bank of England Quarterly Bulletin*, Vol. 47, No. 1, pages 112–17.

Huang, Y and Neftci, S (2003), 'What drives swap spreads, credit or liquidity?', *ISMA Centre Working Papers in Finance no. 2003–05*.

Leland, H and Toft, K (1996), 'Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads', *Journal of Finance*, Vol. 51, pages 987–1,019.

Liu, J, Longstaff, F and Mandell, R (2002), 'The market price of credit risk: an empirical analysis of interest rate swap spreads', *NBER Working Paper no. 8990*.

Merton, R (1974), 'On the pricing of corporate debt: the risk structure of interest rates', *Journal of Finance*, Vol. 29, pages 449–70.

Panigirtzoglou, N and Scammell, R (2002), 'Analysts' earnings forecasts and equity valuations', *Bank of England Quarterly Bulletin*, Spring, pages 59–66.

Tucker, P (2007), 'Macro, asset price, and financial system uncertainties', *Bank of England Quarterly Bulletin*, Vol. 47, No. 1, pages 122–30.