# Term structure effects in relative credit spread volatility

Duration Times Spread (DTS) has become a broadly accepted measure of spread exposure in credit portfolios, supported by extensive empirical evidence that credit spread volatility is proportional to spread level.

A pivotal argument for the DTS paradigm is based on the observation that relative spread volatilities are more stable than absolute spread volatilities. In this article, we examine relative spread volatilities across the credit sector using data from bond and CDS markets. We find that relative spread volatilities show a clear dependence on maturity, with higher values observed at shorter maturities. We explore the possible root causes of this phenomenon – the exaggerated nature of relative spread changes when spreads are low, the effect of spread curve inversions when spreads are high – and conclude that different forces dominate in different market conditions.

We then turn our attention to the portfolio management implications of our findings. Are adjustments needed to a system based on allocations of DTS contributions to industry groups? We conclude that for portfolio managers who take only incidental exposures to spread curve slope trades, the overall risk due to the effects explored here should be acceptably small. For managers who tend to take significant active risk based on explicit spread curve views, we explore several ways in which the DTS framework can be modified to form more precise risk estimates of such positions. One approach would have managers tally separately their DTS exposures to long and short maturity cells within each sector; another would have them scale the DTS exposures of each bond by a maturity-dependent factor before summing them up by sector. A further refinement would make the adjustment dependent on the slope of the issuer spread curve.

Jay Hyman
+972 3 623 8745
jay.hyman@barclays.com

Anando Maitra
+44 (0)20 3134 0091
anando.maitra@barclays.com

Simon Polbennikov
+44 (0)20 3134 0752
simon.polbennikov@barclays.com

www.barclays.com

# 1. Does relative spread volatility depend on maturity?

In 2005, we introduced Duration Times Spread (DTS)[1] as the preferred measure of spread exposure in credit portfolios. This approach is based on the idea that spread change across a given sector of the credit markets tends to follow a relative shift paradigm, rather than one of parallel shift, and was supported by extensive empirical studies that document this relationship based on 16 years of data from corporate bond markets. We have shown that as a result, spread volatility tends to be proportional to spread level, and excess return volatility tends to be proportional to DTS. Subsequent studies indicated that the results were not confined to the realm of US corporate bonds, but also extend to other spread asset classes with a significant default risk such as credit default swaps, European corporate and sovereign bonds, and emerging market sovereign debt denominated in US dollars.[2] We have since reviewed the model's performance during the global financial crisis of 2007-2009, and found it to have stood up well to this extreme out-of-sample test.[3]

More recently, we were approached by an investor who had been using the DTS model as the basis for hedging a credit portfolio with a strong maturity bias. Essentially, this investor attempted to replicate the returns of a broad credit index using only short-maturity bonds, leveraging them to match the DTS contributions of the index.[4] The investor was aware that this position entails a large exposure to a reshaping of the spread curve, and was therefore not particularly surprised by the magnitude of the tracking errors experienced. However, they noticed over time that their portfolio seemed to be systematically over-hedged. When the index experienced positive excess returns, their portfolio earned even more; when the index excess returns were negative, theirs were even more negative. Their conclusion: when applied to this specific application, the DTS approach produces biased hedge ratios.

In response, we have carried out an extensive analysis of the term structure of credit spread changes, using data from the corporate bond and credit default swap (CDS) markets in the US and Europe. Empirical studies focused on this effect confirm that relative spread volatilities tend to be higher at shorter maturities. This is true at the aggregate level, as represented by the spreads of CDX and iTraxx contracts, as well as for individual issuer spreads in the CDS and corporate bond markets, in both currencies studied. We then explore the root causes of this phenomenon. We find two key explanations. Inversions of issuer spread curves during periods of stress, and their recovery afterward, certainly can cause short-dated spreads to be more volatile, on both an absolute and relative basis. In more normal times, the key finding is that the relative spread paradigm underlying DTS applies more consistently across issuers than across the spread curve of a given issuer. That is, when spreads widen across an industry, they tend to move proportionally, with wider spreads widening by more. When an issuer curve widens, however, it tends to move closer to a parallel shift than to a pure relative shift. These findings lead to an understanding that the ratio of relative spread volatilities may not be constant over time, but it can depend on the level and slope of issuer spread curves.

[1] Ben Dor, A., Dynkin, L., Houweling, P., Hyman, J., van Leeuwen, E. and Penninga, O., "A New Measure of Spread Exposure in Credit Portfolios", Lehman Brothers, 2005.
[2] For example, see Ben Dor, A., S. Polbennikov, and J. Rosten. (2007). "DTS (Duration Times Spread) for CDS: A New Measure of Spread Sensitivity. Journal of Fixed Income 16(4): 32–44 and Ben Dor, A., A. Desclée, J. Hyman, A. Maitra, and S. Polbennikov. "Managing European Sovereign Spread Risk", Barclays Capital, July 2010.
[3] Ambastha, M., Ben Dor, A., and Dynkin, L., "DTS (Duration Times Spread) in the Credit Crunch: Did It Live Up to Expectations?", Barclays Capital, April 2, 2009.
[4] This strategy may be motivated by historical evidence that Sharpe ratios of corporate bonds tend to be higher at shorter maturities over the long term. See Ambastha, M., Ben Dor, A., Dynkin, L., and Hyman, J., "Do Short-Dated Corporates Outperform Long-Dated Corporates? A DTS-Based Study", *Lehman Brothers Global Relative Value*, 10 March 2008.

How should these observations affect portfolio manager practices? We address this critical question from several different angles. First, we demonstrate that for a bond portfolio manager who manages DTS exposures by industry, but does not explicitly control the maturity profile within each industry, the incidental exposures to this term structure effect are likely to be immaterial. Only when managers intentionally target a particular portion of the credit spread curve does this effect need to be considered carefully.

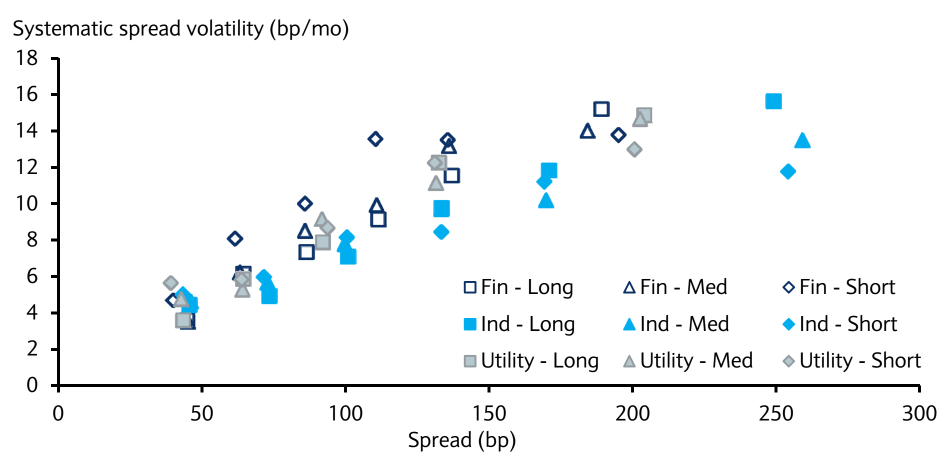
Second, for managers who do engage in credit slope trades on a substantive basis, what is the best way to measure the risk of such trades? For this application, we present and discuss several ways in which the DTS paradigm can be enhanced to improve its ability to measure and manage credit risk along the term structure of spreads.

The article is structured as follows. Section 2 outlines our previous work on DTS and recaps the main conclusions. Section 3 documents a maturity effect in relative spread volatility, based on empirical evidence from the CDS and corporate bond markets in the US and Europe. In Section 4, we seek to understand these results based on the dynamics of issuer spread curves and explore whether the spread volatility ratios depend on curve slope. In Section 5, we detail one method by which a DTS-based risk model can account for the maturity effect in credit spreads, and compare its performance with that of a more conventional model in which the maturity effect is not taken into account. We then seek to identify the portfolio situations in which this technique provides a significant improvement in accuracy. Section 6 discusses several alternative enhancements to the DTS approach, and Sector 7 concludes with a discussion of portfolio applications and recommendations for model implementation.

## 2. Credit spread exposure: Duration Times Spread (DTS)

Previous studies have shown that the spread volatility of credit securities is proportional to spread level across a wide range of spreads.[5] Indeed, Figure 1 from our 2005 publication shows the dependence of spread change volatility on spread level across industry, maturity, and spread level buckets of the US corporate index. The dependence seems to be linear with few outliers.

**Figure 1: Volatility of systematic spread changes versus spread level based on IG credit data and monthly observations (September 1989 – January 2005)**

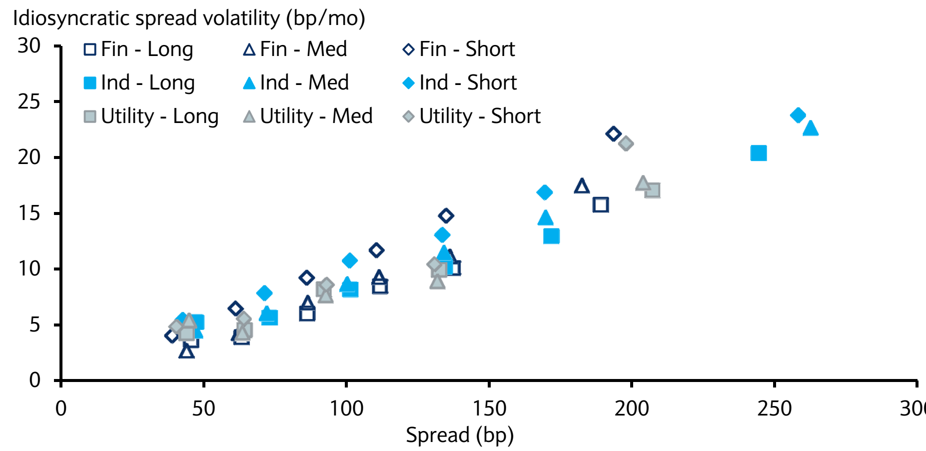



Source: Barclays Research

[5] See Ben Dor et al, "A New Measure of Spread Exposure in Credit Portfolios", 2005.

The pattern in Figure 1 is consistent with a view that when spreads change across an industry, they do not tend to shift in parallel; rather, wider spreads are likely to widen by more. The greater a bond's spread, the greater its exposure to a systematic spread widening. Similarly, the larger a bond's duration, the larger the effect of any spread widening on excess return. This suggests that exposures to credit sectors should be measured in terms of the product of the two, contributions to DTS, rather than to duration contributions alone. This conclusion holds not only for systematic risk at the sector level, but also for idiosyncratic spread risk. Figure 2 demonstrates that idiosyncratic spread volatility also increases linearly with spread.[6]

**Figure 2: Pooled idiosyncratic spread volatility vs. spread level, computed separately by sector, duration, and spread bucket; sample includes monthly observations for all bonds rated Aaa – Baa (September 1989 – January 2005)**




Source: Barclays Research

The linear relationship between spread volatility and spread level holds across different sector and maturity buckets. Figures 1 and 2 suggest that to measure the spread risk of a credit portfolio, it is sufficient to know its DTS exposure, while the exact sector and maturity structure of the portfolio play a secondary role.

In subsequent work, we revisited the results of Figures 1 and 2 to double-check for maturity effects. Upon close examination of these figures, in addition to the general linear trend, one can notice that observations marked by circles, representing the shortest maturity cell, tend to have higher spread volatilities for a given spread level than the corresponding triangles (medium maturities) and squares (long). A regression analysis confirmed this second-order effect with mildly significant results.

A more significant maturity dependence was suggested by our search for a theoretical basis for DTS based on the Merton model that represents debt and equities as complementary contingent claims on corporate value. In that work,[7] we developed an expression that relates spread volatility to spread level and showed that it is nearly linear in the region of interest for practical portfolio management. However, the theory found that the slope of this relationship – which should be closely related to relative spread volatility – should be inversely proportional to maturity. This very strong level of maturity dependence was quite

[6] Idiosyncratic spread change of a bond is calculated as the difference between bond and sector (defined by industry and maturity) spread changes, where sector spread change represents the systematic change.
[7] Ben Dor, A., L. Dynkin, and J. Hyman, *A Theoretical Basis for DTS (Duration Times Spread).*

out of line with our observed empirical results; we attributed this discrepancy to the simplifying assumptions that were needed to make the model tractable.

In this article, unlike our previous empirical studies, we examine directly the relative spread changes of individual securities. That is, rather than observing absolute spread volatilities across an asset class over an extended time period, and relating these to average spread levels over that time, we will now normalise the spread change of each security by its spread as of the beginning of that month. This emphasis on the volatility of relative spread changes will help us bring the maturity dependence effect into sharper focus.

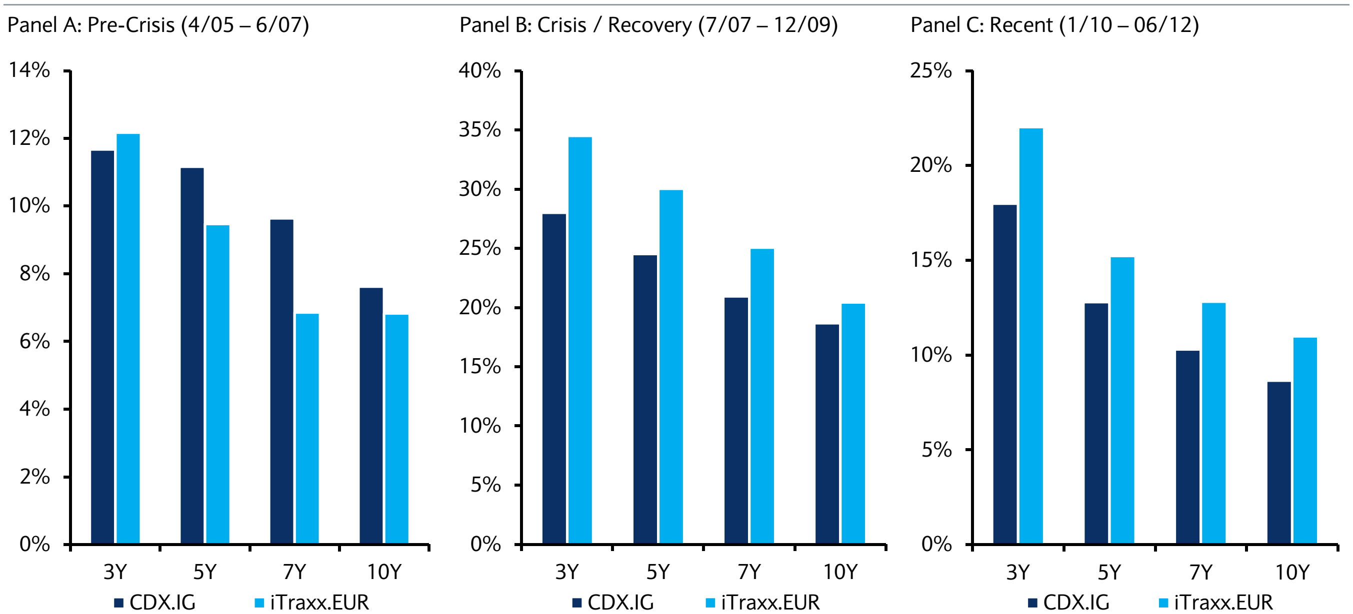
## 3. Maturity effect in relative spread change volatilities: Empirical evidence

### Empirical evidence from synthetic credit: CDX, iTraxx, and single-name CDS

We start our analysis with the credit default swap (CDS) market, which has become increasingly important. CDS contracts are naturally suited to study maturity-dependent effects because each issuer typically has traded contracts with different tenors, including 3, 5, 7, and 10 years. Among these, the 5- and 10-year contracts tend to have superior liquidity, while the 3- and 7-year points can be somewhat less liquid.[8]

Let us begin with monthly volatilities of relative spread changes of iTraxx.EUR and CDX.IG indices at different maturity points. We calculate the volatilities of the on-the-run time series for each of these indices with maturities of 3, 5, 7, and 10 years over three periods: from April 2005 to June 2007 (pre-crisis),[9] from July 2007 to December 2009 (global financial crisis and recovery), and from January 2010 to June 2012. Figure 3 shows the results. Higher volatility of shorter maturity contracts is evident for iTraxx and CDX in all three time periods.

**Figure 3: Term structure of relative spread change volatilities (%/month) for CDX.IG and iTraxx.EUR contracts**




Source: Barclays Research

[8] Details on the CDS market can be found in "Standard Corporate CDS Handbook", Barclays Capital, February 2010.
[9] Our dataset for CDX contracts does not go back as far; the results shown for CDX in the pre-crisis period are from March 2006 – June 2007.

While the magnitude of relative spread volatility has changed significantly over time, the decrease in relative spread volatility with increasing maturity seems to be remarkably stable. Figure 4 illustrates this relationship in the form of ratios between relative spread volatilities at different maturities. We have chosen to use the 5-year point on the curve as the reference point; the ratios in Figure 4 show that relative spread volatilities are greater for maturities shorter than 5 years and lower for longer maturities.

**Figure 4: Ratios of relative spread volatilities to the 5-year value (April 2005 – June 2012)**

| | CDX | | | | iTraxx | | | |
|---|---|---|---|---|---|---|---|---|
| | **Early** 3/06-6/07 | **Crisis** 7/07-12/09 | **Recent** 1/10-6/12 | **Full Period** 3/06-6/12 | **Early** 4/05-6/07 | **Crisis** 7/07-12/09 | **Recent** 1/10-6/12 | **Full Period** 4/05-6/12 |
| 3y | 1.05 | 1.14 | 1.41 | **1.20** | 1.28 | 1.15 | 1.45 | **1.23** |
| 5y | 1.00 | 1.00 | 1.00 | **1.00** | 1.00 | 1.00 | 1.00 | **1.00** |
| 7y | 0.86 | 0.85 | 0.80 | **0.84** | 0.72 | 0.83 | 0.84 | **0.83** |
| 10y | 0.68 | 0.76 | 0.68 | **0.73** | 0.72 | 0.68 | 0.72 | **0.69** |

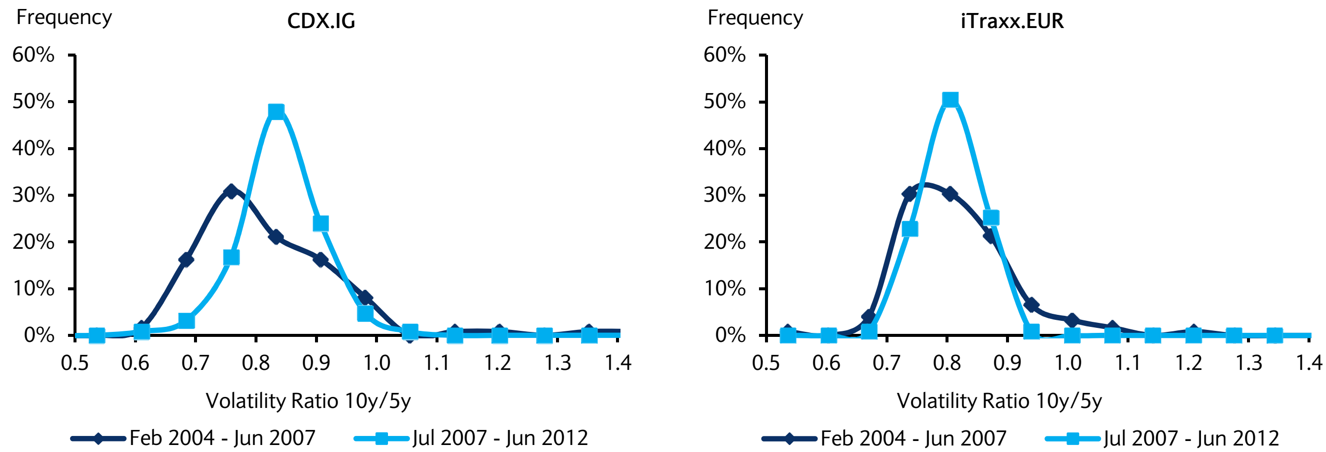
Source: Barclays Research

Do the results shown in Figures 3 and 4 represent characteristics specific to portfolio CDS products such as CDX and iTraxx? For example, might they be influenced disproportionately by the spread behaviour of the widest credits in the market? To rule out this possibility, we studied the relative spread volatilities of individual-issuer CDS of different tenors. Using the historical spreads of individual issuers represented within the CDX.IG and iTraxx.EUR contracts, at tenors of 3, 5, 7 and 10 years, we calculated the relative spread volatility of each issuer at each tenor, over the entire data sample and during different sub-periods.[10] Figure 5 plots the distribution of the ratio of volatilities between the two most liquid points on the curve, the 5-year and 10-year tenors. In Figure 4, the relative spread volatility at the 10-year point tends to be about 0.7 times that of the 5-year volatility for the market as a whole; Figure 5 shows that this tends to be true at the individual issuer level as well. The results vary across issuers from about 0.6 to 1.0, with the bulk of the distribution around the 0.8 level.

Using data from February 2004 through June 2012, we found that the relative spread volatility was greater at the 5-year maturity than at the 10-year maturity for 98% of the individual issuers we tracked. Furthermore, we checked that this pattern tends to hold for different maturity pairs as well. A pattern of strictly decreasing relative spread volatilities from 3 to 10 years was observed in about 95% of the issuers, in both the US and European CDS markets.

[10] Our CDS data set covered 125 constituents of CDS.IG and 123 constituents of iTraxx.EUR.

**Figure 5: Distributions of 10y/5y volatility ratios across constituents of CDX.IG and iTraxx.EUR**

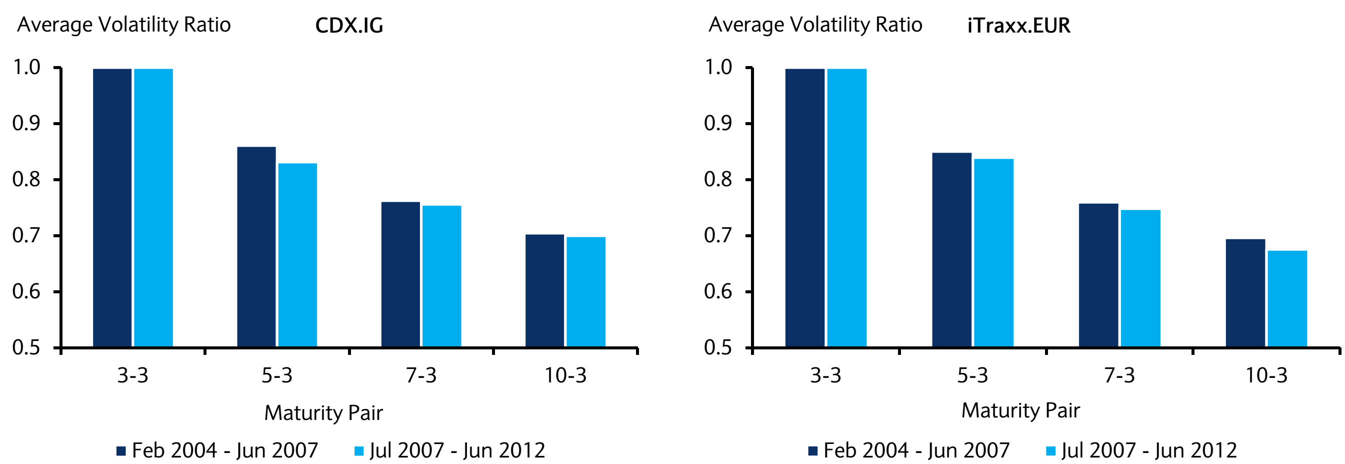



| | CDX.IG | | | | iTraxx.EUR | | | |
|---|---|---|---|---|---|---|---|---|
| | Avg | StDev | Min | Max | Avg | StDev | Min | Max |
| Feb 2004 – Jun 2007 | 0.82 | 0.13 | 0.28 | 1.39 | 0.82 | 0.11 | 0.50 | 1.51 |
| Jul 2007 – Jun 2012 | 0.84 | 0.06 | 0.64 | 1.09 | 0.80 | 0.05 | 0.69 | 0.91 |
| Feb 2004 – Jun 2012 | 0.83 | 0.07 | 0.38 | 1.05 | 0.81 | 0.04 | 0.70 | 0.94 |

Source: Barclays Research

Volatility ratios are quite stable over time. Figure 6 shows the average ratios of relative spread change volatilities for constituents of CDX.IG and iTraxx.EUR with different maturities to the volatility of the 3-year contract. These volatility ratios monotonically decline with maturity. Even though volatility levels are different for the pre-crisis and post-crisis periods, their ratios stay similar.

**Figure 6: Average volatility ratios of constituents of CDX.IG and iTraxx.EUR for different maturities**




| | CDX.IG | | | | iTraxx.EUR | | | |
|---|---|---|---|---|---|---|---|---|
| Period | 3-3 | 5-3 | 7-3 | 10-3 | 3-3 | 5-3 | 7-3 | 10-3 |
| Feb 2004 - Jun 2007 | 1.00 | 0.86 | 0.76 | 0.70 | 1.00 | 0.85 | 0.76 | 0.70 |
| Jul 2007 - Jun 2012 | 1.00 | 0.83 | 0.76 | 0.70 | 1.00 | 0.84 | 0.75 | 0.68 |
| Feb 2004 - Jun 2012 | 1.00 | 0.84 | 0.75 | 0.70 | 1.00 | 0.84 | 0.75 | 0.68 |

Source: Barclays Research

## Empirical evidence from corporate bond markets

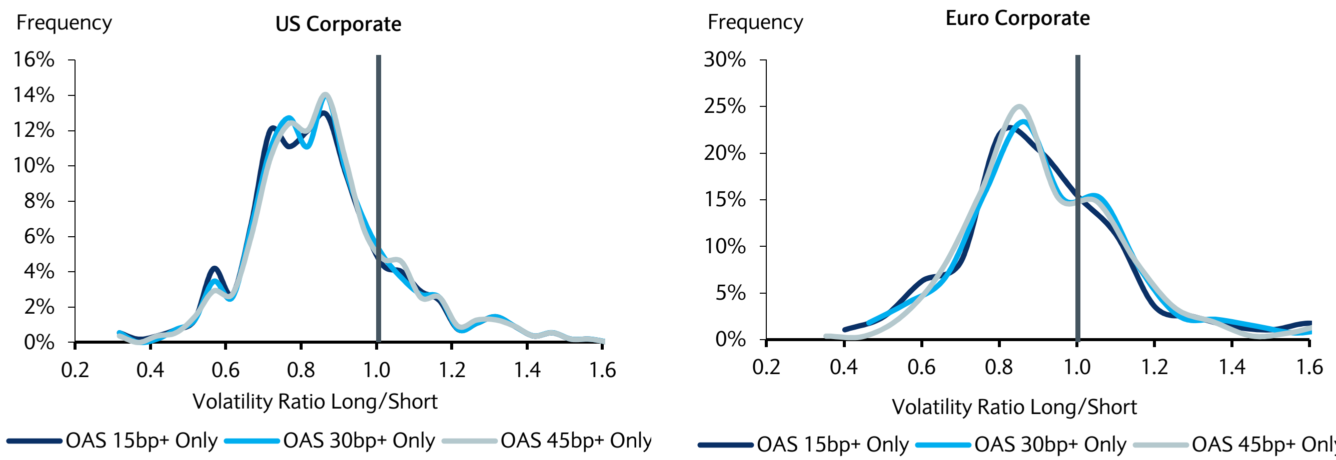
Is the phenomenon of higher relative spread volatility at shorter maturities limited to CDS markets, or is it a characteristic of corporate bond markets as well? We now analyse the term structure of relative spread volatilities in the US and European corporate bond markets.[11] Unlike the CDS markets, where the market can set spreads for all maturities on all issuers, bond market data allow spread observations only at maturity points corresponding to bonds that have been issued. We therefore adopt an approach similar to the one we used for CDS, but using a coarser maturity partition. Each month, we identify issuers within Barclays US and Euro Corporate indices that have at least one bond outstanding in each of two maturity buckets: 1-5 and 5-10 years. For each of these issuers, we calculate the average monthly relative spread changes within each maturity bucket. The resulting time series of average relative spread changes are used to calculate volatilities for the short (1-5y) and long (5-10y) maturity buckets for each issuer.[12] We can then calculate the ratio between the two for each issuer.

Figure 7 shows the distribution of the volatility ratio of long-maturity to short-maturity bonds across eligible issuers. Distributions for US and Euro corporate bonds are reported separately. In Figure 5, for the ratio of 10-year volatility to 5-year volatility in CDS markets, the distribution is centred around 0.8; however, the bond data show a higher incidence of ratios greater than 1.0 (issuers with greater relative spread volatilities at the long end). The tables below show sample statistics of volatility ratios. These results confirm that relative spread volatilities of shorter maturity bonds (1-5y) are typically higher than those of longer maturity bonds (5-10y).

One possible explanation for this phenomenon could be that shorter maturity bonds tend to have low spreads and, as a result, their relative spread volatilities are high. To check this, we repeat the exercise a few times by excluding bonds with spreads below a certain threshold. Figure 7 reports results for threshold levels of 15bp, 30bp, and 45bp. The results do not seem to be very sensitive to the spread threshold; we therefore conclude that the higher relative spread volatilities observed for shorter maturity bonds are not simply an artifact caused by very high relative spread changes of near-zero spreads.

[11] We exclude subordinated, callable, putable, and zero coupon bonds from our analysis. We should also note that for corporate bond spread data, we use OAS relative to the Treasury curve and not L-OAS relative to the Libor curve.
[12] The overall historical sample covers the period from March 2001 to June 2012. Issuers with less than 12 months of spread history are excluded. We also exclude observations corresponding to extreme events: single-month spread widening beyond 200% and tightening of 100%. These observations are likely to correspond to poor quality data (missing observations) or to issuers going into distress.

**Figure 7: Distributions of volatility ratios of long and short maturity bonds across US and Euro corporate issuers**



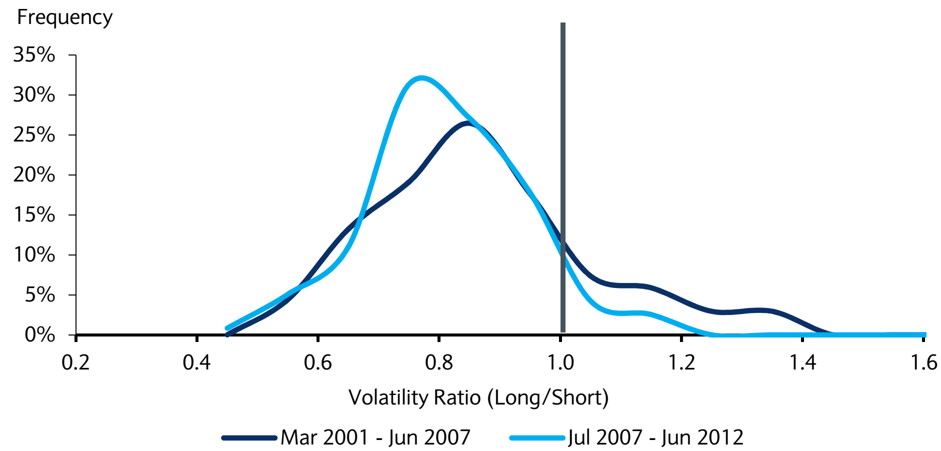

| | US Corporate | | | | Euro Corporate | | | |
|---|---|---|---|---|---|---|---|---|
| Universe | No Iss | Avg | Med | StDev | No Iss | Avg | Med | StDev |
| OAS > 15bp | 550 | 0.85 | 0.83 | 0.19 | 285 | 0.94 | 0.89 | 0.27 |
| OAS > 30bp | 550 | 0.86 | 0.84 | 0.19 | 278 | 0.96 | 0.91 | 0.30 |
| OAS > 45bp | 549 | 0.86 | 0.85 | 0.19 | 264 | 0.97 | 0.90 | 0.52 |

Source: Barclays Research

As with the CDS results, we wanted to be sure that our findings in the cash bond market were not biased by mixing results from two different time periods. For most issuers, the volatility ratios reported over the whole period are presumably dominated by their spread behaviour during the crisis period. Might the results have been different in earlier years? Furthermore, the results shown in Figure 7 mix data from different issuers for which the spread histories cover different time periods. For example, spread data are available for Agilent Technologies Inc in both maturity buckets from September 2009, but not before, while the spread data for AT&T Canada Inc are included only until February 2002, when it was downgraded below investment grade and excluded from the index. To address these issues, we repeated our analysis after making two changes in the procedure: we limit the analysis to issuers that have spread changes available over the whole sample period from March 2001 to June 2012; and we tabulate the volatility ratios separately over two distinct time periods: March 2001 to June 2007 and July 2007 to June 2012.[13] Figure 8 shows the distributions of relative spread change volatility ratios of long and short maturity bonds in the two periods. In the earlier period, the volatility ratio distribution seems to be skewed more positively than in the later period, but the overall conclusion of higher relative spread volatility for shorter maturity bonds is in line with our previous results.

[13] Here we focus on US corporate issuers since a similar procedure for Euro corporate bonds would leave few issuers in the sample.

Figure 8: Distribution of volatility ratios of long and short maturity US corporate bonds




| Period | No Iss | Avg | Med | StDev |
|---|---|---|---|---|
| Mar 2001 – Jun 2007 | 68 | 0.87 | 0.84 | 0.18 |
| Jul 2007 – Jun 2012 | 118 | 0.81 | 0.81 | 0.13 |

Source: Barclays Research

## 4. Interpretation: How do spread curves move?

We have found that relative spread volatilities are greater at shorter maturities. How should we understand this finding in terms of the dynamics of how spread curves change? One possible explanation is that spread curves tend to move in parallel even when they have positive slopes. If, for example, an issuer has spreads of 40bp at the 2-year point and 100bp at the 10-year point, and the curve widens in parallel by 10bp, this will constitute a relative spread change of 25% at the short end and 10% at the long end. In this example, a pure relative spread change of 15% might have the 2-year spread widen by 6bp while the 10-year spread widens by 15bp. This example makes it clear how in a positively-sloped curve environment, short-dated spreads can easily have lower absolute spread volatilities but still have greater relative spread volatilities.

Another factor that may contribute to this phenomenon is the fact that spread curves can invert. A credit cycle can go from having short-dated spreads being lower than long-dated spreads (as is normal) to having short-dated spreads be higher – and then back again. In such a scenario, it is clear that while all spreads will have widened and then tightened over the cycle, the short-dated spreads will have widened by more and then tightened by more.

The desire to distinguish between these two possible root causes for this phenomenon was one reason we subdivided the data sample in the above studies. The sample from 2007 to 2012 includes the dramatic spread changes that accompanied the global financial crisis, including significant spread inversions for many issuers; prior to 2007 we did not see a macro crisis of this magnitude. Were we to have found that relative spread volatilities are higher at the short end only in the first half of the study, we might have focused on the parallel shift hypothesis; were we to have found it much stronger in the latter half of the sample, we would conclude that curve inversions are the primary cause. The fact that this phenomenon is observed in both parts of the sample shows us that this result is not due to one of these causes exclusively. It is possible, for example, that the parallel shift effect is the main one in the pre-crisis period, and curve inversion is the main effect during the crisis.

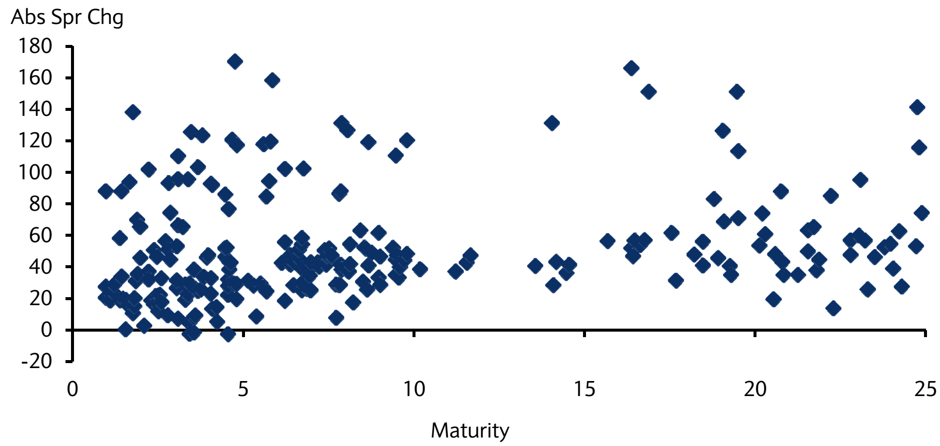
Why should it matter to us what drives the results? If the key message stemming from this data is that spread curves tend to shift in parallel, or closer to a pure parallel shift than to a purely relative spread change, then the volatility ratios may not be constant over time, but rather dependent on the slope of the curve. When curves are relatively flat, the difference would not be as pronounced as when they are steeply sloped.

Are we suggesting that the DTS model is wrong, and that spread changes tend to take place as parallel shifts rather than relative shifts? Certainly not. Before we attempt to address this question systematically, let us illustrate the issues involved by taking a close look at the spread changes observed in a single sector of the US corporate bond market in a single month. Figure 9 plots the spread changes in US Communications bonds during August 2011 in three different ways. In Panel A, we plot absolute spread changes against maturity. We can easily see that there was a sector-wide increase in spreads; this could be characterised as having an average shift of about 50bp, but there is plenty of variation around this mean, and maturity does not seem to be the key determinant of spread change. Similarly, in Panel B, we plot relative spread change against maturity. Here we can perhaps see that the relative spread change was typically about 30%; once again, the dependence on maturity is not so strong. In Panel C, we plot absolute spread change against beginning spread. Here we see very clear evidence that higher-spread issues widened by more, and that a relative spread change of 30% is a much better characterisation of what happened in the industry this month than a parallel shift of 50bp. Looking back at Panels A and B, we can also notice that Panel A shows significant variation around the mean all along the maturity spectrum, while in Panel B we see considerably more variation at the short end of the curve.

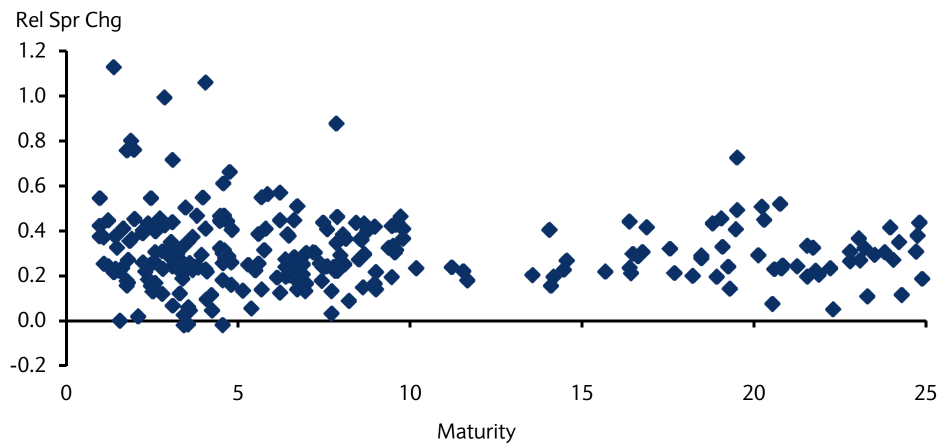
One possible explanation that could be consistent with these observations is that the concept of relative spread shift applies more precisely in the cross-sectional dimension than along the term structure. A perception of increased risk in a sector is accompanied by a widening of spreads across the sector, with issuers at wider spreads widening by more. However, the issuer curve of any given issuer may move in a manner closer to a parallel shift. Thus, if issuer A trades at twice the spread of issuer B (at the same maturity), we should expect it to have twice the spread volatility as well; but if the 10-year spread is double that of the 2-year spread within a single issuer curve, the implications for volatility may be different.

**Figure 9: Spread changes of bonds in US Communications sector, August 2011**

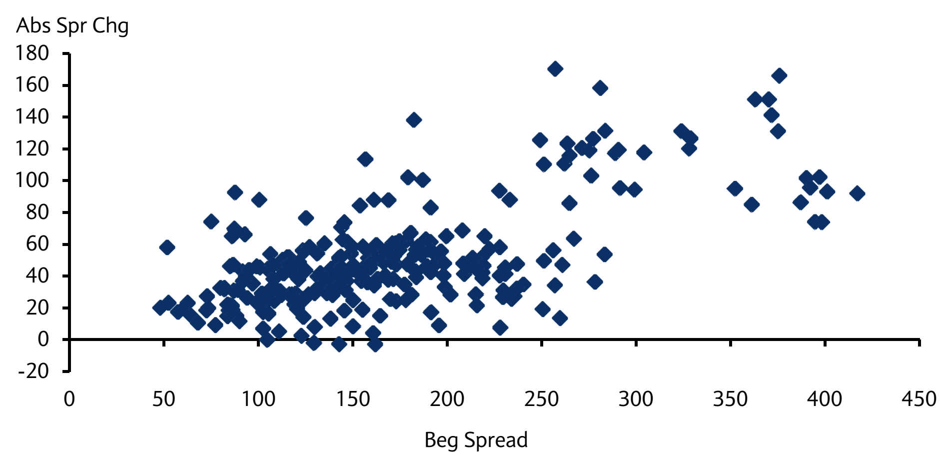
**Panel A: Absolute spread change vs. maturity**




**Panel B: Relative spread change vs. maturity**




**Panel C: Absolute spread change vs. beginning spread**



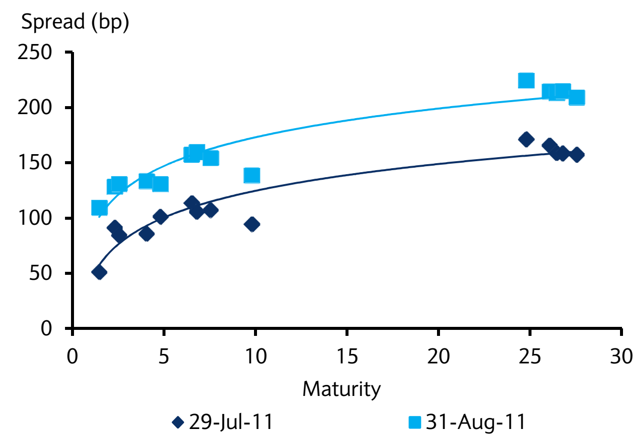

Source: Barclays Research

Let us try to examine directly how the spread widening event shown in Figure 9 was reflected in the spread curves of specific communications industry issuers. In Figure 10, we identify four issuers within this sector that had 12 or more issues outstanding in August 2011, and show how each of their spread curves changed in the course of the month. We find that there is no simple one-size-fits-all rule that characterises these changes. All four issuers exhibited positively-sloping spread curves, but the pattern of the spread changes varied. Roughly speaking, it would seem that AT&T and NewsAmerica (shown in the two top panels) experienced near-parallel spread widenings. (These, of course, would be interpreted as larger relative spread shifts at the short end.) Only Verizon Communications, shown in Panel D, would seem to follow a uniform relative spread change, in which higher spreads increased by more in a roughly proportional fashion. At Comcast (Panel C), the curve steepened as it rose, causing spread changes that were larger at the long end in either absolute or relative terms.

To determine which of these modalities is most likely to be dominant in a given spread environment, we formulated an additional study using our CDS dataset.

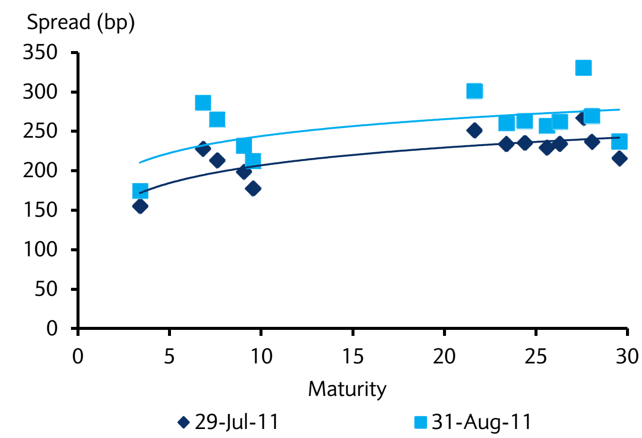
**Figure 10: Changes in issuer spread curves, US Communications sector, August 2011**

**Panel A: AT&T**



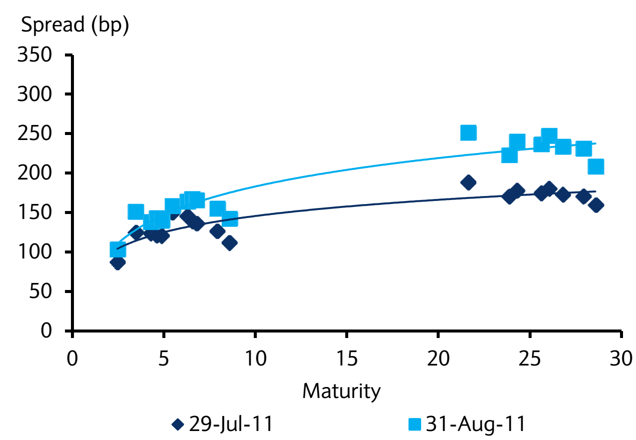

Source: Barclays Research

**Panel B: NewsAmerica**



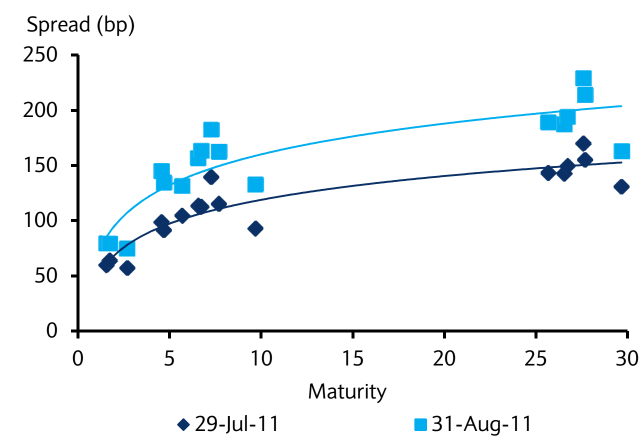

Source: Barclays Research

**Panel C: Comcast**




Source: Barclays Research

**Panel D: Verizon Communications**




Source: Barclays Research

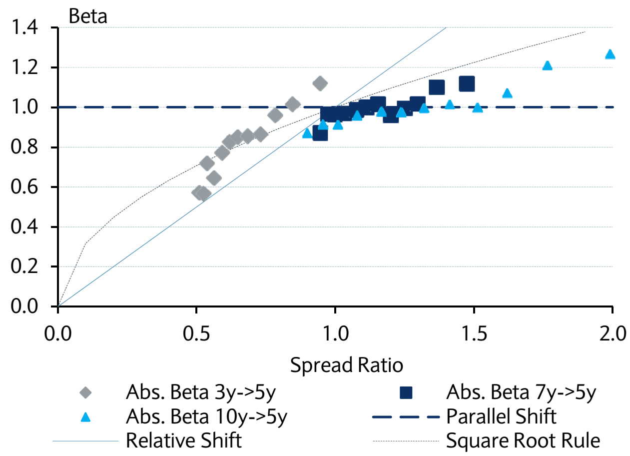
To directly measure the extent to which spread curves follow parallel or relative spread changes, we lined up our database of CDS spread changes by issuer. Using the change in the 5-year spread in a given month as a reference, by how much has the spread tended to change at other points along the curve? For example, we might regress the 10-year spread change of a given issuer against its 5-year spread change. What coefficient would we expect to find? If spread curves tend to change in parallel, the coefficient should be 1 – ie, a 10bp shift in the 5-year should be accompanied by a 10bp shift in the 10-year. However, if a pure relative shift paradigm dominates, then we should expect the coefficient to be equal to the ratio of spreads in the initial curve. The problem with such a regression would be that this ratio changes over time. Therefore, instead of running this regression using time series data for a single issuer, we first pool all of our observations across issuers and months and then partition by spread ratio. Within each cell of this partition, we then have collections of observations of paired spread changes from different issuers and different months, all with similar beginning-of-month spread ratios. Across these paired spread changes in each such cell, we regress the 10-year spread change against the 5-year spread change and see if the result is closer to the initial spread ratio or to one.[14] We similarly address the spread changes at 3-years and 7-years: each, in turn, is analysed with reference to the 5-year point. The results of this analysis are shown in Figure 11.

Panel A of Figure 11 shows the results using data from the entire available time period, from January 2004 through June 2012. If spread curves follow a pure parallel shift, the regression results should follow the horizontal line, showing a beta coefficient of 1.0 regardless of the slope of the curve. If they follow a pure relative spread shift, they should follow the solid diagonal line, in which the coefficient observed in each cell is equal to the ratio of spreads that characterises that cell. The results in Panel A seem to be mixed. The absolute beta of the 3-year spreads shows a clear dependence on the spread ratio; in the cell where the 3-year spreads are half that of the 5-year spreads, the sensitivity to spread changes is about half as well. (In flatter curves, where this spread ratio is closer to one, the beta is greater than one.) However, results for the 7-year and 10-year spreads seem to show much less dependence on the initial spread ratio; they tend to shift in parallel with the 5-year spread for all but the steepest curves. Even then, when the 10-year spread is double the 5-year spread, it tends to move by only about 1.3 times as much.

[14] Formally, if we let $\Delta s_{10}^{it}$ represent the spread change experienced at the 10-year point by issuer *i* during time period *t*, we carry out the regression $\Delta s_{10}^{it} = \beta \Delta s_5^{it} + \varepsilon_{10}^{it}$ across a slice of observations selected across different months and issuers such that the ratios of initial spreads, $s_{10}^{it} / s_5^{it}$, have nearly the same value. The slices were obtained by dividing the sample into 10 deciles by this spread ratio, except that the decile with the lowest spread ratio was further divided into three, to better discriminate between flat and inverted curves. The resulting values of $\beta$ are then plotted against the spread ratios in Figure 11. The same partition of the data is used to form Figure 12, except that there the regressions are carried out on relative spread changes: $\frac{\Delta s_{10}^{it}}{s_{10}^{it}} = \beta \frac{\Delta s_5^{it}}{s_5^{it}} + \varepsilon_{10}^{it}$.

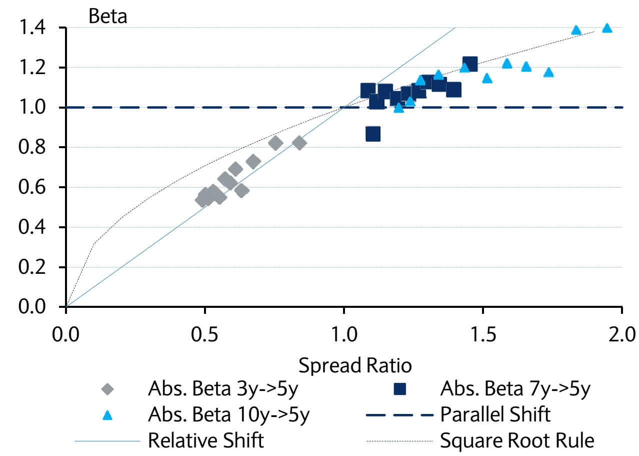
**Figure 11: Absolute spread betas for US CDS as a function of spread ratio over different time periods**

**Panel A: Entire time period – January 2004 to June 2012**



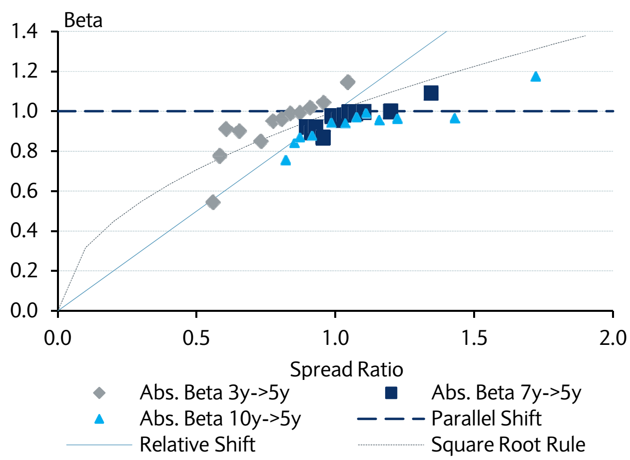

Source: Barclays Research

**Panel B: Quiet period – January 2004 to June 2007**



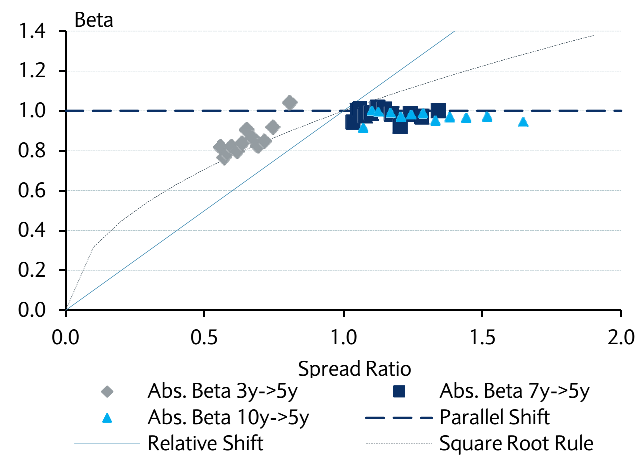

Source: Barclays Research

**Panel C: Crisis period – July 2007 to December 2009**




Source: Barclays Research

**Panel D: Recent period – January 2010 to June 2012**




Source: Barclays Research

Note: The spread ratio plotted on the x-axis is the ratio of the spread at the selected point on the curve (3y, 7y or 10y) to the 5y spread of the same issuer, indicating the slope of the issuer credit curve. For the 7y and 10y datasets, this means that observations further to the right correspond to curves that are more positively sloped; for the 3y dataset, ratios less than one correspond to positive slope and greater than one to an inverted spread curve. The spread beta plotted here for each such dataset is a regression coefficient representing how many bp the 3y (or 7y or 10y) spread will tend to move for each 1bp move in the 5y spread of the same issuer.

Do these results vary over time? Panel B, using data from the low-volatility period of January 2004 through June 2007, shows the 3-year data conforming almost perfectly to a relative shift paradigm, while the 7-year and 10-year data lie somewhere between the pure parallel and pure relative shifts. In Panel C, data from the volatile period of July 2007 to December 2009 seem to show an interesting dog-leg pattern for the 7-year and 10-year data. First of all, these points now span a range in which the initial spread ratio is sometimes above 1 (a positively-sloping spread curve in which longer spreads are higher) and sometimes below 1 (an inverted spread curve). We seem to find that the positively sloped curves move in a near-parallel fashion from 5 years and up, but if the curve inverts, and the 10-year spread is just 0.8 times that of the 5-year spread, then its spread change tends to be just 0.8 times that of the 5-year change. In the most recent data period, shown in Panel D, we seem to detect near-parallel movement of issuer curves across the board.

In addition to the two straight lines corresponding to a parallel absolute shift (slope=0) or a parallel relative shift (slope=1) in spreads, each of the four panels of Figure 11 also shows a dotted curve that lies between these two extremes. This depicts a square root rule, in which the beta of spread changes follows the square root of the spread ratio. Under this rule, when the spread curve is positively sloped, longer-dated spreads will tend to move by more on an absolute basis, but by less in relative terms, than shorter-dated spreads. This curve seems to fit especially well to the 7y and 10y data in Panel B and the 3y data in Panel D. We will discuss the square root rule further in Section 6.

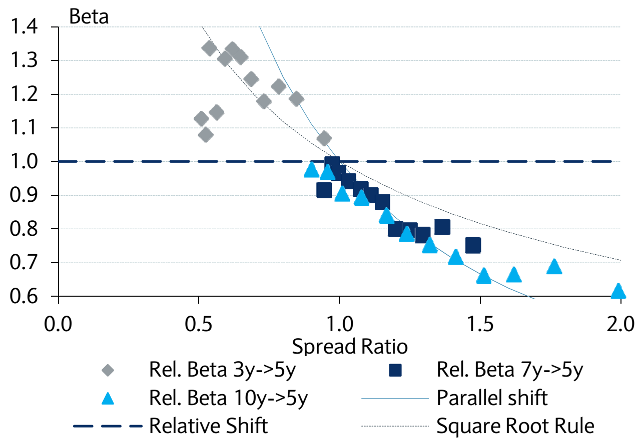
Having seen that the movement of issuer curves lies somewhere between relative and parallel shifts, we can then turn our question around. If we want to work within a paradigm of relative spread shifts (which we do because it works so well cross-sectionally), is there an adjustment factor that we should use to correct for differing sensitivities at different points on the curve? To answer this question, we repeat the regressions of Figure 11 using a relative spread change paradigm. We start with the same dataset, partitioned the same way by beginning spread ratio, but now we regress the observed *relative* spread change at each point on the curve (3-year, 7-year or 10-year) against the *relative* spread change of that issuer at the 5-year point. In this analysis, a pure relative spread shift would give us results that follow the horizontal line corresponding to a coefficient of one independent of the initial spread ratio. A pure parallel shift would follow the solid curve, which corresponds to $y=1/x$; that is, if the 10-year spread is double that of the 5-year, its relative spread change would appear only half as big. The square root rule is once again shown as a dotted curve between these two extremes.

The results, shown in Figure 12, once again show clearly that a pure relative shift is not the dominant mode of changes in issuer curves. As in Figure 11, the results that come closest to a relative spread shift are those shown for the 3-year spreads in Panel B. The relative spread betas observed in this quiet time period tend to be about 1.1, just slightly above a pure relative shift. The results for the 7-year and 10-year relative spread betas show them to be closer to the parallel shift paradigm.

How do these results relate to the volatility ratios that we reported earlier in this article? The data in Figure 4 showed that over the long term at an aggregate level, the relative spread volatility at the 3-year point has been about 1.2 times that of the 5-year, and that of the 10-year point about 0.7 times that of the 5-year. Figures 5 and 7 show that for individual names, the ratios of the volatilities 10-year spreads to the corresponding 5-year spreads tend to range from 0.6 to 1.0, centered around 0.8. In Figure 12, we see confirmation for these ratios on average. The relative spread betas observed for the 10-year point relative to the 5-year indeed range from 0.6 to 1.0, depending on the time period and the spread ratio. However, Figure 12 also shows a clear dependence on spread ratio. If we know the slope of an issuer spread curve, we should be able to form a better estimate of this relative spread beta than to just use a long-term average value. When curves are flat, the beta is close to one; if the curve is steeper, the relative spread beta is reduced and can be substantially less than 0.8. In Section 6, we will discuss how this information may be used to form an enhanced estimate of spread volatility.

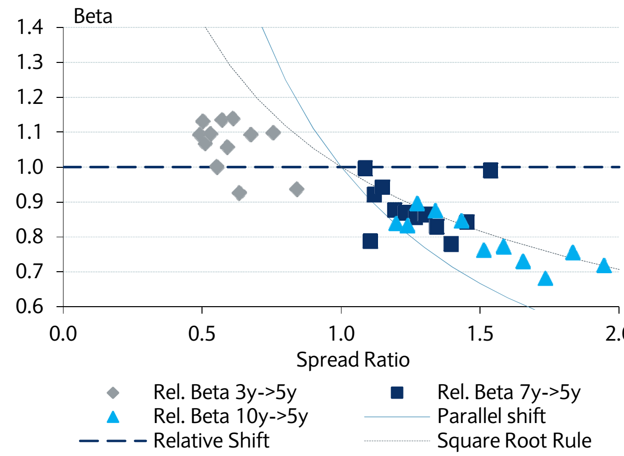
**Figure 12: Relative spread betas for US CDS as a function of spread ratio over different time periods**

**Panel A: Entire time period – January 2004 to June 2012**



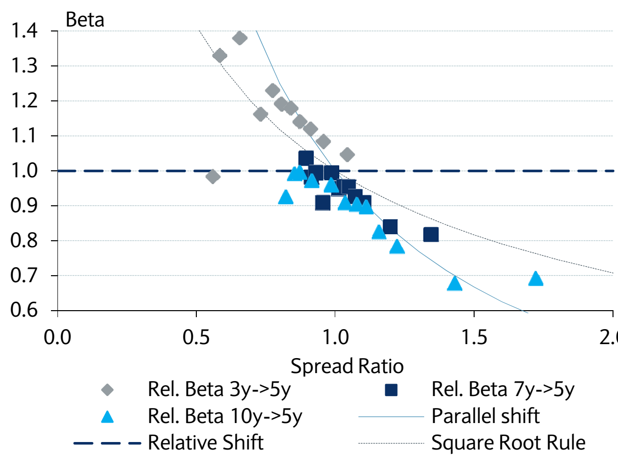

Source: Barclays Research

**Panel B: Quiet period – January 2004 to June 2007**



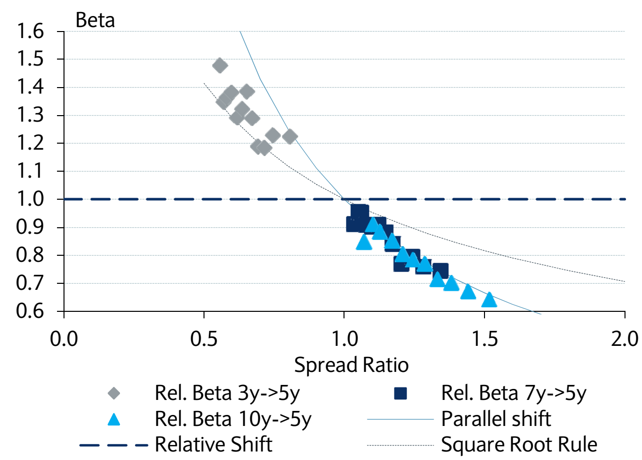

Source: Barclays Research

**Panel C: Crisis period – July 2007 to December 2009**




Source: Barclays Research

**Panel D: Recent period – January 2010 to June 2012**




Source: Barclays Research

Note: The spread ratio plotted on the x-axis is the ratio of the spread at the selected point on the curve (3y, 7y or 10y) to the 5y spread of the same issuer, just as in Figure 11. The relative spread beta plotted here for each such dataset is a regression coefficient representing how large a relative spread change tends to occur in the 3y (or 7y or 10y) spread compared to the relative spread change at the 5y point for the same issuer.

## 5. Effect of maturity dependence on DTS-based risk estimation

How significant is the term structure dependence of relative spread volatilities in estimating portfolio risk due to credit spread changes? To answer this question, we start with a simple pro-forma credit spread risk model based on DTS, in which the systematic risk factors are considered to be proportional spread changes by industry sector, and the portfolio exposures to these factors are the DTS contributions to each sector. One possible modification to such a model would be to partition each sector by maturity to represent the possibility that the relative spread change at each end of the curve is different. The expanded version of the model should always have more explanatory power, but the additional complexity involved in doubling the number of factors argues against making this change unless the difference is truly substantial. In this section, we compare these two versions of the model.

We start the analysis by estimating monthly realisations of systematic spread factors in a given sector. Our first specification does not distinguish between short and long maturity bonds. The factor realisation is estimated by regressing excess returns (defined as returns over duration matched government bonds) of individual bonds in a given sector on their DTS exposures.[15]

(1) Excess Return(i, t) = DTS(i, t-1) x F(t) + e(i, t)

This equation separates realised excess returns of individual bonds into the systematic and idiosyncratic parts. The factor realisations F(t) estimated for a given sector in this model correspond to uniform relative spread changes across the sector, independent of maturity.

Specification (1) does not take into account maturity effects in credit spread risk. However, relative spread changes of long and short maturity bonds can behave differently. To address this issue, we consider an alternative specification that allows for separate systematic factors for bonds of short and long maturities. Their realisations are estimated by regressing the excess returns of individual bonds on short and long DTS exposures.

(2) Excess Return(i, t) = $DTS_S$(i, t-1) x $F_S$(t) + $DTS_L$(i, t-1) x $F_L$(t) + e(i, t),

where $DTS_S$ is the short DTS exposure[16] and $DTS_L$ is the long DTS exposure. In this case, the estimated factor realisations $F_S$(t) and $F_L$(t) represent the relative spread changes experienced across the short-maturity and long-maturity portions of the sector, respectively. Regressions (1) and (2) are run independently for different industry sectors.[17]

We carry out these regressions each month from March 2001 through June 2012 to evaluate the importance of the maturity effect when measuring the systematic excess returns of individual bonds. The regressions measure the extent to which the cross-sectional variation in bond excess returns can be captured by systematic risk factors using each of the two models considered. The model with additional factors should always achieve higher explanatory power; the question is whether the additional accuracy is sufficient to justify the additional model complexity. We find that the importance of the second factor varies greatly over time and sector; for some sectors in some months, the difference between the two can be quite dramatic. However, if we aggregate the results across all sectors and observed months, we find that the explanatory power of the model increases only modestly when we go from one factor per sector to two; the overall R-squared rises from 0.54 to 0.59.

However, our goal in calibrating these two versions of this simple pro-forma risk model was not merely an academic exercise to see which model fits the data better. Rather, we aim to construct a practical test of how much of a difference this modeling adjustment makes in the model's ability to properly measure portfolio risk in different situations. For this purpose, we create diversified portfolios by partitioning the index into three maturity cells and treating the contents of each cell as a separate portfolio. For each such portfolio, we track the actual excess return each month. We also calculate the portfolio excess returns

[15] We use a slightly modified definition of DTS to account for excess return volatility of securities with low spreads: DTS = Max(20, OAS) x OAD.
[16] Ideally, the short and long DTS exposures $DTS_S$ and $DTS_L$ should be calculated directly as sensitivities of bond prices to spread shocks at the short and long ends of the curve, respectively. However, as these numbers are not available, we proxy them using the Key Rate Duration (KRD) exposures of each bond. For fixed-rate credits, the sum of the KRDs should roughly equal the spread duration. We use the sum of the 6m, 2y, and 5y Key Rate Duration (KRD) contributions multiplied by OAS to represent $DTS_S$, and $DTS_L$ is approximated by the sum of the 10y, 20y, and 30y KRD contributions of a bond multiplied by its OAS.
[17] We consider 14 industry sectors: basic industry, capital goods, consumer cyclical, consumer non-cyclical, energy, technology, transportation, communications, electric, natural gas, banking, brokerage, finance companies, and insurance. REIT bonds are excluded because of small number of issuers in some months.

explained by each of our two risk models by multiplying the portfolio exposures (DTS contributions) by the estimated factor realisations (relative spread changes). The unexplained part of the returns is then simply the difference between the realised excess returns of the portfolios and the part explained by the systematic factors. In Figure 13, we tabulate the overall portfolio return volatility, the volatility of the unexplained return, and the percentage of variance explained by the systematic risk factors. These results are shown for portfolios composed of different maturity sub-sectors of the index, over two different time periods, using both the one-factor and two-factor models.

By design, the portfolios shown in the top three rows of Figure 13 have been biased by limiting them to a particular maturity sector of the market. For example, the top row gives the results for the part of the index with maturities of 5 years or less. In the case of the one-factor model, we are taking risk factor realisations that represent the relative spread change observed across an entire sector, and multiplying these by a factor loading that comes from short-maturity DTS contributions only. We find that this tends to understate risk: the percentage of variance explained by the one-factor model for the short-maturity portfolio is only 84-88%, compared with 94-95% for the two-factor model. To clarify, for the 0-5 year maturity bucket, only the short-dated DTS is populated, and only the corresponding short-dated factor realisation is used even in the two-factor model. However, the two-factor model calibrates this short-dated factor to volatilities of only short-dated bonds (allowing it to reflect their higher relative spread volatility) rather than to an average volatility across all maturities as in the one-factor model. During the latter time period, the two-factor model reduces the unexplained volatility from 57.9bp/month to 32.1bp/month for this portfolio. In the central subset of the index with maturities of 5 to 10 years, we find that a single set of factors is largely sufficient to model the systematic spread risk. For the long-maturity cell, with maturities over 10 years, we once again find that the two-factor model adds more explanatory power, but still not as much as in the shortest cell.

**Figure 13: Comparison of 1- and 2-factor models at explaining volatility for diversified bond portfolios with different maturity profiles**

| | March 2001 - June 2007 | | | July 2007 – June 2012 | | |
|---|---|---|---|---|---|---|
| | Portfolio volatility (bp/m) | Unexplained volatility (bp/m) / Percentage of variance explained | | Portfolio volatility (bp/m) | Unexplained volatility (bp/m) / Percentage of variance explained | |
| | | **1-factor model** | **2-factor model** | | **1-factor model** | **2-factor model** |
| Mat [0-5] | 37.2 | 13.0 / 87.8% | 8.9 / 94.3% | 147.4 | 57.9 / 84.6% | 32.1/ 95.2% |
| Mat [5-10] | 78.1 | 14.8 / 96.4% | 10.9 / 98.1% | 236.4 | 35.2 / 97.8% | 25.5 / 98.8% |
| Mat [10+] | 127.7 | 28.7 / 94.9% | 18.1 / 98.0% | 356.1 | 59.5 / 97.2% | 38.8 / 98.8% |
| Aggregate | 71.6 | 8.9 / 98.4% | 8.4 / 98.6% | 224.7 | 30.9 / 98.1% | 25.4 / 98.7% |

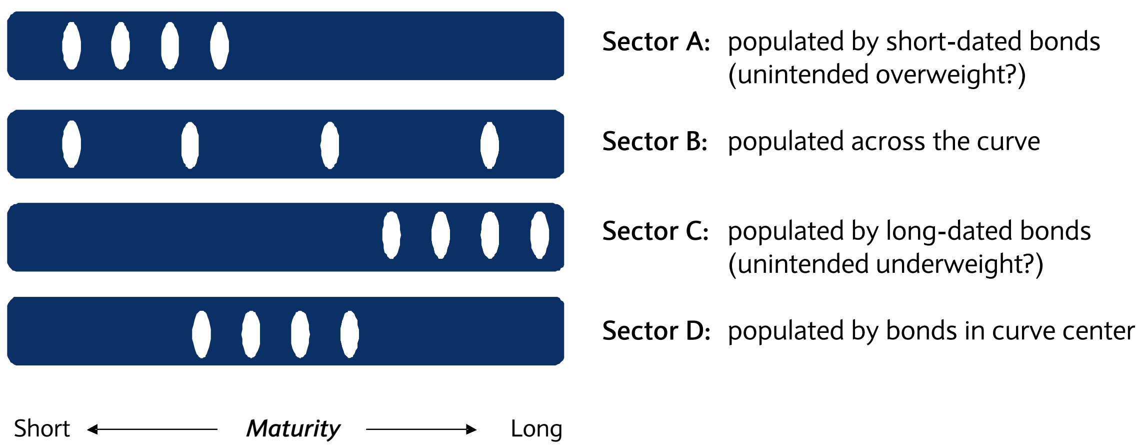
Source: Barclays Research

The bottom row shows the overall results of the two models at explaining the excess returns of the index as a whole. We find that both models explain more than 98% of the index excess return (with the remainder representing non-systematic risk) in both time periods; of course, the magnitude of the unexplained volatility, in bp/month, is much greater in the period that includes the global financial crisis than in the calm period preceding it. Also, in both time periods, the two-factor model achieves somewhat greater explanatory power, but not by a convincing margin. Why is the one-factor model so successful over the whole index? Part of the answer is that the factor realisations were calculated from data in the whole index. However, we see above that we are somewhat less successful at fitting either the long end or the short end alone. The explanation is that there is a diversification effect across the returns unexplained by the one-factor model for long and short maturity portfolios. This model tends to underestimate the magnitude of portfolio returns for shorter maturity bonds (1-5y) and overestimate them for longer-maturity bonds (10+y). When the portfolios are combined, their unexplained returns tend to offset each other. As a result, the unexplained volatility of the aggregated portfolio is relatively small.

The extent to which the term structure effect can distort the estimated risk of a portfolio has thus been shown to depend on the portfolio characteristics. When the portfolio has a strong bias to the short end of the curve, the effect can be significant. If the portfolio is well-diversified across maturities in every sector, then the effect is minor.

Where does this leave a portfolio manager who has not intentionally introduced a maturity bias into his portfolio, but has controlled for maturity only on the aggregate level? The aggregate portfolio shown above included a balanced exposure to long-maturity and short-maturity bonds within every sector. However, if a portfolio is being managed to match a certain set of DTS exposures by sector, without explicit attention to the maturity profile, then some sectors may well be filled in with a bias to the short end of the curve while others are biased long. This is illustrated in Figure 14, which depicts a portfolio's maturity allocation by sector; some sectors are biased towards a particular maturity, while other sectors are represented by a balanced allocation across the curve. Sector A is shown to be populated by short-dated bonds. Due to the term structure effect, this could result in an effective overweight to Sector A. Similarly, Sector C is biased to the long end, possibly resulting in an effective underweight. Must a manager be concerned about the effect of such unintended risk exposures that might creep into a portfolio?

**Figure 14: Illustration of a portfolio with different maturity distributions in each sector**

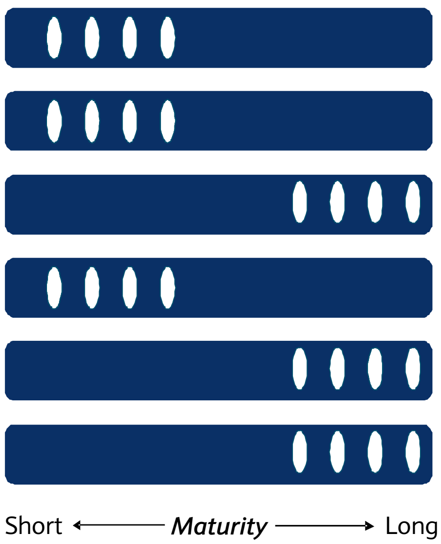



Source: Barclays Research

To address this question, we attempt to track the US Corporate Bond index with portfolios containing a highly exaggerated set of risk exposures of this type. We assume that the overall DTS exposure of the index within each industry sector is matched by the portfolio. However, the exposures within a given sector can be biased towards short or long maturities. We simulate two different portfolio situations: one in which the portfolios are intentionally biased to the short end, and one in which the overall portfolio maturity profile is controlled, such that any maturity biases in one sector will be offset in some other sector.

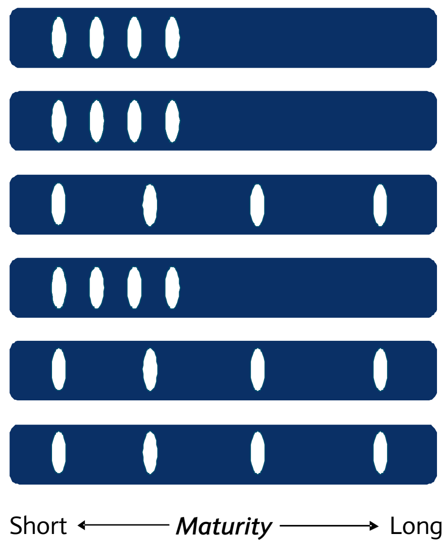
The two types of portfolios we construct in our simulation are depicted schematically in Figures 15 and 16. As a first step, we select several sectors in which the portfolio holdings are to be biased towards short-maturity bonds. In the illustrated example, we have decided to implement this short-maturity tilt in Sectors A, B and D. The difference between the two portfolios is that in Figure 15, we take an offsetting long-maturity tilt in sectors C, E and F. In Figure 16, the portfolio's maturity profile in these sectors is populated along the curve, following the benchmark, with no tilt to either end. The result of this is that the portfolio shown in Figure 15, while it may be exposed to steepening and flattening of spread curves in specific sectors, is largely insulated from a systematic slope change across the entire corporate market; the portfolio in Figure 16 is exposed to a systematic steepening or flattening.

**Figure 15: Example portfolio with offsetting tilts**




Source: Barclays Research

**Figure 16: Example portfolio with bias to short end**




Source: Barclays Research

We simulated 1000 random portfolios constructed according to each of these two paradigms, as follows. We partitioned the US Corporate Bond Index along a 14 x 2 grid of 14 sectors and two maturity cells (above and below 5 years). For each portfolio each month, we randomly select a subset of sectors to be biased to the short end. This is accomplished by multiplying the allocation to the 0-5y cell for that sector by 1.5; the allocation to the over-5y maturity cell for that sector is decreased such that the overall DTS exposure for the sector remains unchanged.[18] For the short-biased portfolios (Figure 16), this completes the portfolio construction; the unselected sectors are unchanged from the index. To create maturity-balanced portfolios, we introduce offsetting tilts towards the longer maturities in all of the sectors not tilted to the short end, as in Figure 15. In these sectors, we decrease the allocation to the short end and increase the allocation to the long end to match the net DTS exposure.[19] We apply this procedure for each month from January 2004 through June 2012 and calculate a time series of realised excess returns for each of our 1000 simulated portfolios. For each such time series, we measured the realised tracking error volatility and the portfolio beta with respect to index excess returns, over three subsets of our data sample. Figure 17 displays the median tracking errors and betas observed for each type of

[18] We do not insist on matching market value allocations, either by sector or overall. As portfolio performance is measured exclusively in terms of excess returns, there should be no bias introduced by this procedure. A portfolio that generates excess returns is in any case a fully financed portfolio; the distortion introduced here would imply that both the corporate bond positions and the offsetting Treasury hedge positions are replaced by greater notional values of shorter-duration securities.
[19] The size of the offsetting tilts to the long end is not fixed, but will depend on the relative weights of the short-tilted and long-tilted sectors. The long tilt is sized such that the net DTS exposure shifted to the long end across all sectors is equal and opposite to the net DTS exposure shifted to the short end, and our portfolio DTS matches that of the index.

portfolio in each time period. We find that the tracking errors induced by maturity mismatches within specific sectors tend to be quite small, especially compared with the overall index excess return volatility. Furthermore, we find that controlling for maturity exposures at the portfolio level is largely sufficient to correct for any biases at the individual sector level. While the short-biased portfolios do indeed appear to be overexposed to the index, those for which maturity was controlled at the portfolio level achieve a median beta of 1.00. Interestingly, data from the most recent time period show that the short-biased portfolios have tended to generate a more marked increase in tracking error than in previous periods while showing a less pronounced increase in portfolio beta.

**Figure 17: Observed median tracking error volatility and market beta for simulated portfolios**

| | Median tracking error volatility (%/month) | | | Median beta of portfolio returns to Index | | |
|---|---|---|---|---|---|---|
| | Early (1/04-6/07) | Crisis (7/07-12/09) | Recent (1/10-6/12) | Early (1/04-6/07) | Crisis (7/07-12/09) | Recent (1/10-6/12) |
| Maturity-balanced portfolios | 0.02 | 0.20 | 0.04 | 1.00 | 1.00 | 1.00 |
| Short-biased portfolios | 0.03 | 0.21 | 0.08 | 1.03 | 1.05 | 1.01 |
| Index excess return volatility | 0.38 | 2.79 | 1.31 | | | |

Source: Barclays Research

## 6. Fine-tuning the model: Possible enhancements to DTS

In the first half of this article, we established that direct measurement of relative spread volatilities shows that they tend to be higher for shorter-dated spreads. This was found to be true for aggregate-level spreads as well as for individual issuers, and was corroborated in CDS and corporate bond markets in the US and in Europe. As a result, a portfolio manager seeking to track a broad corporate index by matching its DTS exposures but filling these exposures by leveraging exposures to short-maturity bonds will be overexposed to the market. However, in the previous section, we showed that DTS-hedged portfolios that do not intentionally express a strong maturity tilt are unlikely to experience significant risk as a result of this effect.

For a majority of investors, we therefore conclude that as long as there is some overall control of the maturity profile in a portfolio, it is not critical to track the sector-level DTS contributions stemming from bonds of different maturities. However, some investors do want to systematically overweight short-dated corporates – perhaps to express a view on curve reshaping, or perhaps to reflect a view that they represent a better long-term risk/return trade-off. If they would like to implement such a position while remaining hedged against market-wide spread changes, they need to know the correct hedge ratio to use. By what factor should the DTS contribution of the portfolio's short-maturity positions in a sector differ from the index's longer-dated DTS contribution to that sector to minimise risk? More generally, if we wanted to model credit spread risk as accurately as possible, how might we adjust the DTS paradigm to accommodate what we have learned about the term structure dependence of relative spread volatility?

Several different approaches can be taken to this problem. One is the approach taken in the prior section. If we subdivide each sector in two and build a risk model with two DTS factors per sector, one for long maturities and one for short maturities, then the correlations between these two factors observed in the covariance matrix can be used to help calculate the necessary hedge ratios. Such a model will have the additional advantage of being able to measure the extent to which a portfolio is exposed to steepening or flattening of the spread curve within each sector. However, one can question whether the marginal improvement in accuracy that this approach could offer would justify the cost, both in terms of computational overhead and in the clarity of reports.

A second, less extreme approach would be to add a single slope factor that represents a common slope change in all sectors simultaneously. We have not explicitly tested such a model in this study, but it follows the spirit of the simulation exercise in the previous section. A large exposure to this factor would indicate that a portfolio contains a systematic slope exposure, but for a portfolio with slope exposures taking different signs in different sectors, these would be allowed to offset each other.[20]

A third approach would be indicated by the early results of this paper, for example, as summarised by Figure 4. The DTS exposure of a given security would be adjusted by a multiple of its maturity. The DTS contributions of short-maturity bonds would thus be increased, and those of long-maturity bonds would be decreased. Following this adjustment, these contributions would be aggregated into a single exposure for each sector.

A fourth possible approach is suggested by the results of Section 4. Figure 12 shows clearly that the sensitivities of short-dated and long-dated spread changes to those at the 5-year point are in fact not constant over time, but vary with the slope of the spread curve. The adjustment to be imposed on the DTS of a particular 3-year bond depends not only on the spread of that bond, but also on the shape of that issuer's spread curve – so we would also want to know the spread of a 5-year bond from the same issuer.[21] If issuer A has a flat curve with a spread of 50bp at all maturities, and issuer B has a spread of 50bp at 3 years but 100bp at 5 years, we would estimate a higher spread volatility for a 3-year bond from issuer B even though it has the same spread as the one from issuer A.

Our conclusion regarding Figures 11 and 12 was that the observed dynamics of spread curves lie somewhere between a pure parallel shift and a pure relative shift. This leads us to suggest a square root rule, which describes a relationship somewhere between the two.

In a pure parallel shift paradigm, we would find that regardless of the slope of the curve, the absolute spread volatilities are the same for all maturities; therefore, points on the curve with higher spreads would appear to have much lower relative spread volatilities. In the pure relative shift paradigm, the relative spread volatility would be constant across the curve, and the absolute spread volatilities at different points would be proportional to the spread ratio. We have found neither of these to be empirically confirmed, and the square root rule shown in the middle column of Figure 18 represents a closer fit to reality than either of the extremes. Absolute spread volatilities are indeed higher for maturities with higher spread levels, but not linearly so.

[20] This, in fact, is essentially the approach taken in the Barclays Global Risk Model. Within each currency, the model uses a single DTS factor for each corporate sector, and a single slope factor for the entire corporate market (although the slope factor is not DTS-based). See Naldi et al (2009) for details.
[21] Note that this feature makes this type of rule more complex to implement. The characteristics of a given bond are not sufficient to define its risk sensitivities in such a scheme; one also needs to establish the shape of the issuer spread curve.

**Figure 18: The square root rule – finding middle ground between absolute and relative spread shift paradigms**

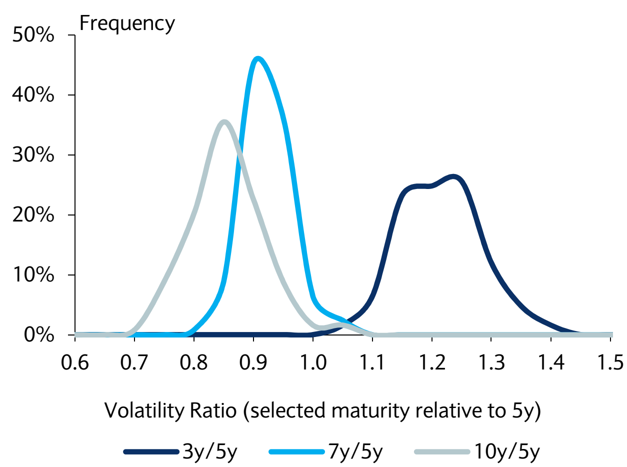
| Parallel Shift | Square Root Rule | Pure Relative Shift |
|---|---|---|
| $\sigma_{10}^{abs} = \sigma_5^{abs}$ | $\sigma_{10}^{abs} = \sqrt{\frac{s_{10}}{s_5}}\sigma_5^{abs}$ | $\sigma_{10}^{abs} = \frac{s_{10}}{s_5}\sigma_5^{abs}$ |
| $\sigma_{10}^{rel} = \frac{s_5}{s_{10}}\sigma_5^{rel}$ | $\sigma_{10}^{rel} = \sqrt{\frac{s_5}{s_{10}}}\sigma_5^{rel}$ | $\sigma_{10}^{rel} = \sigma_5^{rel}$ |

Source: Barclays Research

As a first test of the square root rule, we revisit the distribution of relative spread volatility ratios for US CDS issuers. In Figure 5, we showed that the ratio of 10-year spread volatility to 5-year spread volatility tended to be about 0.80, with values of 1.0 or more found to be quite rare. Now we adjust these numbers based on the square root rule. We take the monthly spread change at each maturity, and instead of treating the basis of this spread change to be the beginning-of-month spread at that maturity, we use the square root rule to obtain a beginning-of-the-month spread between that at our selected maturity and that of the 5-year. For example, we use a particular issuer has a 3y spread of 90bp and a 5y spread of 160bp. If we adjust our reference spread by the square root rule to a level of $\sqrt{90 \cdot 160}$ = 120bp, then a subsequent spread change of 12bp will be seen as a 10% relative spread change rather than a 13.3% change. Once the relative spread changes have been adjusted in this manner, the observed volatility ratios converge towards one, as illustrated in Figure 19. Panel A shows the distributions before adjustment; as we have seen earlier, the results are centred around a ratio of 0.8 for the 10y/5y ratio and about 1.2 for the 3y/5y ratio. As shown in Panel B, the distributions after adjustment have shifted towards the middle, such that they centre around 1.0 for all maturities.

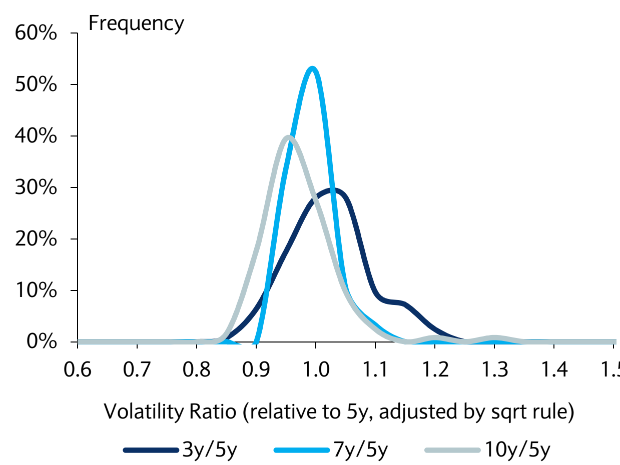
**Figure 19: Distributions of relative spread volatility ratios (ratio of spread volatility at selected maturity to volatility of 5y spreads) among individual US CDS issuers, before and after adjustment by square root rule**

**Panel A: Distributions of unadjusted volatility ratio**




Source: Barclays Research

**Panel B: Distributions of volatility ratios after adjustment**




Source: Barclays Research

To illustrate exactly how this could play out in a portfolio setting, we will work through a simple hedging example. Suppose that instead of purchasing a given 10y bond, we will represent this credit risk exposure in the portfolio using a 3y bond from the same issuer. We will need to buy a greater par value of the shorter-maturity bond to get an equivalent level of risk exposure; Figure 20 shows how this hedge ratio might be set according to four different approaches.

**Figure 20: Computing hedge ratios using the different approaches**

| Hypothetical bond data | | | | Maturity adjustment | | Slope adjustment | |
|---|---|---|---|---|---|---|---|
| Maturity | Duration | Spread | DTS | Constant factor | Maturity-adjusted DTS | Adjusted spread | Slope-adjusted DTS |
| 3y | 2.8 | 50 | 140 | 1.2 | 168 | 63.2 | 177 |
| 5y | 4.5 | 80 | 360 | 1.0 | 360 | 80.0 | 360 |
| 10y | 8.0 | 100 | 800 | 0.8 | 640 | 89.4 | 716 |
| 10y / 3y Ratio | 2.86 | 2.00 | 5.71 | 0.67 | 3.81 | 1.41 | 4.04 |

Source: Barclays Research

In a simple duration-hedging approach, we would purchase 2.86 times as much of the 3y bond as we would of the 10y bond (hedging out the Treasury exposures in either case). Using a pure DTS approach, since the 10y spread is double that of the 3y, the hedge ratio doubles to 5.71 for the example shown. Our research indicates that the best hedge ratio would be somewhere between these extremes. The maturity-based adjustment, which scales the 3y and 10y DTS exposures by constant factors of 1.2 and 0.8, respectively, produces a hedge ratio of 3.81. The slope-based adjustment uses the square-root rule to set the adjusted spread of the 3y as the geometric average of the 3y and 5y spreads; the 10y spread is similarly adjusted to be between the 5y and 10y spreads. The net result in this example is that where the DTS model increases the simple duration hedge by a factor of 2, the slope-adjusted DTS increases it only by a factor of $\sqrt{2}$ , to 4.04.

For the example shown in Figure 20, with a positively-sloped curve, the two adjustments to the DTS model produce hedge ratios that are fairly similar. However, if we change the assumed spread curves in the above example, we can see that this is not always the case. Figure 21 shows the hedge ratios that are obtained for a few different issuer spread curve assumptions. The hedge based on duration remains the same regardless of the spreads. The pure DTS approach generates very large hedge ratios when the curve is steep, converges to the duration hedge when the curve is flat, and gets even smaller when the curve inverts. The constant maturity adjustment always reduces the hedge ratio by a factor of two-thirds (the ratio of the constant factors for the two maturities, 0.8/1.2); note that when the spread curve is flat, the maturity-adjusted DTS hedge ratio is smaller than the pure duration hedge ratio. The slope-adjusted approach always produces a result that is between the pure duration hedge and the pure DTS hedge, and the three are identical when the curve is flat.

**Figure 21: Computing hedge ratios under different issuer spread curves**

| Issuer spread curves | | | 10y / 3y hedge ratios | | | |
|---|---|---|---|---|---|---|
| 3y | 5y | 10y | Duration | DTS | Maturity-adjusted DTS | Slope-adjusted DTS |
| 20 | 50 | 60 | 2.86 | 8.57 | 5.71 | 4.95 |
| 50 | 80 | 100 | 2.86 | 5.71 | 3.81 | 4.04 |
| 80 | 90 | 100 | 2.86 | 3.57 | 2.38 | 3.19 |
| 100 | 100 | 100 | 2.86 | 2.86 | 1.90 | 2.86 |
| 300 | 250 | 200 | 2.86 | 1.90 | 1.27 | 2.33 |

Source: Barclays Research

## 7. Conclusion

Duration Times Spread (DTS) has become a broadly accepted measure of spread exposure in credit portfolios. Its broad endorsement by institutional asset managers is supported by the empirical fact that spread volatility is a linear function of spread level. In prior theoretical work based on the Merton model, we had found that the model predicted higher relative spread volatilities at shorter maturities. Nevertheless, in our prior studies of spread changes and excess returns at the asset class level, we did not focus on the differences between maturity groups. In the current analysis, we started with direct observations of relative spread changes and firmly established that the relative spread change volatility of shorter maturity instruments is indeed higher than that of longer maturity instruments. This phenomenon was found to manifest itself in synthetic (CDS, iTraxx, and CDX) and corporate bond markets for US and European credits.

For CDS markets, the effect can be studied and quantified in a straightforward way since contracts for the same issuer with different maturities are readily available. We find that compared with the relative spread volatilities of 5-year CDS, those of 10-year CDS are 20% lower, on average, and those of 3-year contracts are about 20% higher, on average. These differences have been persistent over time. In bond markets, where a coarser approach to maturity partitioning is appropriate, we similarly find that relative spread volatilities in longer maturities (5-10 years) are about 20% lower than in shorter maturities (1-5 years). We conclude that the linear dependence of spread volatility on spread level is very clear cross-sectionally (when comparing bonds of similar maturities from different issuers), but may need to be adjusted when looking across the term structure of spreads.

In a portfolio context, these conclusions are highly relevant for managers who take active positions along the credit curve. In particular, if one seeks to match the sector exposures of a broad index by using only short-maturity bonds, leveraging the position to match the DTS contributions of the index, the resulting portfolio will tend to be over-hedged. For such a manager, a refinement of the DTS approach may help produce a more accurate hedge. We have presented several different possible approaches to this problem, offering differing levels of accuracy and complexity. For managers who do not actively impose a maturity bias of this nature in their portfolios, we have presented evidence that it should be sufficient to manage the net DTS contributions to each sector as long as the overall maturity profile of the portfolio remains in line with that of the index. For those who wish to model sector exposures in portfolios with extreme credit curve tilts more accurately, we discussed four possible enhancements:

- Splitting a single systematic credit spread factor for a given sector into short-dated and long-dated factors to allow for calibration to different maturity securities;
- Adding a single additional factor to model systematic exposures to credit slope;
- A slope-based approach that scales the DTS for a given bond by the square root of the ratio of the bond's spread to that of a 5y bond from the same issuer;
- Scaling the DTS exposure of a bond by a function of maturity. For short-dated bonds, the exposure would be scaled up; for long-dated bonds, the exposure would be scaled down. The scaling function that best fit our CDS data sample over the time period we have studied would take values of about 1.2 at the 3y point, 1.0 at the 5y point, and 0.8 at the 10y point.[22]

[22] The empirical study of cash bonds would indicate that the DTS exposures of bonds in the 1-5yr range should be scaled up by 20% relative to the DTS exposures in the 5-10yr range, but does not give as detailed an estimate of how this function plays out along the curve.

Each of these approaches has its advantages and disadvantages, and the model of choice will depend on the investor's portfolio setting and preferences. We prefer the slope-based model in principle, but understand that it poses significant difficulties in implementation. It might be possible to construct an implementation that retains the fundamental spirit of the slope-based model without keeping track of complete spread curves for every issuer. For example, one could consider the average slope of the spread curve across a sector and use this to help calibrate the function used in the maturity-based approach.

A manager may have two different types of questions about his portfolio exposures. We have focused on accurately measuring and managing the overall portfolio risk exposures to issuers and market sectors, and making sure that these betas are not distorted by term structure effects. In addition to this, a manager may be interested in measuring his portfolio's exposure to changes in the shape of the credit curve. For this application, the risk model would need to take one of the first two approaches listed above, which explicitly keep track of different-maturity exposures.

Finally, we would like to emphasize the role played by leverage in this story. The power of DTS lies in its simplicity – the excess return volatility that a given bond position contributes to a portfolio is roughly proportional to its DTS exposure. The current study shows that this simple linear relationship may understate the risk exposure of very low-DTS bonds slightly. The resulting errors, however, will be very small in terms of portfolio excess returns – unless the exposures to these low-risk bonds have been leveraged dramatically. Whenever highly leveraged strategies are employed, care must be taken to consider the effect of small uncertainties in the hedge ratio, which could be magnified into large risks in the portfolio. This can be seen clearly in the simple example in Figure 21. When a 3y bond is used to represent the risk exposure of an equivalent 10y bond, the hedge ratios we obtain range from below 2 to above 8 depending on the model. In situations like this, it is important to pay close attention to the calculation of the hedge ratio. However, in the case of a cash bond portfolio in which leverage is not allowed, such extreme situations are highly unlikely to arise. If a portfolio matches the DTS contributions of its benchmark to all sectors, and the total market value of the portfolio is fully funded, there is much less of a chance of a strong systematic bias towards one end of the curve or the other. In this situation, the pure DTS model should be sufficiently accurate for most purposes.

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