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EMPIRICAL DURATION OF CORPORATE BONDS AND CREDIT MARKET SEGMENTATION



Introduction

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Many portfolio managers with investment grade benchmarks are allowed out-of-benchmark (“core-plus”) allocations to high yield debt. As with any other asset class, they need to understand the effect such allocations have on the overall duration of their portfolio. It is widely acknowledged that the interest rate sensitivity of high yield securities is not necessarily what their stated cash flows imply. Yet there is a wide range of opinion on this issue among portfolio managers. At one extreme, there are those who account for the full analytical duration of the high yield component. At the other extreme are the managers who claim that high yield debt exhibits rather equity-like behavior and ignore the duration contribution of high yield entirely. The majority in between usually have some heuristic rule of thumb – for example, to consider 25% of the analytical duration for high yield bonds.

Uncertainty about the interest rate sensitivity of high yield bonds can severely affect the ability of portfolio managers to express their views on rates accurately. Assume, for example, that a portfolio and its benchmark both have a duration of 5 and that the manager shifts 10% of the portfolio into high yield, also with (analytical) duration of 5. Depending on one’s opinion, the “true” duration of the portfolio is anywhere between 4.5 and 5.0 – a tremendous range for many managers used to tweaking duration in much smaller increments when expressing their views on rates. If the portfolio target duration is 4.80 and the manager is prepared to adjust the Treasury component of the portfolio to hit this target, does he need to add duration or subtract it?

Similar investors’ inquiries have prompted us to publish several studies since 2005 on the empirical duration of U.S. investment grade and high yield bonds.¹ The studies confirmed that empirical durations decline as credit ratings deteriorate and established a relation between empirical duration and the level of spread based on both theoretical and empirical evidence. The findings indicated that the sensitivity to rates decreases as spreads widen, even across bonds with the same credit quality. Similar patterns were found for emerging markets bonds.

The main focus of the initial research was on high yield bonds. The key concern was that high yield managers tended to ignore the yield curve sensitivity of their portfolios, which at that time was becoming increasingly important. As we explored the dependence on spread levels, the operative conclusion was that as spreads continued to tighten, the effective duration of high yield was likely to increase, corresponding to a larger portion of the analytical values. We suggested that ignoring the curve duration is inappropriate in a tight-spread environment.

The ultra-wide spread environment in late 2008 and early 2009 led many investors to ask the opposite question: have investment grade empirical durations declined to levels typical of high yield bonds? Certainly, the spread-dependent relationship we have documented would lead us to expect empirical durations to be significantly lower than analytical durations, even for investment grade bonds.

The extreme conditions in the credit market also served as a true “out-of-sample” test of the earlier results and the framework we suggested for estimating empirical durations. We found that the basic qualitative and quantitative conclusions of the earlier studies have been largely confirmed, although the slope of the spread dependence of empirical duration was flatter than what could have been expected.² Despite the abnormal spread levels that characterized the crisis period beginning in 2007, investment grade bonds seemed reluctant

¹ The complete list of publications on the topic can be found in the Reference Section.

² *Empirical Duration of Corporate Bonds in the Credit Crisis*, May 28, 2009.

to give up interest rate sensitivity, while high yield bonds continued to demonstrate equity-like behavior, with zero or even negative empirical durations.

This clear separation between investment grade debt that stubbornly retained its interest-rate sensitivity even as spreads widened and high yield debt that refused to increase its sensitivity even when spreads tightened was a prominent and consistent feature in all previous studies. Furthermore, default and recovery considerations could not account for the observed gap.

The first part of this paper augments the various pieces we published on the topic and provides a unified and coherent treatment of the relation between the analytical and empirical duration of corporate bonds, updated through the recent credit crisis. In the second part, we investigate two alternative explanations for the discontinuity in interest-rate sensitivity between investment and non-investment grade debt.

First, we examine whether the apparent gap is a result of “stale pricing.” Specifically, we test whether differences in pricing conventions and liquidity levels between the two markets mechanically cause high yield bonds to appear to have lower interest rate sensitivity than investment grade bonds. We conduct several tests including using the TRACE (Trade Reporting and Compliance Engine) volume database to examine if our results may be driven by a larger degree of stale pricing in the high yield market relative to investment grade. While we do find a relation between trading volume and pricing dynamics, our results are robust to the existence of stale pricing and there is no indication that the sharp decline in interest rate sensitivity when crossing from investment grade to high yield territory is simply an artifact of the data.

Another possibility was that our findings may have at least partially reflected differences in bond characteristics across rating categories that could affect the observed hedge ratios. To address this concern, we analyze the changes in empirical durations of individual bonds that were downgraded from investment grade to high yield or, conversely, were upgraded from high yield to investment grade. This “event study” approach, where the same population of bonds is examined before and after the downgrade/upgrade date, controls for any bond-specific characteristic.

We find that downgraded bonds experience a large decline in their interest rate sensitivity close to the date of the downgrade. Furthermore, the magnitude of the change in empirical duration is very similar to what we have already documented for the aggregate population of bonds. The reverse patterns are observed for high yield bonds that were upgraded to investment grade.

What, then, can account for the apparent segmentation in the credit markets between investment and non-investment grade bonds? We hypothesize that the reason may be that investors in the two markets use different performance metrics. Investment grade credit managers are typically evaluated in terms of excess returns over Treasuries (or swaps), while high yield managers tend to think in terms of total return and default risk. This difference in approach, and the hedging practices that result from it, may lead to the reduced effect of interest rate movements on high yield valuations. We provide some indirect evidence supporting this theory.

The last section contains a discussion of several practical applications of using empirical duration to hedge the interest rate exposure in credit portfolios.

Empirical Duration – Theory and Evidence

One of the dominant characteristics of a bond portfolio is its sensitivity to interest rates, as captured by its Treasury duration. While any portfolio analytics software will dutifully turn out duration numbers for bonds based on their projected cash flows, the typically negative correlation between rates and spreads can dampen the actual response of corporate bonds to a change in rates. Investors have long been aware of this phenomenon and distinguish between analytical and empirical duration – the amount by which a bonds' absolute return will change, given a particular yield change.

Despite the importance of understanding the relation between analytical and empirical duration and being able to quantify their difference over time, there is no common accepted approach for doing so. Many portfolio managers regress price returns against changes in Treasury yield over “rolling” windows of various length. Others use some heuristic rule of thumb, for example, to consider a fixed proportion of the analytical duration for high yield bonds, while some ignore the issue altogether.

This section provides an updated review of the research we conducted on the relation between empirical and analytical duration over the past several years. To understand under what conditions empirical and analytical duration may differ, we first derive an explicit theoretical linkage between the two. We then describe the estimation methodology and the empirical findings across different rating categories and periods.

The Relation between Analytical and Empirical Duration

Let us assume that in a macro sense, the returns of credit securities can be broadly described by a simple two-factor model, where the factors are a parallel shift in Treasury yield Δy and a relative change in spreads $\Delta s_{rel} = \Delta s / s$. The latter assumption builds on extensive research on the behavior of corporate spreads, in which we found overwhelming evidence that spread changes tend to be linearly proportional to the level of spreads.³

If we assume further that the Treasury duration and the spread duration of a particular security i are approximately the same, and given by D_i , the return to this security can be approximated as follows:

$$(1) \quad R_i \cong -D_i \times \Delta y - (D_i \times s_i) \times \Delta s_{rel}$$

To measure the sensitivity of the overall return to a change in Treasury yields, we use a simple approximation for the relationship between spreads and yields, based on the sample variances and covariance of the two:⁴

$$(2) \quad \frac{\partial s_{rel}}{\partial y} \cong \frac{\text{cov}(\Delta y, \Delta s_{rel})}{\text{var}(\Delta y)} = \frac{\rho_{y,s} \sigma_y \sigma_s}{\sigma_y^2} = \rho_{y,s} \frac{\sigma_s}{\sigma_y}$$

Using the above relationship to obtain the sensitivity of return to a shift in Treasury yield, Δy , we have:

$$(3) \quad \frac{\partial R_i}{\partial y} \cong -D_i - D_i \times s_i \times \frac{\text{cov}(\Delta y, \Delta s_{rel})}{\text{var}(\Delta y)} = -D_i \left(1 + s_i \rho_{y,s} \frac{\sigma_s}{\sigma_y} \right)$$

³ For a detailed analysis of the topic see Ben Dor, A., L. Dynkin, P. Houweling, J. Hyman, E. Leeuwen, and O. Penninga. *DTS (Duration Times Spread): A New Measure of Spread Exposure in Credit Portfolios*. Lehman Brothers, June 2005.

⁴ Notice that the expression in Equation (2) is the estimated coefficient from a univariate regression of changes in relative spread against changes in yields.

The expression in Equation (3) is the theoretical value for what we term empirical duration – the amount by which the absolute return will change given a particular yield change. Since volatilities and spread levels are non-negative, the magnitude of the empirical duration relative to the analytical figure depends on $\rho_{y,s}$, the correlation between yield and relative spread changes. If this correlation is negative, the empirical duration would be lower than the analytical one and may even end up being negative.

Estimation Methodology and Empirical Analysis

The expression derived in Equation (3) can easily be tested by estimating the following regression:

$$(4) \quad R_i = \beta_i \cdot D_i \cdot \Delta y + \gamma_i \cdot D_i \cdot s_i \cdot \Delta y + \varepsilon_i$$

The regression provides a linear approximation for the empirical hedge ratio H_i (the ratio between the empirical duration and the analytical duration) as a function of spread s_i , as follows:

$$(5) \quad H_i^{emp}(S) = \beta_i + \gamma_i \cdot s_i$$

where β_i , is the upper limit of the empirical hedge ratio that might be expected for a bond i as spreads approach zero; the second coefficient, γ_i , which is negative in general, reflects the reduction in hedge ratio as spreads widen.⁵

While estimation of Equation (4) is straightforward in principle, the results may be sensitive to the choice of sample frequency, period, and level of bond return aggregation. We decided to conduct most of the analysis using daily data, for two reasons: to match the hedging frequency employed in practice by portfolio managers and to achieve a larger sample and consequently higher statistical power.

Daily data for individual bonds, however, are unavailable to us prior to 2006, which limits our ability to evaluate the results across different market regimes. We use, instead, aggregated daily return data of six credit rating categories spanning the Barclays Capital Corporate and High Yield Indices (Aaa/Aa, A, Baa, Ba, B and Caa), which are available since August 1998.⁶ The regressions are estimated using the price returns for each rating category and the contemporaneous yield changes of the 10y on-the-run Treasury note. The spread s_i is represented by the option-adjusted spread of all securities (market value weighted) comprising each rating category and is measured with a one-day lag (i.e., based on the previous day's closing mark).

Panel A of Figure 1 displays the regression coefficients estimated over the entire sample period from August 1998 through November 2009, by rating category. The results confirm a strong relationship between hedge ratios and the level of spreads, consistent with Equation (5). The spread slope coefficient is negative and significant (at the 1% confidence level) for all credit ratings, and the sensitivity at the limit (beta) for high grade bonds is close to one as implied from Equation (3). Substituting, for example, the estimated beta and

⁵ If $\rho_{y,s} \frac{\sigma_s}{\sigma_y}$ represented by the coefficient γ_i varies over time, it may cause β_i to be different than the value implied from equation (3), which is one.

⁶ We report results based on bi-weekly data, using individual bonds and after applying different liquidity filters in the next two sections.

gamma for Baa rated bonds (0.85 and -0.02, respectively) in Equation (5) yields an empirical hedge ratio of 0.83 for spreads of 1%, declining to 0.75 for spreads of 5%.

Panel B presents an evaluation of the expression in Equation (3) based on direct observation of daily changes in credit spreads and Treasury yields. For each of the six quality groups, we measure the standard deviation of relative spread changes, as well as the correlation with changes in Treasury yield. We then use these to calculate the linkage factor shown in Equation (2), which gives approximately the amount of relative spread widening one would expect if yields were to drop by a certain amount. This number, along with the average spread level for each quality group over the period, is used to calculate the theoretical hedge ratio – the quantity in parentheses at the end of Equation (3). This number, in turn, can be compared with the average hedge ratio found for each quality group based on the coefficients reported in Panel A.

Figure 1: Treasury Hedge Ratio of Corporate Bonds by Credit Rating

Panel A: Regression-Based Hedge Ratios

Coefficients	Aaa/Aa	A	Baa	Ba	B	Caa
b: hedge ratio limit	0.94	0.92	0.85	0.41	0.15	0.07
t-stat	70.69	58.36	50.66	11.94	2.80	0.79
γ : spread slope	-0.05	-0.05	-0.02	-0.05	-0.03	-0.02
t-stat	-8.19	-7.60	-4.55	-7.85	-4.51	-3.12
R ²	0.79	0.75	0.74	0.06	0.01	0.01
OAS range						
Min	0.37	0.56	1.05	1.46	2.21	3.68
Average	1.04	1.50	2.16	3.92	5.77	10.75
Max	4.71	5.95	7.70	13.75	18.58	28.33
Hedge ratios at:						
Min OAS	0.92	0.89	0.83	0.34	0.08	-0.01
Average OAS	0.88	0.85	0.80	0.22	-0.03	-0.15
Max OAS	0.68	0.64	0.67	-0.26	-0.42	-0.52

Panel B: Model-Based Hedge Ratios

	Aaa/Aa	A	Baa	Ba	B	Caa
σ_s - Vol. of Relative Spread Changes	2.3%	1.8%	1.6%	2.5%	2.0%	1.8%
$\rho_{y,s}$ - Correlation with 10-Year Yield Chg.	-0.14	-0.17	-0.23	-0.50	-0.56	-0.40
σ_y - Vol. of Treasury Yield Changes (bp)	6.4	6.4	6.4	6.4	6.4	6.4
$\rho_{y,s}(\sigma_s / \sigma_y)$ - Linkage Factor	-4.9%	-5.0%	-5.7%	-19.4%	-18.1%	-11.5%
Theoretical Hedge Ratio at avg. spread level (based on Eq. 3)	0.95	0.93	0.88	0.24	-0.04	-0.23

Note: All calculations are based on daily data between August 1, 1998, and November 30, 2009. The results in Panel A are based on estimating Equation (4) separately for each rating category using the daily (market value-weighted) price returns of all bonds comprising each category. Source: Barclays Capital

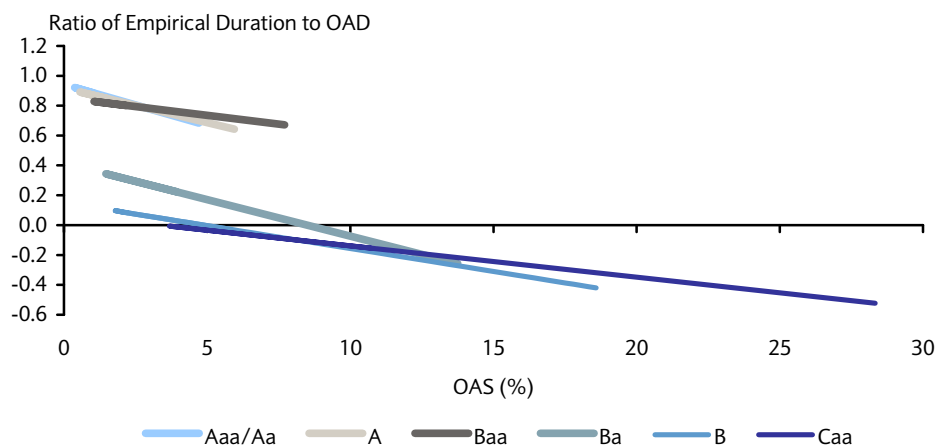
The results in Panel B corroborate the regression-based results, in three ways. First, relative spread volatility is fairly similar across the various quality groups, consistent with our previous research on spread behavior and the formulation in Equation 1. Second, both sets of hedge ratios are similar in magnitude. Third, the steep drop in the hedge ratio to Treasury yields as we cross over into high yield territory is again observed.

Panel B also confirms the findings in Hyman (2007) about the negative correlation between interest rates and credit spreads. This is what makes the return volatility of investment grade credit indices lower than that of Treasuries; here, it shows itself as a decrease in empirical duration as the exposure to credit spread risk grows. As spread increases, the effect of this negative correlation is magnified, as per equation (3); this makes the effect more pronounced for high yield bonds than it is for investment grade bonds. In the extreme, the exposure to credit spread may become high enough to even create negative durations.

Variation in Hedge Ratios across Credit Ratings

Figure 2 displays the hedge ratios as a function of spread, based on the regression coefficients reported in Panel A of Figure 1, over the range of spreads at which bonds from each rating category were trading during the sample period. The plot illustrates that the interest rate sensitivities of the three investment grade ratings form a coherent pattern, decreasing as spreads widen. In contrast, high yield bonds seem almost completely disconnected from interest rates, even at spread levels that overlap with those of investment grade bonds. With hedge ratios near or below zero across most spread levels, high yield securities more closely resemble equities than bonds.

Figure 2: Hedge Ratios as a Function of Spread by Credit Rating



Note: The plot is based on substituting the regression coefficients from Panel A of Figure 1 and the minimum and maximum spread level during the sample period (8/1/1998 - 11/30/2009) separately for each credit rating in Equation 5.
Source: Barclays Capital

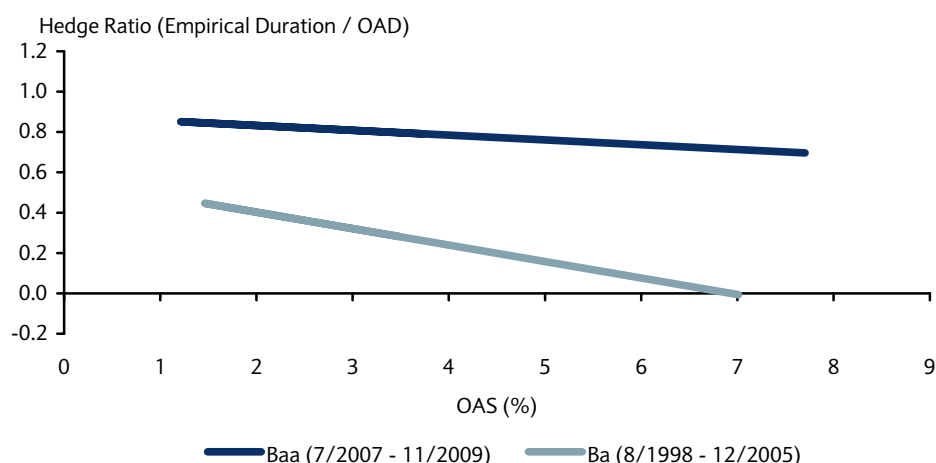
One possible explanation to this sharp difference is that high yield bonds trade mostly on default/recovery expectations and are, thus, less sensitive to Treasury yields. When the likelihood of default is perceived as high, the primary determinant of a bond's value is the assumed rate of recovery upon default. In extreme cases, this may cause all bonds of a given issuer (at the same seniority level) to be marked at the same dollar price, regardless of maturity. In situations such as this, the perceived negative correlation between Treasury yields and spreads is just an artifact of a mis-specified model, in which the bond's price is related to the discounted value of cash flows that the market assumes will never arrive.⁷

⁷ Even in less extreme situations, the pricing of credit-risky securities is influenced by the probabilities that the issuer will default at different times and the assumptions investors make about what the recovery rate would be should this occur. Including the possibility of a recovery event in which we receive a principal payment smaller than the full amount, but earlier in time, lessens the sensitivity of the pricing model to changes in Treasury rates. Berd, Mashal

In our 2005 study, we examined this explanation by repeating the analysis after excluding from the dataset all bonds with a price below 80. This threshold was intended to separate securities “trading on price,” i.e., on estimates of recovery value, from those priced by discounting cash flows to redemption at a spread to Treasuries. However, the results were essentially unchanged and the discontinuity in hedge ratios was still evident, suggesting that the difference in interest rate sensitivities between the two markets cannot primarily be due to considerations of default and recovery.⁸ Furthermore, to the extent that credit risk is broadly captured by the level of spread, one would expect bonds with the same spread level to exhibit similar hedge ratios (as is also implied from Equation 3). While this is generally the case when all bonds are rated either investment grade or high yield, it does not hold across the two markets (Figure 3).

Figure 3 plots the hedge ratios as a function of spread level for Baa bonds during July 2007–November 2009 and Ba rated bonds during August 1998–December 2005.⁹ While the spreads of Baa bonds during the crisis period almost exactly overlapped with those of Ba bonds in the earlier period, their observed hedge ratios were very different, in terms of the absolute value and the sensitivity to spread (i.e., the slope – gamma). It seems that there is a clear separation between the two markets that cannot be accounted for by consideration of default and recovery (at least as captured by spread).

Figure 3: Discontinuity in Hedge Ratios between IG and HY Markets



Note: The plot is based on estimating Equation (4) separately for Baa and Ba rated bonds using the daily (market-value-weighted) price returns of all bonds over different time periods during which they had similar spreads. We use Baa data from July 2007–November 2009 and Ba data from August 1998–December 2005. Source: Barclays Capital

We investigate several alternative explanations to the apparent discontinuity in hedge ratios between high grade and high yield bonds. First, however, we examine to what extent our results are stable over time in different market conditions.

Stability and Predictability of Hedge Ratios

The time that elapsed since we published our initial findings in March 2005 has been anything but uneventful. For example, the average OAS for the A rated portion of the U.S.

and Wang (2004) present a survival-based valuation framework that offers an analytical approach to the calculation of interest rate sensitivity, as opposed to the empirical approach explored here.

⁸ We did not repeat this experiment because of the negative outcome in the prior study. Even more importantly, a price cutoff of 80 would no longer filter out just a small portion of the index. For example, at the end of April 2009, the percentage of bonds trading at 80 or lower in the Barclays High Yield Index was 52%, up from 4% in February 2005.

⁹ The estimation for each rating category was done separately over the respective period.

Corporate Index has widened from 57bp at the end of February 2005 to 188bp at the end of November 2009, after reaching a record wide of 578bp in early December 2008. As the widest observed spread within our earlier dataset was 230bp in October 2002, the recent experience serves as a powerful “out-of-sample” test for past results.

If we were to project empirical hedge ratios as a function of spread based on our 2005 regression estimates, how closely would these projections match the empirical hedge ratios that were actually observed during the recent crisis? Figure 4 compares the extrapolated hedge ratios based on the original set of regression coefficients (shown in Panel A of Figure 6) to the trailing 90-day empirical hedge ratios observed in practice, over June 2005–November 2009.¹⁰ This test is somewhat unfair: a straight-line approximation for a spread-dependent quantity should be applied only for interpolation within the range of spreads used in the fitting procedure. As spreads widened beyond the limits of our earlier data sample, one should be hesitant to use that straight line fit to extrapolate further to the right; yet that is exactly what we are doing in this exercise. Despite these reservations, we found the outcome quite impressive.

The results in Figure 4 suggest that the projected hedge ratios overall provided a fairly good fit, although the empirical hedge ratios exhibited some unstable behavior, especially in volatile markets; both declined as spreads began to widen after June 2007.¹¹ However, the empirical hedge ratios tended to decline less quickly than their projected counterparts, especially in the case of investment grade bonds. Apparently, no matter how much spreads widened, investment grade investors did not stop paying attention to interest rates and continued to trade these securities as bonds, not as equity. Sensitivity to interest rates disappeared only below a certain quality rating threshold.

To investigate this issue more closely, Figure 5 plots the time series of 90-day trailing empirical duration alongside the average spread computed over the same time window, starting in December 1998 until November 2009. The plots confirm the negative relationship between empirical durations and the level of spread. As spreads have risen since the second half of 2007, empirical durations have declined across the board, even for higher quality bonds such as A and Baa. This should not be surprising, given that A spreads in this period were multiples of Ba spreads in February 2005.

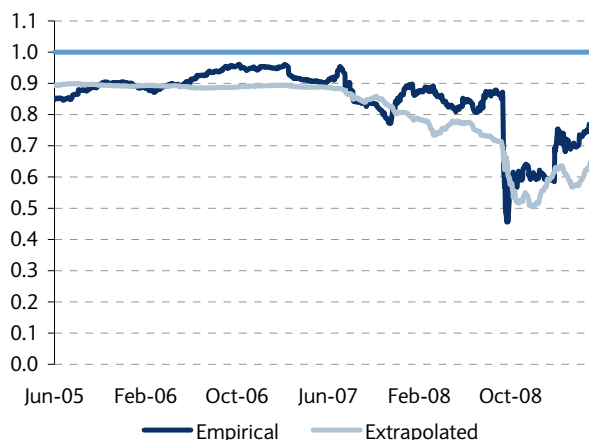
However, extrapolating from prior historical experience would have suggested lower empirical durations than those observed in practice. In spite of investment grade spreads going into traditionally high yield territory, their empirical durations have not reached the low levels observed in high yield. Similarly, a weakening of the spread dependence is observable in the high yield segment. As spreads widened to record levels since mid-2007, empirical durations showed resilience, refusing to fall as low as the historical negative correlation would imply. For example, when Ba spreads topped 600bp in 2002, the corresponding empirical duration was as low as -2; we might have expected it to be even more negative as spreads climbed above 1000bp in early 2009. Yet it never dipped too far below zero.

¹⁰ The analysis starting date in June 2005 reflects the 90-day window beginning in March 2005, when the initial study was published. The results for the two credit rating categories not plotted in Figure 4 (Aaa/Aa and Caa) are similar.

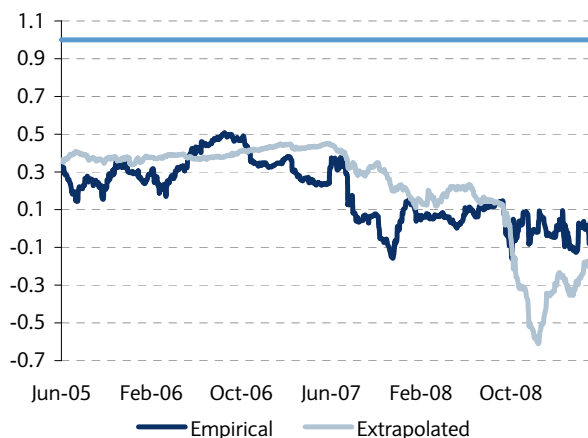
¹¹ For example, a sharp dive in the A empirical duration, later reversed, was caused by the market turmoil that followed the September 2008 bankruptcy of Lehman Brothers, which carried an A rating at the time.

Figure 4: Comparison of Empirical versus Projected Hedge Ratios

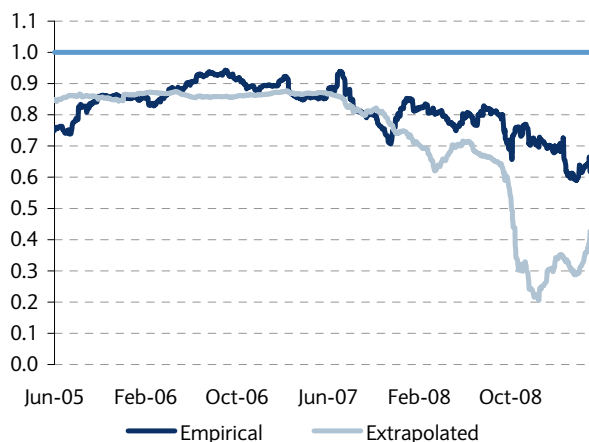
A) U.S. Investment Grade Corporate Index: A



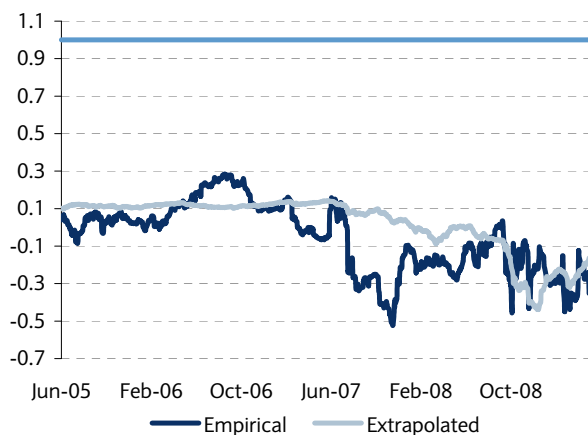
C) U.S. High Yield Index: Ba



B) U.S. Investment Grade Corporate Index: Baa



D) U.S. High Yield Index: B



Note: The empirical hedge ratios are based on regressing price returns against the product of Treasury duration and changes in 10y yield using a trailing 90-day window between June 2005 and November 2009. The projected hedge ratios are extrapolated using the coefficients reported in Panel A of Figure 6.

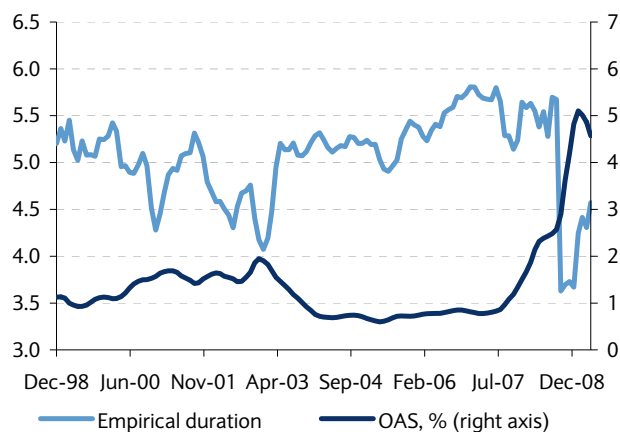
Source: Barclays Capital

While the evidence in Figures 4 and 5 clearly support the relationship between empirical and analytical duration as a function of spread level, they also indicate that the behavior during the crisis period has deviated, to a certain extent, from what one may have expected. It is, therefore, instructive to compare the results from re-estimating Equation 4 over the crisis period of June 2007-November 2009 with the original results spanning August 1998-February 2005.

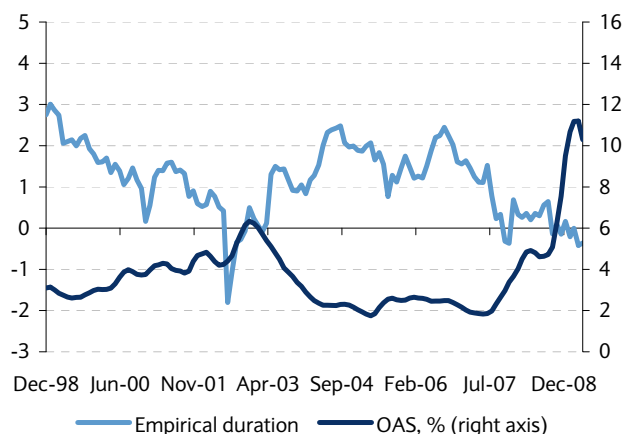
The results reported in Figure 6 indicate that some of the patterns discussed earlier seem to slide up the quality scale. In the tumultuous markets of the credit crisis, even Aaa/Aa securities have a pronounced relationship between their empirical durations and spreads; the observed regression coefficients are remarkably close to those in the earlier period for A rated debt. In contrast, at the lower end of the spectrum, it is the independence between empirical durations and spreads that creeps up to higher quality securities. Now, we do not see any spread dependence even for Ba.

Figure 5: The Relationship between Empirical Duration and Spread Level

A) U.S. Investment Grade Corporate Index: A



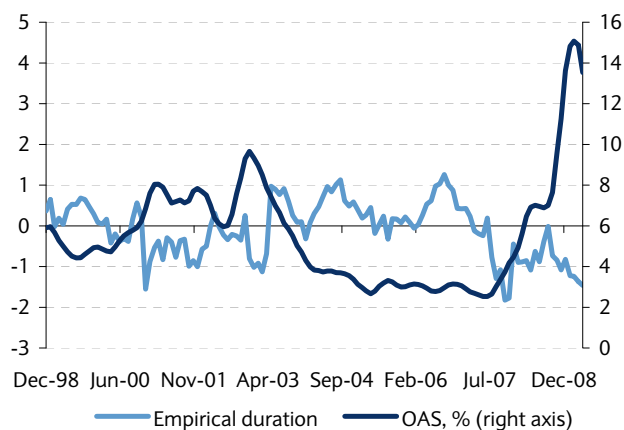
C) U.S. High Yield Index: Ba



B) U.S. Investment Grade Corporate Index: Baa



D) U.S. High Yield Index: B



Note: The empirical durations are based on regressing price returns against changes in the yield of the 10y on-the-run note using a trailing 90-days window between December 1998 and November 2009. Source: Barclays Capital

However, one should be cautious when interpreting the outputs of these regressions, given the lack of statistical significance. All of the t-statistics for this set of regressions are substantially lower than before. This reflects both the smaller number of observations and the dramatic increase in spread volatility. During this crisis period, the Treasury yield change was certainly not the primary driver of price changes of credit bonds; it was secondary at best. In such an environment, it is very difficult to isolate any small effect that yield changes may have had on pricing against the background of extreme spread volatility.

Figure 6: Empirical Hedge Ratios by Credit Rating during the “Credit Crisis”

	Aaa-Aa	A	Baa	Ba	B	Caa
Panel A: Aug 98 - Feb 05						
β : hedge ratio limit	0.90	0.95	0.99	0.60	0.22	0.17
t-stat	34.67	32.72	27.44	9.83	2.74	1.25
γ : spread slope	-0.02	-0.08	-0.11	-0.09	-0.04	-0.02
t-stat	-0.46	-3.48	-6.14	-5.72	-2.80	-1.81
OAS range (%)						
Min	0.37	0.56	1.05	1.46	2.21	3.68
Ave	1.04	1.50	2.16	3.92	5.77	10.75
Max	4.71	5.95	7.70	13.75	18.58	28.33
Hedge ratio at:						
Min OAS	0.89	0.91	0.88	0.47	0.14	0.10
Ave OAS	0.88	0.84	0.76	0.25	0.02	-0.04
Max OAS	0.83	0.49	0.17	-0.61	-0.44	-0.38
Panel B: July 07 - Nov 09						
β : hedge ratio limit	1.02	0.90	0.88	0.05	-0.17	-0.32
t-stat	16.19	13.18	15.68	0.41	-0.91	-1.43
γ : spread slope	-0.08	-0.04	-0.02	-0.01	-0.01	-0.01
t-stat	-3.69	-2.28	-2.00	-0.52	-0.38	-0.55
OAS range (%)						
Min	0.70	0.90	1.21	2.05	2.70	4.30
Ave	2.26	2.92	3.73	6.35	8.44	13.00
Max	4.71	5.95	7.70	13.75	18.58	28.33
Hedge ratio at:						
Min OAS	0.97	0.86	0.85	0.03	-0.19	-0.36
Ave OAS	0.84	0.78	0.79	0.00	-0.23	-0.43
Max OAS	0.65	0.65	0.70	-0.06	-0.30	-0.55

Note: The estimated coefficients are based on Equation (4). The regressions are estimated separately for each rating category using the daily market-value price returns of all bonds comprising each category, between August 1998 and February 2005 (Panel A) or July 2007 and November 2009 (Panel B). Source: Barclays Capital

Segmentation in Credit Markets

The evidence in the previous section suggests that there is a clear separation between the hedge ratios of investment grade and high yield bonds. The sharp drop in hedge ratios when crossing to high yield territory could not be explained by considerations of default and recovery and persisted through the entire sample period despite the sometime unstable behavior of hedge ratios over time. What can account for this phenomenon?

One possibility is that the discontinuous behavior of hedge ratios simply reflects different market pricing conventions for investment grade and high yield bonds. Investment grade bonds are typically quoted as a spread to a Treasury security with similar maturity (“parent”), whereas high yield bonds are quoted on price. Therefore, even when daily quotes for an investment grade bond are unchanged, it would still exhibit interest rate sensitivity in our analysis as long as the Treasury curve has changed. In contrast, for a high yield bond, the price return would be zero, suggesting no sensitivity to Treasury rates.

In liquid markets, securities are transacted frequently and prices are likely to closely reflect the valuations of market participants. However, corporate bonds as an asset class are fairly illiquid,

and most bonds do not trade on any given day. For example, trading volume data for September 2009 reported in TRACE indicate that about half of the bonds in the Corporate and High Yield Indices traded less than 15 times during that month and 25-30% did not trade even once. Furthermore, the average monthly turnover was only about 5% for investment grade bonds and roughly 4% for high yield bonds.¹² As a result, daily corporate bond pricing data mostly reflect traders' quotes, rather than actual transactions. If these quotes are stale, the different pricing conventions between the two markets can create the apparent segmentation we observe. To investigate this hypothesis, we construct several proxies for liquidity and test whether our results are sensitive to the existence of stale pricing.

Potential Stale Pricing and its Effect on Hedge Ratios

Traders' quotes are more likely to accurately reflect the aggregate demand and supply dynamics when markets are liquid. To the extent that stale quotes are less of a concern for more liquid bonds, we examine the variation in interest rate sensitivity across credit ratings conditional on trading volume as a proxy for liquidity. Each month, bonds in our sample are assigned into quintiles based on their total dollar trading volume as reported in TRACE. Quintile breakpoints are determined separately for investment and non-investment grade bonds. We then compute aggregate market-value weighted statistics (price return, spread and spread-duration) separately for each investment grade and high yield quintile.

Figure 7 reports the average traded volume and number of bonds in every quintile by credit rating from January 2007 through November 2009.¹³ Figure 7 clearly illustrates the relative illiquidity of the corporate bond market. For example, bonds rated A in the top quintile have an average monthly trading volume of \$167.8mn, whereas those in the second most liquid quintile have roughly one fifth of that volume. Furthermore, A rated bonds in the bottom quintile were essentially not traded at all, and a similar pattern is evident irrespective of credit quality. Across rating categories, investment grade and high yield bonds in the same quintile exhibit fairly similar turnovers despite the large differences in absolute volume, as the typical amount outstanding of an investment grade bond is two to three times larger than that of a high yield bond.

Figure 7: Liquidity Quintiles: Bond Composition and Volume

Investment Grade						High Yield					
	Q1 -Most Liquid	Q2	Q3	Q4	Q5 -Least Liquid		Q1 - Most Liquid	Q2	Q3	Q4	Q5 -Least Liquid
Bond Composition (Avg. Number of Issues per Month)						Bond Composition (Avg. Number of Issues per Month)					
Aaa/Aa	142	89	63	57	72	Ba	94	106	110	117	106
A	254	257	256	266	235	B	113	119	123	106	125
Baa	213	262	289	286	303	Caa	84	69	63	56	77
Total	609	609	609	610	611	Total	291	294	296	279	308
Trading Volume (\$mn/month)						Trading Volume (\$mn/month)					
Aaa/Aa	188.5	37.3	15.7	5.3	0.3	Ba	79.8	17.9	7.8	2.2	0.0
A	167.8	36.4	15.5	5.1	0.4	B	84.9	18.0	7.9	2.4	0.0
Baa	154.8	35.9	15.2	5.1	0.4	Caa	93.7	18.2	7.9	2.4	0.0

Note: Based on daily transaction data from TRACE between January 2007 and November 2009. Quintile breakpoints are determined separately for investment and non-investment grade bonds each month based on the total trading volume per bond. The aggregate trading volumes are MV-weighted across all bonds in each quintile-rating bucket. Source: Barclays Capital

¹² Hotchkiss and Jostova (2007) report similar results based on a comprehensive dataset of insurance companies transactions from the National Association of Insurance Commissioners (NAIC)

¹³ We do not have access to TRACE data before January 2007. In addition, TRACE market coverage before that date is incomplete.

Is using liquidity (as captured by trading volumes) effective in mitigating stale pricing? While it is difficult to address this question directly, Figure 8 presents some indirect results. Panel A reports the standard deviation of the daily aggregate price returns for all quintile-rating combinations and their durations, whereas Panel B reports the average correlation of price return across volume quintiles, ρ_{q_i, q_j} .¹⁴ If liquid bonds experience more frequent price adjustments than less liquid bonds (within the same credit rating), then the standard deviation of their price returns should be higher. Similarly, return correlations should decline the more distant two quintiles are from each other.

The results from Figure 8 are consistent with both predictions. First, the volatility of price returns for the second quintile is uniformly lower than that of the top quintile for each of the credit rating groups. Furthermore, the magnitude of decline between the top and bottom quintiles (despite the generally higher duration of bonds in the bottom quintile) increases as credit quality deteriorates, consistent with a potentially larger degree of stale pricing for lower credit qualities. Second, the correlation of price returns between any two quintiles declines the further apart they are in terms of their liquidity profiles. For example, ρ_{q_1, q_2} , the correlation between the highest and second-highest liquidity quintile, is 0.85, whereas it is only 0.75 for ρ_{q_1, q_5} . These results suggest that trading volume as a proxy for liquidity is able to capture some cross-sectional variation in bonds' price adjustment dynamic. Hence, more liquid (e.g., traded) bonds are less likely to have stale prices and in particular those comprising the top liquidity quintile.

Figure 8: Price Return Volatilities and Correlations across Liquidity Quintiles⁷

Panel A: Std. of Price Returns (bp/day)	Aaa-Aa	A	Baa	Ba	B	Caa
Q1 - Most liquid	47	59	52	67	86	122
Q2	38	44	46	38	44	77
Q3	40	47	46	35	38	61
Q4	47	50	48	30	33	54
Q5 - Least liquid	52	56	48	39	54	72
Option-adjusted Durations (years)	Aaa/Aa	A	Baa	Ba	B	Caa
Q1 - Most liquid	5.51	6.39	6.92	4.84	4.22	4.21
Q2	4.67	5.85	6.09	4.69	4.04	4.06
Q3	5.19	6.29	6.07	4.56	4.12	4.02
Q4	5.88	6.75	6.14	4.83	4.24	4.23
Q5 - Least liquid	6.58	7.38	6.44	5.01	4.60	4.41

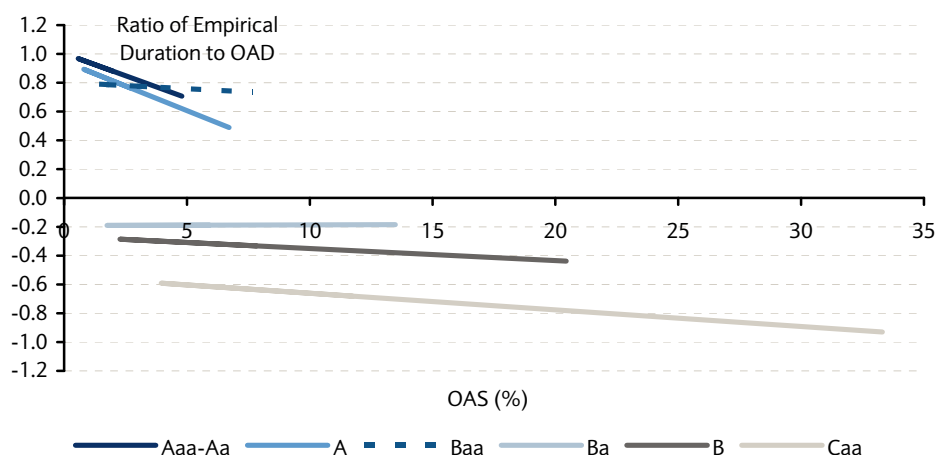
Panel B: Daily price return correlation	Q1 -most liquid	Q2	Q3	Q4	Q5 - Least liquid
Q1 - Most liquid	1.00	0.85	0.77	0.73	0.75
Q2		1.00	0.92	0.87	0.85
Q3			1.00	0.90	0.84
Q4				1.00	0.82
Q5 - Least liquid					1.00

Note: Based on daily transaction data from TRACE between January 2007 and November 2009. Quintile breakpoints are determined separately for investment and non-investment grade bonds each month based on the total trading volume per bond. Panel A reports price returns standard deviations computed using the daily market-value weighted price returns of all bonds in each quintile-rating combination. Panel B reports price return correlations computed between daily price returns of every quintile-rating combination over the sample period and then averaged across all credit ratings groups. Source: Barclays Capital

¹⁴ Values for ρ_{q_i, q_j} in Panel B represent the correlation between daily price returns of quintiles i and j over the sample period averaged across all credit ratings groups.

Figure 9 displays the results of re-estimating Equation 4 separately for each credit rating group using only the most liquid bonds – those comprising quintile 1. The large drop in empirical hedge ratios when crossing from investment grade to non-investment grade territory documented earlier is still evident. For example, despite the extreme market dynamics during the sample period (January 2007-November 2009), Baa bonds maintained a hedge ratio of 0.71, even at spreads of 700bp, whereas high yield bonds exhibited zero or even negative hedge ratios for the same level of spreads. Furthermore, the results are very similar to those reported in Figure 6, despite the difference in population, for , investment grade and high yield bonds.

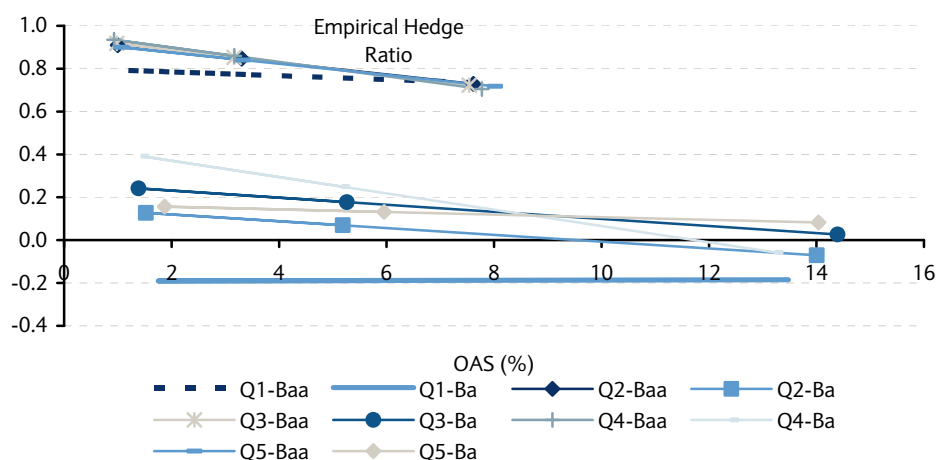
Figure 9: Hedge Ratios as a Function of Spread for Liquidity Quintile 1



Note: The plot is based on estimating Equation (4) separately for each rating category using daily data of all bonds comprising liquidity quintile 1, between January 1, 2007, and November 30, 2009. The resulting coefficients and the minimum and maximum spread level during the sample period are then substituted separately for each credit rating in Equation 5. Source: Barclays Capital

While Figure 9 nicely illustrates the large difference in interest-rate sensitivity for the most liquid subset of investment grade and high yield bonds, it is important to note that the same pattern is also observed for less liquid bonds. Figure 10 plots hedge ratios as function of spread level for Baa and Ba rated bonds separately for all liquidity quintiles. Figure 10 indicates that the gap in hedge ratios between the lowest quality investment grade bonds (Baa) and the highest quality high yield bonds (Ba) is largely independent of their underlying liquidity profile and can be observed even for bonds in quintile 5, where the potential for stale pricing is likely to be the largest.

Figure 10: Hedge Ratios for Baa and Ba Rated Bonds by Liquidity Quintile



Note: The reported coefficients are based on estimating Equation (4). The regressions are estimated separately for each liquidity-rating combination using daily price return between January 2007 and November 2009.

Source: Barclays Capital

In addition to controlling for trading volume, we conduct two more experiments to ensure that the lack of rates sensitivity of high yield bonds is not an artifact of stale pricing. First, we repeat the analysis with bi-weekly rather than daily price returns over the same period as in Figure 1 (August 1998 and November 2009). Using a bi-weekly frequency reduces the likelihood of having unchanged prices, while still keeping the sample size large enough to ensure sufficient statistical power. Second, we attempt to directly identify and exclude observations that possibly reflect stale prices. All bonds comprising the Corporate and High Yield Indices with a sequence of five or more unchanged quotes in any month are excluded from the eligible population of bonds for that month.¹⁵ Equation (4) is then re-estimated separately for the six ratings groups using only the eligible population of bonds from January 2007 through November 2009.

The results from filtering out consecutive unchanged prices and using bi-weekly price returns (not reported for brevity) are almost identical to those using daily data and the entire population of bonds. Once again, they reject the notion that the difference in pricing conventions and relative illiquidity of corporate bonds are responsible for our results.

Hedge Ratios following Rating Changes – An Event Study Approach

The analysis of the relation between analytical and empirical duration has relied so far on using aggregated statistics of various bond portfolios constructed based on credit ratings. This approach was taken, in part, to examine the relation between hedge ratios and credit qualities but mainly to achieve a sufficiently long sample period that reflects diverse credit market conditions.

One disadvantage of using aggregated data is that our findings may reflect, at least partially, differences in bond characteristics across rating categories, which can affect the observed hedge ratios. For example, many of the bonds rated as high yield at issuance are callable. If market perception about the likelihood of a bond being called is materially different than that implied by the option-adjusted duration (OAD) model, it could lead to a large discrepancy between the analytical and empirical duration. If the population of high yield

¹⁵ For investment grade bonds, unchanged quotes are in spread terms whereas for high yield bonds, they are in price terms. On average, about 50% and 4% of the bonds comprising the High yield and Corporate Indices are excluded monthly, respectively.

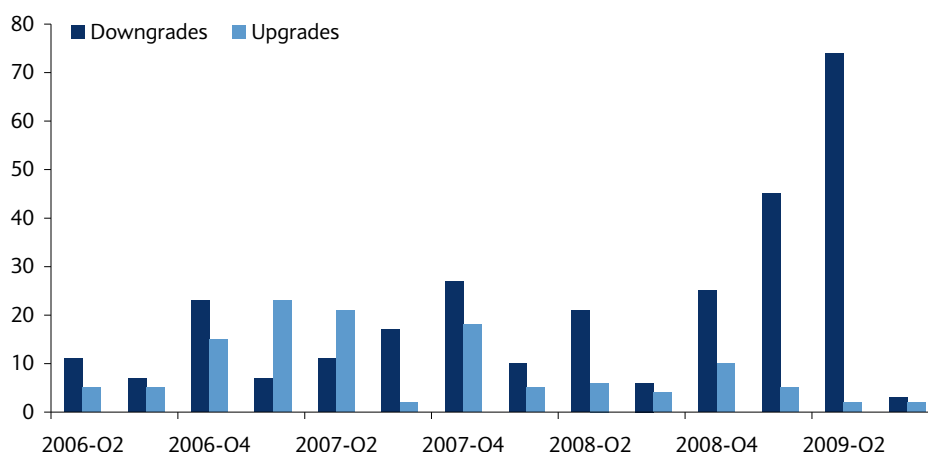
bonds has a higher percentage of callable bonds than in investment grade, or has a systematic difference in any other macro characteristic, perhaps these hidden differences are causing the empirical durations of the two groups to diverge?

To address this issue, we repeat the analysis using daily data on individual bonds that were downgraded from investment grade to high yield status or conversely were upgraded from high yield to investment grade status since 2006. For each bond, we estimate and then analyze the change in hedge ratio before and after the rating "event" (upgrade or downgrade). This "event study" approach controls for all bond-specific characteristics and allows us to conduct a direct test of the difference in hedge ratios between investment grade and high yield bonds.

Data and Methodology

The analysis was carried out for all bonds that were part of the Barclays Corporate and High yield Indices and experienced a "rating-event" between January 1, 2006 and November 30, 2009. A "rating-event" was defined as a downgrade from any investment grade rating to high yield status or conversely an upgrade from any high yield rating to investment grade status.¹⁵¹⁶ We require each bond to have at least 50 data points (after excluding all zero price returns to mitigate potential "stale pricing",) before and after the event (i.e., a minimum of 100 observations per bond).

Figure 11: Frequency of Bonds Experiencing "Rating Events" by Quarter



Note: Based on all bonds that were part of the Barclays Corporate and High yield Indices and experienced a "rating-event" between January 1, 2006 and November 30, 2009. A "rating-event" was defined as a downgrade from any investment grade rating to high yield status or conversely an upgrade from any high yield rating to investment grade status. Source: Barclays Capital

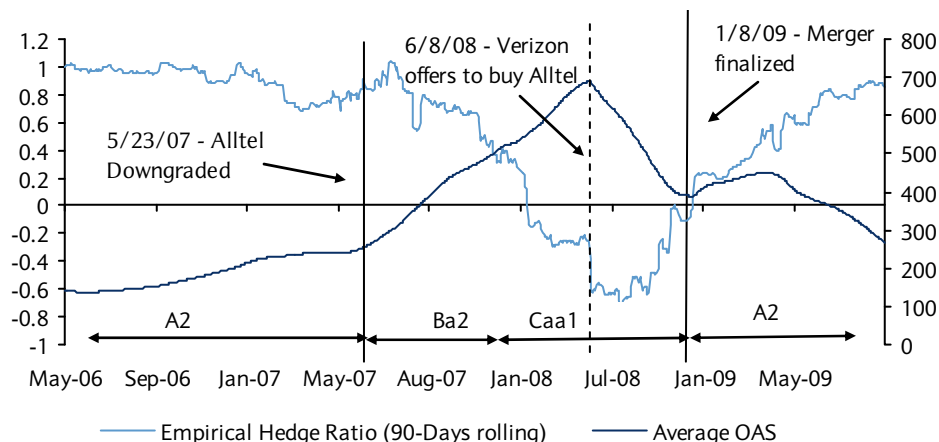
The resulting sample includes 410 rating events of which 123 are upgrades and 287 are downgrades. They represent 402 bonds from 137 individual issuers. Figure 11 displays the total number of rating events by type in each quarter during the sample period. Not surprisingly, the rating events are not uniformly distributed over time. Most of the downgrades occurred during Q3 08 and onward, whereas the upgrades mostly concentrated around the beginning and middle of the period.

Before we report the results of the analysis for the entire sample, it is instructive to look at one specific example. Figure 12 displays the 90-days trailing hedge ratio, average spread (over the same period) and credit rating (shown at the bottom of the chart) for a 30y bond with a

¹⁶ For example, a downgrade from an A-rating to a Baa-rating would not qualify as a "rating-event".

7.875% coupon issued by Alltel in July 2001. The bond has experienced several rating changes since 2006, which makes it an interesting test-case for the relation between hedge ratio and credit quality.

Figure 12: Variation in Alltel 30y Bond Hedge Ratio Following Rating Changes



Note: The plot displays the 90-days trailing hedge ratio, average spread (over the same period) and credit rating for a 30-year bond with a 7.875% coupon issued by Alltel in July 2001 (CUSIP 02039DC). Source: Barclays Capital

Until May 23, 2007, the bond enjoyed an investment grade rating of A2 and exhibited a hedge ratio close to 1, which declined to as low as 0.75 as the bond spread widened to over 200bp, consistent with the estimates for A-rated bonds in Figure 1. Following the downgrade to high yield status (A2 to Ba2), the hedge ratio declined steadily to about 0.4 as spreads widened to 450bp and dropped even further to negative territory (as a low as -0.6) after the bond was further downgraded to Caa1 on November 21, 2007.

The hedge ratio (and spread) reversed course soon after Verizon's offer to acquire Alltel was announced in June 2008, although the bond credit rating remained unchanged. Once the acquisition was completed on January 8, 2009, the bond was upgraded to investment grade status and regained its initial rating (A2). Similarly, the hedge ratio increased (and spread level decreased) gradually from about 0.25 to roughly 0.95 at the end of August 2009, similar to its value at the beginning of 2006.

Empirical Analysis

To study the behavior of hedge ratios for the sample of bonds that experienced a "rating event", we estimated Equation (4) for each bond separately before and after the rating change using all available data except the month during which the rating event occurred, which is excluded. If a bond experienced more than one rating change, we estimate the regression using data up to three months before the next event or starting three months after the previous event to avoid any spill-over effects.

Figure 13 reports summary statistics for the pre- and post-rating event regressions, separately for upgraded and downgraded bonds. The values in Figure 13 represent sample medians rather than means to mitigate the potential effect of outliers. The P-values for the null hypothesis of equal medians before and after the rating event are computed based on the Wilcoxon-Mann-Whitney test.¹⁷

¹⁷ A P-value of < 0.0001 implies that with a 99.99% confidence these parameters have different values before and after the ratings event, and that our results are not simply the results of random noise.

Figure 13: Summary Statistics for Bonds Experiencing a "Rating Event"

	Downgrades			Upgrades		
	Before	After	P-value for Difference	Before	After	P-value for Difference
Beta	1.00	0.45	<0.0001	0.43	0.88	<0.0001
Gamma	-0.04	-0.05	0.021	-0.07	-0.02	0.153
Mean OAS (bp)	255	749		180	360	
Hedge Ratio at Mean OAS	0.86	0.08	<0.0001	0.20	0.80	<0.0001
Bonds with Hedge Ratio Change as Expected	86%			80%		
R-sqr	0.16	0.01	<0.0001	0.02	0.14	<0.0001
Sample Size	287	287		123	123	

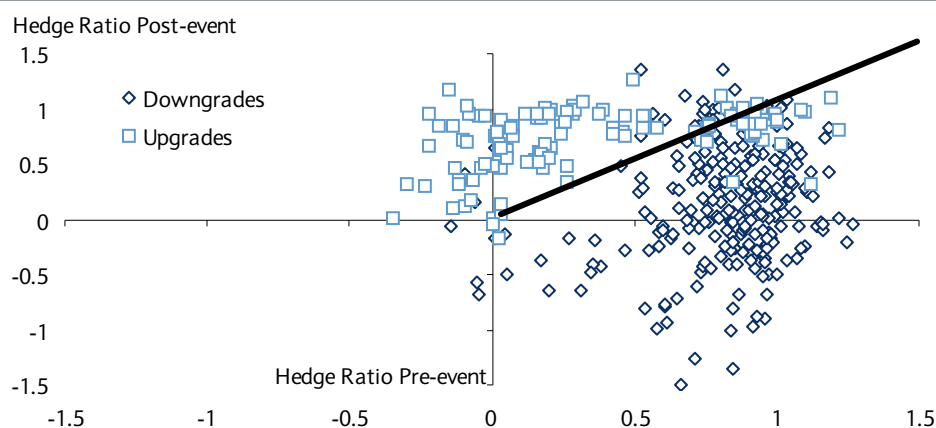
Note: The figures are based on estimating Equation (4) for each bond separately before and after the rating-event using all available data except the month during which the rating-event occurred, which is excluded. If a bond experienced more than one rating change, we estimate the regression using data up to three-month before the next event or starting three months after the previous event. Values for Beta, Gamma, Mean OAS, Hedge ratio and R-sqr are based on the sample median. The P-value reflects the probability that the median values before and after the Rating-event are drawn from the same distribution using the Wilcoxon-Mann-Whitney test. The percentage of hedge ratio change as expected is the proportion of bonds where hedge ratios decreased after a downgrade or increased after an upgrade.

Source: Barclays Capital

The results are overall consistent with our previous findings for upgraded and downgraded bonds. For bonds initially rated investment grade, the typical limit hedge ratio (beta) decreased from 1.00 to 0.45 after the rating change, compared with 0.85 and 0.41 reported in Figure 1 (based on Baa and Ba rated bonds, respectively). The results for upgraded bonds are similar but with the opposite directionality with beta increasing from 0.43 to 0.88. The spread slope coefficient (gamma) is always negative and fairly stable, although for downgraded bonds, the 0.01 difference (from -0.04 to -0.05) is significant at the 5% level. The changes in explanatory power are also in accordance with previous results and highly significant. The regressions R^2 dramatically decline for downgraded bonds (from 0.16 to 0.01) and rise for upgraded bonds (from 0.02 to 0.14).

Not surprisingly, the average spread level for downgraded bonds increased from 255bp before the rating event to 750bp after it. While the similar rise in spread level for bonds that were upgraded may look unreasonable at first, it reflects the general timing of upgrades toward the beginning of the period (Figure 11) and the sharp rise in spreads following the credit crisis.

Hedge ratios (computed by using the estimates of beta, gamma, and the average spread of each bond during the estimation window) for downgraded bonds declined from 0.86 to 0.08, very similar to the results generated by employing the coefficients from Figure 1 (0.79 and 0.05 before and after the rating event, respectively) for the respective spread levels. In addition, the hedge ratios for downgraded bonds before the rating change are very similar to those of upgraded bonds after the rating change (0.80), despite the fact that these are two distinct bonds populations. Figure 14 also reports the percentage of bonds where the hedge ratio changed "as expected" – e.g., consistent with our null hypothesis of a decrease after a downgrade and an increase after an upgrade. In both cases, this "hit ratio" is very high – 86% in the case of downgraded bonds and 80% for upgraded bonds.

Figure 14: Pre- and Post-Rating Event Hedge Ratios for Individual Bonds

Note: Hedge ratios are computed by using the estimates of beta, gamma, and the average spread of each bond during the estimation window. Each observation represents a single bond where the x- and y-axis measure the hedge ratio before and after the rating event, respectively. Source: Barclays Capital

These results are also illustrated in Figure 14. Each observation represents a single bond where the x- and y-axis measure the hedge ratio before and after the rating event respectively. The scatter-plot reveals the sharp contrast in hedge ratios before and after the rating-event. Hedge ratios for downgraded bonds mostly ranged between 0.8 and 1.0, while they were rated investment grade, but hovered around zero after the downgrade with many of the bonds exhibiting negative hedge ratios, similar to what was documented in Figure 2 for high yield bonds. In contrast, for upgraded bonds, almost all observations are located above the 45 degree line, implying that the hedge ratios have increased and most range between 0.6 and 0.8.

Performance Evaluation and Hedge Ratios

The analysis of individual bonds that experienced a rating event confirmed all prior results (both qualitatively and quantitatively), suggesting that data aggregation did not affect our findings. In particular, the sharp drop in hedge ratios when crossing to high yield territory, which we termed "market segmentation" could not be explained by security-specific attributes that characterize high yield bonds. Nor could considerations of credit risk (default and recovery) or differences in pricing conventions between the markets.

We propose the following explanation based on the difference in performance metrics used by investors in the two markets. Despite the fact that seemingly similar securities (corporate bonds) are traded in both, investment grade credit managers are typically evaluated in terms of excess returns over Treasuries (or swaps). High yield managers on the other hand, tend to think in terms of total return and default risk. Such a difference in approach and the hedging practices (or lack of) that result from it is likely to generate the observed reduction in the effect of interest rate movements on high yield valuations, which we observe.

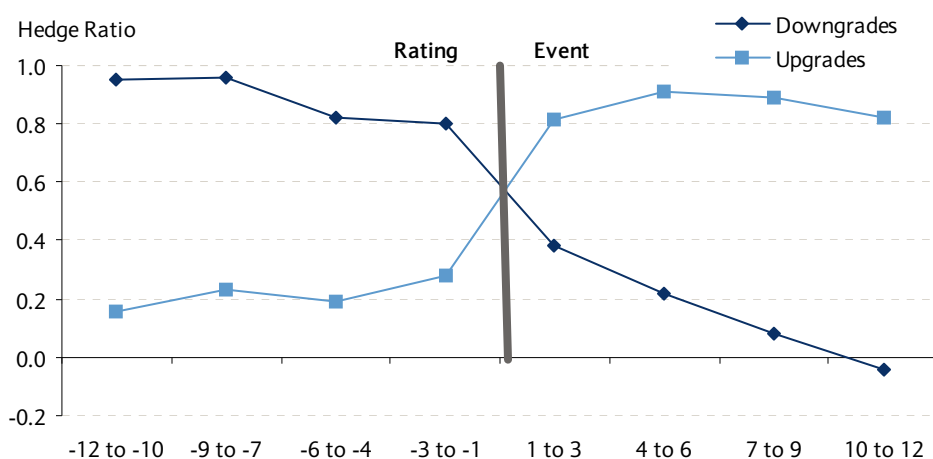
While the hypothesis is simple and intuitive, it is difficult to test directly as we are unable to observe the hedging activity by portfolio managers. Still, the rating event analysis may provide some important, albeit indirect, evidence that supports this theory. Figure 15 plots the median hedge ratio as a function of time relative to the timing of the rating event (separately for downgraded and upgraded bonds). Hedge ratios are estimated over one of 8 3-month, non-overlapping periods spanning the two-year window around the rating event

date.¹⁸ The population of bonds varies across time and declines the more distant the period is from the event date (either before or after).

The results in Figure 15 illustrate the strong discontinuity in hedge ratios around the rating event date. For downgraded bonds, the hedge ratio drops from 0.80 in the three months just before the downgrade to 0.38 in the three months following it. Similarly, the hedge ratio for upgraded bonds rises from 0.28 to 0.81 over the same -periods. In contrast, the degree of variation in the prior and subsequent nine months (-12 to -3 and 3 to 12) are limited. For example, for upgraded bonds, the hedge ratio ranged from 0.16 to 0.23 before the rating change similar to the level just before the rating change. Similarly, the hedge ratio after the upgrade increased initially from 0.81 further to 0.91 but then declined back to 0.82.

One exception is the continued decline of the hedge ratio for investment grade bond after they were downgraded (from 0.38 to -0.04). This reflects the relative clustering of the downgrade events in our sample around the height of the credit crisis. As Figure 11 shows, a total of 144 downgrades occurred between the last quarter of 2008 and the second quarter of 2009. This clustering, coupled with the extreme widening of spreads, resulted in the seemingly continued deterioration of hedge ratios up to a year after the downgrade.

Figure 15: Variation in Hedge Ratio over Time by Rating Event



Note: Each observation represents the median hedge ratio over one of 8 three month, non-overlapping periods spanning the two-year window around the rating event date. Hedge ratios are computed by using the estimates of beta, gamma, and the average spread of each bond during the estimation window. The coefficients are based on estimating Equation (4) separately for each bond with at least 50 data points in a given three-month period.
Source: Barclays Capital

Overall, the pattern of fairly stable hedge ratios up to three months before the rating change, a sharp change around the rating event, and then a renewed stabilization at a new level is fully consistent with our hypothesis. Notice also that this argument implies that such behavior should be observed, even if market participants are able to anticipate the rating changes well in advance. Despite the fact that rating agencies are often slow to incorporate new information and adjust credit ratings accordingly, investment grade bonds pending a downgrade should still exhibit high interest rate sensitivity and vice versa for high yield bonds.

¹⁸ Hedge ratios are computed by using the estimates of beta, gamma, and the average spread of each bond during the estimation window. As before, bonds with less than 50 data points (in any three-month period) are excluded from the median calculation.

Applications of Empirical Duration in Portfolio Management

What are the practical implications of our findings to a portfolio manager? If one is passively managing the duration exposures of a corporate bond portfolio relative to a corporate index, the issue is largely irrelevant. As long as the two sets of duration exposures are systematically matched, and the bonds in the portfolio are qualitatively similar to the benchmark, we would expect them to react similarly to changes in the yield curve. The empirical relationship is more important when a large corporate exposure is hedged purely with Treasuries or swaps. In such cases, if an adjustment is not made, the portfolio might end up over-hedged with respect to rates. Let us examine several such examples in greater detail.

Index Replication with Derivatives

Investors often prefer to replicate a target index with only liquid instruments such as Treasury futures, interest rate swaps, and credit default swaps. Barclays Capital publishes returns on several baskets (known as RBI® - Replicating Bond Index' baskets), which are designed to replicate the returns of various Barclays Capital Indices using combinations of derivatives.¹⁹ The weighting of the basket components is determined such that the target index main analytics are matched to the extent possible.

One of these baskets (RBI-2) is designed to track the Barclays Capital U.S. Aggregate Index using only Treasury futures and interest rate swaps.²⁰ While the rates exposure of the credit component of the index (based on a six-point key rate duration (KRD) profile) is matched, the spread exposure is left unhedged. However, our results suggest that a better tracking should be achieved with a hedge ratio somewhat lower than 1. In other words, the KRDs of the swaps in the basket should be less than the corresponding analytical KRDs used in the standard product. Would such an adjustment lead to an appreciable reduction in TEV?

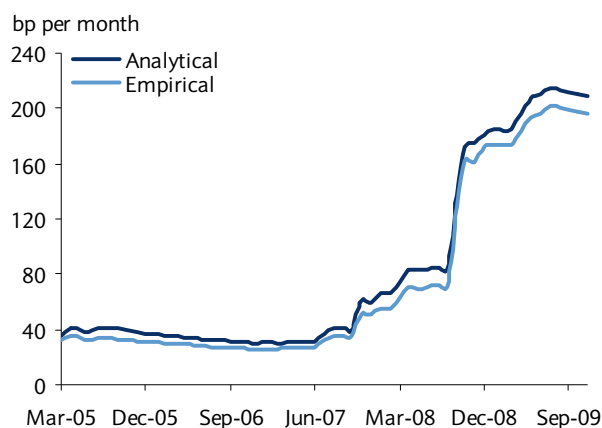
We conducted an experiment in which we re-weighted the swaps in RBI-2 baskets monthly from March 2004 (the product launch date) through November 2009. Each month, we estimated Equation (4), separately for each credit quality group, using an expanding window of daily data (from August 1998). Then, using the market weights and average OAS of each quality group, we calculated a single hedge ratio for the index, applied it to the six KRDs (and therefore the weights) of the swaps in the basket, and computed the basket's return. The resulting time series of these empirical RBI returns was compared with that of the standard, published product to determine whether the tracking error volatility versus the Credit Index was improved by switching to empirical hedging.

¹⁹ See 'Replicating Bond Index Baskets (RBI's): Performance, Risks, and Alternative RBI Baskets', Barclays Capital, October 7, 2009.

²⁰ RBI-2 refers to RBI Series 2. RBI Series 1 uses CDX to add an explicit spread exposure, and its performance is closely linked to the cash-CDS basis.

Figure 16: Credit RBI-2 Based on Empirical and Analytical Durations; Effect on TEV

A) TEV, Empirical Versus Analytical



Source: Barclays Capital

B) TEV Differential (Empirical TEV minus Analytical TEV)



Source: Barclays Capital

The TEV for the overall period of 69 months declined by 13bp, from 209 to 196bp/month. While the reduction in realized TEV is not extremely large, we did not expect it to be. Clearly, the tracking errors reflected first and foremost the mismatch in spread exposure between credit bonds and swaps. It is important to note, however, that improvement in TEV has been consistent through the entire period. Figure 6 displays the TEV on an expanding window, starting at 12 months and working its way to the full 68-month period. Panel A compares the TEV of the standard and empirical RBI. Panel B plots just the difference to highlight the improvement. The plot suggests that the TEV of the empirical RBI has always stayed below that of the standard product and the improvement has actually increased during recent crisis period.

Asset-Liability Management for Pension Funds

Many pension funds manage corporate bond portfolios against liabilities discounted off the Aa corporate curve. The duration of the liabilities is often longer than that of the portfolio. Our study suggests that one-for-one duration matching may over-hedge the portfolio. If interest rates rise but spreads simultaneously tighten, the hedged portfolio will lose value faster than the marked-to-market liabilities, a potentially disastrous scenario. This study may offer some guidance in deciding on the prudent hedge ratio.

Hedging an Active Credit Exposure

A straightforward example is using Treasury futures or swaps to hedge the rates exposure in a credit portfolio. Should the manager use analytical or empirical durations? The answer to this question is more complex than it might seem at first glance. Different types of hedges may be appropriate to express different views; it is important to understand the precise implications and consequences of each approach.

A decision to have an active credit position may express the view that current spread levels are high relative to the investor's estimate of credit risk and that a long-horizon exposure should generate a steady stream of positive carry returns. If the investor has no view on the near-term direction of spread movement, he may wish to hedge this position against mark-to-market volatility stemming from fluctuations in both rates and spreads. If the hedge consists of only Treasury futures and swaps, the overall volatility of the position may be minimized when the hedge ratio to the rates exposure is less than one, as our empirical research suggests.

However, an active credit exposure may also be motivated by a view that spreads will tighten. In this case, an empirical adjustment to the hedge ratios may be counterproductive. Imagine a scenario in which interest rates rise and spreads tighten exactly as implied by the historical relationship between the two. An empirical hedge, reduced to reflect this known correlation, would exactly offset both of these market effects. Is this what the investor intended? In this example, the view that spreads would tighten may prove correct, but would not result in any net profit, as the gain from the spread tightening would be offset by the under-hedged losses from the rise in rates. If, however, the credit overweight were implemented by a full analytical rates hedge, then the position would profit on spread tightening and lose on widening, regardless of what happened to interest rates.

These two approaches can perhaps be expressed most concisely in the context of a simple two-factor risk model. A long credit position has exposure to a yield factor and a spread factor, with a negative correlation between them. Suppose two investors wish to hedge the interest rates risk of this position with a rates-only hedge, but with different goals in mind. The first investor wants to earn the carry of the position, while putting in place the minimum-risk hedge. He will end up with less than complete hedging of the rates exposure, reflecting the negative correlation with the remaining spread exposure. The second investor wants to maintain the exposure to the spread factor, while fully hedging the exposure to the rates factor. She may end up with a greater overall TEV, but a smaller TEV component due to rates, on which she had no view and, therefore, sought neutrality.

Core-Plus Investment in High Yield Bonds

Consider a credit portfolio manager with a core-plus mandate which allows him to make an allocation to high yield bonds. Because of the much lower interest rate sensitivity of high yield bonds, replacing part of his investment grade allocation with an otherwise similar allocation to non-investment grade bonds would shorten the empirical duration of his portfolio. This may carry a practical implication for credit managers who would like to shorten their portfolios' duration in expectation of a rise in interest rates in the near future.

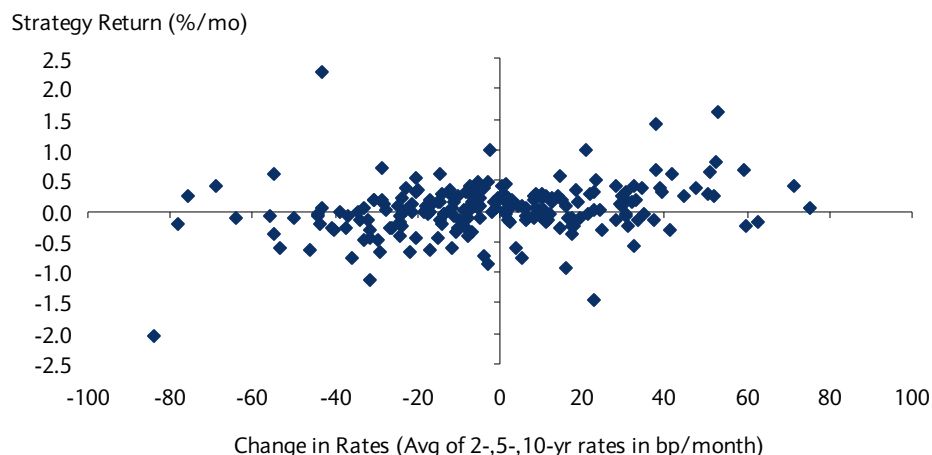
We examine such a strategy, which buys bonds with the highest high yield rating (Ba) and sells short bonds with the lowest investment grade rating (Baa). Since the strategy does not intend to take a view on the direction of credit spreads, it has an additional (long) investment in A-rated bonds to achieve perfect hedging of analytical duration and DTS. In practice, the manager could implement such a strategy as an overlay to his existing portfolio, shifting some of his BBB-rated assets to A-rated and BB-rated bonds.

To implement the strategy, we use all A and Baa-rated bonds in the Barclays Capital U.S. Corporate Index, and Ba-rated bonds in the U.S. High Yield Index, from January 1992 to November 2009. The analysis is conducted within industry sectors to mitigate any sector-specific risk.²¹ The strategy is rebalanced monthly to match the analytical duration and DTS of the long and short positions. Since the long and short positions may not be dollar equivalent, the strategy also invests (or borrows) cash at 1-month USD Libor. The sector-level returns are aggregated to obtain the overall strategy return, weighing each sector by the market value of the Baa-rated bonds in that sector.

²¹ Bonds are classified into one of the following 18 sectors: Finance (Banking, Brokerage, Finance Companies, Insurance, REITs, Other), Industrials (Basic Industry, Capital Goods, Consumer Cyclical, Consumer Non-cyclical, Energy, technology, Transportation, Communications, Other), and Utility (Electric, Natural Gas, Other). To mitigate idiosyncratic risk, the strategy is implemented for a given sector only on months when the sector is populated by at least 20 bonds

Figure 17 plots the strategy monthly returns versus the contemporaneous average change in 2, 5, and 10y rates. If this strategy is short empirical duration as a consequence of the credit market segmentation, the strategy should generate positive returns when rates rally and negative returns in months when rates decline (assuming that credit exposure is perfectly hedged using DTS). The plot indicates some positive relation between the performance of the strategy and the change in interest rates. However, there are many months in which the strategy does not perform according to expectation. For example, the strategy gained 2.3% in December 2008 when rates, on average, declined by 43bp, and lost 1.5% in May 2009 when rates increased by 23bp. A simple performance attribution for the strategy based on regressing the strategy returns against changes in interest rates and credit spreads (measured by changes in AA spread) finds a significant positive loading on change in rates (coefficient of 0.39, t-stat = 3.86), with an insignificant loading on change in credit spreads (coefficient of -0.17, t-stat = -1.09) and a zero intercept. However, the low explanatory power ($R^2 = 8\%$) suggests that there are other factors which influence the performance of the strategy.

Figure 17: Changes in Rates and the Performance of a "Short" Empirical Duration Strategy



Source: Barclays Capital

The relationship between the strategy performance and the change in rates may be more ambiguous in months with small changes in rates, when any effect of the short empirical duration position may be overshadowed by credit shocks or defaults. Figure 18, therefore, tabulates the performance statistics for the strategy in months when the change in rates is positive or negative, as well as when the change in rates is larger than one standard deviation.²² The results suggest that the strategy earns positive average returns when rates rise and negative average returns when rates decline. Moreover, the pattern is stronger when changes in rates exceed one standard deviation with positive (negative) returns in 70% of months with rising (declining) rates.

The performance of the strategy further supports the segmentation between investment grade and high yield credit, and , highlights the importance of considering empirical durations when investing in high yield credit.

²² We calculate the volatility of interest rates as the standard deviation of the average change in 2-,5-, and 10-yr rates, over the January 1992 to November 2009 period, which comes out as 28bp/month

Figure 18: Summary Statistics for "Short" Empirical Duration Strategy

	Positive/Negative Monthly Change in Rates		Monthly Change in Rates > 1 Std. Deviation	
	Rising Rates	Declining Rates	Rising Rates	Declining Rates
Average return (%/mo)	0.10	-0.04	0.25	-0.14
Volatility (%/mo)	0.40	0.45	0.44	0.63
Number of months	101	112	36	37
t-stat	2.49	-0.89	3.39	-1.37
Best Month	1.62	2.26	1.62	2.26
Worst Month	-1.47	-2.06	-0.57	-2.06
% up months	61%	48%	69%	30%

Source: Barclays Capital

Summary

In previous publications prior to the 2007-08 credit crisis, we had conducted a systematic analysis of the relationship between empirical duration of corporate bonds and the level of spreads. These studies demonstrated that empirical duration depends on spread and sensitivity to rates decrease as spreads widen, even for bonds with the same credit quality. Moreover, empirical durations fall sharply when we move from investment grade into high yield territory. A more recent publication updated the analysis through the credit crisis and examined if investment grade empirical durations declined to levels typical of high yield bonds in the ultra-wide spread environment during the crisis. The study found that there is a fundamental qualitative difference between the behavior of investment grade and high yield bonds with respect to interest rates. Specifically, even in ultra-wide spread environments, investment grade credit seems reluctant to give up its interest rate sensitivity, while high yield continues to demonstrate equity-like behavior with zero or negative empirical durations.

This paper unifies and augments all our previous studies on empirical duration of corporate bonds. We document the clear segmentation between investment and non-investment grade bonds with respect to their interest rate sensitivity, and show that the phenomena is not due to stale pricing. That is, differences in pricing conventions and liquidity do not seem to be the reason for the lower empirical durations of high yield bonds. We also show that differences in bond characteristics between investment and non-investment grade cannot possibly account for the observed discontinuity in empirical durations. We analyze the changes in empirical duration of individual bonds that were either downgraded from investment grade to high yield or upgraded from high yield to investment grade status. Since the same population of bonds is examined before and after a downgrade/upgrade, this approach controls for any bond-specific characteristics that may have artificially created the segmentation effect. We find that downgraded bonds experience a large decline in their empirical durations close to the date of downgrade, with the magnitude of the change in empirical duration being close to what we find for the aggregate population of bonds. Similarly, high yield bonds that were upgraded to investment grade status experience a large increase in their empirical durations as well.

Finally, we discuss several practical implications of using empirical durations in managing credit portfolios. The issue is largely irrelevant when managing the duration exposures of a corporate bond portfolio relative to a benchmark since what matters then is whether the durations of the portfolio and the benchmark are matched, be it analytical or empirical

duration. Empirical durations become important when actively hedging a credit portfolio with only Treasuries or swaps, since using analytical durations would generally cause the portfolio to be over-hedged with respect to rates. Empirical durations are also relevant for a credit manager looking to invest in high yield credit as a part of a core-plus mandate. We examine one example in which replacing investment by non-investment grade bonds while matching analytical duration would lead to a short duration position.

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