Risk in Capital Structure Arbitrage*

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Abstract

Capital structure arbitrage attempts to profit from inconsistencies in the relative pricing of a firm's liabilities and typically combines the firm's straight or convertible with its equity. Using a large database on US corporate debt, we examine the risks of portfolios of capital structure arbitrage positions under a variety of hedging strategies but focussing particularly on hedges that include the issuing firm's equity. We also examine strategies that include variables, such as the Fama-French factors, momentum and the S&P, that previous studies have found to be significantly related to corporate debt returns. Second, we use index data to ask whether the relation between corporate debt and these "non-structural" variables is a feature of only recent data or is also evident in long-run data. Finally, we examine the surprisingly low sensitivity of corporate debt and, particularly, high yield debt, to interest rate movements.

Keywords: Capital structure arbitrage, hedging, risk management, structural models, credit risk.

I Introduction

Capital structure arbitrage is a trading strategy that attempts to exploit mispricing between a company's liabilities, most commonly between equity and straight or convertible debt. In recent years such strategies have become increasingly popular, particularly among hedge funds, possibly as a result of the development of the credit default swap market that has allowed market participants to take short positions in a credit risk more easily (Currie and Morris (2002)).

While the mechanics of capital structure arbitrage are now widely understood, there is little formal evidence on its risk. Structural models provide one framework for analyzing the risk but, in the classical models of Merton (1974), Leland (1994), Leland and Toft (1996) and others, a correctly constructed triangular hedge between a company's debt, its equity, and riskless debt should be risk free. On the other hand, recent events in the credit markets suggest that there are times when capital structure arbitrage may be very risky. For example, when S&P downgraded Ford and GM in early 2005, Kirk Kerkorian chose that moment to announce a tender offer for around 5% of GM's stock, resulting in the prices of GM's debt and equity going opposite directions and creating substantial losses for capital structure arbitrageurs.[1]

The academic literature on capital structure arbitrage is limited. Yu (2005) analyzes convergence trades involving credit default swaps (CDS) and equity. He finds these "quite risky" and, in particular, prone to large losses when CDS spreads rise quickly. In an analysis of a number of fixed-income arbitrage strategies, Duarte, Longstaff, and Yu (2005) analyze CDS-based capital structure arbitrage and find that these produce promising Sharpe ratios of approximately 0.8. Agarwal and Naik (2000) analyze the performance of hedge funds following a variety of strategies including capital structure arbitrage. Schaefer and Strebulaev (2005) investigate hedge ratios of

[1] A report by Reuters on 19 May 2005 said: "Market gyrations after a cut in Ford's and General Motors' credit ratings turned predictive models on their heads and, according to market talk, produced huge losses at hedge funds that had effectively sold the companies' equity and bought their debt".

corporate debt against equity and find that, at the level of individual bonds, the quality of the hedge is quite poor, particularly for bonds with higher levels of credit risk.

Unlike Yu (2005) and Duarte et. al. (2005), the focus of this paper is not the *profitability* of capital structure arbitrage but its *risk* and, specifically, its risk at a portfolio level. While Schaefer and Strebulaev (2005) and others have found that the returns on an individual corporate bond are not well explained by the issuing firm's equity and riskless debt, it remains an open question as to whether a significant fraction of the remaining risk is diversifiable. Encouragingly, in his analysis of CDS, Yu (2005) finds that "... when the individual trades are aggregated into monthly capital structure arbitrage portfolio returns, the strategy appears to offer attractive Sharpe ratios ...". (Yu (2005), p. 32).

The focus of this study is, then, the risk of capital structure arbitrage, and the effectiveness of alternative strategies for managing this risk.[2] In this context, it is important to point out that our calculations are carried on portfolios that are chosen in a mechanical, i.e., *passive* manner while, in practice, capital structure arbitrageurs choose positions because they judge the debt and equity to be relatively mispriced. It is possible that these latter positions may be systematically more or less risky than the passive positions we study precisely because of the presence of mispricing but we lack the data on actual capital structure arbitrage positions that would be required to decide this question.

The paper addresses three main questions. First, how much of the risk of hedged positions is diversifiable? This question is important because the earlier work of Schaefer and Strebulaev (2005) shows that, while the *statistical* relation between corporate debt and equity can be identified quite well in large samples, the degree of sensitivity is typically quite small and the

[2] We – along with capital structure arbitrageurs – would also like to be able to say something about the average profitability of this activity, i.e., the α_j's, however, the relatively short period covered by our data makes this impractical.

fraction of the variability in return accounted for by equity is also small. For example, Table IV of Schaefer and Strebulaev reports that the average "beta" of BBB debt against the issuing firm's equity is 0.04. However, even though the t-statistic on this average is large (approximately 13.0) this arises because the size of the cross-section is large rather than because, at the level of an individual bond, equity accounts for a large fraction of the return variability. Indeed, in these same regressions Schaefer and Strebulaev report that, compared with a regression that includes only a Treasury bond, including equity increases the R^2 by only 5% (from 43% to 48%).

While this small increase in the R^2 shows that equity is not a very effective hedge at the level of the individual corporate bond, the high t-statistic for the average beta suggests that at least some significant part of the remaining variability is diversifiable. This is the issue that we examine in this paper by computing the risk of *portfolios* of capital structure arbitrage positions, i.e., where *many* bonds are hedged simultaneously against riskless debt and the *many* underlying equities.

In discussing these results we also examine the relation between the risk of hedged positions and the credit quality of corporate bonds. Previous results on credit spreads on individual bonds suggests that, for bonds with low credit ratings, equity and riskless debt account for less than 50% of the return variability. For example, Collin-Dufresne et al. (2001) find that, for the BBB and BB categories, less than 20% of the variability of credit *spreads* is accounted for by the return on the firm's equity and changes in the riskless yield curve. We therefore investigate how the diversifiability of the remaining risk varies with credit risk.

Of course, as many authors have pointed out (e.g., Collin-Dufresne et al. (2001)), finding that equity and riskless debt provide a poor hedge for corporate debt is inconsistent with the standard structural approach to credit risk. Accordingly, the second issue we address is the contribution of other instruments to the management of the risk in capital structure arbitrage positions. Collin-

Dufresne et al. (2001) and Elton et al. (2001) find that corporate bond returns are related to the Fama-French *HML* and *SMB* factors. Again, since these results have been obtained at the level of individual bonds, we assess their importance in managing risk at the portfolio level.

A natural way in which to estimate the composition of the hedge portfolio is to estimate a regression of the excess return on the corporate bond on a vector of excess returns on hedge instruments. The betas obtained in this way represent the positions in the hedging instruments that provide the minimum variance in-sample hedge. However, to be implementable, the hedge ratios must be estimated using only information available up to the time of portfolio formation. Therefore, as well as an *in-sample* analysis we also calculate the corresponding results when the betas used to construct a hedged position are estimated using only prior data (*out-of-sample analysis*).

Much of the empirical work on credit risk has focussed on *changes in credit spreads* (e.g., Collin-Dufresne et. al. (2001)) rather than on rates of return. Although this difference may appear minor, the sensitivity of credit spreads to the rates of return on hedging instruments has no clear portfolio construction interpretation. In contrast, the corresponding sensitivities of the rate of return on corporate debt give the composition of the minimum variance hedging portfolio. Perhaps because of the difficulty of linking an analysis of credit spreads to the normative problem of hedge construction, none of these studies investigate the out-of-sample properties that we give in Section III.5 [3].

The analysis in Section III provides what is perhaps the main result of the paper which is

[3] The excess return on a position in a corporate bond hedged with a Treasury bond of equal duration, $r^*_{j,t}$, is (approximately) equal to:

$$r^*_{j,t} = MD_j \Delta y - MD_j \Delta y_T = MD_j \Delta S_j$$

where MD_j is the modified duration of both the corporate and Treasury bonds, Δy the change in the yield-to-maturity on the corporate, Δy_T the change in the yield on the Treasury and ΔS_j the change in the corporate minus Treasury spread. Thus $r^*_{j,t}$, the excess return on a position in a corporate bond hedged against the corresponding Treasury bond is – approximately – proportional to the change in the credit spread.

that much of the risk in hedging individual corporate bonds against the equity of the issuing firm and the riskless term structure turns out to be *diversifiable.* What this means is that the return on a *portfolio* of corporate bonds and is explained by the riskless term structure and a *portfolio* containing the equity of the issuing firms to a much greater extent than has previously been observed. Although our analysis is in no sense a test of the structural approach to credit risk, this finding is clearly supportive of the structural approach.

In Section IV we turn our attention to the variables such as VIX and the Fama-French SMB and HML factors that previous studies have found to be related to credit spreads. In almost all cases these studies have been based on individual bond data and, as a result of data availability, have usually spanned a period of less than ten years. In the second part of our study we use long-run data on bond indices to establish whether these variables have a long-run relation to corporate bond returns or whether the results that others have obtained are particular to the relatively short and recent periods that have been studied. Our results show that the sensitivity of corporate debt to the Fama-French factors is indeed a persistent feature of the data, particularly for bonds with lower credit ratings.

Finally, in Section V we turn our attention to the interest rate sensitivity of corporate debt. It has been reported elsewhere in the literature (for example, see Fons (1990), Gautier and Goodman(2003)) that the empirical interest rate sensitivity, or duration of corporate debt is significantly lower than its McCaulay duration. Schaefer and Strebulaev (2005) show that the lower empirical duration is not explained by the Merton model even with the inclusion of interest rate uncertainty. Section V therefore provides some further evidence on this puzzle. Our results suggest, first, that the relation between the empirical interest rate sensitivity of corporate debt and conventional (McCaulay) duration varies significantly across bonds and, second, that at least some of this variation is explained by a bond's maturity, its credit exposure and whether it has an investment grade credit rating. Finally, Section VI concludes.

II Sample Selection and Data Description

In this section we describe the individual bond data used in the first part of the paper and the bond index data used in the second part.

We use monthly prices on individual corporate bonds that are included either in the Merrill Lynch Corporate Master index or the Merrill Lynch Corporate High Yield index. These indexes include most rated U.S. publicly issued corporate bonds. The data cover the period from December 1996 to December 2003 and contain more than 380,000 bond-month observations on about 2140 issuers and 10,400 issues. Detailed information on each bond is obtained from the Fixed Income Securities Database (FISD) as provided by LJS Global Services; equity and treasury bond returns are from CRSP. For riskless rates of return we use constant-maturity US Treasury monthly returns as reported by CRSP. Further details are given in Schaefer and Strebulaev (20045).

Our analysis is performed on a subsample that includes bonds satisfying the following criteria: (1) we can match the bond return data with CRSP and COMPUSTAT (this allows us to use about 62% of the total number of observations); (2) the bond is issued by a U.S. company and denominated in $U.S.;[4] (3) it is possible to match unambiguously the bond issuer with a company in CRSP using the CUSIP; (4) the bond is issued by a non-financial corporation; (5) the bond is straight (i.e. does not have any option-like embedded features); (6) the bond has at least 25 consecutive monthly price observations; (7) the bond has an initial maturity of at least four years.

Table I gives summary statistics for the subsample of 1370 bonds that meet these criteria.

[4]More specifically, the company is of the U.S. origin according to the FISD definition. In particular, its headquarters should be located in the U.S. and it is subject to U.S. legal practice.

All rating categories (from AAA to CCC) are represented in the sample. The categories with the largest numbers of bonds are A and BBB (603 and 539 respectively) but there are also quite large samples of AA (127) and BB (50) bonds. The mean time-to-maturity of decreases – as might be expected – for lower credit ratings but it is interesting to note that the *median* maturity actually increases. The median nominal amount in issue declines from $300 million for AAA to $175 million for B.

The index data used in Section IV are the Merrill Lynch (ML) investment grade and high yield indices and their associated sub-indices. For the Corporate Master Index, qualifying bonds must have at least one year remaining term to maturity, a fixed coupon schedule, at least $150 million outstanding and be rated investment grade based on a composite of Moody's and S&P ratings. The index is re-balanced on the last calendar day of the month. Issues that meet the qualifying criteria are included in the index for the following month. Issues that no longer meet the criteria during the course of the month remain in the index until the next month-end re-balancing at which point they are dropped from the index. For the US High Yield Master Index the minimum nominal amount outstanding is $100 million and bonds must be rated below investment grade, again based on a composite of Moody's and S&P. Our data on the Corporate Master Index start in December 1975 and on the High Yield Index in September 1986. Both indices are rebalanced on the last calendar day of the month.

We also report results on investment grade sub-indices for (i) individual credit ratings (AAA, AA, A and BBB) and (ii) maturity intervals (1-5 years, 5-10 years, 10-15 years and over 15 years). For the sub-investment grade we use sub-indices for the BB, B and CCC rating categories.

III Hedging Portfolios of Corporate Debt

III.1 Estimating Hedge Portfolio Composition

Consider a capital structure arbitrage position at time t in which a corporate bond issued by firm j is hedged with number of instruments. The latter may include firm j's equity, one or more riskless (i.e., Treasury) bonds, the S&P index and so forth. The excess return on this position may be written as:

$$r_{j,t} - \beta_j' r_t^h \tag{1}$$

where $r_{j,t}$ is the excess return on the corporate bond from time $t-1$ to t, r_t^h is the vector of excess returns on the hedging instruments and β_j is a vector of amounts (in dollars) of the hedging instruments that are sold short per dollar of firm j's debt that is held. We refer to the elements of β_j as "hedge ratios"; accordingly, the second term in this expression, $\beta_j' r_t^h$, represents the excess return on the *hedging* portfolio and the entire expression the excess return on the *hedged* portfolio.

The excess return on this hedged position may also be regarded as the *hedging error* which, without loss of generality, may be written as the sum of its mean value α_j and a zero mean variable $\varepsilon_{j,t}$:

$$\alpha_j + \varepsilon_{j,t} = r_{j,t} - \beta_j' r_t^h, \tag{2}$$

or

$$r_{j,t} = \alpha_j + \beta_j' r_t^h + \varepsilon_{j,t}. \tag{3}$$

A natural way to estimate the hedge ratios is via regression. This has the disadvantage that it treats the sensitivities, β_j, as constants while, in general, they are not. Nonetheless the approach has several advantages compared with the alternative of using a model. The first, clearly, is simplicity. Second, it allows us to include in a straightforward way hedging instruments such as the S&P and the Fama-French factors that find no place in standard models.

Our approach, therefore, has two steps. First, at the level of the individual bond, we estimate the hedging portfolio composition and the hedging errors. Second, we aggregate these errors to calculate the *portfolio* hedging error and its risk.

III.2 Implementation

In this Section we describe the calculation of the risk of portfolios of capital structure arbitrage positions, i.e., positions in corporate debt hedged with equity.

The first step is to identify those bonds that are *eligible* for inclusion in month t. We define these as bonds that (1) were in the ML database in month t; (2) had at least four years to maturity in month t; (3) had at least 20 (monthly) return observations in the data set; (4) had no call or other option-related features, i.e., were "straight".

Our portfolio formation rules must accommodate the fact that a bond rated AA, say, in January 1997 may, at some later date, have a different rating. We must also deal with entry to and exit from the database. Accordingly, we present results based on two alternative eligibility rules. Under the first ("5A") a bond is eligible for inclusion in the portfolio for credit rating category K in month t if it belongs to K at the end of the first month in our analysis (January 1997, month τ) and no account is taken of (i) subsequent changes in rating or (ii) subsequent entry into the database of bonds belonging to K. Under the second, simpler rule, ("5B"), a bond is eligible for inclusion in the portfolio for credit rating category K in month t if it belongs to credit rating category K in month t.

Applying one of these two conditions completes the set of five eligibility conditions. The results for these two cases turn out to be substantially similar.

III.3 Hedged Portfolio Returns: In-Sample

The in-sample results are calculated as follows. For each bond in the database meeting criteria (1) to (4) above, (i.e., "eligible") we first estimate the hedge ratios from equation (3) by regressing the excess return on each eligible bond j in month t, $r_{j,t}$, on the excess returns on a set of hedging instruments. These regressions use all the available data from January 1997 to December 2003. We run the in-sample procedure in the following way. For each portfolio formed in month t, we estimate hedge regressions (as specified in the next subsections) for each bond in this portfolio between t and either December 2003 or the last date the bond is recorded in the data set. We next calculate the portfolio hedging errors by averaging the hedging errors for individual bonds within each month and finally calculate the variance of the portfolio hedging errors over time . We follow this procedure for each portfolio formed between January, 1997 and December, 1999 and report the average results over all portfolios.

We present results for *four* alternative sets of hedging instruments: (i) a 10-year and a one-year Treasury bond; (ii) set (i) together with the firm's equity; (iii) set (ii) together with the S&P, the Fama-French factors (SMB & HML) and the momentum mimicking portfolio; (iv) set (i) together with the S&P estimate.

Let $\mathbb{K}_t^A$ [$\mathbb{K}_t^B$] denote the set of bonds that is eligible for inclusion in the hedged portfolio for credit category K in month t under rule 5A [5B]. The corresponding number of bonds is denoted N_t^A [N_t^B]. Under rule 5A, the hedged portfolio at date t invests a fraction $1/N_t^A$ in each of the eligible bonds and takes a short position in the hedging instruments of $1/N_t^A$ times the corresponding vector of estimated betas, $\widehat{\beta}_j$ (equation (3)). The (demeaned) portfolio hedge error for credit category K in month t under rule 5A, $\varepsilon_t^{K,P,A}$, is therefore given by:

$$\varepsilon_t^{K,P,A} = 1/N_t^A \sum_{j \in \mathbb{K}_t^A} \left(r_{j,t} - \widehat{\beta}_j' r_t^h \right) - 1/N_t^A \sum_{j \in \mathbb{K}_t^A} \alpha_j \tag{4}$$

$$= 1/N_t^A \sum_{j \in \mathbb{K}_t^A} \varepsilon_{j,t} \tag{5}$$

The expressions under rule 5B are exactly equivalent.

We now measure the time series variance of the portfolio hedging error, $\varepsilon_t^{K,P,A}$, and express this as a fraction of the variance of the *unhedged* portfolio excess returns. This fraction, which we denote $H^{K,A}$ measures the (in)effectiveness of the hedge:

$$H^{K,A} = \frac{Var(\varepsilon_t^{K,P,A})}{Var(r_t^{K,P,A})}, \tag{6}$$

where:

$$r_t^{K,P,A} = 1/N_t^A \sum_{j \in \mathbb{K}_t^A} r_{j,t}. \tag{7}$$

The *smaller* value of $H^{K,A}$ the better the hedge.

III.4 Results: In-sample

Table II shows the results on in-sample hedging effectiveness using the eligibility rule 5A. The first column, "All", gives the results for a portfolio containing *all* the eligible bonds; the remaining columns gives the results for particular credit ratings.

The first four rows show $H^{K,A}$, defined above, for the four alternative sets of hedging instruments. The final two rows show the maximum and minimum number of bonds in the portfolio in any one month.

For a portfolio composed of all the eligible bonds hedged against one- and ten-year Treasury bonds only, the value of $H^{K,A}$, the variance of the portfolio hedge errors as a fraction of the variance of portfolio returns is 49.6%. Including individual firm equity reduces this fraction by almost a half to 27.5%. This is equivalent to R^2 of over 70%. Including the S&P, the Fama-French HML and SMB factors and the momentum mimicking factor reduces the factional error variance still further to 18.2%.

In the fourth row the hedging instruments are the one- and ten-year Treasury bonds and the S&P index. Comparing this result to the second row we can see that replacing firm equity as a hedging instrument with the S&P produces a much worse hedge. When the S&P is used, the reduction in variance from the "Treasury Curve only" case for the "All" bond portfolio is only around 10% (49.6% to 39.6%) as compared with over 20% when firm equity is used.

It is no surprise that the importance of firm equity in hedging is much greater for lower credit rating categories and, in particular, non-investment grade bonds than for bonds with little credit and, therefore, equity exposure. For AAA and AA the inclusion of firm equity reduces the percentage error variance from 18.7% to 17.9% and 23.3% to 19.4% respectively. Hedging with the S&P rather than firm equity gives 15.2% for AAA and 19.6% for AA. (The hedging error variance for AAA is actually lower with the S&P than with firm equity but the sample size is very small). However, for BBB and even more for BB, the inclusion of firm equity makes a very substantial difference. For BBB the error variance percentage is 47.2% when hedging against the Treasury curve alone and this falls to 27.5% when firm equity is included. For BB the corresponding figures are 92.9% and 26.9%, in other words including firm level equity reduces the error variance percentage by over 60%. The inclusion of the "other" instruments (the S&P,

Fama-French factors and momentum) reduces the error variance further (by around 5% to 10% of the total variance) but the improvement is small compared to the inclusion of firm equity.

The results for the alternative eligibility rule ("5B"), given in Table III, are not substantially different and, although not quite as large as in Table II, the reduction in the risk when firm equity is included rather than the S&P is still substantial. For the BBB category, for example, hedging against the Treasury curve alone produces a hedging error variance of 64.4% of the unhedged returns. Including firm equity reduces this by over 30%, i.e., by almost half, to 33.1% while using the S&P gives a reduction of only around 8% to 56.2%. For BB the results are similar: including firm equity reduces the error variance from 86.0% (using only Treasury bonds) to 47.2%, while with Treasury bonds and the S&P the percentage error variance falls by less than 10% to 77.1%.

In summary, therefore, Tables II and III show that there is a substantial benefit to hedging bonds in the lower credit rating categories with the equity of the issuing firm rather than simply with a broad equity index. Since firm equity provides a relatively poor hedge at the level of the individual firm, the results imply that much of the risk of capital structure arbitrage positions is diversifiable.

The results also provide some modest support for the structural view of credit risk under which, of course, changes in the value of firm equity and in the riskless yield curve should explain 100% of the return variability on corporate debt. While certainly not upheld precisely in the data, this implication holds much better at the portfolio level than for individual bonds. What accounts for the noise in the returns at the individual bond level remains unclear: it could be a "missing factor", "noisy" mispricing or simply noise in the price data.

III.5 Out-of-sample hedging error estimation

For the out-of-sample estimates we start by forming the same portfolio as for the in-sample estimation (we report here only portfolios constructed under rule 5A) at date τ and choose only the bonds that are in the database for at least three years. For each bond we use observations up to three years from month τ and run the following individual regressions:

$$r_{j,t} = \alpha_{j,\tau,\tau+36} + \beta_{j,\tau,\tau+36} r_t^h + \varepsilon_{j,t}, \;\; t = \tau, ..., \tau + 36. \tag{8}$$

In other words, time-series regressions are run for 36 months, and the notation $\beta_{j,\tau,\tau+36}$ underlines the fact that we estimate the hedging regression over the interval from τ to $\tau + 36$.

Then, for each bond that has more than 36 observations we estimate the out-of-sample hedging error for month $\tau + 37$ in the following way:

$$\varepsilon_{j,\tau+37} = r_{j,t} - \left(\widehat{\alpha}_{j,\tau,\tau+36} + \widehat{\beta}_{j,\tau,\tau+36} r^h_{\tau+37} \right). \tag{9}$$

We then re-estimate the hedging regression but including the 37th month and then calculate the out-of-sample hedging error for the 38th month. We continue this procedure until the last month the bond is recorded in the data set. We then compute the out-of-sample portfolio hedging errors and their time series variance. As for the in-sample estimation, we form overlapping portfolios between January, 1997 and December, 1999, and report averages over all these portfolios.

Table IV contains our out-of-sample results. The risk of these positions stems from two sources: first, as before, fluctuations in the bond price that are not accounted for by the hedge instruments and second, errors in predicting the hedge ratios. These results simply use the raw hedge ratios from the regressions on prior data; these are inevitably noisy.[5]

The important result that emerges from this analysis is that the broad pattern of results is quite similar to that in Tables II and III. The error variances are, inevitably, larger in Table IV, but, again particularly for bonds with higher credit exposure, hedging with firm equity substantially dominates hedging with the S&P. For BBB, for example, hedging with firm equity reduces the error variance from 79.7% (yield curve only) to 53.5% while, with the S&P the corresponding reduction is only just over 1% to 78.3%. For BB, the difference is, once again, even more dramatic. Using firm equity the reduction from the "yield curve only" case is from 106% to 47.6% while with the S&P it is reduced only to 92.2%. In all these case, just as in the earlier results, including the Fama-French factors etc. reduces the risk further but the impact is small compared with the effect of including firm equity.

IV Analysis of Bond Indices

The results of the previous section demonstrate that a firm's equity provides a better hedge for its debt than has previously been supposed in the literature. While this is, as we have pointed out, supportive of the structural model of credit risky debt, the sensitivity of corporate debt to instruments such as the Fama-French factors is not predicted in the standard structural "story".[6]

Both Collin-Dufresne et al. (2001) and Elton et al. (2001) – the two studies that have so far examined this question – use the Warga (1998) database and analyze very similar periods. This leaves open the question of whether the sensitivity of corporate debt to the Fama-French

[5]It should be possible to improve the precision of the predicted hedge ratios by making use of cross-sectional information and later versions of this paper will attempt to do this. Thus the results in Table IV should be viewed as representing a lower bound on the effectiveness of the hedging strategies.

[6]While the "other" variables such as the Fama-French factors do not appear in standard structural models, it is not difficult to envisage ways in which other factors could be important. In the standard structural model uncertainty derives only from the value of the firm and the riskless yield curve. However, it is possible that, for example, one or both of the recovery rate and the level of the default boundary exhibit variability that is at least to some degree dependent on the Fama-French factors.

and other factors is persistent phenomenon or is limited to a particular period. This is the issue that we now address and, because reliable long-run price data on individual corporate bonds are not available, we use indices. For investment grade bonds, indices have been available since the mid-1970s and, for high yield debt, since the mid-1980s.

Tables V and VI give summary statistics on the equity related data and the Treasury data respectively and Tables VII and VIII on the Merrill Lynch corporate bond indices. The difference between these last two tables is the period covered by the data. In Table VII the statistics are computed using all the available data for each series. However, although all the series have the same end date, they have different start dates; for example, the broad investment grade index (column one) is available from December 1975 while the single credit category non-investment grade indices (columns 11 - 13) are available only from January 1997.[7] Accordingly, Table VIII presents summary statistics for the maximum common period of the data that is available (January 1997 - December 2004).

Section V discusses the interest rate sensitivity of corporate bonds in some detail. Here the issue is their sensitivity to the remaining three factors and Table IX shows the results of regressing the one-month excess return on each of the indices on the return on the 10-year benchmark Treasury ($RF10Y$), the return on the $S\&P$ and the two Fama-French factors, HML and SMB. These sensitivities are significant in almost all cases. For the broad investment grade (*IG All*) index, for example, the t-statistic on the *S&P* is 5.53 and on *HML* and *SMB* it is 3.18 and 3.68 respectively. Both the sensitivities and their significance are higher for the broad junk bond index (*HY all*) and this pattern is mirrored for the sub-indices.[8]

[7]The start date for each index is given in row 7.

[8]One reason that corporate debt may be sensitive to the *S&P*, *HML* and *SMB* is because the firm's underlying assets (and therefore its equity) are sensitive to these factors. In regressions for individual bonds, including the firm's equity controls for this channel of sensitivity and it is possible to distinguish between sensitivity to *SMB*, say, that derives from the firm's assets and sensitivity that is specific to the bond. However, no such control is possible in an analysis of a bond index and so it is not possible to say for sure whether the sensitivity to *SMB* etc. derives from firm's underlying assets or is specific to the corporate bond market.

Table X shows the corresponding results for the period from January 1997 to December 2004; this is he longest period for which data are available for each of the 13 indices. Overall, the sensitivities are similar to those in Table IX and the significance levels are only slightly lower despite the much shorter time period for investment grade indices (and the correspondingly smaller number of observations). In Table XI we re-run the regression on all available monthly data including changes in *VIX*, the inflation rate (*CPI*) and the momentum mimicking factor (*UMD*). The sensitivities to the *S&P*, *HML* and *SMB* – particularly for junk bonds – are not significantly changed.

A concern consistently expressed about data on corporate bonds is their low level of liquidity and the consequent potential for observed prices to be unreliable and, in particular, non-synchronous (Fisher (1959), Chacko et. al. (2005)).

To study the robustness of our results with respect to the illiquidity of corporate bonds, we perform the following experiment. We assume that we observe each of the independent regressors every month, but observe the true value of corporate bonds less frequently. In particular, at date 0 (the starting date of the index or of the regression subperiod) we observe the true value of the index. In month t the observed value of the index is I_t. Then, in month t, with probability p, the true value, $I_{t+1} = I^*_{t+1}$, is observed, and, with probability $1-p$ the observed value is equal to the last observed value, $I_{t+1} = I_t$. If $p = 1$, corporate bonds are as liquid as regressors. In the benchmark robustness case, we take $p = 4/12$, i.e. on average the true value is observed every three months. We then run regressions many times (simulating the p process anew with each regressions) and report average results in Table XII.

For the junk bond index, for example, the sensitivity to SMB is 0.24 with a t-value of 4.33 compare to 0.23 with a t-value of 6.77 with monthly data. For the S&P and HML the level of the sensitivity is lower and HML in particular becomes insignificant for all investment grade indices. Interestingly, however, SMB remains highly significant, indeed for the investment grade indices the t-statistics are higher on *SMB* than on the S&P. Overall, therefore, and despite the undoubted illiquidity of the market, there is no evidence that the results are strongly sensitive to the illiquidity of corporate bonds.[9]

Finally, in Table XIII we present the results of regressions similar to those in Tables IX and X but for the sub-periods 1975-85, 1985-90 and 1990-95. The question we wish to address is whether the sensitivities to *SMB* and *HML* that are significant in regressions for the entire sample period and for the period since the mid-1990's are also significant for earlier years.

For junk bonds the only data available for these earlier years is the broad index *HY All* and this is available only from 1990. Nonetheless, we see that the sensitivity to *SMB* is highly significant in both the 1985-90 and 1990-95 sub-periods. *HML* is significant in the earlier period and just insignificant for the later period. For investment grade bonds, however, neither *SMB* nor *HML* is significant in the 1985-90 subperiod and, over 1975-85 *HML* is significant but *SMB* is significant for only one of the four maturity buckets.

In summary, and consistent with earlier results, high yield bonds have highly significant sensitivities to *SMB* and *HML* in all periods. For investment grade bonds the sensitivities are lower and not always significant. On some occasions SMB appears more significant than *HML* and on others the reverse is true. In general the sensitivity to both factors increases with declining credit quality.

[9] Although corporate bonds are infrequently traded (Chacko et. al. (2005)), the prices used are quotations rather than transactions and, for this reason, it is moot as to whether these are good or poor proxies for the prices at which transactions would take place.

V The Duration Puzzle

V.1 The Literature

A striking feature of the price of corporate debt is that its sensitivity to the riskless yield curve is significantly smaller than would be predicted by its conventional ("McCaulay") duration (Fons (1990), Gauthier and Goodman (2003), Schaefer and Strebulaev (2005)). This same phenomenon can also be understood in terms of the negative sensitivity of credit spreads to changes in the riskless rate (Longstaff and Schwartz (1995), Collin-Dufresne et. al. (2001)).

A negative relation between the credit spread and the riskless rate is, as Longstaff and Schwartz (1995) point out, a natural consequence of the structural model of credit risk since an increase in the riskless rate decreases the (riskless) present value of the firm's debt and so increases the distance-to-default. So far, however, there is no evidence that structural models are able to account for the *size* – as distinct from the direction – of the interest rate sensitivity of the spread (or, equivalently, the difference between the empirical and conventional duration of corporate debt). For example, using a the Merton model with stochastic interest rates, Schaefer and Strebulaev (2005) find that the durations predicted by the model are much higher than those observed empirically.

V.2 The Empirical Duration of Corporate Debt

In this section we do not attempt – still less claim – to solve this puzzle. What we try to do, however, is document the effect in some detail and outline some issues that future research on this topic might address.

Consider a regression of the type described by equation (3) in which the hedging instruments are the firm's equity and a Treasury bond with T years-to-maturity:

$$r_{j,t} = \alpha_j + \beta_j^E r_t^E + \beta_j^{rf} r_t^{rf,T} + \varepsilon_{j,t}. \tag{10}$$

where r_t^E is the excess return on the firm's equity, β_j^E is the sensitivity to equity, $r_t^{rf,T}$ is the excess return on a T-year Treasury and β_j^{rf} is the sensitivity to the return on the Treasury .

The results of this regression, with $T = 5$ years and for the 1370 individual bonds in our full sample (see Section II), are reported in Table XIV. If the spread were constant and the yield curve were to experience parallel shifts, the instantaneous value of β_j^{rf} would be the *ratio* of the duration of the corporate bond to the duration of the Treasury.

For all 1370 bonds, the average value of the coefficient on the Treasury return is 0.77,[10] in other words, the empirical duration of a corporate bond is, on average, about 77% of the duration of a 5-year Treasury bond. From table I, the average McCaulay duration of the bonds in the sample is 5.63 years and, since this is necessarily larger than the duration of a five-year Treasury, the empirical duration of corporate bonds must indeed be lower than its McCaulay duration.

A problem with the specification of the regression in Equation 10 is that the duration of both the corporate and Treasury bond attenuate with time and, almost certainly, at different rates. Consequently the theoretical value of β_j^{rf} in the regression is also not constant over time. A better (though still imperfect) specification that accommodates changes in durations over time is:

$$r_{j,t} = \alpha_j + \beta_j^E r_t^E + \beta_j^* \left[\left(\frac{D_{j,t}}{D_t^{rf,T}} \right) r_t^{rf,T} \right] + \varepsilon_{j,t}. \tag{11}$$

where $D_{j,t}$ is the McCaulay duration of corporate bond j at time t and $D_t^{rf,T}$ the McCaulay duration of Treasury bond time t. In this case the coefficient β_j^* measures the empirical duration

[10]In the table the coefficients are reported in basis points (i.e., multiplied by 100)

of bond j as a *percentage* of its McCaulay duration.

The results of this regression are given in Table XV. For the entire sample ("All"), we find that, on average, a corporate bond has a duration that is around two-thirds (0.67) of its McCaulay duration. However, as we see from the results for individual credit ratings, the results for investment grade and sub-investment grade bonds are quite different.

Investment grade bonds have durations that are in the region of 70% to 75% of their McCaulay durations. For BB bonds, however, this figure is much lower (0.43) and for B grade bonds the point estimate is actually negative (though insignificantly different from zero). By way of comparison, Fons (1990), using data from 1979 - 1988, obtains estimates of 74% for AAA, 62% for A, 48% for BBB, 55% for BB and 39% for B.

If a bond has a duration that is a fraction β^* of its McCaulay duration, then the sensitivity of its credit spread to changes in the Treasury rate is $(\beta^* - 1)$. Using index data, Longstaff and Schwartz (1995) estimate the sensitivity of spreads by sector. For utility bonds they estimate the sensitivity of spreads to the 30-year Treasury yield as -0.18, implying a value of β^* of 0.82; their corresponding implied estimate of β^* for industrial bonds is 0.37 and for railroad bonds, 0.18.[11] Collin-Dufresne et. al (2001) obtain estimates that imply values of β^* of around 0.85 for investment grade, 0.7 for BB and 0.14 for B. Thus, both our results and those found previously suggest that the empirical duration of corporate debt is lower than its McCaulay duration.[12]

Table XVI repeats the analysis in Table XV but for maturity sub-samples. For the three maturity bands that are less than 12 years (1-5 years, 5-8 years and 8-12 years), the values of β^* are higher than for the entire sample. For example, for A rated bonds, for which the estimate

[11] The data used by Longstaff and Schwartz are Moody's indices.

[12] The estimates of β^* obtained by these earlier studies vary widely. There are many potential reasons for this but two possibilities are: (i) the use of quite different data sets and sample periods, and (ii) the use of different proxies for the Treasury rate (the 5-year rate in Table XV, the 10-year rate in Collin-Dufresne et. al. (2001) and the 30-year rate in Longstaff and Schwartz (1995))

of β^* for the entire sample is 0.71, we obtain estimates of 0.76 (0-5 years), 0.85 (5-8 years) and 0.79 (8-12 years) but only 0.55 for the 12-15 year bucket. The results are much the same for the other investment grade credit ratings: bonds up to 12 years have durations that are in the region of 80%-85% of their McCaulay durations while the results for longer maturities are around 55% to 65%.[13]

For non-investment grade bonds the sensitivities are uniformly lower (although the sample sizes for B-grade bonds are small). For BB we obtain 0.57 for 0-5 years and 5-8 years, 0.34 for 8-12 years and 0.23 for 12-25 years.

V.3 The Cross-Section of Empirical Durations

For the entire sample of 1370 bonds,[14] Figure 1 shows the values of the interest rate sensitivity, β_j^{rf}, estimated in equation (10) against McCaulay duration ("Average duration") .

The figure is quite informative. A large number of those bonds with McCaulay durations of around eight years or less lie on a "boundary" that is approximately the 45 degree line. In other words, for these bonds, empirical and McCaulay duration are approximately equal. Next, bonds that have a McCaulay duration above around eight years – long term corporate bonds – have interest rate sensitivities that are substantially below their McCaulay duration. The behavior of these bonds appears markedly different from the shorter bonds. Finally, for the shorter – less than eight year duration – bonds, there is a certain amount of scatter about the 45 degree boundary with a few bonds having an anomalously *high* interest rate sensitivity while, at the same time, a much larger number have *lower* interest rate sensitivity.

Figure 2 shows a subset of the same data: those bonds with ratings of AAA, AA and A.

[13]The corresponding result for the AAA category is 0.10 but this outlier should be treated with caution since the sample size i this case is just one.

[14]less 11 outliers

The figure is similar to Figure 1 but there are some clear differences. First, bonds with McCaulay durations lower than about eight years, a greater proportion of the empirical durations lie roughly on the 45 degree boundary; in other words there are fewer outliers. Similarly, there are proportionally fewer bonds with long McCaulay durations and very low sensitivities.

Figure 3 shows bonds with a rating of BBB and below, i.e., those that appear in Figure 1 but not in Figure 2. Here, a much smaller proportion lie on the boundary. This sub-sample also includes the small number of bonds, visible in Figure 1, that have short "McCaulay" durations and anomalously high interest rate sensitivity. Altogether, a large proportion of these bonds have lower empirical durations than McCaulay durations.

In summary, these figures show that the low relative duration that bonds have *on average* is not a feature that is uniform across the market. Many bonds, particularly higher quality bonds with durations of under around eight years McCaulay duration, have empirical durations that are quite close to their McCaulay durations. Others, particularly longer term and lower quality bonds have empirical durations that are much lower than McCaulay duration.

Finally Table XVII shows the results of a cross-sectional regression of the determinants of $\widehat{\beta}_j^*$ (equation XV). The table reports the results of three regressions. In all three there is a strongly negative relation between relative empirical duration and duration itself. In other words, as we have seen, empirical duration is, on average, a smaller fraction of McCaulay the longer the McCaulay duration. Second, there is a strong negative relation between relative empirical duration and quasi-market leverage, firm volatility and the coupon rate. All three variables are proxies for credit exposure and the negative sign on each of them implies that increasing credit risk lowers relative empirical duration. Finally, regressions (2) and (3), that include an investment grade dummy, show that, all else equal and investment grade bond has a relative empirical duration that is higher by about 15% of its McCaulay duration.

VI Conclusions

The main result in this paper is encouraging for those charged with managing the risk of capital structure arbitrage positions. Previous work on individual bonds, in particular, Collin-Dufresne et. al. (2001) has suggested that using the issuing firm's equity to hedge corporate debt was unlikely to be effective. At the portfolio level, however, the picture is different since much of the residual risk at the individual bond level turns out to be diversifiable. The differences between the portfolio results described here and those for individual bonds are particularly striking for lower credit ratings. For the BB bonds, for example, the average R^2 at the individual bond level in a regression of returns on Treasury returns and firm equity, is 33%. At the portfolio level the corresponding figure is 73%. (Both figures are for an in-sample analysis).

Second, we confirm the findings of Elton et al. (2001) and Collin-Dufresne et. al. (2001) that corporate debt returns are significantly related to the Fama-French factors, *SMB* and *HML*. In particular we find that these results hold over long periods and over sub-periods. High yield bonds are highly sensitive to the Fama-French factors in all periods; investment grade bonds are less sensitive and, in some periods, their sensitivities are statistically insignificant. From a hedging perspective, however, the importance of the Fama-French factors is less clear. Within sample, hedging against the Fama-French factors naturally reduces portfolio risk but the same is not true out-of-sample and it appears that the hedge ratios of corporate bonds against the Fama-French factors may not be sufficiently predictable for hedging against these factors to make a useful impact on portfolio risk.

Third, and finally, we find that the empirical duration of corporate debt is on average markedly lower than its McCaulay duration but that the degree of difference varies significantly by credit rating and maturity. For low grade debt the difference is substantial. The precise reason for this difference is a topic for further research.

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Table I
Summary statistics for Sample of Bonds used in Analysis

This table reports summary statistics for the bonds used in the analysis. The period covered is 12.1996–12.2003. The sample selection criteria are: (1) we can match the bond return data with CRSP and COMPUSTAT (this allows us to use about 62% of the total number of observations); (2) the bond is issued by a U.S. company and denominated in \$U.S.;[15] (3) it is possible to match unambiguously the bond issuer with a company in CRSP using the CUSIP; (4) the bond is issued by a non-financial corporation; (5) the bond is straight (i.e. does not have any option-like embedded features); (6) the bond has at least 25 consecutive monthly price observations; (7) the bond has an initial maturity of at least four years. Where relevant, statistics are first calculated for each bond and then for averaged across bonds. Each bond is classified by rating on the date of its *first* occurrence in the data set. $T - t$ is the time to maturity remaining on the date of each observation and is given in calendar years. The annual coupon rate is in percent. The nominal value (of the amount outstanding) is in million \$US dollars.

	All	AAA	AA	A	BBB	BB	B	CCC
No. Bonds	1370	23	127	603	539	50	26	2
No. Issuers	396	7	34	158	185	24	10	2
Mean $T - t$	9.50	10.16	9.45	10.13	9.14	7.11	7.39	2.48
Median $T - t$	5.71	4.58	5.25	5.71	5.81	5.61	6.90	2.48
Mean Duration	5.63	6.11	5.55	5.81	5.55	4.87	4.95	2.38
Median Duration	4.73	3.93	4.52	4.78	4.76	4.61	4.76	2.38
Mean Coupon	7.44	6.47	6.83	7.21	7.72	8.25	9.51	4.81
Median Coupon	7.20	6.63	6.75	7.00	7.45	8.00	9.50	4.81
Mean Nominal Value	260.26	324.90	315.54	271.46	254.22	252.19	219.74	229.14
Median Nominal Value	200	300	250	200	200	200	175	200

Table II
Hedging Effectiveness: In-Sample Estimates (Eligibility rule 5A)

Each of the first four rows of the table shows $H^{K,A}$, the variance of the hedged portfolio as a percentage of the variance of the unhedged portfolio for a particular set of hedging instruments (shown in the first column) when the eligibility rule 5A is used. Here "Yield Curve (YC)" means the one- and ten-year Treasury bonds; "Yield Curve + firm equity" means the yield curve instruments and, for each bond, the equity of the issuing firm; "YC + equity + other" means the yield curve instruments, the firm's equity and, in addition, the S&P, the Fama-French factors (SMB & HML) and the momentum mimicking portfolio; "Yield Curve + S&P" means the yield curve instruments and the S&P. T indicates the number of months of data used in the calculations and min (max) the minimum (maximum) number of bonds in the portfolio in any one month.

	All	AAA	AA	A	BBB	BB	B	CCC
Yield Curve only	49.6	18.7	23.3	33.4	47.2	92.9	95.0	95.1
Yield Curve + firm equity	27.5	17.9	19.4	26.0	27.5	26.9	48.1	94.1
YC + Equity + other	18.2	12.9	16.0	17.8	19.7	20.5	42.1	83.3
Yield Curve + S&P	39.6	15.2	19.6	27.6	43.8	74.9	88.6	94.3
T	84	84	84	84	84	84	84	84
N min	200	4	30	77	70	14	0	0
N max	726	14	67	289	278	67	10	1

Table III
Hedging Effectiveness: In-Sample Estimates (Eligibility rule 5B)

Each of the first four rows of the table shows $H^{K,B}$, the variance of the hedged portfolio as a percentage of the variance of the unhedged portfolio for a particular set of hedging instruments (shown in the first column) when the eligibility rule 5B is used. Here "Yield Curve (YC)" means the one- and ten-year Treasury bonds; "Yield Curve + firm equity" means the yield curve instruments and, for each bond, the equity of the issuing firm; "YC + equity + other" means the yield curve instruments, the firm's equity and, in addition, the S&P, the Fama-French factors (SMB & HML) and the momentum mimicking portfolio; "Yield Curve + S&P" means the yield curve instruments and the S&P. T indicates the number of months of data used in the calculations and min (max) the minimum (maximum) number of bonds in the portfolio in any one month.

	All	AAA	AA	A	BBB	BB	B	CCC
Yield Curve only	51.1	19.6	20.4	39.4	64.4	86.0	96.4	
Yield Curve + firm equity	31.3	18.9	17.5	31.4	33.1	47.2	50.6	
YC + Equity + other	19.9	13.7	14.4	21.0	20.6	39.0	44.1	
Yield Curve + S&P	43.6	17.1	18.5	35.4	56.2	77.1	87.1	
T	66.5	66.5	66.5	66.5	66.5	66.5	66.5	66.5
N min	267.7	4.1	32.6	111.1	102.8	12.3	0.5	0.0
N max	574.4	11.9	53.1	226.6	233.7	41.5	7.6	0.0

Table IV
Hedging Effectiveness: Out-of-sample Estimates

Each of the first four rows of the table shows the variance of the hedged portfolio as a percentage of the variance of the unhedged portfolio. The first column shows the hedging instruments that are used. Here "Yield Curve (YC)" means the one and ten-year Treasury bonds are used as hedging instruments; "Yield Curve + firm equity" means the yield curve instruments and, for each bond, the equity of the issuing firm; "YC + equity + "other"" means the instruments in the previous case and, in addition, the S&P, the Fama-French factors (SMB & HML) and the momentum mimicking portfolio. T indicates the number of months of data used in the calculations and min (max) the minimum (maximum) number of bonds in the portfolio in any one month. [Add - out of sample]

	All	AAA	AA	A	BBB	BB	B	CCC
Yield Curve only	90.0	33.8	41.4	73.2	79.7	106.0	104.3	92.9
Yield Curve + firm equity	60.4	34.3	38.8	62.6	53.5	47.6	69.8	3.7
YC + Equity + other	58.9	37.3	45.2	72.8	55.9	41.8	73.2	41.9
Yield Curve + S&P	76.6	30.0	37.7	64.3	78.3	92.2	104.0	72.4
T	48	48	48	48	48	48	48	48
N min	200	4	30	77	70	14	0	0
N max	424	14	53	159	154	41	7	1

Table V
Descriptive Statistics for Equity Related Indices: Jan 1976 - December 2003

The table gives summary statistics for the equity related indices used in the analysis. The variables included are the S&P 500 (SP500), the consumer price index (CPI), the Fama-French SMB, HML and momentum (UMD) factors, the CRSP one-month Treasury bill rate (RF) and the Fama-French one-month Treasury bill rate (RF/FF). The statistics on rates of return are monthly.

	SP500	CPI	SMB	HML	UMD	RF	RF/FF
Mean monthly return	0.85	0.36	0.28	0.44	0.88	0.50	0.50
Total return	13.61	3.48	2.19	3.95	15.58	5.70	5.72
St. dev.	4.36	0.33	3.25	3.14	4.26	0.26	0.25
Min	-21.76	-0.46	-16.69	-12.03	-25	0.06	0.06
Max	13.18	1.52	21.49	13.75	18.38	1.52	1.35
Index start	7512	7512	7512	7512	7512	7512	7512
N. Obs.	348	348	349	348	348	349	349

Table VI
Descriptive Statistics for CRSP Treasury Indices: Jan 1976 - December 2003

The table gives summary statistics for CRSP constant maturity ("Fixed Term") Treasury indices. The statistics on rates of return are monthly.

	30Y	20Y	10Y	7Y	5Y	2Y	1Y	3M
Mean monthly return	0.77	0.82	0.75	0.75	0.71	0.64	0.61	0.55
Total return	12.17	14.66	12.45	12.56	11.18	9.16	8.39	6.75
St. dev.	3.32	3.11	2.43	2.09	1.73	0.99	0.61	0.30
Min	-10.49	-9.36	-6.68	-7.04	-5.80	-3.69	-1.72	0.07
Max	13.31	15.23	10	10.75	10.61	8.42	5.61	2.13
Index start	7512	7512	7512	7512	7512	7512	7512	7512
N. Obs.	349	349	349	349	349	349	349	349

Table VII
Descriptive Statistics on Merrill Lynch Corporate Bond Indices: All Years

The table gives summary statistics on the Merrill Lynch corporate bond indices described in Section II. The first column refers to the broad IG index that includes all maturities and the next four columns to sub-indices chosen on the basis of maturity. The next four columns (AAA to BBB) are credit rating sub-indices of the broad IG index. The remaining four columns give statistics on high yield debt with the first column a broad index and the remaining three chosen on the basis of credit rating. Note that for some indices data on maturity, duration and yield are available only for recent years and that the indices do not all share a common start date (see row 7).

	IG all	IG 1-5Y	IG 5-10Y	IG 10-15Y	IG 15+Y	AAA	AA	A	BBB	HY all	BB	B	CCC
Mean monthly return	0.79	0.72	0.86	0.82	0.86	0.69	0.70	0.71	0.72	0.76	0.60	0.49	0.54
Total return	14.57	9.80	16.34	14.97	17.32	3.70	3.78	3.82	3.90	5.03	1.76	1.55	1.57
St. dev.	2.07	1.07	2.53	2.38	2.66	1.36	1.35	1.35	1.40	1.96	1.76	2.51	3.85
Min	-7.36	-3.17	-6.52	-7.39	-8.52	-4.38	-3.65	-4.39	-4.17	-7.74	-8.15	-7.15	-11.73
Max	11.97	6.60	33.49	13.19	13.94	4.51	4.91	4.62	4.54	8.68	3.95	7.85	11.54
N. Bonds	3981	1085	1159	404	1117	175	564	1695	1302	1028	496	639	18
Index start	7512	7803	7701	7604	7512	8901	8901	8901	8901	8609	9701	9701	9701
Maturity	12.46	3.06	7.52	12.28	25.81	12.50	11.87	11.24	12.40	9.17	8.94	7.37	8.12
Duration	6.45	2.70	5.62	7.82	10.24	6.61	6.36	6.21	6.57	5.51	5.56	5.18	6.91
Yield	8.00	7.29	8.04	8.22	8.73	6.80	6.84	7.09	7.76	11.65	8.42	10.75	4.62
N. Obs.	349	322	336	345	349	192	192	192	192	220	96	96	96

Table VIII

Descriptive Statistics on Merrill Lynch Corporate Bond Indices: Jan 1997 - Dec 2004

The table reports statistics for the same Merrill Lynch indices as in Table VII and for the maximum common period of availability across all the indices (January 1997 - December 2004).

	IG all	IG 1-5Y	IG 5-10Y	IG 10-15Y	IG 15+Y	AAA	AA	A	BBB	HY all	BB	B	CCC
Mean monthly return	0.62	0.54	0.64	0.70	0.71	0.61	0.61	0.62	0.61	0.55	0.60	0.49	0.54
Total return	1.79	1.67	1.83	1.92	1.93	1.78	1.78	1.79	1.78	1.65	1.76	1.55	1.57
St. dev.	1.37	0.71	1.49	1.97	2.26	1.36	1.26	1.37	1.48	2.26	1.76	2.51	3.85
Min	-4.22	-1.61	-4.73	-6.74	-8.16	-4.38	-3.65	-4.39	-4.17	-7.74	-8.15	-7.15	-11.73
Max	3.70	2.07	4.13	5.40	5.70	3.68	3.60	3.64	3.86	6.33	3.95	7.85	11.54
N. Bonds	3774	1339	1194	200	1042	118	431	1705	1521	1370	496	639	18
Index start	9701	9701	9701	9701	9701	9701	9701	9701	9701	9701	9701	9701	9701
Maturity	11.12	3.06	7.53	12.09	27.29	11.42	9.49	10.76	12.05	7.95	8.94	7.37	-0.10
Duration	6.29	2.77	5.92	8.18	11.55	6.44	5.71	6.18	6.61	5.27	5.56	5.18	6.91
Yield	6.28	5.47	6.42	6.78	7.30	5.68	5.64	6.05	6.80	10.68	8.42	10.75	4.62
N. Obs.	96	96	96	96	96	96	96	96	96	96	96	96	96

Table IX
Corporate Bond Index Hedging Regressions: All Available data

The table shows the results of regressing the excess return on corporate bond indices on the excess return on the 10-year Treasury bond and the S&P index and on the Fama-French SMB and HML factors. The regressions are calculated using all the available data for each series and, as a result, are based on different numbers of observations and periods.

	IG all	*HY all*	*IG 1-5Y*	*IG 5-10Y*	*IG 10-15Y*	*IG 15+Y*	*AAA*	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*
Constant	0.14	0.38	0.41	0.31	0.06	0.01	0.20	0.22	0.22	0.20	0.19	0.12	0.06
	(2.62)	(3.31)	(11.62)	(2.58)	(0.95)	(0.19)	(7.43)	(6.85)	(6.05)	(3.92)	(1.18)	(0.53)	(0.16)
RF10Y	0.74	0.16	0.36	0.60	0.86	0.93	0.65	0.64	0.63	0.59	0.22	0.07	-0.12
	(35.88)	(2.96)	(27.07)	(12.83)	(37.54)	(33.57)	(51.65)	(43.22)	(37.89)	(24.62)	(3.04)	(0.65)	(-0.74)
SP	0.07	0.25	0.03	0.05	0.09	0.11	0.04	0.05	0.05	0.10	0.24	0.31	0.43
	(5.53)	(9.46)	(3.01)	(1.68)	(6.17)	(6.22)	(5.86)	(5.69)	(6.06)	(7.81)	(6.57)	(5.77)	(5.17)
HML	0.06	0.16	0.04	0.13	0.09	0.07	0.02	0.02	0.03	0.06	0.16	0.12	0.29
	(3.18)	(4.02)	(3.31)	(2.93)	(4.38)	(3.00)	(2.52)	(1.80)	(2.33)	(3.43)	(3.49)	(1.72)	(2.74)
SMB	0.06	0.23	0.04	0.12	0.08	0.09	0.02	0.02	0.04	0.08	0.17	0.20	0.37
	(3.68)	(6.77)	(3.28)	(3.18)	(4.63)	(4.18)	(3.13)	(2.54)	(3.95)	(5.24)	(4.33)	(3.57)	(4.18)
R^2	0.81	0.37	0.72	0.36	0.83	0.79	0.94	0.91	0.89	0.79	0.34	0.31	0.28
N	347	219	320	334	343	347	191	191	191	191	96	96	96

Table X

Corporate Bond Index Hedging Regressions: January 1997 - December 2004

The table shows the results of regressing the excess return on corporate bond indices on the excess return on the 10-year Treasury bond and the S&P index and on the Fama-French SMB and HML factors. The regressions are calculated using the data from January 1997 to December 2004, the maximum period for which data is available for all the series.

	IG all	*HY all*	*IG 1-5Y*	*IG 5-10Y*	*IG 10-15Y*	*IG 15+Y*	*AAA*	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*
Constant	0.18	0.15	0.36	0.18	0.06	-0.01	0.20	0.24	0.20	0.14	0.19	0.12	0.06
	(2.74)	(0.71)	(8.93)	(2.60)	(0.71)	(-0.10)	(4.68)	(5.03)	(3.35)	(1.52)	(1.18)	(0.53)	(0.16)
RF10Y	0.60	0.11	0.30	0.66	0.88	0.90	0.63	0.57	0.61	0.59	0.22	0.07	-0.12
	(20.00)	(1.17)	(16.92)	(21.98)	(23.19)	(14.93)	(33.56)	(26.91)	(22.55)	(14.58)	(3.04)	(0.65)	(-0.74)
SP	0.08	0.30	0.01	0.08	0.11	0.19	0.05	0.04	0.06	0.12	0.24	0.31	0.43
	(5.53)	(6.35)	(1.13)	(5.14)	(5.49)	(6.06)	(4.79)	(3.57)	(4.47)	(6.02)	(6.57)	(5.77)	(5.17)
HML	0.05	0.15	0	0.05	0.09	0.11	0.03	0.02	0.03	0.07	0.16	0.12	0.29
	(2.32)	(2.58)	(0.22)	(2.51)	(3.45)	(2.67)	(2.59)	(1.36)	(1.72)	(2.58)	(3.49)	(1.72)	(2.74)
SMB	0.06	0.21	0.01	0.06	0.10	0.14	0.03	0.03	0.05	0.09	0.17	0.20	0.37
	(3.74)	(4.18)	(1.41)	(3.44)	(4.76)	(4.18)	(3.37)	(2.50)	(3.22)	(4.09)	(4.33)	(3.57)	(4.18)
R^2	0.81	0.33	0.75	0.84	0.85	0.71	0.92	0.88	0.84	0.70	0.34	0.31	0.28
N	96	96	96	96	96	96	96	96	96	96	96	96	96

Table XI
Corporate Bond Index Hedging Regressions: All Available data

The table shows the results of regressing the excess return on corporate bond indices on the excess return on the 10-year Treasury bond and the S&P index, VIX, the Fama-French SMB and HML factors, the CPI and the momentum factor (UMD) . The regressions are calculated using all the available data for each series and, as a result, are based on different numbers of observations and periods.

	IG all	*HY all*	*IG 1-5Y*	*IG 5-10Y*	*IG 10-15Y*	*IG 15+Y*	*AAA*	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*
Constant	0.23	0.51	0.37	0.22	0.04	0.16	0.20	0.22	0.23	0.23	0.25	0.28	0.10
	(3.89)	(2.66)	(9.13)	(3.79)	(0.57)	(1.45)	(5.03)	(4.67)	(4.33)	(3.04)	(1.23)	(0.95)	(0.23)
RF10Y	0.64	0.19	0.32	0.69	0.88	0.91	0.66	0.65	0.65	0.61	0.25	0.13	-0.06
	(31.90)	(2.89)	(23.26)	(34.07)	(34.45)	(23.43)	(47.47)	(39.30)	(35.37)	(22.91)	(3.28)	(1.21)	(-0.35)
SP	0.05	0.27	0	0.04	0.06	0.10	0.02	0.03	0.03	0.08	0.21	0.25	0.40
	(3.81)	(6.02)	(0.19)	(3.10)	(3.59)	(3.65)	(2.49)	(2.52)	(2.77)	(4.62)	(4.11)	(3.51)	(3.48)
VIX	-0.02	0.03	-0.01	-0.02	-0.02	-0.04	-0.02	-0.03	-0.02	-0.01	-0.02	-0.01	0.04
	(-1.70)	(0.61)	(-0.83)	(-1.71)	(-1.18)	(-1.37)	(-2.38)	(-2.50)	(-1.93)	(-0.76)	(-0.35)	(-0.14)	(0.39)
HML	0.03	0.14	0	0.04	0.06	0.06	0.02	0.02	0.02	0.05	0.15	0.09	0.26
	(2.28)	(3.11)	(0.23)	(2.59)	(3.27)	(2.10)	(1.93)	(1.39)	(1.73)	(2.85)	(3.12)	(1.28)	(2.40)
SMB	0.05	0.24	0.01	0.04	0.07	0.10	0.02	0.02	0.04	0.08	0.17	0.21	0.39
	(4.00)	(6.32)	(1.11)	(3.86)	(4.97)	(4.67)	(2.55)	(1.89)	(3.58)	(5.03)	(4.31)	(3.78)	(4.41)
CPI	0.01	-0.28	0.13	-0	0.24	-0.25	0.07	0.04	0.03	-0.06	-0.09	-0.28	0.26
	(0.05)	(-0.51)	(1.15)	(-0.00)	(1.13)	(-0.78)	(0.62)	(0.26)	(0.22)	(-0.27)	(-0.15)	(-0.34)	(0.20)
UMD	-0.02	-0.09	-0.01	-0.02	-0.01	-0.05	-0.01	-0	-0.02	-0.03	-0.04	-0.10	-0.13
	(-2.30)	(-3.19)	(-1.45)	(-2.51)	(-1.35)	(-3.09)	(-1.26)	(-0.43)	(-2.22)	(-2.58)	(-1.62)	(-2.58)	(-2.19)
R^2	0.87	0.39	0.77	0.88	0.89	0.79	0.94	0.91	0.89	0.78	0.34	0.33	0.29
N	177	177	177	177	177	177	177	177	177	177	95	95	95

Table XII

Corporate Bond Index Hedging Regressions: All Available data, Three-monthly observations

The table shows the results of regressing the excess return on corporate bond indices on the excess return on the 10-year Treasury bond and the S&P index and on the Fama-French SMB and HML factors. A three-month differencing interval is used for calculating returns. The regressions are calculated using all the available data for each series and, as a result, are based on different numbers of observations and periods.

	IG all	*HY all*	*IG 1-5Y*	*IG 5-10Y*	*IG 10-15Y*	*IG 15+Y*	*AAA*	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*
Constant	0.34	0.86	1.19	0.64	0.16	-0.04	0.55	0.57	0.57	0.50	0.38	-0.30	-0.70
	(2.09)	(2.08)	(10.16)	(4.77)	(0.89)	(-0.18)	(6.04)	(4.57)	(4.36)	(2.65)	(0.60)	(-0.38)	(-0.49)
RF10Y	0.84	0.31	0.43	0.72	0.95	1.05	0.72	0.70	0.69	0.66	0.25	0.41	0.24
	(27.77)	(3.06)	(20.54)	(29.22)	(28.05)	(27.49)	(31.94)	(22.59)	(21.33)	(14.19)	(1.54)	(2.04)	(0.65)
SP	0.04	0.26	-0.01	0.02	0.05	0.07	0.02	0.03	0.04	0.09	0.27	0.33	0.55
	(1.93)	(5.48)	(-0.85)	(1.17)	(2.07)	(2.72)	(1.55)	(2.03)	(2.62)	(3.98)	(3.81)	(3.79)	(3.44)
HML	0.02	0.12	0.01	0.02	0.03	0.02	0.01	0.02	0.02	0.03	0.17	0.09	0.25
	(0.98)	(1.99)	(0.30)	(1.09)	(0.90)	(0.78)	(0.44)	(1.13)	(1.29)	(1.35)	(2.41)	(1.08)	(1.53)
SMB	0.08	0.24	0.03	0.06	0.09	0.11	0.03	0.05	0.06	0.10	0.21	0.23	0.40
	(3.46)	(4.33)	(1.95)	(3.18)	(3.58)	(3.98)	(2.97)	(2.94)	(3.72)	(4.27)	(3.17)	(2.85)	(2.70)
R^2	0.88	0.44	0.81	0.90	0.88	0.88	0.95	0.90	0.89	0.80	0.36	0.38	0.31
N	114.00	72.00	105.00	109.00	112.00	114.00	62.00	62.00	62.00	62.00	31.00	31.00	31.00

Table XIII
Corporate Bond Index Hedging Regressions: All Available data

The Table shows sub-period regressions for the regression described in Table ??.

	IG all	*HY all*	*IG 1-5Y*	*IG 5-10Y*	*IG 10-15Y*	*IG 15+Y*	*AAA*	*AA*	*A*	*BBB*
					Panel (a) 1975-85					
RF10Y	0.87		0.41	0.60	0.88	1.05				
	(18.62)		(13.05)	(4.55)	(16.98)	(19.05)				
SP	0.08		0.08	-0.01	0.15	0.09				
	(2.01)		(2.77)	(-0.05)	(3.34)	(2.05)				
HML	0.12		0.14	0.30	0.19	0.13				
	(2.42)		(3.73)	(1.91)	(3.04)	(2.21)				
SMB	0.03		0.05	0.39	0.07	0.03				
	(0.64)		(1.39)	(2.47)	(1.23)	(0.46)				
R^2	0.81		0.75	0.22	0.80	0.82				
N	108.00		81.00	95.00	104.00	108.00				
					Panel (b) 1985-90					
RF10Y	0.66	0.25	0.28	0.56	0.74	0.82	0.68	0.70	0.73	0.69
	(17.54)	(3.31)	(13.53)	(15.42)	(15.27)	(14.57)	(11.30)	(12.28)	(9.10)	(14.26)
SP	0.04	0.17	0.00	0.02	0.06	0.06	0.02	0.04	0.04	0.03
	(1.78)	(5.19)	(0.27)	(0.76)	(2.09)	(1.75)	(0.65)	(1.12)	(0.82)	(1.25)
HML	0.05	0.27	0.02	0.03	0.09	0.06	0.08	0.04	0.06	0.04
	(0.93)	(3.18)	(0.56)	(0.62)	(1.44)	(0.87)	(0.92)	(0.51)	(0.52)	(0.60)
SMB	0.05	0.28	0.01	0.02	0.07	0.08	0.03	0.09	0.11	0.12
	(1.11)	(4.05)	(0.54)	(0.44)	(1.25)	(1.24)	(0.47)	(1.25)	(1.11)	(2.05)
R^2	0.86	0.53	0.78	0.83	0.83	0.81	0.94	0.95	0.90	0.96
N	60.00	40.00	60.00	60.00	60.00	60.00	12.00	12.00	12.00	12.00
					Panel (c) 1990-95					
RF10Y	0.69	0.28	0.35	0.72	0.88	0.83	0.69	0.75	0.68	0.62
	(24.34)	(1.96)	(10.70)	(20.95)	(24.94)	(18.96)	(26.13)	(27.50)	(22.56)	(15.89)
SP	0.02	0.22	-0.02	0.01	0.01	0.07	0.01	0.01	0.02	0.04
	(1.28)	(3.01)	(-1.21)	(0.63)	(0.47)	(2.83)	(0.59)	(0.62)	(1.16)	(2.08)
HML	0.02	0.16	0.02	0.04	0.01	0.03	-0.01	-0.00	0.02	0.06
	(1.43)	(1.84)	(0.83)	(1.72)	(0.27)	(1.01)	(-0.59)	(-0.01)	(1.32)	(2.47)
SMB	0.04	0.44	0.00	0.05	0.05	0.07	0.02	0.02	0.04	0.08
	(2.36)	(5.28)	(0.08)	(2.35)	(2.20)	(2.60)	(0.98)	(0.98)	(2.24)	(3.49)
R^2	0.95	0.49	0.75	0.93	0.95	0.93	0.95	0.96	0.94	0.90
N	59.00	59.00	59.00	59.00	59.00	59.00	59.00	59.00	59.00	59.00

Table XIV
Empirical Duration of Corporate Debt

The table reports the results of the following regression

$$r_{j,t} = \alpha_j + \beta_j^E r_t^E + \beta_j^{rf} r_t^{rf,T} + \varepsilon_{j,t}.$$

The coefficients are average values across the bonds in the sample (and multiplied by 100). The data used are the 1370 bonds of our full sample for the entire sample period from December 1996 to December 2003. N gives the average number of time-series observations in each regression and the number in parentheses is the number of bonds in the sample for each credit category.

	All	AAA	AA	A	BBB	BB	B
Intercept	-0.15	-0.19	-0.19	-0.18	-0.18	0.02	0.62
	(-4.42)	(-4.11)	(-6.36)	(-6.17)	(-4.10)	(0.24)	(2.41)
$r_t^{rf,5}$	77.71	88.84	85.63	84.13	80.32	40.87	-11.83
	(30.93)	(28.35)	(40.72)	(38.39)	(24.58)	(7.40)	(-0.65)
r_t^E	4.26	0.75	1.60	3.48	4.31	9.72	15.85
	(15.75)	(1.30)	(5.02)	(12.46)	(13.54)	(19.99)	(15.95)
$\bar{R}^2$	0.49	0.64	0.61	0.52	0.45	0.32	0.35
N	47.02	57.30	53.28	45.23	47.60	46.96	41.27
	(1370)	(23)	(126)	(620)	(466)	(107)	(26)

Table XV
Empirical Duration of Corporate Debt as Fraction of McCaulay Duration

The table reports the results of the following regression

$$r_{j,t} = \alpha_j + \beta_j^E r_t^E + \beta_j^* \left[\left(\frac{D_{j,t}}{D_t^{rf,T}} \right) r_t^{rf,T} \right] + \varepsilon_{j,t}.$$

The coefficients are average values across the bonds in the sample (and multiplied by 100). The data used are the 1370 bonds of our full sample for the entire sample period from December 1996 to December 2003. N gives the average number of time-series observations in each regression and the number in parentheses is the number of bonds in the sample for each credit category.

	All	AAA	AA	A	BBB	BB	B
Intercept	-0.16	-0.20	-0.21	-0.20	-0.18	-0.01	0.61
	(-4.78)	(-4.60)	(-7.19)	(-6.77)	(-4.12)	(-0.09)	(2.36)
β_j^*	66.91	74.41	76.01	70.71	69.51	43.27	-17.38
	(31.70)	(34.03)	(48.32)	(41.14)	(24.30)	(9.13)	(-0.98)
β_j^E	4.14	0.46	1.46	3.40	4.16	9.62	15.80
	(15.63)	(0.86)	(4.79)	(12.43)	(13.27)	(20.02)	(15.76)
$\bar{R}^2$	0.52	0.70	0.66	0.55	0.48	0.34	0.35
N	47.02	57.30	53.28	45.23	47.60	46.96	41.27
	(1370.00)	(23.00)	(126.00)	(620.00)	(466.00)	(107.00)	(26.00)

Table XVI
Empirical Duration of Corporate Debt as Fraction of McCaulay Duration: by Maturity. Maturities are on the first date of bond entering the data set. For details see Table XV and text

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PANEL A: 0–5 YEARS

	All	AAA	AA	A	BBB	BB	B	CCC
Intercept	0.02	-0.01	-0.02	0.01	0.00	0.06	0.87	0.44
	(1.11)	(-0.21)	(-1.65)	(0.80)	(0.03)	(1.05)	(1.48)	(1.26)
β_j^*	73.86	82.54	80.04	75.89	75.90	56.97	-12.59	-15.12
	(29.34)	(26.29)	(42.10)	(35.76)	(17.44)	(7.00)	(-0.22)	(-0.32)
β_j^E	1.20	0.29	-0.08	0.87	1.84	0.44	19.12	-0.83
	(8.65)	(0.75)	(-0.43)	(6.38)	(10.00)	(1.06)	(6.78)	(-0.34)
$\bar{R}^2$	0.61	0.84	0.78	0.63	0.58	0.38	0.37	-0.03
N	31.47	29.43	31.44	31.26	32.06	30.73	34.25	32.00
	(372.00)	(7.00)	(36.00)	(197.00)	(104.00)	(22.00)	(4.00)	(2.00)

PANEL B: 5–8 YEARS

	All	AAA	AA	A	BBB	BB	B	CCC
Intercept	-0.12	-0.15	-0.18	-0.18	-0.19	0.03	1.42	
	(-3.98)	(-4.62)	(-8.74)	(-7.36)	(-4.97)	(0.32)	(3.22)	
β_j^*	77.36	92.18	89.07	85.18	83.60	57.38	-105.15	
	(28.93)	(26.00)	(47.87)	(38.25)	(24.31)	(8.01)	(-3.23)	
β_j^E	3.39	-0.06	0.58	2.21	3.25	7.51	15.78	
	(15.93)	(-0.14)	(2.48)	(10.06)	(12.60)	(14.17)	(10.85)	
$\bar{R}^2$	0.59	0.77	0.75	0.64	0.57	0.38	0.39	
N	47.58	62.75	55.24	48.84	45.64	45.65	35.86	
	(300.00)	(4.00)	(25.00)	(107.00)	(123.00)	(34.00)	(7.00)	(0.00)

PANEL C: 8–12 YEARS

	All	AAA	AA	A	BBB	BB	B	CCC
Intercept	-0.21	-0.25	-0.21	-0.28	-0.24	0.05	0.31	
	(-5.54)	(-4.22)	(-4.50)	(-8.40)	(-4.62)	(0.39)	(1.06)	
β_j^*	72.40	83.73	80.86	79.33	73.48	34.00	23.85	
	(32.13)	(23.43)	(32.80)	(43.25)	(22.63)	(4.87)	(1.40)	
E^{ret}	4.23	0.70	1.94	3.54	4.46	6.27	14.67	
	(14.34)	(0.99)	(4.69)	(11.20)	(11.65)	(8.15)	(14.38)	
$\bar{R}^2$	0.52	0.69	0.61	0.58	0.47	0.29	0.35	
N	52.51	68.80	62.61	50.25	53.36	48.63	42.08	
	(343.00)	(5.00)	(36.00)	(146.00)	(120.00)	(24.00)	(12.00)	(0.00)

PANEL D: 12–25 YEARS

	All	AAA	AA	A	BBB	BB	B	CCC
Intercept	-0.33	10.43	-0.43	-0.39	-0.26	-0.24	-0.41	
	(-5.36)	(3.33)	(-5.83)	(-6.38)	(-3.00)	(-1.16)	(-0.73)	
β_j^*	52.15	10.43	66.30	55.38	56.03	22.87	17.27	
	(24.72)	(3.33)	(26.23)	(28.04)	(17.90)	(3.24)	(0.85)	
E^{ret}	7.79	10.43	2.67	5.08	6.20	26.70	14.95	
	(15.40)	(3.33)	(3.24)	(8.63)	(9.29)	(22.22)	(4.92)	
$\bar{R}^2$	0.40	10.43	0.54	0.42	0.35	0.36	0.16	
N	58.06	49.00	71.00	52.81	61.28	63.26	60.00	
	(167.00)	(1.00)	(12.00)	(80.00)	(53.00)	(19.00)	(2.00)	(0.00)

Table XVII
Cross-Sectional Analysis of Estimated Ratio of Empirical Duration as Fraction of McCaulay Duration. The Table shows the results of a cross sectional regression with β_j^*, estimated in equation XV as dependent variable.

	(1)	(2)	(3)
Constant	166.00	114.30	114.99
	(23.31)	(22.92)	(23.13)
Duration	-2.47	-2.77	-3.23
	(-3.89)	(-8.96)	(-26.59)
Time to maturity	-0.19	-0.19	
	(-0.77)	(-1.61)	
Quasi-Market Leverage	-70.11	-39.75	-39.74
	(-12.41)	(-13.15)	(-13.14)
Firm Volatility	-142.39	-75.00	-75.01
	(-8.92)	(-8.88)	(-8.88)
Coupon rate	-3.67	-1.61	-1.62
	(-4.70)	(-3.93)	(-3.94)
Inv.Grade Dummy		15.36	15.29
		(8.20)	(8.16)
R^2	0.21	0.48	0.48
N	1359.00	1331.00	1331.00

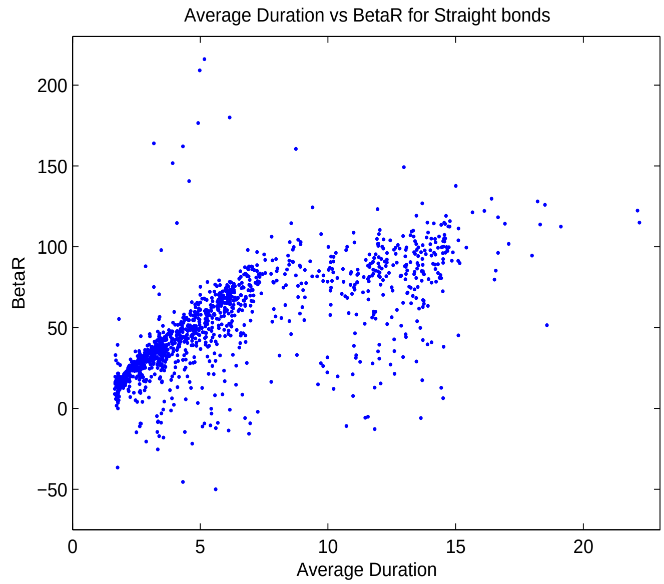

Figure 1. Relationship between empirical duration and McCaulay duration, estimated in equation 10, for straight bonds. Sample size: 1359. McCaulay duration is modified duration averaged over the bond observations. Outliers are eliminated (maturities near 100 years and extreme β_r observations.

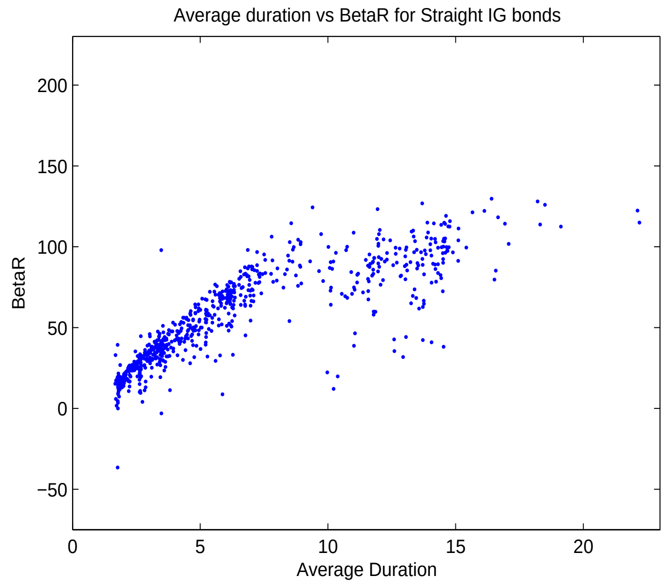

Figure 2. Relationship between empirical duration and McCaulay duration, estimated in equation 10, for straight bonds with rating: AAA,AA and A. Sample size: 760 observations. Bond duration is modified duration. Outliers are eliminated (maturities near 100 years and extreme β_r observations.

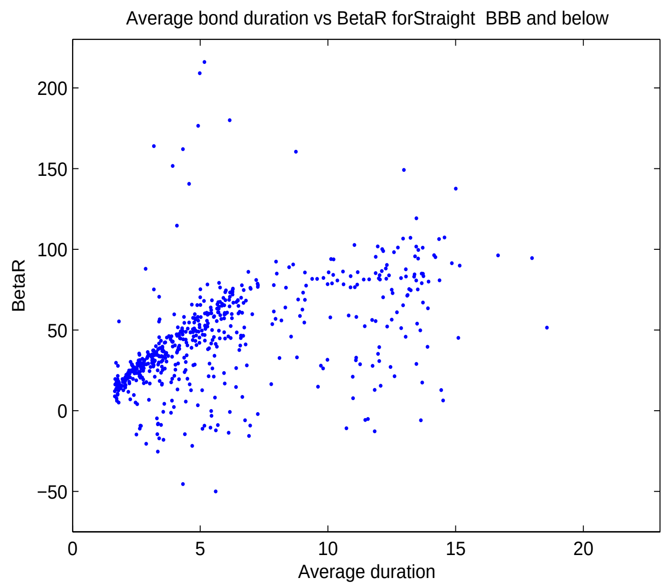

Figure 3. Relationship between empirical duration and McCaulay duration, estimated in equation 10, for straight bonds with rating: BBB and below. Sample size: 569 observations. Bond duration is modified duration. Outliers are eliminated (maturities near 100 years and extreme β_r observations.