Treasury yields and corporate bond yield spreads: An empirical analysis

Gregory R. Duffee
Federal Reserve Board
Mail Stop 91
Washington, DC 20551
202-452-3055
gduffee@frb.gov

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Abstract

This paper empirically examines the relation between the Treasury term structure and spreads of investment grade corporate bond yields over Treasuries. I find that noncallable bond yield spreads fall when the level of the Treasury term structure rises. The extent of this decline depends on the initial credit quality of the bond; the decline is small for Aaa-rated bonds and large for Baa-rated bonds. The role of the business cycle in generating this pattern is explored, as is the link between yield spreads and default risk. I also argue that yield spreads based on commonly-used bond yield indexes are contaminated in two important ways. The first is that they are "refreshed" indexes, which hold credit ratings constant over time; the second is that they usually are constructed with both callable and noncallable bonds. The impact of both of these problems is examined.

JEL Classification: G13

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1. Introduction

This paper empirically examines the relation between the Treasury term structure and spreads of corporate bond yields over Treasuries. This relation is of interest in its own right because it is essential to the calibration and testing of models that price credit sensitive instruments. More broadly, this investigation allows us to address the nature of the biases in commonly-used indexes of corporate bond yields; biases induced by the way these indexes are constructed.

Indexes of corporate bond yields are typically averages of yields on a set of bonds that are chosen based on the characteristics of the bond at the time the average is computed. For example, today's Moody's Industrials Aaa-rated Bond Yield is today's mean yield on a set of Aaa-rated bonds issued by industrial firms that have current prices not too far away from par and have relatively long remaining maturities. Much academic work interprets changes in yield spreads constructed with such indexes as indicative of changes in default risk. This interpretation is subject to a number of potential problems, two of which are likely more important than others.

The first major problem, as discussed by Duffie and Singleton (1995) in the context of indexes of new-issue swap spreads, is that these are "refreshed" indexes. The change in the yield from one period to the next does not measure the change in the mean yield on a fixed set of bonds, but rather the change in the mean yield on two sequential sets of bonds that share the same features; in particular, that share the same credit rating. Hence using these indexes to investigate intertemporal changes in bonds' default risk is problematic because the indexes hold constant a measure of credit quality.

The second major problem is that corporate bond yield indexes are often constructed using both callable and noncallable bonds. Given the objectives of those constructing the indexes, such as Moody's, this is sensible. Until relatively recently, few corporations issued noncallable bonds, hence an index designed to measure the yield on a typical corporate bond would have to be constructed primarily with callable bonds. However, yields on callable bonds will be affected by the value of the option to call. Variations over time in yield spreads on callable bonds will reflect, in part, variations in the option value.

Other, less important problems that affect most indexes of corporate bond yields include coupon-induced changes in duration and state taxes. Given all of these biases, how appropriate is the assumption that changes in yield spreads for such indexes are driven by changes in default risk?

I use month-end data on individual investment-grade bonds included in Lehman Brothers Bond Indexes from January 1985 through March 1995 to examine how yield spreads vary with changes in the level and slope of the Treasury term structure. To illustrate the results discussed in this paper, consider the average month-t yield spread (over the appropriate

Treasury instrument) for a group of noncallable coupon bonds with identical credit ratings and similar maturities. If the Treasury yield curve shifts down by 10 basis points between months t and $t+1$, the average yield spread on this group of bonds rises by between 0.6 and 3.6 basis points. In other words, the price increase in a corporate bond that accompanies a given decrease in Treasury yields is between 6 and 36 percent less than it would be if bond yields and Treasury yields moved one-for-one. The responsiveness of the spread is weak for high-rated bonds (e.g., it is statistically insignificant for Aaa-rated bonds) and strong for low-rated bonds. Although these results are for coupon bonds, any coupon-induced bias in these results is quite small.

I also conclude that, after adjusting for coupon-induced biases, changes in the slope of the term structure of Treasury yields are very weakly negatively related to changes in yield spreads. Surprisingly, although both yields on Treasury bonds and corporate bond yield spreads are linked to the business cycle (well-known facts that I confirm here), I find it difficult to explain the relation between yield spreads and Treasury yields in terms of variations in default risk driven by the business cycle.

I find that, compared with the results discussed above, changes in yield spreads constructed with refreshed indexes of noncallable bonds have much weaker links to changes in Treasury yields. This evidence indicates that refreshed indexes underreact to variations in credit quality because changes in credit ratings capture part of the variability of yield spreads over time.

By contrast, changes in yield spreads constructed with indexes of callable bonds have much stronger links to changes in Treasury yields because the value of the call option negatively varies with Treasury yields. For high-priced callable bonds, most of the variation in yield spreads is caused by variations in the value of the call option.

The next section discusses why the relation between yield spreads and Treasury yields is important and reviews some previous research. The third section describes the database I use. The fourth section analyzes the relation between yield spreads on noncallable bonds and Treasury yields. It also discusses possible biases induced by coupons and state taxes. The fifth section attempts to interpret this relation in terms of default risk and the business cycle. The sixth section explores the behavior of yield spreads constructed with both refreshed indexes of noncallable bond yields and indexes of callable bond yields. Concluding comments are contained in the final section.

2. Yield spreads and the Treasury term structure: An overview

Prices of credit-sensitive instruments depend on the covariances between discounted future obligated cash flows and the probabilities of default at future dates. Hence in order to parameterize pricing models for credit-sensitive instruments, financial economists must understand the joint behavior of default-free discount rates and the market's perception of default risk. Roughly speaking, is the risk of default larger or smaller when the present value of the obligated cash flows is high?

A number of models price interest rate sensitive, default-risky instruments, such as corporate bonds and interest rate swaps, allowing for dependence between the process generating default and the process generating interest rates. One class of models follows the path laid by Merton (1974) and models default as a function of the value of the firm; changes in the value of the firm can be correlated with interest rates. This class includes the models of Cooper and Mello (1991), Abken (1993), Shimko, Tejima, and van Deventer (1993), and Longstaff and Schwartz (1995). They find that the prices of these instruments can be very sensitive to the correlation between the firm's value and interest rates.

Another, more recent class of models simply specifies a default process without tying default to the value of the firm. The probability of default can be correlated with interest rates, as in Lando (1994) and Duffie and Huang (1995). However, one reason this class of models was developed is that the models are very tractable if default probabilities are independent of interest rates. Hence empirical implementation has concentrated on the case of independence, as in Jarrow, Lando, and Turnbull (1994) and Madan and Unal (1994). If the evidence here indicates that independence is a poor assumption, then a major advantage of this class of models disappears.

Models of noncallable zero-coupon corporate bond prices, such as Lando (1994) and Longstaff and Schwartz (1995), imply that variations over time in default risk are accompanied by variations in yield spreads, hence patterns in the behavior of spreads can be used to make inferences about the relation between default risk and interest rates. Longstaff and Schwartz (1995) find that spreads between Moody's Bond Yield Indexes and Treasury bond yields are strongly negatively related to Treasury yields. However, over their sample period, Moody's Indexes were largely composed of yields on callable bonds. I argue later that this strong negative relation is driven by variations in the value of the call option. Kwan (1996) finds similar results (although his objective is different) using individual bond yields, but he also includes both callable and noncallable bonds in his analysis.

This call-option bias is avoided by Iwanowski and Chandra (1995), who examine the relation between Treasury yields and yield spreads of noncallable bonds during the late 1980s and early 1990s. They find a small negative relation between the level of the Treasury yield and yield spreads, and no significant relation between the Treasury slope and spreads. However, they use refreshed yield indexes in their analysis. I argue later that this choice underestimates the responsiveness of yield spreads to Treasury yields because it cannot capture changes in yield spreads on bonds that were upgraded or downgraded in the month. (The Moody's indexes used by Longstaff and Schwartz are also refreshed indexes, but the effect of the call option dominates the effect of the refreshed indexes.)

A related literature examines the return performance of low-grade corporate bonds relative to other assets. The advantage of looking at bond returns instead of yield indexes is that bond returns are not subject to the problem of refreshed indexes. Cornell and Green (1991) find that returns to low-grade bonds are much less responsive to changes in Treasury yields than are returns to high-grade bonds. They attribute this result to the lower duration of low-grade bonds, owing to less restrictive call features and higher coupons. Although callability likely accounts for part of this result, I find that low-quality noncallable bond yield spreads are very sensitive to Treasury yields, and that this result is not driven by high coupon payments. Hence part of the weak responsiveness of low-grade bond returns to changes in Treasury yields likely is driven by a negative correlation between interest rate risk and default risk.

3. Database description

The Fixed Income Database from the University of Wisconsin-Milwaukee consists of month-end data on the bonds that make up the Lehman Brothers Bond Indexes. The version used here covers January 1973 through March 1995. In addition to reporting month-end prices and yields, the database reports maturity, various call, put, and sinking fund information, and a business sector for each bond: e.g., industrial, utilities, and financial. It also reports monthly Moody's and S&P ratings for each bond. Until 1992 the Lehman Brothers Indexes covered only investment-grade firms, hence the analysis in this paper is restricted to bonds rated Baa or higher by Moody's (or BBB by S&P).

The secondary market for corporate bonds is very illiquid compared to the secondary market for corporate equity (stocks), which poses problems for reseachers who wish to use corporate bond prices. Nunn, Hill, and Schneeweis (1986) and Warga (1991) discuss these problems in detail. A useful feature of this dataset is that it distinguishes between "quote" prices and "matrix" prices. Quote prices are bid prices established by Lehman traders. If a trader is unwilling to supply a bid price because the bond has not traded recently, a matrix price is computed. Because quote prices are more likely to reflect all available information than are matrix prices, I use only quote prices in this paper. For more information on this database, see Warga (1991).

Much of the empirical work in this paper uses yields on noncallable bonds. Unfortunately for this area of research, corporations issued few noncallable bonds prior to the mid-1980s. For example, the dataset has January 1984 prices and yields for 5,497 straight bonds issued by industrial, financial, or utility firms. Only 271 of these bonds were noncallable for life. By January 1985, the number of noncallable bonds with price and yield information had risen to 382 (of 5,755). Beginning with 1985, the number of noncallable bonds rose dramatically, so that the dataset contains March 1995 price and yield information on 2,814 noncallable bonds (of 5,291). Because of the paucity of noncallable bonds in earlier years, I restrict my attention to the period January 1985 through March 1995.

4. An analysis of noncallable corporate bond yield spreads

In this section I examine the relation between Treasury yields and yield spreads on corporate bonds that have no option-like features. Therefore I consider only those corporate bonds that are noncallable, nonputable, and have no sinking fund option.

4.1. Data construction

I construct monthly corporate yields, yield spreads (over Treasuries) and changes in spreads for four business sectors (industrial, utilities, financial, and these three combined), four rating categories (Aaa, Aa, A, and Baa), and three bands of remaining maturities (2 to 7 years, 7 to 15 years, and 15 to 30 years). Hence 48 ($4 \times 4 \times 3$) different time series of spreads and changes in spreads are constructed. Their construction is described in detail in the Appendix and summarized here.

My measure of the month t yield spread for sector s, rating i, and remaining maturity m is denoted $S_{s,i,m,t}$. It is the mean yield spread at the end of month t for all bonds with quote prices in the sector/rating/maturity group. I define the monthly change in the spread $\Delta S_{s,i,m,t+1}$ as the mean change in the spread from t to $t+1$ on that exact group of bonds. Note that bonds that were downgraded between t and $t+1$ or that have fallen out of the maturity range between t and $t+1$ will not be included in the set of bonds used to construct the month $t+1$ spread $S_{s,i,m,t+1}$, but they will be included in my measure of the change in the spread from month t to month $t+1$. Most of the results discussed below use yields and spreads based on all combined business sectors, hence I usually drop the business sector subscript s.

Summary statistics for these time series of spreads and changes in spreads are displayed in Table 1. Note that there are many months for which spreads for a given sector's Aaa-rated bonds are missing, owing to a lack of noncallable Aaa bonds. Those observations that are not missing are based on very few bonds. For example, an average of two bonds are used to construct each nonmissing observation for long-term industrial Aaa bonds. Also note that changes in mean yield spreads for the combined business sectors are typically positively autocorrelated at one lag. This positive autocorrelation likely is the result of stale yield spreads for individual bonds.

4.2. Test Methodology

In order to investigate relations between changes in yield spreads and changes in the Treasury term structure, I need variables that summarize the information in the Treasury term structure. Litterman and Scheinkman (1991) and Chen and Scott (1993) document that the vast majority of variation in the Treasury term structure can be expressed in terms of changes in the level and the slope. I therefore use the monthly change in the three-month Treasury bill yield, denoted $\Delta Y_{3m,t}$, and the monthly change in the spread between the 30-year constant maturity Treasury yield and the three-month Treasury bill yield, denoted ΔSL_t for *SL*ope. These monthly changes are month-end to month-end changes so that they are properly aligned with the corporate bond data.

To determine how corporate bond spreads vary with the Treasury term structure, I regress changes in spreads on the future, current and lagged changes in my Treasury term structure variables. The non-contemporaneous changes are included to correct for non-trading, an approach based on Scholes and Williams (1977) that is used by Kwan (1996), Cornell and Green (1991), and others. I therefore estimate regressions of the form

$$\Delta S_{s,i,m,t+1} = b_0 + \sum_{j=-1}^{1} b_{3m,j} \Delta Y_{3m,t+1-j} + \sum_{j=-1}^{1} b_{sl,j} \Delta SL_{t+1-j} + e_{i,m,t+1}. \tag{1}$$

This decomposition of the Treasury term structure on the right-hand-side of (1) is arbitrary in the sense that I could have measured changes in the level of the term structure with changes in the 30-year yield instead of changes in the three-month bill yield. The form of (1) implies that the proper interpretation of the slope coefficients is the effect of a change in the long yield holding the short yield constant.

4.3. Regression results

Table 2 reports OLS estimates of equation (1) for various maturities and credit ratings. To save space, the only results displayed are those for all three business sectors combined. Regressions are run separately for each maturity/credit rating group. I adjust the variance-covariance matrix of the estimated coefficients for generalized heteroskedasticity and two lags of moving average residuals. The significance of asymptotic χ^2 tests that the sums of the coefficients on the leading, contemporaneous, and lagged variables equal zero are shown in brackets.

The results indicate that an increase in the level of the term structure corresponds to a decline in yield spreads. This relation holds for every combination of maturity and credit rating. The point estimates imply that for a 100 basis point decrease in the three month Treasury yield, yield spreads rise by between 6 basis points (medium-term Aaa-rated bonds) and 36 basis points (long-term Baa-rated bonds). This relation is weak for Aaa-rated bonds (it is statistically insignificant for long-maturity and medium-maturity Aaa-rated bonds) and strengthens as credit quality falls. Hence the covariances between changes in the level of the Treasury curve and changes in bond spreads are important in pricing non-Aaa corporate bonds. For such bonds, the average price increase in a corporate bond that accompanies a given decrease in the level of Treasury yields is nearly 20 percent less than it would be if bond yields and Treasury yields moved one-for-one.

Table 2 also reports that the relation between the slope of the term structure and yield spreads is weak. An increase in the slope typically corresponds to a decrease in yield spreads, but this relation is economically and statistically significant only for long-maturity bonds. Later I argue that this strong negative relation for long-maturity bonds is largely the result of a coupon-induced bias.

There is no theoretical reason to believe that corporate bonds spreads from various business sectors should react the same way to changing Treasury yields. In fact, given that different sectors are affected by macroeconomic fluctuations in different ways, it would be surprising to find that bond spread behavior was identical across sectors. To test whether bonds spreads from my three business sectors (industrial, utilities, financial) behaved similarly, I jointly estimate equation (1) for each sector with Seemingly Unrelated Regressions (SUR). I estimate 12 different SURs, one for each combination of credit rating and maturity band. The $\chi^2(4)$ test of equality of $\sum_j b_{3m,j}$ and $\sum_j b_{sl,j}$ across the three sectors is reported in the final column of Table 2.

The χ^2 test rejects, at the 5% level, the hypothesis of constant coefficients across the business sectors only for short-maturity Aaa-rated bonds, and this rejection is likely spurious. As can be seen in Table 1, there are only 25 monthly observations available to jointly estimate the regressions for these yield spreads. Hence from the perspective of statistical significance, there is no compelling evidence that yield spreads for different business sectors react differently to Treasury yields. Perhaps more relevant is the economic significance of the results. In results that are available on request, I find that the estimated coefficients for industrials and utilities are very similar, while estimated level and slope coefficients for financials are somewhat larger than those for the other sectors. The average $\sum_j b_{3m,j}$ for financials is roughly 0.06 greater than the average $\sum_j b_{3m,j}$ for other firms, while the average $\sum_j b_{sl,j}$ for financials is roughly 0.09 greater than the corresponding average for other firms. Hence there is some weak evidence that yield spreads for financial firms behave somewhat differently than yield spreads for other firms. In the remainder of this paper, I ignore this possible difference and use only yield spreads constructed with all business sectors combined.

4.4. An analysis of tax-induced biases

Returns to holding corporate bonds are taxed at the Federal, state, and local levels, while returns to holding Treasury instruments are taxed at only the Federal level. As long as the marginal investor faces a positive state and local marginal tax rate, this tax wedge will affect the yield spread between corporate bonds and Treasury bonds. The wedge also affects the covariance between the yield spread and Treasury yields.

A careful adjustment of yields for tax effects is beyond the scope of this paper. Because taxes are paid on returns, not yields, a complete analysis requires embedding taxes in an equivalent martingale model of stochastic interest rates and default risk, such as those mentioned in Section 2. In this paper I take a simpler approach.

I assume that the taxable return on both Treasury and corporate bonds of a given maturity m equals the Treasury yield for that maturity, denoted $Y_{m,t}$. Essentially, this equates the Treasury yield with the realized return, which is obviously inaccurate. Note that I do not assume that the taxable return on corporate bonds equals the corporate yield—such an assumption ignores the fact that the corporate yield impounds the possibility of default.

In addition, I adopt a simple view of the tax system. I ignore any differences among tax rates on long-term capital gains, short-term capital gains, and ordinary income. I also ignore tax timing issues. I simply assume there is one Federal marginal tax rate and one state marginal tax rate denoted τ_s. Both tax rates are assumed to be nonstochastic. Corporate bonds are taxed at both the Federal and state level, while Treasury bonds are taxed only at the Federal level.

Given these assumptions, the 'after-tax' yield spread (denoted ATS) between corporate bonds and Treasuries is (supressing notational dependence on the business sector):

$$ATS_{i,m,t} = S_{i,m,t} - \tau_s Y_{m,t} \tag{2}$$

Calculations of after-tax spreads are very sensitive to assumptions about marginal state and local tax rates. For example, the mean Treasury yield corresponding to the maturity of the short-term Aaa-rated bonds in my dataset is 7.34% and the mean spread for short-term Aaa-rated bonds is 67 basis points. If the marginal investor has a 5% state and local tax rate, the mean after-tax spread on these bonds is 30 basis points. With a 7% tax rate, the mean after-tax spread is only 16 basis points.

Similarly, the responsiveness of after-tax spreads to changes in Treasury yields also depends on tax rate assumptions. To simplify the analysis of the bias in (1), assume that the change in the m-maturity Treasury yield $Y_{m,t}$ can be written as a linear combination of the change in three-month Treasury yield and the change in the slope between the thirty-year yield and the three-month yield:

$$\Delta Y_{m,t+1} = \alpha_{m,1}\Delta Y_{3m,t+1} + \alpha_{m,2}\Delta SL_{t+1} \tag{3}$$

Obviously $\alpha_{m,1} = 1$ and $\alpha_{m,2} = 0$ for the three-month yield, while $\alpha_{m,1} = 1$ and $\alpha_{m,2} = 1$ for the thirty-year yield. For maturities of three years or more, $\alpha_{m,1}$ ranges from 1.1 to 1.3 and $\alpha_{m,2}$ ranges from 0.8 to 1.0.[1]

Also assume that the relation between after-tax yield spreads and changes in pre-tax Treasury yields is linear:

$$\Delta ATS_{i,m,t+1} = \beta_0 + \beta_1\Delta Y_{3m,t+1} + \beta_2 SL_{t+1} \tag{4}$$

Substituting (2) and (3) into (4):

$$\Delta S_{i,m,t+1} = \beta_0 + (\beta_1 + \tau_s\alpha_{m,1})\Delta Y_{3m,t+1} + (\beta_2 + \tau_s\alpha_{m,2})SL_{t+1} \tag{5}$$

Equation (5) indicates that the sums $\sum_j b_{3m,j}$ and $\sum_j b_{sl,j}$ from equation (1) are upward-biased estimates of the effect of changes in Treasury yields on after-tax bond spreads. Because $\alpha_{m,1}$ and $\alpha_{m,2}$ are in the neighborhood of one for the maturities examined in this paper, the bias in both sums is roughly equal to τ_s. This bias can be large relative to $\sum_j b_{3m,j}$, especially for Aaa-rated bonds. Because of the potential importance of state taxes in the calculation of credit spreads, we need to have a good idea of the marginal state and local tax rate for the marginal holder of corporate bonds before we can evaluate the relation between after-tax spreads and Treasury yields.

Unfortunately for our purposes, it is difficult to identify the appropriate marginal state tax rate. Tax rates vary widely across states. In 1992, the highest marginal state and local tax rates on dividends, interest income and capital gains were as low as zero in a few states and as high as twelve percent in others (Commerce Clearing House 1992). Severn and Stewart (1992) make some heroic assumptions to argue that the marginal state tax rate is no greater than five percent, and likely in region of two to three percent. This is an area where further research is needed, but careful investigation of marginal state tax rates is beyond the scope of this paper.

[1] These figures are based on treating (3) as a regression equation and estimating it over my sample period using constant-maturity Treasury yields.

4.5. An analysis of coupon-induced biases

The building blocks in models of default-risky instruments are not spreads on coupon bonds, but spreads on zero-coupon bonds (or, equivalently, forward rate spreads). However, the yield spread on an m-maturity coupon bond over an m-maturity Treasury coupon bond will differ from the yield spread on an m-maturity zero-coupon bond over an m-maturity Treasury strip if either the default-free term structure or the term structure of zero-coupon bond credit spreads is not flat (Litterman and Iben 1991).

As Iwanowski and Chandra (1995) note, coupon bond yield spreads will also vary with Treasury yields even if zero-coupon bond yield spreads are unrelated to Treasury yields. For example, an increase in the level of the Treasury term structure will shorten the duration of coupon bonds. Because credit spreads are higher for longer-maturity instruments, this decrease in duration will correspond to a decline in observed corporate coupon bond yield spreads.

Here I investigate the empirical importance of this coupon-induced relation between Treasury yields and corporate bond yield spreads.[2] To preview the results, I find that changes in the level of Treasury yields have a negligible effect on yield spreads, but changes in the slope of the Treasury term structure can have a large effect on yield spreads of long-maturity instruments. This "slope bias" appears to explain much of the fact that, as documented in Table 2, yield spreads on long-maturity instruments are more sensitive to changes in the slope of the yield curve (holding the short end fixed) than are yield spreads on shorter-maturity instruments.

I explore this issue by assuming that at a given instant, both the implicit Treasury zero-coupon term structure and the zero-coupon yield spread curve for a particular firm or rating class are linear in maturity. I then examine the comparative statics of changing the level and slope of the Treasury zero-coupon term structure. Hence instead of considering changes in the slope and intercept of the Treasury term structure over the period of a month, which would require a stochastic model of the term structure, I simply consider instanta-

[2] In an earlier version of the paper I report results for zero-coupon bond yield spreads over Treasury strips. However, relatively few zero-coupon bonds have been issued by corporations (for example, no regressions could be estimated for Baa-rated bonds) and the yields on these bonds appear to be contaminated by substantial transitory noise. The results, which are available on request, are mixed. The change in the level of the term structure is negatively related to spreads (except for long-maturity Aaa bonds), but this relation is statistically insignificant for all but short-maturity Aa-rated and A-rated bonds. The change in the slope of the term structure is not statistically significant in any regression. The overall lack of significance may be a consequence of a lack of power owing to a lack of data. No regression is estimated over all observations, and for two regressions, over half of the observations are missing.

neous changes. Denote the continuously-compounded yield on a default-free zero-coupon bond with remaining maturity τ, measured in years, as $r(\tau)$. Denote the continuously-compounded yield on a zero-coupon bond issued by a particular firm with remaining maturity τ as $f(\tau)$, hence the yield spread, denoted s_τ, is given by $s(\tau) = f(\tau) - r(\tau)$. The two term structures are described by (6).

$$r(\tau) = a_r + b_r\tau, \qquad s(\tau) = a_s + b_s\tau \tag{6}$$

Consider a Treasury bond with coupon c_r ($c_r/2$ is paid every six months) and maturity m. This bond has a continuously-compounded yield $Y_{r,c_r,m}$, where the "r" subscript denotes a default-free bond. Some algebra reveals that the effects on $Y_{r,c_r,m}$ of changes in the level and slope of the zero-coupon term structure are given by:[3]

$$\frac{\partial Y_{r,c_r,m}}{\partial a_r} = \frac{c_r/2\sum_{i=1}^{2m} e^{-r(m-(i-1)/2)(m-(i-1)/2)}(m-(i-1)/2) + e^{-r(m)m}m}{c_r/2\sum_{i=1}^{2m} e^{-Y_{r,c_r,m}(m-(i-1)/2)}(m-(i-1)/2) + e^{-Y_{r,c_r,m}m}m} \tag{7}$$

$$\frac{\partial Y_{r,c_r,m}}{\partial b_r} = \frac{c_r/2\sum_{i=1}^{2m} e^{-r(m-(i-1)/2)(m-(i-1)/2)}(m-(i-1)/2)^2 + e^{-r(m)m}m^2}{c_r/2\sum_{i=1}^{2m} e^{-Y_{r,c_r,m}(m-(i-1)/2)}(m-(i-1)/2) + e^{-Y_{r,c_r,m}m}m} \tag{8}$$

Similarly, consider a corporate bond with coupon c_f, maturity m, and yield $Y_{f,c_f,m}$, where the "f" subscript denotes a bond issued by a firm. The partial derivatives of $Y_{f,c_f,m}$ with respect to the level and slope of the zero-coupon term structure (i.e., holding the term structure of zero-coupon credit spreads constant) are given by simple modifications of (7) and (8).[4] To save space I do not include the relevant expressions here.

We are interested in the effects of changes in the level and slope of the Treasury term structure on the coupon bond spread $Y_{f,c_f,m} - Y_{r,c_r,m}$. To facilitate comparisons between these effects and the regression equation (1), I define the "level bias" and "slope bias" as:

[3] These expressions assume that the first coupon payment is made in exactly six months.
[4] In (7) and (8), replace $Y_{r,c_r,m}$, c_r, and $r()$ with $Y_{f,c_f,m}$, c_f, and $r() + s()$ respectively.

$$\text{level bias} \equiv \frac{\partial\left(Y_{f,c_f,m} - Y_{r,c_r,m}\right)}{\partial a_r}\left\{\frac{\partial Y_{r,0,0.25}}{\partial a_r}\right\}^{-1} = \frac{\partial\left(Y_{f,c_f,m} - Y_{r,c_r,m}\right)}{\partial a_r} \tag{9}$$

$$\text{slope bias} \equiv \frac{\partial\left(Y_{f,c_f,m} - Y_{r,c_r,m}\right)}{\partial b_r}\left\{\frac{\partial\left(Y_{r,0.08,30} - Y_{r,0,0.25}\right)}{\partial b_r}\right\}^{-1} \tag{10}$$

The level bias is equivalent to the coupon-induced bias in $\sum_j b_{3m,j}$ in equation (1), while the slope bias is roughly equivalent to the bias in $\sum_j b_{sl,j}$. (The equivalence is only approximate because the 30-year bond yields in (9) and (10) are based on 8% coupons. The constant-maturity Treasury yield used in (1) is based on a coupon bond selling at par.)

These biases will depend on the levels and slopes of Treasury and corporate term structures. For this exercise, I assume that $r(\tau) = 0.07 + 0.001\tau$. This upward-sloping zero-coupon yield curve results in yields on 8% coupon bonds that roughly match the mean level and slope of the Treasury coupon bond term structure for maturities of three, ten and thirty years over my sample period. I assume that $s(\tau) = 0.012 + 0.0005\tau$, which results in yield spreads on 9.5% coupon bonds (over 8% Treasury bonds) that roughly match the mean yield spreads for Baa bonds in Panel D of Table 1.[5]

For this choice of parameters, the level bias is small. For Treasury bond coupons of 8% and corporate bond coupons of 9.5%, the bias is approximately -0.026 for 25-year bonds. For bonds with maturities less than 10 years, the bias is between 0 and -0.004. Intuitively, the level bias is small because bond durations are not very sensitive to changes in the default-free zero-coupon term structure and because the term structure of credit spreads is fairly flat.

By contrast, the slope bias is large, at least for long-maturity bonds. For 25-year bonds, it is -0.138. For shorter-maturity bonds, the slope bias disappears. For example, it is only -0.019 for ten-year bonds. Naturally, for smaller zero-coupon yield spreads, the bias is smaller. For example, if the zero-coupon yield spread is described by $s(\tau) = 0.006+0.0002\tau$, which roughly matches the yield spreads for Aaa-rated bonds in Panel D of Table 1, the bias for 25-year corporate bonds with coupons of 8.8% is -0.064.

[5] Iwanowski and Chandra (1995) estimate such linear spread relations for various business sectors over roughly the same time period. The mean, across business sectors, of their full-sample relations for BBB-rated firms is $s(\tau) = 0.0128 + 0.0003\tau$.

The intuition is straightforward. Future promised cash flows from corporate bonds are discounted more highly than are cash flows from Treasury bonds. In addition, corporate bonds typically have higher coupons than Treasury bonds. These differences imply that corporate bonds have shorter durations than equal-maturity Treasury bonds, and hence are relatively more sensitive to changes in short-maturity discount rates and less sensitive to changes in long-maturity discount rates. Then a change in the slope of the yield curve, holding (say) the short rate fixed, will have a larger effect on a Treasury bond yield than on a equivalent-maturity corporate bond, and therefore will affect the spread between these bonds.

On balance, four conclusions can be drawn from the results in Table 2, combined with the biases induced by taxes and coupons. First, corporate bond yield spreads move inversely with short Treasury yields. Second, the inverse relation is slightly stronger when spreads are computed on an after-tax basis. Third, the inverse relation is stronger for lower-quality bonds than for higher-quality bonds. For example, it is insignificant for Aaa-rated bonds, whereas for Baa-rated bonds, the point estimates imply that a 100 basis point decrease in the level of the Treasury curve corresponds to a 25 basis point increase in the level of yield spreads. Fourth, holding the short end of the Treasury yield curve fixed, changes in the slope of the curve are inversely related to yield spreads, but, after adjusting for a coupon-induced bias in long maturities, this inverse relation is weak.

5. Interpreting the link between yield spreads and interest rates

Why are default-free interest rates and yield spreads related? An obvious possibility is that they are both tied to the business cycle. Much research, such as Stock and Watson (1989), Chen (1991), Estrella and Hardouvelis (1991), and Estrella and Mishkin (1996) has linked the shape of the Treasury term structure to future variations in the business cycle, measured either by NBER dating or the growth rate of Gross Domestic Product (GDP). Earlier research also links measures of corporate default risk to the business cycle. Fons, Carty, and Kaufman (1994) find that future default rates on bonds rated by Moody's are positively correlated with forecasts of future GDP growth. Chen (1991) finds that aggregate corporate bond yield spreads are linked to stock returns, which in turn are linked to future GDP growth.[6]

Further evidence, specific to the 1985–1995 time period examined in this paper, is provided in Table 3. I regress quarterly log changes in real chain-weighted GDP on current

[6] A problem with Chen's analysis is that the aggregate measures of yield spreads do not exclude callable bonds. As shown in Section 6, the value of the call option will vary with the Treasury term structure. Hence even if default risk is unrelated to the business cycle, aggregate yield spreads will vary with the business cycle because Treasury yields vary with the business cycle.

and lagged quarterly changes in yield spreads, which I construct by summing the three monthly changes in yield spreads in the quarter. For each credit rating i and maturity band m, the quarterly change in yield spread during the three months of quarter t is denoted $\Delta S^q_{i,m,t}$. Table 3 reports the results of OLS estimation of (11):

$$\Delta 100 \log(GDP_{t+1}) = b_0 + \sum_{i=0}^{2} \Delta S^q_{i,m,t+1-i} + e_{i,m,t+1} \tag{11}$$

On balance, the results indicate that yield spreads of all maturities and credit ratings fall as economic growth increases. In all regressions, the sum of the coefficients on the current and lagged changes in yield spreads is negative. For six of the twelve regressions, this sum is significantly different from zero at the 5% level.[7] The mean sum of these coefficients across the 12 regressions is -2.13, implying that an increase in yield spreads of 50 basis points corresponds to a decline in the growth rate of GDP of 1.07 percentage points. There is no pattern apparent across maturities or credit ratings. For example, the link between GDP and yield spreads on Baa-rated bonds is not appreciably different from the link between GDP and yield spreads on Aaa-rated bonds.

However, the evidence in Table 2 linking yield spreads and Treasury yields is not completely consistent with a business cycle story. To examine these inconsistencies, we need to take a closer look at the relation between the term structure and the business cycle. The stylized facts are that low yields and a steeply sloped term structure both correspond to a future economic expansion. This paper uses first differences of yields and slopes, so we need to understand the relation between these first differences and economic growth. In some sense, this relation is the opposite of the stylized relation, although of course the relation involving first differences is inextricably linked with the relation involving levels. I summarize the empirical evidence here; more details are available on request.

Over 1985 to 1995, quarterly changes in the level of the three-month Treasury bill yield were strongly positively associated with contemporaneous changes in the quarterly growth rate of real, chain-weighted GDP and weakly positively associated with future changes in the growth rate of real GDP. Quarterly changes in the slope of the Treasury term structure were strongly negatively associated with contemporaneous changes in the contemporaneous real GDP growth rate, and weakly negatively associated with future changes in this growth rate.

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[7] The variance-covariance matrix of the estimated coefficients is adjusted for generalized heteroskedasticity and one lag of moving average residuals. Because test statistics are valid only asymptotically and these regressions have very few observations, these statistics should be interpreted cautiously.

These results are consistent with the stylized facts that low yields and a steep slope forecast future high economic growth. This additional evidence tells us that when the growth arrives, yields rise and the slope falls. Another way to think about these relations is that low yields (or a steep slope) forecast both future economic growth and future increases in yields (or future decreases in the slope).

The results in Table 2 tell us that yield spreads fall when Treasury bill yields rise. This can easily be explained with a business cycle story. When Treasury yields rise, the economy is expanding, so firms are better off, and default probabilities fall. However, Table 2 also tells us yield spreads also fall, albeit weakly, when the slope of the Treasury yield curve steepens. But when the slope of the yield curve steepens, the economy is contracting, so default probabilities should be rising. Hence the slope coefficients in Table 2 are inconsistent with a business cycle story.

In fact, the observed variation of yield spreads with Treasury yields may have little to do with default risk. If this variation were driven by variations in default risk, at least part of the explanatory power of the term structure should captured by stock returns. In other words, adding aggregate stock returns to the right hand side of (1) should reduce the explanatory power of the term structure. Changes in the level and slope of the Treasury term structure are noisy signals of changes in aggregate output, which in turn is a noisy signal of changes in firms' values (which affect the likelihood that firms will default). Aggregate stock returns are direct measures of changes in firms' aggregate equity values, therefore the marginal explanatory power of the term structure should be reduced or even eliminated when the stock returns are included in the regression.

Table 4 documents that this conclusion is not supported by the data. It reports estimates of (12), in which the log monthly return to the S&P 500 from the end of month $t-1$ to t is denoted RET_t:

$$\Delta S_{i,m,t+1} = b_0 + \sum_{j=-1}^{1} \left[b_{3m,j} \Delta Y_{3m,t+1-j} + b_{sl,j} \Delta SL_{t+1-j} + b_{ret,j} RET_{t+1-j} \right] + e_{i,m,t+1} \quad (12)$$

The results in Table 4 show that stock returns move inversely with yield spreads, just as expected. Also as expected, this relation is stronger for lower-rated bonds. Holding the term structure constant, the point estimates imply that a ten percent increase in the S&P 500 corresponds to a 20 basis point decrease in Baa-rated yield spreads (regardless of maturity). The same increase in stock prices corresponds to a 10 basis point decrease in A-rated yield spreads and smaller decreases in higher-rated yield spreads.

However, a comparison of the results in Table 4 with those in Table 2 reveals that the inclusion of stock returns had no important effect on the explanatory power of the level of the term structure. The point estimates of $\sum_j b_{3m,j}$ are little changed by the addition of stock returns as an explanatory variable. If anything, the estimates are further from zero with equation (12) than with equation (1). The inclusion of stock returns has a somewhat greater effect on the explanatory power of the slope of the term structure, but this effect is also in the unexpected direction. The slope coefficient sums in (12) are more negative in every case than corresponding sums in (1). As with (1), the statistical significance of these sums in (12) is, on balance, weak.

The results in Table 4 are troubling. If these variations in yield spreads are not driven by variations in default risk, then we cannot use the behavior of corporate bond yields to parameterize models of credit risk for the purposes of pricing other types of default-risky instruments. Table 4 is, however, not the final word on the subject. Equation (12) is almost certainly misspecified because it assumes a linear relation between stock returns and yield spreads. Any correlation between misspecification error and changes in Treasury yields will show up in the estimated coefficients of (12). Nonetheless, we should at least consider the possibility that the variation between yield spreads and Treasury yields is unrelated to default risk.

An alternative possibility, suggested by bond traders, is a supply and demand story. When bond yields (both Treasury and corporate) fall, firms respond by issuing more bonds, but the Treasury does not do likewise. The relative increase in the supply of corporate bonds lowers the price of corporate debt relative to Treasury debt, and hence widens the yield spread. Although I conjecture that the elasticity of demand for corporate bonds implied by the results in this paper is implausibly close to zero, the hypothesis is not tested here. Another possiblity is suggested by the work of Grinblatt (1995). He argues that yield spreads on short-term corporate instruments are more likely driven by the liquidity of Treasury instruments than the risk of default. It is not implausible to believe that the value of liquidity varies with the Treasury term structure. This hypothesis can presumably be tested with spreads on essentially default-free instruments such as government agency bonds, but I do not pursue this research here.

6. An analysis of alternatively-constructed yield spreads

6.1. Refreshed yield spreads

All corporate bond yield indexes of which I am aware are refreshed indexes, which hold credit ratings fixed over time. This includes the indexes produced by Moody's, Salomon Brothers', and Merrill Lynch. The empirical research that uses aggregate measures of corporate bond yields primarily relies on such indexes. For certain purposes, such as tracking yields on newly-issued bonds, the use of such indexes is appropriate. However, there is a clear potential problem using these indexes to investigate intertemporal changes in bonds' credit quality, because the indexes hold constant a measure of credit quality. Unfortunately, this problem is typically not even mentioned, much less addressed in this research. (Duffie and Singleton (1995) is an exception.)

Spreads of such yield indexes over Treasury yields are likely to underreact to a systematic shock to firms' credit qualities because part of the shock will be reflected in changes in credit ratings. At the extreme, if gradations in credit ratings were sufficiently fine, if rating agencies responded instantaneously to new information, and if rating agencies set ratings in the same way that the market set yield spreads, then yield spreads of refreshed indexes would be constant over time.

Of course, these extreme conditions are not satisfied, therefore the empirical relevance of this potential problem is unclear. I investigate this issue by estimating equation (1) with spreads, over Treasuries, of refreshed yield indexes. The relevant question is to what extent the results differ from the results in Table 2.

For each credit rating i, remaining maturity band m, and month-end t, I constructed mean yield spreads on noncallable corporate bonds.[8] For each credit rating and maturity band, I estimated equation (1) using first differences in the time series of yield spreads as the dependent variable. The results are displayed in Table 5.

The negative relation between changes in yield spreads and changes in the level of Treasury yields is weaker in Table 5 than in Table 2. The mean of the twelve point estimates of $\sum_j b_{3m,j}$ is -0.116 in Table 5, compared to -0.152 in Table 2. As in Table 2, the strength of this negative relation rises as credit quality falls. But in Table 2, this negative relation is statistically significant at the 5% level for one regression using Aaa-rated bonds and for all regressions using bonds rated Aa or below. By constrast, in Table 5, this relation is significant only for the regressions using Baa-rated bonds and one regression using A-rated bonds.

There are two conclusions to draw from this evidence. First, changes in yield spreads produced with refreshed indexes underreact to changes in credit quality. Hence the use of such spreads can lead to incorrect inferences. For example, if we had only the results in Table 5 to guide our analysis, we would conclude that for bonds rated A or above, it would be reasonable to treat yield spreads and Treasury yields as uncorrelated. But as Table 2 documents, this conclusion is false. Second, these results support the view that the variation of yield spreads with Treasury yields is related to variation in default risk. If this variation of yield spreads were unrelated to default risk, then would not be altered by a procedure that held credit quality constant over time.

[8] Details are in the appendix.

6.2. Callable bond spreads

Most commonly available yield indexes use both callable and noncallable bonds. Consider, for example, the composition of Moody's Industrial Indexes as of May 1989. In this month there were nine bonds included in the Aaa Index. All were callable, although two of the nine had not yet reached their date of first call. Eleven of the twelve bonds in May 1989's Aa Index were callable; ten of the eleven were currently callable. Essentially, the composition of Moody's Indexes reflected the composition of the universe of corporate bonds. As mentioned earlier, firms have historically issued many more callable bonds than noncallable bonds.

Longstaff and Schwartz (1995) regressed changes in bond yield spreads constructed with Moody's Indexes on changes in Treasury yields. They found much more negative regression coefficients than those reported in Table 2. Part of the difference between their results and those here are a consequence of the differences in the sample period and the form of the regression. Nonetheless, a qualitative difference between Moody's Indexes and my series remains after adjusting for these effects. For example, when equation (1) is estimated for Moody's Aaa Industrials Index over my sample period, the estimates of $\sum_j b_{3m,j}$ and $\sum_j b_{sl,j}$ are -0.224 and -0.283 respectively, which are roughly 2.5 times the corresponding estimates for Aaa-rated bonds in Table 2.[9]

The callability of the bonds is an obvious possible explanation for the large sensitivities of the Moody's spreads. When yields on (noncallable) Treasuries fall, yields on seasoned callable bonds do not fall as much because the value of the embedded call option rises. Therefore the spread between callable bond yields and noncallable Treasury yields will move inversely with noncallable Treasury yields.

To test whether the callability of the bonds in the Moody's Indexes accounts for these differences, I investigate the following two questions. First, are callable corporate bond spreads more sensitive to movements in Treasury yields than are noncallable corporate bond spreads? Second, does the sensitivity of callable bond spreads depend on how close the bond price is to the call price? For this investigation, I restrict my attention to long-term Aa bonds.

I construct callable long-term Aa bond spreads in the same way that I earlier created spreads on noncallable bonds. For each month t, I form six groups of callable long-term Aa bonds, distinguished by their month t prices and their current call status. One approach would be to divide bonds into those that are currently callable and those that are currently call protected. Instead, in order to allow comparison of my results with those of Fons

[9] For this regression, I created a yield spread by subtracting the 30-year constant maturity Treasury yield from the Moody's Aaa Industrials yield. The results are not sensitive to the precise calculation of the spread.

(1994), I distinguish between bonds that are currently callable and bonds that will remain call protected for at least another year. I drop bonds that are currently call protected but will be callable within a year. I further divide each of these two groups using three price categories: Below 90, between 90 and 100, and greater than 100 (par equals 100).[10]

I estimate equation (1) for each time series of spread changes. The results are displayed in Table 6. Two important conclusions can be drawn from a comparison of the results in this table with those in Table 2. First, the sensitivity of a callable bond's spread to changes in Treasury yields is positively related to the bond's price, as option pricing theory implies. Yield spreads on callable bonds with low prices (less than 90) behave similarly to spreads on noncallable bonds. For both noncallable bonds and currently callable, low-priced bonds, the point estimate of $\sum_j b_{3m,j}$ is -0.17, the point estimate of $\sum_j b_{sl,j}$ is insignificantly different from zero, and the adjusted R^2 is between 0.22 and 0.25.

By contrast, yield spreads on high-priced callable bonds exhibit very strong inverse relationships with changes in Treasury yields. For high-priced (prices above par) currently-callable bonds, the point estimate of $\sum_j b_{3m,j}$ is -0.56. The point estimate of $\sum_j b_{sl,j}$ is almost identical, implying that the relation between yield spreads on these long-term callable bonds and Treasury term structure can be collapsed into a relation between the yield spreads and the long-term Treasury yield. This is not surprising; the call option value of a corporate bond should depend on the Treasury yield of an equivalent-maturity Treasury bond. The adjusted R^2 of this regression is 0.80. Yield spreads on medium-priced bonds fall between high-priced bonds and low-priced bonds in their responsiveness to Treasury yields.

Second, yield spreads constructed with callable, but currently call protected, bonds behave similarly to yield spreads constructed with currently callable bonds. For each price band, the estimated sums $\sum_j b_{3m,j}$ and $\sum_j b_{sl,j}$ for currently callable bonds are slightly more negative than the corresponding sums for currently call-protected bonds. This conclusion suggests that, for certain purposes, it is inappropriate to use yields on temporarily call-protected bonds as proxies for yields on noncallable bonds.

Further evidence that callable bond yield spreads are fundamentally different from noncallable bond yield spreads is illustrated in Fig. 1. In this figure I focus on long-maturity A-rated bonds, which is the only category of long-maturity bonds for which I have no missing observations for noncallable bond yield spreads. Panel A of the figure displays the 30-year constant maturity Treasury yield. Panel B displays both the yield spread I constructed for noncallable long-maturity A-rated bonds and the spread between Moody's

[10] It would be more appropriate to sort bonds by the differences between their current bond prices and their call prices. However, the dataset does not report a call price for callable bonds that are in their call-protection period. Therefore I have no call prices for callable bonds that reach their first call date after March 1995.

Industrial A-rated Bond Yield Averages and the 30-year constant maturity Treasury yield.

There are three interesting features displayed in Panel B. First, the sharp decline in Treasury yields during 1985 and 1986 was matched by a dramatic jump in the Moody's yield spread, while the increase in the spread for noncallable bonds was much smaller. Second, during 1991, the spread on the noncallable bonds jumped, then quickly fell; the Moody's spread rose only slightly. This reflects the inclusion of bonds issued by financial firms in my series of noncallable yield spreads. Third, by the end of the sample, the Moody's spread and the noncallable bond spread tracked closely, even while Treasury yields fell, then rose sharply.

This recent pattern is likely the result of a secular change in the composition of Moody's Bond Indexes. Over time, firms shifted their debt issuance away from callable instruments, and the Moody's Indexes shifted as well. By October 1994, 12 of the 16 bonds included in Moody's A-rated Industrial Bond Index were noncallable. Moreover, three of the four callable bonds included in the Index had prices below 90 in October 1994 (the other barely exceeded 90). Hence these callable bonds act more like noncallable bonds in their responsiveness to Treasury yields.

Spreads on currently callable A-rated bonds are displayed in Panel C, while Panel D displays spreads on callable A-rated bonds that are call-protected for at least a year. In both panels it is clear that the call option affects yield spreads because spreads on high-priced bonds (i.e., those closer to their call price) are higher than spreads on low-priced bonds. This suggests that attempts to measure default risk using yield spreads on callable bonds, even if they are not currently callable, is problematic.

Moreover, the displayed difference between high-priced bond spreads and low-priced spreads likely understates the true difference owing to imprecision in credit ratings. Sorting bonds by price tends to also sort bonds by credit quality, leading to an inverse relation between bond prices and yield spreads. To illustrate this bias, consider two bonds with identical features, issued by two different firms. The bonds have the same credit rating, but the market may view the two firms as having somewhat different credit qualities. The bond issued by the firm with higher perceived credit quality will have a higher price, and a lower yield spread, than the other bond.

A curious feature of Fig. 1 that is not explored in this paper is why spreads on high-priced call-protected bonds did not jump in 1993 as Treasury yields fell. Spreads on high-priced, currently callable bonds jumped when Treasury yields fell during 1986–1987 and during 1993, while spreads on high-priced, call-protected bonds jumped only during the earlier period. Exploring this issue is left for future work.

7. Concluding Remarks

Yield spreads on investment grade noncallable bonds fall when the level of the Treasury term structure rises. The extent of this decline depends on the initial credit quality of the bond; for example, the decline is small for Aaa-rated bonds and large for Baa-rated bonds.

Applying the same empirical analysis to changes in yield spreads based on refreshed indexes of noncallable bond yields produces much weaker results. The use of such indexes holds one measure of credit quality (credit ratings) constant over time, thus attenuating the responsiveness of yield spreads to other variables correlated with credit quality. In other words, the use of refreshed yield indexes to measure changes in credit quality over time will systematically underestimate such changes and, at least for the questions examined in this paper, result in incorrect inferences.

By contrast, there is a very strong negative relation between Treasury yields and yield spreads based on Moody's yield indexes. Moody's indexes, like many other indexes, have historically been constructed primarily with callable bonds. Such yield indexes are sensitive to variations in the values of the bonds' call options, which in turn are sensitive to the level of interest rates. This sensitivity is the source of the strong negative relation: When Treasury yields rise, the value of the option to call a bond falls, lowering the yield on the callable corporate bond, and therefore lowering the yield spread. Hence variations in yield spreads based on such indexes should not be viewed as driven primarily by variations in credit quality.

Both Treasury yields and corporate bond spreads are linked to future variations in aggregate output. However, it is not obvious that this joint link is responsible for the relation between Treasury yields and yield spreads observed in this paper. In fact, preliminary evidence casts some doubt on the notion that this relation is driven by variations in credit quality. This issue, as well as many others identified here, await future research.

Appendix

Mean yields, yield spreads, and monthly differenced yield spreads are constructed for a number of sets of corporate bonds. There are four business sectors examined: (1) industrial firms; (2) utilities; (3) financial firms; (4) all of the above. There are also four rating categories examined: Aaa, Aa, A, and Baa. Three ranges of remaining maturity are considered: (1) Short (two to seven years); (2) medium (seven to fifteen years); (3) long (fifteen to thirty years). The time series of corporate bond yields, spreads, and changes in spreads are constructed as follows.

Fix a business sector, a rating category, and a maturity range. For each month t in

[January 1985, February 1995], I consider all straight bonds (e.g., not convertible or CMO-like) in the given business sector that have, in month t, the appropriate rating and time-to-maturity. I also require that coupon payments (if any) be made semiannually, instead of, say, monthly. (This latter restriction excludes very few bonds.) I use the Moody's rating if it is available, otherwise I use S&P's rating. I then exclude all bonds that are callable or putable at some point in the bond's life, or that have a sinking fund option. I further exclude all bonds that do not have "quote" prices (instead of "matrix" prices) in both months t and $t+1$. I also exclude bonds that are, in either month t or $t+1$, not in a Lehman Brothers index or are about to leave a Lehman Brothers index. Such bonds tend to have more data errors than other bonds in the Database. To eliminate some obvious errors in the data, I also exclude bonds that have a reported coupon greater than 25%, a price less than 1/100 of par or a price greater than twice par.

The result is a set of N_t bonds with corresponding month-end t yields. (Note that there will be a different set of N_t bonds for each combination of business sector, rating category, and maturity range.) These yields are quoted on a bond-equivalent basis, not as continually compounded yields. The mean of these yields is my measure of the month t yield for this sector/rating/maturity. I construct yield spreads for each bond by subtracting an appropriate Treasury yield. The Treasury Department constructs constant maturity yields by interpolating bond-equivalent yields on actively-traded Treasury notes and bonds. I use their reported month-end yields on 2, 3, 5, 7, 10, and 30 year coupon bonds. For each corporate bond i, I construct the appropriate Treasury yield by interpolating between the closest constant maturity yields on either side of bond i's remaining time-to-maturity. The month t spread for this business sector, rating, and maturity is the mean (over the N_t bonds) of the individual bond spreads. If $N_t = 0$, the observation is set to a missing value.

These N_t bonds also have month-end $t+1$ yields. I construct month-end $t+1$ spreads for these bonds in the manner described above. I then calculate, for each bond i, the change in the spread from t to $t+1$. Finally, I calculate the mean (over the N_t bonds) change in the spread from t to $t+1$. This mean is my observation of $\Delta S_{s,i,m,t+1}$ for the given business sector s, rating i, and maturity range m. Again, if $N_t = 0$, this observation is set to a missing value.

When constructing "refreshed" indexes of bond spreads, I alter the above procedure in two ways. First, when constructing the set of N_t bonds for month t, I ignore any month $t+1$ information. For example, a bond can be included in the set of bonds for month t even if it has no quote price for month $t+1$. Second, the monthly change in the spread is defined as the difference between the mean spread on the N_{t+1} bonds in month $t+1$ and the mean spread on the N_t bonds in month t. Hence the measure of the change in the spread is simply the first difference of the time series of spreads.

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Table 1. Summary statistics for corporate bonds in Lehman Brothers dataset that have no option-like features, January 1985 to February 1995.

For a given group of bonds (defined by sector, month t maturity, and month t rating), S_t is defined as the mean yield spread in month t (over the appropriate Treasury instrument) on all noncallable, nonputable bonds with no sinking fund option that have yields based on quote prices in both months t and $t+1$. ΔS_{t+1} is the mean change in the spreads on these bonds from month t to $t+1$. If there are no such bonds in month t, S_t and ΔS_{t+1} are set to missing values.

Panel A. Industrial sector

Maturity[a]	Rating	Num. of Monthly Obser.	Mean Num. of Bonds per Monthly Obs.	Mean Years to Mat.	$\overline{S_t}$	Std. Dev. of ΔS_{t+1}	$AR(1)$ coef. for ΔS_{t+1}
Long	Aaa	62	2.3	28.4	0.59	0.042	0.112
	Aa	101	7.5	20.8	0.87	0.095	−0.002
	A	122	33.7	22.1	1.17	0.141	0.195
	Baa	105	21.5	21.0	1.98	0.192	0.007
Medium	Aaa	40	3.9	10.4	0.47	0.048	0.128
	Aa	116	11.8	9.5	0.69	0.097	−0.016
	A	122	50.6	9.6	0.96	0.108	−0.117
	Baa	122	29.6	8.9	1.48	0.161	0.110
Short	Aaa	107	6.0	3.4	0.46	0.095	−0.265
	Aa	122	15.1	4.0	0.56	0.083	−0.068
	A	122	58.4	4.5	0.87	0.108	0.085
	Baa	122	33.7	4.7	1.49	0.222	0.064

Panel B. Utility sector

Maturity[a]	Rating	Num. of Monthly Obser.	Mean Num. of Bonds per Monthly Obs.	Mean Years to Mat.	$\overline{S_t}$	Std. Dev. of ΔS_{t+1}	$AR(1)$ coef. for ΔS_{t+1}
Long	Aaa	38	2.7	26.1	0.59	0.047	0.124
	Aa	91	1.0	27.4	0.80	0.085	−0.008
	A	98	4.1	20.9	1.01	0.110	0.134
	Baa	66	4.8	23.9	1.73	0.142	0.205
Medium	Aaa	38	5.6	9.8	0.39	0.033	−0.194
	Aa	98	11.5	9.2	0.58	0.086	−0.329
	A	120	17.9	9.1	0.79	0.096	0.006
	Baa	119	20.1	9.7	1.32	0.170	−0.017
Short	Aaa	25	2.0	6.1	0.34	0.026	−0.221
	Aa	90	10.4	4.5	0.54	0.076	−0.246
	A	122	15.8	4.4	0.78	0.091	−0.007
	Baa	122	21.6	4.3	1.15	0.145	0.011

Table 1. (continued)

Panel C. Finance sector

Maturity[a]	Rating	Num. of Monthly Obser.	Mean Num. of Bonds per Monthly Obs.	Mean Years to Mat.	$\overline{S_t}$	Std. Dev. of ΔS_{t+1}	$AR(1)$ coef. for ΔS_{t+1}
Long	Aaa	77	10.4	19.1	0.89	0.107	0.077
	Aa	96	2.0	19.1	1.06	0.089	−0.028
	A	118	7.7	20.0	1.30	0.131	−0.033
	Baa	75	2.7	19.8	1.49	0.184	−0.157
Medium	Aaa	115	7.2	11.0	0.81	0.106	0.052
	Aa	122	8.0	9.0	0.79	0.094	0.104
	A	122	39.5	9.2	1.14	0.152	0.164
	Baa	120	17.0	8.8	1.56	0.223	0.167
Short	Aaa	122	11.1	3.6	0.83	0.092	−0.079
	Aa	122	36.4	3.9	0.75	0.088	0.241
	A	122	96.5	4.0	0.99	0.120	0.226
	Baa	122	29.7	4.3	1.50	0.243	0.348

Panel D. Combined sectors

Maturity[a]	Rating	Num. of Monthly Obser.	Mean Num. of Bonds per Monthly Obs.	Mean Years to Mat.	$\overline{S_t}$	Std. Dev. of ΔS_{t+1}	$AR(1)$ coef. for ΔS_{t+1}
Long	Aaa	105	10.0	23.9	0.79	0.088	0.115
	Aa	103	10.1	21.3	0.91	0.087	−0.005
	A	122	44.4	21.7	1.18	0.125	0.150
	Baa	109	25.5	21.2	1.84	0.177	0.033
Medium	Aaa	115	10.4	10.1	0.77	0.102	0.046
	Aa	122	28.4	9.2	0.71	0.084	0.088
	A	122	107.6	9.4	1.01	0.106	0.149
	Baa	122	65.9	9.1	1.47	0.153	0.170
Short	Aaa	122	16.7	3.8	0.67	0.083	−0.127
	Aa	122	59.1	4.0	0.69	0.083	0.191
	A	122	170.7	4.2	0.93	0.107	0.183
	Baa	122	84.9	4.4	1.42	0.184	0.236

[a] 'Long' maturity bonds are between 15 and 30 years to maturity, 'medium' maturity bonds are between 7 and 15 years to maturity, and 'short' maturity bonds are between 2 and 7 years to maturity.

Table 2. Regressions of changes in corporate bond yield spreads on changes in Treasury yields.

Noncallable bonds issued by industrial, utility, and financial firms are grouped by their month-t credit rating i and remaining maturity m. For each group, mean changes in month-end yield spreads over Treasury yields from t to $t+1$ are denoted $\Delta S_{i,m,t+1}$. The change in the three-month Treasury bill yield is denoted $\Delta Y_{3m,t+1}$ and the change in the spread between the 30-year constant maturity Treasury yield and the three-month bill yield is denoted ΔSL_{t+1}.

$$\Delta S_{i,m,t+1} = b_0 + \sum_{j=-1}^{1} b_{3m,j} \Delta Y_{3m,t+1-j} + \sum_{j=-1}^{1} b_{sl,j} \Delta SL_{t+1-j} + e_{i,m,t+1}$$

Estimation is with OLS. The data range is January 1985 through March 1995. The variance-covariance matrix of the estimated coefficients is adjusted for generalized heteroskedasticity and two lags of moving average residuals. T-statistics are in parentheses. P-values of χ^2 tests are in brackets.

Maturity[a]	Rating	Obs.	$b_{3m,-1}$	$b_{3m,0}$	$b_{3m,1}$	$b_{sl,-1}$	$b_{sl,0}$	$b_{sl,1}$	$\sum b_{3m,j}$	$\sum b_{sl,j}$	Adj. R^2	$\chi^2(4)$ test of equality of coefs across sectors[b]
Long	Aaa	105	0.034	−0.035	−0.078	0.048	−0.048	−0.113	−0.080	−0.114	0.135	4.73
			(1.09)	(1.11)	(2.34)	(1.37)	(1.56)	(3.16)	[.167]	[.070]		[.317]
Long	Aa	103	−0.020	−0.168	0.021	0.003	−0.119	−0.005	−0.167	−0.121	0.221	4.25
			(0.56)	(5.35)	(0.53)	(0.11)	(2.03)	(0.15)	[.012]	[.064]		[.373]
Long	A	122	−0.051	−0.235	0.053	−0.004	−0.217	−0.005	−0.232	−0.226	0.336	5.91
			(1.03)	(5.20)	(1.38)	(1.15)	(0.44)	(1.40)	[.006]	[.017]		[.206]
Long	Baa	109	−0.050	−0.416	0.104	0.042	−0.317	−0.002	−0.362	−0.278	0.397	3.20
			(0.68)	(6.72)	(1.88)	(0.81)	(5.35)	(0.04)	[.000]	[.004]		[.526]
Medium	Aaa	115	0.005	−0.009	−0.056	0.031	−0.001	−0.059	−0.061	−0.028	−0.010	0.91
			(0.17)	(0.24)	(1.19)	(1.02)	(0.02)	(1.34)	[.237]	[.649]		[.924]
Medium	Aa	122	0.000	−0.157	0.043	0.015	−0.102	0.019	−0.114	−0.068	0.230	7.59
			(0.00)	(5.25)	(1.66)	(0.52)	(2.84)	(0.72)	[.016]	[.214]		[.108]
Medium	A	122	−0.037	−0.178	0.092	0.009	−0.118	0.087	−0.124	−0.022	0.242	3.94
			(1.39)	(6.00)	(3.74)	(0.29)	(3.73)	(3.01)	[.005]	[.667]		[.415]
Medium	Baa	122	−0.018	−0.251	0.090	0.035	−0.147	0.040	−0.179	−0.071	0.183	9.02
			(0.44)	(5.22)	(2.16)	(0.87)	(3.12)	(0.70)	[.006]	[.341]		[.061]

Table 2. (continued)

Maturity[a]	Rating	Obs.	$b_{3m,-1}$	$b_{3m,0}$	$b_{3m,1}$	$b_{sl,-1}$	$b_{sl,0}$	$b_{sl,1}$	$\sum b_{3m,i}$	$\sum b_{sl,i}$	Adj. R^2	$\chi^2(4)$ test of equality of coefs across sectors[b]
Short	Aaa	122	0.004	−0.104	0.015	0.031	−0.035	0.006	−0.085	0.001	0.088	30.94
			(0.21)	(2.15)	(0.43)	(1.57)	(1.01)	(0.14)	[.043]	[.975]		[.000]
Short	Aa	122	−0.025	−0.140	0.068	−0.010	−0.033	0.052	−0.098	0.009	0.212	6.41
			(1.05)	(5.43)	(2.40)	(0.40)	(1.47)	(1.96)	[.007]	[.816]		[.171]
Short	A	122	−0.001	−0.190	0.089	−0.016	−0.060	0.074	−0.101	−0.003	0.206	7.13
			(0.03)	(6.20)	(3.28)	(0.54)	(2.36)	(2.24)	[.018]	[.944]		[.129]
Short	Baa	122	−0.034	−0.280	0.088	−0.051	−0.091	0.112	−0.226	−0.030	0.141	4.33
			(0.91)	(6.84)	(2.12)	(1.11)	(2.44)	(1.80)	[.000]	[.714]		[.363]

[a] 'Long' maturity bonds are between 15 and 30 years to maturity, 'medium' maturity bonds are between 7 and 15 years to maturity, and 'short' maturity bonds are between 2 and 7 years to maturity.

[b] The $\chi^2(4)$ tests of equality of the sums of coefficients across industrial, utility, and financial bonds are based on Seemingly Unrelated Regression (SUR) estimation.

Table 3. Regressions of changes in GDP on current and lagged changes in corporate bond yield spreads

Noncallable bonds are sorted by their month-t credit rating and remaining maturity. For each group, mean monthly changes in month-end yield spreads over Treasury yields are constructed, then quarterly changes are constructed by summing the three monthly changes in the quarter. Spreads are expressed in percent per year.

The percent change ($100 \times \log$ change) in real U.S. Gross Domestic Product from quarter t to quarter $t+1$ is regressed on lags 0, 1, and 2 of changes in yield spreads. Each regression is estimated over 1985:Q4 through 1995:Q1, although some observations are missing. Each variance-covariance matrix is adjusted for one lag of moving average residuals. T-statistics are in parentheses. P-values of $\chi^2(1)$ tests that the sum of the three coefficients equals zero are in brackets.

Maturity[a]	Credit Rating	Obs.	Change in spread: Current	First lag	Second lag	Coef. Sum	Adj. R^2
Long	Aaa	29	−0.699	0.085	−0.688	−1.302	−0.050
			(1.86)	(0.29)	(1.47)	[.086]	
Long	Aa	30	−2.115	−1.776	−1.070	−4.961	0.214
			(2.48)	(1.75)	(1.38)	[.005]	
Long	A	38	0.061	−0.569	−0.179	−0.687	0.000
			(0.13)	(2.00)	(0.99)	[.282]	
Long	Baa	34	−0.488	−0.658	−0.373	−1.518	0.089
			(1.20)	(1.71)	(1.38)	[.042]	
Medium	Aaa	30	−0.659	−0.448	−1.653	−2.760	0.115
			(1.22)	(1.30)	(3.10)	[.000]	
Medium	Aa	38	0.131	−0.573	−0.278	−0.720	−0.052
			(0.16)	(1.00)	(0.63)	[.434]	
Medium	A	38	−0.294	−0.456	−0.198	−0.948	−0.026
			(0.56)	(1.04)	(0.77)	[.110]	
Medium	Baa	38	−0.270	−0.591	−0.434	−1.295	0.084
			(0.59)	(1.49)	(1.53)	[.132]	
Short	Aaa	38	−1.121	−1.591	−1.155	−3.867	0.120
			(1.15)	(1.60)	(2.03)	[.044]	
Short	Aa	38	−0.797	−1.603	−0.550	−2.949	0.083
			(0.78)	(1.77)	(0.90)	[.160]	
Short	A	38	−0.766	−1.306	−0.760	−2.832	0.199
			(1.23)	(2.80)	(1.89)	[.020]	
Short	Baa	38	−0.538	−0.675	−0.477	−1.689	0.282
			(1.81)	(2.57)	(1.71)	[.005]	

[a] ‘Long’ maturity bonds are between 15 and 30 years to maturity, ‘medium’ maturity bonds are between 7 and 15 years to maturity, and ‘short’ maturity bonds are between 2 and 7 years to maturity.

Table 4. Regressions of changes in corporate bond yield spreads on changes in Treasury yields and stock returns

Noncallable bonds are sorted by their month-t credit rating and remaining maturity. For each group, mean changes in month-end yield spreads over Treasury yields from t to $t+1$ are regressed on the change in the three-month Treasury bill yield, denoted $\Delta Y_{3m,t}$, the change in the spread between the 30-year constant maturity Treasury yield and the three-month bill yield, denoted ΔSL_t, and the log return to the S&P 500 index, denoted RET_t. A lead and lag of all explanatory variables are included. The data range is January 1985 through March 1995.

The table reports the sums of the coefficients on the leading, contemporaneous, and lagged explanatory variables. P-values of $\chi^2(1)$ tests that the sum equals zero are in brackets. The variance-covariance matrix of the estimated coefficients is adjusted for generalized heteroskedasticity and two lags of moving average residuals.

			Sum of coefs on:			
Maturity[a]	Rating	Obs.	$\Delta Y_{3m,t}$	ΔSL_t	RET_t	Adj. R^2
Long	Aaa	105	−0.084	−0.129	−0.140	0.117
			[.153]	[.053]	[.663]	
Long	Aa	103	−0.176	−0.139	−0.147	0.200
			[.008]	[.053]	[.730]	
Long	A	122	−0.265	−0.307	−0.958	0.370
			[.002]	[.002]	[.020]	
Long	Baa	109	−0.428	−0.452	−2.196	0.501
			[.000]	[.000]	[.000]	
Medium	Aaa	115	−0.069	−0.065	−0.683	−0.011
			[.197]	[.346]	[.190]	
Medium	Aa	122	−0.131	−0.121	−0.632	0.300
			[.006]	[.042]	[.012]	
Medium	A	122	−0.147	−0.085	−0.910	0.264
			[.001]	[.154]	[.016]	
Medium	Baa	122	−0.208	−0.198	−2.106	0.333
			[.004]	[.026]	[.005]	
Short	Aaa	122	−0.098	−0.043	−0.631	0.118
			[.019]	[.313]	[.006]	
Short	Aa	122	−0.119	−0.071	−1.311	0.387
			[.008]	[.127]	[.000]	
Short	A	122	−0.115	−0.068	−1.195	0.286
			[.008]	[.223]	[.007]	
Short	Baa	122	−0.242	−0.127	−1.980	0.210
			[.000]	[.231]	[.054]	

[a] 'Long' maturity bonds are between 15 and 30 years to maturity, 'medium' maturity bonds are between 7 and 15 years to maturity, and 'short' maturity bonds are between 2 and 7 years to maturity.

Table 5. Regressions of changes in "refreshed" corporate bond yield spreads on changes in Treasury yields

Noncallable bonds are sorted by their month-t credit rating and remaining maturity to create time series of yield spreads. First differences in these spreads are regressed on differenced three-month Treasury bill yields ($\Delta Y_{3m,t}$) and the differenced spread between the 30-year constant maturity Treasury yield and the three-month bill yield (ΔSL_t). A lead and lag of both explanatory variables are included. The data range is January 1985 through March 1995.

The table reports the sums of the coefficients on the leading, contemporaneous, and lagged explanatory variables. P-values of $\chi^2(1)$ tests that the sum equals zero are in brackets. The variance-covariance matrix of the estimated coefficients is adjusted for generalized heteroskedasticity and two lags of moving average residuals.

			Sum of coefs on:		
Maturity[a]	Rating	Obs.	$\Delta Y_{3m,t}$	ΔSL_t	Adj. R^2
Long	Aaa	105	−0.083	−0.113	0.127
			[.149]	[.066]	
Long	Aa	102	−0.071	−0.063	0.208
			[.077]	[.093]	
Long	A	122	−0.166	−0.149	0.326
			[.000]	[.004]	
Long	Baa	109	−0.355	−0.297	0.296
			[.000]	[.005]	
Medium	Aaa	113	−0.049	−0.032	−0.017
			[.303]	[.576]	
Medium	Aa	122	−0.030	0.010	0.140
			[.473]	[.818]	
Medium	A	122	−0.073	−0.010	0.221
			[.082]	[.850]	
Medium	Baa	122	−0.183	−0.159	0.101
			[.039]	[.159]	
Short	Aaa	122	−0.045	−0.008	0.054
			[.244]	[.809]	
Short	Aa	122	−0.070	0.013	0.148
			[.069]	[.752]	
Short	A	122	−0.089	−0.002	0.196
			[.040]	[.962]	
Short	Baa	122	−0.178	−0.051	0.099
			[.006]	[.589]	

[a] 'Long' maturity bonds are between 15 and 30 years to maturity, 'medium' maturity bonds are between 7 and 15 years to maturity, and 'short' maturity bonds are between 2 and 7 years to maturity.

Table 6. Regressions of changes in long-term Aa-rated callable corporate bond yield spreads on changes in Treasury yields.

Long-term, Aa-rated callable bonds are sorted by their month-t call status (currently callable or call protected for at least another year) and month-t price. Mean monthly changes in their yield spreads from t to $t+1$ (over Treasuries) are regressed on the change in the three-month Treasury bill yield, denoted $\Delta Y_{3m,t+1}$, and the change in the spread between the 30-year constant maturity Treasury yield and the three-month bill yield, denoted ΔSL_{t+1}. A lead and lag of both explanatory variables are included. The data range is January 1985 through March 1995.

The table reports the sums of the coefficients on the leading, contemporaneous, and lagged explanatory variables. P-values of $\chi^2(1)$ tests that the sum equals zero are in brackets. The variance-covariance matrix of the estimated coefficients is adjusted for generalized heteroskedasticity and two lags of moving average residuals.

Bond type	Bond price (100=par)	Obs.	Sum of coefs on: $\Delta Y_{3m,t}$	ΔSL_t	Adj. R^2
Currently callable	$100 < p_t$	109	−0.562 [.000]	−0.527 [.000]	0.797
	$90 < p_t < 100$	119	−0.263 [.001]	−0.236 [.001]	0.325
	$p_t < 90$	114	−0.166 [.002]	−0.048 [.311]	0.248
Not yet callable	$100 < p_t$	122	−0.471 [.000]	−0.421 [.000]	0.788
	$90 < p_t < 100$	118	−0.192 [.004]	−0.224 [.002]	0.460
	$p_t < 90$	69	−0.072 [.083]	−0.042 [.256]	0.210

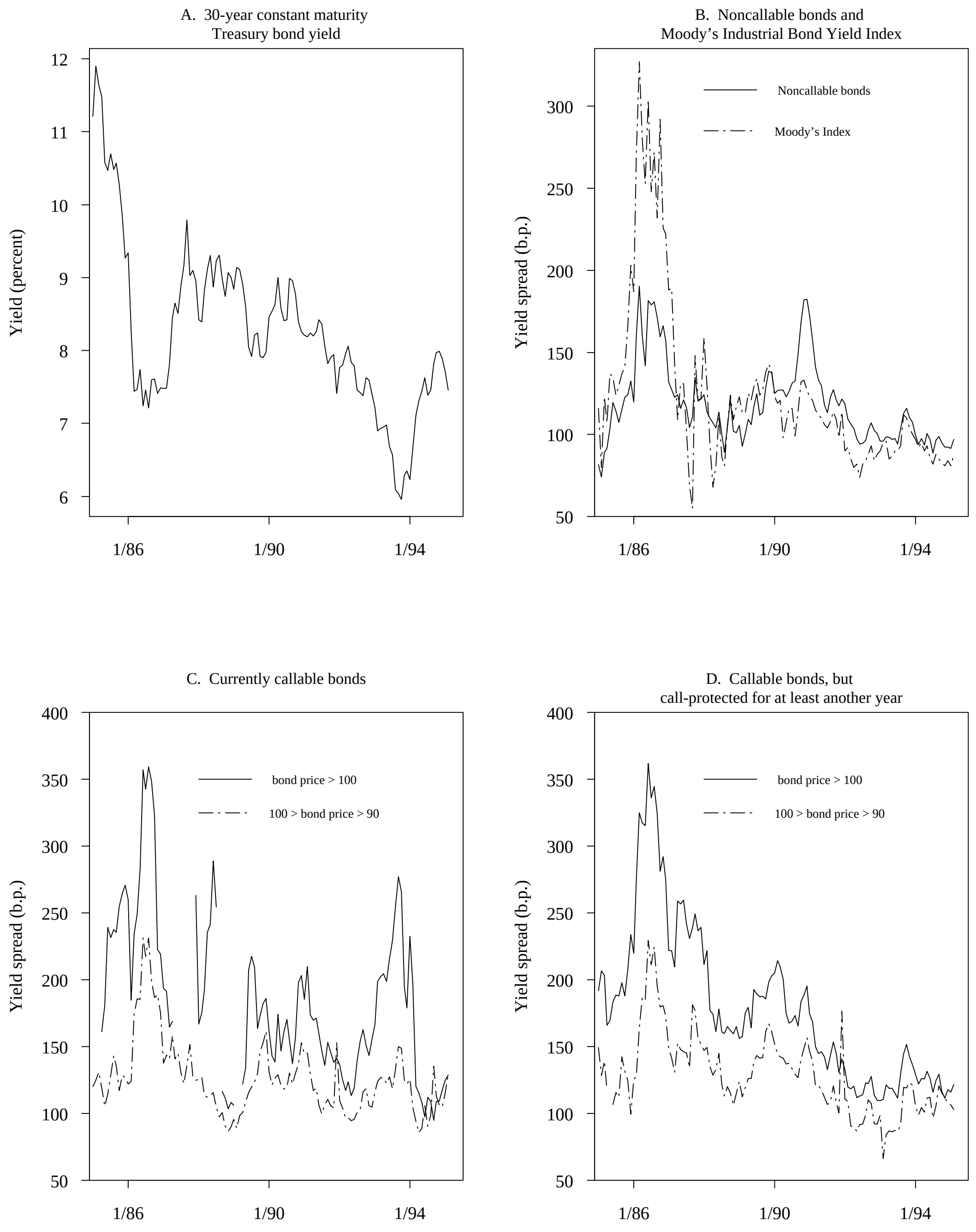

Fig. 1. Treasury yields and mean yield spreads on various groups of A-rated corporate bonds

Industrial, financial, and utility A-rated bonds with between 15 and 30 years to maturity are grouped by their call features, and, if callable, by their price. The appropriate interpolated constant maturity Treasury yield is subtracted from each bond's yield to form yield spreads. Panels B, C, and D display mean yield spreads, in basis points, for the groups; panel B also displays the spread between Moody's A-rated Industrial Bond Yield Average and the 30-year constant maturity Treasury yield.