The Effect of Interest Rate Volatility on Corporate Yield Spreads on both Noncallable and Callable Bonds

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Abstract

This study investigates the relationship between interest rate volatility and yield spreads on both noncallable and callable bonds. We first consider noncallable bonds. If greater interest rate volatility increases a firm's debt volatility, the firm is more likely to reach a critical value for default, thereby leading to a higher yield spread. We find that interest rate volatility is positively related to yield spreads on noncallable bonds. This finding for noncallable bonds is consistent with the structural models of default, which suggest that a firm's volatility should include its debt volatility as well as its equity volatility. Then we investigate whether the positive effect of interest rate volatility on yield spreads is stronger or weaker for callable bonds than for noncallable bonds. We find that the positive effect of interest rate volatility on yield spreads is weaker for callable bonds. This result indicates there is a negative relation between default spreads and call spreads, which is consistent with Acharya and Carpenter (2002) but in contrast to King (2002).

JEL Classification: G12, G13

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The volatility of interest rates plays numerous important roles in finance theory and practice. As one example, the potential for significant adverse changes in interest rates has caused banks, insurance companies, mutual funds and other financial institutions to devise strategies (such as immunization and others) to protect their fixed income portfolios. Sophisticated ways to measure interest rate risk exposure such as value at risk (VAR) have been developed.

The theory of how interest rate volatility affects bond pricing has been developed by numerous authors. For example, advanced bond pricing theory includes interest rate volatility as an important factor where a stochastic process for continuous changes in the short rate is given in terms of a drift term and a volatility term. Continuous changes in bond prices are derived from the short rate process. Veronesi (2010) and others derive expected bond returns as a function of interest rate volatility. In a classic article, Heath, Jarrow, and Morton (1990) derive a bond pricing model where the drift in the short (forward) rate is, in fact, a function of the volatility of short rates.

Empirical estimations of interest rate volatility have investigated alternative specifications of short rate volatility. For example, classic interest rate theories of Merton (1973)[1] and Vasicek (1977) suggest short rate volatility is independent of the level of interest rates while others such as Cox, Ingersoll, and Ross (1985), Black and Karasinki (1991), and Pearson and Sun (1994) maintain the volatility of interest rates depends on the level of interest rates. Brenner, Harjes and Kroner (1996) have found evidence that volatility depends on the level of rates and, also, GARCH processes.

[1] In contrast, the Merton (1974) structural default risk model has no interest rate process, only a firm value process.

Yield spreads have similarly played numerous important roles in finance theory and practice. For example, the spread between long and short rates has been of great interest where some think this spread predicts economic growth. More relevant to this research, the yield spread between instruments of equal maturity is also a topic of great importance. If one considers two equal maturity corporate debt instruments, what is the market determined yield spread and what underlying features determine this spread? Perhaps the most obvious factor is any differential in credit quality (default risk). However, recently, the importance of other factors has also been stressed.

Duffee (1998), in testing the Longstaff and Schwarz (1995) model on both callable and noncallable bonds, found that a greater *level* of interest rates suggests a stronger growth in firm value and thus reduces the spread over U. S. Treasury bonds. Elton, Gruber, Agrawal, and Mann (2001) find that expected default explains a surprisingly small part of spreads while a greater portion of the spread is simply systematic risk similar to that of equities. Chen, Lesmond and Wei (2007) find default risk does not fully explain spreads and stress that liquidity explains a large part of corporate bond spreads. Bao, Pan and Wang (2011) find that liquidity is a very strong determinant of spreads and, in fact, over-shadows credit risk. However, these papers have not addressed the impact of interest rate volatility on yield spreads.

The purpose of this research is to investigate the effect of interest rate volatility on corporate yield spreads for both noncallable and callable bonds. Specifically, interest rate volatility is defined as the standard deviation of the daily one-month Treasury constant maturity rate for the 12 months prior to the bond transaction date.[2] We explore two important and broad questions: 1) how does interest rate volatility affect the yield spread for noncallable corporate

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[2] King and Mauer (2000) measure interest rate volatility as the standard deviation of the 30-year Treasury constant maturity rate over the preceding 12 months. King (2002) measures interest rate volatility as the standard deviation of the 10-year Treasury constant maturity rate over the preceding 12 months.

bonds?, and 2) how does the effect of interest rate volatility on yield spreads differ for noncallable corporate bonds versus callable corporate bonds? While some bond pricing theories suggest that interest rate volatility should be priced in corporate yield spreads, surprisingly, there is no empirical work testing the effect of interest rate volatility on the above types of yield spreads.

We first investigate the effect of interest rate volatility on yield spreads on noncallable bonds. Merton (1974) relates a firm's default risk to the firm's asset volatility. Many studies have considered a firm's equity volatility in the investigation of the yield spread of its bonds by assuming that a firm's (total) asset volatility is determined by its equity. However, as noted by Campbell and Taksler (2003), the asset volatility of a firm with risky debt is determined by both its equity and debt. For example, if a firm has a high level of interest rate volatility and therefore a high level of debt volatility, the firm is more likely to reach a critical value for default, thereby resulting in a high probability of default. Thus, interest rate volatility should be priced in corporate yield spreads.

Acharya and Carpenter (2002) also provide theoretical support for the positive effect of interest rate volatility on noncallable bond spreads. They model a defaultable bond where its spread increases with the volatility of the difference between the host bond price and the firm value.[3] The details of their model are given in the theory and hypotheses section.

We also investigate whether the effect of interest rate volatility on yield spreads is greater or smaller for callable bonds than for noncallable bonds. Since interest rate volatility affects both the firm's option to default and call option values, the effect of interest rate volatility on yield spreads is complex. We note that default and call options are interactive because, for example, a bond default, which tends to be more likely when interest rate volatility is high, makes call

[3] The host bond is a coupon paying bond with no default risk.

option value disappear. As a result, the effect of interest rate volatility on yield spreads may be smaller for callable bonds than for noncallable bonds. On the other hand, interest rate volatility tends to increase call option values because greater interest rate volatility logically increases the volatility of the underlying instrument and thus increases the likelihood that the bond price reaches the call price and total spread is thus larger with greater interest rate volatility. In sum, the differential effect of interest rate volatility on yield spreads for callable bonds is not immediately obvious.

It is important to understand the importance of callable corporate yield spreads. Even though most empirical studies exclude callable bonds from their sample, Berndt (2004) reports that as of April, 2003, roughly 60% of U.S. corporate bonds in the Fixed Income Securities Database (FISD) are callable. Acharya and Carpenter (2002) point out that practitioners generally quote corporate bond prices as yield spreads and most corporate bonds are callable. Therefore, our empirical work includes yield spreads of callable corporate bonds.

We find that interest rate volatility clearly has a strong impact upon noncallable bond spreads after controlling for common bond-level, firm-level, and macroeconomic variables by running a series of pooled OLS regressions. This result is robust to using individual issuers' fixed effects and differencing the time-series. For a noncallable bond, a one percent increase in interest rate volatility increases the yield spread by a very significant amount. We find that this positive effect of interest rate volatility on yield spreads is smaller for callable bonds than for noncallable bonds. This result indicates that an increase in default risk reduces call option values, which is consistent with Kim, Ramaswamy, and Sundaresan (1993), Acharya and Carpenter (2002), and Jacoby and Shiller (2010), but is not consistent with King (2002). Also, we find that the positive effect of equity volatility on yield spreads is smaller or even insignificant for callable bonds. Finally, we find that the average yield spread on callable bonds is greater than that on noncallable bonds, supporting the existence of positive call spreads. This is in contrast to Bao, Pan, and Wang (2011), who include callable bonds in their regressions of yield spreads, but find either negative or insignificant call spreads. Also, Ederington and Stock (2002) point out that studies on the impact of a call option on corporate bond yields such as Kidwell, Marr, and Thompson (1984) and Fung and Rudd (1986) often find that a call option does not affect yields significantly.

Section 1 of the paper explains the theory of how interest rate volatility may affect spreads and also presents our hypotheses. The following section describes the data used and our control variable selection. Subsequently, section 3 presents the main empirical results. Finally, section 4 concludes and summarizes the research.

1. Interest Rate Volatility and Credit Spreads: Theory and Hypotheses

A. Effect of Interest Rate Volatility on Yield Spreads for Noncallable Bonds

Academic research typically classifies models of credit spreads as reduced form versus structural form. In reduced form models there is no process for valuing the assets of the firm as dependent upon the level or volatility of interest rates. Instead, the analyst develops and examines exogenous stochastic processes for probability of default and the recovery rate (in the event of default). The time to default is central to these models and is dependent upon exogenous variables, not firm specific variables. Default is a surprise in reduced form models. Reduced form econometric estimations of swap spreads and corporate bond yields have been performed by, among others, Jarrow and Turnbull (1995), Duffee (1999), and Liu, Longstaff and Mandell (2006).

In structural models, default is frequently triggered by asset value falling below the firm's liabilities. Some structural models are one factor models while others include two or more (multiple) factors. The first structural model was the one factor model of Merton (1974) where the single factor is a stochastic process for value of the firm. Leland and Toft (1996) also developed a one factor model. More recent models tend to have more than one factor where the second factor is commonly a stochastic process for the short rate. Longstaff and Schwartz (1995) developed an early two factor model where the short rate was given as the Vasicek (1977) process for the short rate. It is obvious that two factor structural models where the factors (processes) are 1.) the risk free short rate and 2.) the value of firm assets have strong intuitive appeal because corporate debt yields are often considered to have a risk free component and a risk premium related to default risk.

When the short risk free rate is a factor in a structural model, it is important to note that volatility of the short rate can be described as a constant, as in Longstaff and Schwartz (1995). Alternatively, volatility of the short rate may not be constant but a function of the level of short rates and time as in Acharya and Carpenter (2002) where the short rate is the well-known Cox, Ingersoll and Ross (1985) interest rate process. More specifically, interest rate volatility is not constant but potentially a function of the level of interest rates where higher rates tend to be associated with greater volatility. See Brenner, Harjes and Kroner (1996) who, among others, find that interest rate volatility depends upon the level of interest rates.

Some structural models maintain that strategic default is the appropriate perspective. That is, instead of a default being solely triggered by the condition of assets being less than liabilities, the firm constantly assesses the option to default. In other words, default is viewed more as an endogenous voluntary decision where the firm follows optimization rules. For our analysis, we utilize the multifactor endogenous model of Acharya and Carpenter (2002) as given below. It is appealing for our purposes because it suggests theory of how interest rate volatility can affect yield spreads, defined as the difference between the corporate bond yield and the government bond yield with the same time to maturity as that of the corporate bond.

$$\frac{dV_t}{V_t} = (r_t - \gamma_t)dt + \sigma_{v,t} d\tilde{W}_t \tag{1}$$

$$dr_t = \mu(r_t, t)dt + \sigma(r_t, t)d\tilde{Z}_t \tag{2}$$

$$E[d\tilde{W}_t, d\tilde{Z}_t] = \rho_t dt \tag{3}$$

Here V_t is firm value, r_t is the short term interest rate, γ_t is the firm's payout rate, $\sigma_{v,t}$ reflects volatility of firm value, $\tilde{W}_t$ is a Brownian motion. In the interest rate process, $\mu(r_t, t)$ is the drift, $\sigma(r_t, t)$ is the volatility of the short rate (hereafter σ_r), $\tilde{Z}_t$ is a second Brownian motion, and ρ_t is the instantaneous correlation between the short-term interest rate and firm value processes. It seems intuitive that if the drift for value of the firm is dependent upon r_t, then spreads likely depend on the level of and volatility of the short rate.

By considering a firm with a single bond outstanding, Acharya and Carpenter (2002) model a pure defaultable bond where the option to default is treated as a particular kind of a call option on its host bond. The host bond is a coupon paying bond with no default risk. The host bond has price P_t at time t. At each time t, the firm decides whether to service the debt or not (by defaulting). The pure defaultable bond is a host bond less a call option to default where the strike price is V_t.[4] This is because the firm owners are long in the assets, short on the host bond, and long on the option to default.

[4] This call option is not the option to refund high coupon debt with lower coupon debt. We deal with this type of call option later.

How is the yield spread related to interest rate volatility (σ_r) for pure defaultable bonds? Does σ_r increase or decrease the spread?[5] Acharya and Carpenter (2002) theoretically analyze the effect of σ_r on yield spreads on pure defaultable bonds. They view the yield spread of a pure defaultable bond over its host bond as a transformation of the default option value.[6] They begin with the idea that option value should increase with variance in P_t-V_t, where the time subscript is omitted for brevity.[7] One can decompose the variance of P_t-V_t into the below parts.

$$Var\ (P_t - V_t) = Var\ (P_t) + Var\ (V_t) - 2\ Cov\ (P_t, V_t) \tag{4}$$

Then, one can analyze how interest rate volatility affects each term on the right side.

While Acharya and Carpenter (2002) analyze the impact of σ_r on yield spreads by focusing on $Cov\ (P_t,V_t)$, we focus on $Var\ (P_t)$ and $Var\ (V_t)$. Because Eom, Helwege, and Huang (2004) find that the covariance between the V and r processes is small and insignificant, we do not analyze its impact on the spread.[8] It is obvious that greater σ_r increases the variance of the default free host bond price, P_t, the first term of equation (4). The impact of interest rate volatility upon the second term, variance of V_t, is not as obvious but would appear to tend positive because the variance of V is the weighted average of the volatility of the firm's debt and the firm's equity. Note that Campbell and Taksler's (2003) focus is upon the volatility of equity but they also note the importance of volatility in the firm's debt in determining variance of V.

As in Campbell and Taksler (2003), the volatility of V is expressed as follows:

$$\sigma_{\text{v}} = \left(\frac{D}{D+E}\right)\sigma_d + \left(\frac{E}{D+E}\right)\sigma_e \tag{5}$$

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[5] Acharya and Carpenter (2002) analyze the impact of interest rate volatility by using the correlation between r and V. We suggest that the above process is an alternative that lends more insight.

[6] This is equation (15) in Acharya and Carpenter (2002).

[7] In their model, the payoff of the default option is Max(*P*-*V*, 0). Therefore, the volatility of *P*-*V* increases the option value and therefore the yield spread.

[8] Of course, P_t is determined by r_t

where σ_v is the volatility of the firm, σ_d is the volatility of the firm's debt, σ_e is the volatility of the firm's equity, *D* is the market value of the firm's debt, and *E* is the market value of the firm's equity. Since the volatility of the firm is an increasing function of the volatility of the firm's debt, interest rate volatility is expected to have a positive effect on the volatility of the firm. In sum, we expect yield spreads to increase as σ_r rises because interest rate volatility increases both the host bond price volatility and firm volatility. This leads to the first hypothesis.

Hypothesis 1: Interest rate volatility increases yield spreads.

Our next hypothesis is motivated by the result of Duffee (1998) who finds that bonds with weaker credit quality show a more negative relationship between yield spreads and levels of interest rates than bonds with stronger credit quality. As a consequence, the prices of junk bonds are expected to be more responsive to interest rate volatility than those of investment grade bonds. Therefore, the effect of hypothesis 1 is expected to be greater for junk bonds than for investment grade bonds. This leads to our second hypothesis.

Hypothesis 2: The relationship between interest rate volatility and yield spreads is more strongly positive for junk bonds than for investment grade bonds.

B. Differential Effect of Interest Rate Volatility on Yield Spreads: Noncallable versus Callable Bonds

The next question is whether the expected positive effect of σ_r on yield spreads is stronger or weaker for callable bonds. Chance (1990) views a noncallable corporate bond as a portfolio of a riskless bond and a short position in a put option written on the firm's assets. On the other hand, Kihn (1994) and Jacoby and Shiller (2010) view a callable corporate bond (where callability here means the ability to refund at a call price) as a portfolio of the above noncallable corporate bond and a short position in a refunding call option written on the bond. Therefore, yield spreads of callable corporate bonds consist of both default spreads and call spreads. If interest rate volatility increases default risk, as suggested by Hypothesis 1, the impact of σ_r on call spreads should be affected by the interaction between the call provision and default risk. An important question is whether default risk increases or decreases the call option value.

Kim, Ramaswamy, and Sundaresan (1993) find that a call option value in a government bond is more valuable than that in a corporate bond, suggesting that there should be a negative relation between default risk and a call option value. To address this issue, Acharya and Carpenter (2002) built their theory of corporate bond valuation upon three types of coupon paying bonds: a.) pure defaultable, b.) pure callable, and c.) both defaultable and callable. As previously mentioned, they treat the option to default for the pure defaultable bond as a kind of a call option on its host bond. While the strike price of the pure defaultable bond is firm value (V_t), the strike price of the pure callable bond is a call price (k_t). Since the issuer of a defaultable and callable corporate bond has the option to both default and call, the firm may stop servicing the debt by either a.) exercising the call (paying k_t to replace the bond with lower coupon debt), or b.) giving up the firm where the value is V_t. Importantly, the strike price is the minimum of k_t and V_t.[9]

By noting that the presence of one option destroys the other option, they suggest that there should be a negative relation between default risk and a call option value. Jacoby and Shiller (2010) find empirical evidence to support this negative relation. Thus, if σ_r increases default risk but the increase in default risk weakens the call option value, the positive effect of interest

[9] Here the endogenous model assumes no minimum net worth or cash flow covenants which force the issuer to default.

rate volatility on yield spreads will be weaker for callable bonds than for noncallable bonds. This leads to the following hypothesis.

<u>Hypothesis 3A</u>: The hypothesized positive relation between interest rate volatility and yield spreads is *weaker* for callable bonds than for noncallable bonds.

In contrast to hypothesis 3A, interest rate volatility may increase call option values because greater σ_r increases the volatility of the underlying instrument and thus increases the likelihood that the bond price reaches the call price, k_t. King (2002) finds that σ_r has a positive effect on call option values. Since greater call values increase call spreads for callable bonds, σ_r may increase call spreads for callable bonds. If so, the expected positive impact of interest rate volatility on yield spreads will be stronger for callable bonds than for noncallable bonds. Thus, we suggest the alternative hypothesis below.

<u>Hypothesis 3B</u>: The hypothesized positive relation between interest rate volatility and yield spreads is *stronger* for callable bonds than for noncallable bonds.

C. Differential Effect of Credit Ratings and Equity Volatility on Yield Spreads: Noncallable versus Callable Bonds

The credit rating is the most common proxy for default risk. A bond with weaker credit quality should have a greater credit yield spread. However, it is not clear whether the effect of the credit rating on yield spreads is stronger or weaker for callable bonds than for noncallable bonds. A greater default risk associated with weaker credit quality destroys the exercise of the call option and thus reduces the call option value, as suggested by Acharya and Carpenter (2002). On the other hand, King (2002) empirically finds that a bond with weaker credit quality is associated with a higher call option value. She explains this by suggesting the bond with weaker credit quality is more sensitive to the level of interest rates, thereby leading to a higher price volatility and a higher probability that the bond price reaches the call price. The result of King (2002) is consistent with the finding of Duffee (1998) that bonds with weaker credit quality show a more negative relationship between yield spreads and level of interest rates. This leads to the following alternative hypotheses.

Hypothesis 4A: The positive relation between credit ratings and yield spreads is *weaker* for callable bonds than for noncallable bonds.

Hypothesis 4B: The positive relation between credit ratings and yield spreads is *stronger* for callable bonds than for noncallable bonds.

Campbell and Taksler (2003) find that a firm's equity volatility (σ_e) is positively related with the yield spread on its debt in the cross-section. King (2002) analyzes the determinants of call option values, but she does not take into account the impact of σ_e on call option values. One interesting question is whether σ_e increases or decreases the call option value. As mentioned above, Acharya and Carpenter (2002) suggest that default risk destroys call option value. If σ_e increases the default risk and the increase in the default risk reduces the call option value, the expected positive relation between a firm's equity volatility and the yield spread on its debt should be weaker for callable bonds.

Hypothesis 5: The positive relation between a firm's equity volatility and the yield spread on its debt is weaker for callable bonds than for noncallable bonds.

2. Data and Summary Statistics

A. Data

We use transaction data between 2003 and 2009 from Trade Reporting and Compliance Engine (TRACE). Following Edwards, Harris and Piwowar (2007), we eliminate cancelled, corrected, and repeated interdealer trades. According to Chen, Fabozzi, and Sverdlove (2010), there seem to be some errors in the TRACE yield computations.[10] Therefore, we calculate the yield-to-maturity and use these calculated yields to maturity instead of the yields to maturity provided by TRACE. In order to compute yields, we use the volume-weighted average of all transaction prices during the last trading day of the month in which the bond traded as the end-of-month bond price rather than the last transaction price of the day. Bessembinder, Kahle, Maxwell, and Xu (2009) find that a volume-weighted approach leads to better specified and more powerful statistical tests than an equal-weighted approach. We eliminate observations where the last transaction does not fall between five business days before the last trading day and the last trading day of the month.

We obtain the Treasury constant maturity yields from H.15 release of the Federal Reserve System and measure yield spreads as the difference between the daily yield on the corporate bond and the constant maturity Treasury yield with the same time to maturity. To estimate the entire yield curve, we use a linear interpolation scheme from 1, 2, 3, 5, 7, 10, 20, and 30-year Treasury constant maturity rates. Interest rate volatility is measured as the standard deviation (in %) of the daily one-month Treasury constant maturity rate for the 12 months prior to the bond transaction date.

Bond characteristics are obtained from the Fixed Income Securities Database (FISD) and the issuer's accounting information is obtained from the Compustat database. We exclude bonds unrated by S&P, as Chen, Lesmond, and Wei (2007) do. The credit rating is assigned a cardinalized S&P rating, where AAA=1, . . . , D=22. As in Guntay and Hackbarth (2010), we

[10] They report that some of these apparent errors include entering the time of day in the yield field.

exclude bonds with special features such as putability, convertibility, and sinking fund provisions. Bonds with make-whole provisions are also eliminated. Furthermore, as in Elton, Gruber, Agrawal, and Mann (2001), we exclude floating-rate bonds and bonds with an odd frequency of coupon payments. Following Duffee (1999) and Eom, Helwege, and Huang (2004), we eliminate bonds whose maturity is less than one year because they are less likely to trade. Finally, we obtain equity prices from the Center for Research in Security Prices (CRSP). Equity volatility is calculated as the standard deviation of daily excess returns over the CRSP value-weighted index using 252 daily returns prior to the bond transaction date.

Following Campbell and Taksler (2003), we exclude the top and bottom 1% of yield spreads from our analysis. The imposition of all the screens above results in a sample of 134,167 different bond-month transactions for noncallable bonds and 88,273 different bond-month transactions for callable bonds.

B. Control Variables

The existing literature has included a large number of variables that affect yield spreads for noncallable bonds. Thus, we employ a set of control variables that has been proven to affect noncallable yield spreads. Given that call values should affect call spreads for callable bonds, we also include the determinants of call values expected to influence yield spreads for callable bonds. We use interaction terms between some of these variables and a callable dummy variable.

The short-term interest rate is defined as the one-month Treasury constant maturity rate. According to, among others, Longstaff and Schwartz (1995) and Collin-Dufresne and Goldstein (2001), an increase in the short-term interest rate leads to an increase in the drift of firm value under the risk-neutral measure. Such an increase in the drift of firm value decreases the probability of default, thereby decreasing any default spread. Longstaff and Schwartz (1995) and Duffee (1998) empirically find that there is a negative relation between the level of interest rates and yield spreads. Therefore, we expect the short-term interest rate has a negative impact on yield spreads due to default risk.

Furthermore, call spreads should be positively related to the short-term interest rate. The price of a bond declines as the level of the short-term interest rate rises. Since a call option value is based on the price of the underlying asset, an increase in the level of the short-term interest rate should decrease the call value and call spread. Consistent with this claim, Duffee (1998) finds that the negative relation between interest rates and yield spreads is stronger for callable bonds than for noncallable bonds. Therefore, we expect any negative relation between short, risk free rest interest rates and yield spreads to be stronger for callable bonds. In addition, as mentioned above, Duffee (1998) finds that the negative relation between short-term interest rates and yield spreads is stronger for lower rated bonds because the prices of lower rated bonds associated with higher default risk are more sensitive to the level of interest rates. The negative relation between short, risk free interest rates and yield spreads is thus expected to be stronger for lower rated bonds.

The slope of the yield curve is measured by the difference between the 10-year and 1-year Treasury constant maturity rates. Estrella and Hardouvelis (1991), Estrella and Mishkin (1996), Ederington and Stock (2002), and Breeden (2011) suggest that the slope of the yield curve reflects the market's expectation about the future strength of the economy. Simply put, a strongly positive yield curve suggests the economy will strongly grow while a flat or negative yield curve suggests the economy will grow slowly and even experience negative growth. Of course, a stronger (weaker) outlook for the economy suggests fewer (greater) defaults and less (greater) credit spreads. Thus, the slope of the yield curve is expected to have a negative impact on yield spreads.

The slope of the yield curve could also affect call spreads. As in Stanhouse and Stock (1999), the slope of the term structure may reflect the market's expectation of future interest rates. A greater slope of the term structure reflects the market's expectation of rising interest rates in the future. If the market expects interest rates to rise, call option values are expected to decline. King (2002) finds that call option values are negatively related to the slope of the yield curve. Thus, the negative relation between the slope of the yield curve and total yield spreads is expected be stronger for callable bonds than for noncallable bonds.

A number of recent studies find that liquidity plays an important role in determining yield spreads (Chen, Lesmond, Wei (2007), Guntay and Hackbarth (2010), Bao, Pan, and Wang (2011), and Rossi (2009)). Even though their liquidity measures vary, they all find that liquidity is priced in corporate yield spreads. Guntay and Hackbarth (2010) use the number of *months* a bond traded for the 12 months prior to the bond transaction date divided by 12 as their measure of liquidity. In this measure, a bond may trade only once a month and appear to be as liquid as one that trades every day of a given month. Our measure of liquidity is obtained by dividing the number of *days* a bond traded for the 12 months prior to the bond transaction date by the number of business days during the corresponding period. A negative coefficient is expected for this variable.

We also include remaining time to maturity and coupon rate. The effect of remaining maturity on yield spreads depends on whether the slope of the corporate yield curve is steeper or flatter than that of the government yield curve. If the slope of the corporate yield curve is steeper than that of the government risk free yield curve, the coefficient on maturity will have a positive sign. On the other hand, King (2002) finds that remaining maturity is positively related to call option values in the callable period.

Following Elton, Gruber, Agrawal, and Mann (2001) and Longstaff, Mithal, and Neis (2005), we include coupon rates (in percent) to control for tax effects. While interest payments on Treasury bonds are exempt from state taxes, interest payments on corporate bonds are subject to state taxes. Corporate bonds with higher coupons are taxed more than corporate bonds with lower coupons, so investors should demand a higher rate of return to be compensated for holding bonds with higher coupons.[11] Therefore, we expect a positive relation between coupon rates and yield spreads. In addition, according to King and Mauer (2000), firms tend to call higher coupon bonds first. A higher option value associated with a higher coupon rate is expected to lead to a greater call spread. Thus, the expected positive relation between coupon rates and yield spreads should be greater for callable bonds than for noncallable bonds.

Finally, we include accounting information because it is unclear to investors how credit rating agencies use public information to set credit ratings. Following Blume, Lim, and Mackinlay (1998), Campbell and Taksler (2003), and Chen, Lesmond, and Wei (2007), we include long-term debt to assets and operating income to sales. The ratio of long-term debt to assets is measured by dividing long-term debt by total assets and the ratio of operating income to sales is measured by dividing operating income before depreciation by net sales. Each variable is obtained in the year prior to the yield spread measurement.[12] Since financially risky firms are likely associated with a high level of long-term debt to assets and a low level of operating

[11] Tax rates on capital gains are lower than those on coupons for many investors. Also, capital gains taxes can be deferred.

[12] Following Blume, Lim, and Mackinlay (1998) and Campbell and Taksler (2003), we use the calendar year assigned by COMPUSTAT for comparability of data.

income to sales, we expect a positive sign on the long-term debt to assets and a negative sign on the operating income to sales.

C. Summary Statistics

Summary statistics for the mean and median yield spreads are reported in Table I. We report results by industry, year, rating, and maturity for noncallable bonds and callable bonds, respectively. Not surprisingly, Panel B of Table I shows that the mean and median yield spreads were greater during the financial crisis of 2008 (2008 and 2009 data), reflecting the increase in credit spreads caused by the financial crisis.

**** Insert Table I here ****

Table II provides summary statistics on the variables we use in our analysis. The mean and median yield spreads of callable bonds are higher than those of noncallable bonds. Many studies have found no significant relation between the call provisions and yield spreads. For example, Bao, Pan, and Wang (2011) include callable bonds in their regressions of yield spreads, but find either negative or insignificant call spreads. Also, Ederington and Stock (2002) point out that several studies on the impact of a call option on corporate bond yields find that a call option does not affect yields significantly. On the other hand, King (2002) reports that the average call option value is 2.25% of par. Our results suggest that positive call spreads exist. In addition, callable bonds are associated with longer maturity, which is consistent with Chen, Mao, and Wang (2010). We also find that callable bonds are associated with weaker credit quality and lower liquidity, which should lead to higher yield spreads for callable bonds. [13]

**** Insert Table II here ****

[13] Crabbe and Helwege (1994) found that lower rated bonds are more likely to have a call feature.

3. Empirical Results

A. Effect of Interest Rate Volatility on Yield Spreads for Noncallable Bonds

We first examine time-series variations of our measure of interest rate volatility and yield spreads of noncallable bonds. We plot interest rate volatility and the mean yield spread of each month from 2003 to 2009. A positive time-series relation between interest rate volatility and the yield spreads of noncallable bonds is illustrated in Figure I.

**** Insert Figure I here ****

To further explore the effect of interest rate volatility on yield spreads of noncallable bonds, we estimate the following regression for only noncallable bonds with some variables omitted for various specifications:

$$\begin{aligned} Yield\ Spread_{it} = {} & \beta_0 + \beta_1(\sigma_r)_t + \beta_2 r_t + \beta_3 Slope_t + \beta_4 Rating_{it} + \beta_5(\sigma_e)_{it} + \beta_6 Liquidity_{it} \\ & + \beta_7 Maturity_{it} + \beta_8 Coupon_i + \beta_9 Income\ to\ Sales_{it} + \beta_{10} Debt\ to Assets_{it} \\ & + \beta_{11} Industrial_i + \beta_{12} Financial_i + \varepsilon_{it} \end{aligned} \tag{6}$$

For each bond-month observation, $Yield\ Spread_{it}$ is defined as the difference between the daily yield on the corporate bond and the constant maturity Treasury yield with the same time to maturity, $(\sigma_r)_t$ is defined as the standard deviation of the one-month Treasury constant maturity rate for the 12 months prior to the bond transaction date, r_t is the one-month Treasury constant maturity rate, $Slope_t$ is defined as the difference between the 10-year and 1-year Treasury constant maturity rates, $Rating_{it}$ is defined as a cardinalized S&P rating, where AAA=1, . . . , D=22, $(\sigma_e)_{it}$ is defined as the standard deviation of daily excess returns over the CRSP value-weighted index for firm *i* using 252 daily returns prior to the bond transaction date, $Liquidity_{it}$ is defined as the number of trading days for the 12 months prior to the bond transaction date, $Maturity_{it}$ is defined as the remaining maturity in years for bond *i*, $Coupon_i$ is defined as the coupon rate measured in percent, $Debt\,to Assets_{it}$ is defined as the ratio of long-term debt to total assets, $Income\,to\,Sales_{it}$ is defined as the ratio of operating income before depreciation to net sales, $Industrial_i$ is a dummy variable that takes the value 1 if the bond is an industrial bond, and $Financial_i$ is a dummy variable that takes the value 1 if the bond was issued by a financial firm such as a bank.[14]

The regression results for only noncallable bonds are presented in Table III. The coefficients on σ_r have the hypothesized sign and are significant at the 1% level in all specifications. The last column of Table III shows that a one percent increase in interest rate volatility increases the yield spread by 1.63%. The yield spread is positively related to σ_r after we control for bond-specific, issuer-specific, and macroeconomic variables. The positive sign of σ_r supports the hypothesis that σ_r increases yield spreads.

**** Insert Table III here ****

The negative coefficients on *r* and *Slope* have the expected signs and are significant at the 1% level in all specifications. The negative sign of *r* is consistent with the empirical findings of Longstaff and Schwartz (1995) and Duffee (1998). As expected, the estimated coefficient on the slope of the yield curve is also significantly negative. This result is consistent with the findings that the slope of the yield curve reflects the market's expectation of future interest rates. As in all the previous studies, the positive and significant sign of *Rating* implies that a bond with weaker credit quality has a greater yield spread. In addition, the effect of σ_e on yield spreads is positive

[14] We measure $(\sigma_r)_t$ as the standard deviation of the one-month Treasury constant maturity rate for the one month (not the *12 months*) prior to the bond transaction date. Using this measure of $(\sigma_r)_t$ does not change our major results.

and significant at the 1% level, which is consistent with the findings with Campbell and Taksler (2003). The negative sign of *Liquidity* supports the existence of a liquidity premium. Finally, the negative sign of *Income to Sales* indicates that firms with high levels of operating income to sales are less likely to default, thereby leading to low yield spreads.

We examine whether our findings are robust to different σ_r and σ_e specifications and a different measure of credit ratings. According to the Black-Scholes model in deriving implied volatilities, the effects of σ_r and σ_e on the default option value should be proportional to the square root of the time to maturity. Thus, we use a different specification by replacing σ_r and σ_e with σ_r* $(\text{Maturity})^{1/2}$ and σ_e * $(\text{Maturity})^{1/2}$. In addition, we use a different measure of credit ratings because the yield spread between AAA and AA+ is likely smaller than that between C and D. Furthermore, we reverse the rating scale such that D=1, …, AAA=22 and take logs of all rating levels. The results are shown in Appendix A. The coefficients on σ_r* $(\text{Maturity})^{1/2}$ and σ_e * $(\text{Maturity})^{1/2}$ are both significantly positive and the coefficients on *Rating* are significantly negative.[15] Using the different specification and the different measure of credit ratings does not change the major results reported above.

In order to investigate whether the positive relation between σ_r and yield spreads was caused by the 2008 financial crisis, we run separate regressions for different time periods: the pre-crisis period (2003-2007) and the crisis period (2008-2009).[16] As reported in the first two columns of Table IV, the relation between σ_r and the yield spreads is positive and significant at the 5% and 1% levels during the pre-crisis period and the crisis period, respectively. We also run separate regressions for investment grade bonds (S&P ratings, AAA to BBB-) and junk bonds

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[15] We also add these two interaction terms instead of substituting for σ_r and σ_e. However, the coefficients on these two interaction terms are not significantly positive.
[16] Following Bao et al. (2011), the pre-crisis period excludes 2008 and 2009.

(S&P ratings, BB+ to D). The positive relation between σ_r and yield spread is significant for both investment grade bonds and junk bonds. We also perform fixed effect regressions to investigate whether the positive relation between σ_r and the yield spreads is the product of spurious cross-sectional or time-series correlations. As shown in Table V, the coefficients on σ_r are positive and significant at the 1% level. Therefore, the strongly positive relation between σ_r and the yield spreads is not due to spurious cross-sectional or time-series correlations.

***** Insert Table IV here ****

**** Insert Table V here ****

Finally, we perform regressions of monthly changes in yield spreads on monthly changes in all variables to remove any time-series trends:

$$\begin{aligned}\Delta Yield\ Spread_{it} &= \beta_0 + \beta_1\Delta(\sigma_r)_t + \beta_2\Delta r_t + \beta_3\Delta Slope_t + \beta_4\Delta Rating_{it} + \beta_5\Delta(\sigma_e)_{it} \\ &\quad + \beta_6\Delta Liquidity_{it} + \varepsilon_{it}\end{aligned} \tag{7}$$

where Δ denotes the first difference in each variable and $\Delta Yield\ Spread_{it}$ is the change in yield spreads between two consecutive months. Unlike the previous regressions, here we eliminate Δ *Maturity* and the variables that do not change on a monthly basis. In addition, our measures of $(\sigma_r)_t$, $(\sigma_e)_{it}$, and $Liquidity_{it}$ are different from those of the previous regressions. $(\sigma_r)_t$ is measured as the standard deviation of the daily one-month Treasury constant maturity rate for the *one month* (not the *12 months*) prior to the bond transaction date. $(\sigma_e)_{it}$ is calculated as the standard deviation of daily excess returns over the CRSP value-weighted index using *one month* of daily returns (not *252* daily returns) prior to the bond transaction date. $Liquidity_{it}$ is measured by dividing the number of *days* a bond traded for the *one month* (not the *12 months*) prior to the bond transaction date by the number of business days during the corresponding period. We find a significantly positive relation between monthly changes in σ_r and monthly changes in yield spreads.[17] The last column in Table VI shows that a one percent monthly change in interest rate volatility results in a 0.936% monthly change in the yield spread.

**** Insert Table VI here ****

B. Differential Effect of Interest Rate Volatility, Credit Ratings, and Equity Volatility on Yield Spreads: Noncallable versus Callable Bonds

The regression results for callable bonds are presented in Table VII. [18] We find a positive and significant relation between σ_r and the yield spreads. It is interesting to note that the coefficients on σ_e have the expected sign but are not significant in all specifications. This is consistent with the hypothesis that the positive relation between a firm's equity volatility and the yield spread on its debt is weaker for callable bonds. This can be explained by Acharya and Carpenter (2002) who suggest that default risk destroys call option values. An increase in default risk, driven by an increase in σ_e, seems to reduce the call spread, thereby offsetting the positive effect of σ_e on the default spread.

**** Insert Table VII here ****

We now explore whether the positive relationship between σ_r and yield spreads is different for junk bonds and callable bonds. We run regressions for the full sample of both noncallable and callable bonds with interaction terms. *Junk* is used as a dummy variable that takes the value 1 if the bond is a junk grade bond, and *Call* is used as a dummy variable that takes the value 1 if the bond is callable. As shown in Table VIII, the coefficients on *Junk**σ_r are

[17] The results are similar when we use Newey-West (1987) Standard errors and standard errors that are clustered at the firm and year level.

[18] TRACE reports the lower of yield-to-call (YTC) or yield-to-maturity (YTM) for the yield of a callable bond. We eliminate callable bonds for which the reported yield is lower than our calculated yield-to-maturity by more than 1% because the yield-to-call might be more important than our calculated yield-to-maturity for these callable bonds. Excluding these callable bonds does not change our major results.

positive, supporting our hypothesis that the yields of junk bonds are more sensitive to interest rate volatility than those of investment grade bonds. The coefficients on *Junk*r* are also positive, which is consistent with the findings of Duffee (1998), who reports that the negative relation between yield spreads and the level of interest rates is stronger for lower rated bonds. We also find a positive and significant relation between *Call* and the yield spreads, suggesting that positive call spreads exist. The coefficient on *Call* in the first column indicates the average call spread is 0.523 percentage points after controlling for common bond-level, firm-level, and macroeconomic variables.

**** Insert Table VIII here ****

An interesting question is whether the positive effect of interest rate volatility on yield spreads is stronger or weaker for callable bonds. As previously hypothesized, the two conflicting theories suggest different effects of σ_r on yield spreads of callable bonds relative to noncallable bonds. The negative sign of *Call**σ_r supports the hypothesis that the positive relation between σ_r and yield spreads is *weaker* for callable bonds, because an increase in default risk resulting from an increase in σ_r reduces a call option value.

Similarly, the coefficients on *Call**σ_e are negative and significant in every specification, supporting the hypothesis that an increase in default risk resulting from an increase in σ_e reduces a call option value. On the other hand, the coefficients on *Call*Rating* are significantly positive, which is consistent with the hypothesis that the positive relation between credit ratings and yield spreads is *stronger* for callable bonds than for noncallable bonds. This is consistent with the findings of King (2002), who finds that a bond with weaker credit quality is associated with a higher call option value.

All the other interaction control variables with the call option have the expected signs. The negative effect of the short-term interest rate on yield spreads is significantly stronger for callable bonds, suggesting that call option values are negatively related to the short-term interest rate. This is because the value of a call option is positively related to the bond's price. Furthermore, the sign of *Call*Slope* is as expected. The slope of the yield curve seems to reflect the market's expectation of future interest rates. The call spread becomes smaller as the slope of the yield curve becomes more positive, which indicates that interest rates are expected to rise. The positive sign of *Call*Coupon* suggests that call options are worth more when coupon rates are greater because firms want to lower the cost of borrowing by calling bonds with higher coupons first.

Finally, we examine whether the relation between the determinants of call values and yield spreads on callable bonds is stronger or weaker for high-priced bonds than for low-priced bonds.[19] *HP* is used as a dummy variable that takes the value 1 if the bond price is greater than 100.[20] Following King (2002), we divide callable bonds in the sample into two groups: callable bonds that are in the call protection period and callable bonds that are in the callable period. The results are shown in Table IX. We find that the effects of σ_r, σ_e, and *Rating* on yield spreads on callable bonds are generally weaker for high-priced callable bonds. Acharya and Carpenter (2002) suggest that an increase in default risk reduces call option values. This effect seems to be stronger for high-priced callable bonds, because call option values are more sensitive to the change in default risk when they are in-the-money.

**** Insert Table IX here ****

[19] While a call price is identifiable if it is par, the FISD does not provide clear information of non-par call prices until the bond issues are called. Therefore, we eliminate callable bonds whose call prices are not par. Fourteen percent of callable bonds are eliminated due to call price being unequal to par.
[20] Nineteen percent of callable bonds in the sample are high-price bonds.

4. Conclusions

This paper examines the impact of interest rate volatility on yield spreads for noncallable and then, also, callable bonds. Campbell and Taksler (2003) argue that a firm with a higher level of equity volatility is more likely to default. Given that the total firm volatility also includes the volatility of a firm's bonds, interest rate volatility should affect default risk. The greater the interest rate volatility, the more volatile the price of a bond. As the bond price becomes more volatile, the volatility of firm asset market value increases, thereby leading to an increase in default spread. We find that interest rate volatility is positively related to yield spreads on noncallable bonds.

We find the relationship between interest rate volatility and yield spreads is more strongly positive for junk bonds than for investment grade bonds. Investment grade bonds are unlikely to default, as pointed out by Campbell and Taksler (2003). As a consequence, the positive effect of interest rate volatility on the default spread should be more significant for junk bonds. In addition, we find that the average yield spread on callable bonds is greater than that on noncallable bonds, indicating that the embedded options in callable bonds are priced.

We also investigate whether the effect of interest rate volatility on yield spreads is greater or smaller for callable bonds than for noncallable bonds. Two conflicting theories predict different effects of interest rate volatility on yield spreads on callable bonds versus noncallable bonds. Acharya and Carpenter (2002) suggest that default (call) risk destroys call (default) option values. An increase in default risk, driven by an increase in interest rate volatility, should reduce the call spread, thereby offsetting the positive effect of interest rate volatility on the default spread. On the other hand, interest rate volatility might increase call spreads by inducing a higher price volatility of callable bonds, which is consistent with the finding of King (2002) that a bond with weaker credit quality shows a higher call option value. We find that the effect of interest rate volatility on yield spreads is smaller for callable bonds than for noncallable bonds. Similarly, we find that the positive relation between a firm's equity volatility and the yield spread on its debt is weaker or insignificant for callable bonds.

Appendix A. Regressions for Different σ_r and σ_e Specifications and a Different Measure of Credit Ratings

This table reports the pooled OLS regression results for different σ_r and σ_e specifications and a different measure of credit ratings. σ_r and σ_e are replaced with $\sigma_{r*}(\text{Maturity})^{1/2}$ and $\sigma_{e*}(\text{Maturity})^{1/2}$. Furthermore, we reverse the rating scale such that D=1, …, AAA=22 and take logs of all rating levels. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3	4
Intercept	12.175***	23.609***	22.177***	21.660***
	(9.67)	(13.09)	(16.54)	(11.33)
$\sigma_{r*}(\text{Maturity})^{1/2}$	0.943***	0.136***	0.369***	0.440***
	(7.34)	(2.52)	(5.86)	(6.14)
r		-1.990***	-1.643***	-1.718***
		(-7.02)	(-8.55)	(-6.98)
Slope		-2.373***	-1.946***	-2.050***
		(-6.21)	(-7.63)	(-6.14)
Rating	-4.397***	-5.204***	-5.125***	-5.002***
	(-13.22)	(-17.33)	(-16.45)	(-15.39)
$\sigma_{e*}(\text{Maturity})^{1/2}$	0.279***	0.119***	0.290***	0.180***
	(7.92)	(4.58)	(3.25)	(5.52)
Liquidity	-0.323**	-0.512***	-0.666***	-0.508***
	(-2.06)	(-3.76)	(-5.82)	(-3.82)
Maturity	-0.169***		-0.132***	-0.098***
	(-7.36)		(-3.34)	(-5.42)
Coupon	0.093		-0.015	0.043
	(1.64)		(-0.24)	(0.70)
Long-Term Debt to Assets	0.740 (0.93)	0.931 (1.27)		0.905 (1.20)
Operating Income to Sales	-0.961*** (-15.47)	-1.102*** (-16.46)		-1.017*** (-16.05)
Industrial	0.477**	0.426**	0.495*	0.525***
	(2.47)	(2.19)	(1.94)	(2.96)
Financial	1.046***	1.229***	0.806***	1.155***
	(4.30)	(5.44)	(3.07)	(4.94)
Sample Size	64,875	64,875	75,742	64,875
Adjusted-R^2	0.5335	0.5799	0.5209	0.5932

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Table I. Yield Spreads on Corporate Bonds

This table reports mean and median yield spreads in percentage points. We provide the breakdown by industry (Panel A), year (Pane B), rating (Panel C), and maturity (Panel D). Yield spreads are defined as the difference between the daily yield on the corporate bond and the constant maturity Treasury yield with the same time to maturity. To estimate the entire yield curve, we use a linear interpolation scheme from 1, 2, 3, 5, 7, 10, 20, and 30-year Treasury constant maturity rates. Following Campbell and Taksler (2003), we exclude the top and bottom 1% of yield spreads from our analysis.

	Noncallable Bonds			Callable Bonds		
	N	Mean	Median	N	Mean	Median
Panel A: Breakdown by Industry						
Industrial	39,715	2.667	1.374	17,229	5.070	3.606
Financial	89,947	2.123	0.997	68,788	3.366	2.007
Utility	4,505	2.160	1.305	2,256	2.708	2.346
Panel B: Breakdown by Year						
2003	10,519	0.937	0.762	540	3.608	2.733
2004	15,228	0.868	0.685	2,988	2.202	1.726
2005	25,801	1.405	0.776	12,886	2.813	1.962
2006	25,525	1.395	0.827	18,161	2.344	1.453
2007	20,956	1.586	1.147	19,407	2.216	1.611
2008	17,857	4.716	3.163	16,685	5.244	3.229
2009	18,281	5.158	3.313	17,606	6.089	3.552
Panel C: Breakdown by Rating						
AAA-AA	33,774	1.392	0.865	27,116	1.859	1.501
A-BBB	86,556	1.940	1.014	39,643	3.139	2.107
BB-B	11,528	5.346	3.957	17,278	5.601	4.371
CCC-D	2,309	13.046	9.208	4,236	12.608	9.937
Panel D: Breakdown by Maturity						
2-7 years	99,043	2.165	0.946	24,170	6.314	4.186
7-15 years	22,724	2.295	1.226	34,435	2.845	2.001
>15 years	12,400	3.233	2.157	29,128	2.440	1.830
Total	134,167	2.286	1.100	88,273	3.682	2.267

Table II. Summary Statistics

This table reports summary statistics on the bonds in our sample. Panel A provides summary statistics on noncallable bonds and Panel B provides summary statistics on callable bonds. *Yield spread* is defined as the difference between the daily yield on the corporate bond and the constant maturity Treasury yield with the same time to maturity. Following Campbell and Taksler (2003), we exclude the top and bottom 1% of yield spreads from our analysis. σ_r is measured as the standard deviation (in %) of the daily one-month Treasury constant maturity rate for the 12 months prior to the bond transaction date. *r* is the one-month Treasury constant maturity rate. *Slope* is the difference between the 10-year and 1-year Treasury constant maturity rates. *Rating* is assigned a cardinalized S&P rating, where AAA=1, . . . , D=22. σ_e is calculated as the standard deviation of daily excess returns over the CRSP value-weighted index using 252 daily returns prior to the bond transaction date. *Liquidity* is measured by dividing the number of *days* a bond traded for the 12 months prior to the bond transaction date by the number of business days during the corresponding period. *Maturity* is the bond's remaining time to maturity in years and *Coupon* is the bond's coupon rate in percent. *Long-term debt to assets* is measured by dividing long-term debt by total assets and *operating income to sales* is measured by dividing operating income before depreciation by net sales.

	N	Mean	St.Dev.	Min	Median	Max
Panel A: Noncallable Bonds						
Spread	134,167	2.28	3.54	0.10	1.10	39.80
σ_r	134,167	0.49	0.29	0.05	0.52	1.28
r (%)	134,167	2.59	1.78	0.00	2.60	5.27
Slope	134,167	1.20	1.21	-0.47	1.17	3.39
Rating	134,167	6.39	3.45	1.00	6.00	22.00
σ_e	115,697	1.79	1.63	0.46	1.24	15.36
Liquidity	87,940	0.50	0.33	0.00	0.47	1.00
Maturity (Year)	134,167	6.07	6.55	1.00	3.96	92.28
Coupon (%)	134,167	5.94	1.61	0.94	5.87	16.50
Long-Term Debt to Assets	104,282	0.22	0.16	0.00	0.18	1.55
Operating Income to Sales	104,282	0.18	0.94	-9.51	0.25	5.13
Panel B: Callable Bonds						
Spread	88,273	3.68	4.43	0.10	2.26	38.79
σ_r	88,273	0.55	0.30	0.05	0.55	1.28
r (%)	88,273	2.71	1.90	0.00	2.85	5.27
Slope	88,273	1.07	1.20	-0.45	0.72	3.39
Rating	88,273	7.12	4.95	1.00	6.00	22.00
σ_e	74,425	2.25	2.01	0.46	1.47	0.22
Liquidity	59,422	0.30	0.24	0.00	0.22	1.00
Maturity (Year)	88,273	12.42	7.08	1.00	11.38	87.28
Coupon (%)	88,273	6.17	1.33	0.25	5.85	14.00
Long-Term Debt to Assets	66,888	0.27	0.21	0.00	0.28	1.55
Operating Income to Sales	66,888	0.20	5.43	-421.43	0.26	5.13

Table III. Regressions of Noncallable Corporate Yield Spreads on Explanatory Variables
This table reports the pooled OLS regression results on noncallable bonds. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3	4
Intercept	-3.983***	3.040***	2.623***	2.601***
	(-4.84)	(5.81)	(4.99)	(3.66)
σ_r	**2.770*** **	**1.623*** **	**1.478*** **	**1.630*** **
	(7.36)	**(6.83)**	**(8.34)**	**(6.90)**
r		-1.2382***	-1.289***	-1.373***
		(-6.74)	(-7.04)	(-6.70)
Slope		-1.763***	-1.707***	-1.765***
		(-6.21)	(-6.99)	(-6.22)
Rating	0.293***	0.339***	0.331***	0.329***
	(4.93)	(5.20)	(4.79)	(5.09)
σ_e	0.914***	0.729***	0.989***	0.733***
	(6.69)	(4.73)	(4.12)	(4.78)
Liquidity	-0.188	-0.313*	-0.408***	-0.307*
	(-1.00)	(-1.81)	(-2.67)	(-1.80)
Maturity	0.005		0.002	0.003
	(0.53)		(0.20)	(0.35)
Coupon	0.100**		0.020	0.063
	(2.20)		(0.56)	(1.41)
Long-Term Debt to Assets	1.106 (1.16)	1.148 (1.25)		1.214 (1.30)
Operating Income to Sales	-0.620*** (-5.46)	-0.705*** (-6.27)		-0.713*** (-6.25)
Industrial	0.465**	0.493**	0.378	0.507**
	(2.04)	(2.19)	(1.54)	(2.31)
Financial	0.930***	0.960***	0.625**	1.043***
	(3.07)	(3.17)	(1.98)	(3.33)
Sample Size	64,875	64,875	75,742	64,875
Adjusted-R^2	0.5850	0.6130	0.5822	0.6136

Table IV. Regressions of Noncallable Corporate Yield Spreads for Different Time Periods and Different Credit Qualities

This table reports the pooled OLS regression results on noncallable bonds. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	Pre-Crisis	Crisis	Investment Grade Bonds	Junk Bonds
Intercept	-1.374***	1.421	3.330***	7.396**
	(-5.39)	(1.42)	(4.59)	(2.03)
$\sigma_{\boldsymbol{r}}$	**0.958****	**2.766*****	**1.361*****	**3.633*****
	(2.29)	**(4.89)**	**(9.90)**	**(2.94)**
r	-0.049	-2.578***	-1.115***	-3.976***
	(-0.75)	(-7.07)	(-8.55)	(-5.74)
Slope	-0.021	-2.546***	-1.452***	-5.406***
	(-0.40)	(-6.54)	(-6.49)	(-4.44)
Rating	0.196***	0.612***	0.140***	0.524***
	(3.77)	(7.83)	(3.94)	(4.37)
σ_e	0.393***	0.637***	0.684***	1.572***
	(2.90)	(3.20)	(4.74)	(6.13)
Liquidity	-0.144	-0.529**	-0.485***	-0.088
	(-1.57)	(-2.08)	(-3.56)	(-0.25)
Maturity	0.031***	-0.033	0.004	-0.002
	(10.24)	(-2.62)	(0.51)	(-0.08)
Coupon	0.026	0.115	0.056	0.146*
	(1.17)	(0.98)	(1.64)	(1.77)
Long-Term Debt to Assets	0.989* (1.67)	2.717 (1.59)	0.860 (1.38)	-1.706** (-2.09)
Operating Income to Sales	-0.810 (-1.32)	-0.730*** (-5.54)	-0.650*** (-6.98)	-0.155 (-0.98)
Industrial	0.206	1.474***	0.216**	1.499*
(relative to Utility)	(1.40)	(3.70)	(1.97)	(1.90)
Financial	0.710**	2.362***	0.506***	3.007***
(relative to Utility)	(2.46)	(3.82)	(2.83)	(3.47)
Sample Size	41,623	23,252	57,488	7,387
Adjusted-R^2	0.5185	0.6027	0.5983	0.6408

Table V. Regressions of Noncallable Corporate Yield Spreads with Fixed Effects

This table reports the pooled OLS regression results on noncallable bonds. We include fixed effects for each firm and 6 year dummies. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3
Intercept	3.440***	4.355***	3.800***
	(4.76)	(5.78)	(3.37)
σ_r	**1.565*** **	**1.683*** **	**1.743*** **
	(6.50)	**(4.36)**	**(4.39)**
r	-1.417***	-1.616***	-1.641***
	(-7.19)	(-7.95)	(-8.53)
Slope	-1.822***	-2.028***	-2.075***
	(-6.48)	(-7.03)	(-7.32)
Rating	0.440***	0.315***	0.452***
	(5.81)	(4.37)	(5.71)
σ_e	0.736***	0.785***	0.760***
	(4.47)	(4.35)	(3.43)
Liquidity	-0.483***	-0.205	-0.433***
	(-5.69)	(-1.27)	(-4.65)
Maturity	0.002	-0.004	-0.002
	(0.26)	(-0.54)	(-0.22)
Coupon	0.118***	0.009	0.114***
	(2.89)	(0.23)	(2.79)
Long-Term Debt to Assets	-2.242 (-1.64)	0.897 (0.95)	-2.206 (-1.42)
Operating Income to Sales	-0.574*** (-3.83)	-0.681*** (-5.90)	-0.577*** (-3.36)
Firm Fixed Effects	Yes	No	Yes
Year Dummies	No	Yes	Yes
Sample Size	64,875	64,875	64,875
F-Statistic	7,118.64	474.89	7,758.78

Table VI. Regressions of Changes in Noncallable Corporate Yield Spreads on Changes in Explanatory Variables

We regress monthly changes in the yield spreads of noncallable bonds on monthly changes in σ_r and monthly changes in other independent variables. We include fixed effects for each firm and 6 year dummies.The dependent variable is the difference in yield spreads between two consecutive months. σ_r is measured as the standard deviation of the daily one-month Treasury constant maturity rate for the one month (not the 12 months) prior to the bond transaction date. r is the one-month Treasury constant maturity rate. *Slope* is the difference between the 10-year and 1-year Treasury constant maturity rates. *Rating* is assigned a cardinalized S&P rating, where AAA=1, . . . , D=22. σ_e is calculated as the standard deviation of daily excess returns over the CRSP value-weighted index using one month of daily returns (not 252 daily returns) prior to the bond transaction date. *Liquidity* is measured by dividing the number of *days* a bond traded for the one month (not the 12 months) prior to the bond transaction date by the number of business days during the corresponding period. Δ denotes the first difference in each variable listed below. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3
Intercept	0.014**	-0.303***	-0.306***
	(2.03)	(-15.77)	(-4.43)
$\Delta\sigma_r$	**0.774*** **	**0.938*** **	**0.936*** **
	(5.89)	**(14.54)**	**(7.15)**
Δr	-0.287***	-0.192***	-0.192***
	(-4.79)	(-16.44)	(-3.91)
Δ Slope	-0.232***	-0.147***	-0.146**
	(-3.20)	(-4.83)	(-2.11)
Δ Rating	0.352	0.362***	0.358
	(1.10)	(5.77)	(1.12)
$\Delta\sigma_e$	0.196***	0.187***	0.188***
	(4.34)	(14.82)	(4.20)
Δ Liquidity	-0.334***	-0.328***	-0.330***
	(-8.19)	(-11.63)	(-8.54)
Firm Fixed Effects	Yes	No	Yes
Year Dummies	No	Yes	Yes
Sample Size	82,338	82,338	82,338
F-Statistic	15.95	186.34	33.41

Table VII. Regressions of Callable Corporate Yield Spreads on Explanatory Variables

This table reports the pooled OLS regression results on callable bonds. We include fixed effects for each firm and 6 year dummies. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3
Intercept	6.226***	10.806***	7.319***
	(4.74)	(4.37)	(3.99)
σ_r	**1.270***	**1.966****	**1.981****
	(1.90)	**(2.49)**	**(2.49)**
r	-2.224***	-2.133***	-2.167***
	(-5.07)	(-5.05)	(-5.22)
Slope	-2.618***	-2.722***	-2.799***
	(-5.79)	(-5.50)	(-5.77)
Rating	**0.687****	**0.455*****	**0.683****
	(2.52)	**(4.25)**	**(2.55)**
σ_e	**0.263**	**0.236**	**0.230**
	(0.97)	**(1.00)**	**(0.75)**
Liquidity	-1.091	0.177	-1.026
	(-1.46)	(0.23)	(-1.37)
Maturity	-0.061***	-0.076***	-0.061***
	(-5.46)	(-4.37)	(-5.74)
Coupon	0.344**	-0.319*	0.326**
	(2.23)	(-1.67)	(2.13)
Long-Term Debt to Assets	-3.519 (-0.75)	0.734 (0.59)	-5.260 (-1.03)
Operating Income to Sales	0.019*** (3.42)	0.006** (2.18)	0.017*** (2.71)
Firm Fixed Effects	Yes	No	Yes
Year Dummies	No	Yes	Yes
Sample Size	42,959	42,959	42,959
F-Statistic	20.99	33.20	37.85

Table VIII. Interaction Effects for Callable Bonds

This table reports the pooled OLS regression results on both noncallable and callable bonds. We use interaction terms between the determinants of call values and a callable dummy variable (*Call*) that takes the value 1 if the bond is callable. Junk is a dummy variable that takes the value 1 if the bond is a junk grade bond. We also include fixed effects for each firm and 6 year dummies. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	1	2	3	4
Intercept	4.225**	2.583**	5.513***	4.332***
	(2.43)	(2.09)	(4.75)	(3.21)
σ_r	1.959***	1.079***	1.356***	1.498***
	(3.58)	(4.64)	(3.54)	(4.20)
r	-1.810***	-1.286***	-1.406***	-1.445***
	(-6.74)	(-7.69)	(-8.84)	(-10.11)
Slope	-2.389***	-1.887***	-2.160***	-2.230***
	(-7.22)	(-6.12)	(-6.38)	(-6.88)
Rating	0.647***	0.565***	0.294***	0.568***
	(3.92)	(4.10)	(3.58)	(3.98)
σ_e	0.665**	0.906***	1.017***	0.925***
	(2.23)	(4.15)	(3.62)	(3.34)
Liquidity	-0.571***	-0.623***	-0.198	-0.572***
	(-3.09)	(-4.82)	(-0.98)	(-3.79)
Maturity	-0.571***	-0.006	-0.009	-0.010
	(-4.23)	(-0.80)	(-1.03)	(-1.36)
Coupon	-0.036**	0.100***	-0.010	0.097***
	(2.36)	(3.54)	(-0.23)	(3.91)
Long-Term Debt to	-3.032	-2.529	0.549	-3.050
Assets	(-0.93)	(-1.02)	(0.64)	(-1.15)
Operating Income to	-0.044	-0.019	-0.050	-0.022
Sales	(-0.35)	(-0.48)	(-0.83)	(-0.54)
Junk* σ_r		**3.828*** **	**4.625*** **	**3.866*** **
		(3.34)	**(3.33)**	**(3.31)**
Junk* *r*		-0.946***	-0.752***	-0.940***
		(-9.28)	(-8.60)	(-9.55)
Call	0.523***	3.939***	6.516***	3.212**
	(2.64)	(2.93)	(2.97)	(2.42)
Call* σ_r		**-0.729*** **	**-0.982*** **	**-0.804** **
		(-2.96)	**(-3.01)**	**(-2.55)**
Call* *r*		-0.735***	-0.655**	-0.584**
		(-2.60)	(-2.22)	(-2.01)
Call*Slope		-0.980***	-0.616	-0.665*
		(-2.79)	(-1.64)	(-1.71)
Call*Rating		**0.111** **	**0.132*** **	**0.112** **
		(2.21)	**(2.66)**	**(2.31)**
Call* σ_e		**-0.550** **	**-0.701** **	**-0.559** **
		(-2.14)	**(-2.25)**	**(-2.04)**
Call*Maturity		-0.048***	-0.047***	-0.042***
		(-3.67)	(-2.64)	(-3.83)
Call* Coupon		0.183**	-0.306	0.179**
		(2.17)	(-1.61)	(2.11)
Firm Fixed Effects	Yes	Yes	No	Yes
Year Dummies	Yes	No	Yes	Yes
Sample Size	107,834	107,834	107,834	107,834
F-Statistic	51.10	157.47	97.86	180.43

Table IX. Interaction Effects for High-Priced Callable Bonds

This table reports the pooled OLS regression results on callable bonds. We use interaction terms between the determinants of call values and a high-priced dummy variable (*HP*) that takes the value 1 if the bond price is greater than 100. We also include fixed effects for each firm and 6 year dummies. The dependent variable is the yield spread. t-statistics based on robust standard errors, clustered at the firm level, are reported in parentheses below estimated coefficients. *, **, and *** signify significance at the 10%, 5%, and 1% level, respectively.

	Call Protection Period	Callable Period
Intercept	5.438***	10.404**
	(4.31)	(2.59)
σ_r	0.879**	3.256**
	(2.37)	(2.49)
r	-1.262***	-2.598***
	(-6.97)	(-3.93)
Slope	-1.975***	-3.368***
	(-4.92)	(-4.18)
Rating	0.003	1.218***
	(0.02)	(7.48)
σ_e	0.526***	0.078
	(4.65)	(0.22)
Liquidity	0.167	-1.483
	(1.26)	(-1.24)
Maturity	-0.031***	-0.143***
	(-7.39)	(-4.18)
Coupon	0.242***	0.822***
	(3.26)	(3.94)
Long-Term Debt to	-7.473*	-37.580**
Assets	(-1.74)	(-2.50)
Operating Income to	4.244	2.286
Sales	(1.47)	(0.80)
HP* $\boldsymbol{\sigma_r}$	**-0.652*** **	**-2.599** **
	(-2.96)	**(-2.26)**
HP* *r*	0.476***	0.732
	(3.67)	(1.48)
HP*Slope	0.980***	1.036*
	(4.07)	(1.79)
HP*Rating	**-0.012**	**-0.252*** **
	(-0.92)	**(-3.19)**
HP* $\boldsymbol{\sigma_e}$	**-0.302*** **	**-22.437* **
	(-5.43)	**(-1.74)**
HP*Maturity	0.003	0.012
	(0.28)	(0.23)
HP* Coupon	-0.297***	-0.147
	(-2.72)	(-0.63)
Firm Fixed Effects	Yes	Yes
Year Dummies	Yes	Yes
Sample Size	14,976	19,059
F-Statistic	1,514.10	231.45

Figure I. Time-Series Variations in Interest Rate Volatility and Yield Spreads of Noncallable Bonds
This figure plots interest rate volatility and the mean yield spread of each month from 2003 to 2009. Interest rate volatility is measured as the standard deviation (in %) of the daily one-month Treasury constant maturity rate for the 12 months prior to the bond transaction date. Yield spreads are defined as the difference between the daily yield on the corporate bond and the constant maturity Treasury yield with the same time to maturity. To estimate the entire yield curve, we use a linear interpolation scheme from 1, 2, 3, 5, 7, 10, 20, and 30-year Treasury constant maturity rates.