THE JOURNAL OF FINANCE • VOL. LVIII, NO. 6 • DECEMBER 2003

Equity Volatility and Corporate Bond Yields

JOHN Y. CAMPBELL and GLEN B. TAKSLER*

ABSTRACT

This paper explores the effect of equity volatility on corporate bond yields. Panel data for the late 1990s show that idiosyncratic firm-level volatility can explain as much cross-sectional variation in yields as can credit ratings. This finding, together with the upward trend in idiosyncratic equity volatility documented by Campbell, Lettau, Malkiel, and Xu (2001), helps to explain recent increases in corporate bond yields.

DURING THE LATE 1990s, THE U.S. EQUITY and corporate bond markets behaved very differently. As displayed in Figure 1, stock prices rose strongly, while at the same time, corporate bonds performed poorly. The proximate cause of the low returns on corporate bonds was a tendency for the yields on both seasoned and newly issued corporate bonds to increase relative to the yields of U.S. Treasury securities. These increases in corporate–Treasury yield spreads are striking because they occurred at a time when stock prices were rising; the optimism of stock market investors did not seem to be shared by investors in the corporate bond market.

There are several reasons why the prices of corporate bonds might diverge from the prices of corporate equities. First, stock prices will increase if investors become more optimistic about future corporate profits. Optimistic expectations benefit stock prices much more than bond prices, since stockholders receive all residual profits, while corporate bondholders receive no more than the promised payments of principal and interest. This explanation does not account for the behavior of corporate bond yields in the late 1990s, however, because yield spreads on corporate bonds over Treasuries should fall, not rise, if investors become optimistic about corporate profits and thus reduce their expected probabilities of default. Second, there might be a composition effect if corporate bonds are issued by different companies than those that dominate value-weighted equity indexes. Third, an increase in the liquidity premium on corporate bonds relative to Treasury bonds might drive down corporate bond prices without any effect on equity prices. Fourth, the yields on newly issued corporate bonds might vary because of changes in the special features of these bonds, for example, an increase in the value of call provisions. Such an increase would drive down the prices and drive

*Campbell is with the Department of Economics, Harvard University, and NBER. Taksler is with Citigroup Global Markets. The views expressed are those of the author, not necessarily those of Citigroup Global Markets. The authors are grateful to Peter Hecht, Jeremy Stein, and an anonymous referee for helpful comments, and to Vardges Levonyan for able research assistance.

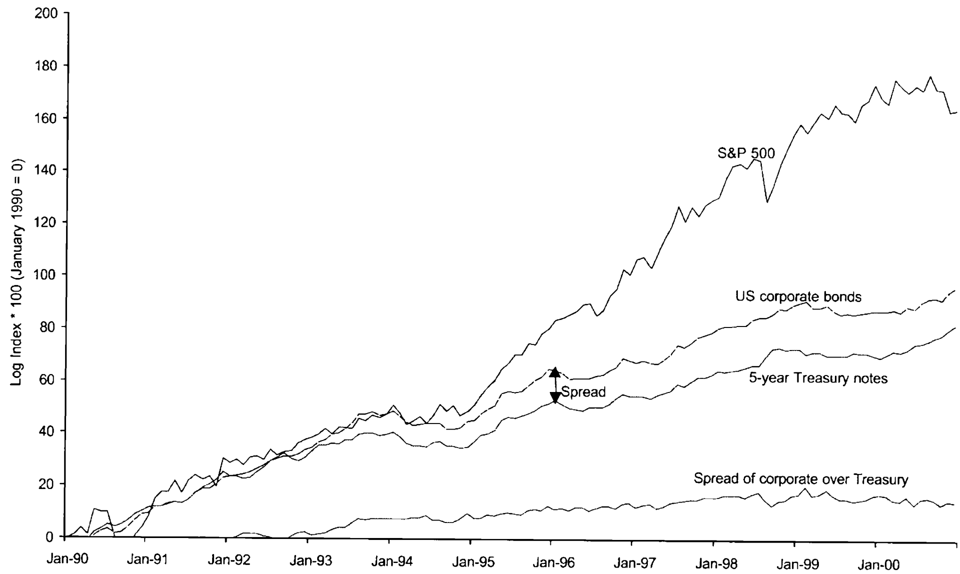

Figure 1. Monthly index comparisons, 1990 to 2000. Cumulative returns on the S&P 500 index, U.S. corporate bonds, and 5-year U.S. Treasury notes, from the Global Financial Database. Spread of corporate over Treasury is the difference between the cumulative returns on these two asset classes.

up the yields on newly issued bonds, but it would not have any effect on seasoned bond prices. Finally, volatility has opposite effects on stock and bond prices. Given expected profits, volatility of firm value hurts bondholders, because it increases the probability of default; it has a corresponding positive effect for equityholders. Thus, volatility should drive up the yields on both new and seasoned corporate bonds.

Merton (1974) initiated the modern analysis of corporate debt by pointing out that the holders of risky corporate bonds can be thought of as owners of riskless bonds who have issued put options to the holders of the firm's equity. When volatility increases, the value of the put options increases, benefiting equityholders at the expense of bondholders. The volatility that is relevant for option value, and thus for corporate debt, is *total* firm volatility, including both idiosyncratic volatility and systematic or market-wide volatility. This is important because idiosyncratic volatility can move very differently from market-wide volatility. In particular, Campbell et al. (2001) point out that idiosyncratic volatility has trended upwards since the mid-1970s, while market-wide volatility has undergone temporary fluctuations but no trend increase. The findings of Campbell et al. suggest that increasing idiosyncratic volatility could have depressed corporate bond prices and supported corporate equity prices, during the past few decades and during the late 1990s in particular.

The relevance of increasing idiosyncratic volatility is illustrated in Figure 2. This figure plots the average yield spread on A-rated corporate bonds, as reported by the credit rating agency Standard and Poor's (S&P), from January 1965

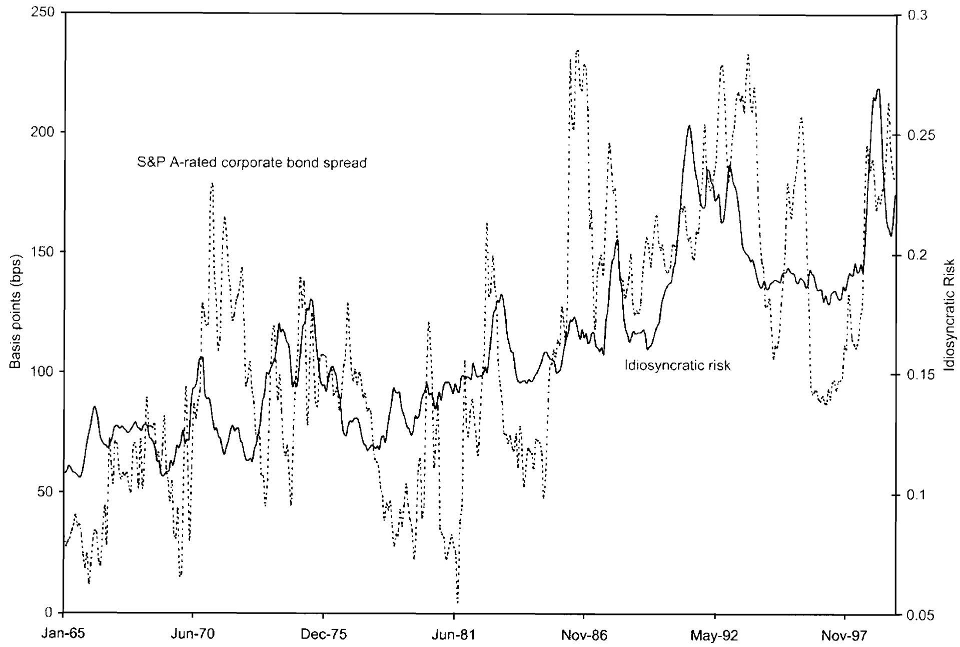

Figure 2. S&P A-rated corporate bond yield spread versus idiosyncratic risk. We plot the average yield spread on S&P A-rated corporate bonds and a 6-month backward moving average of idiosyncratic risk. Idiosyncratic risk is calculated from the monthly cross-sectional standard deviation of individual stock returns by Goyal and Santa-Clara (2003).

through December 1999. It also plots a six-month backward moving average of idiosyncratic volatility, calculated from monthly cross-sectional data on individual stock returns by Goyal and Santa-Clara (2003). The two series display a common upward trend and substantial correlation in their movements at intermediate frequencies; the correlation of the levels of the two series is about 0.7. The total volatility of a typical individual firm behaves in a similar fashion. The volatility of the market index, by contrast, has no upward trend and is much less closely related to the S&P corporate bond yield spread, with a correlation of only about 0.1.[1]

The purpose of this paper is to measure the causes of variation, across companies and over time, in corporate bond yield spreads. Specifically, we evaluate the volatility effect while controlling for three factors: composition effects, the demand for the liquidity provided by Treasury bonds, and special features of corporate bonds. We first study corporate bond pricing in a large panel data set, the Fixed Income Securities Database (FISD) on corporate bond characteristics,

[1] We note that average yield spreads reported by Moody's have a smaller upward trend and are about equally correlated with idiosyncratic volatility and market volatility. We discuss both the S&P and Moody's data in more detail in sections I and III below.

matched to the National Association of Insurance Commissioners (NAIC) database on bond transactions in the period 1995 to 1999. We present new evidence that equity volatility explains as much variation in corporate credit spreads as do credit ratings. Controlling for general factors such as the reference Treasury rate, issue size, years to maturity, and time-series dummies, we find that equity volatility and credit ratings each explain about a third of the variation in corporate bond yield spreads. This finding is robust to the use of issuer fixed effects. We also explore the longer-term time-series behavior of corporate bond yields, as summarized by S&P and Moody's yield indexes, and find that movements in idiosyncratic volatility help to explain these movements in average yields over time.

There is a large theoretical literature on the pricing of corporate bonds. This literature distinguishes between "structural" and "reduced form" models. In structural models, a firm is assumed to default when the value of its liabilities exceeds the value of its assets, in which case bondholders assume control of the company in exchange for its residual value. Black and Scholes (1973), Merton (1974), and Ingersoll (1977) are some of the classic papers in this area. More recently, Longstaff and Schwartz (1995) argue that the corporate yield spread should vary inversely with the benchmark Treasury yield, and they find evidence to support this prediction. Collin-Dufresne and Goldstein (2001) develop a structural model in which a firm can issue new debt, thereby increasing the risk of default and lowering the recovery rate in the event of default.

A difficulty with the structural approach is that investment-grade corporate bonds very rarely default. Elton et al. (2001) argue on this basis that expected default can account for only a small part of the yield spread for investment-grade corporate over Treasury bonds, while state taxes (which are payable on corporate interest but not on Treasury interest) are relatively much more important. Huang and Huang (2000) reach a similar conclusion.

Reduced form models, by contrast, assume exogenous stochastic processes for the default probability and the recovery rate. These models can allow for premia to compensate investors for illiquidity and systematic credit risk. They can be fit econometrically to data on swap spreads and corporate bond yields (Jarrow and Turnbull (1995), Duffie and Singleton (1997, 1999), Duffee (1999), Liu, Longstaff, and Mandell (2000)). The added flexibility of the reduced-form approach allows default risk to play a somewhat greater role in the pricing of corporate bonds.

Our paper undertakes a less structured econometric analysis, asking what observable variables are correlated with corporate bond yields cross-sectionally and over time. There are several other recent papers in a similar spirit. Collin-Dufresne et al. (2001) find that a single unobserved factor, common to all corporate bonds, drives most variation in credit spread changes. Kwan (1996) shows that changes in a firm's stock price are negatively correlated with contemporaneous and future changes in the yields of its bonds. Duffee (1998) shows that yield spreads vary more strongly with benchmark Treasury rates for callable bonds than for noncallable bonds. But these papers have done little to explore the effect of equity volatility on the cross-sectional variation, long-term time-series behavior or recent movements of corporate yield spreads. Our paper attempts to fill this gap in the academic literature.[2]

The remainder of the paper is organized as follows. Section I describes our panel data and the restrictions we impose on it. This section also examines trends in corporate bond spreads between 1995 and 1999. We find that, even after considering bonds without option-like features, credit spreads have been rising. However, this widening is not as large as would appear from the indexes produced by the credit rating agencies.

Section II links our data with equity and accounting data to investigate the link between equity volatility and corporate yield spreads. We present evidence that rising equity volatility dramatically raises the cost of borrowing. This effect is robust to a choice of a market model to define idiosyncratic volatility, the use of issuer fixed effects, and several other specification choices. This section also shows that the effect of volatility on corporate yield spreads is much stronger than would be predicted by the simple structural model of Merton (1974). Thus, our results pose another challenge to theorists; not only are corporate yield spreads higher on average than would be predicted by the Merton model, they are also more sensitive to movements in equity volatility.

Section III returns to the time-series data, using an updated version of the idiosyncratic volatility series of Campbell et al. (2001), provided to us by Goyal and Santa-Clara (2003). We show that equity volatility helps to explain the movements of corporate yield spreads over the past several decades, and particularly in the late 1990s. Section IV concludes.

I. Data Description

Our data come from the Fixed Investment Securities Database (FISD) and National Association of Insurance Commissioners (NAIC) transactions data. The FISD database (LJS Global Information Services, 2000) contains issue- and issuer-specific variables such as callability, credit ratings, and sector, on all U.S. corporate bonds maturing in 1990 or later. The NAIC database consists of all 1995 to 1999 transactions by life insurance companies, property and casualty insurance companies, and Health Maintenance Organizations (HMOs) as distributed by Warga (2000). This database is an alternative to the no longer available Warga (1998) database used by Duffee (1998), Blume, Lim, and MacKinlay (1998), Elton et al. (2000, 2001), Hecht (2000), and Collin-Dufresne et al. (2001).

According to the Flow of Funds accounts published by the Federal Reserve, insurance companies hold about one-third of outstanding corporate bonds. Thus, the NAIC database should be adequately representative of corporate bond transactions. Other important holders include foreign residents (15% to 20%),

[2] The financial press has been more sensitive to the relation between equity volatility and corporate bond spreads. For instance, in October 2000, the *Financial Times* wrote, "The increased volatility in the equity markets is another sign of the rising risks faced by companies, and bond investors are starting to re-price their investments." (Chaffin and Van Duyne, 2000, p. 25).

households (15%), pension and retirement funds (15%), mutual funds (5% to 10%), and commercial banks (5%).

We restrict our sample to fixed-rate U.S. dollar bonds in the industrial, financial, and utility sectors that are noncallable, nonputtable, nonsinking fund, and nonconvertible. To ensure that we consider bonds backed solely by the creditworthiness of the issuer, we exclude issues with asset-backed and credit-enhancement features. While this last restriction eliminates almost one-quarter of corporate debt issues reported in the Flow of Funds accounts, the yield spread on asset-backed bonds represents the creditworthiness of the collateral rather than the creditworthiness of the issuer. As such, we must exclude these issues.

Additionally, we only consider bonds whose average Standard and Poor's and Moody's credit rating lies between AA (Aa) and BBB (Baa). For bonds rated by only one of S&P or Moody's, we use that agency's credit rating. We eliminate AAA (Aaa) bonds because the NAIC data for these issues appear particularly problematic. For instance, in 1995 our data show the average spread for medium-term (7 to 15 year) AAA-rated bonds as 109 basis points above the closest benchmark treasury, which is higher than the 100 basis point spread for A-rated bonds. This problem is even more acute in the financial sector, where in 1995 and 1996, the data suggest that AAA-rated bonds yielded roughly 30 basis points more than BBB-rated bonds. Elton et al. (2000, 2001) find similar problems with AAA-rated bonds in their data set. These authors also remove AAAs from their samples.

We eliminate non-investment-grade (high-yield) debt, because insurance companies often limit, or altogether prohibit, their purchase of these issues. Additionally, for insurance companies in our sample, the National Association of Insurance Commissioners' Securities Valuation Office requires a modest reserve ratio of 1% for AAA-rated bonds and 2% for BBB or better-rated bonds, but this reserve ratio jumps to 5% for BB (non-investment-grade) debt. Since yield spreads are set by the market as a whole, which does not face NAIC reserve requirements, the spread on non-investment-grade debt is particularly unattractive to insurance companies. Non-investment-grade transactions in our database are likely to be unrepresentative of the general market.

As a final data screen, we eliminate the top and bottom 1% of spreads from our analysis to reduce apparent error in the NAIC data.[3] Removing all bonds with special features (call, put, sinking fund, asset-backed, convertible), floating rate coupons, non-investment-grade bonds, and bad data leaves us with approximately 52,000 different bond-month transactions.

A. Summary Statistics

We calculate the yield to maturity on each bond in the sample and its spread over the closest benchmark U.S. treasury in a particular month. For the benchmark Treasuries, we use the CRSP Fixed Term indexes, which provide monthly

[3] We explored several alternative cutoffs (0%, 2%, 5%, 10%, 20%, and 25%) before deciding on the 1% screen. The results of the paper are not particularly sensitive to the exact screen used.

yield data for notes and bonds of 1, 2, 5, 6, 10, 20, and 30 target years to maturity. Implicitly, we are assuming that each transaction occurs at the end of the month, when the CRSP Fixed Term indexes are published, but this should have little impact on the measured spread.

Table I summarizes the mean spread each year for the industrial, financial, and utility sectors, and for an aggregate of all three sectors. Following Duffee (1998), we also group the bonds by maturity, classifying them as short-term if they have 2 to 7 remaining years to maturity, medium-term if they have 7 to 15 remaining years to maturity, and long-term if they have 15 to 30 remaining years to maturity. We report results by credit rating, using the S&P rating scheme for notational convenience; thus we record a Moody's Aa as AA and Baa as BBB.

Table I shows that financials have the highest yield spreads, about 10 basis points higher than all sectors for medium-term bonds and 20 basis points higher for long-term bonds. There is no consistent pattern in the relative spreads on utilities and industrial bonds. Across sectors, A-rated bonds tend to yield about 20 basis points higher than AAs, and BBB-rated bonds yield 30 to 60 basis points higher than As. Yield spreads are considerably higher in 1998 and 1999 than in earlier years.

It is important to have a sense of the number of transactions in each category in our sample. We have 22,629 short-term, 14,503 medium-term, and 6,288 long-term transactions. About half the transactions in this sample are on bonds with an A credit rating and 30% to 40% on bonds with a BBB credit rating. The financial sector has the most transactions, and the utility sector the least. There are

Table I

Average Corporate Bond Yield Spreads

Using panel data between 1995 and 1999, we report corporate bond yield spreads, in basis points, over the closest benchmark Treasury by credit rating and years to maturity. All bonds are in U.S. dollars and have no callable features (call, put, sinking fund, convertibility).

	All sectors						
	AA	A	BBB	Total	Industrial Total	Financial Total	Utility Total
Panel A: Breakdown by Maturity, 1995–1999							
Short (2–7 years)	61	81	127	92	99	89	85
Medium (7–15 years)	76	99	145	112	117	109	102
Long (15–30 years)	94	118	163	135	133	144	130
Panel B: Breakdown by Year, All Maturities 2–30 Years							
1995–1999	70	92	140	105	112	99	96
1995	71	92	131	101	105	98	96
1996	56	67	97	75	78	72	73
1997	58	71	98	78	81	77	71
1998	80	111	167	127	137	119	116
1999	85	112	175	133	141	125	126

only 42 AA long-term utility transactions in the sample, as utility issues are typically lower rated.

B. Comparison with Credit Rating Agency Spreads

It is interesting to compare our data with the average corporate yield spreads reported by S&P and Moody's. In Figure 3, we plot the average spreads implied by our subset of the NAIC data along with the spreads reported by the rating agencies over the period since 1995 covered by the NAIC data. To make the figure easier to follow, we only plot A-rated bond spreads, but the results are similar for other rating categories. We see that the S&P index is often higher than the Moody's index, on the order of 80 to 100 basis points in late 1995 to 1996 and 30 to 50 basis points in late 1998 to 1999. This is partly accounted for by the greater weight of industrial issues in the S&P index. Our NAIC spreads are lower overall, which makes sense because the rating agencies include debt with callable features and we do not. Adding transactions for bonds with callable features back into the NAIC data brings our spreads slightly closer to the S&P and Moody's indexes.

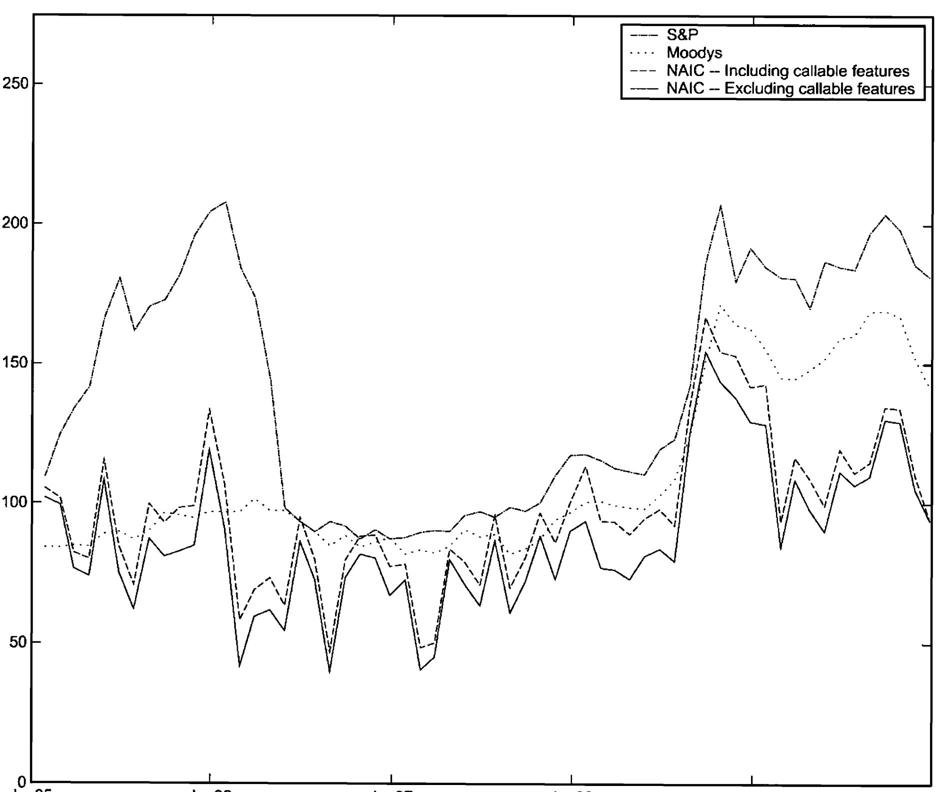

Figure 3. A-rated corporate bond yield spreads over U.S. Treasuries, 1995 to 1999. For A-rated corporate bonds, we compare the average yield spreads of S&P, Moody's, and a panel of corporate bonds traded by insurers between 1995 and 1999 (NAIC).

It is noteworthy that after the financial turmoil of the late summer of 1998, yield spreads in the NAIC data declined to precrisis levels by February 1999, whereas the rating agency spreads did not fall significantly. We do not have a good explanation for this; the exclusion of callable features from our NAIC series seems to account for only a small portion of the discrepancy. We leave further exploration of this topic to future research.

II. Equity Volatility and the Cross Section of Corporate Bond Yields

We now consider how an issuer's equity volatility influences the yield spread on its debt. In the simple framework of Merton (1974), corporate debt is a risk-free bond less a put option on the value of the firm's assets. The strike price equals the face value of the debt and reflects the limited liability of equityholders in the event of bankruptcy. A firm with more volatile equity is more likely to reach the boundary condition for default. Investors, recognizing this risk, should require additional compensation in the form of a higher yield spread over the risk-free rate. Importantly, this is true even if investors are risk neutral or default risk is idiosyncratic. Volatility affects the spread by changing the expected payoff on corporate debt, even if it does not change the expected return or risk premium on the debt.

To explore this effect, we use the NYSE, AMEX, and Nasdaq CRSP daily stock files for equity data and the COMPUSTAT annual full-coverage, industrial, and research files for accounting data. To ensure comparability of data, we adjust the COMPUSTAT fiscal year to the relevant calendar year. For each transaction, we consider the equity data for the 180 days prior to (not including) the bond trade and accounting data for the previous calendar year. This procedure ensures that all data are known to the market when a bond purchase or sale takes place. From our initial subset of the NAIC database, approximately 30,000 transactions are from publicly traded companies with available CRSP data in the transaction month. Further restricting to available COMPUSTAT data leaves us with about 22,000 transactions.

We run our regressions both with and without the credit rating on each bond. If both Moody's and Standard and Poor's rated an issue on a given transaction date, we use the average rating. If only Moody's or Standard and Poor's rated an issue, we consider that agency's rating.

We also consider accounting data because the meaning of a bond's credit rating is somewhat unclear. If credit ratings predict yield spreads, this tells us that credit rating agencies use relevant information effectively, but it tells us nothing about what information is relevant because only credit rating agencies know exactly what goes into a rating. If one is interested in the mapping from firm characteristics and market conditions to bond yields, it is more appropriate to consider the objective data that might go into a credit rating, such as financial leverage and other accounting ratios.

Specifically, we consider four accounting variables: pretax interest coverage, operating income to sales, long-term debt to assets, and total debt to capitalization.[4] These are similar to the measures used in Blume et al. (1998), Collin-Dufresne et al. (2001), and earlier papers (Pinches and Mingo (1973), Pogue and Soldofsky (1969)). High levels of the first two variables indicate financially healthy firms and are likely to produce a low yield spread. High levels of the second two variables indicate highly levered firms and imply a high yield spread. To conform with the underlying theory of contingent claims valuation, total debt to capitalization uses market (not book) value of equity as of 1 day prior to the bond transaction date.

Rather than measure interest coverage continuously, we break it into four groups. Blume et al. (1998) argue that a change in interest coverage from four to six (the means for BBB- and A-rated bonds, respectively) may result in a bond upgrade. A similar change from 20 to 22 would likely have no effect since the mean interest coverage for AAA-rated bonds is 13. We therefore anticipate that particularly low pretax interest coverage may convey more information about the risk of an issuer than high interest coverage. To account for this possibility, we create dummy variables to indicate whether pretax interest coverage is less than 5, between 5 and 10, between 10 and 20, or greater than 20.

To summarize firm-level risk and return, we compute the mean and standard deviation of daily excess returns, relative to the CRSP value-weighted index, for each firm's equity over the 180 days preceding (not including) the bond transaction date. Thus, we avoid estimating betas for individual firms on the market index, effectively imposing a beta of one (and an alpha of zero) in the market model. Campbell, Lo, and MacKinlay (1997, p. 156) call this a "market-adjusted-return" model. We also include the mean and standard deviation of daily market returns, where the market is defined as the CRSP value-weighted index over the same 180 days. We expect the standard deviation of daily excess returns to have a positive effect on yield spreads; the standard deviation of daily index returns may also have a positive effect to the extent that it influences the total standard deviation of firm returns. We expect recent past stock returns to have a negative effect on yield spreads, as documented by Kwan (1996).

We use the closest benchmark Treasury rate and the difference between the 10- and 2-year Treasury rates to describe the level and slope of the term structure, respectively. Longstaff and Schwartz (1995) argue that the expected sign on the level of the Treasury rate is negative, because a higher interest rate increases the drift of the risk-neutral process for the value of the firm. In turn, this lowers the risk-neutral probability of default and the corporate bond yield spread. Collin-Dufresne et al. (2001) reason that the slope of the term structure

[4] Similar to Blume et al. (1998), our accounting variables are as follows, with COMPUSTAT item numbers in parentheses. Pretax interest coverage is the ratio of [operating income after depreciation (178) + interest expense (15)] to [interest expense (15)]. Operating income to sales is [operating income before depreciation (13)] to [net sales (12)]. Long-term debt to assets is [total long-term debt (9)] to [total assets (6)]. Total debt to capitalization is [total long-term debt (9) + debt in current liabilities (34) + average short-term borrowings (104)] to [total liabilities (181) + market value of equity (from CRSP)]. Each COMPUSTAT variable is obtained as of the end of the previous calendar (not fiscal) year. The market value of equity is obtained as of 1 day prior to the bond transaction date.

provides a measure of uncertainty about the economy, as well as an expectation of future short rates.

We want to control for liquidity effects on corporate bonds relative to Treasury bonds. This is particularly important because the Asian, Long Term Capital Management, and Russian financial crises all occur during our sample period. To proxy the demand for liquidity, we include the difference between the 30-day Eurodollar and Treasury yields. The expected coefficient on this variable is positive, as a wider spread indicates a flight to quality or liquidity, which will increase the required compensation for holding corporate bonds (Longstaff (2002)). To proxy for cross-sectional differences in corporate bond liquidity, we include issue size in the regression. Following Elton et al. (2000), we also include the coupon rate because bonds with higher coupons are taxed more throughout the life of the bond, making them less desirable than bonds with lower coupons. Finally, we include 12 month dummies (January through December) to capture seasonal effects.

Our regressions proceed as follows. First, we report the results of ordinary least squares (OLS) regressions treating each transaction as an independent observation. Second, we remove pure cross-sectional variation in issuer quality by estimating fixed effects for each bond issuer. Third, we remove the time-series variation in average yields by replacing the 11 month dummies (February through December) with 59 monthly time dummies (February 1995 to December 1999). Once we have demonstrated that equity volatility helps to determine corporate bond yield spreads in each framework, we consider interaction effects and evaluate the robustness of the results in the next subsection.

Table II reports the results of OLS regressions. Coefficients are reported with t-statistics below them in parentheses, and bold face is used to indicate coefficients that are significant at the 0.1% level or better. We report the results for all sectors but reach similar conclusions for each individual sector. Odd numbered columns report results without equity volatility; even numbered columns repeat the regressions with equity volatility. One should interpret the coefficient estimates as follows. In column 2, if the standard deviation of daily excess returns rises by one percentage point, then the corporate bond spread rises by 222 basis points. If the standard deviation of annualized excess returns rises by one percentage point, then the corporate bond spread rises by $222/\sqrt{252} = 14$ basis points. Similarly, if the mean daily (annualized) index return increases by one percentage point, then the corporate bond spread falls by 105 (7) basis points.

Several observations are notable. First, including equity volatility raises the adjusted R-squared by 6 to 10 percentage points (even numbered columns minus odd numbered columns). The coefficient on the standard deviation of excess returns is highly significant with a t-statistic of 34–40. Both results suggest that volatility is an important determinant of corporate bond yield spreads.

Second, equity volatility matters at least as much as credit ratings. A regression of yield spreads on equity volatility (column 2) results in an adjusted R-squared nearly two percentage points higher than a regression of spreads on credit ratings (column 3). This observation makes sense because equity volatility

Table II

Explaining Corporate Bond Yield Spreads

Using panel data between 1995 and 1999, we regress corporate bond yield spreads over the closest benchmark Treasury against the variables listed below. Eleven month dummies are included in the regressions but omitted from this table. All equity data is for the 180 days preceding each bond trade. OLS t-statistics appear in parentheses. Bold denotes significance at the 0.1 percent level.

	Regression							
	1	2	3	4	5	6	7	8
Equity volatility								
Std. dev. of daily excess return (percent)		**221.81**		**189.16**		**238.14**		**199.24**
over preceding 180 days		**(39.42)**		**(34.52)**		**(39.93)**		**(34.00)**
Std. dev. of daily index return (percent)		29.17		46.07		7.24		36.44
		(1.52)		(2.49)		(0.38)		(1.96)
Mean daily excess return (percent)		**– 32.07**		**– 34.22**		**– 31.50**		**– 33.31**
		(– 15.13)		**(– 16.74)**		**(– 14.85)**		**(– 16.22)**
Mean daily index return (percent)		**– 105.03**		**– 102.92**		**– 108.66**		**– 104.88**
		(– 14.13)		**(– 14.37)**		**(– 14.69)**		**(– 14.65)**
Market capitalization relative to CRSP-value		**– 30.30**		**– 10.48**		**– 26.21**		**– 9.88**
weighted index (percent)		**(– 21.32)**		**(– 7.17)**		**(– 17.65)**		**(– 6.54)**
Credit ratings								
A or worse (relative to AA)			**17.74**	**13.37**			**17.91**	**13.18**
			(18.11)	**(13.98)**			**(18.17)**	**(13.65)**
BBB or worse (relative to AA)			**32.99**	**26.58**			**32.33**	**26.19**
			(43.52)	**(35.44)**			**(40.75)**	**(33.59)**
Accounting data								
Pretax interest coverage < 5					**8.65**	0.72	3.84	– 1.36
					(5.58)	(0.49)	(2.60)	(– 0.96)
5 ⩽ pretax interest coverage < 10					– 2.49	**– 6.52**	3.53	– 1.60
					(– 1.66)	**(– 4.63)**	(2.46)	(– 1.17)
10 ⩽ pretax interest coverage < 20					– 2.62	**– 7.97**	**5.57**	– 2.21
					(– 1.55)	**(– 4.97)**	**(3.45)**	(– 1.42)

Pretax interest coverage ⩾ 20					0.37	**– 12.86**	5.73	– 7.22
					(0.14)	**(– 5.09)**	(2.24)	(– 2.94)
Operating income to sales (percent)					**– 13.41**	**– 20.93**	**– 9.79**	**– 17.55**
					(– 4.85)	**(– 7.99)**	**(– 3.73)**	**(– 6.92)**
Long-term debt to assets (percent)					**31.18**	**19.46**	– 1.69	– 3.64
					(8.59)	**(5.72)**	(– 0.48)	(– 1.09)
Total debt to capitalization (percent)					**9.76**	**– 8.85**	**22.80**	5.86
					(3.61)	**(– 3.46)**	**(8.83)**	(2.34)
Macroeconomic and other variables								
Closest benchmark Treas. rate (percent)	**– 31.07**	**– 24.21**	**– 31.90**	**– 25.16**	**– 30.98**	**– 24.58**	**– 31.68**	**– 25.30**
	(– 38.41)	**(– 29.80)**	**(– 41.89)**	**(– 32.13)**	**(– 38.71)**	**(– 30.38)**	**(– 41.70)**	**(– 32.30)**
10 yr.–2 yr. Treasury (percent)	**– 12.77**	2.37	– 4.09	6.21	**– 9.12**	2.62	– 3.51	5.48
	(– 5.06)	(0.83)	(– 1.72)	(2.27)	**(– 3.64)**	(0.93)	(– 1.47)	(2.00)
30-day Eurodollar–Treasury (percent)	**25.28**	**12.53**	**24.52**	**12.34**	**25.18**	**12.41**	**24.34**	**12.29**
	(15.62)	**(7.48)**	**(16.11)**	**(7.64)**	**(15.75)**	**(7.45)**	**(16.04)**	**(7.62)**
Issue size (log)	**– 2.54**	0.47	0.01	0.51	**– 1.90**	0.43	0.28	0.60
	(– 6.17)	(1.15)	(0.04)	(1.30)	**(– 4.61)**	(1.04)	(0.71)	(1.50)
Years to maturity	**2.36**	**2.10**	**2.28**	**2.12**	**2.35**	**2.09**	**2.30**	**2.12**
	(47.29)	**(44.71)**	**(48.51)**	**(46.73)**	**(47.52)**	**(44.48)**	**(48.92)**	**(46.54)**
Coupon rate (percent)	**7.41**	**8.77**	**5.43**	**7.14**	**7.21**	**8.32**	**5.67**	**7.03**
	(22.64)	**(28.68)**	**(17.49)**	**(23.97)**	**(22.14)**	**(27.22)**	**(18.22)**	**(23.56)**
Industrial (relative to Utility)	**– 8.27**	**– 10.70**	**– 9.64**	**– 13.38**	– 1.57	**– 9.18**	**– 8.02**	**– 13.80**
	(– 5.03)	**(– 6.89)**	**(– 6.21)**	**(– 8.91)**	(– 0.95)	**(– 5.84)**	**(– 5.07)**	**(– 9.01)**
Financial (relative to Utility)	**– 7.88**	**– 10.19**	– 1.41	**– 4.97**	3.09	– 2.71	– 0.55	– 4.23
	(– 4.61)	**(– 6.38)**	(– 0.87)	**(– 3.21)**	(1.53)	(– 1.43)	(– 0.29)	(– 2.31)
Constant	**250.49**	**120.53**	**191.31**	**115.66**	**221.28**	**128.53**	**174.83**	**120.63**
	(26.73)	**(12.14)**	**(21.47)**	**(12.08)**	**(22.91)**	**(12.69)**	**(18.91)**	**(12.29)**
Number of transactions	21568	21568	21568	21568	21568	21568	21568	21568
Adjusted R^2	0.258	0.362	0.343	0.408	0.276	0.370	0.348	0.410
F	395.44	511.26	537.01	572.80	317.03	408.78	411.84	454.33

can reflect continuous information that distinguishes bonds with the same credit rating, as well as recent information that may not yet be reflected in a bond's credit rating.

Third, equity volatility and credit ratings may be used in tandem to better explain bond spreads. Including both variables in the regression (column 4) results in an adjusted R-squared five percentage points higher than volatility alone and seven percentage points higher than credit ratings alone. This result suggests that credit ratings capture some information that is not contained in volatility.

Fourth, credit ratings explain more of the yield spread than accounting data (columns 3–6). This is not surprising, because a credit rating is designed to convey information not contained elsewhere. Additionally, our accounting data is updated only at the close of the previous calendar year, while our credit ratings may be updated at any time. We note that total debt to capitalization results in the wrong sign (negative) in column 6.

Fifth, adding accounting variables on top of credit ratings (columns 7 and 8) does not meaningfully raise the adjusted R-squared over credit ratings alone. The accounting variables generally have the expected signs when significant, with the exception of pretax interest coverage, which takes the wrong sign (positive) in column 7.

Sixth, the estimated coefficient on the standard deviation of daily excess returns is much larger than the coefficient on the standard deviation of daily index returns. This might seem surprising, since what matters in a contingent claims model is the total risk of the firm. Note, however, that we include standard deviations, not variances, in the regression, so total risk does not equal the sum of idiosyncratic and market risk. Also, we are using lagged measures of risk to proxy for expectations of future risk. Campbell et al. (2001) find that movements in idiosyncratic risk are more persistent than movements in market risk, which would imply that lagged idiosyncratic risk should receive a greater weight in predicting future risk. Finally, the regression includes other independent variables that are strongly correlated with market risk; for example, the closest benchmark Treasury rate and the standard deviation of daily index returns have a correlation of about $-2/3$.

The explanatory power of recent equity returns and volatility, as compared with credit ratings, makes good sense. All data going into a credit rating should be captured in the equity price. Equity markets reflect up-to-date information, whereas credit ratings may be revised infrequently and with a lag. In the extreme, Ederington, Yawitz, and Roberts (1987) argue that investors fully anticipate rating changes and rating changes almost never affect bond returns. Since one might view equity as junior debt, where a dividend is paid only when the firm does not default, equity investors should take into account default probabilities, recovery rates, and relevant accounting ratios. From this standpoint, the only thing surprising about the link between equity volatility and bond spreads is that it has attracted so little attention from empirical researchers.

At this point we have shown that yield spreads vary directly with equity volatility across companies. If General Motors' (GM) equity is less volatile than Ford's, then GM faces a lower yield spread than Ford. We now consider the pattern within a single company. Within GM, is the yield spread on GM debt lower when GM's equity is less volatile?

The answer is yes, as reported in the first two columns of Table III. In this table we continue to report *t*-statistics for equity volatility, but to save space we report only coefficients for control variables. We continue to use bold face to denote statistical significance of a coefficient at the 0.1% level. The table applies fixed effects to each of our 581 bond issuers and finds similar results to the basic OLS regressions. The coefficient on the standard deviation of daily excess returns is almost unchanged. The *t*-statistic is smaller but still highly significant, despite a marked increase in the coefficient and significance of the total debt to capitalization accounting variable. While not reported in this table, it is also noteworthy that equity volatility continues to explain more of the yield spread than do credit ratings alone.

One potential objection is that the regressions may simply be picking up time-series variation in the data. To address this concern, columns 3 and 4 of Table III consider the same regressions, but replace the seasonal dummies (February to December) with monthly time dummies between February 1995 and December 1999. Once again, the results are substantially similar (and are not sensitive to the inclusion of issuer fixed effects).

The monthly time dummies represent unexplained time-series variation in average corporate yield spreads. If we compare the monthly time dummies from a regression of yield spreads on credit ratings and accounting variables (Table III, column 3) with the dummies from a regression that also includes equity volatility (Table III, column 4), we find that the latter dummies have a mean closer to zero and a smaller standard deviation (20 basis points rather than 22). This shows that equity volatility captures some of the time-series variation that otherwise would be left to dummy variables.

Finally, to ensure the reasonableness of our standard errors, we run a cross-sectional regression each month and calculate Fama–MacBeth (1973) estimates and standard errors. The coefficient on the standard deviation of daily excess returns over the preceding 180 days is 126 with a *t*-statistic of 13, so our results remain highly significant with this conservative approach to estimation and inference.

A. Interaction Effects

We have demonstrated that equity volatility helps to determine corporate bond yield spreads in the cross section. There remains the question of how the firm's capital structure interacts with other determinants of the yield spread. We consider three interactions: total debt to capitalization with equity volatility, long-term debt to assets with equity volatility, and long-term debt to assets with the closest benchmark Treasury rate.

The ratios of total debt to capitalization and long-term debt to assets may influence the strength of the volatility effect, because investors may regard a company with almost no debt as unlikely to default even when the issuer's equity is highly volatile. Simply put, a firm is unlikely to go bankrupt over a small amount of debt. On the other hand, a company with relatively high debt and particularly

Table III

Regressions with Issuer Fixed Effects

Using panel data between 1995 and 1999, we regress corporate bond yield spreads over the closest benchmark Treasury against the variables listed below. We include fixed effects for each bond issuer and either 11 month dummies or 59 monthly time dummies. All equity data is for the 180 days preceding each bond trade. The values for *t*-statistics appear in parentheses. Bold denotes significance at the 0.1 percent level.

	Regression			
	1	2	3	4
Issuer fixed effects	Yes	Yes	Yes	Yes
Eleven month time dummies	Yes	Yes	No	No
Fifty-nine monthly time dummies	No	No	Yes	Yes
Equity volatility				
Std. dev. of daily excess return (percent) over preceding 180 days		**200.20**		**91.04**
		(27.26)		**(11.25)**
Std. dev. of daily index return (percent)		5.50		
		(0.29)		
Mean daily excess return (percent)		**– 15.57**		**– 14.57**
		(– 7.00)		**(– 6.71)**
Mean daily index return (percent)		**– 110.78**		
		(– 16.37)		
Market capitalization relative to CRSP-value wghtd. index (percent)		– 1.72		– 9.74
		(– 0.40)		(– 2.33)
Credit ratings				
A or worse (relative to AA)	**9.82**	**6.68**	0.44	1.26
BBB or worse (relative to AA)	**18.46**	**15.49**	**15.89**	**15.39**
Accounting data				
Pretax interest coverage < 5	1.00	– 2.68	0.22	– 1.57
5 ⩽ pretax interest coverage < 10	– 5.35	– 7.87	– 2.60	– 4.36
10 ⩽ pretax interest coverage < 20	– 5.03	– 8.96	– 4.40	– 6.37
Pretax interest coverage ⩾ 20	– 2.90	– 9.78	4.53	– 1.02
Operating income to sales (percent)	– 20.89	– 32.33	– 25.69	**– 32.42**
Long-term debt to assets (percent)	14.03	– 10.14	**– 37.12**	– 27.67
Total debt to capitalization (percent)	**110.61**	**85.98**	**102.07**	**77.34**
Macroeconomic and other variables				
Closest benchmark Treas. rate (percent)	**– 32.95**	**– 26.95**	**– 24.33**	**– 25.00**
10 yr.–2 yr. Treasury (percent)	1.73	5.13		
30-day Eurodollar–Treasury (percent)	**22.75**	**11.45**		
Issue size (log)	**2.80**	**2.16**	1.15	1.17
Years to maturity	**2.36**	**2.26**	**2.20**	**2.22**
Coupon rate (percent)	**5.21**	**6.03**	**6.23**	**6.22**
Constant	**122.01**	**93.89**	**160.73**	**161.82**
Number of transactions	21568	21568	21568	21568
Number of issuers	581	581	581	581
R^2 within	0.289	0.337	0.385	0.391
R^2 between	0.323	0.437	0.405	0.486
R^2 overall	0.257	0.336	0.340	0.392
F	327.33	342.99	184.75	181.61

volatile equity is at particularly high risk of bankruptcy, and this risk should be reflected in a higher yield spread.

The benchmark Treasury rate is also relevant for a firm with long-term debt. A higher Treasury rate increases the nominal return on potential investments, but the nominal interest cost of long-term borrowing stays the same because the firm already has issued bonds at a fixed rate of interest. Equivalently, a higher Treasury rate reduces the market value of liabilities more than the market value of assets. From either perspective, an increase in the Treasury rate should reduce the probability of default for a firm with high long-term debt. The effect of the Treasury rate should be weaker for a firm with medium- and short-term liabilities, since a higher Treasury rate raises the cost of rolling over short-term debt and, therefore, has little effect on the market value of the firm's liabilities.

Table IV explores these interaction effects using OLS and the same reporting conventions as Table III. We break the interaction variables into approximate

Table IV

Interaction Effects

Using panel data between 1995 and 1999, we regress corporate bond yield spreads over the closest benchmark Treasury against the variables listed below. Eleven month dummies are included in the regressions but omitted from this table. All equity data is for the 180 days preceding each bond trade. OLS *t*-statistics appear in parentheses. Bold denotes significance at the 0.1 percent level.

	Regression and Interaction Variable			
	1 Long-term debt to assets	2 Long-term debt to assets	3 Total debt to capitalization	4 Total debt to capitalization
Interaction effects				
Std. dev. excess return*		**105.37**		**62.30**
(1/10 ⩽ Interaction variable < 1/4)		**(7.56)**		**(4.33)**
Std. Dev. excess return*		**103.75**		**108.85**
(1/4 ⩽ Interaction variable < 1/3)		**(6.61)**		**(6.60)**
Std. Dev. excess return*		**135.33**		**109.35**
(Interaction variable ⩾ 1/3)		**(8.72)**		**(7.63)**
Treasury rate* (1/10 ⩽ Long-term	**−5.74**	−1.30		
debt to total assets < 1/4)	**(−3.91)**	(−0.88)		
Treasury rate* (1/4 ⩽ Long-term	−2.96	1.26		
debt to total assets < 1/3)	(−1.84)	(0.77)		
Treasury rate* (Long-term debt	**−7.00**	−2.99		
to total assets ⩾ 1/3)	**(−4.03)**	(−1.73)		
Equity volatility				
Std. dev. of daily excess return (percent) over preceding 180 days		**91.01**		**106.81**
Std. dev. of daily index return (percent)		54.37		50.79

continued

Table IV
(continued)

	Regression and Interaction Variable			
	1 Long-term debt to assets	2 Long-term debt to assets	3 Total debt to capitalization	4 Total debt to capitalization
Mean daily excess return (percent)		**−32.75**		**−31.26**
Mean daily index return (percent)		**−103.34**		**−104.71**
Market capitalization relative to CRSP-value weighted index (percent)		**−12.29**		**−12.81**
Credit ratings				
A or worse (relative to AA)	**17.96**	**13.11**	**17.63**	**13.26**
BBB or worse (relative to AA)	**31.77**	**25.65**	**32.31**	**26.05**
Accounting data				
1/10 ≤ Interaction variable < 1/4	**35.73**	−11.79	0.26	**−11.86**
1/4 ≤ Interaction variable < 1/3	12.41	−31.60	1.99	**−21.89**
Interaction variable ≥ 1/3	**39.20**	−11.70	**17.18**	**−11.95**
Pretax interest coverage < 5	0.36	−2.50	0.67	**−6.02**
5 ≤ pretax interest coverage < 10	−1.59	**−4.20**	1.03	**−6.60**
10 ≤ pretax interest coverage < 20	−0.42	**−5.05**	1.22	**−7.06**
Pretax interest coverage ≥ 20	0.93	**−8.65**	0.07	**−11.66**
Operating income to sales (percent)	−6.95	**−13.35**	−2.63	**−14.61**
Long-term debt to assets (percent)			**−10.95**	**−10.95**
Total debt to capitalization (percent)	**27.40**	**12.36**		
Macroeconomic and other variables				
Closest benchmark Treas. rate (percent)	**−27.71**	**−24.76**	**−31.58**	**−25.21**
10 yr.–2 yr. Treasury (percent)	−3.15	6.13	−3.47	5.73
30-day Eurodollar–Treasury (percent)	**24.42**	**12.85**	**24.33**	**12.55**
Issue size (log)	−0.19	0.08	−0.22	0.27
Years to maturity	**2.29**	**2.09**	**2.28**	**2.09**
Coupon rate (percent)	**5.55**	**6.84**	**5.66**	**6.88**
Constant	**158.16**	**136.18**	**183.31**	**137.93**
Number of transactions	21568	21568	21568	21568
Adjusted R^2	0.348	0.410	0.351	0.410
F	372.96	384.58	418.03	417.95

quartiles: less than 10%, 10 to 25%, 25% to one-third, and greater than one-third. While the relationship is not monotonic, it does appear that equity volatility is more important for firms with high long-term debt to assets and high total debt to capitalization. Similarly, the impact of the Treasury rate is stronger on firms with high ratios of long-term debt to assets. Even allowing for interaction effects, equity volatility continues to be an important determinant of bond yield spreads, as evidenced by a higher adjusted R^2 statistic in columns 2 and 4. These results are not sensitive to the inclusion of issuer fixed effects or time dummies.

B. Robustness Checks

We now address the robustness of our findings. We first consider changes in the definition of idiosyncratic volatility and the number of days used to calculate it. For each bond transaction, we estimate a market model on the preceding 180 calendar days of the issuer's equity. From this, we multiply the daily index return by beta (dropping the implicit assumption of the earlier market-adjusted-return model that beta equals one) and calculate the idiosyncratic return and its standard deviation. We rerun this procedure using 90, 270, and 360 calendar days of the issuer's equity. The results are robust to these changes. To save space, we do not report them in detail here, but they can be found in the NBER Working Paper version of this paper (Campbell and Taksler, 2002). Idiosyncratic risk takes on a t-statistic of about 35 to 40 in the OLS regressions, 25 to 30 in the issuer fixed-effects regressions, and 10 in the issuer fixed-effects regressions with monthly time dummies. The coefficient on equity volatility using 180 or more days of data exceeds that of 90 days, suggesting that a fairly long time window is needed to measure the volatility that is relevant to corporate bond investors.

As a further test of our results, we follow the procedure of Elton et al. (2001) to eliminate coupon effects from corporate bond yields. Elton et al. suggest that, because arbitrage arguments hold with zero-coupon spot rates, it makes sense to model zero-coupon yields from a coupon-paying corporate bond and the corresponding Treasury. This modeling procedure involves separating out bonds by month, sector, and credit rating to fit 540 yield curves (60 months $\times$ 3 sectors $\times$ 3 credit ratings), using the estimation method of Nelson and Siegel (1987) outlined in Appendix A.

For each month, we estimate the price of a corporate bond as fit by the Nelson–Siegel procedure for that bond's sector and credit rating. Following Elton et al., we compare this price with the actual price, eliminating observations where the difference is $5 or more. We then transform prices into yields to maturity and calculate the actual yield less the estimated yield. Within each sector and credit rating, we regress this yield difference on equity volatility, plus or minus credit ratings, and state variables. The expected sign on a plus (minus) credit rating is negative (positive). For example, an A+ bond should have a lower yield spread than the spread that is fitted to all bonds with A+, A, and A− ratings.

Table V presents illustrative results for industrial bonds in columns 1 through 3. The drastic reduction in R-squared is not surprising, since we have subtracted out all variation across sectors and credit ratings and over time by calculating deviations from the fitted Nelson–Siegel yields. Idiosyncratic volatility remains highly significant for bonds rated A or below.

To see how much difference the Nelson–Siegel method makes, columns 4 through 6 of Table V run the same regressions using actual bond yield spreads for each sector and credit rating. We include 59 monthly time dummies to account for the subtraction of time-series variation in the Nelson–Siegel estimation procedure. The results are very similar to those in columns 1 through 3. This leaves us with two additional results. First, equity volatility affects corporate bond yields even within relatively homogeneous groups of bonds in the same sector

Table V

Regressions with Nelson–Siegel Yield Spreads

Using panel data between 1995 and 1999, we regress two measures of industrial corporate bond yield spreads against the variables listed below. In columns 1 to 3, we model the price of each bond following Nelson and Siegel (1987) and regress the corresponding actual minus estimated yield spread against the variables listed below. In columns 4 to 6, we regress actual corporate bond yield spreads over the closest benchmark Treasury against the variables listed below plus 59 monthly time dummies. All equity data is for the 180 days preceding each bond trade. OLS *t*-statistics appear in parentheses. Bold denotes significance at the 0.1 percent level.

	Dependent variable					
	Actual minus estimated yield spread for each credit rating			Actual yield spread over Treasury for credit rating		
	AA 1	A 2	BBB 3	AA 4	A 5	BBB 6
Equity volatility						
Std. dev. of daily excess return	23.26	**67.83**	**73.74**	60.83	**68.32**	**96.75**
(percent)	(1.09)	**(8.34)**	**(9.92)**	(2.26)	**(7.08)**	**(11.13)**
Std. Dev. of daily index return	– 32.84	**– 63.23**	**– 110.10**	– 219.52	**– 618.21**	– 467.79
(percent)	(– 1.18)	**(– 4.11)**	**(– 5.60)**	(– 0.84)	**(– 4.42)**	(– 2.71)
Mean daily excess return	3.75	**– 11.46**	**– 26.95**	0.04	**– 11.51**	**– 31.68**
(percent)	(0.69)	**(– 4.46)**	**(– 9.50)**	(0.01)	**(– 4.03)**	**(– 10.13)**
Mean daily index return	3.89	– 6.82	– 13.62	– 40.01	– 34.08	– 52.07
(percent)	(0.30)	(– 1.01)	(– 1.54)	(– 0.91)	(– 1.64)	(– 1.88)
Credit ratings						
Plus rating* Years to maturity	0.48	**– 1.81**	**– 1.26**	1.15	**– 1.44**	**– 0.71**
Minus rating* Years to maturity	0.50	**0.79**	**1.48**	**0.85**	**1.12**	**2.18**
S&P stronger than Moody's	– 2.29	– 1.24	1.32	– 0.27	– 0.04	3.13
Moody's stronger than S&P	5.33	– 3.89	– 0.58	5.90	– 3.56	0.88
Other variables						
Coupon rate (percent)	**3.07**	**3.81**	**3.31**	1.69	**1.86**	1.53
Age less than one year	– 3.60	– 1.29	2.11	– 1.19	0.89	**6.02**
Constant	**– 27.67**	**– 34.54**	**– 36.29**	55.09	**103.43**	**100.78**
N	784	3338	2844	784	3338	2844
Adjusted R^2	0.043	0.121	0.117	0.454	0.541	0.630
F	4.53	47.05	38.63	10.57	58.80	72.07

with the same credit rating. Second, it is not clear that an analysis of corporate bond yield spreads must measure spreads in relation to a zero-coupon curve. We obtain very similar results whether we use the Nelson–Siegel methodology or not.

To summarize, our analysis suggests that equity volatility is an important determinant of corporate bond yield spreads. In the cross section, volatility can explain as much of the yield spread as can credit ratings. This finding continues to hold when we include fixed effects for each bond issuer and when we control for monthly time-series variation. Equity volatility is particularly important for firms with a high ratio of long-term debt to assets. These results are robust to the use of a market model with an estimated beta, the use of a longer or shorter time window to estimate volatility, and the use of the Nelson–Siegel method to adjust for the slope of the term structure.

C. The Volatility Effect and Contingent Claims Analysis

At this point, one might ask how our results compare with the predictions of a standard contingent claims model. To answer this question, we turn to Merton (1974), who derives a formula for the credit spread based on an issuer's leverage, volatility, a bond's years to maturity, and the risk-free rate. We make the simplifying assumption that the volatility of a firm is determined solely by its equity (not debt). Then, using the mean value of the input parameters for each of our 581 issuers, we compute the partial derivative of the credit spread with respect to equity volatility. Appendix B outlines the estimation procedure.

A key step in applying the Merton contingent claims model is deriving the volatility of an issuer's total value from the volatility of its equity. We use two extremes, neither realistic, to obtain a range of predictions of the model. We use these extremes simply to provide a crude comparison between our results and those of structural models, in the hope that this will stimulate further research on the subject. Jones, Mason, and Rosenfeld (1984) link issuer volatility to equity volatility in a more careful manner.

First, we calculate asset volatility under the assumption that corporate debt is riskless (an assumption that is inconsistent with a model of risky debt). Using this procedure, we are able to explain about 10% of the actual change in spread due to equity volatility. For each one percentage point increase in annualized total volatility, the contingent claims model suggests a mean increase in yield spread of 1.64 basis points. Regressing the actual credit spread on annualized total volatility in the NAIC data set gives a coefficient of 16.00. For comparison, the contingent claims model explains about 27% of the level of actual spreads in our database (a theoretical mean of 39 basis points, compared to an actual mean of 141 basis points).

Alternatively, we assume that corporate debt is very risky, setting the proportional volatility of an issuer's bonds equal to the volatility of its stock. Using this procedure, we are able to explain about 22% of the actual change in spread due to equity volatility (a contingent claims partial derivative of 3.46 divided by a regression coefficient of 16.00). For comparison, the contingent claims model now overstates the level of actual spreads, with a theoretical mean of 168 basis points compared to the actual mean of 141 basis points.

These results leave us with a puzzling mismatch between our econometric results and the predictions of a standard structural model. An important topic for future research will be to develop structural models in which equity volatility has a larger effect on corporate bond yields, perhaps through jumps in firm value or a risk premium on systematic credit risk.

III. Equity Volatility and the Time Series of Corporate Bond Yields

We now explore the longer-term time-series behavior of corporate bond yield spreads, as summarized by the Standard and Poor's and Moody's yield indexes. Our motivation is straightforward. First, our cross-sectional data set is limited in that it restricts our analysis to the years 1995 to 1999. The importance of equity volatility may be an aberration of the late 1990s that does not apply to earlier years. Second, Campbell et al. (2001) point out that idiosyncratic volatility has trended upwards since the mid-1970s, while market-wide volatility has undergone temporary fluctuations but no trend increase. These findings suggest that increasing idiosyncratic volatility could have depressed corporate bond prices yet supported equity prices during the late 1990s. A longer time series of data allows us to analyze this hypothesis.

To measure corporate bond yields, we use the S&P and Moody's A-rated bond yield indexes over the period 1963 to 1999. These two indexes move in a similar fashion, with a noticeable tendency to increase when the stock market is weak or volatile, as in the mid-1970s, the early 1980s, and the period around the stock market crash of 1987. However, S&P reports higher yields than Moody's during the 1990s and therefore S&P yield spreads show a stronger tendency to increase over the 1963 to 1999 period. This is partially accounted for by S&P's greater weight on industrial issues.

To measure idiosyncratic volatility, we use an updated version of the idiosyncratic volatility series of Campbell et al. (2001), estimated from the cross-sectional dispersion of monthly stock returns and provided to us by Goyal and Santa-Clara (2003). We calculate a 6-month moving average of both market and idiosyncratic risk, proxying for the 180 days of firm-level equity data used in the previous section. To control for aggregate leverage, we use the aggregate ratio of corporate bonds to assets as reported by the Flow of Funds accounts. As a measure of liquidity, we include monthly debt turnover in U.S. Government securities, provided to us by Fleming (2000).[5]

Table VI reports regression results for the S&P A-rated corporate bond index in columns 1 through 3, and for the Moody's index in columns 4 through 6. (We find similar results if we use an equal-weighted index of AAA, AA, A, and BBB-rated issues.) The coefficient on idiosyncratic risk is smaller in the time series than in our earlier cross-sectional regressions, but is significant in column 2 for both indexes, with a t-statistic of about 19 for S&P and 4 for Moody's. When we add aggregate leverage and debt turnover to the regression (column 3), debt turnover has the wrong sign (positive), and only the S&P coefficient remains significant. Recalling the stronger upward trend of the S&P data, it is interesting to note that the adjusted R-squared on the regression without equity volatility is about 30 percentage points higher for S&P than for Moody's. With equity volatility, the adjusted R-squared for S&P is 50 to 55 percentage points higher than for Moody's.

[5] The Flow of Funds accounts report equity at market value, although debt is measured at book value. The definition of debt turnover is the daily average of the total volume of dealer transactions in U.S. Government securities, as reported to the Federal Reserve Bank of New York, relative to marketable debt.

Table VI

Explaining Time-Series Variation in Corporate Yield Spreads

Using a time series between January 1963 and December 1999, we regress the Standard and Poor's and Moody's A-rated corporate bond yield spreads against a six-month moving average of idiosyncratic and market risk. OLS t-statistics appear in parentheses. Bold denotes significance at the 0.1 percent level.

	Standard and Poor's (S&P)			Moody's		
	1	2	3	4	5	6
Equity volatility						
Idiosyncratic risk		**9.15**	**5.56**		**2.58**	1.32
		(19.19)	**(9.13)**		**(3.66)**	(1.34)
Market risk		14.86	51.04		**174.10**	**179.94**
		(0.48)	(1.78)		**(3.77)**	**(3.89)**
Macroeconomic and other variables						
10-year Treasury rate (percent)	0.36	**− 2.42**	**− 8.44**	**5.51**	**4.42**	**5.41**
	(0.42)	**(− 3.75)**	**(− 9.30)**	**(5.73)**	**(4.63)**	**(3.70)**
10-year minus 2-year Treasury (percent)	**49.98**	**29.37**	**22.87**	**11.41**	6.06	4.83
	(16.20)	**(11.68)**	**(9.56)**	**(3.29)**	(1.63)	(1.26)
Aggregate ratio of corporate bonds to assets (percent)			**3.01**			− 1.37
			(6.65)			(− 1.87)
Debt turnover (percent)			**5.88**			4.88
			(5.35)			(2.76)
Constant	**0.81**	**− 0.40**	**− 0.30**	**0.60**	0.21	**0.51**
	(11.82)	**(− 5.00)**	**(− 3.20)**	**(7.83)**	(1.82)	**(3.36)**
Number of observations	444	444	444	444	444	444
Adjusted R^2	0.370	0.661	0.719	0.086	0.145	0.159
F	131.23	216.78	189.88	21.74	19.74	14.92

Figure 4 puts the results of column 2 in graphical perspective for A-rated S&P corporate bonds. An in-sample prediction using equity volatility captures the broad trends of actual yield spreads, performing particularly well in the 1970s and early 1980s. Over our 37-year horizon, the root mean squared error with equity volatility is about 12 basis points lower than without equity volatility (33 versus 45 basis points). Neither series performs particularly well in the late 1990s, although the in-sample prediction with equity volatility performs better than the prediction without volatility.

In Figure 5, we repeat the column 2 regression of S&P A-rated yield spreads, this time for 1963 to 1994. We then predict out-of-sample yield spreads for 1995 to 1999 with and without equity volatility, plotting them against actual A-rated yield spreads. The prediction of yield spreads with equity volatility is uniformly higher than the prediction without volatility, resulting in one-half of the root mean squared error (34 versus 67 basis points). Although the series without volatility performs better for the 1 year between mid-1996 and mid-1997, the series

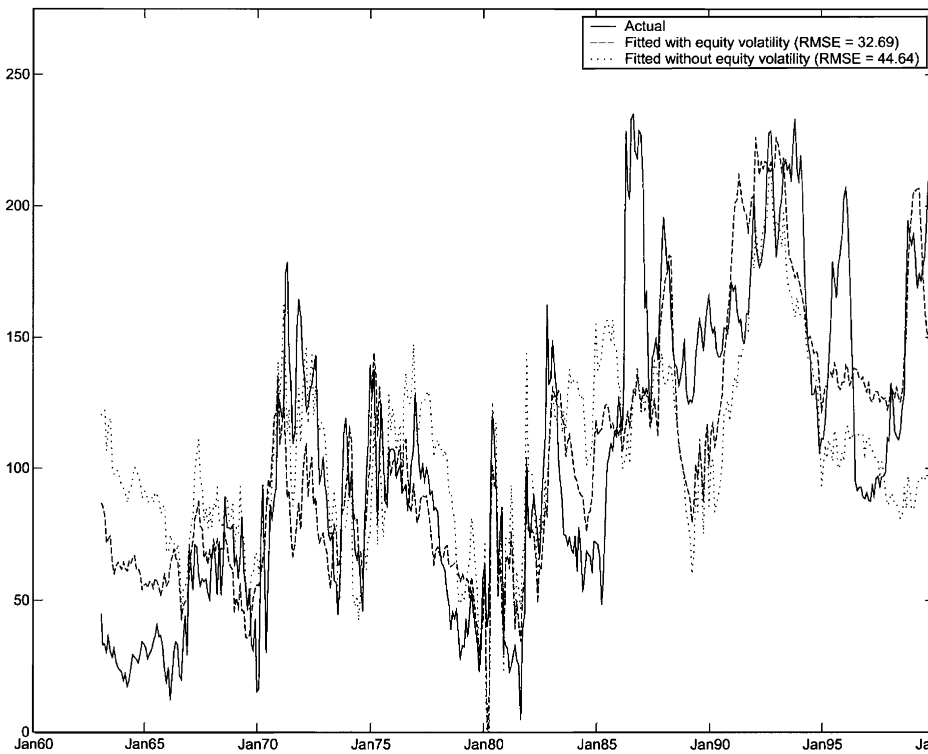

Figure 4. S&P actual versus in-sample fitted yield spreads for A-rated corporate bonds. S&P A-rated corporate bond yield spreads in basis points over the period 1963 to 1999. We also report in-sample fitted spreads based on a model with equity volatility (Table VI, column 2) and without equity volatility (Table VI, column 1).

with volatility captures the upswing in credit spreads beginning August 1998 and remains high through the end of 1999. Overall these results suggest that equity volatility is an important factor in understanding the movements in aggregate corporate bond yield spreads, both over the last few decades and in the late 1990s.

IV. Conclusion

In this paper, we have documented a link between rising idiosyncratic equity risk and increasing yields on corporate bonds relative to Treasury bonds. These two phenomena have been noted before, but there has been little research on the empirical connection between them.

Our analysis has proceeded as follows. First, we have compared the average yield spreads reported by Standard and Poor's and Moody's with a panel data set on corporate bond transactions between 1995 and 1999. We have found that credit spreads widened in the late 1990s, although less in the panel data set than in the spread indexes reported by the rating agencies.

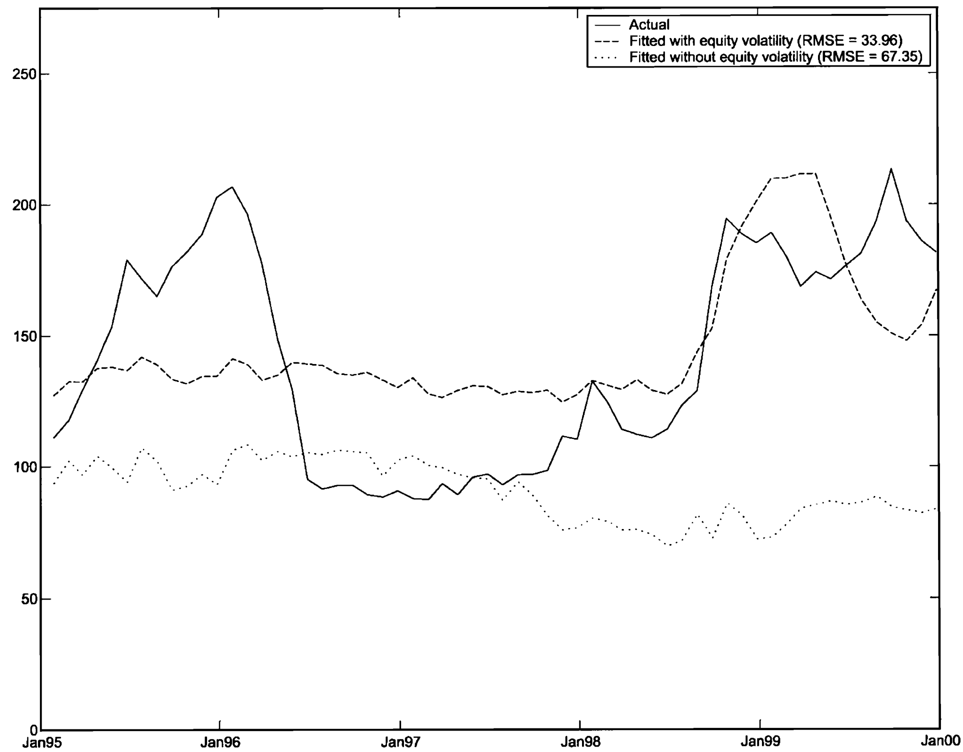

Figure 5. S&P actual versus out-of-sample fitted yield spreads for A-rated corporate bonds. S&P A-rated corporate bond yield spreads in basis points over the period 1995 to 1999. We also report out-of-sample fitted spreads based on a model estimated over the period 1963 to 1994 with equity volatility (Table VI, column 2) and without equity volatility (Table VI, column 1).

Second, we have provided evidence that idiosyncratic equity volatility is directly related to the cost of borrowing for corporate issuers. Our data suggest that volatility can explain as much cross-sectional variation in yields as can credit ratings, and that volatility contributes explanatory power even in the presence of credit ratings. These findings are robust to the inclusion of fixed effects for each bond issuer, the inclusion of monthly time dummies, the market model used to define idiosyncratic returns, the time window used to measure volatility, and the estimation of a zero-coupon term structure to control for maturity effects.

Third, using Standard and Poor's and Moody's corporate bond yield indexes between 1963 and 1999, we have shown that aggregate corporate yield spreads widen during periods of higher idiosyncratic risk. Thus, equity volatility helps to explain not only recent movements in corporate yield spreads, but also their longer-term upward trend.

This paper has used a relatively unstructured econometric approach to explore the effect of equity volatility on the cost of corporate borrowing. The effect appears to be much stronger than can be explained by the standard structural model of Merton (1974). An important challenge for future research will be to develop theoretical models that can account for the strong empirical relationship between equity volatility and corporate bond yields.

Appendix A. Estimating the Zero-Coupon Yield Curve

Following Elton et al. (2001), we adopt the procedure of Nelson and Siegel (1987) to estimate the zero-coupon yield curve. For each month, we fit the following equations to all bonds in a sector-credit rating combination:

$$B(t) = \exp\{-r(t)\cdot t\}, \tag{A1}$$

$$r(t) = \beta_0 + (\beta_1 + \beta_2)\left(\frac{1-\exp\{-\beta_3 t\}}{\beta_3 t}\right) - \beta_2 \exp\{-\beta_3 t\}, \tag{A2}$$

where $B(t)$ is the present value of a payment to be received t periods in the future, $r(t)$ is the spot rate, and β_0, β_1, β_2, and β_3 are parameters of the model.

We estimate 540 corporate zero-coupon yield curves (60 months $\times$ 3 sectors $\times$ 3 credit ratings) and 60 Treasury zero-coupon curves over the period January 1995 through December 1999. We define the zero-coupon yield spread as the difference between the corporate and Treasury spot rates. As described in the text, we regress the difference between the actual yield spread and the estimated yield spread on the variables in Table V.

Appendix B. Estimating the Volatility Effect under Contingent Claims Analysis

Merton (1974) derives the following formula for the yield spread of a firm that issues risky debt:

$$R(\tau) - r = -\frac{1}{\tau}\ln\left\{\Phi\left[h_2\left(d,\sigma_V^2\tau\right)\right] + \frac{1}{d}\Phi\left[h_1\left(d,\sigma_V^2\tau\right)\right]\right\}, \tag{B1}$$

where $\Phi(x)$ denotes the standard normal cumulative distribution function evaluated at x, $R(\tau)$ the yield to maturity on the bond provided the firm does not default, r the risk-free rate, τ the number of years until maturity, and σ_V^2 the volatility of the firm's assets. Also, $h_1\left(d,\sigma_V^2\tau\right) = -\left(\sigma_V^2\tau/2 - \ln(d)\right)/\sigma_V\sqrt{\tau}$, $h_2\left(d,\sigma_V^2\tau\right) = -\left(\sigma_V^2\tau/2 + \ln(d)\right)/\sigma_V\sqrt{\tau}$, and $d = D\exp(-r\tau)/V$.

The variable D represents the face value of the firm's liabilities. The firm defaults at time $T(\tau = 0)$ if liabilities exceed the value of the firm. Should the firm default, bondholders take over the firm and equityholders receive nothing.

The model leaves open the issue of how to estimate σ_V^2. For the purpose of a rough comparison with our reduced form results, we choose to adopt a very simple framework with two extremes, neither of which is realistic.

First, we assume that the firm's debt is approximately riskless, so that its market value equals its face value. This assumption is inconsistent with a model of risky debt, but again, we are simply trying to obtain a basic comparison with our regressions. With the value of a firm (V) equal to the market value of debt plus the market value of equity (E), we have $dV = dE$. This implies that firm volatility is $\sigma_E = \sigma_V(1 + D/E)$.

Second, we assume that the proportional volatility of the firm's debt is the same as that of its equity. We then have $\sigma_E = \sigma_V$.

We assume that D equals the book value of liabilities (from COMPUSTAT), E equals the market value of equity (from CRSP), and σ_E the annualized standard deviation of total equity returns from the 180 days preceding a bond transaction. Using this framework, we estimate the change in yield spread due to a change in equity volatility. Taking the partial derivative of equation (B1) with respect to equity volatility gives:

$$\frac{\partial[R(\tau) - r]}{\partial \sigma_E} = \frac{\sqrt{\frac{2}{\pi}}\left[\exp\left\{-\frac{1}{2}[h_1(\cdot)]^2\frac{\partial h_1(\cdot)}{\partial \sigma_E}\right\} + d\exp\left\{-\frac{1}{2}[h_2(\cdot)]^2\frac{\partial h_2(\cdot)}{\partial \sigma_E}\right\}\right]}{2\tau(\Phi[h_1(\cdot)] + d\Phi[h_2(\cdot)])} \tag{B2}$$

where

$$\frac{\partial h_1(\cdot)}{\partial \sigma_E} = -\frac{\sqrt{\tau}}{2\left(1 + \frac{D}{E}\right)} - \frac{\left(1 + \frac{D}{E}\right)\ln(d)}{\sigma_E^2\sqrt{\tau}} \tag{B3}$$

$$\frac{\partial h_2(\cdot)}{\partial \sigma_E} = -\frac{\sqrt{\tau}}{2\left(1 + \frac{D}{E}\right)} + \frac{\left(1 + \frac{D}{E}\right)\ln(d)}{\sigma_E^2\sqrt{\tau}} \tag{B4}$$

for the assumption of riskless debt, and

$$\frac{\partial h_1(\cdot)}{\partial \sigma_E} = -\frac{\sqrt{\tau}}{2} - \frac{\ln(d)}{\sigma_E^2\sqrt{\tau}} \tag{B5}$$

$$\frac{\partial h_2(\cdot)}{\partial \sigma_E} = -\frac{\sqrt{\tau}}{2} + \frac{\ln(d)}{\sigma_E^2\sqrt{\tau}} \tag{B6}$$

for the assumption that $\sigma_E = \sigma_V$.

For all bond transactions of a given issuer, we take the mean value of D, E, σ_E, τ, and r (defined as the closest benchmark Treasury). Using these mean values, we estimate the partial derivative of the issuer's spread with respect to equity volatility, as discussed in the text.

REFERENCES

Black, Fischer, and Myron Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637–654.

Blume, Marshall E., Felix Lim, and A.Craig MacKinlay, 1998, The declining credit quality of U.S. corporate debt: Myth or reality? *Journal of Finance* 53, 1389–1413.

Campbell, John Y., Martin Lettau, Burton G. Malkiel, and Yexiao Xu, 2001, Have individual stocks become more volatile? An empirical explanation of idiosyncratic risk, *Journal of Finance* 56, 1–43.

Campbell, John Y., Andrew Lo, and A.Craig MacKinlay, 1997, *The Econometrics of Financial Markets.* (Princeton University Press, Princeton, NJ).

Campbell, John Y., and Glen B. Taksler, 2002, Equity volatility and corporate bond yields, NBER Working Paper No. 8961.

Chaffin, Joshua, and Aline Van Duyne, 2000, Corporate bond crisis grows amid credit fears: Industrial groups worst hit as spreads widen in U.S. and Europe, *Financial Times* October 12, 25.

Collin-Dufresne, Pierre, and Robert S. Goldstein, 2001, Do credit spreads reflect stationary leverage ratios? *Journal of Finance* 56, 1929–1957.

Collin-Dufresne, Pierre, Robert S. Goldstein, and J. Spencer Martin, 2001, The determinants of credit spread changes, *Journal of Finance* 56, 2177–2207.

Duffee, Gregory R., 1998, The relation between treasury yields and corporate bond yield spreads, *Journal of Finance* 53, 2225–2241.

Duffee, Gregory R., 1999, Estimating the price of default risk, *Review of Financial Studies* 12, 197–226.

Duffie, Darrell, and Kenneth J. Singleton, 1997, An econometric model of the term structure of interest-rate swap yields, *Journal of Finance* 52, 1287–1321.

Duffie, Darrell, and Kenneth J. Singleton, 1999, Modeling term structures of defaultable bonds, *Review of Financial Studies* 12, 687–720.

Ederington, Louis H., Jess B. Yawitz, and Brian E. Roberts, 1987, The informational content of bond ratings, *Journal of Financial Research* 10, 211–226.

Elton, Edwin J., Martin J. Gruber, Deepak Agrawal, and Christopher Mann, 2000, Factors affecting the valuation of corporate bonds, Unpublished paper, New York University.

Elton, Edwin J., Martin J. Gruber, Deepak Agrawal, and Christopher Mann, 2001, Explaining the rate spread on corporate bonds, *Journal of Finance* 56, 247–278.

Fama, Eugene F., and James D. MacBeth, 1973, Risk, return and equilibrium, *Journal of Political Economy* 81, 607–636.

Fleming, Michael J., 2000, Financial market implications of the Federal debt paydown, *Brookings Papers on Economic Activity* 2, 221–251.

Goyal, Amit, and Pedro Santa-Clara, 2003, Idiosyncratic risk matters!, *Journal of Finance* 58, 975–1008.

Hecht, Peter, 2000, The cross section of expected firm (not equity) returns, Unpublished paper, Harvard Business School.

Huang, Jingzhi, and Ming Huang, 2000, How much of the corporate–Treasury yield spread is due to credit risk? Unpublished paper, Graduate School of Business, Stanford University.

Ingersoll, Jonathan E., 1977, A contingent-claims valuation of convertible securities, *Journal of Financial Economics* 4, 289–321.

Jarrow, Robert A., and Stuart M. Turnbull, 1995, Pricing derivatives on financial securities subject to credit risk, *Journal of Finance* 50, 53–85.

Jones, E. Philip, Scott P. Mason, and Eric Rosenfeld, 1984, Contingent claims analysis of corporate capital structures: An empirical investigation, *Journal of Finance* 39, 611–625.

Kwan, Simon H., 1996, Firm-specific information and the correlation between individual stocks and bonds, *Journal of Financial Economics* 40, 63–80.

Liu, Jun, Francis A. Longstaff, and Ravit E. Mandell, 2000, The market price of credit risk: An empirical analysis of interest rate swap spreads, Unpublished paper, UCLA.

LJS Global Information Services, Inc., 2000, Fixed Investment Securities Database, Powell, Wyoming.

Longstaff, Francis A., 2002, The flight-to-liquidity premium in U.S. Treasury bond prices, NBER Working Paper No. 9312.

Longstaff, Francis A., and Eduardo S. Schwartz, 1995, A simple approach to valuing risky fixed and floating rate debt, *Journal of Finance* 50, 789–819.

Merton, Robert C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449–470.

Nelson, Charles R., and Andrew F. Siegel, 1987, Parsimonious modeling of yield curves, *Journal of Business* 60, 473–489.

Pinches, George E., and Kent A. Mingo, 1973, A multivariate analysis of industrial bonds ratings, *Journal of Finance* 28, 1–16.

Pogue, Thomas F., and Robert M. Soldofsky, 1969, What's in a bond rating? *Journal of Financial and Quantitative Analysis* 4, 201–228.

Warga, Arthur D., 1998, Fixed income database, University of Houston, Houston, Texas.

Warga, Arthur D., 2000, National Association of Insurance Commissioners Database, University of Houston, Houston, Texas.