LIQUIDITY AND YIELD SPREADS OF CORPORATE BONDS

DISSERTATION

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By

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ABSTRACT

Corporate bond bid-ask spreads explain 40 percent of the temporal variation in yield spreads when daily individual bond data are used. Other known yield spread determinants such as the level and slope of the treasury yield curve, aggregate equity returns and implied volatility jointly explain only 10 percent of the yield spread variation. On average, approximately 60 percent of the bid-ask spread is impounded in the corporate yield spread. The estimates of the yield spread sensitivity to bid-ask spread changes are remarkably stable across bonds with different Standard & Poor's credit grades ranging from AAA to CC. This evidence supports the view that corporate bond liquidity is an important yield spread determinant.

Dedicated to those who encourage others.

Correction does much, but encouragement does more.

Johann Wolfgang Von Goethe

The finest gift you can give anyone is encouragement. Yet, almost no one gets the encouragement they need to grow to their full potential. If everyone received the encouragement they need to grow, the genius in most everyone would blossom and the world would produce abundance beyond the wildest dreams.

Sidney Madwed

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CHAPTER 1

LIQUIDITY AND YIELD SPREADS OF CORPORATE BONDS

1.1 Introduction

What factors determine the difference in yields between the corporate and government debt is an important issue that has recently received much attention from both the finance academics and practitioners. Understanding the difference between the corporate and government bond yields, which is called *yield spread*[1], is of paramount importance in many practical situations. For instance, fixed income portfolios of defaultable bonds, whose interest rate risk is hedged away by taking short positions in Treasury securities, become very sensitive to yield spreads. Therefore, the factors that drive yield spreads determine the risk of such portfolios, and they require understanding and measurement.

The yields of corporate bonds should be higher than the government bond yields for several reasons. One reason is the *expected default loss*. Some corporate bond issuers will be unable to meet their debt repayment obligations, and in such event of default, the bond investors will recover only a portion of their original investment. In contrast, Treasury securities are considered to be virtually default-free. Investors, therefore, should require a higher yield on corporate bonds relative to Treasuries. Another reason for the yield spread is *tax premium*. Interest payments on corporate bonds are subject to taxation at the state level whereas government bonds are free from state taxes. This differential tax treatment contributes to the yield spread.

Bond *liquidity* is another salient yield spread determinant. Indeed, while the Treasury debt market is one of the most liquid markets in the world, the secondary market for corporate bonds is notorious for its illiquidity[2]. The corporate bond market illiquidity exhibits itself in low trading volumes and high transaction costs, and therefore should be reflected in bond prices and yields to compensate investors for the related liquidity risks and costs of transacting. Recent advances in defaultable bond pricing incorporate liquidity into the bond pricing models[3]. Empirical studies of bond *liquidity* as a yield spread determinant have been very limited, however, mainly due to data availability and data quality issues.

This paper is an empirical investigation of the relationship between the corporate bond liquidity and yield spreads. The relationship is studied at the individual bond level using daily corporate bond bid-ask spreads as a main liquidity proxy.

The importance of understanding the effects that bond liquidity has on corporate yield spreads was highlighted by the financial crisis of 1998. During the crisis, dramatic revaluations were observed in the fixed income markets. For example, only in August 1998 the yield spread of the Merrill Lynch High Yield Master Index[4] increased by over 40 percent relative to its prior 5-year average. This is illustrated in Figure 1.1. During the crisis, the opinion that liquidity was the dominant factor for pricing defaultable bonds was a prevalent point of view expressed by many market participants, including the following quotes by the Merrill Lynch Chief High Yield Strategist:

> "The most direct effect of the Asian crisis, which culminated in Russia's default on domestic debt, was the sharp rise in yield spreads…"
>
> "Rise in risk premiums in emerging markets debt … spread to the investment-grade and the high-yield sectors of the U.S. corporate bond market."
>
> "There's been no wave of bankruptcies or credit problems, so the losses mystify some people, but it's been all liquidity."
>
> "A precipitous drop in liquidity, which caused the yield spread between low-rated issues and Treasuries to widen sharply, produced a historically low return."[5]

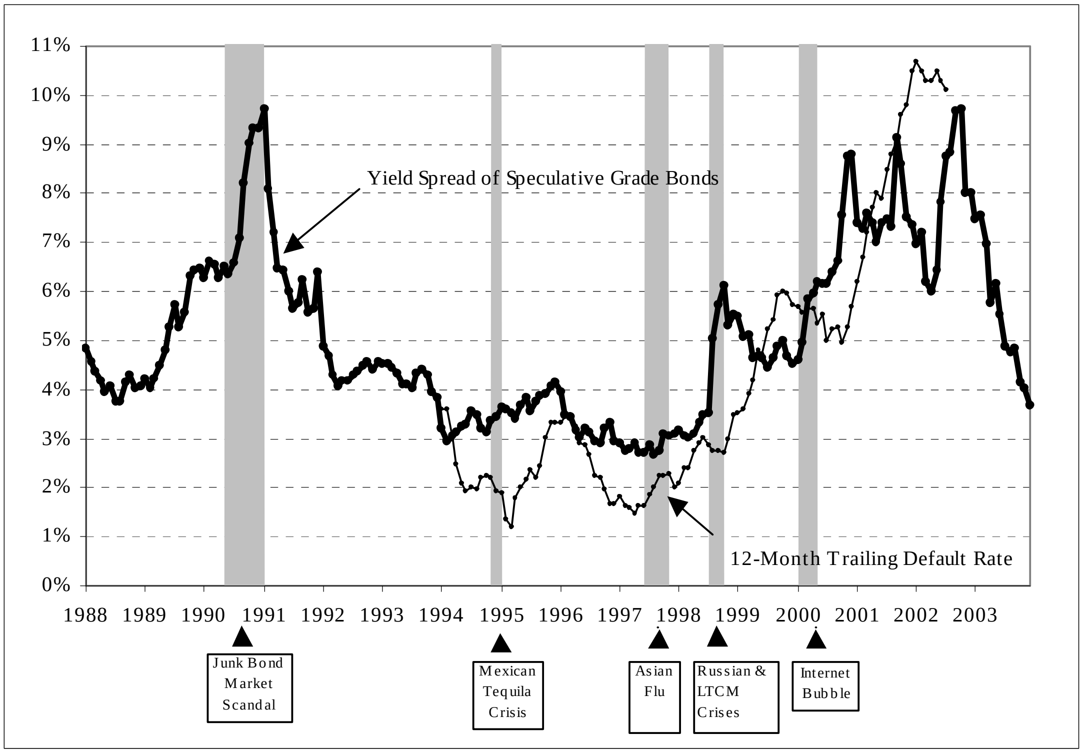

Figure 1.1. Yield Spread of High Yield Bonds.
Yield spread is the difference between the yield on the Merrill Lynch High Yield Master Index and the 10-year Treasury rate. The Moody's 12-month trailing default rate is calculated on the issuer basis.

In this paper, the crisis of 1998 is used as a natural experiment for studying the relationship between the corporate bond liquidity and yield spreads.

The rest of this chapter is organized as follows. The next section reviews the related literature on the determinants and properties of yield spreads as well as on the role of liquidity in pricing of assets. Then, I describe the data sources, sample construction, and discuss the methodology. After that, I describe and discuss the statistical tests and conclude.

1.2 Related Literature

1.2.1 Determinants and Properties of Yield Spreads

Beginning with the pioneering articles by Black and Scholes (1973) and Merton (1974) different contingent claims models have been proposed for pricing corporate liabilities[6]. However, the ability of this approach to explain yield spreads was questioned by empirical work. Kim, Ramaswamy and Sundaresan (1993) note that the conventional contingent claims model due to Merton (1974) is unable to generate default premiums in excess of 120 basis points while over the 1926-1986 period the yield spreads on Baa rated corporate bonds ranged from 51 to 787 basis points and averaged 198 basis points. Recently, Eom, Helwege and Huang (2004) directly test structural models of corporate bond pricing. The authors point out severe systematic biases of these models in estimating corporate bond spreads. An important question is how much liquidity premium, which is ignored in the contingent claims models, affects yield spreads.

Empirical research aimed at discovering the determinants of yield spreads and their relative contributions to the spreads dates back to the seminal work of Fisher (1959), who formulated and empirically confirmed the hypothesis that the average premium on a firm’s bonds depends on the risk that the firm will default and on the bonds’ liquidity. Fisher (1959) uses the market value of all publicly traded bonds that the firm has outstanding and bond trading volume as his liquidity proxies.

Cook and Hendershott (1978) investigate the relative contributions of taxes, risk, and relative security supplies as the determinants of the movements of the long-term Aa deferred-call utility bond spreads in 1961-1975. They find that the tax treatment is the most important of these factors, and that relative security supplies lacks support as a significant factor contributing to the observed spread. Buser and Hess (1986) document a strong influence of the corporate default premium on the ratio of tax-equivalent government yields.

Yawitz, Maloney, and Ederington (1985) develop a model of bond prices and yield spreads that incorporates the effect of both taxes and differences in default probabilities. Using the 1965-1981 data they find that the spread between the after-tax yield on a taxable government bond and a prime grade municipal is approximately four times as large as the spread between the yields on the prime and medium grade municipal bonds, suggesting that the tax-free municipal bonds have significant risk premiums embodied in their yields. Garman and Fridson (1996) quantify the high yield market's fluctuating riskiness in a regression of high yield spreads on credit risk, illiquidity risk, and monetary conditions proxies. Pedrosa and Roll (1998) study the nondiversifiable systematic risk in corporate bond credit spreads. They point out that as investors alter their beliefs about the general outlook for the economy, they reassess the probability of default for all corporate bonds. This suggests that investors' subjective perception of the overall economic conditions may be an important factor in determining corporate yield spreads.

The relation between Treasury yields and corporate yield spreads conveys information about the covariation between default-free discount rates and the market's perception of default risk. Duffee (1998) studies this relation using monthly data on investment-grade corporate bonds from 1985 through 1995. He finds modest negative relation, which is stronger for lower-rated bonds.

Elton, Gruber, Agrawal and Mann (2001) attempt to decompose the yield spread into separate components due to expected default loss, tax premium, and non-diversifiable systematic risk premium. The authors admit that "Liquidity may play a role in the risk and pricing of corporate bonds". However, they "…like other studies, abstract from this influence." Investigation of the liquidity effects is omitted probably due to the lack of data to adequately proxy for liquidity.

Collin-Dufresne, Goldstein and Martin (2001) demonstrate that monthly changes in such potential yield spread determinants as the riskless spot rate, the slope of the yield curve, the bond-issuing firm leverage, the volatility of firm value, the probability and magnitude of a downward firm value jump, and the business climate – that should in theory determine credit spread changes – have limited explanatory power. The authors find that regression residuals are driven by a single unidentified common factor, which explains 70 percent of the variation in residuals. This observation is interpreted as evidence that aggregate rather than firm-specific factors are more important for credit spread changes and that the stock and bond markets may be segmented. The authors use the following variables to proxy for corporate bond liquidity. The first proxy is the proportion of actual versus estimated end-of-month prices in the Warga (1998) corporate bond database. The second proxy is the estimated changes in the on-the-run minus off-the-run 30-year Treasury yields are used to measure liquidity. If liquidity decreases, the spread between the on-the-run and off-the-run bonds increases. Finally, a relationship between the swap and corporate bond markets is utilized. If liquidity in the swap market deteriorates, it is likely that liquidity in the corporate bond market will deteriorate as well. All these liquidity proxies are found to lack explanatory power – they are not significant in the estimated regressions. Therefore, the authors conclude that "…the dominant component of monthly credit spread changes in the corporate bond market is … independent of both changes in credit risk and typical measures of liquidity."

An overview of the different factors and their proxies used in prior studies to explain yield spreads is given in Table 1.1.

Factors and Proxy Variables	Article
Default Probability	
Credit Ratings	Collin-Dufresne, Goldstein, Martin (2001)
Firm's Leverage	Fisher (1959) Collin-Dufresne, Goldstein, Martin (2001)
Volatility of Firm's Income or Value	Fisher (1959)
Time of Operations Without Default	Fisher (1959)
Actual Default Rate	Garman, Fridson (1996)
Index of Lagging Economic Indicators	Fridson, Jónsson (1995)
Capacity Utilization	Garman, Fridson (1996)
Recovery Ratio	Elton et al. (2001)
Tax Status	
State Tax Rates	Cook, Hendershott (1978); Elton et al. (2001)
Local Tax Rates	Elton et al. (2001)
Liquidity	
Bid-Ask Spread	
Volume of Trading	Fisher (1959)
Size of Bond Issue	Fisher (1959); Crabbe, Turner (1995)
Mutual Fund Flows as % of Fund's Assets	Garman, Fridson (1996)
Liquid Assets as % of Total Fund's Assets	Garman, Fridson (1996)
% of actual vs. estimated prices in database	Collin-Dufresne, Goldstein, Martin (2001)
On- vs. off-the-run Treasury yield spread	Collin-Dufresne, Goldstein, Martin (2001)
Swap market liquidity	Collin-Dufresne, Goldstein, Martin (2001)
Economic and Monetary Conditions	
Treasury Yields/Curve	Garman, Fridson (1996); Duffee (1998) Houweling, Hoek, Kleinbergen (1999) Christiansen (2000)
Stock Index Return	Collin-Dufresne, Goldstein, Martin (2001)
Fama and French (1996) SMB factor	Elton et al. (2001)
Change in CPI	Garman, Fridson (1996)
M2-M1	Garman, Fridson (1996)
Bond Maturity	Helwege, Turner (1999)
Risk Aversion (Investor Confidence)	Cook, Hendershott (1978)

Table 1.1. Yield Spread Determinants and Their Proxies.
This table summarizes the yield spread determinants studied in the finance literature and the variables used to proxy for them.

1.2.2 Liquidity, Asset Pricing, and Yield Spreads

One of the first studies that incorporates liquidity into asset pricing is a paper by Amihud and Mendelson (1986), who propose a model and empirically support its prediction that the expected stock return is an increasing and concave function of the bid-ask spread. Elaborating on their earlier work, Amihud and Mendelson (1991) study the effects of liquidity on pricing of Treasury bonds. They find that the yields of Treasury bills are lower than those of otherwise identical government notes in their final coupon period by 70 to 110 basis points.

Empirical fixed-income microstructure research in general, and the liquidity impact on pricing of risky bonds in particular, has been lagging behind due to the lack of available data. There are several exceptions, however. Schultz (2001) "peeks behind the curtain" of the corporate bond market by studying its trading costs and practices. He reports the following findings: (1) the average round-trip trading costs are about $0.27 per $100 of par value; (2) the costs are lower for larger trades; (3) small bond dealers charge more; and (4) there is no evidence that lower-rated bonds are more costly to trade.

Hotchkiss and Ronen (1999) use daily and hourly high yield bond transaction prices to examine the informational efficiency of the corporate bond market relative to the market for the underlying stock. They find that the relative informativeness of high yield bond prices is driven largely by the bonds' liquidity rather than by the structure of the dealer market for corporate bonds.

Chakrawarty and Sarkar (1999) conduct a comparative study of liquidity in the U.S. corporate, municipal and government bond markets. They find that after controlling for other factors, the municipal bond realized bid-ask spread is higher than the government bond spread by about 9 cents per $100 par value, but the corporate bond spread is not. In the corporate and municipal markets the realized bid-ask spread increases in the remaining time to maturity of a bond. The corporate bond spread also increases in credit risk and age of a bond.

This paper contributes to the above literature by being the first study of the time-series relationship between the corporate bond bid-ask spreads and yield spreads using daily data. The data is described in the next section.

1.3. Data

1.3.1 Sample Construction from the Warga Database

The data panel of the corporate bond bid and ask yields is constructed in two steps. First, a set of corporate bonds is identified using the Fixed Income Securities Database supplied by Lehman Brothers and distributed by Warga (1998), which is commonly referred to as the Warga database. Then, for each bond identified in step one, the time series of the daily closing bid and ask yields are obtained from the Bloomberg historical database of bond prices.

The Warga Database is one of the most comprehensive collections of publicly offered U.S. Corporate bond data. The database contains bond descriptive characteristics such as the date of issue and maturity, coupon rate and frequency, dollar amount outstanding, credit ratings, optionality features and industry code of the issuing firm.

For each month from January 1990 to March 1998 I identify all industrial noncallable and nonputtable bonds. The resulting sample contains 3,413 bond issues. Of these 3,413 bonds, the Bloomberg[7] database contains price data for 1,952 issues[8]. I eliminate the observations for which the bid and ask yields are either missing, non-positive, above 100 percent, or equal to each other (zero bid-ask spread) as such observations probably indicate erroneous records in the database. Additionally, all bonds with the coupon payment frequency different from semiannual as well as the bonds with a sinking fund provision are excluded from the sample due to their different pricing.

The bonds with less than one year to maturity have been noted to have extremely sensitive yield spreads to even small price changes (see, for example, Ericsson and Renault (2002)). If a bond has less than one year to maturity[9], I exclude it from my sample. Additionally, I exclude from the sample the bonds with more than 30 years to maturity for the following reason. In the subsequent sections, the corporate bond yield spreads are computed by subtracting from the bond's yield the Treasury rate of the corresponding maturity. Since the longest available constant maturity Treasury rate series has the maturity of 30 years, extrapolating the corresponding treasury rate beyond 30 years is likely to lead to substantial errors. Therefore, the bonds with more than 30 years to maturity are excluded from the sample.

The observations with the zero or near-zero bid-ask spread changes probably indicate that either the bond price quotes were not updated due to lack of trading activity in the bond during that day or errors in the recorded data. If the one day bid-ask spread change is less than one basis point, I exclude such observation from the data set.

In order to have adequate sample sizes for the estimation of the time series regression models at the individual bond level, I retain in my sample only the bonds with 40 or more available daily observations. The final sample contains 252 bonds issued by 130 companies with a total of 36,432 daily observations during the period from January 3, 1990 to June 25, 2004, the average of 145 daily observations per bond.

The descriptive statistics for both the Bloomberg sample of 252 bonds and the Warga database sample of 3,413 bonds, which is representative of the corporate bond population, are presented in Table 1.2. The Bloomberg sample contains larger issues than the general bond population: $250 million versus $150 million median amount outstanding. It also has shorter maturity bonds at the time of issuance: the median of 7.76 years to maturity versus 10.0 years to maturity in the population. The bonds in the Bloomberg sample have slightly higher coupons: the median coupon of 7.86 percent versus 7.70 percent in the overall bond population. A median bond from the Bloomberg sample matures in November 2003.

Warga Database Sample of 3,413 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	150.0	199.0	158.8	1.0	1,500.0
Coupon, %	7.70	7.77	2.31	0.00	17.25
Matur. at Issue, Years	10.0	12.68	14.30	0.25	160.0
Issue Date	30-Jun-1992	-	-	1-Nov-1886	31-Mar-1998
Maturity Date	1-Jun-2001	-	-	28-Feb-1990	1-Mar-2098

Bloomberg Sample of 252 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	250.0	311.2	207.7	2.0	1,300.0
Coupon, %	7.86	7.83	1.70	0.00	13.00
Matur. at Issue, Years	7.76	10.39	7.60	1.75	30.00
Issue Date	13-Sep-1993	-	-	1-Oct-1898	15-Mar-1998
Maturity Date	23-Nov-2003	-	-	15-Aug-1995	15-Feb-2028

Table 1.2. Descriptive Statistics of the Samples of Corporate Bonds.

The distribution of the bonds and their issuers across S&P rating classes is given in Table 1.3. My Bloomberg sample of 252 bonds consists of 198 investment grade issues (80 percent), 51 speculative grade “junk” bonds (20 percent), and three bonds not rated by S&P.

Additionally, for subsequent analyses, I define four credit rating groups by grouping bonds according to their prevalent S&P credit rating. Group “AA” includes all bonds in the sample, which are rated AA+, AA, and AA- by S&P on average. Group “A” consists of all bonds rated A+, A, and A-. Group “BBB” contains all bonds rated BBB+, BBB, and BBB-. All bonds in the “Junk” group are rated by S&P below investment grade. The number of bonds and their issuers across the rating groups are given in Table 1.3. The sample has 26 bonds (10 percent) in group AA, 70 bonds (28 percent) in group A, 102 bonds (41%) in group BBB, and 51 speculative grade bonds (20%).

S&P Rating	Bonds	Issuers
All	252	130
High Grade	198	93
	(80%)	(73%)
High Yield	51	34
	(20%)	(27%)
AAA	6	5
AA+	3	3
AA	9	4
AA-	8	4
A+	15	10
A	48	18
A-	7	5
BBB+	22	9
BBB	24	13
BBB-	56	22
BB+	16	9
BB	8	5
BB-	10	4
B+	2	2
B	8	7
B-	4	4
CCC+	1	1
CCC	0	0
CCC-	1	1
CC	1	1
Not Rated	3	3

Credit Group		
AA	26	16
	(10%)	(12%)
A	70	33
	(28%)	(25%)
BBB	102	44
	(41%)	(34%)
Junk	51	34
	(20%)	(26%)

Table 1.3. Distribution of Bonds Across S&P Rating Classes.

1.3.2 Treasury and Equity Index Data

I use the following Treasury interest rate data. The Treasury rates with constant maturities of 3 months, 6 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 30 years are obtained from the Federal Reserve[10].

The yields on Treasury securities at "constant maturity" are interpolated by the U.S. Treasury from the daily yield curve. This curve, which relates the yield on a security to its time to maturity, is based on the closing market bid yields on actively traded Treasury securities in the over-the-counter market. These market yields are calculated from composites of quotations obtained by the Federal Reserve Bank of New York. The constant maturity yield values are read from the yield curve at fixed maturities of 3 and 6 months and 1, 2, 3, 5, 7, 10, 20, and 30 years. This method provides a yield for a 10-year maturity, for example, even if no outstanding security has exactly 10 years remaining to maturity.

In this paper, the Treasury rate corresponding to a corporate bond of a certain maturity is computed by way of linear interpolation between the two constant maturity Treasury rates with adjacent maturities. For instance, for a corporate bond with 8.5 years to maturity a corresponding Treasury rate is calculated as the average of the 7 and 10 year constant maturity Treasury rates.

The equity index and equity index option data is obtained from Bloomberg. In the subsequent sections, I use daily S&P 500 index returns as well as daily percentage changes of the VIX equity implied volatility index, which represents an average of the implied volatilities of near-the-money options on the S&P 100 index.

1.3.3 Computation of the Yield Spreads

Different methods for calculating the spread between the Treasury and corporate bond yields have been proposed. The *traditional yield spread* is calculated as the difference between the yield to maturity of the corporate bond and the yield to maturity of the Treasury bond with the same maturity. This method does not take into account the term structure of interest rates.

A more sophisticated way to calculate the yield spread is to compare the corporate bond with a portfolio of Treasury securities that has the same pattern of cash flows. Such *static spread* is a measure of the spread that the investor would realize over the entire Treasury spot rate curve if the bond is held to maturity. It is not a spread off one point on the Treasury yield curve as the traditional yield spread. The static spread is calculated as the spread that will make the present value of the cash flows from the corporate bond, when discounted at the Treasury spot rate plus the spread, equal to the corporate bond's price. The difference between the traditional and static yield spreads will be higher for longer maturity bonds and for steeper yield curves.

Elton, Gruber, Agrawal and Mann (2001) propose yet another measure, the *spot spread*. It is defined as the difference between yield to maturity on a zero-coupon corporate bond (corporate spot rate) and the yield to maturity on a zero-coupon government bond of the same maturity (government spot rate). There are several reasons that make using spots preferable to using yield to maturity on coupon debt. First, the yield to maturity depends on coupon. If yield to maturity is used to define the spread, the spread will depend on the coupon. Second, theoretical arbitrage arguments hold with spot rates rather than with yields to maturity. Finally, calculating spread as a difference in yield to maturity on coupon-paying bonds with the same maturity means one is comparing bonds with different duration and convexity. The disadvantage of using spot rates is that they need to be estimated.

In this paper, I use the traditional yield spread, as it is a commonly used simple measure. I believe that this method's bias due to a mismatch of the cash flows from the corporate and government bonds is a second order effect. It could *attenuate* the yield spread, and thus it would bias my tests against finding a relationship between the yield spreads and bid-ask spreads. Therefore, the true relationship might be slightly stronger than the one detected by the tests.

1.4. The Empirical Relationship Between Corporate Bond Yield Spreads and Bid-Ask Spreads

1.4.1. Theoretical Considerations

The main purpose of this paper is to empirically explore the relationship between the yield spreads and bid-ask spreads of corporate bonds. What relationship between these variables should be expected on the theoretical grounds? Higher bid-ask spreads imply higher costs of trading. In addition, the higher bid-ask spread bonds may be subject to higher levels of the liquidity risks. That is, the less liquid bonds with higher bid-ask spreads should have higher promised yield in order to compensate investors for the higher transaction costs and liquidity risks. Therefore, the higher yields would imply higher yield spreads. Consequently, one should expect a positive relationship between the bond bid-ask spreads and yield spreads. This positive relationship should be expected both between the levels of the variables and between their changes.

The precise form of the relationship is probably nonlinear. Its study requires assuming some form of a bond pricing model. For the purposes of the present paper, I deliberately refrain from imposing any assumptions or using any specific bond pricing model. Instead, I focus on empirically exploring the relationship between small daily changes of the corporate bond yield spreads and bid-ask spreads. A linear model should be an adequate first order approximation in this case. The estimates from the linear model would answer my main research question about the relationship between bond yield spreads and bid-ask spreads. The linear model estimates should not, however, be unduly extrapolated for large deviations in the variables or for the relationship between their levels. For large changes, the higher order effects may become dominant, and a linear extrapolation would incorrectly represent the true nonlinear underlying relationship leading to substantial errors.

For the purposes of the subsequent model estimation, the variables are defined as follows. The (yield-based) bid-ask spread of corporate bond i on day t, BAS_{it}, is defined as the difference between the bond's quoted bid yield and its ask yield at the close of trading that day. YS_{it} denotes the bond's traditional yield spread computed as previously described. ΔBAS_{it} and ΔYS_{it} are the daily changes of the variables. The daily changes are the differences in the values (levels) of the variables between two consecutive trading days (t-1) and t.

In the next sections, I first estimate pooled cross-sectional time-series regression models for the whole sample of bonds and for each credit rating group separately. Then, I proceed with a more in-depth exploration of the temporal relationship between the bond yield spreads, bid-ask spreads and other yield spread determinants by estimating time series regressions at the individual bond level.

1.4.2. The Univariate Pooled Regression Model

As a first step in exploring the relationship between the yield spreads and bid-ask spreads of the U.S. corporate bonds, the following univariate pooled time-series cross-sectional regression model is estimated:

$$\Delta YS_{it} = \alpha + \beta \cdot \Delta BAS_{it} + \varepsilon_{it} \qquad (1)$$

The estimation period is from January 3, 1990 to June 25, 2004. The total sample consists of 36,432 observations from 252 U.S. corporate bonds with S&P ratings ranging from AAA to CC. The estimation results are reported in Table 1.4 both for the overall bond sample and for the four credit rating group subsamples.

	Rating Groups				
	All Bonds	**AA**	**A**	**BBB**	**Junk**
Intercept	0.003**	-0.001	0.003**	0.003**	0.005
	(2.8)	(-0.8)	(3.3)	(2.9)	(0.8)
ΔBAS	0.601***	0.771***	0.677***	0.595***	0.508***
	(82.5)	(86.5)	(113.3)	(69.0)	(19.1)
Df	36,431	2,884	13,160	14,182	5,756
$\mathbf{R^2_{adj}}$	0.158	0.722	0.494	0.252	0.060

Table 1.4. Pooled Time-Series Cross-Sectional Regression of the Corporate Bond Yield Spread and Bid-Ask Spread Daily Changes.
The following polled time-series cross-sectional regression model is estimated for the overall sample of 252 bonds and by the credit rating group: $\Delta YS_{it} = \alpha + \beta \cdot \Delta BAS_{it} + \varepsilon_{it}$. The t-statistics are given in parentheses below the corresponding coefficient estimates. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

A strong relationship between the variables is evident. The regression coefficient estimates are highly statistically significant in all cases. For the overall sample, the coefficient value of 0.601 indicates that on average approximately 60 percent of the bid-ask spread is impounded in the yield spread for a U.S. corporate bond. On average, a 10 basis point increase in bid-ask spreads is associated with a 6 basis point yield spread increase.

The sensitivity of the yield spread changes to bid-ask spread changes is monotonic with respect to the credit rating of bonds. It increases from 0.508 for the speculative grade group, to 0.595 for group BBB, further to 0.677 for A rated bonds, and to 0.771 for the AA group of the most highly rated bonds in the sample. The standard errors of the coefficient estimates - which are of the order of 0.01 (not reported individually) - indicate that the coefficient values are statistically significantly different from each other.

The bid-ask spread variation explains 15.8 percent of the yield spread variation in the overall sample as evidenced by the adjusted R^2. The explanatory power of the model – in line with the behavior of the coefficients – increases monotonically from 6 percent for the speculative grade bonds to 25 percent for the BBB group, further to 49 percent for the A group, and to 72 percent for the bonds in the AA credit rating group.

Next, I explore in more depth the temporal aspect of the relationship between the yield spreads and bid-ask spreads.

1.4.3. The Individual Bond Univariate Time-Series Regressions

The pooled regression model above treats observations for all bonds and dates as drawn from the same distribution. This may not be completely justified as one should expect a closer relationship between the observations on the same bond rather than between observations from very different bond issues. Similarly, the observations made on the same day should have a natural tendency to be more closely linked than the observations made far apart in time. Therefore, in addition to the pooled regression models, which are estimated over groups of bonds, I estimate the following time-series regressions for each of the 252 individual bond issues in the sample:

$$\Delta YS_t = \alpha + \beta \cdot \Delta BAS_t + \varepsilon_t \qquad (2)$$

The estimation results are summarized in Table 1.5 in the following fashion. Mean adjusted R^2 across all individual regressions and mean coefficient values are presented. The t-statistics corresponding to the coefficients are calculated from the cross-sectional variation of the estimates by dividing each reported coefficient value by the standard deviation of all estimates and scaling by the square root of the number of estimates.

	Rating Groups				
	All Bonds	**AA**	**A**	**BBB**	**Junk**
Intercept	0.002	-0.003**	0.000	0.003*	0.003
	(0.8)	(-2.7)	(0.1)	(1.8)	(0.3)
ΔBAS	0.566***	0.557***	0.521***	0.531***	0.689***
	(14.6)	(15.2)	(7.6)	(11.5)	(5.0)
Bonds	252	26	70	102	51
$\mathbf{R^2_{adj}}$	0.416	0.540	0.486	0.403	0.353

Table 1.5. Time-Series Regressions of the Corporate Yield Spread Daily Changes on Bid-Ask Spreads Changes.
The following time-series regression model is estimated for each of the 252 individual bond issues: $\Delta YS_t = \alpha + \beta \cdot \Delta BAS_t + \varepsilon_t$. The t-statistics are given in parentheses below the corresponding coefficient estimates. Reported coefficient values and their associated t-statistics are computed as follows. For each of the N_k bonds in rating group k, regression model is estimated. The reported coefficients are averages of the resulting N_k regression estimates for the coefficient on each variable. The corresponding t-statistics are calculated from the cross-sectional variation of the N_k estimates for each coefficient by dividing each reported coefficient value by the standard deviation of the N_k estimates and scaling by the square root of N_k. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

In line with the pooled regression above, all bid-ask spread coefficients are highly statistically significant. In the overall sample, the coefficient value is 0.566. It is close to the pooled regression coefficient of 0.601. This provides more supporting evidence that approximately 60 percent of the corporate bond bid-ask spreads is impounded in the yield spreads. The fact that the estimates of the yield spread sensitivity to bid-ask spreads in the overall sample are very close in both models adds confidence regarding the estimate of the strength of the relationship between the yield spread and bid-ask spread changes.

The explanatory power, however, is quite different for the two models. The adjusted R^2 of 15.8 percent from the pooled regression in the overall sample is substantially lower than the 41.6 percent average value in the time-series regressions. A principal difference between the models is that the pooled regression attempts to capture the cross-sectional variation in yield spreads in addition to its temporal variability, while the latter is the sole focus of the time-series regression model. From comparing the observed values of R^2 for both models, it appears that the bid-ask spread explains the temporal variation in yield spreads substantially better than its cross-sectional variability.

The behavior of the coefficient values across credit rating groups is different in the pooled and time-series regressions. While the pooled regression coefficients decrease monotonically as bonds' credit quality deteriorates, the time-series regression coefficients do not.

In fact, the time-series regression coefficients for the different credit rating groups are not statistically significantly different from each other. I test the hypothesis that the mean coefficients of all credit rating groups are equal to each other with an unbalanced[11] design ANOVA model. The hypothesis can not be rejected. The F-value for the model equals 0.99 with the p-value of 0.40. Therefore, I conclude that the temporal sensitivity of the corporate bond yield spreads to bid-ask spreads is stable across S&P credit grades.

The pattern of the pooled regression coefficient estimates across credit rating groups suggests that the cross-sectional explanatory power of the bid-ask spread for corporate bond yield spreads is better for higher rated bonds.

1.4.4. Multiple Determinants of the Yield Spreads.

Thus far in this chapter, I find a strong relationship between the corporate bond yield spreads and bid-ask spreads in a univariate setting. Now, I turn to checking the robustness of the detected relationship to inclusion of other known yield spread determinants. I adopt a framework close to the one used by Collin-Dufresne, Goldstein and Martin (2001) for my exploration of multiple yield spread determinants. Table 1.6 lists the explanatory variables, which are used in the subsequent analyses in addition to the bond bid-ask spread.

Variable	Definition	Expected Sign of the Relationship
Δr^{10}	Daily change in the 10-year constant maturity Treasury rate.	Negative
$(\Delta r^{10})^2$	Squared daily change in the 10-year constant maturity Treasury rate.	Uncertain
Δslope	Slope of the Treasury yield curve is defined as the difference between the 10-year and 2-year Treasury rates. Daily changes of the slope are used.	Negative
VIX	Daily percentage change of the VIX equity implied volatility index.	Positive
S&P	Daily S&P index returns.	Negative

Table 1.6. Yield Spread Determinants and Predicted Signs of the Relationships.

In a manner identical to the univariate time-series regression model above, for each of the 252 sample bonds, I estimate a time-series multiple regression model using all factors listed in Table 1.6 in addition to the bid-ask spread. The results are summarized in Table 1.7 in the same way as for Table 1.5 above. Namely, the mean adjusted R^2 and the mean coefficient values across all individual bond time-series regressions are presented for the overall sample and by credit rating group. The t-statistics corresponding to the coefficients are calculated from the cross-sectional variation of the estimates by dividing each reported coefficient value by the standard deviation of all estimates and scaling by the square root of the number of estimates.

			Rating Group		
	All Bonds	**AA**	**A**	**BBB**	**Junk**
Intercept	0.004	-0.003**	-0.001	0.004*	0.009
	(1.3)	(-2.7)	(-0.8)	(2.2)	(0.7)
Δr^{10}	-0.106**	-0.025	-0.110***	-0.123*	-0.157
	(-2.7)	(-1.2)	(-4.0)	(-2.8)	(-0.9)
$(\Delta r^{10})^2$	-0.163	-0.174	0.095	-0.084	-0.741
	(-1.0)	(-0.9)	(0.5)	(-0.4)	(-1.2)
Δslope	-0.048	0.086	-0.064	0.015	-0.171
	(-0.5)	(1.3)	(-0.9)	(0.2)	(-0.4)
S&P	0.005	-0.02	0.001	0.004	0.012
	(1.6)	(-0.7)	(0.4)	(1.3)	(1.0)
VIX	0.001	-0.001	-0.000	0.002**	0.001
	(1.5)	(-0.6)	(-0.8)	(2.8)	(0.3)
ΔBAS	0.544***	0.567***	0.502***	0.523***	0.615***
	(15.6)	(15.8)	(7.0)	(10.9)	(6.0)
Bonds	252	26	70	102	51
R^2_{adj}	0.479	0.549	0.509	0.465	0.427

Table 1.7. Time-Series Regressions of the Corporate Yield Spread Daily Changes on Bid-Ask Spread Changes and Other Determinants.
A multiple time-series regression model is estimated for each of the 252 individual bonds in the sample. The mean coefficient and R^2 values are reported. The t-statistics are given in parentheses below the corresponding coefficient estimates. Reported coefficient values and their associated t-statistics are computed as follows. For each of the N_k bonds in rating group k, regression model is estimated. The reported coefficients are averages of the resulting N_k regression estimates for the coefficient on each variable. The corresponding t-statistics are calculated from the cross-sectional variation of the N_k estimates for each coefficient by dividing each reported coefficient value by the standard deviation of the N_k estimates and scaling by the square root of N_k. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

The bid-ask spread average coefficients are fairly close to the average estimates from the univariate time-series model above. Therefore, the previously established relationship between the U.S. corporate bond yield spreads and bid-ask spreads is robust to inclusion of other determinants. Majority of the coefficient estimates for the remaining explanatory variables are not statistically significant. The sign of the relationships are largely in line with the expectations listed in Table 1.6.

In order to determine the contribution of the bid-ask spread determinant to the explanatory power of the model, I estimate the same multiple time-series regressions with the bid-ask spread variable omitted. Table 1.8 presents the results.

	Rating Group				
	All Bonds	**AA**	**A**	**BBB**	**Junk**
Intercept	0.005	0.002	0.000	0.005*	0.012
	(1.8)	(0.3)	(0.3)	(2.2)	(1.0)
Δr^{10}	-0.154***	-0.054	-0.168***	-0.153***	-0.233
	(-3.4)	(-1.4)	(-5.2)	(-3.2)	(-1.2)
$(\Delta r^{10})^2$	-0.043	-0.050	0.019	-0.286	-0.876
	(-0.2)	(-0.2)	(0.1)	(-1.0)	(-1.2)
Δslope	-0.019	0.052	-0.055	-0.011	0.036
	(-0.2)	(0.7)	(-0.8)	(-0.1)	(0.1)
S&P	0.004	-0.000	0.002	0.003	0.009
	(1.4)	(-0.0)	(0.8)	(0.7)	(0.8)
VIX	0.001	-0.002	0.000	0.002*	0.000
	(1.2)	(-1.1)	(0.4)	(2.3)	(0.2)
Bonds	252	26	70	102	51
R^2_{adj}	0.101	0.084	0.088	0.110	0.111

Table 1.8. Time-Series Regressions of the Corporate Yield Spread Daily Changes on the Typical Determinants Except Bid-Ask Spread Changes.
A multiple time-series regression model is estimated for each of the 252 individual bonds in the sample. The mean coefficient and R^2 values are reported. The t-statistics are given in parentheses below the corresponding coefficient estimates. Reported coefficient values and their associated t-statistics are computed as follows. For each of the N_k bonds in rating group k, regression model is estimated. The reported coefficients are averages of the resulting N_k regression estimates for the coefficient on each variable. The corresponding t-statistics are calculated from the cross-sectional variation of the N_k estimates for each coefficient by dividing each reported coefficient value by the standard deviation of the N_k estimates and scaling by the square root of N_k. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

The mean explanatory power of the model is about 10 percent for all bonds. It increases to 48 percent when the bid-ask spread variable is included. Therefore, I conclude that the corporate bond bid-ask spread is a primary yield spread determinant.

1.5. Conclusions

This paper empirically investigates the role of the U.S. corporate bond liquidity in yield spreads. Bond liquidity is proxied for by daily changes in the bid-ask spreads of individual bonds. Linear regression model estimates suggests that the bid-ask spread of corporate bonds is a major yield spread determinant. Alone, it explains over 40 percent of the temporal variability in yield spreads, while all remaining factors account for just 10 percent of the yield spread variation.

On average, approximately 60 percent of the bid-ask spread is impounded in the corporate yield spread. A 10 basis point increase in bid-ask spread translates into a 6 basis point yield spread increase on average. The estimates of this sensitivity are remarkably stable across bonds of different Standard & Poor's bond credit ratings ranging from AAA to CC. These results are established for the period from January 1990 to June 2004. The results have important consequences for corporate bond pricing. In particular, failure to properly account for variation in bid-ask spreads, and the corresponding effect on yields could produce systematic biases in interpolation methods, "matrix" methods, and other methods used to estimate yields for bonds that do not trade on a day of particular interest[12].

Overall, I conclude that corporate bond liquidity is a primary determinant of the yield spreads. It must be taken into account when determining prices and risks of corporate bonds.

In the next chapter, the relationship between the bond yield spreads and liquidity is studied further using the financial crisis of 1998 as a natural experiment.

CHAPTER 2

LIQUIDITY AND YIELD SPREADS OF CORPORATE BONDS DURING THE FINANCIAL CRISIS OF 1998

2.1 The Financial Crisis of 1998

2.1.1 Description of the Crisis

A financial crisis of unprecedented scale spread around the globe in 1997-1998. The International Monetary Fund used over $100 billion to bailout the affected countries. The crisis peaked in August 1998, when Russia declared a moratorium on servicing its foreign debt, defaulted on its domestic debt, and effectively devalued its currency. A month later, the near-failure of large hedge fund Long Term Capital Management (LTCM) was perceived to have nearly impaired the world's financial system[13]. "Functioning well, most participants take it for granted. Functioning poorly, it becomes a vehicle for financial contagion" – testified the U.S. Federal Reserve Chairman Greenspan (1998a).

Many financial markets in different countries exhibited extreme price behavior during the crisis period. The U.S. stock market alone lost more than $1.5 trillion in value during just three trading days following August 27, 1998. This represents about 8 percent of the World's GDP and 40 times the total amount of the Russia's defaulted debt. The percentage losses in the U.S. corporate bond markets were even larger. It is important to understand whether these large changes in market valuations are rationally justified by the decreased expected future payoffs of the securities or whether they are the result of an irrational "contagion" – changes in investors' subjective valuation not directly related to the future cash flows from the financial claims.

There can be at least three possible reasons for the decrease in security values during the crisis. The first reason is that the aggregate credit risk could increase as a result of the crisis. Security prices would decline to reflect the investors' required compensation for the higher expected default losses. The second reason is that the crisis could adversely affect liquidity of the market. The corresponding illiquidity premium would hurt the prices. Finally, while no changes could occur to either liquidity or credit conditions, the investors' increased aversion to risk would result in a lower demand for the unchanged risky assets, depressing the prices. The three proposed explanations are not mutually exclusive.

It is important to distinguish between the possible causes of price declines during the crisis for many practical considerations. For instance, a long-term investor with a large portfolio of defaultable bonds, who intends to hold the bonds till maturity, faces lower expected future bond payments if the default risk is the reason for the market revaluations. If this makes his investment objective unattainable, he needs to change the portfolio composition, that is, to trade. On the other hand, if the market revaluations are caused solely by the liquidity effects, then the investor's future cash flows will remain unchanged despite the temporary portfolio value decline. In this case, there is no need to trade.

The opinion that liquidity was the dominant corporate bond pricing factor during the crisis of 1998 was a prevalent point of view, expressed by many market participants. Greenspan (1998b) also favors the liquidity and risk aversion explanations in his November 5, 1998 speech, noting

> "…the remarkable increase in risk aversion and an increased propensity for liquidity protection in both the United States and Europe in recent months without significant signs of underlying erosion in our real economies, tightened monetary policy, or higher inflation."

Another important reason to understand the nature of the effects of the crisis on the financial markets and to discriminate between the alternative mechanisms is that they call for different regulatory actions to deal with the crisis as well as they imply that different institutional structures constitute a stable financial system, which is resilient against crises.

2.1.2 Fixed-Income Markets During the Crisis of 1998

The crisis had especially large and long-lasting impact on the fixed income markets. The fixed income assets exhibited drastic price changes in the weeks following Russia's default on August 17, 1998 and the LTCM crisis in September. The yield spreads of both the U.S. investment grade and high yield corporate bonds widened sharply in August. For example, the spread between the Merrill Lynch High Yield Master Index over the ten-year Treasury bond surged more than 150 basis points to over 500 basis points in August 1998 after spending more than two and a half years at levels below 350 basis points, as shown in Figure 1.1. The spread averaged 570 basis points during the rest of the year, 70 percent higher than its 340 basis points mean during the preceding 5-year period.

In the third quarter of 1998, following Russia's default, large Wall Street financial firms realized hundreds of millions of dollars in losses on their long positions in risky bonds coupled with short positions in Treasuries, which were intended to hedge the interest rate risk[14]. Indeed, Treasuries and corporates used to move more or less in unison for several years prior to August 1998. In Autumn 1998, however, the whole Treasury yield curve fell as illustrated in Figure A.3[15]. At the same time, the market for speculative grade bonds had the worst month in eight years, dropping 7 percent in price on average. One likely reason for the decline in Treasury yields is the investors' global uncertainty, triggered by Russia's default, which lead them to liquidate their positions in risky securities in favor of the liquid government debt, mostly of shorter maturities. This phenomenon is known as the "flight to quality". Greenspan (1998b) notes that

> "In the wake of the Russian debt moratorium on August 17, demand for risky assets, which had already declined somewhat, suddenly dried up. This, in the United States, induced dramatic increases in yield spreads… Even more startling is the surge for liquidity protection that has manifested itself through significant differentiation in yields among *riskless* assets according to their degree of liquidity. We are all familiar with the dramatic rise in late September in the illiquidity premium for off-the-run Treasury securities, or the spreads on government sponsored agency issues."

Trading losses of many Wall Street firms were so substantial that they were unwilling to quote reasonable prices or to make a market in corporate bonds. Brokers were extremely reluctant to take on additional inventory. On the other hand, in need of cash to meet a wave of redemptions, mutual funds – a dominant group of high-yield investors – were forced to dump their junk-bond holdings quickly, depressing the prices. This reduced liquidity, sending the corporate-bond market into a severe crisis.

In the following sections, I test hypotheses about the liquidity impact on corporate bonds' yield spreads during the crisis. Next, I describe the data.

2.2 Description of the Data.

2.2.1 Sample Construction from the Warga Database

A sample of straight (noncallable) industrial corporate bonds is constructed using the Warga database in the following way. The latest available (March 1998) file from the Warga database is used to identify bond issues. Only the industrial bonds are retained in the sample. All bonds with a callability feature are eliminated. Only trader-priced (rather than matrix-priced) bonds that mature after March 31, 1998 are kept. The resulting sample contains 1,710 bonds. Descriptive statistics for the Warga database sample are presented in Table A.1. The median issue has $200 million amount outstanding, coupon of 7.47 percent, 10 years to maturity at time of issuance, and matures in October 2006. The distribution of the bonds across the S&P rating classes is given in Table A.2. Out of the 1,710 bonds in my Warga sample, 1,485 bonds (87 percent) have investment grade, and the remaining 225 “junk” bonds (13 percent) have a speculative rating assigned by S&P.

2.2.2 Bloomberg Generic Bid and Ask Bond Prices

Bloomberg L. P. is a major provider of the current and historical price data for a wide range of securities. The company collects daily quoted bid and ask prices and yields from a number of corporate bond dealers. A representative quote across bond dealers for each day is recorded as a “generic” bond price quotation. The Bloomberg generic bond prices are average market consensus prices calculated using Bloomberg’s proprietary methodology from the prices contributed by bond dealers.

These prices are meant to represent actual trading interest in a bond at any time. If Bloomberg believes that a consensus price can not be reasonably assigned at a point in time, the bond is marked as "not priced".

Of the 1,710 bonds from the Warga sample, 352 (21 percent) are found in the Bloomberg database. Descriptive statistics of this Bloomberg sample of 352 bonds are given in Table A.1. One difference between the Warga and Bloomberg samples is that the Bloomberg sample covers slightly larger issues – the median amount outstanding is $250 million versus $200 million for the Warga sample. These larger issues tend to have slightly lower coupons and yields, and shorter durations. The credit quality of the bonds in both samples is approximately equal, with about 12 percent of each sample rated below the investment grade by S&P.

Initially, the time series of the Bloomberg generic daily bids and asks were manually collected for the period from August 1 to October 31, 1998. This period consists of 13 trading weeks (65 trading days) and includes both the Russian default and the LTCM crisis. Due to the missing data, each bond's prices are available on average 34 of the 65 trading days during the study period. In order to reduce the severity of the missing data issues in subsequent time-series tests, the Bloomberg sample of the 352 bonds is further reduced to form a subsample of the 99 "frequently priced" bonds using the following rule. A bond is included in the frequently priced subsample if its prices are available at least once during any 12 of the 13 weeks of the period from August 1 to October 31, 1998.

The frequently priced bonds have Bloomberg prices available on 59 of the 65 trading days on average. The investment grade bonds are priced marginally more frequently than the high yield bonds. The investment grade bond prices are available 94 percent of the time, while the high yield bond prices available 90 percent of the time. The descriptive statistics of the frequently priced subsample are given in Table A.1. The average issue in this subsample is still larger than in the previously discussed samples. The median amount outstanding of a frequently priced issue is $400 million. 14 percent of the bonds in the frequently priced subsample are rated below the investment grade compared to 12 percent in the overall sample – the difference is minor. The maturity, duration, coupon rate, and yield averages in the Bloomberg subsample are close to these measures in the larger samples. Therefore, there are the reasons to believe that the subsample of the frequently priced bonds is representative of the population of the straight industrial U.S. corporate bonds.

The time series of the Bloomberg generic bond prices and yields were collected for the 99 frequently priced bonds once again for a longer time period, when the Bloomberg automated data download capabilities became available. The time period of the available data can be different for each bond, and it can begin as early as December 20, 1989 and end on November 20, 2001.

2.2.3 Bloomberg Data Issues

One issue detected in the automatically downloaded Bloomberg data is that despite the fact that no data is missing, a tangible portion of the bid and ask quotes coincide, that is the reported bond bid-ask spread is zero. I treat the zero bid-ask spread observations as missing. This further reduces the sample of bonds with a long history of the time-series of bid-ask spreads to 78 issues. The descriptive statistics of this subsample of 78 frequently priced bonds with non-zero bid-ask spreads are given in Table A.1. This subsample contains on average still larger issues than the previously discussed samples. The median amount outstanding of a frequently priced issue is $500 million. While these bonds' coupons and yields are not very different from those in the population, they have shorter durations of 5.68 years versus 6.27 years in the Warga sample. Credit quality of the sample is similar to that of the general population. 9 of the 78 bonds (11.5 percent) are rated below investment grade, while in the Warga database sample of 1,710 this percentage is slightly higher at 13.2 percent for the speculative grade bonds.

The equal-weighted yield spread for the Bloomberg sample of 78 bonds is plotted in Figure A.1 from 1990 to 2001. The effect of the financial crisis of 1998 is salient in the graph: The spread increases from its customary levels below 1 percent to above 1.5 percent in the second half of the year. For the same sample and time period, Figure A.2 plots the equal-weighted bid-ask spread. Curiously, there is little effect observable in 1998. However, the Asian crisis of 1997 seems to have had a dramatic impact on the bond bid-ask spreads.

2.3 Corporate Bond Yield Spreads and Bid-Ask Spreads During the Crisis

2.3.1 Yield Spreads Increase During the Crisis

One clear observation during the financial crisis of 1998 is that the yield spreads of the U.S. corporate bonds increased significantly in August. As we saw earlier in Figure 1.1, the yield spread of the Merrill Lynch High Yield Index rose 151 basis points during the month. In line with the behavior of this index, the yield spreads for our subsample of the speculative grade bonds rose on average by 82 basis points in August as illustrated in Figure A.4. The yield spreads peaked at 315 basis points in October 1998, exceeding the first half-year mean of 170 basis points by 85 percent, and declined for the rest of the year.

In order to rigorously document the yield spread changes, I perform a paired t-tests for the month-to-month changes using the Bloomberg sample of 99 frequently priced bonds. Results of the tests are reported in Table A.3. The largest yield spread increase is observed in August 1998 at 39.7 basis points. It is also highly significant with the t-value of 11.6. The yield spreads increased further in September (by 10 basis points on average), and October (by 17 basis points), followed by the declines in November and December of 23 basis points and 4 basis points, respectively. These yield spread changes are plotted in Figure A.4 for each credit rating group. Group “AA” consists of 22 corporate bonds rated AA- and higher by S&P, group “A” consists of 32 bonds rated between A- and A+, 31 bonds rated between BBB- and BBB+ are in group “BBB”, and 14 junk bonds are rated below BBB-. As expected, the lines do not cross: The higher the bond credit quality, the lower its yield spread.

A closer look at the yield spreads behavior during the crisis period is achieved with the daily observations plotted in Figure A.5 for the four credit rating groups. It appears that yield spreads rose fairly quickly during two periods: during the last two weeks of August (the Russian crisis) and during the first days of October, being rather flat the rest of the time. It is interesting to note the lock-step movements of the yield spread for the three investment grade groups in contrast with the speculative grade group.

2.3.2. Corporate Bond Liquidity Proxies During the Crisis

The bid-ask spread is the main variable that is used in this paper to proxy for liquidity of corporate bonds. There are several important advantages of the bid-ask spread as a liquidity proxy. First, it is available for individual bond issues while the other proxies measure only the aggregate bond market liquidity. Second, its values are determined by the market, and, therefore, they are observable at any point in time, and they are fairly objective. Finally, the daily data frequency is higher than the data frequency of the other potential liquidity proxies. The summary statistics for the bid-ask spread are given in Table A.4. The overall mean bid-ask spread is $0.32, and it is narrower for higher quality bonds. The time-series behavior of the daily average bid-ask spreads by the credit rating group during the crisis is illustrated in Figure A.6. The AA group's mean bid-ask spreads are always lower than those of the BBB group. The A group's line lies between the AA and BBB with rare exceptions. The speculative grade bonds' bid-ask spread data has very large variability, and it can be observed at either high or low extreme. At least for the BBB group, it seems that the bid-ask spread is higher during the second half of the observation period: It is below \$0.35 prior to September 15, 1998, and it is mostly above \$0.35 afterwards. This period of the higher bid-ask spreads (lower liquidity) is observed just prior to and after the LTCM rescue. LTCM along with major Wall Street firms had accumulated large positions in corporate bonds, which became unattractive to buyers at the time due to their risks. Therefore, the positions were illiquid, and this is reflected in the wider bid-ask spreads.

Next, I look at the month-to-month bid-ask spread change. I test the significance of the change with a paired t-test. The test results are presented in Table A.5. The only significant increase is observed in September. The sample average bid-ask yield difference increases by 1.06 basis points in September 1998. The increase is significant at the 0.01 level. This bid-ask spread increase follows the year's largest monthly yield spread increase of 39.7 basis points in August. This sequence of events leads to a conclusion that the bond market liquidity followed rather than caused the yield spread increase.

Besides the bid-ask spread, I consider several additional liquidity proxies. The first variable is the percentage of the missing data in the sample on a given day. The idea is that the less liquid the corporate bond market is on a given day, the more bonds will not trade and will have missing data for that day. The percentage of the bonds in the Bloomberg sample that have nonmissing data is shown in Figure A.7. The total sample size is 352. The average number of bonds with available prices is

183, or 52 percent. Based on this liquidity measure, the market is less liquid in late-August to early September, and most of October 1998.

The relationship between the frequency that a bond is priced and its bid-ask spread is illustrated in Figure A.8 for the period of the financial crisis from August to October 1998. As expected, these two liquidity proxies are related: the more frequently a bond is priced, the lower is its bid-ask spread. The bonds that are priced less than 50 percent of the time have the bid-ask yield difference around 7 basis points, while the bonds which are priced during each of the 65 days of the crisis have on average the bid-ask yield difference around 4.5 basis points.

Size of the bond issue is one of the very first liquidity proxies used in the literature, in particular, by Fisher (1957). The rationale is that larger bond issues trade more frequently, and are more liquid. I investigate the relation between the size of the bond issue and the bid-ask spread level. Figure A.9 shows a scatter plot of the median bid-ask yield differences of the individual bond issues and their sizes. The expected relationship is observed: Larger issues tend to have lower bid-ask spreads. The median bid-ask yield difference drops from about 8 basis points for the smaller size issues of $100 to $200 million to about 4 basis points for the issues with amounts outstanding above $500 million.

Some inferences about liquidity can be drawn from the high-yield mutual fund data presented in Table A.8. High yield mutual funds is a dominant investor group in the speculative grade bonds: Together with insurance companies and pension funds they hold more than 60 percent of the market. Studying cash flows of the high yield funds can provide insight into the connection between investors' actions and bond price behavior. Large outflows can create liquidity-reducing imbalances and contribute to increases in bond yields. The funds' total assets decreased by approximately $13 billion (about 10 percent) from July to August, 1998. August was an extreme month for the year in several respects. First, redemptions and exchanges within the mutual fund families peaked at $3,824 million and $3,008 million, respectively. Total net sales and exchanges in August were negative $2,961 million in stark contrast with all other months. This was driven largely by net exchanges within families of funds, an indicator of sophisticated investors' activities. Sales were lowest in August and September, but highest in November, indicating the restored investor confidence in speculative grade bonds. The proportion of liquid assets held by funds was highest from September to November, exceeding 6 percent. The decision of the funds' managers to hold more liquid assets probably indicates the perceived lower market liquidity and their readiness to meet higher then usual redemption levels during this period, if necessary.

Another natural liquidity proxy is the bond trading volume. Salomon Smith Barney publishes a daily index of the dealers' subjective perception of the bond trading volume as "light", "moderate", or "heavy". During the crisis period from August 1 to October 31, 1998, the volume index was recorded as "moderate" on all days except August 14, when the trading was "light". August 14, 1998 is a Friday preceding the Russian default announcement on Monday, August 17. Yet another way to study the bond market liquidity is based on the view that during the periods when the market is less liquid, bond price volatility is higher.

To summarize the evidence from all liquidity proxies used, I conclude that after August 1998, for which the evidence is mixed, liquidity decreased in September, stayed low in October and improved afterwards. Since the yield spreads increased most in August, and then again to a smaller degree in September and October, returning to the lower levels in November and December, this evidence indicates that additional factors beyond liquidity contributed to the yield spread changes during the crisis of 1998.

2.4 Relationship Between the Bond Yield Spreads and Bid-Ask Spreads During the Crisis

In order to explore the relationship between the changes in yield spreads and bid-ask spreads during the crisis period, two models are estimated. A pooled time-series cross-sectional regression of the month-to-month corporate yield spread changes (ΔYS) on bid-ask spread changes (ΔBAS) is estimated. In addition, a random effects model

$$\Delta YS_{it} = \alpha + \beta \cdot \Delta BAS_{it} + u_i + v_t + \varepsilon_{it}$$

is estimated. Both models are estimated using the sample of 99 Bloomberg frequently priced bonds and two time periods. I choose the period from January to July 1998 as a benchmark period, and the period from August to December 1998 as a crisis period. The estimation results are presented in Tables A.6 and A.7. They are similar for both models. During the benchmark period, the bid-ask spread explains approximately 6 percent of the yield spread variation. However, during the crisis the significance of the coefficient disappears and the adjusted R^2 is close to zero. These results provide additional evidence that it was not liquidity but a different factor that accounts for the yield spread changes during the crisis of 1998.

2.5. Conclusions

This chapter investigates the role of liquidity in the large, sharp, and persistent increase in the U.S. corporate yield spreads over Treasury rates during the financial crisis of 1998. During the crisis, a large yield spreads increase was followed by a significant increase in the bid-ask spreads. This sequence of events leads to a conclusion that bond market liquidity followed rather than caused the yield spread increase.

The tests indicate that contrary to the usual relationship between the bond yield spreads and bid-ask spreads during the non-crisis times, the association between these variables weakens during the crisis. This supports the hypothesis that additional factors beyond liquidity contributed to the yield spread changes during the financial crisis of 1998.

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Appendix A.

Tables and Figures for Chapter 2.

Warga Database Sample of 1,710 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	200.0	224.8	157.5	3.0	1,932.5
Coupon, %	7.47	7.73	1.34	0.00	14.00
Yield, %	6.67	6.86	1.13	0.00	22.13
Duration, Years	6.27	7.04	3.89	0.00	28.72
Matur. at Issue, Years	10.00	17.44	15.32	2.00	100.00
Issue Date	21-Jun-1995	-	-	12-Mar-1985	31-Mar-1998
Maturity Date	1-Oct-2006	-	-	15-Jul-1998	1-Mar-2098

Bloomberg Database Sample of 352 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	250.0	324.9	204.9	100.0	1,300.0
Coupon, %	7.25	7.46	1.07	5.20	11.00
Yield, %	6.46	6.60	0.58	5.85	9.57
Duration, Years	5.86	6.52	3.93	0.90	14.80
Matur. at Issue, Years	10.00	16.74	17.55	2.00	100.00
Issue Date	30-Nov-1994	-	-	20-Mar-1986	30-Mar-1998
Maturity Date	15-Oct-2005	-	-	1-Sep-1999	1-Mar-2098

Frequently Priced Bloomberg Database Subsample of 99 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	400.0	458.5	255.3	100.0	1,300.0
Coupon, %	7.25	7.38	0.95	5.20	9.50
Yield, %	6.52	6.58	0.48	5.90	8.15
Duration, Years	6.17	7.08	3.96	1.37	14.78
Matur. at Issue, Years	10.00	18.36	19.49	2.00	100.00
Issue Date	9-Feb-1996	-	-	1-Dec-1989	25-Mar-1998
Maturity Date	30-Mar-2006	-	-	1-Sep-1999	1-Mar-2098

Non-Zero Bid-Ask Spread Frequently Priced Bloomberg Subsample of 78 Bonds					
Variable	**Median**	**Mean**	**St.Dev.**	**Min**	**Max**
Amount Out, $ mil.	500.0	485.5	263.3	100.0	1,300.0
Coupon, %	7.25	7.46	0.95	5.88	9.50
Yield, %	6.42	6.52	0.45	5.90	7.74
Duration, Years	5.68	6.54	3.91	1.37	14.74
Matur. at Issue, Years	10.00	16.55	16.80	1.42	99.12
Issue Date	29-Jun-1995	-	-	1-Dec-1989	15-Mar-1998
Maturity Date	1-Jun-2005	-	-	1-Sep-1999	15-May-2097

Table A.1. Descriptive Statistics of the Corporate Bonds for Different Samples.
The duration and yield statistics are computed using the March 1998 Warga data.

S&P Rating	Warga Database Sample		Bloomberg Sample		Frequently Priced Sample		Non-Zero Bid-Ask Spread Sample	
	Bonds	**Issuers**	**Bonds**	**Issuers**	**Bonds**	**Issuers**	**Bonds**	**Issuers**
All	1,710	606	352	160	99	55	78	41
High Grade	1,485 (86.8%)	472 (77.9%)	309 (87.8%)	126 (78.8%)	85 (85.9%)	43 (78.2%)	69 (88.5%)	32 (78.0%)
High Yield	199 (13.2%)	134 (22.1%)	43 (12.2%)	34 (21.3%)	14 (14.1%)	12 (21.8%)	9 (11.5%)	9 (22.0%)
AAA	26	10	15	7	1	1	1	1
AA+	22	5	9	4	2	2	2	2
AA	59	19	27	9	12	4	11	4
AA-	55	23	21	10	7	4	4	2
A+	118	41	36	13	10	6	9	4
A	300	77	79	26	20	11	16	8
A-	166	60	14	9	2	2	2	2
BBB+	209	59	45	16	11	4	6	2
BBB	285	101	20	13	4	1	4	1
BBB-	245	77	43	19	16	8	14	6
BB+	83	46	19	14	8	6	5	5
BB	36	20	10	7	3	3	3	3
BB-	27	9	4	3	2	2	1	1
B+	20	17	6	6	1	1	0	0
B	16	10	2	2	0	0	0	0
B-	10	8	1	1	0	0	0	0
CCC+	3	3	1	1	0	0	0	0
CCC	2	2	0	0	0	0	0	0
CCC-	1	1	0	0	0	0	0	0
CC	1	1	0	0	0	0	0	0
NR	26	17	0	0	0	0	0	0

Table A.2. Distribution of Bonds in the Samples Across S&P Credit Rating Classes.

Variable	Yield Spread Change, basis points						
Month	**AA**	**A**	**BBB**	**Junk**	**Total**	**T-value**	**N**
Jan-98	-3.7	-0.0	3.5	-5.8	-0.40	-0.3	77
Feb-98	-5.0	-4.2	-7.1	-4.0	-5.20***	-6.2	76
Mar-98	-3.3	-4.2	-2.2	-2.8	-3.20**	-3.3	82
Apr-98	-1.7	0.1	-4.2	4.6	-0.80	-1.0	88
May-98	3.1	1.8	0.4	8.1	2.85***	3.8	86
Jun-98	6.4	8.7	2.9	0.8	5.21***	4.4	88
Jul-98	-1.1	-1.1	-2.4	-7.4	-2.30	-1.5	85
Aug-98	23.5	31.7	42.3	90.6	39.69***	11.6	90
Sep-98	9.5	5.4	6.3	34.3	9.93***	4.3	91
Oct-98	8.6	13.1	16.3	62.6	17.34***	5.1	89
Nov-98	-10.1	-16.4	-23.5	-70.7	-23.40***	-7.0	78
Dec-98	-6.8	-1.8	-2.1	-9.7	-4.00**	-2.7	68

Table A.3. Means of the Yield Spread Monthly Changes.
This table presents means of the yield spread month-to-month changes for four credit rating groups. The t-statistics are for the paired t-test of the null hypothesis that the month-to-month yield spread change for all bonds equals zero. Statistical significance at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

Variable	Bid-Ask Spread, cent				
Statistic	AA	A	BBB	Junk	Total
Median	28.6	31.4	34.9	36.3	32.3
Mean	28.6	29.2	34.4	39.4	31.9
St. Dev.	13.2	13.8	18.4	27.0	17.7
Min	3.2	3.2	3.6	0.5	0.5
Max	61.1	52.5	101.9	113.4	113.4
N	285	368	317	152	1,122

Table A.4. Descriptive Statistics of the Bid-Ask Spread Levels Across Rating Groups.
Pooled time-series cross-sectional statistics for bid-ask spreads are presented for four credit rating groups.

Variable	Bid-Ask Yield Difference Change, basis points						
Month	AA	A	BBB	Junk	Total	T-value	N
Jan-98	-1.82	0.63	-0.49	-0.45	-0.40	-0.8	77
Feb-98	-0.13	0.57	0.92	-0.26	0.39	0.7	76
Mar-98	-0.10	-0.28	0.42	1.31	0.17	0.3	82
Apr-98	0.33	-0.36	0.30	0.13	0.07	0.2	88
May-98	-0.46	0.06	-1.11	5.86	0.57	0.7	86
Jun-98	-0.70	0.53	0.19	-3.21	-0.49	-0.6	88
Jul-98	0.91	-0.66	-0.52	0.63	-0.01	-0.0	85
Aug-98	-0.16	-0.21	0.00	-0.50	-0.17	-0.5	90
Sep-98	0.03	1.36	0.91	3.14	1.06*	2.4	91
Oct-98	1.74	-0.56	-0.23	0.14	0.20	0.3	89
Nov-98	0.02	0.44	-0.52	-0.58	-0.07	-0.2	78
Dec-98	-1.46	-0.60	0.13	0.86	-0.32	-0.8	68

Table A.5. End-Of-Month Means of the Bond Bid-Ask Yield Difference Month-to-Month Changes.

Method	Pooled Regression			
Period	Benchmark		Crisis	
Intercept	-0.041***	(-4.1)	-0.144***	(-7.0)
∆BAS	0.323***	(6.0)	0.114	(0.6)
Df	564		145	
R^2_{adj}	0.058		-0.004	

Table A.6. Pooled Regression of Corporate Yield Spreads on Bid-Ask Spreads.
Pooled time-series cross-sectional regression of the end-of-month corporate yield spread changes on bid-ask spread changes is estimated for the benchmark period, from January to July 1998, and the crisis period, from August to December 1998. The t-statistics are given in parentheses. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively. The model is estimated using the Bloomberg sample of the 99 frequently priced bonds.

Method	Random Effects Regression			
Period	Normal		Crisis	
Intercept	-0.054	(-1.2)	-0.136	(-1.5)
∆BAS	0.298***	(6.1)	0.012	(0.1)
Df	563		126	
R^2_{adj}	0.062		0.000	

Table A.7. Random Effects Regression of Yield Spreads on Bid-Ask Spreads.
A two-way random effects regression model $\Delta YS_{it} = \alpha + \beta \cdot \Delta BAS_{it} + u_i + v_t + \varepsilon_{it}$ of the end-of-month corporate yield spread changes on bid-ask spread changes is estimated for the benchmark period, from January to July 1998, and the crisis period, from August to December 1998. The model is estimated using the Bloomberg sample of the 99 frequently priced bonds. The t-statistics are given in parentheses. Statistical significance of the coefficients at the 10%, 1% and 0.1% levels is denoted by *, **, and ***, respectively.

Month	Total Assets	Liquid Ratio	Sales	Redempt	Net Flow	Exchg. In	Exchg. Out	Net Exchg	Net Sales + Net Exchg.
Jan-98	109,424.9	5.93%	4,522	1,789	2,733	1,368	667	701	3,434
Feb-98	114,024.6	5.29%	4,313	1,794	2,519	883	680	203	2,721
Mar-98	118,233.3	4.76%	4,868	2,322	2,546	1,258	1,081	177	2,723
Apr-98	118,985.7	3.71%	3,784	2,117	1,667	871	1,187	(316)	1,352
May-98	120,344.7	5.01%	3,632	1,810	1,822	882	741	141	1,963
Jun-98	121,390.4	5.41%	3,748	2,093	1,656	884	986	(101)	1,555
Jul-98	124,233.9	5.19%	3,817	1,848	1,969	1,337	897	440	2,410
Aug-98	111,008.3	5.04%	3,141	3,824	(683)	731	3,008	(2,278)	(2,961)
Sep-98	110,667.3	6.11%	3,129	2,177	952	1,072	1,218	(146)	806
Oct-98	108,295.9	6.24%	3,344	2,321	1,023	1,480	1,646	(166)	857
Nov-98	119,840.9	6.11%	5,701	1,892	3,809	2,077	710	1,367	5,176
Dec-98	117,449.7	4.54%	4,062	3,151	911	952	2,011	(1,059)	(149)
Jan-99	119,948.9	5.53%	4,062	2,335	1,727	1,471	1,257	214	1,941
Feb-99	120,147.3	4.60%	3,356	2,330	1,026	866	1,070	(204)	822
Mar-99	123,411.3	5.60%	4,586	3,032	1,554	1,984	1,413	571	2,125
Apr-99	127,370.1	5.17%	3,958	2,522	1,437	1,163	1,035	128	1,565
May-99	122,786.3	3.77%	2,939	3,120	(181)	690	2,093	(1,403)	(1,584)
Jun-99	122,625.3	4.70%	3,113	2,218	896	761	950	(189)	707
Jul-99	122,826.9	4.23%	3,796	2,998	799	1,449	1,466	(17)	782
Aug-99	120,010.2	5.08%	2,842	2,887	(45)	809	1,317	(508)	(553)
Sep-99	117,123.4	5.37%	2,140	2,382	(242)	498	1,208	(710)	(952)
Oct-99	115,712.6	5.18%	2,006	2,009	(3)	751	938	(187)	(190)
Nov-99	118,352.9	4.96%	3,392	2,577	815	1,593	1,044	550	1,364
Dec-99	116,908.6	4.30%	3,014	3,717	(703)	965	1,993	(1,028)	(1,731)
Jan-00	114,262.3	4.59%	2,261	2,807	(546)	796	1,664	(868)	(1,414)
Feb-00	114,065.7	5.03%	2,851	2,665	186	944	1,350	(406)	(220)
Mar-00	109,338.2	4.53%	2,696	3,545	(850)	939	1,957	(1,018)	(1,867)
Apr-00	106,816.1	5.10%	2,104	2,359	(255)	930	1,400	(470)	(725)
May-00	102,910.3	5.53%	1,951	2,622	(671)	524	992	(468)	(1,139)

Table A.8. Cash Flows of High Yield Mutual Funds[16].
All values are in millions of dollars except the liquid ratio, which is in percent.

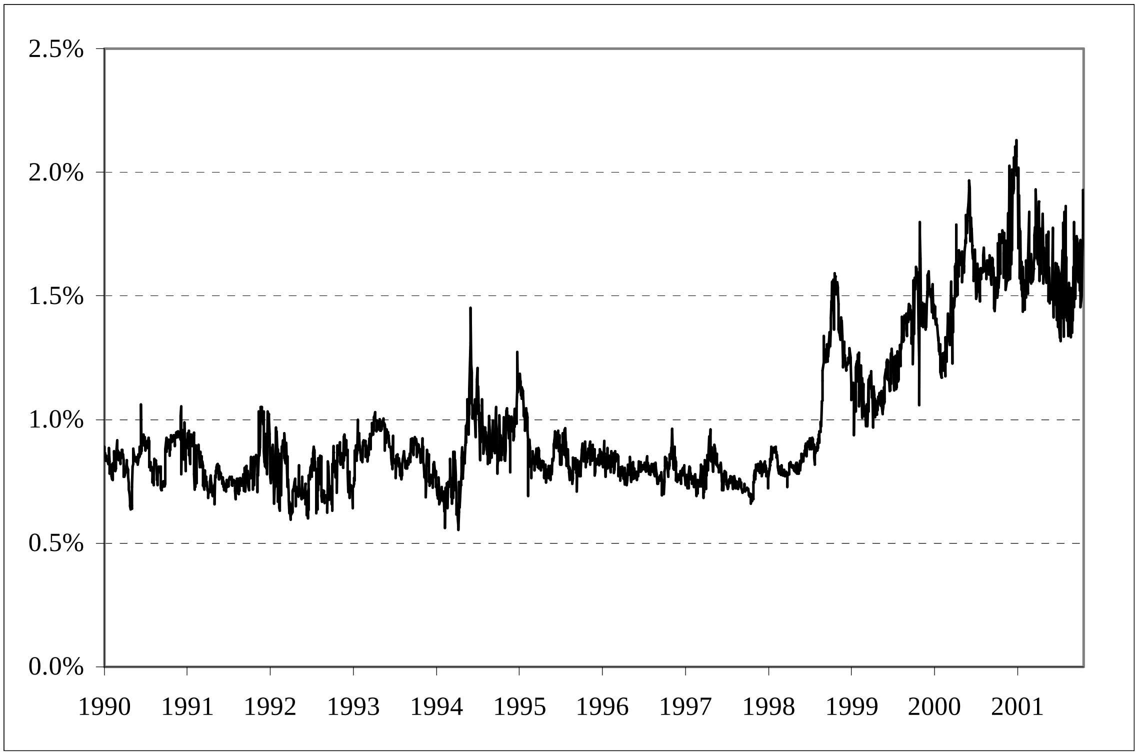

Figure A.1. Equal-Weighted Sample Average Yield Spread.
The equal-weighted average yield spread is plotted for the sample of the 78 frequently priced bonds with nonzero bid-ask spread.

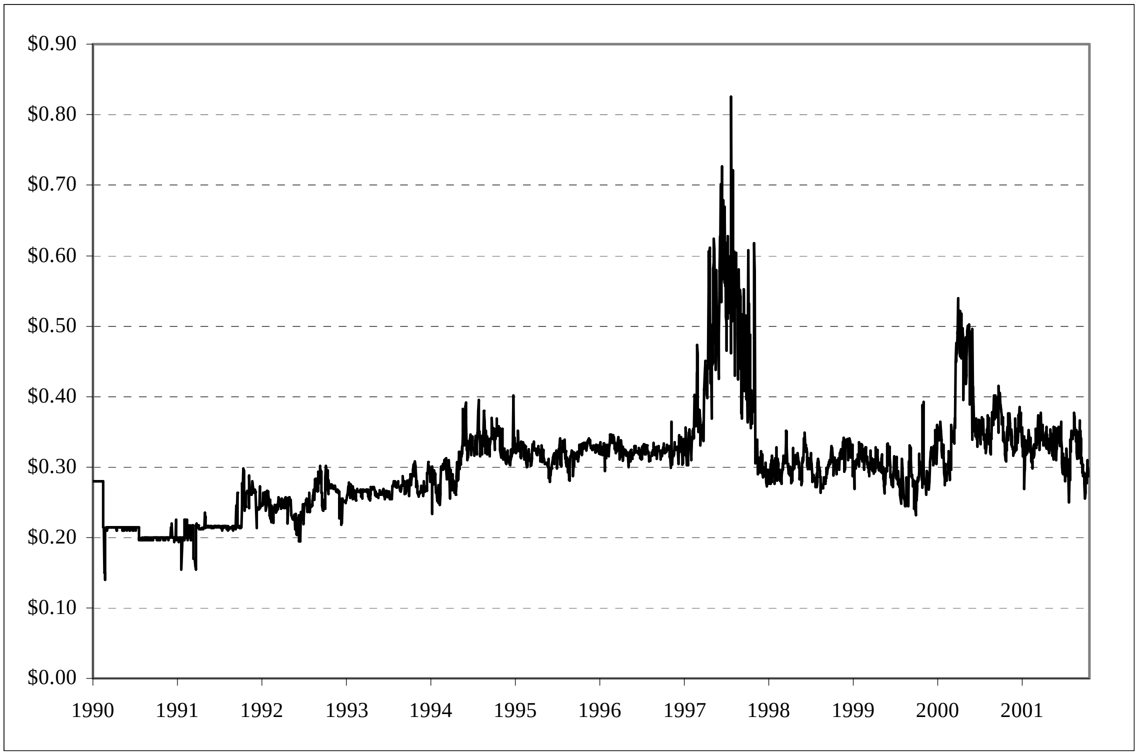

Figure A.2. Equal-Weighted Sample Average Bid-Ask Spread.
The equal-weighted average bid-ask spread is plotted for the sample of 78 frequently priced bonds with nonzero bid-ask spread.

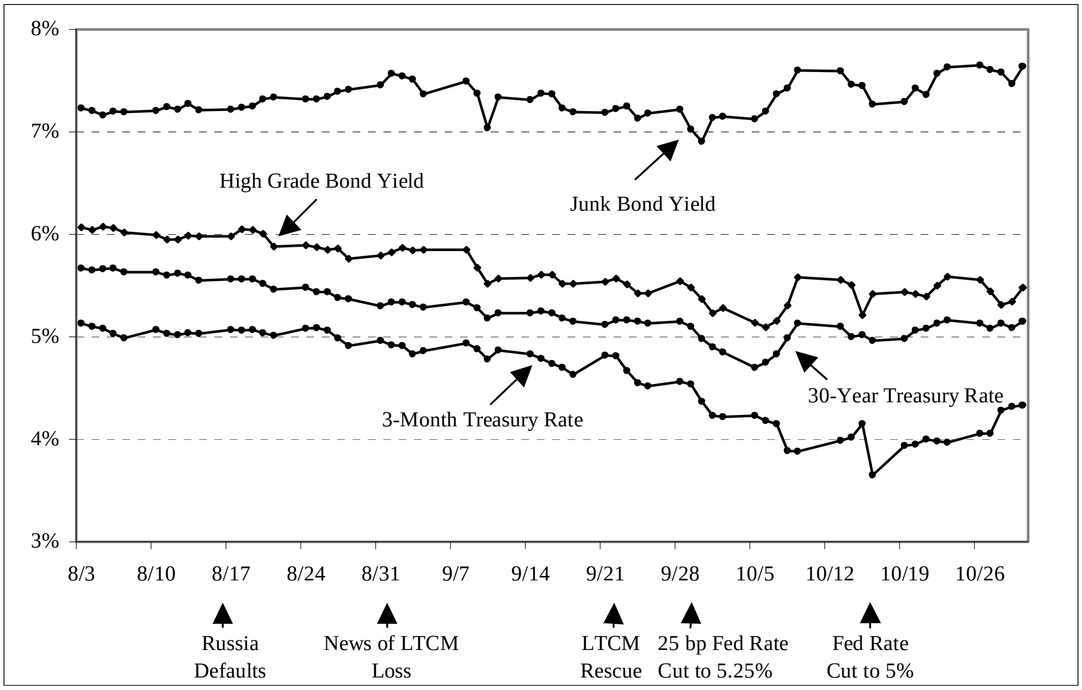

Figure A.3. Daily Yields on Treasury and Corporate Bonds in 1998.
Constant maturity Treasury rates are from the Federal Reserve Statistical Release. Daily cross-sectional means of corporate yield spreads are plotted for the frequently priced subsamples of 85 investment grade and 14 high yield bonds.

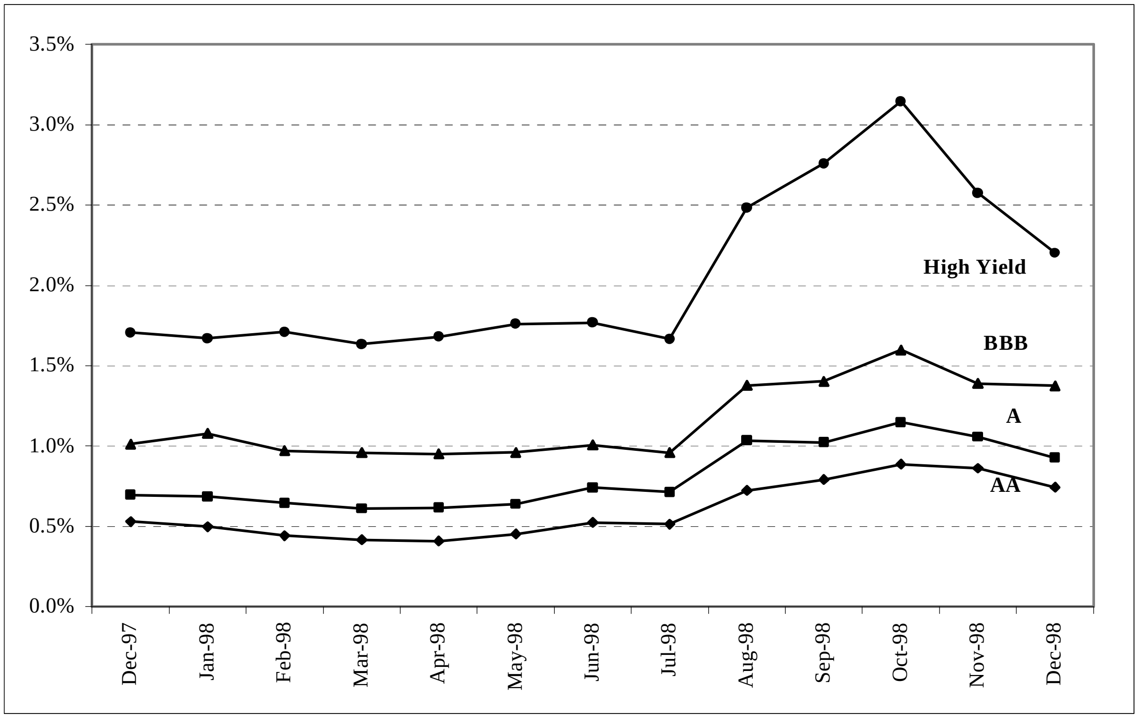

Figure A.4. End-Of-Month Yield Spreads of Corporate Bonds.
Cross-sectional means of the end-of-month yield spreads are plotted for the four credit rating groups.

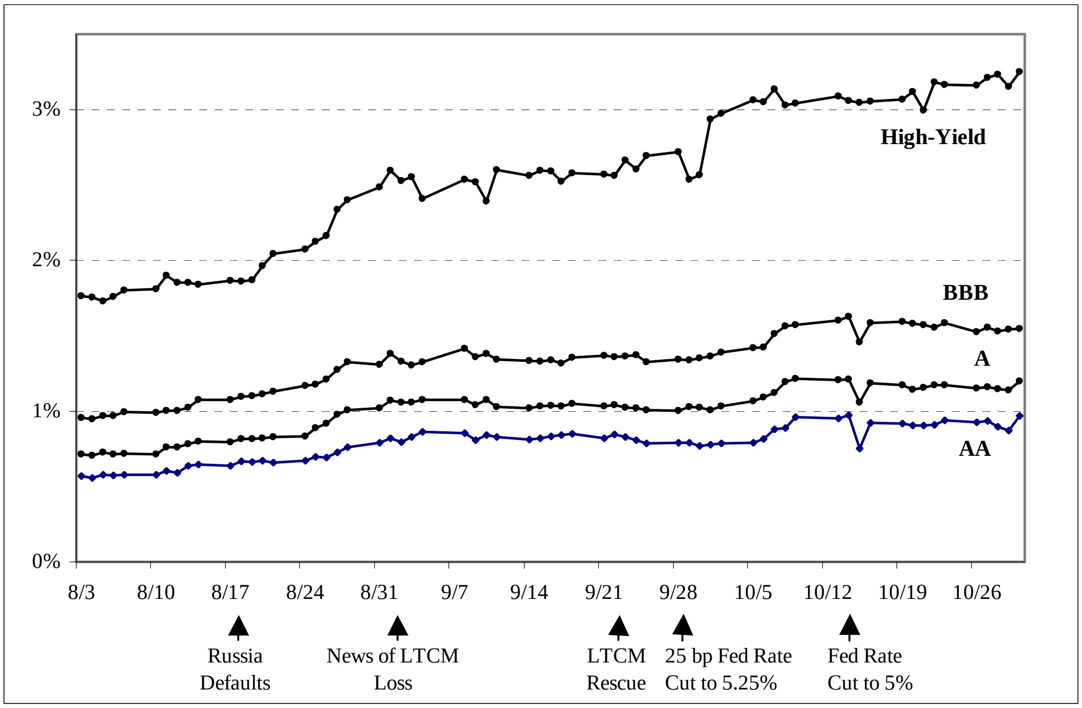

Figure A.5. Yield Spreads of Corporate Bonds.
Daily cross-sectional averages of the yield spreads are plotted by credit rating group.

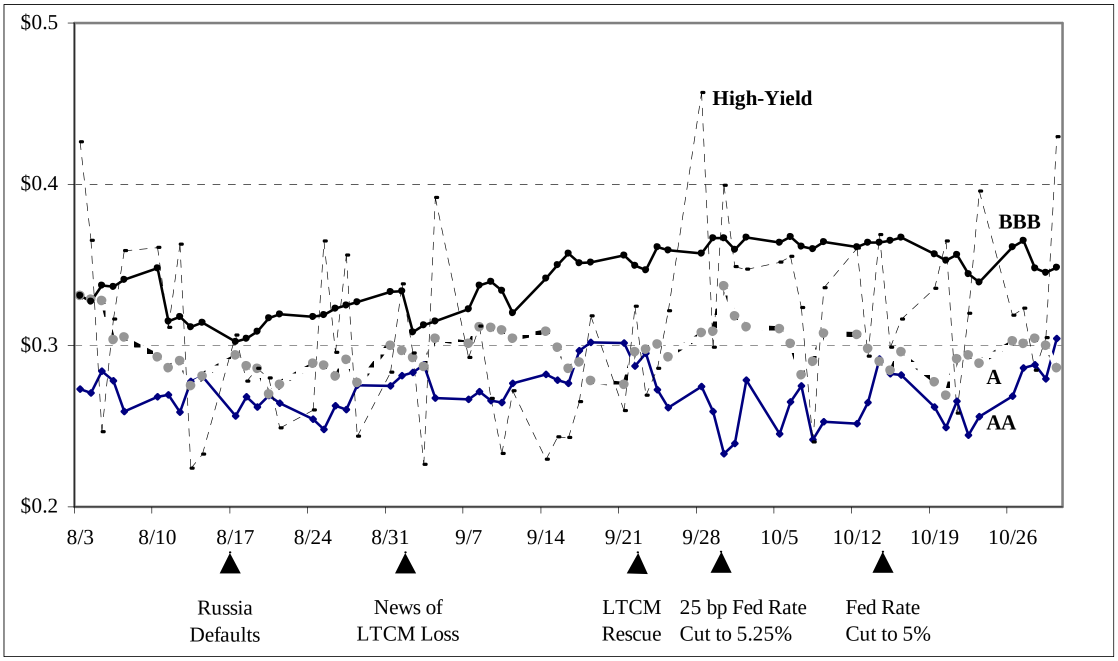

Figure A.6. Bond Daily Bid-Ask Spreads by Credit Rating Group.
Daily cross-sectional averages of the bid-ask spreads are plotted by credit rating group.

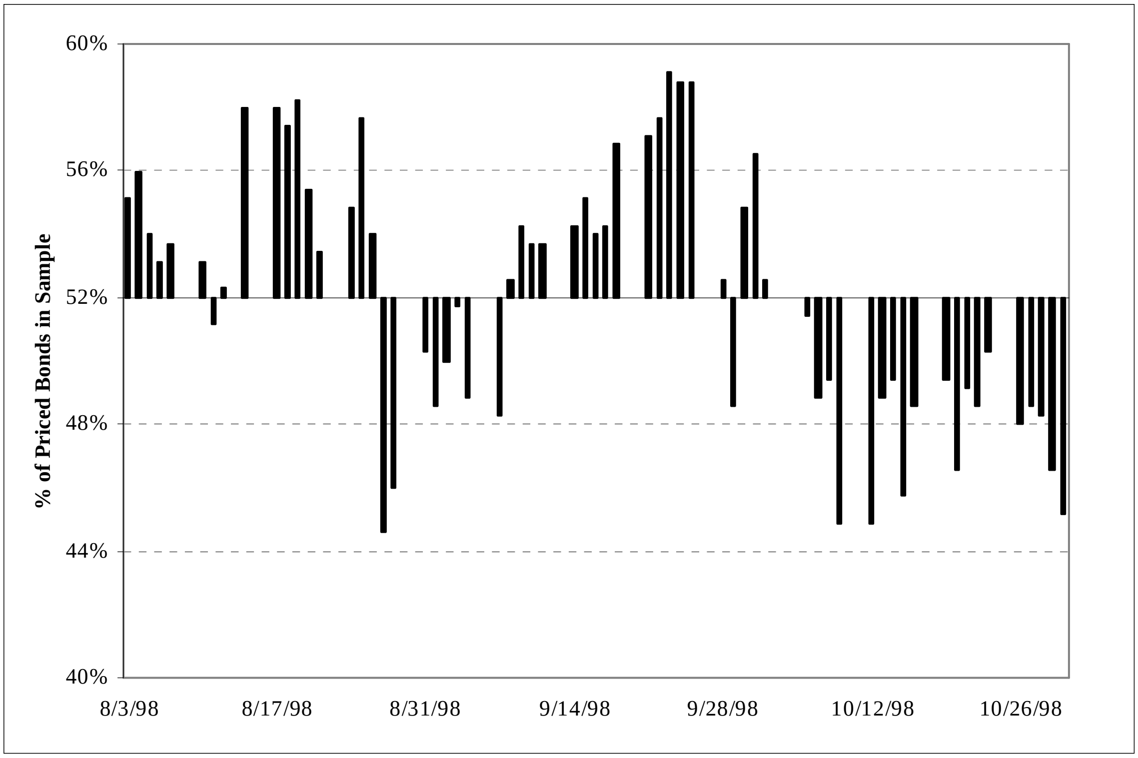

Figure A.7. Corporate Bond Market Activity During the Crisis of 1998.
Percentage of the issues in the Bloomberg sample of 352 bonds that have nonmissing price data is plotted for each day of the financial crisis, from August 1 to October 31, 1998.

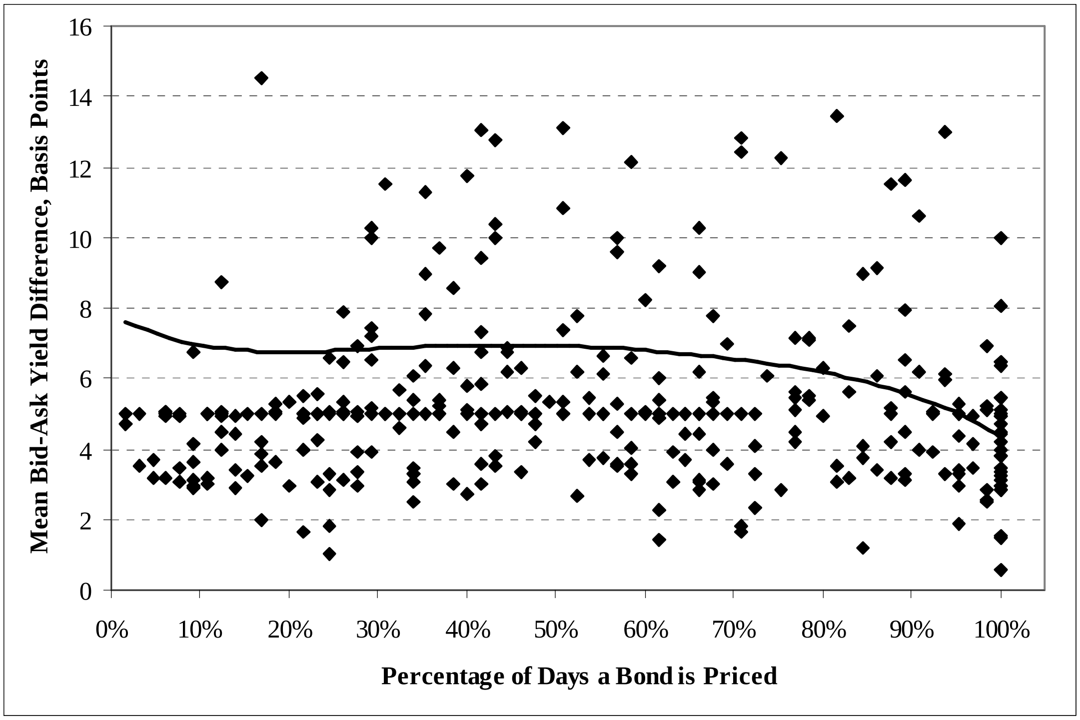

Figure A.8. Bid-Ask Spread and Pricing Frequency.
A scatter plot and a trend line of the mean bid-ask yield difference and the percentage of days that a bond has a Bloomberg generic price available. The sample consists of 352 bonds.

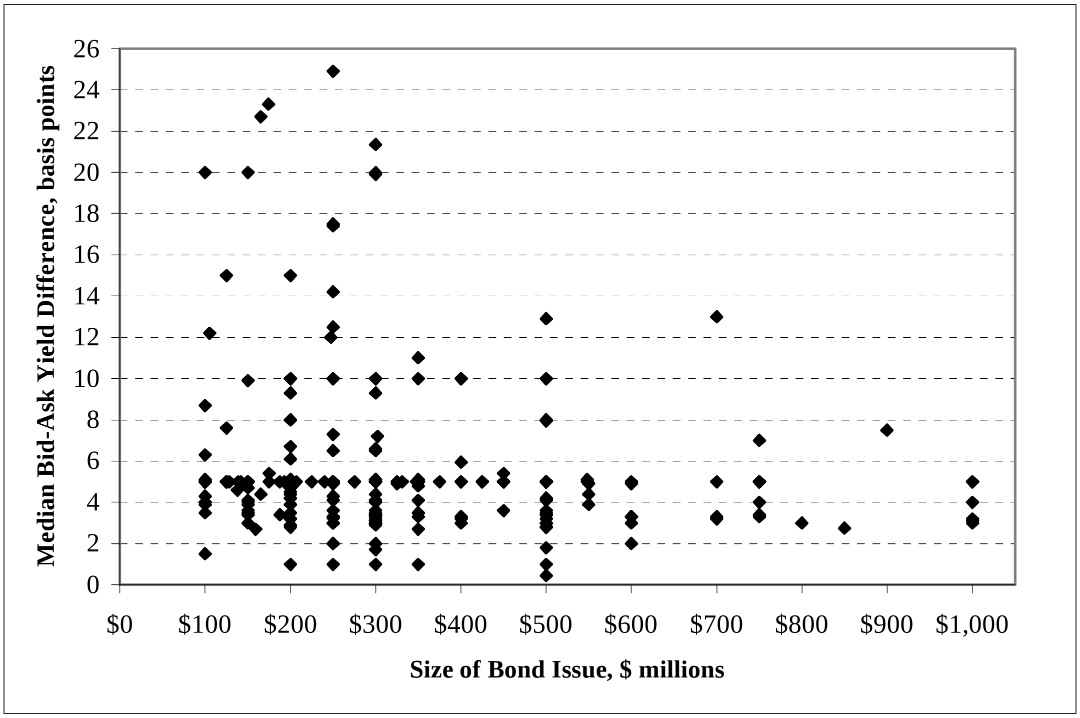

Figure A.9 Bid-Ask Spread and Size of Bond Issue.
The relationship between the bond issue size and its liquidity is presented as a scatter plot of the median bid-ask yield difference (in basis points) and the size of the bond issue (in million dollars). The sample consists of 352 bonds. Outlier issues above $1 billion and bid-ask spreads above 25 basis points are not shown.

END NOTES

[1] Other terms commonly used to denote the yield spread are credit spread and default spread.

[2] Fixed income securities are traded largely over the counter, and these markets are known for their illiquidity and opaqueness. Warga (1991) discusses various implications of the illiquidity of the secondary market for corporate bonds relative to the stock market.

[3] One of the first steps to incorporate liquidity into defaultable bond pricing is undertaken by Duffie, Pedersen, and Singleton (2003), who introduce a liquidity component into the bond pricing approach of Duffie and Singleton (1999).

[4] The Merrill Lynch High Yield Master Index is the value-weighted composite index of the U.S. dollar-denominated cash-paying bonds rated by both S&P and Moody's below investment grade. Private placement bonds (rule 144A) are not included in the index.

[5] Quotes are from Fridson (1999), Fridson and Okashima (2000) and The Wall Street Journal, September 8, 1998.

[6] Longstaff and Schwartz (1995), Leland and Toft (1996), Jarrow, Lando and Turnbull (1997) and Duffie and Singleton (1999) to mention just a few. See Eom, Helwege and Huang (2004) for a review and empirical tests of the structural corporate bond pricing models.

[7] Bloomberg L. P. is a major provider of the current and historical price data for a wide range of securities. For corporate bonds, the company calculates average market consensus prices by using its proprietary methodology and prices contributed to Bloomberg by bond dealers as well as any other relevant information. These prices are meant to represent actual trading interest in a bond at any time. If Bloomberg believes that a consensus price can not be reasonably assigned at a point in time, the bond can be marked as "not priced".

[8] At the time of data collection, July 2004.

[9] Because of the indication that the bond prices recorded in the Warga database are handled with significantly greater care (potentially more accurate) for the bonds included in the Lehman indices, some researchers retain only index-constituent bonds in their samples. This, in particular, excludes all bonds with less than one year to maturity, whose yield spreads are noted to be extremely sensitive to small price changes. If only the Lehman index bonds are retained in my sample, the total number of the daily yield observations would decreases dramatically by almost 80 percent,

even though the number of issues in the sample would decrease only modestly by 12 percent. In order to avoid the large dataset reduction, I only exclude the bonds with less than one year to maturity, but retain in my sample the bonds even if they are not contituents of the Lehman indices. Another reason not to exclude the bonds, which are not Lehman index constituents is that this would eliminate all non-investment grade bonds from the sample.

[10] Source: Federal Reserve Statistical Release, publication H.15.

[11] The unbalanced design is needed due to the different number of bonds in each rating group.

[12] In effect, a method based on simply interpolation imputes to a non-traded bond an implied bid-ask spread that is equal to the interpolated bid-ask spread for bonds that are traded. Under an alternative assumption, the implied bid-ask spread for a non-traded bond is at least as large as the largest spread for any of the traded bonds used for the interpolation.

An alternative for imputing the yield for a of non-traded bonds is to perform the following operations: (1) remove all of the yield premium for bid-ask spread in all traded bonds; (2) interpolate based on net yields; and (3) add back a premium as deemed appropriate for an imputed bid-ask spread premium of the non-traded bond.

Based on an average estimate for the yield premium of roughly half of the bid-asked spread, an approximate rule of thumb could be to simply use the ask yield as the net yield on the grounds that "yield" is typically measured as the average of the

bid yield and the ask yield. Under this rule of thumb, all of the premium for the bid-ask spread is impounded in the bid yield relative to the ask yield, or net yield. Accordingly, a simple rule would say to base all interpolations on ask yields and then add an imputed bid ask premium for non-traded bonds. Absent evidence to the contrary, one could assume that the imputed bid-ask spread for a non-traded bond would be as large, or larger, than the largest bid-ask spread observed for the day. However, estimation techniques could presumably improve on this guess.
(I would like to acknowledge Professor Buser's help in my understanding of these issues).

[13] U.S. Federal Reserve Chairman Alan Greenspan (1998a) testified that "had the failure of LTCM triggered the seizing up of markets, substantial damage could have been inflicted on many market participants, including some not directly involved with the firm, and could have potentially impaired the economies of many nations, including our own."

[14] For instance, Morgan Stanley Dean Witter & Co. announced that its fixed-income businesses had approximately $110 million net loss for the quarter that ended August 31, 1998 (Wall Street Journal, September 4, 1998).

[15] All Chapter 2 tables and figures are given in Appendix A.

[16] Source: Merrill Lynch.