

The Components of Corporate Credit Spreads:

Default, Recovery, Tax, Jumps, Liquidity, and Market Factors

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May 1999

This Revision December 2001

*We thank Capital Management Sciences (CMS) for providing the credit spread data. Earlier versions were presented at a CMS Fixed Income Conference in Phoenix, Arizona in September 1999, in Discussion at the April 2000 UCLA Liquidity Conference, at the ICBI Risk Conference in Geneva, Switzerland in December 2000, and at the University of Washington in April, 2001. Comments on this draft are welcome. Please contact Robert Geske at UCLA at 310-825-3670 or at rgeske@anderson.ucla.edu.

ABSTRACT

This paper analyzes the components of corporate credit spreads. The analysis is based on a structural model that can offer a framework to understand the decomposition. The paper contends that default risk may correctly represent only a small portion of corporate credit spreads. This idea stems both from empirical evidence and from the following theoretical assumptions underlying contingent claim models of default: that markets for corporate stocks and bonds are (i) perfect, (ii) complete, and (iii) trading takes place continuously. Thus, in these models there are no transaction or bankruptcy costs, no tax effects, no liquidity effects, no jump effects reflecting market incompleteness, and no market risk factors effecting the pricing of corporate stocks or bonds. The paper starts with the use of a modified version of the Black-Scholes-Merton diffusion based option approach. We estimate corporate default spreads as simply a component of corporate credit spreads using data from November 1991 to December 1998, which includes the Asian Crisis in the Fall, 1998. First we measure the difference between the observed corporate credit spreads and option based estimates of default spreads. We define this difference as the *residual spread*. We show that for AAA (BBB) firms only a small percentage, 5% (22%), of the credit spread can be attributed to default risk. We show that recovery risk also cannot explain this residual spread. Next, we show that state taxes on corporate bonds also cannot explain the residual. We note that the pure diffusion assumption may lead to underestimates of the default risk. In order to include jumps to default, we next estimate what combined jump-diffusion parameters would be necessary to force default spread to eliminate the residual spread. In each rating class on average firms would be required to experience annual *jumps* that decrease firm value by 20% and increase stock volatility by more than 100% *over their observed volatility* in order to eliminate the residual spread. We consider this required increase in stock volatility to be unrealistic as the sole explanation of the residual spread. So next we consider whether the unexplained component can be partly attributable to interest rates, liquidity, and market risk factors. We find the following empirical results: i) increases in liquidity as measured by changes in each firm's trading volume significantly reduces the residual spread, but does not alter the default spread; ii) increases in stock market volatility significantly reduces the residual spread by increasing the default spread relative to the credit spread, and iii) increases in stock market returns significantly increases the residual spread by reducing the default spread relative to the credit spread. This paper concludes that credit risk and credit spreads are not primarily explained by default and recovery risk, but are mainly attributable to taxes, jumps, liquidity, and market risk factors.

1. Introduction

Corporate credit risk and the credit spread compensation for that risk has become an increasingly important topic. The credit risk on a corporate balance sheet is one of the new frontiers of interest to the derivative marketplace. The advent of credit derivatives illustrates the market's attempt to measure and control that risk. This paper presents an analysis of the components of credit risk reflected in the corporate credit spread.

In the United States market for corporate bonds, credit spreads are generally measured and quoted as the yield difference between a government bond and a corporate bond *properly* adjusted for coupon and maturity. This yield difference is often attributed solely to default risk. However, since highly rated corporations have little probability of default, this credit spread seems too large to be explained solely by default risk.

Corporate default risk has been modeled by a variety of methods. Early approaches include discriminant analysis, logit models, or mortality tables.¹ Later methods follow from either a structural or reduced form based on an assumption that either the firm's value or the bond's value follows a stochastic process that permits a positive probability of default. Structural default models typically utilize option theory and the balance sheet for structure, assume a diffusion process for the evolution of firm value, and use the observed stock price, stock volatility, interest rates, and specifics about the firm's capital structure and default triggers to solve for the default spread.² Reduced form models generally assume a Poisson process for the corporate bond distribution and use observed credit spreads to calibrate the jump process parameters.³

The default spreads computed from a structural, option-based approach generally underestimate the empirically observed credit spreads. This difference between observed credit spreads and calculated default spreads may be understandable since most option models assume perfect and complete markets where trading takes place continuously.

¹ See Altman, Haldeman, and Nammacher (1977), Altman (1989), and Queen and Roll (1987).

² Structural models with non-stochastic interest rates that generalize the basic Black-Scholes and Merton models are Black and Cox (1976), Geske (1977), Shimko, Tejimo, and van Deventer (1993), Leland (1995), and Leland and Toft (1996). Models that include stochastic interest rates are Kim, Ramaswamy, and Sundaresan (1993), Longstaff and Schwartz (1995), Saá-Requejo and Santa-Clara (1997), and Brys and de Varnne (1997). Structural models will not generally match bond spreads by construction, require more data, and are notably better for explaining than forecasting.

³ Reduced form models such as Das and Tufano (1996), Jarrow, Lando, Turnbull (1997), Duffie and Singleton (1997), and Duffee (1999) take observed bond prices as a given input in calibrating the model. Reduced form models will match bond spreads by construction, generally require less data, and notably are better for forecasting than explaining.

Thus, in pricing corporate stocks and bonds as options these partial equilibrium assumptions imply there are no tax effects, no liquidity effects, no incomplete market consequences of jumps, and no market risk effects. Yet both equilibrium models and microstructure models of corporate stock prices have theoretical reasons and empirical results confirming the importance of market risk effects, tax effects, and liquidity effects.⁴ We anticipate corporate bond spreads (prices) are also sensitive to similar effects.

Historically, in the United States, corporate bond markets have been much less liquid than both government bonds and stocks. The lack of liquidity in the corporate bond market is reflected both in the need for matrix pricing and in the size and volatility of the infrequently observed bid-ask spread. Corporate bonds are also taxed differently than government bonds since they are taxed at the state level. Furthermore, Longstaff (1999) has argued that corporate bond markets are illiquid and are thought to be incomplete.⁵ Thus, it seems likely that the credit spread between corporate and government bonds may be only partly attributed to default risk. So the residual difference between the observed credit spread and this measured default spread may also be attributed to other factors such as taxes, liquidity, and market risks. Hereafter, the difference between the observed credit spread and the estimated default spread is termed the *residual spread*.

Furthermore, the relevant stochastic process for the firm dynamics in most structural model approaches to pricing corporate bonds is generally assumed to be a diffusion process. This diffusion assumption may also partly account for calculated default spreads underestimating the observed credit spreads. It may be that the assumption of a jump-diffusion process for the evolution of firm values is more realistic.

Still, in spite (and perhaps because of the intractability) of these well-known market complications and imperfections, most of the literature on corporate credit risk has presumed that the credit spread is primarily attributable to default risk. Early work with the contingent claim approach revealed that these models of default risk did not explain a large portion of the credit spread.

The literature on structural approaches to corporate security valuation begins with Black-Scholes (1973) and Merton (1974). They model corporate liabilities as contingent claims to the firm's assets. The primary source of uncertainty in all these models is the evolution of the firm's assets, while some models have added stochastic interest rates as a second source of uncertainty.

⁴ Campbell, Ammer (1993), Chen Roll, Ross (1986), Elton, Green (1998), Fama, French (1993), Fisher (1959), Helewege, Kleinman (1997), Helewege, Turner (1996), Litterman, Scheinkman (1991), Sarig, Warga (1989a, 1989b), Severn, Schwert (1992), Wei, Dajiang (1997), and Chordia, Roll, Subrahmanyam (2000) investigate many of these effects on both stocks and bonds.

Merton (1974) assumes that the default trigger occurs on the date the debt matures if the firm's value is less than the debt's face value.⁶ The firm's securities are valued as contingent claims to the firm's assets where the terminal payoffs differentiate the types of securities. For example, stockholders have the residual claim to the firm's assets after the bondholders are paid in full, which resembles a European call option with strike price equal to the debt's face value.

The actual or observed credit spread is generally measured as the bond's market yield minus the comparable risk free Treasury yield. The default spread as defined herein is a theoretical measure of the default component of the credit spread. Investigators who estimate default spreads from the Merton model for public companies are typically calibrating the model to the firm's equity price and equity volatility. Equity data is used because it is the firm's most liquid contingent claim. This is in contrast to corporate debt where matrix pricing and averages of bid-ask spreads are used extensively due to infrequent trading. Furthermore, calibrating the structural model to observed matrix bond spreads (prices) results in the measured default spread equaling the observed credit spread, and then implied stock prices are not equal to observed market prices. Thus, the implication of calibrating to bond spreads would be that our defined residual spread will equal zero and there would be no components to the observed credit spread. Credit risk would be entirely attributed to default risk. However, we do not expect credit spreads to be completely explained by default risk. By calibrating to liquid equity prices, we generate a residual spread that is not constrained to have an expected value of zero.

Jones, Mason, and Rosenfeld (1984) were the first to implement the Merton contingent claim approach to estimate the default spread. While they did find that the default spread was less than the credit spread, there was some support for the contingent claim approach, especially for the non-investment grade bonds in their sample. Their firm sample was small (137 firms) and covered a time period when corporate embedded options (calls and puts) were more prevalent in the corporate bond market.⁷

Our paper is most similar to a recent paper by Elton, Gruber, et al (2001). While they do not use a theoretical approach to model the default spread, the authors do provide a decomposition of the credit spread into default, tax, and market risk components. For the default component of the

⁵ CMS, Jeffreys & Co., Lehman Brothers, Longstaff (1999) and Warga (1991) have all reported corporate bond illiquidity and market incompleteness is reflected in both the size and volatility of the bid-ask spread and the need for matrix pricing. Some market-makers say, "corporate bonds trade by appointment and loans trade not at all."

⁶ Black and Cox (1976), Longstaff and Schwartz (1995), Leland and Toft (1996), Briys and de Varnne (1997) and Saa-Requeo and Santa-Clara (1997) assume that default can occur at any time prior to the final maturity of the bonds. Geske (1977) assumes that default can occur at multiple dates whenever payout obligations are scheduled.

⁷ Lehman Brothers and CMS data both reveal that today embedded options in corporate bonds comprise a minor (less than 2%) fraction of the market. In this study all corporate bonds with embedded options are excluded from our data.

credit spread they use two measures of an actual rating transition matrix and default vector, one from Moody's and one from S&P. Their empirical results support our theoretical measurement and empirical finding that the default spread is not a major component of the credit spread for investment grade corporate bonds. They conclude that the tax factor and especially the market risk and return factors are the more significant components of the credit spread.

This paper is organized as follows. Section 2 describes the modified Merton (1974) model and the calculation of the default spreads. Section 3 describes the data set of actual credit spreads and the data sources needed for estimating the Merton default spreads. Section 4 examines the economic and statistical properties of the residual spread. Section 5 offers some concluding remarks.

2. Implementing An Option Approach to Default

The Merton model assumes the firm's capital structure is comprised of non-dividend paying equity, S , and one zero coupon debt issue, B . The firm's assets or liabilities are assumed to follow the diffusion process as in equation (1) with no payouts, where both the volatility and term structure of risk free interest rates are assumed to be either constant or deterministic:⁸

$$\frac{dV}{V} = \mu_V dt + \sigma_V dz. \quad (1)$$

Default occurs when the firm's value, V , is less than a critical or trigger threshold at the time the debt matures. This model typically assumes the default threshold is exogenously set at the debt's face value. Strict priority rules are assumed in case of default where debt holders receive the entire firm and equity holders receive nothing.

2.1 Payouts

The original Merton model does not include payouts to security holders. Payouts of a general nature are difficult to incorporate into the original model while trying to maintain closed form solutions. The most realistic payout structure would be a fixed coupon rate for debt and a fixed stock dividend that may grow over time. Merton (1974) and Black and Cox (1976) show a closed form solution for this payout structure in the continuous time case when one assumes that the debt is a perpetuity⁹. Geske (1977) shows that this payout structure can be modeled and solved as a sequence of compound options.

An alternative approach to incorporate an arbitrary payout structure is to accrue all dividends and interest payments to the debt's maturity¹⁰. The accrued value of interest and dividends are treated as additional debt to be paid at the maturity date. The additional debt will increase the default threshold the firm must clear to remain solvent. The main difference between debt payouts and the debt principle is payouts occur over the life of the debt and thus are less risky than the prin-

⁸ Here the Merton model is modified to include payouts and a fractional recovery rate.

⁹ Leland and Toft (1996) define a fixed coupon payment but leave the dividend rate as the residual of a continuous drain of the firm's assets.

¹⁰ Roll (1977) and Vasicek (1984) both account for dividends in a similar way by reducing the current stock price with the present value of the expected dividends. This assumption has mitigating effects as it implies increases in the default threshold, reduces current firm value, and reduces firm volatility

principal. To model this, we assume payouts are to be given priority over the repayment of the firm's debt principal. This priority assumption reflects the fact that interest and dividends are collected prior to the maturity of the debt when the principal is repaid.

Payouts are assumed to accrue at the risk free rate for tractability and also to reflect their higher priority and lower default risk. The accrued value of the dividends and interest at maturity, T , is given by

$$D = \frac{1}{P(t, T)} \sum_1^T d(1 + g)^{(i-1)} P(t_i, T) \quad (2)$$

$$I = \frac{1}{P(t, T)} \sum_1^T cP(t_i, T) \quad (3)$$

where d is the initial dividend at time t , c is the coupon rate on the debt, g is the assumed growth rate of the dividends, and $P(t_i, T)$ is the risk free discount bond price at time t_i maturing at time T . This method could be used to accommodate any pre-specified payout.

2.2 Security Valuation

Debt and equity securities are priced as contingent claims to the firm's assets where the differentiation between securities is in the boundary conditions. In the Merton model, a firm's equity can be considered equivalent to a call option on the firm's assets with strike price equal to the debt's face value. The resulting solution is equivalent to the Black and Scholes (1972) and Merton (1973) call option formula.

The inclusion of dividends and interest payments changes the payoff structure from the original Merton model. Equity holders have the residual claim to the firm's assets plus an additional claim to the accrued dividends. For simplicity, the accrued dividends and interest are assumed to have equal priority. Further, since both dividend and interest would be paid before the debt principal, both are assumed to have priority over the principal. Thus, the equity payoff structure at maturity is summarized as follows:

$$S(V_T, \sigma_v, T) = \begin{cases} \frac{D}{D+I} V_T & \text{if } V_T < (D+I) \\ D & \text{if } D+I+M > V_T > (D+I) \\ D+V_T-(D+I+M) & \text{if } D+I+M < V_T \end{cases} \quad (4)$$

Evaluating the above equity payoff structure at time t yields:

$$S(V, \sigma_v, T) = VN(d_1) - P(t, T)M N(d_1 - \sigma_v \sqrt{T}) + \frac{D}{D+I} \left[V - V N(k_1) + P(t, T)(D+I)N(k_1 - \sigma_v \sqrt{T}) \right] \quad (5)$$

$$d_1 = \frac{\log\left(\frac{V}{(M+D+I)P(t, T)}\right) + \frac{1}{2}\sigma_v^2 T}{\sigma_v \sqrt{T}} \quad (6)$$

$$k_1 = \frac{\log\left(\frac{V}{(D+I)P(t, T)}\right) + \frac{1}{2}\sigma_v^2 T}{\sigma_v \sqrt{T}} \quad (7)$$

where S is stock price, M is debt principal paid at maturity T , D and I are escrowed dividend and interest paid at maturity T , $N(\cdot)$ is the cumulative standard normal distribution, and $P(t, T)$ is the price of a risk free discount bond. Bondholders are the priority claim holders and thus the maximum firm value available to bond holders is $V - S$.

2.3 Recovery Model

When default occurs, bondholders recover the full value of the firm and equity holders receive only the value of the dividends. We modify the Merton model to allow for a fractional recovery in case the firm defaults. Dead weight costs relating to the firm's default such as lawyer fees, administration expenses, or lost opportunities due to the firm's uncertainty can result in debt holders receiving less than the total firm value. Betker (1997) estimates the direct administration costs relating to bankruptcy at around 5% of firm value. Additional default costs can also arise from deviations in absolute priority where equity holders gain at the expense of bondholders. Studies

such as Eberhart, Moore, and Rosenfeldt (1990) find deviations of around 9% for firms that were technically insolvent¹¹. Estimates of the actual recovery rate for bondholders is around 45-60% as documented in Altman (1992) and Franks and Torous (1994).

In this implementation, a fractional recovery rate is assumed such that bondholders receive less than the entire firm value in case the firm defaults. The firm can be viewed as comprised of three parts, debt, equity, and default costs, C ,

$$V = S + B + C \quad (8)$$

The terminal payoff to the default costs can be summarized as:

$$C(V, T) = \begin{cases} 0 & \text{if } V_T > M + D + I \\ (1 - \alpha)(V_T - D - I) & \text{if } D + I < V_T < M + D + I \\ 0 & \text{if } V_T < D + I \end{cases} \quad (9)$$

where the fractional recovery rate is denoted as α . Evaluating the above payoff structure results in default costs equal to:

$$C = (1 - \alpha) \left[V \left[N(k1) - N(d1) \right] - (D + I) P(t, T) \left[N(k1 - \sigma\sqrt{T}) - N(d1 - \sigma\sqrt{T}) \right] \right] \quad (10)$$

Herein, default costs are subtracted from the firm value available for debt coverage because dividend and interest payments are assumed to have been paid prior to the default. The original Merton assumes a full recovery rate, $\alpha = 1$, which implies default costs, $C = 0$.

2.4 Default Spread

The market value of the debt can be written as the discounted value of the face value. Discounting is done at the risk free rate plus a risk premium that represents compensation for default risk. The value of the debt can be written as:

$$B = (M + I) P(t, T) e^{-\gamma T} \quad (11)$$

¹¹ They estimate deviations of 3-5% on average but these include firms where the assets were still above the value of the debt holder's claims.

Solving equation (11) for the default spread, γ , gives:

$$\gamma = \frac{-\log\left(\frac{B}{P(t,T)(M+I)}\right)}{T} \quad (12)$$

where the bond value is obtained from equations (5)-(10). The default spread is calculated for each firm and is the additional compensation necessary for an investor to bear the default risk.

2.5 Residual Spread

This section discusses why the corporate credit spread might not be completely explained by default risk. Here we consider recovery rates, state taxes, other stochastic processes, liquidity, and market risk factors. As previously stated, we assume that credit spreads are comprised of the default component and a residual component. Thus, the credit spread, CS , is just the sum of the default spread, DS , and the residual spread, RS

$$CS = DS + RS. \quad (13)$$

In this paper the default spread is given by a theoretical model and the residual spread is defined as that portion of the observed credit spread not accounted for by the default spread.¹²

2.5.1 Recovery Risk

In structural models the amount recovered in case of default depends on how much of the firm value remains when default is triggered. As previously stated the default boundary can be modeled as either fixed or variable, changing either deterministically or randomly. In most cases when default is noticed (triggered) there is already a loss so 100% recovery is not generally possible. Also, we will show that while the recovery rate used has a significant effect on the magnitude of the default spread it cannot lead to a complete explanation of the credit spread. This is because the default probability is so small the recovery assumption conditional on default is less important to the total credit risk.

2.5.2 Taxes

In contingent claim models, a simple method to incorporate taxes is in the boundary condition in a manner similar to Scholes (1981). An investor's receipt from the proceeds of an investment in corporate bonds relative to otherwise similar proceeds from a U.S. Treasury security is reduced by the state tax rate. However, state income taxes are only paid on the coupons, not the principal. Thus, in our scenario the boundary value of the government's tax claim is

$$\begin{aligned} Tax_T &= \tau I & V_T &\geq (D + I) \\ &= \frac{\tau I}{D + I} V_T & V_T &< (D + I) \end{aligned} \quad (14)$$

where τ is the state tax rate, which is only applied to the interest payments. Even in the absence of default risk an investor would only be willing to buy corporate bonds at a lower price or higher spread to otherwise equivalent state tax-free bonds. The value of the government tax claim is:

$$Tax = \tau \frac{I}{D + I} \left(V - \left[VN(k_1) - (D + I)P(t, T)N(k_1) - \sigma\sqrt{T} \right] \right) \quad (15)$$

Then the corporate bond value is value of the firm less the stock value, bankruptcy costs, and taxes, or $B = V - S - \text{Bankruptcy costs} - \text{Taxes}$.

Since state income taxes are significantly different across states (ranging from 0 to 10 percent), there could develop a clientele effect on the demand for these bonds. Without considering all possible nuances, Elton and Gruber, et al (2001), estimate that on average this state tax effect might account for at most 20 percent of the corporate credit spread.¹³ They conclude that the combination of both default risk and state taxes will not explain the observed corporate credit spreads. Thus, this residual spread must contain other components.

2.5.3 Other Stochastic Processes For Firm Value

¹² See Elton & Gruber, et al (2001) who use rating agency migration and default data to compute the default spread.

¹³ We neglect the "benefit" of tax losses used against gains. Also see Severn and Schwert (1992) on these tax effects.

Most structural models to date (those referenced above) assume that a diffusion process describes the changes in the firm value. Alternatively, most reduced form models to date assume that a jump process describes the movement of corporate bond prices. Of course either of these assumed processes is possible, as is the combination of a jump-diffusion process. A recent paper by Delianedis and Geske (1998) provides evidence that structural models based on an assumed diffusion process are capable of explaining rating migrations (up, down, and to default), often many months prior to the actual rating change. However, it is still quite possible that a jump component is present in the credit spread. Thus, in order to examine the resultant credit spread sensitivity to the assumed driving process we modify the Merton model for a jump-diffusion process. Given the magnitude of the underlying credit spread, we see what jump frequency, jump amplitude, and resulting increased stock price volatility would be necessary to explain that portion of the credit spread not explained by the pure diffusion model of default and recovery risk.

Following Merton (1976, 1979), assume the firm value follows a jump-diffusion process. Define T as the maturity of the debt, λ as the mean number of jump arrivals per unit of time weighted by the amount of the firm's value movement if a Poisson event occurs, and there are n independent and identically distributed random variables. Assume that the movement of the firm value if a jump occurs is lognormally distributed with a variance δ^2 . Then the value of the firm for the combined process is the sum of the diffusion values weighted by the possible Poisson arrivals and is given by:

$$V = \sum_{n=1}^{\infty} \frac{e^{-\lambda T} (\lambda T)^n}{n!} V(\sigma_n) \quad (16)$$

where the firm volatility as modified for the combined process is

$$\sigma_n^2 = \sigma_v^2 + \frac{n\lambda\delta^2}{T}. \quad (17)$$

These equations allow us to search for what jump amplitude and jump frequency are necessary to drive the residual spread to zero, implying that the credit spread is solely attributable to default risk.¹⁴ In addition we will be able to find the resulting stock volatility resulting from these jumps

¹⁴ See Merton (1976, 1979) and Ross (1976).

and can compare it to the observed stock volatility for firms in different rating classes with corresponding leverage, debt maturity, and volatility characteristics.

As already mentioned, corporate bonds trade very infrequently, which implies a thin secondary market for the vast majority of bonds. The percentage of corporate bonds with daily, or even weekly or monthly price observations reflecting actual trades is very small.¹⁵

Thus, even with no default risk, a premium should be necessary to compensate investors for the risk of having to sell or hedge a position in these thin markets. Market credit spreads should reflect this extra risk as a separate addition to default risk. The extra risk should be primarily a part of the residual spread.¹⁶

Furthermore, some hedge fund investors in corporate bonds who desire to hedge instead of sell are known to hedge a portion of their bond investment with the firm's stock because the bonds lack liquidity. In a corporate bond hedge portfolio constructed by including stock to hedge a portion of the bond's risk, the number of shares of stock necessary to hedge a specific amount of the bond's risk can be directly computed. This method of hedging illiquid corporate bonds with the firm's equity suggests that the volume of daily stock trading might be related to the residual spread. Corporate bonds issued by firms with greater stock trading volume might be easier to hedge. Thus, we will also examine whether stock-trading volume is a significant component of the residual spread.

2.5.5 Market Factors

In most contingent claim models, the stock price, stock volatility, leverage, interest rates, recovery rate and the resulting default probability are the main factors contributing to the default spread. Since stock prices have been shown to depend on market factors, and since risky bonds can be modeled as part stock and part bond, it may not be surprising to find that corporate bond spreads also possess market factors. Thus, we will examine whether market factors are also a significant component of the residual spreads.

¹⁵ See Warga (1991) for a discussion of the problems relating to corporate bond prices and the necessity of using "evaluated" prices.

¹⁶ Grinblatt (1997) argues that liquidity is the reason for the interest rate swap spread between the AA+ LIBOR swap rate and the default free Treasury rate. This extra risk may not be completely independent of default risk or hedging risk. Also see Ioannides, Skinner (1999) and Ramaswami (1991) on hedging corporate bonds.

3. Data and Construction of Credit Spreads and Default Spreads

Estimating the residual spread requires the data necessary to measure both firm default spreads and credit spreads. The default spreads calculated herein require the data for the Merton model modified for payouts and a fractional recovery rate. The default spreads are calculated for a cross section of U.S. firms for the period November 1991 to December 1998. The time period corresponds to the credit spread data that has been provided by CMS (Capital Management Sciences) Bond Edge. The discussion below explains the data source and use in this research.

3.1 Credit Spreads

Monthly credit spreads for an index of industrial corporate bonds was obtained from Capital Management Sciences (CMS) for the period November 1991 through December 1998. The credit spreads are calculated from individual non-callable corporate bonds taking coupons into account. The industrial credit spreads correspond closely to the default-spread sample. Non-callable bonds are important to use because the Merton model assumes the firm's debt has no option features.

The credit-spread data is given for the four major investment grade rating classes and is quoted as the spread above an equivalent maturity treasury rate. For each rating category, a term structure of credit spreads is also provided where the bonds in each rating category are divided into groups based on their duration. The maturities of the actual bonds are longer than the duration groups due to coupons. The duration groups range from 1 year to over 10 years. Using duration groups is convenient because implementation of the Merton model requires computing the duration of the balance sheet debt. Thus, this term structure of the credit spreads allows us to construct an index of credit spreads that match the duration of the Merton default spreads.

3.1.1 Description of CMS Credit Spread Data

The following describes the spreads derived by CMS¹⁷ that are based on a comprehensive, descriptive database for investment grade corporate and government bonds. The spreads are derived from bond prices supplied to CMS by Interactive Data Corporation (IDC). The prices for corporate bonds are a combination of traded prices, latest bids, and evaluated prices¹⁸, where the latter are derived from market levels for similar bonds (similar in quality, rating, industry, and duration). Any price that violates a CMS “reasonableness” check is eliminated from the population by an algorithm that compares the change in the bond’s price from the prior rate compared to average changes for other bonds with similar characteristics. Such differences can typically be attributed to a recording or input error in the file supplied by IDC. In rare instances, the issuing company could have been experiencing some type of “credit event” (perhaps like Enron) that had been captured by the market price but had not yet been recognized by the rating agencies.

A subset of all available issues is used to compute an average of the median spreads for each issue in each sector of the corporate bond market. First, all bonds with option features (calls, puts, and/or sinking fund options) are eliminated. Only fixed rate, non-perpetual, bullet-maturity bonds are used. The subset of bonds chosen consists of large issues from recognizable, “household” names where liquidity is better than for smaller issues, and therefore observable pricing is more frequent and likely to be most accurate. Recently issued bonds are favored as candidates to be added to the subset population, as recent trading of these issues tends to provide the best information about current prices and spread levels. Bonds that are on “credit watch” for possible upgrade or downgrade from one of the major rating agencies are eliminated from the set of bonds used to compute spreads on a given date. When actual rating changes occur, affected bonds would be eligible for inclusion in a different subset of issues used to compute average spreads for a given sector or quality.

For example, a bond rated “AA” on one date and “A” on another date could be included in the subset of bonds used to compute average spreads for “AA-rated” bonds on one date, and in the subset used to compute average spreads for “A-rated” bonds on another date. All of the bonds used to compute the average spreads for each sector were bonds that are included in the major bond market indices (such as the Lehman Brothers, Salomon Brothers or Merrill Lynch bond indices). This eliminated all bonds with a maturity of less than one year.

¹⁷ CMS Bond Edge is a leading provider of analytical software and data to institutional fixed income professionals.

¹⁸ CMS and Warga state that evaluated or matrix prices are common for corporate bonds because of thin markets.

3.1.2 Computing Credit Spreads

As stated above, corporate spreads are defined by CMS as the difference between the yield-to-maturity of the corporate bond and the yield-to-maturity of a US Treasury security with the same option-adjusted duration as the corporate bond.¹⁹ Duration adjusts for differences in coupon rates. Although bond traders typically quote corporate bond spreads in terms of the difference between the yield-to-maturity of a given bond and the yield-to-maturity of a Treasury with the same maturity date, even this convention is changing.²⁰

The spreads for each corporate bond of a given duration were averaged within each of the rating categories (AAA, AA, A and BBB) and for different major market sectors (Industrials, Financials, Utilities and International or Yankee bonds). For example, if the subset contained fifteen AA-rated Industrial bonds with a duration of 5.0, the average spread for those fifteen bonds was reported as the “AA-Industrial spread – 5 year duration”.

A few general observations can be made about the spread levels. First, the corporate credit spread curve is typically upward-sloping. In other words, spreads tend to increase with duration. This is consistent with the notion that since changes in credit risk affects long-duration bonds more than short-duration bonds. Investors are compensated for this increased risk (it can be shown that a change in spread levels has the same impact as a change in interest rate levels on the price of a corporate bond). Also, spreads are always higher for lower-rated bonds. For example, spreads for AA-rated bonds are always lower than spreads for single-A or BBB-rated bonds. Finally, spread levels exhibit much less volatility over the time period up until the market crisis in the Fall of 1998, when a “flight-to-quality” caused corporate spreads to widen dramatically and caused a notable decline in liquidity in the corporate bond markets.

3.2 Measuring Default Spreads

Default spreads are calculated with the modified Merton model from data for the firms listed on CRSP and on COMPUSTAT for the period overlapping the CMS credit spread data. To be

¹⁹ Since none of the bonds in the subset used to compute the spreads had any embedded options, their option-adjusted durations were equal to their modified Macaulay’s durations. Spreads in each rating category except AAA are based on more than 100 firms each month.

included, a firm must have valid stock and balance sheet data monthly for the period November 1991 to December 1998. Equity and interest rate data is updated monthly while balance sheet data is updated quarterly. Aggregate indices are formed based on S&P's four investment grade rating categories: AAA, AA, A, and BBB. The S&P ratings are obtained from quarterly COMPUSTAT and constitute a composite rating representative of the firm's debt. All firms with at least one rating between AAA and BBB- are included in the sample. Aggregating the Merton default spreads into rating categories is necessary to compare to the CMS credit spreads. The indices are constructed with the median default spread each month for all rating categories.

Stock volatility is calculated as the standard deviation of the previous 60 daily returns. To be included, a firm must have at least 45 valid observations within the past 60 days. A fractional recovery rate of 60% is assumed for all firms. This is the combination of loss associated to bankruptcy, reorganization, or deviations from priority rules.²¹

To implement the Merton model a number of assumptions regarding the firm's capital structure must be made that reduce the balance sheet to a single liability and duration. The Merton model assumes a single debt structure while most firms' debt structure is more complicated. To simplify the firm's liability structure, it is assumed that a firm is comprised of short-term debt and long-term debt. The short-term debt is defined as current liabilities less a netting of the portion of accounts payable that are covered by liquid securities such as marketable securities or cash. The maximum netting allowed is equal to the amount of accounts payable. The long-term debt is defined as the total liabilities less the current liabilities. The Merton model single debt issue has a face value, M , that here is equal to the duration-adjusted sum of the short term and long-term debt.²²

To calculate the duration of M requires assumptions regarding the maturities of the short-term and long-term debt issues. A maturity of 1 year is assumed for the short-term debt and a maturity of 10 years is assumed for the long-term debt. The MacCaulay duration of the long and short-term debt is computed using the current term structure of risk-free interest rates and represents the duration, T , of the Merton debt issue M .

²⁰ In recent months, some US bond market participants have begun to quote spreads relative to the interest rate swap curve. This is due to the decreasing supply of US Treasury securities, which has caused some anomalies in the shape of the Treasury yield curve that do not reflect changes in the credit outlook for corporate bonds.

²¹ Altman (1992 and Franks and Torous (1994) have estimated the write down for senior debt at 47% and 53%, respectively. This loss encompasses both bankruptcy costs and the firm value being below the default threshold.

²² COMPUSTAT firms that do not report current liabilities are excluded. COMPUSTAT reports debt maturity buckets of 1, 2, 3, 4, 5, 7, 10, and greater than 10 years. In an earlier paper Delianedis and Geske (1998) report that calculating duration based either on the exact buckets or on two appropriately constructed short term (1 year) and long term (10 year) buckets makes little difference in the qualitative results.

The risk-free discount rates are derived from U.S. Treasury notes as obtained from Data Resources Incorporated (DRI). The maturities range from 6 months to 10 years. Zero coupon rates are constructed by assuming constant forward rates between the treasury maturities and stripping the coupons from the appropriate treasury bonds.

The stock dividend is calculated as the annualized quarterly dividend multiplied by the number of shares. Dividends are assumed paid annually for the duration of the debt. The initial dividend is assumed to grow annually at a 2% rate. The sum of the accrued yearly dividends is denoted as D . Interest is assumed paid on the long-term debt and preferred stock at the prevailing risk free rate, and the accrued interest is denoted as I . The dividend and interest are accrued at the prevailing risk free rate, which reflects their higher priority.

3.3 Evaluation of Firm Value and Firm Volatility

The Merton model has two unobservable variables, V and σ_v . All other variables, such as interest rates, dividends, interest expense, debt's face value and maturity, are observable. To estimate the firm value and volatility, a minimum of two equations is needed that relate these unobservable quantities. We chose to match the Merton model to the firm's stock value and stock volatility.²³ Equity data is generally used because actual daily prices are observable and equity is the firm's most liquid security.

The equation relating the stock value to the firm value and firm volatility is given in (5) and the equation relating the stock volatility to the firm value and firm volatility is given by

$$\sigma_s = Std\left(\frac{dS}{S}\right) = \frac{V}{S} S_v \sigma_v = \frac{\sigma_v V}{S} \left(N(d1) + \frac{D}{D+I} (1 - N(k1)) \right) \quad (18)$$

The system of two equations and two unknowns can be solved to arrive at V and σ_v . Due to the non-linear nature of the two equations, numerical methods are necessary to solve the system of two equations in two unknowns.

4. Analysis of Credit Spreads and their Components

²³ Alternatively, we could match the Merton model to a firm's bond yield (price) and bond yield volatility. This would result in the default spread being equal to the credit spread by construction. The stock value equals the firm value minus the bond price, which would not necessarily be equal to the observed market value of the equity.

In this section we present the results of the measurement of credit spreads for the investment grade rating categories and the analysis of their components. We begin with a presentation of the magnitude, volatility, distribution characteristics, and interrelations of corporate credit spreads and default spreads. (See Appendix for Tables)

4.1 Credit Spreads

Table 1 presents both the credit and default spreads for about 500 investment grade firms for the 86 monthly observations from November 1991 to December 1998. The table is divided into two panels, A and B, in order to examine the effects of the “Asian/Long Term Capital Credit Crisis in the Fall of 1998” on the properties of the credit and default spreads (hereafter Asian/LTC).

The median CMS credit spreads for the four investment grade (AAA, AA, A, BBB) rating categories are 36, 48, 70, and 117 basis points, respectively. Also as expected, the volatility of the credit spreads generally increases as the rating decreases, except for the AAA category, which is a small sample (on average less than 10 firms per year). Further, while credit spreads increased dramatically during the Asian/LTC Crisis, Table 1 illustrates that the inclusion of this period in the total sample does not significantly alter the average of the median credit spreads over the 7-year period (this period represents only 6 of 86 observations).²⁴ Table 1 also shows that this is not the case for the default spreads.

4.2 Default Spreads

The median Merton default spreads presented in Table 1 for the same investment grade rating categories (AAA, AA, A, BBB) over the same time period are 2, 3, 11 and 26 basis points, respectively. Again as expected, the volatility of the default spreads increases as the credit rating decreases. However, here the inclusion of the Asian/LTC Crisis in the sample does have a significant impact on the average of the median default spreads over the same 7-year period. When the Fall 1998 is included, median default spread increases are in the range of 50% to 100%, and the default spread volatility also increases significantly.

When comparing the credit and default spreads a notable difference is the credit spreads have much larger medians relative to their volatility. The ratio of the median divided by the volatility for the CMS credit spreads are all greater than 2.5, while the same ratio is less than 1 for all the default spreads. This occurs partly because the default spreads exhibit higher kurtosis and positive

²⁴ Credit spreads have remained higher since the Fall of 1998. For example, now the spread on single A > 100 b.p.

skewness as compared to the CMS credit spreads. The inter-quartile ranges for the default spreads show that there is significant overlap between the rating categories, while this overlap does not occur for the credit spread. Also, the somewhat lower volatility of credit spreads in the period excluding the Asian/LTC Crisis is no doubt partly due to smoothing done in the construction of the credit spread indices.

The main result here, that corporate default spreads on average are generally much less than the observed credit spread, is consistent with early results of Jones, Mason, Rosenfeld (1984) and the more recent results of Elton and Gruber, et al (2000).

4.3 Residual Spreads

Table 2 presents results similar to Table 1 for the residual spread. This table also has two panels, A and B, with and without including the Asian/LTC Crisis, respectively. More specifically, the residual spread is constructed by subtracting the *median* default spread from the median credit spread. The median default spread is used because it is less subject to outliers. This is especially important for a sample of investment grade firms, which naturally have lower default spreads than non-investment grade firms. A measurement of a large default spread for an investment grade firm would have a disproportionate effect on the mean default spread while minimal effect on the median default spread.

In Table 2, Panel A, the residual spread medians are similar to the previous credit spread medians because of the small default spreads. The residual spread as a function of credit rating also behaves like the credit and default spreads, increasing as the ratings decrease. However, for investment grade bonds this is attributed to the average credit spread generally increasing faster than the average default spread as credit ratings decrease. Also, as expected, the volatility of the residual spread also increases as the ratings decrease. Furthermore, the residual spread displays non-normality with the quartile break points being non-symmetric about the median.

Table 2, Panel B presents the residual spread omitting the Asian/LTC crisis. The residual spread magnitude is about the same except for the BBB firms where the spread is about 10% higher. As expected, without the Asian/LTC Crisis the residual spreads are less volatile as measured by the standard deviations.

Table 3 presents a summary of the default, credit, and residual spreads in basis points, and illustrates what proportion of the credit spread is unexplained by default risk, or the residual spread as a percent of the credit spread. The median residual spread accounts for 78% of the BBB credit

spreads and over 95% for the AAA credit spreads. Alternatively stated, default risk only accounts for about 5% of the AAA credit spread and 22% of the BBB credit spread, respectively, during this total sample period. Thus, for investment grade firms, the majority of the credit risk is unexplained by default risk. As should be expected, the percentage of the credit spread unexplained by default risk is larger for the higher rated firms suggesting default is a less important factor in higher rated firms. This is consistent with Carty (1999) who documents that there were no actual defaults for AAA firms for the 1977 to 1997 period.

Since default risk leaves unexplained about 80% to 95% of investment grade credit spreads, the primary focus of the remaining analysis is to determine what additional factors might explain this risk. However, before proceeding to this objective we present an analysis of the correlation between these spreads with and without the Asian/LTC Crisis.

4.3.1 Correlation and Diversification Potential Across Corporate Rating Classes

Table 4 has three panels. Panel A presents the correlation of the credit spreads with the default spreads across the various rating categories. Panel B presents the correlation of credit spreads with themselves across the rating categories, and Panel C presents the correlation of default spreads with themselves across the rating categories. As with many economic variables, a crisis event tends to increase correlation and thus reduce potential diversification. Table 4 confirms this crisis-correlation effect. In all three panels the inclusion of the Asian/LTC Crisis increases the correlations across rating categories.

Panel A presents the most dramatically different results depending on whether the Asian/LTC Crisis is included or not. When the crisis is included, the correlation between the credit spreads and default spreads are all positive and range from .199 to .769. The correlations between like rating categories are all above .49. When omitting the Asian/LTC Crisis, the correlations are much lower with some even being negative.

Thus, Table 4 demonstrates that for a portfolio of investment grade corporate bonds the diversification effect of holding bonds of different ratings is significantly reduced during a crisis such as the Asian Crisis in the Fall of 1998. Furthermore, this “crisis diversification mitigation” is most pronounced for that portion of credit risk unexplained by default risk, the residual risk.

Finally, in Panels B and C in Table 4 the credit spreads and default spreads show a similar pattern of the correlation generally being higher for nearer rating classes. As expected, rating categories that are closer should share more characteristics than the more distant rating categories and thus be more correlated. This result is consistent with the default probability results of

Delianedis and Geske (1998) and with correlation results given in Das and Tufano (1996) and Pedrosa and Roll (1999).

4.4 Residual Spread Components

Longstaff and Schwartz (1992) and Duffee (1998) have documented a negative relationship between credit spreads and interest rates and equity returns. The use of equity and interest rate variables is intended to capture the dual nature of corporate bonds as part equity and part debt. Economic variables have been used by Helewege, Kleinman (1997) to explain default rates, a primary input to the default spreads. This paper extends the analysis to focus especially on that portion of credit risk unexplained by default risk. Thus, this part of our analysis is most similar to the recent paper by Elton and Gruber, et al (2001). The main difference in is we use a contingent claim model to estimate the default spread. Elton and Gruber, et al, use the actual default rates reported by Moody's and S&P to estimate that portion of the credit spread explained by default risk. As has already been shown, we arrive at the same conclusion that default risk explains a relatively small fraction of the credit spread.

What might explain the remainder of the credit spread? First, conditional on default, we focus on whether different recovery assumptions might account for a large portion of the residual spread. We report that recovery cannot explain the residual spread. Next, we report that state taxes can only account for a portion of the residual spread (similar to Elton and Gruber, 2001). Next we show that a jump-diffusion process also cannot explain the remainder of the residual spread without implying unreasonable equity volatility when compared to actual equity volatility.

Thus, we must rely on other macroeconomic factors similar to those used by the above previous researchers, such as the short-term risk-free interest rate, the risk-free term premium, the equity mar-

ket return, and a measure of equity market total risk.²⁵ However, a further difference from previous research is we use the trading volume constructed from each firm for each rating category to attempt to isolate a "liquidity" factor. As previously stated, equity trading volume can be thought of as a proxy for liquidity because hedging of corporate debt can be better accomplished in the more liquid equity market. Some corporate bond managers/traders use equity to hedge the default risk of the firm while interest rate risk is hedged through use of risk-free treasuries.

²⁵ See Bevan, Garzarelli (2000), Duffee (1998) and Cornell, Green (1991) on bond spreads.

The risk-free interest rate used is the yield on the 6-month treasury bill and the risk-free term premium used is the difference between the 10 year and 6 month treasury yield. The equity market return is taken as the total return on the CRSP value weighted index. We use the square of the equity market return as a measure of market risk. Monthly equity trading volume (number of trades) constructed for each rating category from each firm in the default spread sample is defined as the log of the total number of shares traded.²⁶

4.4.1 Recovery and Taxes

Table 5 illustrates how the default spreads vary with the recovery rate in Panel A, and with state taxes in Panel B. In contingent claims models the recovery rate is imposed after the default event as a fraction of firm value. Thus, unless the model represents a continuous first passage to default, some amount of firm value will have been lost at the discrete obligation dates. Panel A shows the default spreads increase as the recovery rate decreases, and range from about 1 (17) to 8 (72) basis points for AAA (BBB) firms when the recovery rate of firm value after the default trigger varies from 100% to 0%. This illustrates that the recovery assumption is generally less important in these models because the default probability is so small. These results are consistent with the results reported in Jones, Mason, and Rosenfeld (1985) and in Elton and Gruber, et al, (2001).

Table 5, Panel B, investigates what effect different state tax rates would have on the spread. A fractional recovery rate of about 80% across the different tax rates is assumed for this comparison because this implies an effective recovery of about 55% after the loss in firm value is observed at the default boundary. These tax consequences will be an upper bound on the magnitude of the effect because pension investors in corporate bonds are not obligated to pay state taxes.²⁷ As ex-

pected, state taxes significantly increase the measured spread, from 2 (29) b.p. to 22 (59) b.p. for AAA (BBB) at a maximum state tax rate of 10%. However, as found by Elton and Gruber, et al, (2001), this is still not enough to explain the remaining unexplained residual, so other factors must be considered.

4.4.2 Jump-Diffusion Process

²⁶ Recently, Chordia, Roll, Subrahmanyam (2000) and others have begun to analyze volume influences on prices.

²⁷ Pensions hold the majority of corporate bonds and do not pay state taxes, while insurance, mutual and hedge fund holdings are taxed.

Table 6 presents the results for the Merton model when the firm follows a jump-diffusion process. The top panel represents the firm leverage, firm volatility, and stock volatility for the base case with no jumps. Next, the base case parameters are modified with an additive jump process and the jump frequency (1 or 2 jumps/year) and amplitude are varied until the default spread is equal to the credit spread and the residual spread is zero.

This table shows that the firm value would have to instantaneously jump down about 20% (14%) with 1 (2) jump per year. The firm volatility would concomitantly have to increase by about 75% to 150% for AAA to BBB firms. The interpretation of the well-known elasticity equation (18) is that the stock volatility is always greater than the firm volatility because of leverage. This implies that the stock volatility would have to increase by more than 100% over the actual observed volatility in order for a model where jumps added to a diffusion result in default spreads that can completely explain the residual spread. Experiments that keep the equity-implied volatility with jumps about equal to the observed volatility reveal that jumps cannot explain the residual spread. Thus, while jumps may explain a portion of the residual spread it is unlikely that jumps can explain it entirely. So, we next consider other factors that might explain the residual spread.

4.4.3 Analysis of Other Components of the Residual Spread

The significance and sensitivity of the residual spread to other economic factors is determined by regressing changes in the residual spread for each rating category on changes in these factors. Median residual spreads are used. The economic variables are the risk free interest rate, r_f , the term premium, $PREM$, the equity market return, r_s , the log of the volume of equity shares traded, VOL , and the square of the equity market return, r_s^2 .

The following regression is run for the 4 investment grade rating categories.

$$\Delta RS = \alpha + \beta_1 \Delta r_f + \beta_2 \Delta PREM + \beta_3 r_s + \beta_4 \Delta VOL + \beta_5 \Delta r_{US}^2 + \varepsilon \quad (19)$$

Table 7 illustrates the regression results where changes in the residual spread are regressed on the anticipated explanatory variables.²⁸ Standard errors are adjusted using the Newey-West procedure. We find the following: i) increases in liquidity measured by changes in each firm's trading volume significantly reduces the residual spread by reducing the credit spread without significantly altering the default spread, ii) increases in stock market volatility significantly reduces the residual spread by increasing the default spread relative to the credit spread, and iii) increases in stock market returns significantly increases the residual spread by reducing the default spread relative to the credit spread.

Similar to Longstaff and Schwartz (1995) and others, we also find that risk free interest rate changes, while significant for the small sample of AAA firms that may behave more like default free bonds, are relatively insignificant for the other rating categories, as are the term premium changes.

5 Conclusion

²⁸We individually analyzed these effects on the credit and default spreads but only report the residual spread results.

This paper investigates the components of credit spreads on corporate bonds. The traditional view is default risks and recovery risks are the primary components of corporate credit spreads. This paper concludes that default and recovery risks are only minor components of corporate spreads. The major components include taxes, jumps, liquidity, market risk factors, and to a small extent interest rate factors.

Here default spreads are estimated from a version of the Merton model modified to include payouts, recovery, and taxes. The difference between the observed corporate credit spread and the theoretically measured default spread is defined as a residual spread that could include recovery, tax, jumps, liquidity, and market risk factors. The option approach to measuring default risk is founded on assumptions of perfect and complete securities markets for corporate stocks and bonds and the ability to trade continuously. Thus, in pricing corporate stocks and bonds these assumptions imply there are no tax frictions, no jump effects that would nullify complete markets, no liquidity effects, and no market risk factors.

That corporate bonds are much less liquid than either stocks or government bonds is reflected in their necessary matrix pricing and wide and volatile bid-ask spreads. For stock prices we have both theoretical and empirical reasons to believe in the importance of a market risk factors, taxes, and liquidity effects. We show bond prices are also sensitive to similar factors.

We estimate default spreads and then constructs residual spreads for a large sample of corporate credits for the period November 1991 to December 1998. The residual spread represents the substantial percent of the credit spread, ranging from 78% of the credit spread for BBB firms to about 95% for the AAA and AA firms. We find that the residual spread is larger for the lower rated firms and is more volatile as measured by standard deviation. The small default spreads are similar with Elton, Gruber, Agrawal, and Mann (2001) who use actual data on migration and default from both Moody's and S&P to empirically estimate default spreads on corporate bonds. Thus, the option approach is shown to be able to correctly capture default risk but cannot explain the extra components in the credit spread.

Next, we show that differential recovery assumptions also cannot explain the residual spread, and note as Elton, et al, (2001) that taxes can explain part but not all of the residual spread. Noting that the pure diffusion assumption may lead to underestimates of the default risk, we next estimate what combined jump-diffusion parameters would be necessary to eliminate this residual spread. In each rating class on average firms would have to experience annual *jumps* that decrease firm value by about 20% and increase stock volatility by 100% over their observed volatility. Thus, while infrequent, large jumps may explain a portion of the residual spread, jumps result in unrealistic

implied equity volatility when used to make default risk a major part of the credit spread. Finally, we investigate the effects of economic other factors on residual spreads empirically. We find in general that i) increases in liquidity measured by changes in a measure of firm trading volume significantly reduces the residual spread by reducing the credit spread without altering the default spread, ii) increases in stock market volatility significantly increases the default spread relative to the credit spread and thus reduces the residual spread, and iii) increases in stock market returns significantly reduces the default spread relative to the credit spread and thus increases the residual spread. We also find that risk free interest rate changes and their term premium changes are relatively insignificant.

This paper concludes that credit risk and credit spreads are not primarily attributable to default risk, but instead are mainly attributed to recovery, tax, liquidity, and market risk factors. The question of why corporate credit spreads have increased and remained high since the Fall of 1998 remains for future research.

Appendix

Table 1

Credit and Default Spreads

Reported in basis points are the averages of the medians, quartiles, and standard deviations for each rating category with and without the Fall 1998 Asian/LTC crisis. “Firms” indicates the average number of firms per month during this period.

Panel A: With Asian/LTC Crisis

Nov 1991 – Dec 1998

Rating ilt Spread						Credit Spread	
	Med	1Q	3Q	Std	Firms	Med	Std
AAA	1.6	0.0	7.7	3.1	18	35.5	13.3
AA	2.9	0.4	15.0	8.2	71	47.6	10.3
A	11.4	2.7	43.0	19.8	193	70.0	14.5
BBB	26.1	6.6	81.4	52.3	188	117.1	25.4

Panel B: Without Asian/LTC Crisis

Nov 1991 – June 1998

Rating	Default Spread				Credit Spread	
	Med	1Q	3Q	Std	Med	Std
AAA	1.1	0.0	5.7	2.1	33.2	9.8
AA	1.1	0.1	8.9	2.3	45.7	7.3
A	7.1	1.2	30.1	4.1	67.1	9.1
BBB	14.4	3.2	50.8	8.6	114.5	23.0

Table 2

Residual Spreads

Reported in basis points are the averages of the medians, quartiles, and standard deviations of the residual spreads for each investment grade rating category with and without including the Asian/LTC Crisis of the Fall of 1998.

Panel A: With Asian/LTC Crisis

Nov 1991 – Dec 1998					
Rating	Med	1Q	3Q	Std	% Med
AAA	33.89	35.49	27.79	14.18	0.95
AA	44.70	47.15	32.56	9.51	0.94
A	58.57	67.28	26.95	19.27	0.84
BBB	91.01	110.59	35.75	34.79	0.78

Panel B: Without Asian/LTC Crisis

Nov 1991 – June 1998					
Rating	Med	1Q	3Q	Std	% Med
AAA	32.10	33.21	27.52	14.20	0.97
AA	44.58	45.59	36.78	9.26	0.98
A	59.99	65.90	37.03	17.67	0.89
BBB	100.13	111.29	63.33	25.39	0.87

Table 3

Summary of Spreads

For Diffusion Models

Nov 1991 – Dec 1998

Rating	Default		Credit		Residual		Residual % CS
	Med	Std	Med	Std	Med	Std	
AAA	1.6	3.1	35.5	13.3	33.9	14.18	95.4%
AA	2.9	8.2	47.6	10.3	44.7	9.51	94.0%
A	11.4	19.8	70.0	14.5	58.6	19.27	83.7%
BBB	26.1	52.3	117.1	25.4	91.0	34.79	77.7%

- Spreads are in basis points. Default spread is calculated with the Merton model with accrued dividends and interest payments and a 45% loss associated with default. The model is calibrated such that the equity price and volatility are matched exactly. The default spread is the average over time of the cross-sectional medians for firms in each rating class. Credit spread data is from CMS for matched duration. Residual spread is the difference.

Table 4**Credit, Default, and Residual Spread Correlations**

Panel A: Credit and Default Spread Correlation									
Default→ With Asian/LTC Crisis ↓					Without Asian/LTC Crisis ↓				
Credit ↓	AAA	AA	A	BBB		AAA	AA	A	BBB
AAA	0.632	0.487	0.540	0.199	AAA	0.267	0.037	-.042	-.291
AA	0.613	0.682	0.725	0.396	AA	0.042	-.040	-.077	0.335
A	0.591	0.680	0.756	0.490	A	-.317	0.057	-.136	0.183
BBB	0.644	0.678	0.769	0.493	BBB	-.263	0.111	0.096	0.129
Panel B: Credit Spread Correlation									
	AAA	AA	A	BBB		AAA	AA	A	BBB
AAA	1.000	0.762	0.760	0.274	AAA	1.000	0.591	0.495	-0.089
AA	0.762	1.000	0.905	0.577	AA	0.591	1.000	0.815	0.429
A	0.760	0.905	1.000	0.712	A	0.495	0.815	1.000	0.640
BBB	0.274	0.577	0.712	1.000	BBB	-0.089	0.429	0.640	1.000
Panel C: Default Spreads Correlation									
	AAA	AA	A	BBB		AAA	AA	A	BBB
AAA	1.000	0.727	0.745	0.774	AAA	1.000	0.661	0.282	0.315
AA	0.727	1.000	0.970	0.933	AA	0.661	1.000	0.523	0.614
A	0.745	0.970	1.000	0.977	A	0.282	0.523	1.000	0.870
BBB	0.774	0.933	0.977	1.000	BBB	0.315	0.614	0.870	1.000

Table 5**Effects of Fractional Recovery Rates****And Taxes On Default Spreads*****Nov 1991 – Dec 1998***

<u>Panel A:</u>		Fractional Recovery Rates (FRR)					
Rating		100%	80%	60%	40%	20%	0%
AA AAA		0	2	4	5	7	8
AA AA		1	3	5	7	9	11
A A A		6	14	20	27	33	39
BB BBB		17	29	40	50	61	72

<u>Panel B:</u>		Variable Tax Rate with FRR= 80%					
Rating		0%	2%	4%	6%	8%	10%
AA AAA		2	6	10	14	18	22
AA AA		3	9	14	20	26	31
A A A		14	18	24	31	38	45
BB BBB		29	33	39	46	52	59

- Spreads are in basis points. Default spread is calculated with the Merton model with accrued dividends and interest payments and a variable recovery associated with default. The model is calibrated such that the equity price and volatility are matched exactly. The default spread is the average over time of the cross-sectional medians for firms in each rating class. Credit spread data is from CMS for matched duration. Residual spread is the difference.

Table 6**Jump-Diffusion Models****Necessary Jump Parameters and Volatility**

CS>DS	Rating	AAA	AA	A	BBB
S/V		.80	.75	.64	.55
V Vol Implied		.191	.170	.160	.157
S Vol Observed		.238	.226	.246	.278
No Jumps					
CS=DS	Freq/Year	Ampli tude			
Additive	1	19%	20%	18%	22%
Additive	2	14%	14%	13%	15%
V Vol Implied		.330	.337	.352	.425
Jumps					

- Assess the impact on default spreads of a jump-diffusion model instead of a pure diffusion model for the firm value. Default spreads are estimated with a jump-diffusion process for the firm value following Merton (1976, 1979). Jumps are assumed distributed lognormal with zero mean. The observed stock volatility is reported.
- Base case is the Merton model with no jumps and the default spread is much less than the credit spread.
- Next the base case parameters are used and a jump process is added (Additive). Jump magnitude is increased until the default spreads are equal to the credit spreads. The frequency of the jumps is annual. Table shows the necessary total firm volatility, which is about the same for the necessary jump scenarios.

Table 7

Residual Spread

Regression Analysis of Components

$$\Delta RS = \alpha + \beta_1 \Delta \log(Vol) + \beta_2 r_f + \beta_3 \Delta Prem_t + \beta_4 r_{Stk,t} + \beta_5 \Delta r_{Stk,t}^2 + \varepsilon_t$$

Rating	α	Log(Vol)	r_f	PREM	r_{Stk}	r_{Stk}^2	R^2
AAA	0.003	0.006	-0.071	-0.025	0.082	0.129	0.017
t-stat	0.487	0.149	-1.888	-0.769	0.262	0.488	
AA	-0.007	-0.122	-0.056	-0.051	0.582	-0.236	0.025
t-stat	-0.985	-1.964	-1.069	-1.323	1.376	-0.597	
A	-0.017	-0.245	-0.019	-0.080	1.330	-0.772	0.096
t-stat	-1.763	-2.179	-0.331	-1.775	2.266	-1.559	
BBB	-0.041	-0.513	0.064	-0.088	2.264	-1.670	0.070
t-stat	-1.915	-1.821	0.572	-0.770	2.326	-2.044	

- Regressions of changes in the residual spread on changes in a measure of trading volume, the level of risk free rate, changes in the slope of term premium, US equity market return, and volatility as changes in the squared US equity market return, and the adjusted R^2 are reported. The adjusted R^2 is much higher (45-60%) when explaining the level on the residual spread.

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