The Information Content of Option-Implied Volatility for Credit Default Swap Valuation

Charles Cao Fan Yu Ken Zhong[1]

First Draft: November 10, 2005

Very Preliminary | Comments Welcome

[1]Cao and Zhong are from the Pennsylvania State University, and Yu is from the University of California, Irvine.

The Information Content of Option-Implied Volatility for Credit Default Swap Valuation

Abstract

We find that historical and option-implied equity volatility can both explain a significant portion of the time-series variation of credit default swap (CDS) spreads. However, the implied volatility dominates historical volatility among firms with higher CDS spread volatilities, higher option volume and open interest, and lower credit ratings, as well as during sub-periods with larger CDS spread changes. We also estimate a simple structural credit risk model in order to generate out-of-sample CDS spread forecasts. Assessing the performance of the model with implied volatility as well as the commonly-used historical volatility, we reach conclusions similar to those from our regression analysis. Our finding is consistent with the anecdotal evidence surrounding recent accounting scandals at Worldcom and Tyco. It highlights the importance of choosing the right measure of volatility in understanding the dynamics of CDS spreads.

1 Introduction

According to structural credit risk models such as Merton (1974), asset volatility is one of the key determinants of individual firm credit spreads. This prediction has received strong empirical support in a number of recent studies. For example, Campbell and Taksler (2003) find that idiosyncratic firm-level volatility can explain the cross-sectional variation of corporate bond yield spreads. Cremers, Driessen, Maenhout and Weinbaum (2004) show that the option-implied volatility and the implied volatility skew improve upon the ability of historical volatility in explaining the time-series and cross-sectional variation in bond spreads. Similar findings are obtained when individual firm credit risk is represented by the more novel credit default swap (CDS) spreads. For example, Benkert (2004) finds implied volatility to be more important than historical volatility in determining CDS spreads. Zhang, Zhou and Zhu (2005) show that realized volatilities and jump risk measures extracted from high-frequency returns data contain additional information for CDS spreads. Other studies, such as Ericsson, Jacobs and Oviedo-Helfenberger (2004) and Avramov, Jostova and Philipov (2004), find no evidence of a "mysterious" principal component driving credit spread changes when individual firm volatilities are included in their analyses, reversing an earlier result due to Collin-Dufresne, Goldstein and Martin (2001). Given the ability of implied volatility to forecast future realized volatility in many different markets, it is perhaps not surprising that implied volatility is superior to historical volatility at explaining CDS spreads.[1]

In this paper, we focus on the relationship between the CDS spread and the option-implied volatility. In contrast to the extant literature, however, we take a closer look at the origin of such a relationship. Recent research has shown that the information content of the options market can help predict future stock returns under certain conditions. For example, Cao, Chen and Griffin (2005) find that call volume imbalances and next-day stock returns are strongly related prior to takeover announcements, but are unrelated during "normal" periods. Pan and Poteshman (2004) find a predictive relation between the option volume and future stock returns that becomes stronger when there is a larger presence of informed traders. To the extent that volatile CDS spreads are associated with the presence of informed trading, option-implied volatility can be especially helpful in predicting CDS spreads during such periods. Indeed, there is growing evidence that the CDS

[1]For tests of implied volatility as a predictor of future realized volatility in different markets, see Jorion (1995), Amin and Ng (1997), and Christensen and Prabhala (1998), among others.

market itself provides a price discovery channel for other markets. For instance, Hull, Predescu and White (2004) find that CDS spreads can forecast rating downgrades. Longstaff, Mithal and Neis (2003) and Blanco, Brennan and Marsh (2004) present evidence of CDS spread changes leading bond spread changes. Acharya and Johnson (2005) find CDS spread changes to forecast stock returns, especially given bad news. Taken together, these two lines of research seem to suggest an interesting link between CDS spreads and option-implied volatilities, created by the presence of informed trading in both markets.

We contrast the information content of implied volatility to that of historical volatility in predicting CDS spreads using two different methodologies. First, we follow the existing literature in adopting a regression-based framework. However, rather than estimating a panel regression model, we conduct a time-series regression for each firm in our sample. This allows us to relate the explanatory power of both volatility measures to cross-sectional differences among the firms. Specifically, we divide the firms into sub-groups based on their CDS spread volatility, option volume and open interest, and credit rating. We also divide the sample period for each firm into three sub-periods according to a moving average measure of CDS spread volatility. We find that both the size of the implied volatility coefficient and its statistical significance increase monotonically with these category variables.[2] In contrast, the historical volatility is at best described as marginally significant in the presence of the implied volatility, and often loses its statistical significance altogether when the implied volatility turns out to be the most informative for CDS spreads. Overall, our regression results suggest that the implied volatility works best as a predictor of CDS spreads when a firm has highly volatile CDS spreads along with actively-traded stock options.

To more effectively address the inherently nonlinear relationship between the CDS spread and its key determinants, our second methodology relies on structural credit risk models, which use equity prices, asset volatility, along with the capital structure of a firm to calculate its CDS spreads. Specifically, for each firm day in the sample period, we estimate the parameters of a structural model by minimizing the sum of squared pricing errors over a preceding period. We then use the estimated model with updated inputs to generate one-day ahead CDS spread forecasts. Because the structural model requires a key input of equity volatility, we have a choice between historical and implied volatility. Consequently, this procedure allows us to examine the out-of-sample performance

[2] We measure credit rating on a numerical scale, with lower integers assigned to more highly-rated issuers.

of the model under different volatility inputs.

By calling on a structural model to help decipher the information content of implied volatility, we follow a well-trodden path by practitioners to use structural models in CDS valuation.[3] Currie and Morris (2002), for example, give a vivid account of how traders use CreditGrades, an industry benchmark based on the first passage structural model of Black and Cox (1976), for conducting capital structure arbitrage trading.[4] The CreditGrades Technical Document (2002) presents a detailed analysis of the pricing performance of the CreditGrades model. In particular, it shows that the 1,000-day historical volatility results in the best fit to market CDS spreads. Yet, the same document uses a case study of Worldcom to suggest that "The long-term historical volatility estimator used in CreditGrades is robust in reasonably stable periods. However, when a firm's stock or credit moves suddenly, the historical volatility can lag true market levels. In these cases, it is constructive to examine implied volatility levels." Similarly, the CreditGrades Overview (2002) shows that for the case of Tyco, "when the CreditGrades model is run using implied volatilities, the resulting creditgrades are much more in line with market spreads."

[Insert Figure 1 here.]

To offer our own illustration, Figure 1 shows the AT&T market spreads and the CreditGrades spreads generated with the 252-day historical volatility and our implied volatility measure, respectively. The CreditGrades model is estimated using 100 daily observations prior to April 1, 2002. Because the implied volatility is much more volatile than the historical volatility, this figure shows that the use of implied volatility in the calibration exercise results in a more volatile predicted CDS spread. Consequently, if the market spread is relatively stable, we would expect the predicted CDS spread based on historical volatility to track the market spread more closely. However, the use of implied volatility yields a much better fit to the market spread around the telecommunications industry meltdown in mid-2002. In contrast, the predicted spread based on historical volatility missed the mark completely.

[Insert Figure 2 here.]

[3]The academic literature shows that structural models generally price CDS more accurately than corporate bonds. See Jones, Mason and Rosenfeld (1984), Eom, Helwege and Huang (2004), and Ericsson, Reneby and Wang (2005). This difference is usually attributed to liquidity and other non-default components in bond spreads. See Elton, Gruber, Agrawal and Mann (2001), Longstaff, Mithal and Neis (2004), and Ericsson and Reneby (2003, 2004).

[4]See Duarte, Longstaff and Yu (2005) and Yu (2005) for a comprehensive analysis of capital structure arbitrage.

Figure 2 shows the CDS spread, implied volatility, and historical volatility for a few obligors. The feature common to these obligors is that each has undergone a period with heightened CDS spread volatility. This figure shows that, indeed, the overall pattern of implied volatility closely resembles that of the CDS spread, while historical volatility appears “too smooth” relative to the other two series.

Our out-of-sample pricing analysis shows that the intuition from these figures holds broadly across our sample of 220 firms. Averaged across the entire sample, the pricing error with implied volatility is about the same as that with historical volatility. However, a further analysis reveals that the ratio between the two pricing errors is lower for firms with higher CDS spread volatility, higher option open interest, and lower credit rating. This confirms the results of our previous regression analysis. Therefore, while the information from implied volatility appears to be “drowned out” by the presence of market microstructure noise in option prices during “normal periods,” it becomes useful when the market turns turbulent. In short, our results suggest that the information from individual stock options can be beneficial for understanding the pricing in the CDS market during volatile periods. It lends support to current research effort to jointly model options and CDS in either a reduced-form or a structural framework.[5]

The rest of this paper is organized as follows. In Section 2 we explain the major data sources and variables used in our study. In Section 3 we conduct a regression-based analysis of the information content of historical and implied volatilities for CDS spreads. In Section 4 we present a pricing analysis of the relationship between CDS spreads and implied volatilities. This section begins with a brief introduction to the structural model used in the analysis. We conclude with Section 5.

2 Data

The variables used in our study derive from four major databases. We describe these databases and the associated variables below.

2.1 Credit Default Swaps

Credit default swaps (CDS) are a class of credit derivatives that provide a payoff linked to the loss-given-default on bonds or loans of a reference entity, triggered by a credit event such as default,

[5] Examples are Hull, Nelken and White (2004) and Carr and Wu (2005).

bankruptcy, failure to pay, or restructuring. The buyer pays a premium as a percentage of the notional value each quarter, denoted as an annualized spread in basis points, and receives the payoff from the seller when the credit event occurs. Fueled by participation from banks, insurance companies, and hedge funds, the CDS market has been doubling in size each year during the past decade, reaching \$8.42 trillion in notional amount outstanding by the end of 2004.[6] Because of this dramatic growth in market size and liquidity, academic research has increasingly turned to the CDS market for measures of credit risk.

In this paper, we use five-year CDS spreads taken from a comprehensive dataset from the Markit Group. This dataset provides daily composite CDS spreads on over 1,000 North American obligors from 2001 to 2004. The daily spreads are calculated from quotes contributed by over 30 banks, and undergo a statistical procedure where outliers and stale quotes are removed. In addition, three or more contributors are needed before a composite spread is computed. This level of coverage is probably the most complete among all CDS datasets available to date. We use only the five-year spreads because five-year contracts constitute well over 85 percent of the entire CDS market.[7]

2.2 Stock Options

Our source for options data is OptionMetrics, which provides daily closing prices, open interest, and volume on exchanged-traded stock and index options in the U.S. from 1996 to 2004. In addition, the dataset comprises a set of implied volatilities for standardized strike prices and maturities, which are generated using interpolation. However, because the OptionMetrics implied volatilities are extracted from just four options with moneyness and maturity straddling the given standardized values, we find that they can be quite sensitive to vagaries of the options market such as discrete maturity and moneyness effects and substantial bid ask spreads.[8] For the purpose of our study we only require one measure of volatility per firm day and are less concerned with the volatility smile or term structure effects. Therefore, we use the binomial model for American options to estimate a level of volatility that would minimize the sum of squared pricing errors across all put options with nonzero open interest. The choice of nonzero open interest emphasizes the information content of

[6] For details, see the International Swaps and Derivatives Association 2004 year-end market survey.

[7] See Hull, Predescu, and White (2004).

[8] For example, the OptionMetrics 30-day at-the-money put-implied volatility would be interpolated from four put options with strike prices straddling the forward stock price and maturities straddling 30 days. As the included options approach expiration and the current stock price changes, one or more of the four options will be replaced by other options, often causing a spurious change in the estimated implied volatility.

options that are currently in use by market participants. The use of all put options, not just four as used by OptionMetrics, reduces the distortion in the implied volatility measure attributed to the periodic switching from one contract to another.

Following Cremers et al. (2004), we also compute an implied volatility skew measure as the difference between the implied volatility of a put option with a strike-to-spot ratio closest to 0.92 and the ATM implied volatility, further divided by the difference in the strike-to-spot ratio. As shown by Bakshi, Kapadia and Madan (2003), the implied volatility skew measure is intimated linked to the skewness of the risk-neutral stock return distribution. Consequently, this measure should also have an effect on the pricing of credit default swaps, whose payoff is triggered by a "left-tail" event. This also explains our preference for the implied volatility of put options.

2.3 Stock Returns and Balance Sheet Variables

We obtain stock prices, common shares outstanding, and daily stock returns from CRSP, and the book value of total liabilities from Compustat. We calculate both the 252-day and the 1,000-day historical volatilities, and define the firm leverage ratio as total liabilities divided by the sum of total liabilities and the market capitalization.

2.4 Market Variables

Collin-Dufresne, Goldstein and Martin (2001) show that market variables can explain a significant part of the time-variation of bond spreads. We therefore include the following market variables in our regression analysis:

- *Marke-level returns and volatilities.* We use the S&P 100 implied volatility (VIX) and implied volatility skew, obtained from OptionMetrics, and the S&P 500 return and historical volatility, obtained from CRSP.

- *Default-free term structure level and slope.* For the term structure level we use the five-year Treasury bond yield. For the slope, we calculate the difference between the ten-year and the two-year yields. Both variables are obtained from Datastream.

- *Market-level credit risk.* We use the Baa yield from Moody's.

- *Bond market liquidity.* We take the ten-year swap yield minus the 10-year Treasury yield, and the 30-day Eurodollar rate minus the 30-day CD rate, both obtained from Datastream.

2.5 Summary Statistics

We combine variables from all four sources to arrive at our final sample for the regression analysis. First, we eliminate obligors in the financial, utility, and government sectors because of the difficulty in interpreting their capital structure variables. We then require that the obligors have 1) more than 377 observations of the CDS spread, the 252-day historical volatility, and the leverage ratio, and 2) more than 100 observations of the implied volatility skew. These requirements ensure that each obligor has close to 1.5 years of daily data available for the firm-level time-series regression analysis. The second requirement turns out not to be binding once the first requirement is met. This leaves us with a final sample of 220 firms.

[Insert Table 1 here.]

Table 1 reports the cross-sectional summary statistics of the time-series mean of the variables. The sample firms appear to be very large, with a mean market capitalization in excess of $20 billion. The average firm has also done remarkably well during the sample period. The annualized mean daily stock return is 20.99 percent. In contrast, the mean return on the S&P 500 index is only -2.30 percent in the same period.

For the volatility measures, the mean firm-level OptionMetrics put-implied volatility is 42.76 percent, slightly larger than the firm-level historical volatility of 40.43 percent. However, there appears to be some differences between the OptionMetrics put-implied volatility and the implied volatility inferred from all put options with positive open interest. Namely, the latter measure has a slightly lower cross-sectional mean (38.80 percent vs. 42.76 percent) and standard deviation (9.68 percent vs. 11.38 percent). This is consistent with the latter volatility measure containing less market microstructure noise. We also observe that the mean S&P 100 implied volatility skew of 1.13 is more than twice as large as the mean firm implied volatility skew of 0.55. This is consistent with the finding of Bakshi, Kapadia and Madan (2003).

[Insert Table 2 here.]

Lastly, Table 2 reports the distribution of the number of options in various maturity and moneyness categories. Across all options covered by OptionMetrics, the distribution across moneyness and maturity appears to be fairly uniform. However, only near-the-money options (those with moneyness between 0.8 and 1.2) are heavily traded. While this suggests that we should focus on near-the-money options, options with positive trading volume seem to be a relative minority of the total. On the other hand, the distribution of put options with open interest is similar to the distribution of all options, and they constitute about 40 percent of the total number of options.

3 Regression Analysis

In this section we present a regression analysis of the information content of implied volatility for CDS spreads. Following the discussion in Section 2.2, we use the implied volatility estimated from all put options with nonzero open interest.

3.1 Benchmark Regressions

We conduct time-series regressions for each of the 220 firms, in which the dependent variable is the CDS spread. In Table 3, we start with univariate regressions, pitting the CDS spread against either the 252-day historical volatility or the implied volatility. We then take the residuals from the first step and regress them on the other explanatory variable.

[Insert Table 3 here.]

We find a strong relation between the CDS spread and the two volatility measures that is both statistically and economically significant. A one percent increase in the historical (implied) volatility raises the CDS spread by about 4.1 (5.6) basis points. The volatility coefficients are highly significant, with average regression t-statistics in excess of 12 (15). Table 2 also presents the percentage of cases out of the 220 individual firm regressions in which the t-statistics are greater than 1.96. For the univariate regression with historical (implied) volatility, 92 (99) percent have t-statistics greater than 1.96. Another piece of evidence indicating the strong link between historical (implied) volatility and CDS spreads is that the volatility measure alone accounts for 36 (56) percent of the time-series variation of CDS spreads.

While both volatility measures are important, there is some evidence that the implied volatility measure has an edge over historical volatility in explaining CDS spread changes. This is evident from the higher average R^2 (56 vs. 36 percent) and the higher average t-statistics (15.88 vs. 12.46) in the univariate regressions with implied volatilities, and the fact that implied volatility explains a larger portion of the residuals (23 vs. 9 percent) from the first-stage regressions. It is also reflected in the larger percentage of cases with t-statistics greater than 1.96 when implied volatility is used in the univariate regressions (99 vs. 92 percent) or used to explain residuals from regressing the CDS spread on historical volatility (94 vs. 59 percent).

[Insert Table 4 here.]

In Table 4, we expand the set of regressors to include additional variables as described in Section 2. We find that the effect of these additional variables on the CDS spread, if any, is consistent with theoretical predictions and the extant empirical evidence. For example, the average coefficient on the firm implied volatility skew is positive, although generally not statistically significant. This accords with the implied volatility skew being a proxy of the risk-neutral skewness of the stock return distribution—the larger the skew, the higher the probability of default and the CDS spread. The average coefficient on the firm leverage ratio is positive but not significant. The firm stock return, a variable that is often used as a substitute for leverage, appears insignificant. The lack of significance of these two variables could be due to multicollinearity when both are included in the same regression equation.

Among the market variables, we observe negative coefficients for the Treasury term structure level and slope. This is consistent with the evidence from corporate bond yield spreads (see Duffee (1998, 1999)). The coefficient for the Baa yield is positive and significant, which can be attributed to the close relationship between bond and CDS markets (see Blanco, Brennan and Marsh (2004) and Longstaff, Mithal and Neis (2004)). Surprisingly, none of the market volatility and return variables are significant. This suggests that the information content of market-level volatilities is subsumed by firm-level volatilities.

With this laundry list of additional variables included in the regressions, the average R^2 of the time-series regressions has increased from 63 percent in Regression One to 85 percent in Regression Four. We notice that in the most exhaustive Regression Four, the firm implied volatility still comes up significant, with an average t-statistics of 4.43. In contrast, the firm historical volatility becomes insignificant with an average t-statistics of only 1.26. The cross-sectional distribution of t-statistics appears to be tighter for implied volatility than for historical volatility—the former has 73 percent of cases out of 220 with t-statistics greater than 1.96, while the latter has only 45 percent such cases. We also conduct one-sided test of whether the implied volatility coefficient (β_2) is greater than the historical volatility coefficient (β_1). At the ten percent significance level, we find that in 47 percent of the cases we would reject $\beta_2 = \beta_1$ in favor of $\beta_2 > \beta_1$. On the other hand, we would reject $\beta_1 = \beta_2$ in favor of $\beta_1 > \beta_2$ in only 23 percent of the cases.

Overall, with the benchmark regressions we find that both the implied volatility and the historical volatility are important determinants of the time-variation in the CDS spread. Each has its unique information content that is not shared by the other measure, although the evidence suggests that implied volatility has an edge over historical volatility in predicting CDS spreads.

3.2 By CDS Spread Volatility

To develop a better understanding of the information advantage of implied volatility over that of historical volatility, we divide our sample according to several firm characteristics and summarize the firm-level regressions for each sub-group.

First, we divide the 220 firms into three groups according to the volatility of their CDS spreads over their respective sample period. The major difference between implied volatility and historical volatility is that the former reflects current market expectations, while the latter is an equally-weighted average of past information. As such we would expect implied volatility to be more informative than historical volatility for obligors whose CDS spread is changing more rapidly.

[Insert Table 5 here.]

Table 5 presents evidence supporting this conjecture. For the least volatile group of firms (Group 1), the average coefficient for implied volatility is 80.87 and the average t-statistics is 3.17. However, it increases to 177.50 for Group 2 and 666.02 for the most volatile group. The average t-statistics also increases monotonically, to 3.87 for Group 2 and 6.25 for Group 3. The percentage of firms with t-statistics greater than 1.96 is 64 percent for Group 1, 74 percent for Group 2, and 81 percent for Group 3. In contrast, we do not find the coefficient of historical volatility to follow this pattern. Specifically, historical volatility becomes stronger as we move from Group 1 to Group 2, but then loses its significance among the most volatile group of firms. For the least volatile group, we would reject $\beta_2 = \beta_1$ in favor of $\beta_2 > \beta_1$ in 42 percent of the cases and reject $\beta_1 = \beta_2$ in favor of $\beta_1 > \beta_2$ in 25 percent of the cases. For the most volatile group, these numbers are 59 and 15 percent, respectively. These results confirm a more important role for implied volatility as the CDS market becomes more active.

As the volatility of CDS spreads increases, Table 5 shows that they become more sensitive to leverage ratio and a number of market risk variables such as the five-year Treasury yield, the swap spread, and the Baa yield. Because firms with more volatile CDS spreads are also more likely to have higher average CDS spreads, this can be attributed to a nonlinear relation between CDS spreads and the included variables.

3.3 By Option Volume and Open Interest

Many individual stock options are thinly-traded and suffer from liquidity problems. This results in high bid-ask spreads relative to option premiums and bid-ask bounce in closing prices. We would therefore expect the information content of implied volatility to be reduced by the presence of market microstructure noise in option prices. To examine this effect, we divide the firms into three groups according to the ratio of option volume to stock volume. We adopt this metric because it is the ease in trading options relative to the underlying stock that is likely to affect the information content of option-implied volatility.

[Insert Table 6 here.]

Table 6 shows that, indeed, the implied volatility becomes a more significant regressor as the option-stock volume ratio increases. For Group 1, the coefficient of implied volatility is 233.64, already more than double the size of the coefficient for historical volatility. However, it increases further with the option-stock volume ratio, and its statistical significance increases as well. For Group 3, the implied volatility coefficient is 428.73, more than five times the size of the corresponding historical volatility coefficient. This relationship appears to be monotonic, which is also reflected in the percentage of β_2 with t-statistics greater than 1.96. In contrast, the size of the historical volatility coefficient is the smallest among the group with the largest option-stock volume ratio, and in none of the regressions is it statistically significant. Moreover, our one-sided coefficient tests seem to return more cases with $\beta_2 > \beta_1$ and fewer cases with $\beta_1 > \beta_2$ as the option volume increases.

Incidentally, the firm-level implied volatility is the only independent variable whose coefficient becomes larger and more significant with the option volume. The coefficients of other independent variables, such as leverage and the Baa yield, are either insignificant or becomes smaller with the option volume. Taken together with the behavior of the implied volatility coefficient, this shows that the information content of implied volatility is intimately tied to the liquidity of the options market.

In addition to the option volume, we investigate an alternative measure of the quality of options market information, the open interest. In some sense, the open interest could be a better measure of the size of the options market because it does not suffer from the double counting of offsetting transactions. We construct a normalized measure by dividing the option open interest by the total common shares outstanding.

[Insert Table 7 here.]

Table 7 largely confirms the findings with option volume. Namely, the coefficient on historical volatility is insignificant, while the coefficient on implied volatility is consistently significant and becomes the largest in the group with the highest option open interest. As in Table 6, the only other variable that is consistently significant is the Baa yield.

3.4 By Credit Rating

Because the Merton (1974) model predicts a nonlinear relation between credit spreads and firm structural characteristics, we also divide the sample according to stock return volatility and leverage ratio. However, the results of these exercises are similar to partitioning by the credit rating of the firm.[9] The credit rating is related to the overall level of credit risk of the firm, and may contain information not captured by stock return volatility and leverage ratio. Hence only the set of results related to credit rating are presented here.

[Insert Table 8 here.]

[9] More specifically, we use the credit rating of the senior unsecured debt of the firm. Furthermore, this is the "instantaneous" credit rating at the end of 2004 and not the mean rating over the sample period, as only the former is available in our CDS dataset.

Table 8 confirms that there is a nonlinear relationship between the CDS spread and many of the included independent variables. This is evident in light of many of the average coefficients whose magnitude becomes larger as the credit rating migrates from AA and above to BB and below. In particular, the size of the average implied volatility coefficient and its average t-statistics are both increasing as the credit quality of the firm declines. While this observation is consistent with a nonlinear dependence between the CDS spread and equity volatility, our previous results from partitioning the sample by CDS volatility, option volume, and open interest suggest that this does not completely explain the relationship between CDS spread and implied volatility.

3.5 Interaction between Implied Volatility and CDS Spread Volatility

In Section 3.2 we have shown that implied volatility becomes more informative for firms with higher CDS spread volatility. The CDS spread volatility used in that analysis is derived from changes in the CDS spread across the entire sample period for a firm. It still leaves unanswered the question whether implied volatility would be more informative during specific sub-periods in which the CDS spread experiences dramatic changes. This is an interesting question because many firms in our sample have gone through periods of financial distress, bankruptcy filings, or accounting restatements, with skyrocketing CDS spreads. To study this issue more carefully, we construct dummy variables that indicate less, median, or more volatile CDS spreads by ranking within the sample period for each firm a 30-day centered moving average volatility of its CDS spreads. We then interact these dummy variables with the firm-level implied volatility and include them in the benchmark regression of Section 3.1.

[Insert Table 9 here.]

Table 9 presents the results from this regression for three groups of firms partitioned by their CDS spread volatility as in Table 5. The basic pattern in Table 5 is reproduced here. Namely, the coefficient of implied volatility increases monotonically with CDS spread volatility. More interestingly, the coefficient of implied volatility also increases monotonically when the sub-period for each firm changes from "less volatile" to "more volatile." Therefore, the CDS-implied volatility relationship appears to be present in both the cross-section and the time-series.

4 Pricing Analysis

In light of the different behavior of firm-level historical and implied volatility in CDS spread regressions, we conduct a pricing analysis using a structural model whose equity volatility input can be either historical or implied volatility.

4.1 The Model

The model that we use for the pricing analysis is called CreditGrades, an industry benchmark for evaluating CDS spreads, jointly developed by RiskMetrics, JP Morgan, Goldman Sachs, and Deutsche Bank. This section contains a brief introduction to the model, the details of which can be found in the CreditGrades Technical Document (2002). Although a plethora of extensions have followed the basic structural model of Merton (1974), we choose this industry model for two reasons. First, it appears to be widely adopted by practitioners in proprietary trading.[10] Second, it contains an element of uncertain recovery rate, which helps to increase short-term spreads.[11] Our analysis can be easily adapted to other structural models. We plan to do this in a later revision.

The CreditGrades model assumes that under the pricing measure the firm's value per equity share is given by

$$\frac{dV_t}{V_t} = \sigma dW_t,$$

where W_t is a standard Brownian motion and σ is the asset volatility. The firm's debt per share is a constant D and the default threshold as a percentage of debt per share is

$$L = \overline{L}e^{\lambda Z - \lambda^2/2},$$

where $\overline{L} = E(L)$, Z is a standard normal random variable, and $\lambda^2 = var(\ln L)$. Note that the firm value process is assumed to have zero drift. This assumption is consistent with the observation of stationary leverage ratios and the model of Collin-Dufresne and Goldstein (2001).

Default is defined as the first passage of V_t to the default threshold LD. The density of the default time can be obtained by integrating the first passage time density of a geometric Brownian motion to a fixed boundary over the distribution of L. However, CreditGrades provides an approximate solution to the survival probability $q(t)$ using a time-shifted Brownian motion, yielding the

[10] See Currie and Morris (2002).

[11] Few of the extant structural models have this feature, with the exception of Duffie and Lando (2001), Cetin et al. (2004), and Collin-Dufresne, Goldstein, and Helwege (2003).

following result:[12]

$$q(t) = \Phi\left(-\frac{A_t}{2} + \frac{\ln d}{A_t}\right) - d \cdot \Phi\left(-\frac{A_t}{2} - \frac{\ln d}{A_t}\right),$$

where $\Phi(\cdot)$ is the cumulative normal distribution function,

$$\begin{aligned} d &= \frac{V_0}{\overline{L}D} e^{\lambda^2}, \\ A_t^2 &= \sigma^2 t + \lambda^2. \end{aligned}$$

With constant interest rate r, bond recovery rate R, and the survival probability function $q(t)$, it can be shown that the CDS spread for maturity T is

$$c = -\frac{(1-R)\int_0^T e^{-rs} dq(s)}{\int_0^T e^{-rs} q(s)\, ds}.$$

Substituting $q(t)$ into the above equation, the CDS spread for maturity T is given by

$$c(0,T) = r(1-R)\frac{1 - q(0) + H(T)}{q(0) - q(T)e^{-rT} - H(T)},$$

where

$$\begin{aligned} H(T) &= e^{r\xi}\left(G(T+\xi) - G(\xi)\right), \\ G(T) &= d^{z+1/2}\Phi\left(-\frac{\ln d}{\sigma\sqrt{T}} - z\sigma\sqrt{T}\right) + d^{-z+1/2}\Phi\left(-\frac{\ln d}{\sigma\sqrt{T}} + z\sigma\sqrt{T}\right), \\ \xi &= \lambda^2/\sigma^2, \\ z &= \sqrt{1/4 + 2r/\sigma^2}. \end{aligned}$$

Normally, the equity value S as a function of firm value V is needed to relate asset volatility σ to a more easily measurable equity volatility σ_S. Instead of using the full formula for equity value, CreditGrades uses a linear approximation $V = S + \overline{L}D$ to arrive at

$$\sigma = \sigma_S \frac{S}{S + \overline{L}D}.$$

This completely specifies the CreditGrades model. In summary, the model requires the following eight inputs to generate a CDS spread: the equity price S, the debt per share D, the interest rate r, the average default threshold $\overline{L}$, the default threshold uncertainty λ, the bond recovery rate R, the time to expiration T, and finally the equity volatility σ_S.

[12] The approximation assumes that W_t starts not at $t = 0$, but from an earlier time. In essence, the uncertainty in the default threshold is shifted to the starting value of the Brownian motion.

4.2 Estimation Procedure

Out of the eight input variables to the CreditGrades model, three are unobserved. They are the average default threshold $\overline{L}$, the default threshold uncertainty λ, and the bond recovery rate R. Therefore, for each firm day in our sample, we use the preceding 100 daily observations to estimate these three parameters by minimizing the sum of squared relative pricing errors. Clearly, selecting a shorter estimation period will reduce the in-sample fitting error. However, this does not necessarily guarantee a better out-of-sample performance. Ultimately the choice of the estimation period is empirically driven.

Once the parameters have been estimated, the next step is to use the estimated parameters at time t with the stock price, debt per share and interest rate at $t+1$ to generate a CDS spread. Therefore, while $\left(\overline{L}, \lambda, R\right)$ are used "out-of-sample," the other inputs to the model, (S, D, r, σ_S), are always kept up to date. This is what we mean by "one-day-ahead forecast" of the CDS spread in the pricing analysis. We then compare these predicted CDS spreads with the observed spreads to calculate, for each of the 220 firms, the out-of-sample root-mean-squared relative pricing error (RMSE). Recalling that the model is re-estimated each day, we also compute a time-series average of the in-sample RMSE for each firm.

4.3 Results

Across all 220 firms, the average in-sample and out-of-sample RMSE are 0.2558 and 0.3863, respectively, when the 252-day historical volatility is used in the estimation. When the same estimation uses the implied volatility, the respective RMSE are 0.2734 and 0.3719. It seems that historical volatility performs slightly better in-sample but marginally worse out-of-sample than implied volatility.

However, it is difficult to assess the relative performance between the two volatility measures with just these four numbers. To more carefully examine the balance between historical and implied volatility, we conduct a cross-sectional regression using the ratio of the out-of-sample RMSE with implied volatility to the out-of-sample RMSE with historical volatility as the dependent variable. For the independent variables we use CDS spread volatility, option volume, and open interest, as well as other control variables such as credit rating, leverage ratio, and total assets.

[Insert Table 10 here.]

Panel A of Table 10 presents the summary statistics of the regression variables (all variables are time-series means). First of all, the distribution of RATIO_IN clearly has most of its mass to the right of 1. This is a clear indication that, for most firms, historical volatility generates lower in-sample fitting errors. The distribution of RATIO_OUT, however, is more evenly spread across 1. This is the main motivation for checking if using implied volatility results in better out-of-sample performance for a subset of firms. For the other variables, we first note that our sample consists entirely of large investment-grade firms. Second, the CDS spread volatility variable is extremely positively skewed—its mean is higher than the third quartile, and its standard deviation is more than three times its mean value. Third, the average firm has about 1,500 puts traded and 54,000 puts outstanding on an average day.[13]

Panel B of Table 10 presents the correlation among the regression variables. Pearson correlation coefficients with p-values less than 0.05 are marked with an asterisk. First, the out-of-sample RMSE ratio is negatively related to CDS spread volatility, put option volume, put option open interest, and credit rating. As expected, firms with higher leverage and lower credit rating have higher CDS spread volatility. However, the correlations between CDS spread volatility and option volume and open interest are insignificant, indicating that better performance from implied volatility is not just limited to firms with higher spreads.

[Insert Table 11 here.]

Table 11 then presents the regression results. We find that the univariate relation between the out-of-sample RMSE ratio and the CDS spread volatility, option open interest, and credit rating persists in the multivariate setting. However, the option volume variable appears to be insignificant. To put these coefficients into perspective, consider the mean value of RATIO_OUT at 1.038. A one-standard-deviation increase in the CDS spread volatility would lower it to 0.988. A one-standard-deviation increase in the option open interest would lower it further to 0.838. Lower the credit rating by one standard deviation reduces RATIO_OUT still to 0.781. It appears that for

[13]One contract is for selling 100 shares of the underlying stock.

firms with higher CDS spread volatility, lower rating, and higher option open interest, the implied volatility is especially informative for predicting CDS spreads. This result is broadly consistent with our regression findings in Section 3.

We also repeat the estimation procedure using an estimation period of 25 observations instead of 100. In this case, for historical volatility the average in-sample and out-of-sample RMSE are 0.1413 and 0.2369, respectively. With implied volatility, the respective RMSE are 0.1674 and 0.2680. Therefore, it appears that both the in-sample and out-of-sample pricing errors are somewhat lower than in the case with a 100-day estimation period. The regression analysis in this case (presented in Column 2 of Table 11), however, shows that the results remain qualitatively the same.

5 Conclusion

Which volatility measure, historical or implied volatility, is more useful for predicting credit default swap spreads? This is the main question of the paper. Our motivation comes from two sources. First, the academic literature, using credit spread regressions, finds that both measures are useful for predicting bond and CDS spreads, but stops short of investigating the differences between the two measures. Second, there is some anecdotal evidence surrounding the recent accounting scandals, where traders allege that implied volatility fed into a structural pricing model would explain the volatile CDS spreads much better than when historical volatility is used.

Using conventional firm-level time-series CDS spread regressions as well as a more novel pricing analysis, we find that the information content of implied volatility for CDS valuation is concentrated in a special subset of the firms. Specifically, the implied volatility coefficient in the CDS spread regressions becomes larger for firms with larger CDS spread volatility, option volume and option interest, and lower rating. In addition, the ratio between the out-of-sample RMSE with implied volatility and the out-of-sample RMSE with historical volatility is lower for precisely these firms in a pricing analysis using a Merton-type structural model. The differences are both statistically and economically significant.

References

[1] Acharya, V., T. Johnson, 2005, Insider trading in credit derivatives, Working paper, London Business School.

[2] Amin, K., V. Ng, 1997, Inferring future volatility from the information in implied volatility in Eurodollar options: A new approach, *Review of Financial Studies* 10, 333-367.

[3] Avramov, D., G. Jostova, and A. Philipov, 2004, Credit risk changes: Common factors and firm-level fundamentals, Working paper, University of Maryland.

[4] Bakshi, G., N. Kapadia, and D. Madan, 2003, Stock return characteristics, skew laws, and the differential pricing of individual equity options, *Review of Financial Studies* 16, 101-143.

[5] Benkert, C., 2004, Explaining credit default swap premia, *Journal of Futures Markets* 24, 71-92.

[6] Black, F., and J. Cox, 1976, Valuing corporate securities: Some effects of bond indenture provisions, *Journal of Finance* 31, 351-367.

[7] Blanco, R., S. Brennan, and I. W. Marsh, 2004, An empirical analysis of the dynamic relationship between investment grade bonds and credit default swaps, Working paper, Bank of England, forthcoming in the *Journal of Finance*.

[8] Campbell, J., and G. Taksler, 2003, Equity volatility and corporate bond yields, *Journal of Finance* 58, 2321-2349.

[9] Cao, C., Z. Chen, and J. Griffin, 2005, Informational content of option volume prior to takeovers, *Journal of Business* 78, 1073-1109.

[10] Carr, P., and L. Wu, 2005, Stock options and credit default swaps: A joint framework for valuation and estimation, Working paper, New York University.

[11] Cetin, U., R. Jarrow, P. Protter, and Y. Yildirim, 2003, Modeling credit risk with partial information, Working paper, Cornell University, forthcoming, *Annals of Applied Probability*.

[12] Christensen, B. J., and N. R. Prabhala, 1998, The relation between implied and realized volatility, *Journal of Financial Economics* 50, 125-150.

[13] Collin-Dufresne, P., and R. Goldstein, 2001, Do credit spreads reflect stationary leverage ratios? *Journal of Finance* 56, 1929-1958.

[14] Collin-Dufresne, P., R. Goldstein, and J. Helwege, 2003, Are jumps in corporate bond yields priced? Modeling contagion via the updating of beliefs, Working paper, Carnegie Mellon University.

[15] Collin-Dufresne, P., R. Goldstein, and J. S. Martin, 2001, The determinants of credit spread changes, *Journal of Finance* 56, 2177-2207.

[16] CreditGrade Technical Document, 2002, http://www.creditgrades.com/resources/pdf/CGtechdoc.pdf.

[17] CreditGrades Overview, 2002, http://www.creditgrades.com/resources/pdf/CreditGrades_narrative.pdf.

[18] Cremers, M., J. Driessen, P. Maenhout, and D. Weinbaum, 2004, Individual stock option prices and credit spreads, Working paper, Yale University.

[19] Currie, A., and J. Morris, 2002, And now for capital structure arbitrage, *Euromoney*, December, 38-43.

[20] Duffee, D., 1998, The relation between Treasury yields and corporate bond yield spreads, *Journal of Finance* 53, 2225-2241.

[21] Duffee, D., 1999, Estimating the price of default risk, *Review of Financial Studies* 12, 197-226.

[22] Duffie, D., and D. Lando, 2001, Term structure of credit spreads with incomplete accounting information, *Econometrica* 69, 633-664.

[23] Duarte, J., F. A. Longstaff, and F. Yu, 2005, Risk and return in fixed income arbitrage: Nickels in front of a steamroller? Working paper, UCLA.

[24] Elton, E., M. Gruber, D. Agrawal, and C. Mann, 2001, Explaining the rate spreads on corporate bonds, *Journal of Finance* 56, 247-277

[25] Eom, Y., J. Helwege, and J. Huang, 2004, Structural models of corporate bond pricing: An empirical analysis, *Review of Financial Studies* 17, 499-544.

[26] Ericsson, J., K. Jacobs, and R. Oviedo-Helfenberger, 2004, The determinants of credit default swap premia, Working paper, McGill University.

[27] Ericsson, J., and J. Reneby, 2003, Valuing corporate liabilities, Working paper, McGill University.

[28] Ericsson, J., and J. Reneby, 2004, Liquidity and credit risk, Working paper, McGill University, forthcoming in the *Journal of Finance*.

[29] Ericsson, J., J. Reneby, and H. Wang, 2005, Can structural models price default risk? Evidence from bond and credit derivative markets, Working paper, McGill University.

[30] Hull, J., M. Predescu, and A. White, 2004, The relationship between credit default swap spreads, bond yields, and credit rating announcements, *Journal of Banking and Finance* 28, 2789-2811.

[31] Hull, J., I. Nelken, and A. White, 2004, Merton's model, credit risk, and volatility skews, *Journal of Credit Risk* 1, 1-27.

[32] Jones, E. P., S. P. Mason, and E. Rosenfeld, 1984, Contingent claims analysis of corporate capital structures: An empirical investigation, *Journal of Finance* 39, 611-625.

[33] Jorion, P., 1995, Predicting volatility in the foreign exchange market, *Journal of Finance* 50, 507-528.

[34] Leland, H., and K. B. Toft, 1996, Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads, *Journal of Finance* 51, 987-1019.

[35] Longstaff, F., S. Mithal, and E. Neis, 2003, The credit-default swap market: Is credit protection priced correctly? Working paper, UCLA.

[36] Longstaff, F. A., S. Mithal, and E. Neis, 2004, Corporate yield spreads: Defalt risk or liquidity? New evidence from the credit-default swap market, Working paper, UCLA, forthcoming in the *Journal of Finance*.

[37] Merton, R., 1974, On the pricing of corporate debt: The risk structure of interest rates, Journal of Finance 29, 449-470.

[38] Pan, J., and A. Poteshman, 2004, The information in option volume for future stock prices, Working paper, MIT, forthcoming in the *Review of Financial Studies*.

[39] Yu, F., 2005, How profitable is capital structure arbitrage? Working paper, University of California, Irvine.

[40] Zhang, B. Y., H. Zhou, and H. Zhu, 2005, Explaining credit default swap spreads with equity volatility and jump risks of individual firms, Working paper, Moody's KMV.

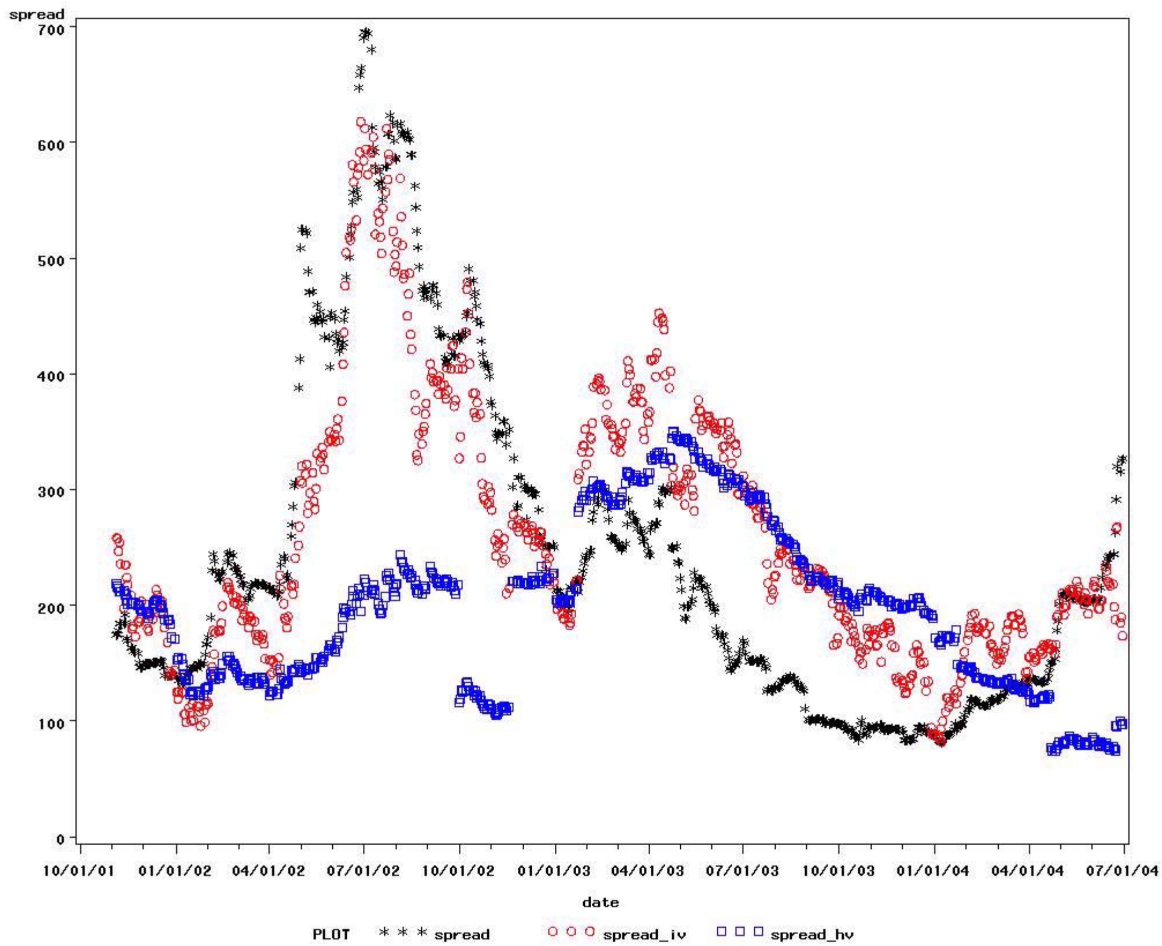
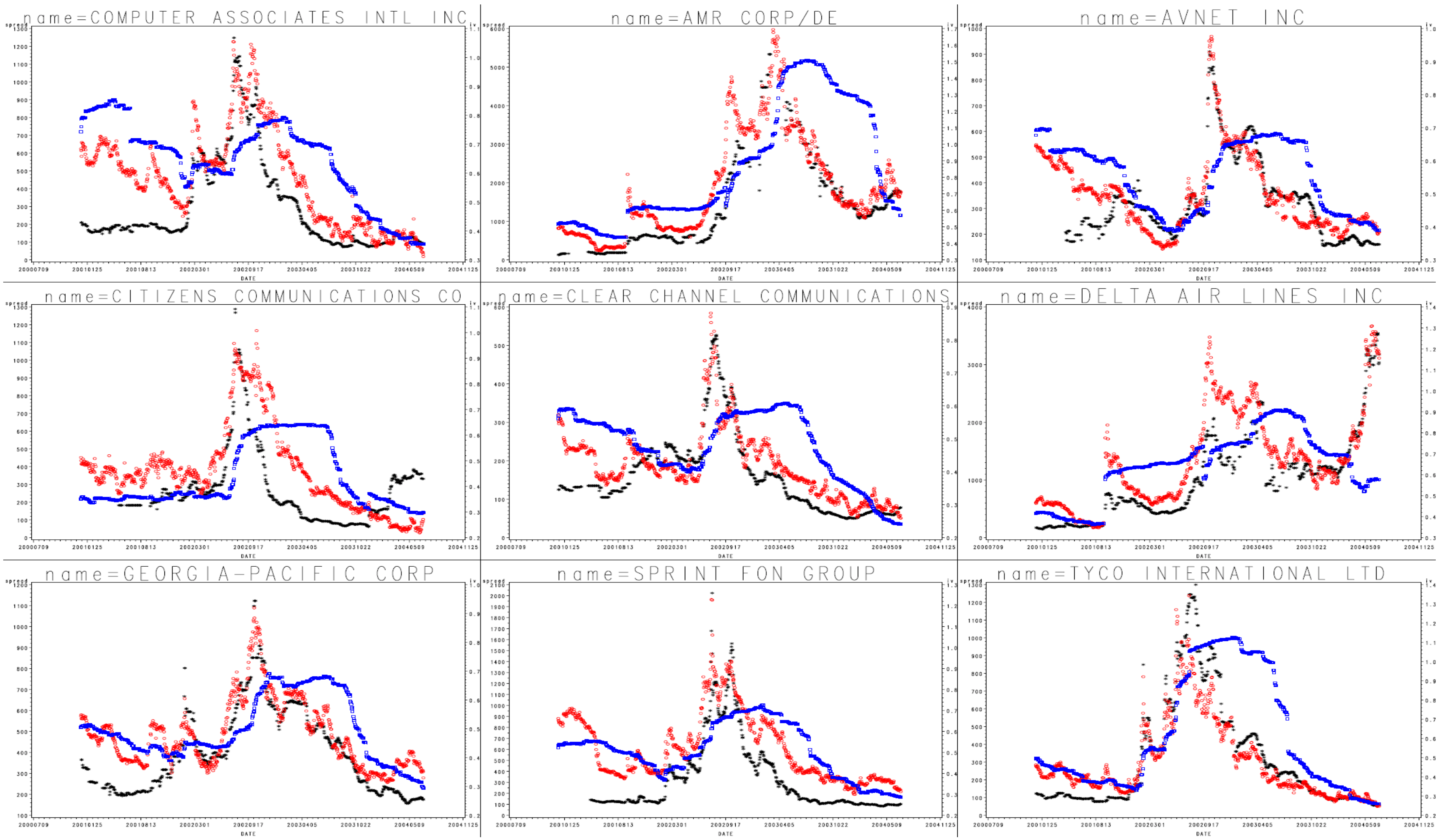


Figure 1: AT&T market CDS spreads and CreditGrades CDS spreads produced with 252-day historical volatility and our option-implied volatility measure.



CDS Spread * * * **Implied Volatility** ○ ○ ○ **Historical Volatility** □ □ □

Figure 2 Time-Series of CDS Spread, Historical Volatility, and Option-implied Volatility for Selected Firms

CDS Spread is 5-year composite spread. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day.

Table 1 Summary Statistics

For each variables, Panel A reports cross-sectional summary statistics of the time series means of 220 sample firms. Panel B reports summary statistics of market variables. Each variable is computed as follows. CDS Spread is 5-year composite spread. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility (OptionMetrics) is the 30-day standardized ATM implied volatility of put option provided by OptionMetrics. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. The sample period is from January 2001 to June 2004.

Panel A: Firm Level Variables

	Mean	Q1	Median	Q3	Standard Deviation
CDS Spread	147.76	48.63	82.77	175.24	181.33
Historical Volatility	0.4043	0.3241	0.3694	0.4499	0.1290
Implied Volatility	0.3880	0.3251	0.3661	0.4281	0.0968
Implied Volatility (OptionMetrics)	0.4276	0.3531	0.3996	0.4673	0.1138
Implied Volatility Skew	0.5544	0.4574	0.5192	0.6034	0.1655
Leverage Ratio	0.4580	0.3370	0.4689	0.5965	0.1940
Firm Stock Return	0.2099	0.0839	0.1785	0.2908	0.1932
Total Asset ($m)	23,632	5,158	11,230	24,358	52,169
Market Capitalization ($m)	20,880	3,536	9,222	19,036	37,300

Panel B: Market Level Variables

	Mean	Q1	Median	Q3	Standard Deviation
Market Historical Volatility	0.2148	0.1889	0.2197	0.2414	0.0401
Market Implied Volatility	0.2322	0.1847	0.2177	0.2811	0.0673
Market Implied Volatility Skew	1.1283	0.6853	0.8828	1.2291	0.8011
Market Return	-0.0230	-0.1690	-0.1019	0.1558	0.1907
Treasury Rate	0.0371	0.0304	0.0355	0.0449	0.0079
Yield Curve Slope	0.0190	0.0180	0.0205	0.0230	0.0057
Bond Liquidity 1	0.0055	0.0040	0.0051	0.0070	0.0019
Bond Liquidity 2	-0.0001	-0.0002	-0.0001	0.0000	0.0003
BAA Rate	0.0736	0.0675	0.0756	0.0795	0.0065

Table 2 Distribution of Option Contracts

This table reports cross-sectional average of the number of and percentage (in parentheses) of option contracts in each moneyness and maturity category. Moneyness is defined as the ratio of spot price divided by strike price for calls and strike price divided by spot price for puts. Maturity is the number of days to expiration date. The sample period is from January 2001 to June 2004.

Panel A: All Contracts

Maturity \ Moneyness	< 0.8	0.8 - 1.0	1.0 -1.2	>1.2	Sub-Total
< 30 days	2036 (3.67)	2640 (5.66)	2246 (4.85)	2416 (4.45)	9338 (18.63)
31 - 90 days	3519 (6.28)	4526 (9.69)	3853 (8.29)	4168 (7.63)	16066 (31.89)
91 -180 days	3184 (5.68)	3659 (7.77)	3095 (6.61)	3729 (6.80)	13667 (26.86)
>180 days	2976 (4.95)	3113 (6.37)	2649 (5.47)	3424 (5.82)	12162 (22.62)
Sub-Total	11715 (20.58)	13938 (29.50)	11842 (25.22)	13737 (24.70)	51233 (100.00)

Panel B: Contracts with Volume

Maturity \ Moneyness	< 0.8	0.8 -1.0	1.0 -1.2	>1.2	Sub-Total
< 30 days	179 (0.85)	1197 (9.50)	1017 (8.37)	307 (1.64)	2700 (20.36)
31 - 90 days	481 (2.33)	2248 (18.15)	1396 (10.72)	430 (2.20)	4555 (33.40)
91 -180 days	640 (3.19)	1847 (15.27)	932 (7.00)	386 (1.95)	3806 (27.41)
>180 days	678 (3.08)	1354 (9.82)	648 (4.22)	387 (1.72)	3067 (18.84)
Sub-Total	1979 (9.44)	6646 (52.73)	3993 (30.31)	1510 (7.52)	14128 (100.00)

Panel C: Contracts with Open Interest

Maturity \ Moneyness	< 0.8	0.8 -1.0	1.0 -1.2	>1.2	Sub-Total
< 30 days	1431 (3.24)	2377 (6.64)	1944 (5.36)	1485 (3.25)	7237 (18.49)
31 - 90 days	2572 (5.88)	3871 (10.68)	2951 (7.96)	2498 (5.55)	11893 (30.07)
91 -180 days	2789 (6.28)	3540 (10.08)	2761 (7.65)	2676 (5.86)	11765 (29.87)
>180 days	2549 (5.12)	2705 (6.96)	1960 (4.83)	2375 (4.66)	9589 (21.57)
Sub-Total	9341 (20.52)	12493 (34.36)	9616 (25.80)	9034 (19.32)	40484 (100.00)

Panel D: Contracts with Open Interest – Put only

Maturity \ Moneyness	< 0.8	0.8 -1.0	1.0 -1.2	>1.2	Sub-Total
< 30 days	745 (3.68)	1171 (6.81)	951 (5.34)	653 (2.80)	3520 (18.63)
31 - 90 days	1312 (6.63)	1862 (10.65)	1434 (7.84)	1139 (4.89)	5747 (30.01)
91 -180 days	1348 (6.70)	1705 (10.15)	1362 (7.68)	1313 (5.53)	5727 (30.06)
>180 days	1186 (5.21)	1247 (6.59)	976 (4.82)	1226 (4.68)	4636 (21.30)
Sub-Total	4590 (22.22)	5985 (34.20)	4722 (25.68)	4332 (17.90)	19630 (100.00)

Table 3 Two-Step Regressions

Cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for 220 sample firms. For each firm, we conduct the following two-step time-series regressions. In the first step, dependent variable is daily CDS Spreads (5-year composite spread). In the second step, the dependent variable is the residuals from the first step. Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	First Step	Second Step
	$CDS_t^i = \alpha_0^i + \alpha_1^i HistVol_t^i + \varepsilon_t^i$	$\varepsilon_t^i = \beta_0^i + \beta_1^i IV_t^i + \eta_t^i$
Intercept	-36.71	-135.71
	(-2.73)	(-13.29)
Historical Volatility	413.51	
	(12.46)	
Implied Volatility		296.91
		(12.83)
Adjusted R2	36%	23%
Percentage of t's >=1.96 (Volatility)	92%	94%
	$CDS_t^i = \alpha_0^i + \alpha_1^i IV_t^i + \varepsilon_t^i$	$\varepsilon_t^i = \beta_0^i + \beta_1^i HistVol_t^i + \eta_t^i$
Intercept	-101.56	-27.90
	(-5.91)	(-3.32)
Historical Volatility		71.06
		(2.91)
Implied Volatility	564.42	
	(15.88)	
Adjusted R^2	56 %	9%
Percentage of t's >=1.96 (Volatility)	99%	59%

Table 4 Time-series Regression Analysis of CDS Spreads

Cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for 220 sample firms. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	1	2	3	4
Intercept	-121.73	-189.29	-194.70	-248.07
	(-7.58)	(-2.97)	(-2.82)	(-3.14)
Historical Volatility	125.33	118.93	155.50	96.30
	(2.56)	(1.81)	(2.50)	(1.26)
Implied Volatility	491.66	371.00	353.36	307.53
	(10.51)	(7.89)	(5.59)	(4.43)
Additional Firm Specific Variables				
Implied Volatility Skew		9.48	8.55	5.35
		(0.93)	(1.18)	(0.77)
Leverage Ratio		148.02	155.24	158.76
		(0.98)	(1.03)	(0.95)
Firm Stock Return		-3.32	1.93	1.33
		(-0.35)	(0.02)	(0.34)
Market Volatility Variables				
Market Historical Volatility			-37.15	72.24
			(-1.05)	(-0.01)
Market Implied Volatility			-27.06	-83.66
			(0.11)	(-0.85)
Market Implied Volatility Skew			0.45	-0.01
			(0.26)	(0.05)
Macro Variables				
Stock Market Return				5.94
				(0.27)
Treasury Rate				-883.94
				(-1.53)
Yield Curve Slope				-295.90
				(-1.18)
Bond Liquidity 1				2645.60
				(1.13)
Bond Liquidity 2				-216.08
				(0.00)
BAA Rate				1738.75
				(2.69)
Adjusted R^2	63%	74%	79%	85%
Percentage of t's >=1.96 (β_1, Historical Volatility)	54%	47%	50%	45%
Percentage of t's >=1.96 (β_2, Implied Volatility)	94%	87%	79%	73%
Percentage of t's >= 1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_2>\beta_1$)	70%	64%	47%	47%
Percentage of t's <= -1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_1>\beta_2$)	14%	14%	26%	23%

Table 5 Regressions of CDS Spreads Partitioned by CDS Spread Volatility

This table reports the cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for the three sub-groups based on the volatility of CDS spreads. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	Group1 (least volatile)	Group2	Group3 (most volatile)
Intercept	-33.44	-169.08	-542.77
	(-1.73)	(-3.91)	(-3.77)
Historical Volatility	25.60	163.22	99.16
	(0.67)	(2.17)	(0.93)
Implied Volatility	80.87	177.50	666.02
	(3.17)	(3.87)	(6.25)
Additional Firm Specific Variables			
Implied Volatility Skew	0.43	2.73	12.92
	(0.35)	(0.73)	(1.23)
Leverage Ratio	-5.44	93.63	389.00
	(0.11)	(1.34)	(1.39)
Firm Stock Return	0.73	1.40	1.86
	(0.42)	(0.24)	(0.35)
Market Volatility Variables			
Market Historical Volatility	-3.89	-88.80	311.61
	(-0.07)	(-0.98)	(1.05)
Market Implied Volatility	-12.59	-43.39	-195.55
	(-0.46)	(-1.09)	(-1.01)
Market Implied Volatility Skew	0.01	0.49	-0.53
	(-0.04)	(0.34)	(-0.15)
Macro Variables			
Stock Market Return	-0.44	12.81	5.37
	(0.08)	(0.60)	(0.14)
Treasury Rate	-420.98	-965.68	-1264.05
	(-1.74)	(-1.75)	(-1.11)
Yield Curve Slope	-397.70	-1321.25	845.30
	(-1.54)	(-2.14)	(0.15)
Bond Liquidity 1	715.21	2362.46	4863.02
	(1.00)	(1.29)	(1.10)
Bond Liquidity 2	-168.43	-296.67	-182.05
	(-0.08)	(0.00)	(0.08)
BAA Rate	854.36	2096.62	2260.37
	(2.97)	(3.22)	(1.86)
Adjusted R^2	81%	85%	89%
Percentage of t's >=1.96 (β_1, Historical Volatility)	38%	58%	37%
Percentage of t's >=1.96 (β_2, Implied Volatility)	64%	74%	81%
Percentage of t's >= 1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_2>\beta_1$)	42%	39%	59%
Percentage of t's <= -1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_1>\beta_2$)	25%	30%	15%
Number of firms in each group	73	74	73

Table 6 Regressions of CDS Spreads Partitioned by Volume Ratio

This table reports the cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for the three sub-groups based on Volume Ratio, which is defined as option volume divided by stock volume. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	Group1 (smallest)	Group2	Group3 (largest)
Intercept	-204.52	-246.18	-293.54
	(-3.22)	(-2.67)	(-3.54)
Historical Volatility	101.02	112.20	75.46
	(1.39)	(1.21)	(1.18)
Implied Volatility	233.64	260.87	428.73
	(3.39)	(3.91)	(5.98)
Additional Firm Specific Variables			
Implied Volatility Skew	1.34	5.77	8.93
	(0.30)	(0.83)	(1.17)
Leverage Ratio	130.13	99.85	247.12
	(0.88)	(0.57)	(1.41)
Firm Stock Return	15.23	-12.04	1.00
	(1.32)	(-0.42)	(0.12)
Market Volatility Variables			
Market Historical Volatility	105.98	108.39	1.84
	(0.46)	(0.17)	(-0.64)
Market Implied Volatility	-22.83	-76.60	-151.64
	(-0.28)	(-1.12)	(-1.16)
Market Implied Volatility Skew	0.27	-0.13	-0.16
	(0.27)	(-0.13)	(0.03)
Macro Variables			
Stock Market Return	8.42	9.35	0.01
	(-0.19)	(0.49)	(0.52)
Treasury Rate	-662.97	-1296.33	-686.88
	(-1.27)	(-1.70)	(-1.63)
Yield Curve Slope	-850.06	-554.10	519.99
	(-1.71)	(-1.28)	(-0.55)
Bond Liquidity 1	3568.54	1693.62	2687.68
	(1.36)	(1.00)	(1.03)
Bond Liquidity 2	-262.80	-751.13	373.02
	(0.01)	(-0.10)	(0.08)
BAA Rate	1690.28	2461.87	1054.20
	(2.78)	(2.65)	(2.64)
Adjusted R^2	86%	84%	86%
Percentage of t's >=1.96 (β_1, Historical Volatility)	44%	45%	45%
Percentage of t's >=1.96 (β_2, Implied Volatility)	66%	73%	81%
Percentage of t's >= 1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_2>\beta_1$)	44%	43%	53%
Percentage of t's <= -1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_1>\beta_2$)	30%	20%	19%
Number of firms in each group	73	74	73

Table 7 Regressions of CDS Spreads Partitioned by Option Open Interest

This table reports the cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for the three sub-groups based on Option Open Interest. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	Group1 (smallest)	Group2	Group3 (largest)
Intercept	-159.97	-171.53	-413.76
	(-3.06)	(-2.15)	(-4.22)
Historical Volatility	67.78	59.86	161.76
	(1.21)	(1.01)	(1.56)
Implied Volatility	235.92	234.98	452.69
	(3.48)	(3.95)	(5.86)
Additional Firm Specific Variables			
Implied Volatility Skew	1.17	2.73	12.18
	(0.34)	(0.72)	(1.25)
Leverage Ratio	67.85	48.97	360.98
	(0.78)	(0.27)	(1.80)
Firm Stock Return	10.66	-2.61	-4.00
	(1.25)	(-0.17)	(-0.06)
Market Volatility Variables			
Market Historical Volatility	149.23	1.99	66.45
	(0.40)	(0.04)	(-0.46)
Market Implied Volatility	-26.81	-22.81	-202.18
	(-0.42)	(-0.59)	(-1.56)
Market Implied Volatility Skew	0.13	0.24	-0.39
	(0.20)	(-0.03)	(-0.01)
Macro Variables			
Stock Market Return	9.42	16.61	-8.34
	(-0.07)	(0.28)	(0.61)
Treasury Rate	-570.10	-1419.51	-654.88
	(-1.41)	(-1.55)	(-1.65)
Yield Curve Slope	-771.31	-1203.98	1100.03
	(-1.69)	(-1.71)	(-0.14)
Bond Liquidity 1	2557.95	2493.32	2887.62
	(1.05)	(1.24)	(1.09)
Bond Liquidity 2	-1408.86	2148.52	-1420.29
	(-0.11)	(0.16)	(-0.05)
BAA Rate	1591.19	2337.07	1279.79
	(2.97)	(2.50)	(2.60)
Adjusted R^2	85%	83%	88%
Percentage of t's >=1.96 (β_1, Historical Volatility)	40%	45%	49%
Percentage of t's >=1.96 (β_2, Implied Volatility)	67%	73%	79%
Percentage of t's >= 1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_2>\beta_1$)	47%	45%	49%
Percentage of t's <= -1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_1>\beta_2$)	30%	19%	21%
Number of firms in each group	73	74	73

Table 8 Regressions of CDS Spreads Partitioned by Credit Rating

This table reports the cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for the four sub-groups based on Credit Rating. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	AA and above	A	BBB	BB and below
Intercept	-60.24	-81.80	-244.77	-584.33
	(-1.14)	(-2.25)	(-3.68)	(-3.69)
Historical Volatility	53.64	20.52	131.66	129.12
	(1.80)	(0.63)	(1.68)	(0.87)
Implied Volatility	77.51	194.79	281.60	638.65
	(2.54)	(3.89)	(4.61)	(5.38)
Additional Firm Specific Variables				
Implied Volatility Skew	1.64	1.89	4.16	15.47
	(1.48)	(0.48)	(0.70)	(1.19)
Leverage Ratio	32.75	-28.06	127.46	586.65
	(-1.02)	(-0.11)	(1.20)	(2.58)
Firm Stock Return	4.84	-2.54	4.30	-2.28
	(0.24)	(0.00)	(0.55)	(0.28)
Market Volatility Variables				
Market Historical Volatility	59.45	-24.71	-14.49	478.45
	(-0.13)	(-0.26)	(-0.33)	(1.36)
Market Implied Volatility	-9.28	-20.20	-43.14	-325.52
	(0.21)	(-0.75)	(-0.75)	(-1.66)
Market Implied Volatility Skew	-0.05	0.21	0.16	-0.82
	(-0.17)	(0.11)	(0.10)	(-0.10)
Macro Variables				
Stock Market Return	6.68	8.59	1.23	15.03
	(0.46)	(0.53)	(0.11)	(0.26)
Treasury Rate	381.23	-618.97	-1351.38	-394.34
	(-0.88)	(-1.78)	(-1.68)	(-0.96)
Yield Curve Slope	956.65	-671.19	-1214.49	2503.08
	(-1.06)	(-1.53)	(-1.81)	(1.13)
Bond Liquidity 1	1709.11	1251.72	2715.99	4964.94
	(1.25)	(1.09)	(1.15)	(1.09)
Bond Liquidity 2	-959.13	1218.98	-49.66	-2705.13
	(-0.19)	(0.07)	(0.01)	(-0.07)
BAA Rate	-283.63	1354.12	2460.95	966.34
	(2.59)	(3.16)	(2.83)	(1.56)
Adjusted R^2	83%	82%	87%	86%
Percentage of t's >=1.96 (β_1, Historical Volatility)	62%	40%	50%	32%
Percentage of t's >=1.96 (β_2, Implied Volatility)	62%	70%	75%	76%
Percentage of t's >= 1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_2>\beta_1$)	38%	47%	45%	55%
Percentage of t's <= -1.64 (h_0: $\beta_2=\beta_1$ vs. h_1: $\beta_1>\beta_2$)	38%	22%	27%	11%
Number of firms in each group	13	60	109	38

Table 9 Interaction between Implied Volatility and CDS Volatility

This table reports the cross-sectional averages of coefficients, t statistics (in parentheses), and adjusted R-squares of time-series regressions for the three sub-groups based on the volatility of CDS spreads over their respective sample period. The implied volatility is interacted with the dummies of CDS spread volatility ranking within each firm. For each firm and each time-series regression, the dependent variable is daily CDS Spreads (5-year composite spread). Each independent variable is computed as follows. Historical Volatility is 252-day historical volatility. Implied Volatility is calculated by minimizing the sum of squared errors of all put-options with open interests for each day. The dummy for CDS volatility is based on the ranking of 30-day centered moving average volatility of CDS spread within each firm. Implied Volatility Skew the difference between implied volatilities of an OTM and an ATM put divided by the difference in strike-to-spot ratios. Leverage Ratio is the ratio of total liability over the sum of total liability and market capitalization. Firm Stock Return is the 252-day average firm stock return. Market Historical Volatility is 252-day historical volatility of S&P500 index return. Market Implied Volatility is the 30-day standardized ATM implied volatility of VIX index put option provided by OptionMetrics. Market Implied Volatility Skew is the implied volatility skew of VIX index put option. Treasure Rate is 5-year US Treasury constant maturity rate. Yield Curve Slope is the difference between 10-year and 2-year US Treasury rates. Stock Market Return is the 252-day average return of S&P500 index. BAA Rate is the average yield of U.S. corporate bonds rated BAA by Moody's. Bond Liquidity 1 is the difference between 10-year Swap and 10-year US Treasury rates. Bond Liquidity 2 is the difference between 30-day Eurodollar and 30-day US CD rates. N.W. standard errors (Newey and West 1987) are used (5 lags). The sample period is from January 2001 to June 2004.

	Group1 (Smallest)	Group2	Group3 (largest)
Intercept	-26.90	-142.81	-523.06
	(-1.40)	(-3.34)	(-3.49)
Historical Volatility	31.61	172.37	118.82
	(0.80)	(2.28)	(1.03)
Implied Volatility*Dummy of Less Volatile CDS	67.44	141.91	595.31
	(2.74)	(3.10)	(5.36)
Implied Volatility*Dummy of Median Volatile CDS	70.11	152.71	606.31
	(2.86)	(3.34)	(5.49)
Implied Volatility*Dummy of More Volatile CDS	78.50	171.77	646.98
	(3.23)	(3.82)	(6.18)
Additional Firm Specific Variables			
Implied Volatility Skew	0.39	2.75	11.83
	(0.30)	(0.78)	(1.16)
Leverage Ratio	-1.51	99.69	407.29
	(0.23)	(1.47)	(1.45)
Firm Stock Return	0.96	1.66	4.37
	(0.48)	(0.27)	(0.41)
Market Volatility Variables			
Market Historical Volatility	-6.41	-97.95	309.56
	(-0.15)	(-1.07)	(1.05)
Market Implied Volatility	-10.21	-37.85	-189.10
	(-0.35)	(-0.96)	(-0.95)
Market Implied Volatility Skew	0.02	0.51	-0.45
	(-0.01)	(0.42)	(-0.11)
Macro Variables			
Stock Market Return	0.21	9.68	8.00
	(0.09)	(0.44)	(0.20)
Treasury Rate	-335.08	-739.62	-1046.01
	(-1.43)	(-1.34)	(-1.04)
Yield Curve Slope	-400.24	-1202.38	627.81
	(-1.55)	(-1.98)	(0.11)
Bond Liquidity 1	793.19	2326.32	5103.19
	(1.16)	(1.35)	(1.19)
Bond Liquidity 2	-221.88	-284.62	573.76
	(-0.08)	(0.01)	(0.10)
BAA Rate	717.39	1641.63	1919.24
	(2.54)	(2.48)	(1.70)
Adjusted R^2	82%	87%	90%
Number of firms in each group	73	74	73

Table 10 Properties of Regression Variables

Panel A reports the cross-sectional summary statistics of the regression variables. Panel B reports their cross-sectional correlations. For each firm day in our sample we estimate the CreditGrades model and use the estimated parameters to calculate one-day-ahead forecasts of CDS spreads. RATIO_OUT is the ratio between the out-of-sample RMSE by fitting the CreditGrades model with implied volatility and the out-of-sample RMSE by fitting the CreditGrades model with historical volatility. RATIO_IN is ratio between the average in-sample RMSE with implied volatility and the average in-sample RMSE with historical volatility. CDS Spread Volatility is the volatility of the CDS spread across the sample period in basis points. Put Option Volume, Put Option Interest, Leverage Ratio, Total Assets, and Rating are time-series means of the respective daily variables.

Panel A: Summary Statistics

	Mean	Q1	Median	Q3	Standard Deviation
RATIO_OUT	1.0381	0.8237	1.0242	1.2049	0.3462
RATIO_IN	1.1815	0.9712	1.1787	1.3804	0.3786
CDS Spread Volatility	103.66	18.59	36.22	90.09	368.00
Put Option Volume	1,515	93	465	1,517	3,275
Put Open Interest	54,002	3,589	15,259	53,665	103,387
Leverage Ratio	0.4580	0.3370	0.4689	0.5965	0.1940
Total Assets ($m)	23,632	5,158	11,230	24,358	52,169
Rating	3.8409	3.0000	4.0000	4.0000	0.9543

Panel B: Correlations

Variables	RATIO_OUT	CDS Spread Volatility	Put Option Volume	Put Open Interest	Leverage Ratio	Total Assets	Rating
RATIO_OUT	1.0000	-0.2187*	-0.1641*	-0.2119*	-0.0672	-0.0890	-0.2009*
CDS Spread Volatility	-0.2187*	1.0000	0.0124	0.0520	0.2598*	-0.0167	0.4228
Put Option Volume	-0.1641*	0.0124	1.0000	0.9358*	-0.1562*	0.5348*	-0.1333*
Put Open Interest	-0.2119*	0.0520	0.9358*	1.0000	-0.0472	0.6564*	-0.0600
Leverage Ratio	-0.0672	0.2598*	-0.1562*	-0.0472	1.0000	0.1876*	0.5356*
Total Assets	-0.0860	-0.0167	0.5348*	0.6564*	0.1876*	1.0000	-0.2079*
Rating	-0.2009*	0.4228*	-0.1333*	-0.0600	0.5356*	-0.2079*	1.0000

Table 11 Regression Analysis of Structural Model Pricing Errors

Coefficients, t statistics (in parentheses), and adjusted R-squares of cross-sectional regressions for 220 sample firms. The dependent variable is RATIO_OUT, the ratio between the out-of-sample RMSE by fitting the CreditGrades model with implied volatility and the out-of-sample RMSE by fitting the CreditGrades model with historical volatility. The estimation period for the model can be either 100 or 25 daily observations. CDS Spread Volatility is the volatility of the CDS spread across the sample period in basis points. Put Option Volume, Put Option Interest, Leverage Ratio, Total Assets, and Rating are time-series means of the respective daily variables.

	100-Day Estimator	25-Day Estimator
Intercept	1.2670	1.8443
	(11.70)	(11.82)
CDS Spread Volatility	-0.0001369	-0.0001540
	(-2.04)	(-1.59)
Put Option Volume	0.02235	0.03279
	(1.05)	(1.07)
Put Open Interest	-0.00145	-0.00218
	(-1.90)	(-1.99)
Leverage	0.1145	-0.1207
	(0.73)	(0.2270)
Total Assets	0.0002423	0.0004668
	(0.00070)	(0.46)
Rating	-0.0595	-0.0973
	(-1.76)	(-2.00)
Adjusted R^2	0.0894	0.1142