Credit Default Swap Spreads and Variance Risk Premia*

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Abstract

We find that variance risk premium, defined as the spread between the option-implied and expected variances, has a prominent explaining power for the credit default swap spreads at individual firm level. Such a predictability cannot be crowded out by those of the market and firm level credit risk factors identified in previous research. We demonstrate that the strong predictability of the implied variance for credit spreads is mostly explained by both variance premium and expected variance. Our finding suggests that the variance risk premium is a relatively clean measure of a firm's exposure to macroeconomic uncertainty or systematic variance risk, while the option-implied and expected variances may be more contaminated by the idiosyncratic variance risk. Such a result is consistent with a setting that the firm's asset is exposed to the priced time-varying systematic variance risk.

JEL Classification: G12, G13, G14.
Keywords: Variance Risk Premia, Credit Default Swap Spreads, Option-implied Variance, Expected Variance, Realized Variance.

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Abstract

We find that variance risk premium, defined as the spread between the option-implied and expected variances, has a prominent explaining power for the credit default swap spreads at individual firm level. Such a predictability cannot be crowded out by those of the market and firm level credit risk factors identified in previous research. We demonstrate that the strong predictability of the implied variance for credit spreads is mostly explained by both variance premium and expected variance. Our finding suggests that the variance risk premium is a relatively clean measure of a firm's exposure to macroeconomic uncertainty or systematic variance risk, while the option-implied and expected variances may be more contaminated by the idiosyncratic variance risk. Such a result is consistent with a setting that the firm's asset is exposed to the priced time-varying systematic variance risk.

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1 Introduction

It has long been recognized in literature that a critical component of systematic risk could be absent in the existing credit risk models (Jones, Mason, and Rosenfeld, 1984; Elton, Gruber, Agrawal, and Mann, 2001; Collin-Dufresne, Goldstein, and Martin, 2001; Huang and Huang, 2003). As evidenced by the recent credit crisis, a possible missing economic uncertainty or systematic variance risk factor plays a prominent role in affecting credit risk-related security prices. To investigate this important issue in an effort to shed light on improving the credit risk modeling, we construct individual firm's variance risk premium that captures the firm's exposure to macroeconomic uncertainty or systematic variance risk, in the context of Bollerslev, Tauchen, and Zhou (2009b) and Drechsler and Yaron (2008), and carry out an extensive investigation on the cross-sectional relationships between credit spreads and variance risk premia.[1]

Previous research presents empirical evidence that implied variance is always informationally more efficient than realized variance in predicting credit spreads (see, Cao, Yu, and Zhong, 2006; Berndt, Lookman, and Obreja, 2006; Carr and Wu, 2008a; Buraschi, Trojani, and Vedolin, 2009, among others). However, it remains unclear to what extent the predictability comes from better informational efficiency of option market, from risk premium changes, or from expected variance changes. By decomposing option-implied variance, we provide a clear economic interpretation as to where the predictability exactly comes from. In particular, we investigate quantitatively to what extent the predicting power of implied variance is due to risk premium or variance risk changes.

There is a great deal of debate as for whether the idiosyncratic volatility risk is priced positively, negatively, or not priced at all in the cross-section of stock returns (see, Ang,

[1] The systematic risk implication is also consistent with recent research that recognizes the linkage among macro-economic conditions, equity risk premia and credit risk pricing (see, e.g., David, 2008; Bhamra, Kuhn, and Strebulaev, 2009; Chen, Collin-Dufresne, and Goldstein, 2009; Chen, 2009). However, such a equilibrium-structural approach that explains mostly the "representative" firms has limited explaining power for the cross-section of individual firm's credit spreads with respect to economic uncertainty risk.

Hodrick, Xing, and Zhang, 2009; Cao and Han, 2009; Fu, 2009; Goyal and Saretto, 2009; Huang, Liu, Rhee, and Zhang, 2009, among others). It is possible that these conflicting findings are due to the model specific ways of separating systematic versus idiosyncratic variance risks and caused by potential model misspecifications. For explaining credit spreads, conceptually the variance risk premium variable will isolate only the systematic variance risk which must be priced in all risky assets. This is because, by construction, the risk neutral and objective expectations of firms' idiosyncratic variance risk should cancel out with each other.

We demonstrate empirically that VRP has a significant predicting power for credit default swap (CDS) spreads at the individual firm level. Such a predictability complements that of the macro-economic and firm specific credit risk determinants suggested by existing theoretical models and previous empirical evidence. In addition, VRP, as a firm-level variation risk measure, dominates the well-documented market-level variation risk measure VIX in capturing the market systematic risk to predict CDS spreads. Moreover, the predicting power of VRP for credit spreads increases as the credit quality of the CDS contracts deteriorates. This is an important finding in that the VRP may capture the systematic variance risk exposures of the underlying firm asset dynamics and therefore explains a large chunk of *systematic* credit spread variations. The VRP constructed with implied variance from at-the-money put option has a stronger predicting power than alternatives from call options or different moneyness.

In an effort to answer the important question as to where the predicting power of option-implied variance on credit spreads comes from, we decompose implied variance into VRP and expected variance. Although all three explanatory variables have almost the same statistical significance in predicting the positive risk premia in CDS spreads, we find that both VRP and expected variance can substitute most of the explaining power of the implied variance, especially for the CDS spreads of 1-3 year maturities. Nevertheless, VRP and expected variance are two equally important components in terms of predicting credit spreads, suggesting that there may be a two-factor structure of the implied variance dynamics behind the superior explaining power for CDS spreads. We also find that the predicting power of VRP for credit spreads at the firm level decreases gradually as time passes by, which is qualitatively similar to the aggregate level evidence that the predictive power of VRP for credit spreads peaks at the short end (Zhou, 2009). Such a result is also consistent with the findings in literature that the option implied risk premia are successful in explaining the large credit spread variations (Cremers, Driessen, and Maenhout, 2008a; Coval, Jurek, and Stafford, 2009).

Finally, to understand why VRP is an ideal measure for firms' exposures to systematic variance or economic uncertainty risk, we argue that the risk-neutral expectation and physical expectation of the total variance only differ for priced systematic component, but remain the same for non-priced idiosyncratic component. As supported in our empirical analysis, the first principle component of VRP across all firms explains 80% of the total variation, while that of implied variance only explains 37%. Therefore the informational efficiency of implied variance may be largely due to credit and option markets comovement, while the economic interpretation of implied variance in terms of explaining credit spreads resides largely on VRP, which captures the systematic risk premium changes. Campbell and Taksler (2003), Cremers, Driessen, Maenhout, and Weinbaum (2008b), Ericsson, Jacobs, and Oviedo (2004), and Zhang, Zhou, and Zhu (2009) also examine the role of firm-level volatility risk in the determination of bond and CDS spreads. However, we emphasize the nature of VRP as isolating the firm's exposure to the economic uncertainty or systematic variance risk factor.

The rest of the paper will be organized as the following: Section 2 introduces the VRP measure and our empirical methodology; followed by a description of data sources and summary statistics in Section 3; then Section 4 presents empirical findings of VRP with respect to predicting CDS spreads; and Section 5 concludes.

2 Variance Risk Premia and Empirical Methodology

In this section, we introduce the construction of the variance risk premium (VRP) measure for individual firms, following the recent literature in defining the market variance risk premium as a difference between the option-implied return variance and forecasted realized variance. Then we outline our empirical strategy for explaining the credit spreads of individual firms, using such a firm specific variance risk premium variable, together with key market and firm control variables—noticeably the short rate and leverage ratio.

2.1 Constructing the VRP Measure for Individual Firms

We start our construction of the VRP measure for individual firms with estimating the option-implied variance which, denoted by IV_t, represents the market's risk-neutral expectation of the return variation between time t and $t+1$, conditional on time t information, which can be expressed as

$$IV_t = E_t^Q[\text{Variance}(t, t+1)]. \tag{1}$$

It has been established in literature that for highly liquid market indices, like the S&P 500, a *model-free* formula for computing the option-implied variance can be implemented easily, even though only a limited number of strikes being available (Carr and Madan, 1998; Britten-Jones and Neuberger, 2000; Jiang and Tian, 2005; Bollerslev, Gibson, and Zhou, 2009a). However, for individual firms, the liquidity of options of different moneyness and maturities is still a big concern. Therefore we follow the existing literature to focus on the implied variance from out-of-the-money put options (see, e.g., Cao, Yu, and Zhong, 2006, and the references therein).

Our implied variances are obtained from OptionMetrics, which employs the Cox-Ross-Rubinstein (CRR) binomial tree model and a curve-fitting approach to build the volatility surface across strikes and maturities for individual entities (Cox, Ross, and Rubinstein, 1979).[2] With the volatility surface, we are able to compute a panel of option-implied vari-

[2]We may alternatively construct our own measures of implied volatilities using option portfolios. However,

ances based on out-of-the-money, at-the-money and in-the-money put and call options.

In order to define the realized variance that we use in estimating the expected variance, let p_t denote the logarithmic price of equity. The realized variance over the discrete $t-1$ to t time interval may be measured as:

$$RV_t \equiv \sum_{j=1}^{n} \left[p_{t-1+\frac{j}{n}} - p_{t-1+\frac{j-1}{n}(\Delta)} \right]^2 \longrightarrow \text{Variance}(t-1, t), \tag{2}$$

where the convergence relies on $n \to \infty$; i.e., an increasing number of within period price observations. As demonstrated in the literature (see, e.g., Andersen, Bollerslev, Diebold, and Ebens, 2001a; Barndorff-Nielsen and Shephard, 2002), this "model-free" realized variance measure based on high-frequency intraday data can provide much more accurate ex-post observations of the unobserved return variance than those based on daily returns.

For a monthly horizon and monthly data frequency, where IV_t is the end-of-month risk-neutral expected variance for the next month, and RV_t is the realized variance of the current month, we adopt a linear forecast of the objective or statistical expectation of the return variance as $RV_{t+1} = \alpha + \beta IV_t + \gamma RV_t + \epsilon_{t+1}$, and the expected variance is simply the time t forecast of realized variance from t to $t+1$ based estimated projection coefficients,

$$EV_t \equiv \widehat{RV}_{t+1} = \widehat{\alpha} + \widehat{\beta} IV_t + \widehat{\gamma} RV_t. \tag{3}$$

Implied variance from options market is a better or more efficient forecast for expected variance than the historical variance based on low-frequency daily return data (Jiang and Tian, 2005). While realized variance based on high-frequency data also has remarkable forecasting power for future realized variance (Andersen, Bollerslev, Diebold, and Labys, 2001b). Putting these two together, a joint forecast model with one lag of implied variance and one lag of realized variances seems to do a decent job in forecasting expected variances (Drechsler and Yaron, 2008).

given the close similarity between the methodologies, self-constructed implied variance could of no significant difference compared to that computed based on the volatility surface provided by OptionMetrics.

The variance risk premium, or VRP, underlying our key empirical findings is defined as the difference between the ex-ante risk-neutral expectation and the objective expectation of future return variation over the $[t, t+1]$ time interval,

$$VRP_t \equiv IV_t - EV_t. \tag{4}$$

Such a construct at the market level has been shown to possess remarkable capability in forecasting the short-run movements in credit spread indices, with short term interest rate as a control for fundamental economic condition (Zhou, 2009). Here we are going to investigate in detail how VRP of individual firms can help us to understand the firms' credit risk premia.

2.2 Empirical Implementation Strategy

We examine the relationship between credit spreads and variance risk premium (VRP) in the presence of market and firm level credit risk determinants suggested by theory and empirical evidence. We will focus on monthly data to avoid picking up the market microstructure induced high frequency comovements. For spreads and implied variance, they are just the last available end-of-month daily observations. Because missing dates and stale quotes signify that daily or even weekly data quality is not reliable, and if we just ignore the daily missing values, we will artificially introduce some serial dependent measurement errors in the dependent variable—CDS spread. Monthly data will give us more conservative but reliable results and is typically of the shortest horizon, compared to quarterly or annual data, for picking up the low frequency risk premia movements.

As suggested by the structural form credit risk models (Merton, 1974), leverage is the most important credit risk determinant—all else being equal, a firm with higher leverage has a higher likelihood of default. The market leverage ratio, denoted by $LEV_{i,t}$, is computed as the book value of debt over the sum of the book value of debt and market value of equity. Moreover, structural models predict that risk-free interest rates negatively influence the credit spread (Longstaff and Schwartz, 1995). Under the risk-neutral measure, high interest rates lead the firm's underlying asset value to grow at a higher rate, reducing the likelihood of financial distress. Therefore, CDS spreads should be determined by the leverage ratio of the underlying firm and the risk-free spot rate. We define the risk-free rate variable to be the one-year swap yield, denoted by r_t.

Empirical research also shows that in practice, CDS spreads contain compensation for non-default risks as well as risk premia which may be difficult to identify without the aggregate macro variables. Henceforth, we will not limit our analysis to the traditional theoretically motivated regressors but augment our set of variables by the following market variables: (1) the S&P 500 return, denoted by $S\&P_t$ to proxy for the overall state of the economy; (2) the option-implied variance based on the S&P 500 index options denoted by VIX_t^2; (3) Moody's default premium slope, denoted by DPS_t, is computed as *Baa* yield spread *minus Aaa* yield spread to capture the default risk premium in the corporate bond market; and (4) the difference of five-year swap rate and five-year Treasury rate, denoted by STS_t, as a proxy for fixed income market illiquidity, which is expected to increase with CDS spreads. As indicated by the recent empirical research, e.g., in Collin-Dufresne, Goldstein, and Martin (2001) and Longstaff, Pan, Pedersen, and Singleton (2007), VIX turns out to be a lead explanatory variable for both corporate and sovereign credit spreads, similar to short rate and leverage ratio. To be comparable with the variance risk premium definition and consistent with the popular variance swap contract, we use VIX-squared on monthly basis as an additive systemic risk measurement.

For firm characteristic variables, besides market leverage, we include the following controls: (1) the natural logarithm of sales, denoted by $SALE_{i,t}$. As a proxy for firm size, $SALE$ should influence CDS spread analogously—a larger firm will attract more investor attention, hence have more liquid credit default swap spreads with lower spreads, all else being equal; (2) asset turnover, denoted by $ATO_{i,t}$, is computed as sales divided by total assets; (3) return on assets, denoted by $ROA_{i,t}$, is computed as earnings divided by total assets; (4) price-earnings ratio denoted by $PE_{i,t}$; and (5) market-to-book ratio, denoted by $MB_{i,t}$. Firm asset turnover, market-book ratio and return on assets are all expected to be negatively related to CDS spreads, in the notion that firms of high profitability and future growth tend to have lower credit risk. Price-earnings ratio may have two opposite effects on CDS spreads: on the one hand, high price-earnings ratio implies high future asset growth reducing the likelihood of financial distress and credit risk. On the other hand, high growth firms tend to have high return volatilities that increase credit risk.

Given the nature of our panel data, we adopt the robust standard error approach of Petersen (2009) to account for both firm and time effects in large panel data sets. Therefore, the above discussions suggest the following regression equation

$$\begin{aligned} CDS_{i,t}, &= \alpha_i + \beta_{i,1} VRP_{i,t} + \beta_{i,2} LEV_{i,t} + \beta_{i,3} r_t + \beta_{i,4} VIX_t^2 + \beta_{i,5} S\&P_t \\ &+ \beta_{i,6} DPS_t + \beta_{i,7} STS_t + \beta_{i,8} SALE_{i,t} + \beta_{i,9} PE_{i,t} \\ &+ \beta_{i,10} MB_{i,t} + \beta_{i,11} ROA_{i,t} + \beta_{i,12} ATO_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{5}$$

To examine the intertemporal predictability of VRP for CDS spreads, we carried out the following regressions:

$$CDS_{i,t}, = \alpha_i + \beta_{i,1} VRP_{i,t-h} + \sum_{j=1}^{n} \theta_{i,j} \times \text{control}_{i,j} + \varepsilon_{i,t} \tag{6}$$

where h represents various time intervals for lag, ranging between zero to twelve months, and n denotes the total number of control variables as used in equation (5). Our conjecture is that lagged VRP exhibits predictability on CDS spreads with up to a twelve month lag, and such a predictability phases out as the lag, h, increases.

3 Data Description and Summary Statistics

To conduct the empirical study, we collect data on CDS spreads, options, macroeconomic variables, firm equity and balance sheet information from various sources. The summary statistics of CDS spreads, variance risk premia (VRPs), and other market wide or firm-specific controls, are discussed here to set the background for examining the critical link between CDS spreads and VRPs.

3.1 Data Sources

We use credit default swap (CDS) premia as a direct measure of credit spreads. Compared to corporate bond yield spreads, CDS spreads are not subject to the specification of benchmark risk-free yield curve and less contaminated by non-default risk components (Longstaff, Mithal, and Neis, 2005; Ericsson, Reneby, and Wang, 2006).

Our daily single-name CDS spreads are obtained from a database compiled by the Markit group. The data set reports average recovery rates used by data contributors in pricing each CDS contract. The sample period covers January 2001 to December 2008. We restrict our sample to US dollar denominated CDS written on US entities that are not in the government, financial, or utilities sectors. We further eliminate the subordinated class of contracts because of its small relevance in the database and its unappealing implications for credit risk pricing. The maturities of Markit CDS contracts range between 6 months and 30 years. We focus on the most popular and liquid 5-year CDS contracts with modified restructuring clauses in our benchmark analysis. CDS spreads of contract maturities ranging between 1- and 10-year are used for robustness checks. After cleaning and matching the CDS data with reliable option, equity and balance sheet information, we are left with 23,099 monthly observations of 540 entities in our study. For each entity, the monthly CDS spreads are matched with the monthly variance risk premia.

We obtain from OptionMetrics the individual firm volatility surface data, with which we compute a panel of option-implied variance based on out-of-the-money, at-the-money and in-the-money put and call options respectively. The implied variance of 30-day out-of-the-money put options is used as our benchmark measure of VRP, while others are used for comparison and robustness checks.

We compute high-frequency realized variances using information in TAQ database that contains the intraday equity trading data spaced by 15 minutes during trading hours. Following the method outlined in previous section, we first calculate the daily variance based on the high-frequency data, then aggregate and annualize it to construct monthly realized variance. Next we estimate expected variance that is of the same maturity as the implied variance. All types of VRPs are then matched with CDS spreads on a firm-month basis.

For market and firm-account information, they are most recently available monthly or quarterly variables. Firm quarterly balance-sheet data are acquired from COMPUSTAT. For market variables, the swap rates, constant maturity Treasury yields and Moody's *Aaa* and *Baa* yields are acquired from the Federal Reserve Board research website. Daily S&P 500 index returns come from CRSP. VIX is downloaded from the CBOE website.

3.2 Summary Statistics

Table 1 presents the summary statistics—average across the 540 firms—of the five-year CDS spreads and our benchmark VRP measure (Panel A), together with implied, realized, and expected variances (Panel B). The average Moody's and S&P ratings of the CDS reference entities range between AAA and CCC. A majority of the CDS ratings are A and BBB (27% and 44% respectively). The average of CDS spreads in our sample is 153 basis points. They increase monotonically from 17 to 605 basis points as the credit ratings of the CDS reference entities deteriorate from AAA to CCC. And this relationship appears to be non-linear—CDS spread and its standard deviation increase more significantly as the credit rating deteriorates further. The difference between the average CDS spreads for AAA grade and AA grade is 4 basis points, whereas the difference between those for CCC grade and B grade is 236 basis points. The CDS spreads display positive skewness of 0.99 and leptokurtosis of 4.41.

Like the CDS spreads, VRP displays significant variations across rating groups. The average of the benchmark VRP measure for the full sample is 43.34 (monthly in percentage-squared), increasing from 19 to 89 as CDS reference entities' credit ratings drop from AAA to CCC. High credit risk entities tend to be associated with high VRPs, and the relationship appears to be more linear than CDS spreads. The CDS spreads display positive skewness of 1.17 and leptokurtosis of 5.30.

As shown in Panel B of Table 1, implied variance and its standard deviation are much higher than either realized variance or expected variance, while they all have similar skewness and kurtosis. It is possible, as argued later on, implied variance may have a larger idiosyncratic component than expected variance. The persistence or AR(1) coefficients for VRP, implied and expected variances are 0.45, 0.59 and 0.63 respectively, suggesting that VRP is less persistent compared to the variance measures.

We group our sample into three sub-samples by CDS ratings. The first group contains CDS of AAA, AA and A grades, the second group contains CDS of BBB grade, and the third group contains CDS of speculative grades ranging between BB and CCC. The three sub-samples contain $7,666$, $10,055$ and $5,378$ firm-month observations respectively. Figure 1 plots the time-series of the five-year CDS spreads of whole sample and three sub-groups. The CDS spreads decrease gradually from the peaks in late 2002, then increase again as the financial crisis approaches in mid 2007. The spreads of investment grade CDS in year 2008 are higher than those in year 2002, whereas the spreads of speculative grade CDS are lower than their 2002 level. That highlights the nature of the recent financial crisis, which is mainly fueled by the heightening of systematic risk or economic uncertainty and affects disproportionally the high investment grade credit spreads. The difference between the investment grade and speculative grade CDS spreads, however, becomes widened during 2007-2008, potentially due to the "fly-to-quality" effect during the financial crisis that drives up the compensation for credit risk.

Figure 2 further illustrates the dynamic relationships among CDS spreads, VRP, VIX and leverage ratio for a representative firm in our sample: General Motor (GM). The CDS spread line and VRP line resemble each other closely over time. In particular, the two lines move closely during GM downgrading in year 2005 and in the recent financial crisis. In addition, the CDS spreads tend to co-move with the firm's leverage ratio. A visual examination of the relationship between CDS spreads and VIX suggests that the option-implied market volatility measure may not provide powerful prediction on GM's credit spreads. For instance, the two lines move in exactly opposite direction during the period between year 2004 and

2006. Like the VRP line, the implied variance line moves closely with the CDS spread line for GM, confirming the documented close tie between implied variance and CDS spreads for individual firms (Cao, Yu, and Zhong, 2006; Carr and Wu, 2008b).

Table 2 reports the descriptive statistics for our market and firm level control variables—average across 540 entities for the latter. The averages of one-year swap rate is 3.37%. The firms in our sample have an average market leverage ratio of 40%. The oscillation however is significant with a standard deviation of 6%. For simplicity we omit the discussion of other control variables, given that they are similar to those reported in literature.

4 Empirical Results and Analysis

In this section, we show that various VRP measures display a consistent significant predictability for CDS spreads in the presence of other credit risk determinants. In particular, VRP dominates the well-known market-level variation risk measure VIX in capturing the systematic variance risk in predicting CDS spreads. The predictive power of VRP for credit spreads increases as CDS credit quality deteriorates. VRP and expected variance are are two indispensable components of the option-implied variance in predicting the individual firms' credit spreads. Consistent with market level evidence, firm level VRP does predict a positive credit risk premium in a short horizon. Although implied variance has a higher prediction R-square, VRP is a less persistent explanatory variable and has a larger systematic component than the implied variance.

4.1 The Benchmark Regressions

Table 3 reports the regression results of the relationship between five-year CDS spreads and benchmark VRP computed with implied variance from 30-day out-of-the-money put options *minus* 30-day expected variance estimated from high-frequency data. Regression 1 reports that CDS spreads are positively related to VRP in the univariate regression. The t-statistic is a significant 8.19. Regression 2 shows that the relationship between CDS spreads and VRP remains intact in the presence of the popular market variance measure VIX. Importantly, CDS spreads are negatively and significantly correlated to VIX with a coefficient of -1.12. This is different from previous research that finds a positive relationship between CDS spreads and VIX (Ericsson, Reneby, and Wang, 2006) without using VRP, thus yields important evidence that VRP dominates VIX in capturing a systematic market variance risk component in explaining CDS spreads. Consistent with previous studies, we find that leverage ratio plays a significant role in affecting positively CDS spreads, as argued in theory (Merton, 1974) and reported empirically (Collin-Dufresne, Goldstein, and Martin, 2001). As default risk increases via the leverage channel, CDS spreads increase as well. However, as shown in Regression 3, the predictability of VRP for CDS spreads remains strong in the presence of leverage ratio.

Regression 4 reports the full-scale regression results after including all control variables. The coefficient of VRP decreases slightly from 1.91 in the univariate regression to 1.64 but remains statistically significant at 1% level and the robust t-statistics is quite stable. The decrease in the value of the coefficient is expected given that other market variables may capture the risk associated with macro-economic uncertainties as well. VRP remains contributing substantial predictability for CDS spreads in addition to that from the control variables identified in all previous studies.

Among the market variables, the coefficient of swap rate is negative but marginally insignificant. An increase in short rate usually signals an improving economic situation, in which firms' profits increase reducing the likelihood of financial distress. Alternatively, when the central bank is increasing short rate in an inflationary setting, nominal debt would be less valued, while equity would become more valuable—hence lowers default boundary. In other words, default risk is decreasing in the risk-free rate, hence CDS spreads are relatively lower. The coefficient of the default premium slope is positive, consistent to the notion that CDS and corporate bond markets are closely related (Blanco, Brennan, and Marsh, 2005; Ericsson, Jacobs, and Oviedo, 2004; Zhu, 2006). The coefficient of the fixed income market illiquidity, measured as the difference between swap rate and Treasury rate, is positive and significant. This can be explained in two ways. CDS spreads themselves may contain compensation for illiquidity risk (Tang and Yan, 2008). Alternatively, the "fly-to-quality" effect in bond market drives up required returns for holding credit risky bonds as well as the insurance premia against credit risk. The coefficient of S&P 500 return is negative but insignificant.

For firm level variables, price-earnings ratio, market-to-book ratio, return on assets, and log sales are all negatively correlated to CDS spreads. The coefficients of market-book ratio and log sales are statistically significant at 1% level, while that of return on assets is marginally significant at 10% level. The results support the intuition behind the structural form credit risk models in that firms of higher profitability and future growth tend to have relatively smaller probability of insolvency. Price-earnings ratio may have two opposite impacts on CDS spreads. On one hand, high price-earnings ratio implies high future asset growth that reduces the likelihood of financial distress and credit risk. On the other hand, high growth firms are typically young firms with volatile earnings that increase credit risk. The result suggests that the first effect dominates the second, but the net effect is not statistically significant. The negative and significant coefficient of log sales is consistent with the notion that securities for large firms attract better investor attention and marketability. It lends support to the argument that CDS spreads contain compensation for illiquidity risk (Tang and Yan, 2008).

The adjusted R^2 for the univariate regression is 0.24, highlighting the strong explanatory power of VRP for CDS spreads. Adding VIX as an additional explanatory variable to the regression has almost no impact on the adjusted R^2. It confirms that firm-level variation risk measure dominates the well-documented market-level variation risk measure in explaining CDS spreads. Including leverage ratio in the regression increases the adjusted R^2 to 0.42, possibly capturing the firm-specific default risk in the spirit of Merton (1974). Further adding all other control variables increases the adjusted R^2 to 0.45. Among all variables, VRP and leverage ratio are the two most powerful explanatory variables affecting CDS spreads.

4.2 VRP, Implied Variance, and Expected Variance

Previous studies find that individual firm credit risk is related to option-implied volatilities. However, it remains unclear to what extent the predictability comes from better informational efficiency of option market, from risk premium changes, or from expected variance changes. We attempt to provide a clear economic analysis on where the predictability exactly comes from. In particular, we investigate whether the predicting power of implied variance is due to risk premium shocks or variance risk shocks. In doing so, we carry out regressions in which VRP competes against implied variance and expected variance.

Table 4 reports the regression results of regressing the CDS spreads of various CDS maturities on those variables. The univariate regression results, as shown in Panel A, indicate that VRP alone could explain 24-26% of variations in CDS spreads, expected variance alone explains about 28-35%, and implied variance explains about 31-35%. The evidence suggests that variance risk premia and implied variance's information efficiency in forecasting realized variances are two important components contributing to the implied variance's strong predicting power for CDS spreads.

In the first step of the multivariate examination, we include implied variance, together with either VRP or expected variance, in the regressions. Panel B shows that the coefficients of VRP are driven negative in the presence of implied variance while those of expected variance remain positive, but both have insignificant coefficients for 1-, 2-, and 3-year CDS contracts and marginal significant coefficients for 5-, 7-, and 10-year CDS contracts. This confirms our conjecture that, as a part of implied variance, both variance risk premia and expected variance may be completely crowded out, if the term structure of implied variance is indeed driven by a single risk factor—which seems true at the short end but not quite so at the long end. Notice that the adjusted R^2 increases from 0.32 to 0.36, as CDS maturity increases from one year to ten years, suggesting that implied variance has a stronger predicting power than VRP for CDS spreads for longer contract maturities.

In the second step, we regress CDS spreads on VRP together with expected variance that captures information on expected variation shocks. The coefficients of both VRP and expected variance are positive and statistically significant at 1% level across CDS maturities, suggesting that VRP and expected variance are two important components in implied variance that help to explain individual firm credit spreads. The coefficients of VRP decrease slightly from 0.81 to 0.64, whereas the coefficients of expected variance increase from 1.06 to 1.61, as the CDS maturities increase from one year to ten years. The results imply that variance risk premia is more likely a short-term predictor, while expected variance shocks tend to have longer term impacts on CDS spreads. Further more, there may be a two-factor structure in the term structure of implied variance, such that both VRP and expected variance components are useful for predicting the CDS risk premia.

4.3 Economic Interpretation as Systematic Variance Risk

To further appreciate the subtle relationships between VRP and implied variance in predicting credit spreads, we report a principle component analysis on these variables. As shown in Table 5, the first principle component explains 80% of the total variation in VRP, while it only explains 37% in implied variance. And the first four principlal components cumulatively explains 95% of VRP variation versus only 55% of implied variance. In other words, VRP is likely a cleaner measure of firms' exposure to systematic variance or economic uncertainty risk relative to the option-implied variance, which captures both systematic and idiosyncratic variances. Therefore, the superior predictive power of implied variance may come from the co-movements between option prices and CDS spreads driven by the short-term market microstructure information and/or firm idiosyncratic characteristics, in other words, the informational efficiency of option and credit markets relative to underlying equity market.

As a simple illustration, notice that the total variance of firm i at time $t+1$ comprises of both systematic and idiosyncratic components

$$\text{Total Variance}_{i,t+1} = \text{Systematic Variance}_{i,t+1} + \text{Idiosyncratic Variance}_{i,t+1}, \tag{7}$$

where the "Systematic Variance" is really a confounding of firm i's exposure to market variance risk and market variance risk itself. Then, VRP—the difference between the risk-neutral and objective expectations of variance—can be shown as

$$\begin{aligned} VRP_{i,t} &\equiv E_t^Q\left[\text{Total Variance}_{i,t+1}\right] - E_t\left[\text{Total Variance}_{i,t+1}\right] \\ &= E_t^Q\left[\text{Systematic Variance}_{i,t+1}\right] - E_t\left[\text{Systematic Variance}_{i,t+1}\right] + 0, \end{aligned}$$

because idiosyncratic variance is not priced by construction, hence its risk-neutral and objective expectations cancel out. Therefore, one can easily conclude that firm specific VRP is simply firm i's exposure to market variance risk times market VRP,

$$VRP_{i,t} = \text{Exposure to Market Variance Risk}_{i,t} \times \text{Market Variance Risk Premium}_t.$$

In other words, VRP of individual firms really captures the compensations for bearing the systematic variance risk or economic uncertainty risk that is changing over time, which is consistent with the finding that a missing systematic risk factor may hold the key for explaining the credit spread puzzle(s) (see, Collin-Dufresne, Goldstein, and Martin, 2001, among others). Under a typical assumption that firm i's exposure to systemic variance risk is constant, then a factor analysis would reveal that the first principle component must explain 100% of the variation in the cross-section of firm VRPs, while for implied and expected variances its explaining power must be small in the presence of idiosyncratic variance components. As further illustrated in Table 5, the first principle component explains 57% of the total variation in expected variance, and the first four principal components cumulatively explains 75%; far less than corresponding 80% and 95% by the difference between implied and expected variances, or VRPs. This may help us to understand the linkage between the market level predictability evidence of VRP for credit spreads (Zhou, 2009) and the firm level predictability evidence presented here. In other words, the time series evidence on the predictability of VRP must be reconciled with the cross-sectional evidence of VRP.

4.4 Robustness Checks

For robustness check and to identify which VRP measure best predicts credit risk, we run the same regressions with VRPs computed with realized variance. The regression results are reported in Table 6. Overall, we find very consistent results for VRP computed with expected and realized variances. Importantly, the significant predictability of VRP for CDS spreads cannot be crowded out by other credit risk proxies for both VRP measures. The univariate regression coefficients are 1.91 and 1.44 with similar statistical significance at 1% level. The adjusted R^2s are 0.24 and 0.18. The VRP constructed with expected variance marginally outperform that constructed with realized variance, reflected in both t-statistics and adjusted R^2s. The results of the regressions with all control variables included paint the same picture.

We carry out regression analysis of CDS spreads on VRPs computed from options with different moneyness and alternative calls. Besides out-of-the-money put option-implied variance, we use implied variances computed from at-the-money and in-the-money put options, together with out-of-the-money, at-the-money and in-the-money call options. As reported in Table 7, all VRP measures display consistently significant predictability for CDS spreads in the presence of other credit risk predictors. Among them, the VRPs constructed with the implied variances from at-the-money put options possess the strongest predicting power. This is demonstrated in the slope coefficients, t-statistic, and adjusted R^2. The VRPs constructed with in-the-money put options show the smallest slope coefficients among all measures. Comparing the VRPs constructed with put and call options, we find that the VRPs estimated with implied variances from put options have marginally stronger predicting power, reflected in both higher coefficient values and adjusted R^2s.

We regress CDS spreads on VRP for the three sub-samples respectively. As reported in Table 8, in univariate regressions, the coefficients for the AAA-A, BBB, and BB-CCC groups increase significantly from 0.32 to 0.81 and then 2.34. The adjusted R^2s are 0.21, 0.21 and 0.25. VRP appears to have much stronger predictability on credit spreads for the

CDS written on bonds issued by low credit quality entities. The credit spreads of low quality issuers contain relatively higher compensation for risk associated with the systemic variance risk. This is also true for implied and expected variances. Comparing the coefficients of VRP and other variance measures, we find that credit spreads are most sensitive to VRP and expected variance, especially for speculative grade firms. Implied variance has the highest adjusted R^2s, but the lowest slope coefficients.

Finally, we examine the intertemporal effects of VRP for CDS spreads. We carried out the regression stipulated in equation (6) to study how the predictability of VRP for CDS spreads changes as time passes by. Table 9 shows the regression results of CDS spreads on lagged VRPs from zero month to twelve months. Panel A reports that, in univariate regressions, both the coefficient values and t-statistics decrease from 1.91 and 8.19 to 1.14 and 4.16, respectively, as the lag increases from zero to twelve months. The R^2 decreases monotonically from 0.24 to 0.09. The result in fact is qualitatively similar to Zhou (2009) in that the predicting power of both firm and market level VRPs on credit spreads peaks at one month, then drops as horizon increases. The difference is in the magnitude as firm level VRP's predicting power decreases more slowly. As Table 1 indicates, the persistence level or AR(1) coefficient of firm VRP (0.45) is much higher than that of the market VRP (0.26 as in Zhou, 2009), which may partially explain the slower decay found in this paper. Panel B reports the results with VIX and firm leverage ratio included in the regressions. Leverage ratio illustrates chronically reduced predicting power over time. Similar to the benchmark case, the market variance measure VIX is driven to have a negative sign in the presence of the firm level VRP in the regression.

5 Conclusions

We estimate the variance risk premia (VRPs) of individual firms, using the difference between option-implied variance and expected variance constructed from high-frequency equity returns. We demonstrate that VRP has a significant predictive power credit default swap spreads at individual firm level. Importantly, such a predictability cannot be substituted for by that of market and firm level credit risk factors identified in previous research. In addition, VRP dominates the well-documented market-level variation risk measure VIX in capturing market systematic variance risk to predict CDS spreads. The predictive power of VRP for credit spreads increases as the credit quality of CDS deteriorates.

By decomposing the implied variance, we demonstrate that both VRP and expected variance are important components in option-implied variance that help to explain individual firms' credit spreads. Empirical evidence also suggests that the superior explaining power of implied variance for CDS spreads may be due to the microstructure market comovements or due to the informational efficiency of implied variance in the short horizon. Implied variance has a larger idiosyncratic variance component, while VRP is more driven by a systematic variance component. Therefore VRP may turn out to be a much cleaner measure of the firms' exposures to macroeconomic uncertainty or systematic variance risk, which is potentially a promising concept in explaining some of the cross-sectional asset pricing puzzles.

References

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Heiko Ebens (2001a), "The Distribution of Realized Stock Return Volatility," *Journal of Financial Economics*, vol. 61, 43–76.

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Paul Labys (2001b), "The Distribution of Realized Exchange Rate Volatility," *Journal of the American Statistical Association*, vol. 96, 42–55.

Ang, Andrew, Robert Hodrick, Yuhang Xing, and Xiaoyan Zhang (2009), "High Idiosyncratic Volatility and Low Returns: International and Further U.S. Evidence," *Journal of Financial Economics*, vol. 91, 1–23, Forthcoming.

Barndorff-Nielsen, Ole and Neil Shephard (2002), "Econometric Analysis of Realised Volatility and Its Use in Estimating Stochastic Volatility Models," *Journal of Royal Statistical Society, Series B*, vol. 64, 253–280.

Berndt, Antje, Aziz A. Lookman, and Iulian Obreja (2006), "Default Risk Premia and Asset Returns," *working paper CMU*.

Bhamra, Harjoat, Lars-Alexander Kuhn, and Ilya Strebulaev (2009), "The Levered Equity Risk Premium and Credit Spreads: A Unified Framework," *Working Paper, Standford University*.

Blanco, Roberto, Simon Brennan, and Ian W. Marsh (2005), "An Empirical Analysis of the Dynamic Relationship Between Investment-Grade Bonds and Credit Default Swaps," *Journal of Finance*, vol. 60, 2255–2281.

Bollerslev, Tim, Michael Gibson, and Hao Zhou (2009a), "Dynamic Estimation of Volatility Risk Premia and Investor Risk Aversion from Option-Implied Volatilities," *Review of Financial Studies, Forthcoming*.

Bollerslev, Tim, George Tauchen, and Hao Zhou (2009b), "Expected Stock Returns and Variance Risk Premia," *Review of Financial Studies*, vol. 22, 4463–4492.

Britten-Jones, Mark and Anthony Neuberger (2000), "Option Prices, Implied Price Processes, and Stochastic Volatility," *Journal of Finance*, vol. 55, 839–866.

Buraschi, Andrea, Fabio Trojani, and Andrea Vedolin (2009), "The Joint Behavior of Credit Spreads, Stock Options and Equity Returns When Investors Disagree," *Working Paper, Imperial College London*.

Campbell, John T. and Glen B. Taksler (2003), "Equity Volatility and Corporate Bond Yields," *Journal of Finance*, vol. 58, 2321–2349.

Cao, Charles, Fan Yu, and Zhodong Zhong (2006), "How Important is Option-Implied Volatility for Pricing Credit Default Swaps?" *Working Paper, UC Irvine*.

Cao, Jie and Bing Han (2009), "Cross-Section of Stock Option Returns and Stock Volatility Risk Premium," *University of Texas at Austin Working Paper*.

Carr, Peter and Dilip Madan (1998), "Towards a Theory of Volatility Trading," In Volatility: New Estimation Techniques for Pricing Derivatives. Chap.29, 417-427, R. Jarrow (ed.). London: Risk Books.

Carr, Peter and Liuren Wu (2008a), "Stock Options and Credit Default Swaps: A Joint Framework for Valuation and Estimation," *New York University, Working Paper*.

Carr, Peter and Liuren Wu (2008b), "Variance Risk Premia," *Review of Financial Studies*, Forthcoming.

Chen, Hui (2009), "Macroeconomic Conditions and the Puzzles of Credit Spreads and Capital Structure," *Journal of Finance*, vol. forthcoming.

Chen, Long, Pierre Collin-Dufresne, and Robert S. Goldstein (2009), "On the Relation Between the Credit Spread Puzzle and the Equity Premium Puzzle," *Review of Financial Studies*, vol. 22, 3368–3409.

Collin-Dufresne, Pierre, Robert Goldstein, and Spencer Martin (2001), "The Determinants of Credit Spread Changes," *Journal of Finance*, vol. 56, 2177–2207.

Coval, Joshua, Jakub Jurek, and Erik Stafford (2009), "Economic Catastrophe Bonds," *The American Economic Review*, vol. 99, 628–666.

Cox, John, Stephen Ross, and Mark Rubinstein (1979), "Option Pricing: A simplified approach," *Journal of Financial Economics*, vol. 7, 229–263.

Cremers, K., J. Driessen, and P. Maenhout (2008a), "Explaining the Level of Credit Spreads: Option-Implied Jump Risk Premia in a Firm Value Model," *Review of Financial Studies*, vol. 21, 2209–2242.

Cremers, Martijn, Joost Driessen, Pascal J. Maenhout, and David Weinbaum (2008b), "Individual Stock-Option Prices and Credit Spreads," *Journal of Banking and Finance*, vol. 12, 2706–2715.

David, Alexander (2008), "Inflation Uncertainty, Asset Valuations, and the Credit Spreads," *Reveiew of Financial Studies*, vol. 21, 2487–2534.

Drechsler, Itamar and Amir Yaron (2008), "What's Vol Got to Do With It." Working Paper, University of Pennsylvania.

Elton, Edwin, Martin Gruber, Deepak Agrawal, and Christopher Mann (2001), "Explaining the Rate Spread on Corporate Bonds," *Journal of Finance*, vol. February, 247–278.

Ericsson, Jan, Kris Jacobs, and Rodolfo Oviedo (2004), "The Determinants of Credit Default Swap Premia," *Working paper McGill University*.

Ericsson, Jan, Joel Reneby, and Hao Wang (2006), "Can Structural Models Price Default Risk? Evidence from Bond and Credit Derivative Markets," *Working Paper, McGill University*.

Fu, Fangjian (2009), "Idiosyncratic Risk and the Cross-Section of Expected Stock Returns," *Journal of Financial Economics*, vol. 91, 24–37.

Goyal, Amit and Alessio Saretto (2009), "Option Returns and Volatility Mispricing," *Journal of Financial Economics*, vol. forthcoming.

Huang, Jay and Ming Huang (2003), "How Much of the Corporate-Treasury Yield Spread is Due to Credit Risk? A New Calibration Approach," *Working paper Pennsylvania State University*.

Huang, Wei, Qianqiu Liu, Ghon Rhee, and Liang Zhang (2009), "Return Reversals, Idiosyncratic Risk and Expected Returns," *Review of Financial Studies*, vol. forthcoming.

Jiang, George and Yisong Tian (2005), "Model-Free Implied Volatility and Its Information Content," *Review of Financial Studies*, vol. 18, 1305–1342.

Jones, Philip, Scott Mason, and Eric Rosenfeld (1984), "Contingent Claims Analysis of Corporate Capital Structures: An Empirical Investigation," *Journal of Finance*, vol. 39, 611–627.

Longstaff, Francis, Sanjay Mithal, and Eric Neis (2005), "Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit-Default Swap Market," *Journal of Finance*, vol. 60, 2213–2253.

Longstaff, Francis, Jun Pan, Lasse Pedersen, and Kenneth Singleton (2007), "How Sovereign is Sovereign Credit Risk?" *National Bureau of Economic Research, Working Paper*.

Longstaff, Francis A. and Eduardo S. Schwartz (1995), "Valuing Credit Derivatives," *Journal of Fixed Income*, vol. June, 6–12.

Merton, Robert C. (1974), "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance*, vol. 29, 449–4790.

Petersen, Mitchell A. (2009), "Estimating Standard Errors in Finance Panel Data Sets: Comparing Approaches," *Review of Financial Studies*, vol. 22, 435–480.

Tang, Dragon Yongjun and Hong Yan (2008), "Liquidity, Liquidity Spillovers and Credit Default Swaps," *Working paper, University of Hong Kong*.

Zhang, Benjamin, Hao Zhou, and Haibin Zhu (2009), "Explaining Credit Default Swap Spreads with the Equity Volatility and Jump Risks of Individual Firms." *Review of Financial Studies, Forthcoming*.

Zhou, Hao (2009), "Variance Risk Premia, Asset Predictability Puzzles, and Macroeconimc Uncertainty," *Working Paper, Federal Reserve Board*.

Zhu, Haibin (2006), "An Empirical Comparison of Credit Spreads Between the Bond Market and the Credit Default Swap Market," *Bank of International Settlements, Working Paper*.

Table 1: Descriptive statistics - CDS spreads, VRP, IV, EV and RV

This table presents the summary statistics—average across the 540 firms—of the five-year CDS spreads and our benchmark VRP measure (Panel A), together with implied, realized, and expected variances (Panel B). The VRP is computed as the spread between 30-day out-of-the-money put option-implied variance and high-frequency expected variance. The average Moody's and S&P ratings of the CDS reference entities range between AAA and CCC. The numbers of firms in each rating category are reported in the second column in Panel (A). AR(1) denotes autocorrelation with one lag.

Panel A: The means of the statistics of CDS spreads and VRP across individual firms

		CDS Spread					VRP				
Rating	Number of Firms	Mean	SD	Skewness	Kurtosis	AR(1)	Mean	SD	Skewness	Kurtosis	AR(1)
AAA	7	17.31	11.94	1.55	6.00	0.88	18.52	17.24	1.59	6.46	0.60
AA	17	20.93	10.26	0.98	3.67	0.90	22.76	20.34	1.85	8.32	0.52
A	104	34.19	17.79	1.34	5.08	0.87	28.77	25.53	1.47	5.84	0.51
BBB	200	76.84	38.69	1.10	4.42	0.87	33.66	27.61	1.30	5.77	0.45
BB	133	220.83	85.49	0.91	4.76	0.83	55.17	35.86	1.04	4.77	0.40
B	65	368.94	119.77	0.39	2.97	0.78	67.22	40.60	0.87	3.85	0.43
CCC	14	605.21	234.90	0.70	3.57	0.84	89.25	44.07	0.33	3.77	0.42
Total	540	153.17	58.02	0.99	4.41	0.85	43.34	30.37	1.17	5.30	0.45

Panel B: The means of the statistics of IV, RV and EV across individual firms

	Implied Variance					Realized Variance					Expected Variance				
Rating	Mean	SD	Skewness	Kurtosis	AR(1)	Mean	SD	Skewness	Kurtosis	AR(1)	Mean	SD	Skewness	Kurtosis	AR(1)
AAA	53.19	34.19	1.62	6.51	0.68	32.73	22.43	1.97	5.01	0.57	34.66	17.15	1.64	6.47	0.72
AA	59.30	34.78	1.66	7.19	0.61	35.38	22.14	1.85	4.60	0.54	36.54	15.90	1.55	6.44	0.63
A	81.39	45.11	1.40	5.33	0.63	50.58	31.85	1.74	3.91	0.56	52.62	22.22	1.42	5.36	0.68
BBB	100.50	49.59	1.29	5.41	0.59	62.98	35.56	1.48	2.92	0.53	66.84	25.28	1.32	5.46	0.64
BB	159.19	64.31	1.10	4.77	0.55	95.77	44.95	1.17	2.08	0.51	104.02	33.19	1.14	4.92	0.58
B	200.24	78.64	0.99	4.20	0.60	120.68	57.58	1.08	1.45	0.56	133.01	45.23	1.08	4.28	0.63
CCC	258.59	73.92	0.42	4.18	0.48	158.88	52.50	0.51	-0.16	0.23	169.34	39.01	0.41	3.60	0.45
Total	125.66	54.82	1.19	5.07	0.59	76.22	38.48	1.36	5.66	0.53	82.32	28.37	1.22	5.11	0.63

Table 2: Summary statistics - the market and firm characteristic variables

This table reports the descriptive statistics of the market and firm level control variables. For firm characteristics, we report the averages of the statistics across 540 firms. The averages of one-year swap rate is 3.37%. The average default premium slope (Moody's *Baa* rate *minus* *Aaa* rate) is 0.99% and the average liquidity measure (five-year swap rate *minus* constant maturity Treasury rate) is 0.54%. The average market leverage ratio is 40% with a standard deviation of 6%. AR(1) denotes autocorrelation with one lag.

Variable	Mean	SD	Skewness	Kurtosis	AR(1)
Market Level					
VIX Squared Monthly (%)	34.42	23.98	1.41	5.16	0.84
S&P 500 Return (%)	-0.02	1.98	-0.17	4.15	-0.17
Swap (1 year, %)	3.37	1.47	0.06	1.56	0.98
Baa - *Aaa* (%)	0.99	0.22	0.64	2.36	0.95
Swap - CMT (5 year, %)	0.54	0.16	0.85	2.68	0.90
Firm Level					
Leverage Ratio	0.40	0.06	0.36	2.97	0.92
Asset Turnover (%)	1.09	0.15	0.09	3.03	0.83
Price-earnings Ratio	16.39	53.46	0.22	8.29	0.81
Market/Book Ratio	2.32	10.60	0.27	3.59	0.89
Return on Assets (%)	5.69	6.46	-0.70	7.80	0.70
Annualized Sales ($ billion)	14.40	3.09	0.27	2.78	0.93
Firm Assets ($ billion)	16.15	3.27	0.17	2.91	0.97

Table 3: The CDS spreads and VRP

This table reports the regression results of five-year CDS spreads on the benchmark VRP computed with the 30-day out-of-the-money put option-implied variance (monthly) *minus* 30-day high-frequency expected variance (monthly). Regression (1) is for the univariate regression; regression (2) shows the relationship between CDS spreads and VRP in the presence of VIX (monthly squared in percentage); regression (3) further includes firm leverage ratio; and regression (4) includes all other control variables. We adjust two-dimensional (firm and time) clustered standard errors in the regressions as in Petersen (2009).

	Regression			
Independent Variable	(1)	(2)	(3)	(4)
VRP	1.91	2.16	1.75	1.64
	(8.19)	(8.04)	(8.90)	(7.70)
VIX Squared		-1.12	-1.04	-1.25
		(-3.90)	(-4.21)	(-5.20)
Market Leverage			367.32	361.49
			(9.58)	(8.92)
S&P 500 Return				-0.50
				(-0.34)
Swap Rate (1 Year)				-2.56
				(-1.63)
Baa - *Aaa*				18.87
				(1.38)
Swap Rate - CMT (5 Year)				49.18
				(2.47)
Asset Turnover Ratio				5.75
				(1.05)
Price-earnings Ratio				-0.02
				(-1.49)
Market/Book Ratio				-0.02
				(-3.30)
Return on Assets				-45.41
				(-1.77)
Log Sales				-19.19
				(-4.92)
Constant	33.77	57.30	-71.68	48.49
	(5.94)	(11.96)	(-5.87)	(1.62)
Adjusted R^2	0.24	0.26	0.42	0.45

Table 4: VRP versus implied variance and expected variance

This table compares the predictability of VRP on CDS spreads to that of implied and expected variances for different CDS maturities. Panel A reports the univariate regression results for VRP, implied and expected variances. Panel B reports the regression results of CDS spreads on each pairs of VRP, implied and expected variances respectively. We adjust two-dimensional (firm and time) clustered standard errors in the regressions as in Petersen (2009).

Panel A: Univariate regressions

	CDS					
	1-year	2-year	3-year	5-year	7-year	10-year
VRP	1.65	1.81	1.91	1.91	1.91	1.92
	(7.33)	(6.96)	(7.85)	(8.19)	(8.03)	(7.90)
Adjusted R^2	0.24	0.24	0.26	0.24	0.24	0.24
Implied Variance	0.95	1.05	1.13	1.17	1.17	1.17
	(8.27)	(8.01)	(9.15)	(9.77)	(9.70)	(9.61)
Adjusted R^2	0.31	0.32	0.35	0.35	0.35	0.35
Expected Variance	1.54	1.73	1.88	1.99	1.98	1.99
	(8.08)	(7.98)	(9.12)	(9.91)	(9.91)	(9.78)
Adjusted R^2	0.28	0.30	0.33	0.35	0.34	0.35

Panel B: with each pairs of VRP, implied variance and expected variances

	CDS					
	1-year	2-year	3-year	5-year	7-year	10-year
VRP	-0.25	-0.42	-0.59	-0.95	-0.91	-0.97
	(-0.93)	(-1.33)	(-1.87)	(-2.83)	(-2.79)	(-2.86)
Implied Variance	1.06	1.24	1.40	1.60	1.58	1.61
	(6.91)	(6.83)	(7.65)	(8.08)	(8.24)	(8.12)
Expected variance	0.25	0.42	0.59	0.95	0.91	0.97
	(0.93)	(1.33)	(1.87)	(2.83)	(2.79)	(2.86)
Implied Variance	0.81	0.82	0.81	0.65	0.67	0.64
	(4.07)	(3.56)	(3.72)	(3.07)	(3.12)	(2.91)
VRP	0.81	0.82	0.81	0.65	0.67	0.64
	(4.07)	(3.56)	(3.72)	(3.07)	(3.12)	(2.91)
Expected Variance	1.06	1.24	1.40	1.60	1.58	1.61
	(6.91)	(6.83)	(7.65)	(8.08)	(8.24)	(8.12)
Adjusted R^2	0.32	0.33	0.36	0.36	0.36	0.36

Table 5: Principal Component Analyses of CDS Spreads, VRP, IV and EV

This table reports the principal component analyses of CDS spreads, VRP, implied and expected variances. We select firms with 48 monthly observations starting in January 2004. The sample contains 217 firms. VRP is explained mostly by first three components (92.8% cumulatively), whereas IV and EV are driven marginally by several components. Robustness checks with various samples show that sample selection does not change the results qualitatively.

	CDS Spreads		VRP		IV		EV	
Component	Explained %	Cumulatively %	Explained %	Cumulatively %	Explained %	Cumulatively %	Explained %	Cumulatively %
1	59.66	59.66	80.07	80.07	36.83	36.83	56.95	56.95
2	13.88	73.54	9.15	89.22	9.81	46.63	10.31	67.26
3	5.51	79.05	3.58	92.80	4.77	51.40	4.86	72.12
4	4.42	83.47	1.77	94.57	3.95	55.35	2.76	74.87
5	3.25	86.73	1.29	95.86	3.57	58.93	2.33	77.21
6	2.77	89.50	1.07	96.94	3.18	62.11	2.09	79.30
7	1.86	91.35	0.56	97.49	2.95	65.06	1.70	80.99
8	1.57	92.92	0.51	98.00	2.54	67.60	1.64	82.63
9	1.26	94.19	0.36	98.36	2.40	70.00	1.35	83.98
10	1.10	95.29	0.21	98.57	2.09	72.09	1.16	85.14

Table 6: CDS spreads and VRPs of various measures

This table reports the regression results of CDS spreads on VRPs computed with expected and realized variances. For each VRP measure, we report the results of both univariate regression and the regression with all control variables included. The results demonstrate consistent and significant predictability of VRP on credit spreads. We adjust two-dimensional (firm and time) clustered standard errors in the regressions as in Petersen (2009).

	VRP estimated with			
Independent Variable	Expected Variance		Realized Variance	
VRP	1.91	1.64	1.44	1.07
	(8.19)	(7.70)	(8.15)	(7.47)
VIX Squared		-1.25		-0.68
		(-5.20)		(-3.45)
Market Leverage		361.49		376.42
		(8.92)		(8.33)
S&P 500 Return		-0.50		0.96
		(-0.34)		(0.65)
Swap Rate (1 Year)		-2.56		-3.32
		(-1.63)		(-1.99)
Baa - *Aaa*		18.87		24.40
		(1.38)		(1.77)
Swap Rate - CMT (5 Year)		49.18		81.54
		(2.47)		(3.83)
Asset Turnover Ratio		5.75		6.53
		(1.05)		(1.15)
Price-earnings Ratio		-0.02		-0.02
		(-1.49)		(-1.62)
Market/Book Ratio		-0.02		-0.02
		(-3.3)		(-3.31)
Return on Assets		-45.41		-62.19
		(-1.77)		(-2.32)
Log Sales		-19.19		-20.61
		(-4.92)		(-5.17)
Constant	33.77	48.49	45.26	34.53
	(5.94)	(1.62)	(8.37)	(1.05)
Adjusted R^2	0.24	0.45	0.18	0.40

Table 7: CDS spreads and VRPs of different implied variances

This table reports the regression results of CDS spreads on VRPs computed from different measures of implied variances. Besides the benchmark out-of-the-money (OTM) put option-implied variance, we use implied variances computed from at-the-money (ATM) and in-the-money (ITM) put options, together with out-of-the-money (OTM), at-the-money (ATM) and in-the-money (ITM) call options. All VRP measures display consistently significant predictability on CDS spreads in the presence of market and firm level credit risk determinants. We adjust two-dimensional (firm and time) clustered standard errors in the regressions as in Petersen (2009).

	VRP constructed with implied variance from					
	Put option			Call option		
Dependent Variable	OTM	ATM	ITM	OTM	ATM	ITM
VRP	1.64	2.73	1.25	1.46	2.62	1.57
	(7.7)	(7.54)	(6.63)	(7.1)	(7.71)	(7.42)
VIX Squared	-1.25	-1.2	-0.54	-0.44	-1.05	-1.19
	(-5.2)	(-5.07)	(-3.19)	(-2.97)	(-4.85)	(-4.95)
Market Leverage	361.49	344.7	390.18	371.99	361.1	363.47
	(8.92)	(9.65)	(8.17)	(7.76)	(9.13)	(8.85)
S&P 500 Return	-0.5	-1.28	-1.51	-0.35	-0.29	-0.11
	(-0.34)	(-0.87)	(-1.41)	(-0.37)	(-0.22)	(-0.08)
Swap Rate (1 Year)	-2.56	-3.8	-4.3	-2.04	-3.5	-2.48
	(-1.63)	(-2.25)	(-2.63)	(-1.41)	(-2.13)	(-1.59)
Baa - Aaa	18.87	30.56	42.81	44.85	29.45	20.01
	(1.38)	(2.3)	(3.69)	(3.93)	(2.24)	(1.47)
Swap Rate - CMT (5 Year)	49.18	38.15	32.44	45.55	43.64	47.74
	(2.47)	(1.87)	(1.91)	(2.77)	(2.22)	(2.41)
Asset Turnover Ratio	5.75	6.38	10.22	6.07	7.53	5.68
	(1.05)	(1.23)	(1.74)	(1.02)	(1.41)	(1.03)
Price-earnings Ratio	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
	(-1.49)	(-1.57)	(-1.68)	(-1.8)	(-1.57)	(-1.48)
Market/Book Ratio	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02
	(-3.3)	(-2.36)	(-2.23)	(-2.46)	(-2.53)	(-3.25)
Return on Assets	-45.41	-32.6	-66.76	-76.06	-40.5	-49
	(-1.77)	(-1.33)	(-2.44)	(-2.86)	(-1.58)	(-1.88)
Log Sales	-19.19	-16.75	-21.83	-15.9	-18.61	-19.39
	(-4.92)	(-4.35)	(-5.43)	(-3.7)	(-4.85)	(-4.96)
Constant	48.49	34.65	58.14	4.31	43.6	49.77
	(1.62)	(1.19)	(1.81)	(0.12)	(1.46)	(1.65)
Adjusted R^2	0.45	0.48	0.38	0.37	0.46	0.44

Table 8: CDS spreads and VRP, IV, EV and RV by CDS rating

This table reports the regression results of CDS spreads on VRP, implied and expected variances for three sub-samples: AAA-A, BBB, and BB-CCC. The first sub-sample contains CDS of AAA, AA and AA grades. The second contains CDS of BBB grade. The third sub-sample contains CDS of speculative grades ranging between BB and CCC. The three sub-samples contain 7,666, 10,055 and 5,378 firm-month observations respectively. Two-dimensional (firm and time) clustered standard errors in the regressions are adjusted as in Petersen (2009). To be focused, we omit reporting the multivariate regression results for the control variables, given their similarity to those reported in Table 6 and 7.

	Rating	Univariate Regression			Regression with All Control Variables		
Variable	Group	Coefficient	T-statistic	Adjusted R^2	Coefficient	T-statistic	Adjusted R^2
VRP	AAA-A	0.32	8.77	0.21	0.18	7.32	0.51
	BBB	0.81	11.07	0.21	0.54	7.17	0.36
	BB-CCC	2.34	6.88	0.25	1.80	6.10	0.45
IV	AAA-A	0.20	9.08	0.27	0.12	7.40	0.53
	BBB	0.49	12.45	0.27	0.37	8.98	0.40
	BB-CCC	1.39	7.73	0.32	1.16	6.92	0.50
EV	AAA-A	0.37	8.64	0.26	0.21	6.43	0.52
	BBB	0.80	10.47	0.24	0.60	7.74	0.39
	BB-CCC	2.15	6.84	0.27	1.72	5.80	0.47

Table 9: CDS spreads and lagged VRPs (the inter-temporal effect)

This table reports the regression results of CDS spreads on lagged VRPs from zero month to twelve months. Panel A reports that, in univariate regressions, both the coefficient values and t-statistics decrease from 1.91 and 8.19 to 1.14 and 4.16 respectively as the lag increases from zero to twelve months. The R^2s decrease from 0.24 to 0.09. Panel B reports the results of the regressions with VIX and firm leverage ratio included. Same inter-temporal pattern is observed. We adjust two-dimensional (firm and time) clustered standard errors in the regressions as in Petersen (2009).

Panel A: VRP univariate

	CDS												
	t+0	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
VRP	1.91	1.84	1.77	1.70	1.63	1.57	1.51	1.44	1.38	1.33	1.25	1.19	1.14
	(8.19)	(7.82)	(7.29)	(6.80)	(6.40)	(5.93)	(5.55)	(5.15)	(4.83)	(4.54)	(4.38)	(4.24)	(4.16)
Adjusted R^2	0.24	0.23	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.09

Panel B: VRP with VIX and leverage ratio

	CDS												
	t+0	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
VRP	1.75	1.70	1.66	1.61	1.54	1.51	1.46	1.42	1.40	1.37	1.30	1.25	1.23
	(8.90)	(8.55)	(8.04)	(7.54)	(7.15)	(6.63)	(6.31)	(5.94)	(5.71)	(5.48)	(5.39)	(5.28)	(5.35)
VIX	-1.04	-1.05	-1.10	-1.13	-1.14	-1.17	-1.22	-1.30	-1.40	-1.46	-1.46	-1.47	-1.52
	(-4.21)	(-4.24)	(-4.40)	(-4.42)	(-4.43)	(-4.45)	(-4.57)	(-4.84)	(-5.25)	(-5.47)	(-5.52)	(-5.59)	(-5.89)
Leverage	367.33	366.66	364.08	359.84	354.84	348.76	343.67	338.42	332.52	326.90	323.60	320.15	316.18
	(9.58)	(9.33)	(9.10)	(8.88)	(8.63)	(8.47)	(8.24)	(8.08)	(7.90)	(7.75)	(7.55)	(7.40)	(7.31)
Adjusted R^2	0.42	0.41	0.40	0.38	0.36	0.34	0.33	0.31	0.30	0.29	0.28	0.27	0.27

Figure 1: The time series of the five-year CDS spreads

This figure plots the five-year CDS spreads of full sample and three sub-samples. We group the CDS spreads into three sub-samples by CDS ratings. The first group contains CDS of AAA, AA and AA grades. The second group contains CDS of BBB grade. The third group contains CDS of speculative grades ranging between BB and CCC. The three sub-samples contain 7,666, 10,055 and 5,378 observations respectively. The CDS spreads decrease gradually from the peaks in late 2002, then increase again as the financial crisis approaches in year 2007. The spreads of investment grade CDS in year 2008 are higher than those in year 2002, whereas the spreads of speculative grade CDS are lower then their 2002 level. That highlights the nature of the recent financial crisis which was fueled mostly by the financial distress of highly rated credit products. The difference between the CDS spreads for investment grade and speculative group CDS however becomes widen potentially due to the "fly-to-quality" effect during the financial crisis, driving up compensation for credit risk.

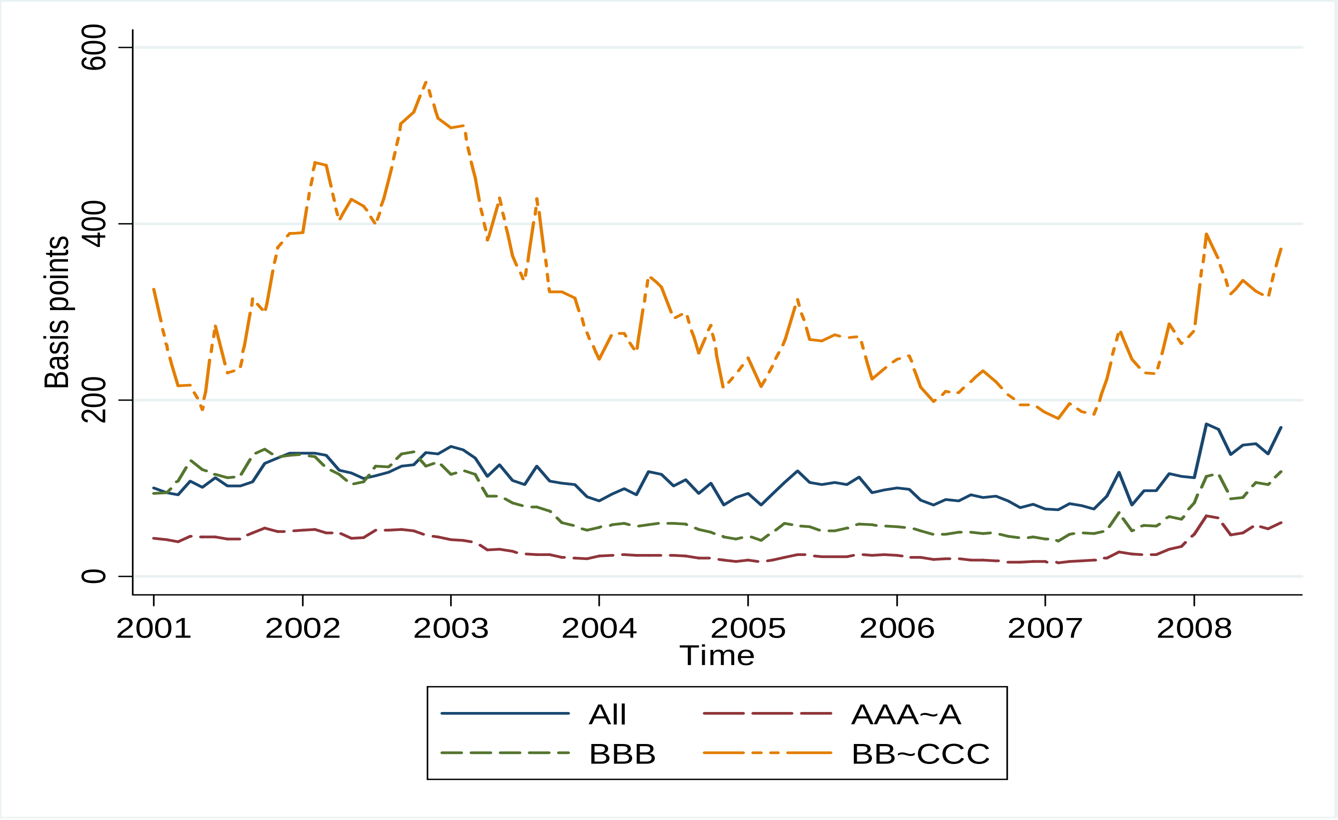

Figure 2: The time series of CDS spreads, VRP, Leverage ratio and VIX for General Motor Ltd.

This figure illustrates the dynamic relationships among CDS spreads, VRP, VIX and leverage ratio for a representative firm in our sample: General Motor (GM). The CDS spread line and VRP line resemble each other closely over time. In particular, the two lines move closely during GM downgrading in year 2005 and in the recent financial crisis. In addition, the CDS spreads tend to co-move with the firm's leverage ratio. A visual examination of the relationship between CDS spreads and VIX suggests that the option-implied market volatility measure may not provide powerful prediction on GM's credit spreads. For instance, the two lines move in exactly opposite direction during the period between year 2004 and 2006. Like the VRP line, the implied variance line moves closely with the CDS spread line for GM.