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Abstract

This paper analyzes the determinants of credit default swap spread changes for a large sample of US non-financial companies over the period between January 2002 and March 2009. In our analysis we use variables that the literature has found have an impact on CDS spreads and, in order to account for possible non-linear effects, the theoretical CDS spreads predicted by the Merton model. We show that our set of variables is able to explain more than 50% of CDS spread variations both before and after July 2007, when the current financial turmoil began. We also document that since the onset of the crisis CDS spreads have become much more sensitive to the level of leverage while volatility has lost its importance. Using a principal component analysis we also show that since the beginning of the crisis CDS spread changes have been increasingly driven by a common factor, which cannot be explained by indicators of economic activity, uncertainty, and risk aversion.

JEL Classification: G12, G13.
Keywords: credit default swaps, bond spreads, credit risk, Merton model.

Contents

* Bank of Italy, Economics, Research and International Relations.

1. Introduction[1]

Empirical work on the determinants of credit risk – the risk of default of borrowers – has traditionally looked at corporate spreads, that is spreads between corporate and government bonds.[2] The common finding has been that only a small share of observed spreads can be actually considered as a compensation for the risk of default of borrowers, whereas the greatest share can be traced back to taxes and liquidity issues, and to the presence of other systematic risk factors (e.g. Elton et al., 2001, Amato and Remolona, 2005, and Driessen, 2005).

Although the bond market has traditionally been regarded as the best place in which the creditworthiness of a borrower can be evaluated, in recent years there has been a huge development of financial instruments, called credit derivatives, that are specifically designed to make credit risk easily tradable.[3] Among these innovative instruments, credit default swaps (CDSs) have proved particularly successful. Essentially, a CDS works like an insurance contract: the policy holder (i.e. the buyer of protection) pays a premium to the insurer (i.e. the seller of protection) in order to receive compensation if a particular event occurs. In the case of CDSs this event, called a credit event, usually includes bankruptcy, failure to pay and restructuring and, for sovereign issuers, repudiation and moratoria. Generally speaking all these events are subsumed in the term "default". The main difference between a CDS and an insurance contract is that, while in the case of insurance the policy holder gets a reimbursement only for the actual damages suffered, with a CDS it is possible to buy or sell protection against credit events independently from the real exposure to the risk of default of the reference entity. A CDS can thus be used not only for hedging credit risk but also for taking pure speculative positions, as with forward and futures contracts. This aspect clearly distinguishes the CDS market from the bond market. While the short selling of bonds, i.e. of credit risk, is usually limited by the low level of liquidity of the repo market, especially for high-yield bonds, and by the short maturity of repo contracts, CDSs allow investors to short sell credit risk easily. Thanks to this characteristic, the CDS market has been growing dramatically during the last few years. According to the International Swap and Derivatives Association (ISDA) the notional value of outstanding CDSs has increased from 1 to 62 trillion USD between 2001 and 2007. The notional amount of outstanding CDSs was so large that it turned out to be a serious potential source of instability during the financial turmoil triggered by the subprime crisis in the United States because of the corresponding counterparty risks. In

[1]The views expressed in the article are those of the authors and do not involve the responsibility of the Bank of Italy. We would like to thank Giuseppe Cappelletti, Giuseppe Grande and Marcello Pericoli for their helpful comments and suggestions. All remaining errors are our own. The original version of this paper focused on CDSs denominated in euro; an electronic copy is currently available at http://www.greta.it/credit/credit2005/Friday/Poster/05_DiCesare_Guazzarotti.pdf. The most recent version of this paper is forthcoming in *Finance and Banking Developments*, Charles V. Karsone (eds.), New York, Nova Publishers.

[2]We use the terms "credit spreads" and "credit premia" as synonyms of "corporate spreads" and "CDS spreads". By "corporate spreads" or "bond spreads" we mean the differential between the yields of bonds issued by private companies and the yields of government bonds with similar characteristics. We also use the term "risk-free yields" as a synonym of "government bond yields".

[3]See the Committee on the Global Financial System (2003).

order to reduce these risks, CDS market dealers started entering multilateral netting of CDS contracts, thus reducing the notional amount of outstanding CDS to 39 trillion by the end of 2008 (see European Central Bank, 2009a). According to Fitch Ratings (2006) CDSs represent more than a half of the whole credit derivatives market.[4]

Because of its particular features, the CDS market is potentially much more efficient than the bond market in signaling the creditworthiness of borrowers. The relationship between bond and CDS markets has been the subject of several academic papers. Blanco et al. (2005) find that CDS and bond markets reflect firm-specific characteristics equally in the long run, while in the short run CDS prices appear to be more efficient than bond spreads in the price discovery process. Zhu (2004) confirms that credit risk tends to be priced equally in the two markets in the long run and that the derivatives market seems to lead the cash market in anticipating rating events and in price adjustments. Other literature (Hull et al., 2004, Norden and Weber, 2004, Di Cesare, 2005) which analyzes the relationship between CDS spreads and credit ratings show that the CDS market is usually very effective in anticipating rating changes.

The development of the CDS market has also attracted researchers' interest in analyzing whether factors that determine corporate spreads are also relevant for CDS spreads. As said before, the nature of CDSs is such that this question does not have an obvious answer. The aim of this paper is to contribute to this literature by analyzing how the recent financial turmoil has changed the way that credit risk is priced in the CDS market. Most of existing literature use data from the early stage of the CDS market only, thus not taking into account more recent developments. To the best of our knowledge, only Annaert et al. (2009) and Raunig and Scheicher (2009) analyze the period following the onset of the current financial turmoil in July 2007, but they focus on the banking sector. Moreover, with the exception of Alexander and Kaeck (2008) and Pires et al. (2009), no other paper takes into account the non-linear relationship between CDS spreads and default factors. In this paper we use a large data set of CDS quotes on US non-financial companies from January 2002 to March 2009 that allow us to analyze the effects of the recent financial turmoil on the determinants of CDS spread changes. We also take into account the issue of non-linearity by explicitly using a theoretical CDS spread calculated using the Merton model in our regressions. In this respect, our paper is similar in spirit to Byström (2006) which uses the CreditGrades model to calculate theoretical CDS spreads and compare these with empirically observed spreads for CDS indices (iTraxx) covering Europe. Byström (2006) finds that theoretical and empirical spread changes are significantly correlated. Given that the specific functional form provided by a theoretical model could misspecify the true relationship between CDS spreads and default factors, we also add in our regressions the single default factors separately as well as other factors that theory and empirical evidence found to be significant in explaining credit spreads.

Our main results are: i) the inclusion of a theoretical CDS spread in our regressions improves the explanatory power of the fundamental variables. Our extended model is able to explain 54% of the variations in CDS spreads in the pre-crisis period (from January 2002 to June 2007) and 51% in the crisis period (from July 2007 to March 2009), which is higher

[4]More detailed information about the CDS market can be found in European Central Bank, 2009b.

than previous findings of studies on corporate bond and CDS spread changes; ii) when the theoretical spread calculated from the Merton model is introduced in the regressions, the coefficient of equity volatility decreases significantly; that of leverage, on the contrary, maintains its usefulness in explaining CDS spread changes; iii) the contribution of leverage to the explanation of CDS spread changes is much higher during the crisis than before, as investors appear to have become more aware of individual risk factors; at the same time, the impact of equity volatility substantially decreases, possibly because the large swings in implied volatility that have characterized the crisis period have made this indicator a poor proxy for long-term asset volatility; iv) the overall capacity of the model to explain CDS changes is almost the same before and during the turmoil, thus highlighting that the underlying risk factors identified by the literature as relevant for the pricing of the credit risk have maintained their explanatory power also in a period of remarkable stress for the CDS market; v) during the crisis CDS spreads appear to have been moving increasingly together, driven by a common factor that our model was able to explain only in part.

The following section surveys the literature on the determinants of credit spreads and on previous empirical studies. In Section 3 we describe the model introduced by Merton (1974) and the way in which it can be used to estimate model-based CDS spreads. In Section 4 we describe the dataset and the statistical methodology used in the paper to look for the determinants of CDS spread movements. Our results are reported in Section 5 and Section 6 concludes.

2. A review of the literature on credit spreads

This section briefly reviews the main contributions to the literature on the determinants of credit spreads. Early research on this topic has focused on assessing how much of observed bond spreads can be explained by structural default factors, that is by factors that theoretical models of default suggest are linked to credit risk. Then, having observed that bond spreads predicted by theoretical models are generally much lower than observed spreads, the academic research has turned its attention to investigating the origins of such unexplained extra yields, testing for alternative hypotheses.

2.1. Main determinants of credit spreads

Credit risk models are usually divided into structural and reduced-form models.[5] Under the first approach the liabilities of a firm are seen as a contingent claim on the assets of the firm itself and default occurs when the market value of the assets, which is modeled as a stochastic process, reaches some limit. The reduced-form approach, instead, postulates that default occurs randomly, due to some exogenous factor(s) whose probability of occurring, dubbed the “intensity”, is modeled and calibrated using market data. Models belonging to this latter class are also called intensity-based models. Reduced-form models

[5] Giesecke (2004) provides an interesting survey of both approaches. He also introduces the incomplete information approach that, strictly speaking, can be seen as an extension of the structural approach.

have been praised by practitioners because of their capacity, by construction, to fit market data, but structural models have been usually seen by academics as better suited to analyzing the determinants of credit risk. Although the capacity of individual structural models to describe the actual behavior of credit risk is still a matter of debate (e.g. Anderson and Sundaresan, 2000, Eom et al., 2004, Tarashev, 2005, and Ericsson et al., 2007), during the last few years there has been a new strand of literature that, departing from any specific model, aimed at measuring the explanatory power for observed credit spreads of the variables that structural models predict are theoretically linked to credit risk.

The first structural model on credit risk was introduced by Merton (1974) and because of its importance is described in detail in the next section. For the moment it will suffice to say that in the Merton model a default occurs when the market value of the firm, which is assumed to be described by a random process, is below the face value of the outstanding debt at the maturity of the debt itself. In that case the shareholders give the assets of the firm up to the bondholders. Merton's intuition was that a bond subject to credit risk can be seen as a combination of a long position in a risk-free bond and short position in a European put option sold to the shareholders with a strike price equal to the face value of the risky bond. In this setting, the price of the risky bond can be determined through standard option pricing methods which link its value to the parameters of the stochastic process driving the firm value and to the level of outstanding debt. The prediction of the Merton model is that credit spreads should be a function of the following variables:

i) *risk-free interest rate*: the risk-free interest rate represents the drift of the process describing the value of the assets of the firm under the risk-neutral measure. Higher interest rates increase the future expected value of the assets, thus reducing credit spreads;

ii) *nominal outstanding amount of debt*: the nominal value of the debt represents the threshold at which default is triggered. A higher amount of debt makes default more likely so that higher credit spreads are expected;

iii) *firm value*: higher values for the assets of the firm make the regular payment of the debt more likely and credit spreads are expected to be lower;

iv) *asset volatility*: higher asset volatility increases the value of the put option granted to the shareholders, thus increasing the compensation required by the bondholders through higher credit spreads.

The aim of the Merton model and other structural models is to explain the share of the bond spreads which arises from credit risk using a small number of factors such as those just described. However, there are other factors not linked to credit risk that have been shown to be a non-negligible part of bond spreads. These include:

i) *taxes*, to the extent that credit instruments and government bonds are subject to different tax rates;

ii) *liquidity*, as risky credit instruments have lower volumes and higher transaction costs than government bonds;

iii) *supply and demand shocks*, which can affect both corporate and government bond markets;

iv) *systematic risk factors*, such as those prevailing in the equity and in the corporate bond markets (e.g. Elton et al., 2001).

During the last few years these additional factors have led to a growing empirical literature on credit spreads that has used the CDS market as its object of research. Working on CDS quotes has at least three advantages with respect to using bond spreads. First, the CDS market already quotes in terms of a "spread", so that it is not necessary to introduce another market in the analysis, like that of government bonds, which can be subject to its own specific factors. Second, CDS contracts are rather standardized, while bonds are characterized by non-homogeneity in terms of coupons, maturities, outstanding amounts, embedded options, and so on, which make comparisons difficult. Finally, because of the nature of CDSs as derivatives contracts, CDS quotes should be less prone to supply and demand effects than the bond market, which is constrained by the physical nature of bonds.

2.2. Empirical studies

Given the relatively recent development of the CDS market, empirical work on the determinants of credit risk has traditionally looked at corporate spreads. A first group of empirical studies identifies factors that can explain why corporate spreads are much larger than what would be predicted by historical rates of default and recovery rates (the so-called "credit spread puzzle"). Elton et al. (2001) identify the expected default loss, a tax premium, and a risk premium for the systematic, and thus not diversifiable, part of the risk on corporate bonds, as the main components of credit spreads. Following the same line of research, Driessen (2005) shows that risk premia for liquidity and jump-to-default risks are also important components of bond spreads. Amato and Remolona (2005) propose an alternative explanation for the "credit spread puzzle" arguing that, while previous studies mostly focused on the expected loss component of credit risk, extra spreads may actually compensate for non-diversifiable credit risk. Their argument is that the high degree of skewness in bond returns makes diversification more difficult: the size of the portfolio required to reduce the probability of extreme losses by diversification is actually very large and thus difficult to attain in practice. Due to this difficulty investors in corporate bonds would require additional premia in the form of higher spreads.

A second group of studies on corporate spreads departs from trying to reconcile historical default losses with observed credit premia and instead aims at explaining credit spreads in a purely statistical way by regressing (changes in) observed spreads on (changes in) factors that theoretical models suggest are relevant in determining both default and non-default components of credit spreads. The advantage of this approach is that it allows the impact of any single fundamental factor on credit spreads to be estimated directly. Collin-Dufresne et al. (2001) initiate this strand of research by showing how factors that should represent the main explanatory variables for credit spreads, according to structural default models, actually explain only 25% of observed bond spread changes. They also show that the missing component is represented by a common risk factor which is independent of equity, swap and Treasury returns. They conclude that bond spread changes are mostly driven by supply and demand shocks which are specific to the corporate bond market and independent of both default and liquidity factors. Campbell and Taksler (2003) focus on the effect of equity volatility on corporate bond yields. They show that idiosyncratic firm-level volatility can explain as much cross-sectional variation in yields as can credit ratings. In the same vein, Guazzarotti (2004) investigates the determinants of changes in individual credit spreads of non-financial European corporate bonds by looking at the relevance of both structural default factors (like leverage, asset volatility, and the level and slope of the risk-free yield curve) and of some non credit-risk factors (e.g. market liquidity and market risk). He finds that: i) default risk factors account for less than 20% of total variation of credit spreads; ii) liquidity risk and aggregate market risk factors, although significant, explain only an additional 10%; iii) the remaining part of credit spread changes remains unexplained. More recently, Avramov et al. (2007) analyze the capacity of structural models to explain changes in corporate credit risk using a set of common factors and company-level fundamentals. They are able to explain more than 54% (67%) of the variation in credit spread changes for medium-grade (low-grade) bonds with no clearly dominant latent factor left in the unexplained variation. Cremers et al. (2008) introduce measures of volatility and jump risks that are based on individual stock options to explain bond spreads. They show that implied volatilities of individual options contain useful information for credit spreads and improve on historical volatilities when explaining the cross-sectional and time-series variations in a panel of corporate bond spreads.

Turning to the empirical analysis on CDS spreads, one of the first papers on the topic is that by Aunon-Nerin et al. (2002). As the credit derivatives market was still in its infancy when that paper was written, the sample of CDSs which has been used is rather small and with a predominance of financial companies. Moreover, the analysis is conducted on the levels of the variables thus leaving the door open to econometric problems related to the non-stationary nature of the data.[6] Greatrex (2008) digs deeper into the relevance of these econometric issues for the study of the determinants of CDS spreads and shows that variables commonly used for this kind of analysis are usually non-stationary in levels but stationary in first differences; running regressions on non-stationary variables could result in high values for the R^2 statistics but also in inefficient coefficient estimates, sub-optimal forecasts, and invalid significance tests (Granger and Newbold, 1974). Ericsson et al. (2009), in a paper circulating since 2004, use data for the period 1999-2002 and show that estimated coefficients of a limited number of theoretical determinants of default risk are consistent with the theory. Among these factors, volatility and leverage have substantial explanatory power. Moreover, a principal component analysis of spreads and residuals indicates limited evidence for a residual common factor, confirming that the variables explain a significant amount of the variation in the data. Zhang et al. (2005) focus on information arising from the equity market. They show that volatility and jump risk measures derived from the equity market using high frequency data, together with credit

[6] More recently, Abid and Naifar (2006) performed an analysis on CDS spread levels.

ratings, macroeconomic conditions, and firms' balance sheet information, can explain up to 77% of the total variation of CDS spreads. However, their results are obtained using variables in levels and are subject to the same econometric problems mentioned above. More recently, some works have focussed on CDSs on banks and on the differences between the periods before and after the recent financial crisis. Annaert et al. (2009) show that: i) the determinants of changes in bank CDS spreads exhibit significant time variation; ii) variables suggested by structural credit risk models are not significant in explaining bank CDS spread changes, either in the period prior to the crisis or in the crisis period itself; iii) some of the variables used as proxies of the general economic conditions are significant, but the magnitude of the coefficient estimates and their sign have changed over time. Raunig and Scheicher (2009) also find the crisis had an impact on the pricing of CDSs on banks. In particular, they show that the perception of bank credit risk by market participants approaches the level of the most risky non-bank companies.

3. Merton Model

As we already mentioned, Merton (1974) introduces the first model of credit risk based on the structural approach. Merton assumes that the whole debt of a firm is represented by a zero-coupon bond maturing at time T, with face value D. Moreover, the market value of the firm's assets V_t between 0 and T follows a geometric Brownian motion given by

$$dV_t = rV_t dt + \sigma V_t dW_t \tag{1}$$

where r and σ are constants representing, respectively, the risk-free interest rate and the volatility of the process. Merton assumes that a default occurs if the value of the firm at time T is lower than D. In that case the ownership of the firm is transferred from the shareholders to the creditors. In this framework the creditors of the firm can be seen as holding a long position in a risk-free zero-coupon bond and a short position in a European put option granted to the shareholders. The underlying of the option is represented by the assets of the firm, the strike price is equal to D and the maturity is T. The spread between corporate and government yields is the compensation required by creditors for selling the put option.

Similarly, the equity value can be seen as the value of a European call on the assets of the firm, with the strike price equal to D and maturity T. The value of equity at time T, denoted E_T, is thus given by $\max(0, V_T - D)$. Using standard option valuation tools (Black and Scholes, 1973), one obtains

$$E_t = V_t N(d_1) - e^{-r(T-t)} D N(d_2) \tag{2}$$

at time $t < T$, where

$$d_1 = \frac{\log(V_t/D) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}$$
$$d_2 = d_1 - \sigma\sqrt{T-t}$$

and $N(x)$ is the standard normal cumulative distribution function evaluated at x. The value of the debt at time t, which we denote with D_t, is thus equal to $V_t - E_t$. It is also possible to recover the expected costs of default C_t as the difference between the face value of the debt, discounted at the risk-free rate, and the actual value of the debt, that is

$$C_t = e^{-r(T-t)}D - D_t$$

In this simple framework, in which the default can occur only at the maturity of the debt, the annual spread s_t of a CDS with quarterly payments and T years to maturity is such that it makes C_t equal to

$$D\frac{s_t}{4}\sum_{n=1}^{4T}\exp\left(-r\frac{n}{4}\right),$$

that is

$$s_t = \frac{4C_t/D}{\sum_{n=1}^{4T}\exp\left(-r\frac{n}{4}\right)}$$

In order to use the Merton model to estimate the CDS spread it is thus necessary to have four ingredients: the level of the risk-free interest rate, the face value of the firm's total debt, its market value and the volatility of its assets. Although the last two variables are not directly observable, for listed firms it is nonetheless possible to observe the market value of equity and to estimate the historical volatility. In the case in which there are options written on the shares of the firm it is also possible to have a forward-looking measure of the equity volatility, which is the volatility implied by stock option prices. Equity value and equity volatility can therefore be used directly as proxies for asset value and asset volatility. However, they can also be used to obtain estimates of asset value and asset volatility. In fact, applying Ito's lemma the dynamics of E_t is given by a geometric Brownian motion with diffusion coefficient equal to $\sigma V_t \frac{dE_t}{dV_t}$, where the last term is the derivative of the equity with respect to the value of the assets (a quantity commonly called "the delta"), and is equal to $N(d_1)$. Under the further assumption that the dynamics of the equity can be described by a geometric Brownian motion with diffusion coefficient $\sigma_E E_t$, one has that

$$E_t = V_t N(d_1)\frac{\sigma}{\sigma_E}. \tag{3}$$

Given the other observable variables, it is thus possible to solve using numerical methods the system of non-linear equations (2) and (3) for the values of the two unknown variables V_t and σ.

Figure 1 shows the theoretical spread s_t on a 5-year CDS obtained using the Merton model as a function of the volatility of the equity (Panel A), for three different levels of the ratio of total assets ($A_t = D + E_t$) to equity (E_t) – the definition of leverage we adopt throughout the paper – and as a function of the leverage (Panel B), for three different levels of volatility. The risk-free interest rate is assumed to be fixed at 4%. All values are in percentages except for the CDS spread which is in basis points. As made clear by the figure, the main driver of the CDS spread in the Merton model is the level of volatility. When the volatility of the equity falls below 30, the CDS spread is almost negligible, no matter what the leverage is. In fact, for $\sigma_E = 30$ the theoretical CDS spread is still below 10 basis points even when the amount of debt is twice the value of equity (leverage=300). As the level of equity volatility increases, the theoretical CDS spread surges sharply and the relative (absolute) difference among firms with different leverages decreases (increases). If Panel A shows that the relationship between the theoretical CDS spread and the volatility of the equity is non-linear, an even stronger non-linearity arises when the theoretical CDS spread is expressed as a function of the leverage. Panel B, in fact, not only confirms the relevance of the equity volatility for the level of the theoretical spread but also shows a non-monotone relationship between the CDS spread and the leverage of the firm. This pattern arises from the fact that, when numerically solving equations (2) and (3), it turns out that higher levels of debt are associated with lower levels of asset volatility. This is because the higher the leverage the lower the weight the equity volatility receives as an estimator of the volatility of the whole value of the firm. Hence, at some point the negative impact that the higher debt has on the credit risk of the firm starts to be more than compensated by the positive impact of a decreasing asset volatility.

The Merton model, due to its simplicity, provides a nice tool for understanding how fundamental variables, such as leverage and asset volatility, affect credit spreads. However, there are several features of real financial markets that are not taken into account by the model and that have led to many other extensions. [7] The three main drawbacks of the model are:

1. *There is only one kind of debt securities.* In the Merton model only the case of a single zero-coupon bond is considered. Not only do most corporate bonds pay coupons but firms usually issue several kinds of bonds with different characteristics;
2. *Default occurs only at the maturity of the debt and if and only if the value of the assets is below the face value of the debt.* In the real world default can occur at any time before the maturity of the debt if the firm fails to meet any kind of obligation, such as the payment of coupons. Moreover, bankruptcy is a process that usually involves several forms of cost which can result in models with default barriers different from the face value of the debt (e.g. Leland and Toft, 1996);
3. *Volatility is assumed to be constant for all maturities.* Empirical work on option pricing shows that implied volatility is not constant, neither for different strikes nor for different maturities. This means that volatility implied by equity options, which have maturity usually up to one year, could be a biased estimator of the volatility of equity over longer horizons.

All these caveats have to be borne in mind when evaluating the results of any empirical application of the Merton model like the one we describe in the next section.

4. Methodology

In this section we describe the data, the model and the statistical methodology used in our analysis.

[7] For several extensions of the Merton model, see Cossin and Pirotte (2001) and references therein.

4.1. Data description

We started by selecting all CDS contracts in US dollars available through Bloomberg with maturity equal to 5 years (which are usually the most liquid contracts), written on the senior debt of US non-financial firms. We used end-of-day mid quotes for CDSs. In order to have data on market capitalization we restricted our sample to listed firms. For each company we gathered quarterly data on current liabilities, non-current liabilities, and cash and equivalents, from Bloomberg for the period between January 2002 and March 2009. We also collected daily data on companies' market capitalization, stock returns, and implied volatility derived from equity options. We then selected those contracts for which we could recover all data for at least 3 years, ending up with a sample of 167 companies. As a proxy of the risk-free interest rate curve we used the zero-coupon curve calculated by Datastream on US government bonds. We also collected daily data on the average levels of credit spreads for AA and BBB-rated US industrial companies (the option-adjusted spreads for the Merrill Lynch corporate industrial indices for US companies with AA and BBB ratings), a broad US equity market index (the S&P Composite index), and a broad index of US market implied volatility (the VIX index). In our regressions we use monthly average data for CDS spreads and for all other daily financial indicators. Quarterly balance sheet data were linearly interpolated. In order to control for the quality of CDS data we dropped daily observations whenever equal to the value of the previous day; we also dropped those monthly observations based on less than 5 daily data. Our final dataset, after dropping any firm-month observation with one or more missing values, includes 11,084 firm-month observations: 8,140 in the pre-crisis period (from January 2002 to June 2007) and 2,944 in the crisis period (from July 2007 to March 2009).

The historical behavior of a few of our variables is shown in Figure 2. The plot shows the huge increase of CDS spreads after the onset of the financial crisis. It also makes apparent the negative relationships of CDS spreads with stock returns and government bond yields as well as the positive relationship with the level of volatility. All these facts are coherent with the theory underlying the Merton model. Some descriptive statistics of our dataset are reported in tables 1 to 2. As mentioned earlier, average CDS spreads increase sharply in the crisis period, from 87 to 199 basis points (Table 1). As expected, average CDS spreads increase with leverage (Table 2). They are much higher for firms in the Consumer cyclical and the Communication/Technology sectors (respectively, 137 and 93 basis points before the crisis and 392 and 200 basis points in the crisis period; Table 3). The theoretical spreads derived from the Merton model are consistently much lower than the observed ones (the average values in the whole sample period are 71 and 116, respectively); however, they appear to replicate spread variations through sectors and leverage classes rather well. Leverage and implied volatility also rise drastically during the crisis. Leverage is highest in the Utilities and Consumer cyclical sectors, lowest in Communication/Technology. Volatility is highest in the Consumer cyclical sector and lowest in the Consumer non-cyclical and Utilities sectors.

4.2. Empirical models and testing methodology

As described in Section 3, the Merton model posits that credit spreads are a function of the value and volatility of the assets, the face value and maturity of the debt and the risk-free interest rate. As discussed in that section, the Merton model also implies that the relationship between CDS spreads and default factors is highly non-linear.

In order to test for the capacity of the Merton model to explain observed CDS spreads, we run the following univariate regression:

$$s(i,t) = \beta_0 + \beta_1 \bar{s}(i,t) + \epsilon(i,t), \tag{Model 1}$$

where $i = 1, \ldots, n$ denotes a specific firm and $t = 1, \ldots, m$ a specific time period. The variable $\bar{s}$ is the theoretical CDS spread calculated using the Merton model with the following assumptions: the face value of the debt, whose maturity is assumed to be equal to 5 years, is equal to the total of balance sheet liabilities net of cash; the value of the equity is equal to the market capitalization of the firm; the volatility of the equity is equal to the mean of implied volatilities calculated from call and put options; the risk-free interest rate is given by the 5-year zero-coupon rate on US government bonds.

Since Model 1 may not be able to fully describe the relationship between observed CDS spreads and default factors because of its simplifying assumptions, we also estimate the following three-factor linear model which has been used in other empirical works on the determinants of CDS spreads (e.g. Ericsson et al., 2009):

$$s(i,t) = \beta_0 + \beta_1 \sigma_E(i,t) + \beta_2 L(i,t) + \beta_3 r(t) + \epsilon(i,t). \tag{Model 2}$$

As for the explanatory variables, σ_E is the implied volatility calculated as the mean of implied volatilities derived from call and put options, L is the leverage calculated as the ratio of total assets (current and non-current liabilities, net of cash and equivalents, plus market capitalization) to market capitalization, and r is the 5-year zero-coupon rate on US government bonds. We opted to use implied volatility as a proxy of equity volatility to partially correct for the backward-looking nature of the historical volatility of share prices and because of its superiority in explaining CDS spreads (see Campbell and Taksler, 2003).

If the non-linearities implied by the Merton model had some additional explanatory power we would expect that, once we add the theoretical spread to the linear model, the portion of total variation explained by the model increases and the linear terms lose significance. Thus, we also estimate a third model which is a combination of the previous two models:

$$s(i,t) = \beta_0 + \beta_1 \bar{s}(i,t) + \beta_2 \sigma_E(i,t) + \beta_3 L(i,t) + \beta_4 r(i,t) + \epsilon(i,t). \tag{Model 3}$$

Finally, we estimate an extended model in which we include other variables, generally used in the literature on the determinants of credit spreads, such as the (log) returns of the firms' stocks, the slope of the yield curve (the difference between the 10-year and the 1-year zero-coupon rates on US government bonds), an index of the premium required by investors to hold riskier assets (the difference between the average OASs of the Merrill

Lynch indices for US industrial companies with BBB and AA ratings), an equity market index (the log of the S&P Composite index), and an index of market uncertainty (the VIX index).

$$\begin{aligned} s(i,t) = \beta_0 &+ \beta_1 \bar{s}(i,t) + \beta_2 \sigma_E(i,t) + \beta_3 L(i,t) + \beta_4 r(i,t) \\ &+ \beta_5 STOCK(t) + \beta_6 SLOPE(t) + \beta_7 OAS(t) \\ &+ \beta_8 SPCI(t) + \beta_9 VIX(t) + \epsilon(i,t). \end{aligned} \qquad \text{(Model 4)}$$

The expected signs for the additional variables are:

- $STOCK$: a negative sign is expected, as higher stock values should signal higher future profitability and higher capacity of the firms to meet their obligations;
- $SLOPE$: the sign is uncertain. On the one hand, higher values for the slope should predict higher future risk-free rates, which should have a negative impact on CDS spreads. On the other hand, the increase in expected future interest rates may reduce the number of profitable projects available to the company and, in turn, increase credit spreads. Moreover, it has to be pointed out that we are already including a 5-year interest rate in our regressions. In our setting, a higher level for the slope would imply, *ceteris paribus*, a lower level for the short-term interest rate which is usually associated with worsening economic conditions and higher credit spreads;
- OAS: a positive sign is expected, as the higher the premium required by investors to hold riskier securities the higher should be the compensation required to hold credit risk;
- $SPCI$: the sign is uncertain. On the one hand a broad market increase of equity values should signal better economic conditions and a lower probability of default for the companies, and have a negative impact on CDS spreads. On the other hand, in our regressions we have already included individual stock returns that should take into account firm-specific expectations about profitability much better than broad market measures. In our setting, a broad market increase of equity values signals, *ceteris paribus*, a relatively bad performance of individual firms, so that a positive effect on CDS spreads could otherwise be expected;
- VIX: a positive sign is expected, as the higher the uncertainty in the market the higher the value of the put option that the bondholders implicitly sell to the shareholders when buying credit risk.

The four models are estimated in first-differences by running pooled OLS regressions with standard errors that allow for time correlation at firm level. As we said, models in first-differences are preferred to those in levels in order to isolate unobserved individual factors which do not vary over time and account for the possible problem of non-stationarity of the processes for CDS spreads.[8] As a robustness check, we also estimate Model 4 with

[8] We found that the augmented Dickey-Fuller test, run separately for each CDS time series, does not reject the null hypothesis of the presence of a unit-root in almost all cases.

a panel regression with fixed effects.[9]

We then compare the results across groups of firms defined according to the level of leverage or the economic sector. We abstract from factors not linked to credit risk which the literature has documented are significant in the corporate bond market (such as taxes, liquidity and supply and demand shocks) on the assumption that for the CDS market they are less relevant. However, we recognize that the lack of liquidity in the CDS market following the onset of the crisis could have an impact on our estimates and so we try to control for that by using the CDS bid-ask spread change as an instrument to distinguish between contracts that were hit by different liquidity shocks during the crisis. In particular, we run a set of regressions for subgroups of contracts defined according to the size of the change in the average bid-ask spread on CDS contracts from before to after the onset of the crisis.[10]

Finally, we perform a principal component analysis on CDS spread changes and regression residuals from Model 4 in order to assess to what extent the model reduces the weight of the first components of spreads variation. This analysis is conducted on a balanced sub-sample of 34 firms with complete monthly data from January 2003 to December 2008.

5. Results

In this section we report the results of our estimates. In order to have a comparison with previous literature we first discuss results for the four models presented in Section 4 in the pre-crisis period (January 2002 to June 2007) and then we asses how results change after the onset of the crisis (July 2007 to March 2009).

5.1. The pre-crisis period

As shown in Table 4, by regressing observed CDS spreads on the theoretical spreads obtained using the Merton model for the period before the onset of the crisis we find that, as expected, the coefficient of the theoretical spread (0.32) is positive and highly significant, and the explanatory power of the model (adjusted R^2 statistics equal to 0.25) is comparable to previous studies on the determinants of CDS spread changes (e.g. Ericsson et al., 2009). However, the coefficient is significantly different from the value of one that is predicted by theory.

Turning to Model 2, all the estimated coefficients have the expected signs and are strongly significant. In particular, a one percentage point increase in the levels of volatility

[9] The test by Hausman (1978) implies that the model with random effects cannot be rejected; a panel data analysis with random effects did not result in appreciable differences.

[10] We were not able to estimate directly the effect of liquidity on spreads as our dependent variable is defined as the average between the bid and the ask prices and adding the bid-ask spread as an extra right-hand variable would have resulted in a misspecified model. For a study on the determinants of CDS bid-ask spreads, see Meng and ap Gwilym (2008).

and leverage raises the CDS spread by 2.72 and 0.35 basis points, respectively. A similar increase in the interest rate level determines a drop of 3.56 basis points for the CDS spread. The adjusted R^2 statistics (0.48) is much higher than in Model 1; this aspect suggests that the Merton model constrains the effects of the single factors on CDS spreads in ways that are not fully consistent with market data.

In Model 3, where the theoretical spread is added to the more traditional three-factors model, the coefficients of the theoretical spread, volatility and interest rate are all lower in absolute terms when compared with the previous models. Moreover, the coefficient of volatility shows a large loss of significance, which is probably due to the high level of correlation with the theoretical spread (70 per cent). The linear contribution of leverage, on the contrary, remains basically unchanged and highly significant; this could be due to the fact that the Merton model is not very sensitive to changes in leverage (see Figure 1). The adjusted R^2 statistics increases further from 0.48 to 0.52, highlighting the positive contribution to the model of the theoretical spread, which should partly take into account the non-linearities embedded in the pricing of CDSs.

In Model 4, the other explanatory variables that the literature has indicated as important determinants of credit spreads (such as, individual stock returns, the slope of the yield curve, an indicator of risk aversion in the bond market, and a broad market stock index return) have the expected signs and all but the indicator of broad market uncertainty (the VIX index) have significant effects on CDS spreads.[11] However, their overall contribution to the explanatory power of the model is marginal, as the adjusted R^2 statistic only rises from 0.52 to 0.54.

Tables 5 shows that results obtained running a panel regression with fixed effects confirm those obtained with the pooled OLS regression, both in terms of absolute values and the significance of the coefficients. We also checked that our results are robust to the filtering procedures applied to the original data such as the dropping of stale quotations and of observations referring to months with few CDS quotes. We also verified that results remain basically unchanged when we limit the analysis to a balanced dataset including only a subset of companies with complete data in the period from 2003 to 2008.

All in all, results suggest that factors predicted by the theory as being relevant for credit spreads have indeed a good explanatory power. Moreover, the theoretical spread calculated using the Merton model does convey specific information on credit risk that cannot be captured by the linear models, supporting the hypothesis that non-linearities are important in explaining credit spreads.

5.2. The crisis period

The financial crisis has disrupted credit markets, causing spreads and volatility to surge and market liquidity to evaporate (e.g. International Monetary Fund, 2008). The impact of these events on the pricing of credit risk is a matter of debate. On the one hand, one might expect that the crisis, by amplifying the importance of systemic risk factors, has

[11] The coefficients of *SLOPE* and *SPCI*, whose signs are theoretically uncertain, are positive.

caused a generalized increase of spreads (almost) independently from the fundamental characteristics of firms. On the other hand, the crisis could have exacerbated the differences between firms belonging to different classes of risk, as investors have become more aware of idiosyncratic risk factors. In order to assess the impact of the financial crisis on the pricing of risk, we compare the results in the pre-crisis period with those obtained during the crisis period. Table 4 reports the results of the regressions for our four models in both periods, as well as the tests on the differences between the two periods.

As for Model 1, the striking fact is the drop in both the coefficient of the theoretical spread and the explanatory power of the model, from 0.32 and 25% before the start of the crisis, to 0.20 and just 7%, respectively. This indicates that during the crisis the empirical relationship between CDS spreads and default factors is no longer described by the specific functional form of the Merton model.

This interpretation is confirmed by looking at the results from Model 2, where the default factors are included in the regression separately and the functional form between the default factors and the CDS spreads is not determined by the theoretical model. In this case we actually find a moderate increase in the explanatory power of the model from before to during the crisis. Moreover, all the coefficients maintain the expected signs and are highly significant. However, the impact of equity volatility on CDS spreads more than halves, suggesting that the wide swings in implied volatility, which have characterized the crisis period, have probably made this indicator a poor proxy for long-term asset volatility. This fact could also explain the loss of importance in Model 1 of the theoretical spread, which is mostly driven by volatility changes (see Figure 1). At the same time, during the crisis spreads have become much more sensitive to changes in leverage (from 0.35 to 0.92) and interest rates (from -3.56 to -41.21). On the one hand, the increased importance of leverage may reflect a greater awareness by investors of firm-specific characteristics. On the other hand, the increased relevance of interest rates probably reflects the fact that during the crisis risk-free interest rates have been interpreted as better proxies of economic activity: lower interest rates should signal worse economic conditions and higher credit risks.

Changes in the results of Model 3 from the pre-crisis period to the crisis period are rather similar to those of Model 2, given the negligible impact of the theoretical spread during the crisis.

In Model 4, the interest rate coefficient also loses its significance during the crisis, possibly in favor of the slope of the yield curve. Given the negative relationship between the slope of the yield curve and short-term interest rates, for a given level of longer term yields – for which our regressions already control for – the positive coefficient on the slope of the yield curve seems to indicate that the CDS market has been looking at short-term interest rates as a better indicator of economic activity than longer-term interest rates. Lower short-term rates (and a higher slope) are associated with worsening economic conditions and greater CDS spreads.

Overall, during the crisis the proportion of explained variations decreases only slightly, from 54% to 51% in Model 4, confirming that the model works rather well also in this case. This result highlights that the underlying risk factors identified by the literature as relevant for the pricing of credit risk have maintained their explanatory power also in a period of remarkable stress for the CDS market. In this regard, the CDS market appears to have continued to price credit risk in much the same fashion as it did before the crisis.

Table 5 shows that our estimates for the crisis period are also confirmed by a panel regression with fixed effects.

Finally, we performed a principal component analysis on CDS spread changes and regression residuals from Model 4. The analysis shows that during the crisis CDS spreads appear to have been moving increasingly together, as reported in Figure 3. The fraction of CDS variations explained by the first component increases from 45% to 62% during the crisis period. When the analysis is repeated using the residuals of Model 4, the two values drop to 25% and 40%, respectively, thus confirming the ability of the model to capture a substantial part of the common factors underlying the spread changes. Our result suggests that spread changes during the crisis are increasingly driven by common or systematic factors and less by firm-specific factors. In order to take into account time varying factors, we repeated the analysis including monthly dummy variables but the findings were mostly unchanged. Given that general indicators of economic activity, uncertainty, and risk aversion are already included in our model, our results seem to point to the presence of a market-specific factor that hit CDSs during the crisis in forms that are not fully reflected in other markets. A large part of CDS spread variations during the crisis is thus still to be explained.

5.3. Further analyses

In order to dig deeper into previous results we repeated the analysis based on Model 4 on sub-groups of firms defined according to the level of leverage, the economic sector, and the size of the change in the average bid-ask spreads for CDSs from before to during the crisis.

Analysis by leverage quartiles

In Table 6 we report the results for an analysis based on the average level of leverage of the firms. First of all, we note that the explanatory power of the model is highest for the companies with leverage in the highest quartile (0.63 in the pre-crisis period) and lowest for the companies in the lowest quartile (0.25). As the two groups are also associated with the highest and lowest levels of CDS spreads, these results confirm previous findings that structural models can better explain the credit spreads for firms with relatively lower credit quality (e.g. Collin-Dufresne et al. 2001, for an analysis on corporate spreads, and Greatrex, 2008, for comparable results on CDSs). We also note that for firms with low leverage the explanatory power of the model increases substantially during the crisis, to 0.35. The increased explanatory power of the model for firms with low levels of leverage does not derive from factors related to firm-specific characteristics (such as leverage and volatility), but from market-wide factors such as the interest rate and the market price of risk (as captured by the significant increase of the coefficient of the corporate bond spread). For firms with the highest levels of leverage, the leverage itself is the variable whose coefficient increased more significantly during the crisis, pointing to the fact the investors became more concerned about the particular weaknesses of the balance sheets of those firms.

Analysis by economic sector

Table 7 reports the results for the sectoral analysis. We notice that, across sectors, the model explains the highest proportion of variation for companies in the Utilities and Consumer Cyclical sectors, which are also the ones with the highest levels of leverage. During the crisis model performance sharply increases for firms in the Basic materials/Energy and Consumer non cyclical sectors, which are characterized by relatively low levels of leverage, volatility, and CDS spreads, probably reflecting the fact that these firms have been perceived as relatively riskier than before the crisis. Actually, for these sectors the theoretical spreads calculated using the Merton model show the highest levels of relative increase from before to after the onset of the crisis (see Table 3). Overall, this is further evidence of the capacity of the model to price CDSs of riskier companies better.

Analysis by liquidity change

In order to check whether the change of liquidity in the CDS market had any impact on the capacity of the model to explain CDS spread variations, we repeated our analysis on the basis of the bid-ask spread on CDS contracts. In particular, we grouped firms into four quartiles according to the change in the average bid-ask spread they experienced from before to after the onset of the crisis. The results are reported in Table 8. The interesting result is that the overall explanatory power of the model remains broadly the same during the crisis period for both the contracts in the lowest and highest quartiles of bid-ask spread changes. For firms in the highest quartile, moreover, all coefficients of the regression, except for that related to leverage, do not show any significant change during the crisis. These results suggest that the lack of liquidity experienced in the CDS market during the crisis, as proxied by larger bid-ask spreads, did not modify the basic relationships between CDS spread changes and their explanatory factors.

6. Conclusion

In this paper we analyze the determinants of CDS spread changes (based on a sample of 167 US non-financial firms over the period between January 2002 and March 2009), using the variables that the literature has found to have a theoretical and empirical impact on CDS spreads. We include in our regressions the theoretical spread implied by the Merton model in order to deal with the non-linear relationships between the individual characteristics of the firms and CDS spreads. We find that the inclusion of this additional term improves the capacity of changes in the fundamental variables to explain changes in CDS spreads. When the theoretical spread calculated using the Merton model is introduced in the regressions, the coefficient of the equity volatility decreases significantly, because of the high sensitivity of the Merton model to this parameter. On the contrary, leverage, which has only second-order effects on the theoretical spreads, maintains its usefulness in explaining CDS spread changes. The extended model is able to explain 54% of the variations in CDS spreads in the pre-crisis period and 51% in the crisis period, which is higher than previous findings of studies on corporate bond and CDS spread changes.

We also analyze how the financial crisis has changed the way in which credit risk is priced in the CDS market. We find that the contribution of the leverage of the firms to the explanation of CDS spread changes is much higher during the crisis than before, as investors appear to have become more aware of individual risk factors. At the same time, the impact of equity volatility substantially decreases, possibly because the large swings in implied volatility during the crisis period have made this indicator a poor proxy for long-term asset volatility. We also find that the overall capacity of the model to explain CDS changes is almost the same before and during the turmoil, thus highlighting that the underlying risk factors identified by the literature as relevant for the pricing of the credit risk have maintained their explanatory power even in a period of remarkable stress for the CDS market.

Finally, we show that during the crisis CDS spreads appear to have been moving increasingly together, driven by a common factor that our model was only partly able to explain. Given that the model includes general indicators of economic activity, uncertainty, and risk aversion, our results point to the presence of a market-specific factor that hit the CDS market during the crisis in forms not fully reflected in other markets. The exact identification of this factor is an interesting topic for further research.

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Tables and figures

Table 1. Descriptive statistics of the data set

CDS spreads are end-of-day mid quotes. The theoretical spread is the spread calculated using the Merton model. Leverage is defined as the ratio of total assets (total liabilities plus market capitalization) to market capitalization. Volatility is the mean of implied volatilities on call and put stock options. CDS spreads and theoretical spreads are in basis points; leverage and volatility are in percentages; market capitalization is in millions of US dollars.

	Mean	Median	Standard deviation	Min.	Max.
Whole period (January 2002 – March 2009)					
CDS spreads	116	54	221	6	7,995
Theoretical spreads	71	3	213	0	1,862
Leverage	219	175	190	94	6,044
Volatility	35	30	19	7	369
Market capitalization	25,939	13,616	39,549	58	420,623
Pre-crisis period (January 2002 – June 2007)					
CDS spreads	87	47	122	6	2,811
Theoretical spreads	31	1	108	0	1,793
Leverage	214	174	162	94	4,420
Volatility	31	28	13	7	369
Market capitalization	25,951	13,555	39,810	481	386,416
Crisis period (July 2007 – March 2009)					
CDS spreads	199	89	366	10	7,995
Theoretical spreads	184	23	348	0	1,862
Leverage	234	179	252	104	6,044
Volatility	47	39	25	7	223
Market capitalization	25,906	14,086	38,824	58	420,623

Table 2. Descriptive statistics of the firms: breakdown by leverage

The breakdown refers to the average leverage of the firms in the whole period. The table reports the mean values of the indicated variables, expect for the number of observations. CDS spreads are end-of-day mid quotes. The theoretical spread is the spread calculated using the Merton model. Leverage is defined as the ratio of total assets (total liabilities plus market capitalization) to market capitalization. Volatility is the mean of implied volatilities on call and put stock options. CDS spreads and theoretical spreads are in basis points; leverage and volatility are in percentages; market capitalization is in millions of US dollars.

Leverage quartiles	Number of observations	CDS spreads	Theoretical spreads	Leverage	Volatility	Market capitalization
Whole period (January 2002 - March 2009)	11,084	116	71	219	35	25,939
108-148	2,789	59	27	132	32	43,972
148-186	2,809	82	62	166	33	24,719
186-242	2,894	101	71	210	35	18,069
242-1,527	2,592	233	128	380	40	16,643
Pre-crisis period (January 2002 - June 2007)	8,140	87	31	214	31	25,950
108-148	2,009	45	7	131	28	44,197
148-186	2,023	59	26	161	29	24,752
186-242	2,174	77	25	206	31	17,764
242-1,527	1,934	170	66	364	35	17,451
Crisis period (July 2007 - March 2009)	2,944	199	184	234	47	25,906
108-148	780	96	79	135	41	43,391
148-186	786	142	156	180	44	24,635
186-242	720	172	213	223	49	18,990
242-1,527	658	416	311	428	55	14,265

Table 3. Descriptive statistics of the firms: breakdown by sector

The table reports the mean values of the indicated variables, expect for the number of observations. CDS spreads are end-of-day mid quotes. The theoretical spread is the spread calculated using the Merton model. Leverage is defined as the ratio of total assets (total liabilities plus market capitalization) to market capitalization. Volatility is the mean of implied volatilities on call and put stock options. CDS spreads and theoretical spreads are in basis points; leverage and volatility are in percentages; market capitalization is in millions of US dollars.

	Number of observations	CDS spreads	Theoretical spreads	Leverage	Volatility	Market capitalization
Whole period (January 2002 - March 2009)	11,084	116	71	219	35	25,939
Industry	1,984	83	69	206	34	27,991
Communications/Technology	1,738	118	66	178	35	41,476
Basic materials/Energy	1,973	76	57	186	35	20,086
Consumer cyclical	2,752	204	127	279	42	18,746
Consumer non-cyclical	1,752	74	31	185	29	31,790
Utilities	885	88	24	285	27	14,656
Pre-crisis period (January 2002 - June 2007)	8,140	87	31	214	31	25,951
Industry	1,416	65	36	202	30	28,025
Communications/Technology	1,328	93	42	170	32	41,661
Basic materials/Energy	1,432	57	14	186	30	18,475
Consumer cyclical	2,026	137	48	268	35	19,098
Consumer non-cyclical	1,285	61	11	177	26	32,529
Utilities	653	80	18	292	25	14,212
Crisis period (July 2007 - March 2009)	2,944	199	184	234	47	25,906
Industry	568	127	152	214	45	27,905
Communications/Technology	410	200	144	205	43	40,879
Basic materials/Energy	541	127	171	184	48	24,352
Consumer cyclical	726	392	349	309	60	17,764
Consumer non-cyclical	467	110	87	208	38	29,756
Utilities	232	111	41	266	32	15,904

Table 4. The determinants of CDS spread changes

The values in the table are obtained by running a pooled OLS regression for all observations in the selected period, with standard errors that allow for time correlation at firm level. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	Model 1			Model 2			Model 3			Model 4		
	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.
Theoretical spread	0.32***	0.20***	−0.12***				0.18***	0.00	−0.18	0.16***	−0.03	−0.20
Volatility				2.72***	1.29***	−1.43***	1.22*	1.25	0.03	0.99	1.67	0.68
Leverage				0.35***	0.92***	0.57***	0.37***	0.92***	0.55***	0.35***	0.91***	0.56***
Interest rate				−3.56***	−41.21***	−37.65***	−2.49***	−41.26***	−38.78***	−3.19**	−15.61	−12.42
Stock return										−0.42***	−0.17	0.26
Slope of yield curve										3.29*	9.44**	6.15
Corporate spread										0.56***	0.65***	0.09
S&P Composite										1.01***	1.01	0.00
VIX										0.27	−0.53	−0.79
Intercept	−0.64**	14.26***	14.9***	−0.13	−1.17	−1.04	−0.35	−1.16	−0.81	0.44*	−3.10**	−3.54**
Adjusted R^2	0.25	0.07		0.48	0.50		0.52	0.50		0.54	0.51	
No. obs.	8,140	2,944		8,140	2,944		8,140	2,944		8,140	2,944	

Table 5. The determinants of CDS spread changes: pooled and panel regressions

The table compares the results from pooled OLS and panel fixed-effect regressions run on the same sample. Standard errors allow for time correlation at firm level. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	Pre-crisis		Crisis		Difference	
	Coeff.	t-Stud.	Coeff.	t-Stud.	Coeff.	t-Stud.
Pooled OLS regression						
Theoretical spread	0.16***	2.63	−0.03	−0.25	−0.20	−1.29
Volatility	0.99	1.25	1.67	0.60	0.68	0.24
Leverage	0.35***	9.65	0.91***	5.19	0.56***	3.16
Interest rate	−3.19**	−2.52	−15.61	−1.61	−12.42	−1.26
Stock return	−0.42***	−3.57	−0.17	−0.32	0.26	0.51
Slope of yield curve	3.29*	1.84	9.44**	2.27	6.15	1.34
Corporate spreads	0.56***	8.22	0.65***	4.37	0.09	0.61
S&P Composite	1.01***	4.27	1.01	1.64	0.00	−0.01
VIX	0.27	0.65	−0.53	−0.44	−0.79	−0.61
Intercept	0.44*	1.76	−3.10**	−2.02	−3.54**	−2.33
Adjusted R^2	0.54		0.51			
Panel fixed effect regression						
Theoretical spread	0.16***	2.63	−0.04	−0.28	−0.20	−1.31
Volatility	0.96	1.22	1.62	0.61	0.69	0.24
Leverage	0.34***	9.59	0.93***	5.21	0.57***	3.18
Interest rate	−2.95**	−2.28	−15.76*	−1.73	−12.90	−1.35
Stock return	−0.44***	−3.59	0.05	0.09	0.34	0.68
Slope of yield curve	3.04*	1.66	9.13**	2.18	6.60	1.46
Corporate spreads	0.56***	8.26	0.67***	4.56	0.10	0.64
S&P Composite	1.05***	4.29	0.70	1.10	−0.12	−0.20
VIX	0.30	0.75	−0.50	−0.43	−0.80	−0.62
Intercept	0.41*	1.82	−3.56	−1.30	−3.38**	−2.22
Adjusted R^2	0.54		0.50			
No. obs.	8,140		2,944			

Table 6. The determinants of CDS spread changes by leverage

The values in the table are obtained by running a pooled OLS regression for all observations in the selected period and quartile of the firms' average leverage, with standard errors that allow for time correlation at firm level. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on the US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	1st quartile (< 148)			2nd quartile (148 − 186)			3rd quartile (186 − 242)			4th quartile (> 242)		
	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.
Theoretical spread	0.17***	0.04	−0.13**	0.21***	0.09**	−0.12*	0.18**	0.03	−0.15	0.09	−0.18	−0.27
Volatility	0.09	−0.06	−0.15	−0.20	−0.67	−0.48	0.08	0.46	0.37	2.19**	4.04	1.84
Leverage	0.91**	0.95**	0.04	0.21	0.66***	0.45*	0.46**	0.75***	0.29	0.28***	0.86***	0.58***
Interest rate	1.19	−20.61***	−21.80***	−4.43**	−28.24***	−23.81***	−3.64**	−28.66***	−25.01***	−5.83	8.56	14.38
Stock return	−0.05	−0.26	−0.22	−0.59***	−0.47	0.12	−0.05	−0.16	−0.11	−0.96***	−0.49	0.47
Slope of yield curve	0.36	8.67**	8.31*	3.95*	9.95**	6.00	2.43	2.17	−0.26	5.04	8.71	3.68
Corporate spreads	0.24***	0.44***	0.20**	0.39***	0.40***	0.01	0.52***	0.57***	0.05	1.15***	1.15**	0.00
S&P Composite	0.35	0.76***	0.41	0.82***	0.57	−0.25	0.46	0.78	0.33	2.70***	1.62	−1.08
VIX	0.74	0.13	−0.61	0.83**	0.11	−0.72	0.63	−0.44	−1.08	0.35	−0.49	−0.84
Intercept	−0.47	−3.45***	−2.98***	0.05	−2.95*	−2.99*	0.24	−3.76***	−3.99***	1.24*	−0.64	−1.87
Adjusted R^2	0.25	0.35		0.43	0.33		0.30	0.39		0.63	0.52	
No. obs.	2,009	780		2,023	786		2,174	720		1,934	658	

Table 7. The determinants of CDS spread changes by sector

The values in the table are obtained by running a pooled OLS regression for all observations in the selected sector and period, with standard errors that allow for time correlation at firm level. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	Industrial			Communications & Technology			Basic materials & Energy		
	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.
Theoretical spread	0.27**	0.04	−0.22*	0.16***	0.05	−0.11	0.04	0.05	0.02
Volatility	−0.71**	1.33	2.04*	0.01	0.20	0.18	0.12	0.34	0.22
Leverage	0.14	0.51	0.37*	0.89***	0.81***	−0.08	0.41*	0.36***	−0.05
Interest rate	0.12	−21.34***	−21.46***	−9.95**	−44.12*	−34.17	−1.53	−30.19***	−28.66***
Stock return	−0.49*	−0.11	0.37	−0.55*	0.40	0.96	0.07	−0.46*	−0.53*
Slope of yield curve	1.08	−0.14	−1.22	10.39**	−8.36	−18.75	2.03	2.21	0.18
Corporate spreads	0.41***	0.36*	−0.05	0.71***	1.13***	0.42	0.51***	0.29***	−0.23
S&P Composite	0.40	−0.35	−0.75	2.02***	0.66	−1.36	0.45*	0.06	−0.39
VIX	0.41	−1.81**	−2.21**	2.02**	−0.87	−2.89	0.56*	−1.08*	−1.64**
Intercept	0.11	−2.87	−2.98	−0.16	−5.28	−5.12	0.29	−1.48	−1.77
Adjusted R^2	0.33	0.40		0.46	0.18		0.25	0.50	
No. obs.	1,416	568		1,328	410		1,432	541	

(Cont.)

Table 7. (cont.) **The determinants of CDS spread changes by sector**

The values in the table are obtained by running a pooled OLS regression for all observations in the selected sector and period, with standard errors that allow for time correlation at firm level. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	Consumer cyclical			Consumer non-cyclical			Utilities		
	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.
Theoretical spread	0.06	−0.14	−0.19	0.11	0.07**	−0.04	0.40***	0.08***	−0.33***
Volatility	2.11*	2.57	0.46	1.01***	0.03	−0.97**	−0.50	−0.54	−0.03
Leverage	0.30***	0.94***	0.63***	−0.16***	0.23***	0.39***	0.74**	−0.21	−0.95**
Interest rate	0.00	19.49	19.48	−2.42	−25.43***	−23.01***	−14.18**	−31.25***	−17.06*
Stock return	−0.75***	−1.86	−1.11	−0.60*	−0.64***	−0.04	0.79	−1.26***	−2.04**
Slope of yield curve	−2.27	16.89	19.16	3.98	19.41***	15.44**	23.40***	−2.32	−25.72***
Corporate spreads	0.90***	1.45***	0.55	0.16***	0.19**	0.03	0.75***	0.41***	−0.34
S&P Composite	1.67**	2.11	0.44	−0.10	0.89***	0.99**	1.51	1.83***	0.32
VIX	0.05	−0.25	−0.30	−0.66	0.42	1.08	1.75	1.90***	0.15
Intercept	0.70	−4.04	−4.74	0.57	−4.19***	−4.75***	0.79	−0.82	−1.61
Adjusted R^2	0.64	0.62		0.20	0.57		0.74	0.40	
No. obs.	2,026	726		1,285	467		653	232	

Table 8. The determinants of CDS spread changes by liquidity change

The values in the table are obtained by running a pooled OLS regression for all observations in the selected period and quartile of the firms' liquidity change, with standard errors that allow for time correlation at firm level. The liquidity change is defined as the change in the average bid-ask spread of the CDSs, at the firm level, from before to after the onset of the crisis. Monthly data from January 2002 to March 2009; the pre-crisis period goes from January 2002 to June 2007; the post-crisis period from July 2007 to March 2009. The explanatory variables are changes in the monthly averages of: the estimated theoretical spread for firm i at time t; the implied volatility of options written on the stocks of firm i at time t; the leverage ratio of firm i at time t; the 5-year zero-coupon interest rate on the US government bond at time t; the log of the stock value of firm i at time t; the slope of the zero-coupon curve on US government bonds (10-1 yrs) at time t; the Merrill Lynch industrial bond average spread (BBB-AA) at time t; the log of the S&P Composite stock index at time t; the VIX volatility index at time t; a constant term. Observed and theoretical spreads and the corporate spread are in basis points, all other variables are in percentages. Significance levels: *** = 1%; ** = 5%; * = 10%.

	1st quartile (< -0.9)			2nd quartile ($-0.9 - 1.1$)			3rd quartile ($1.1 - 5.5$)			4th quartile (> 5.5)		
	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.	Pre Crisis	Crisis	Diff.
Theoretical spread	0.25***	0.02	−0.23**	0.20***	0.04*	−0.16**	0.21***	0.01	−0.20***	0.20***	−0.22	−0.42
Volatility	0.07	0.36	0.29	0.44**	0.07	−0.37	−0.06	0.72*	0.77	−0.04	3.76	3.81
Leverage	0.26**	1.46***	1.21***	0.11	0.65**	0.55**	0.09	0.32***	0.23*	0.43***	0.86***	0.43**
Interest rate	−6.65**	−18.20***	−11.55***	−0.87	−17.03***	−16.16***	−2.01**	−24.84***	−22.83***	−1.08	9.14	10.21
Stock return	−0.66*	0.86**	1.52**	−0.13	0.16	0.28	−0.03	−0.33	−0.30	−0.71***	−0.63	0.08
Slope of yield curve	10.84***	7.93**	−2.91	−0.52	6.73***	7.25***	2.01	4.92	2.92	−1.13	3.76	4.90
Corporate spreads	0.65***	0.2***	−0.45***	0.15***	0.24***	0.09*	0.38***	0.74***	0.36***	0.84***	1.58***	0.75
S&P Composite	0.91**	0.57*	−0.33	0.11	0.03	−0.08	0.41***	0.41	0.00	2.18***	0.31	−1.87
VIX	0.50	0.46	−0.04	0.09	−0.07	−0.16	0.92**	−0.81*	−1.73***	1.42*	0.07	−1.36
Intercept	0.28	−3.37***	−3.65***	−0.26	−3.17***	−2.91***	−0.03	−4.01***	−3.98***	0.13	−3.11	−3.24
Adjusted R^2	0.51	0.48		0.21	0.43		0.33	0.41		0.47	0.52	
No. obs.	2,155	709		1,953	750		1,757	733		1,811	752	

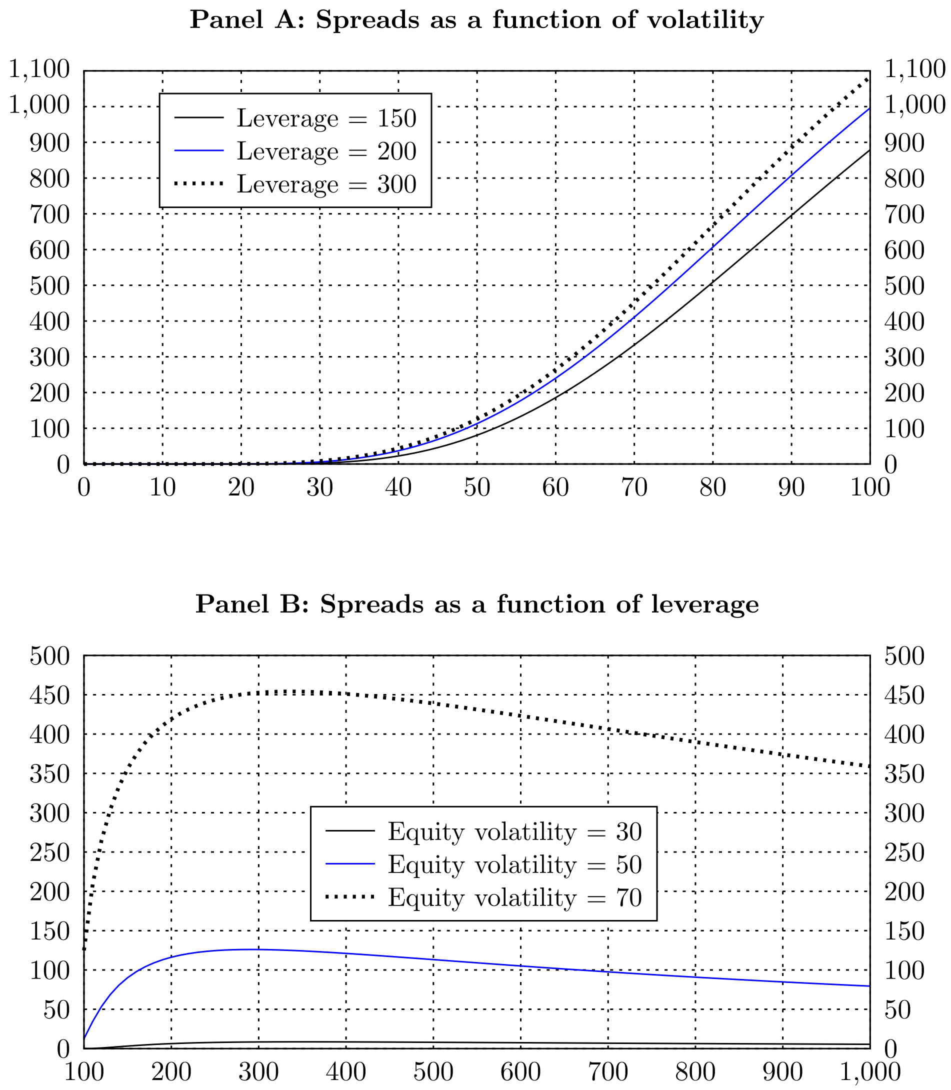
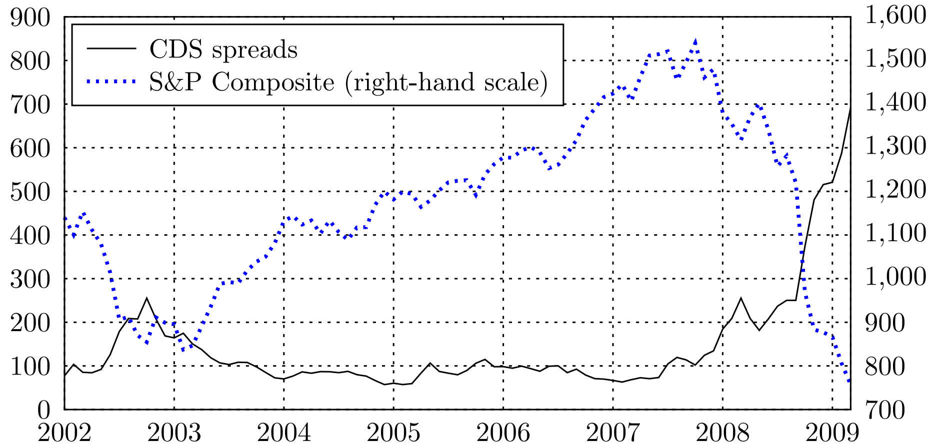


Figure 1. Theoretical CDS spreads generated by the Merton model
Theoretical CDS spreads on the debt of firms with different leverage (or equity volatility) calculated using the Merton model, as a function of equity volatility (or leverage). The spreads are supposed to be paid with a quarterly frequency, the risk-free interest rate is constant and equal to 4% and the maturity of the debt is 5 years. Leverage is defined as the ratio of total assets (total liabilities plus market capitalization) to market capitalization. Theoretical CDS spreads are in basis points; equity volatility and leverage are in percentages.

Panel A: CDS spreads and S&P Composite



Panel B: Equity market volatility and risk-free interest rates

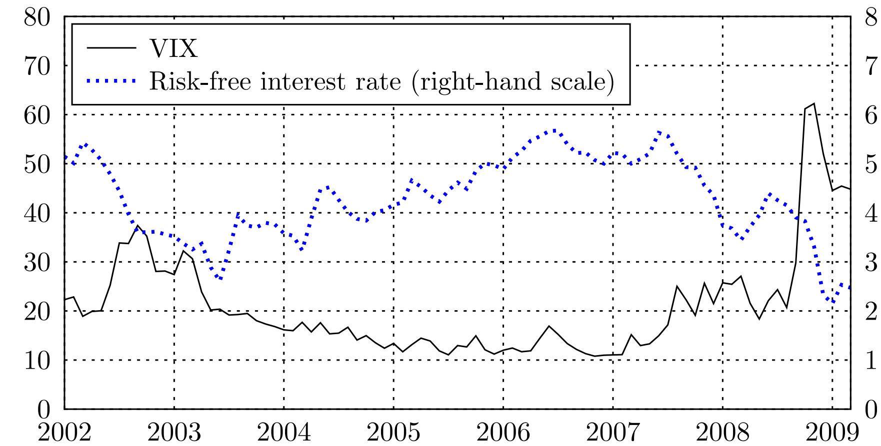


Figure 2. Time series of CDS spreads and other financial series
Monthly averages. CDS spreads are in basis points; the risk-free interest rate is in percentages and is the zero-coupon 5-year rate on US Government bonds.

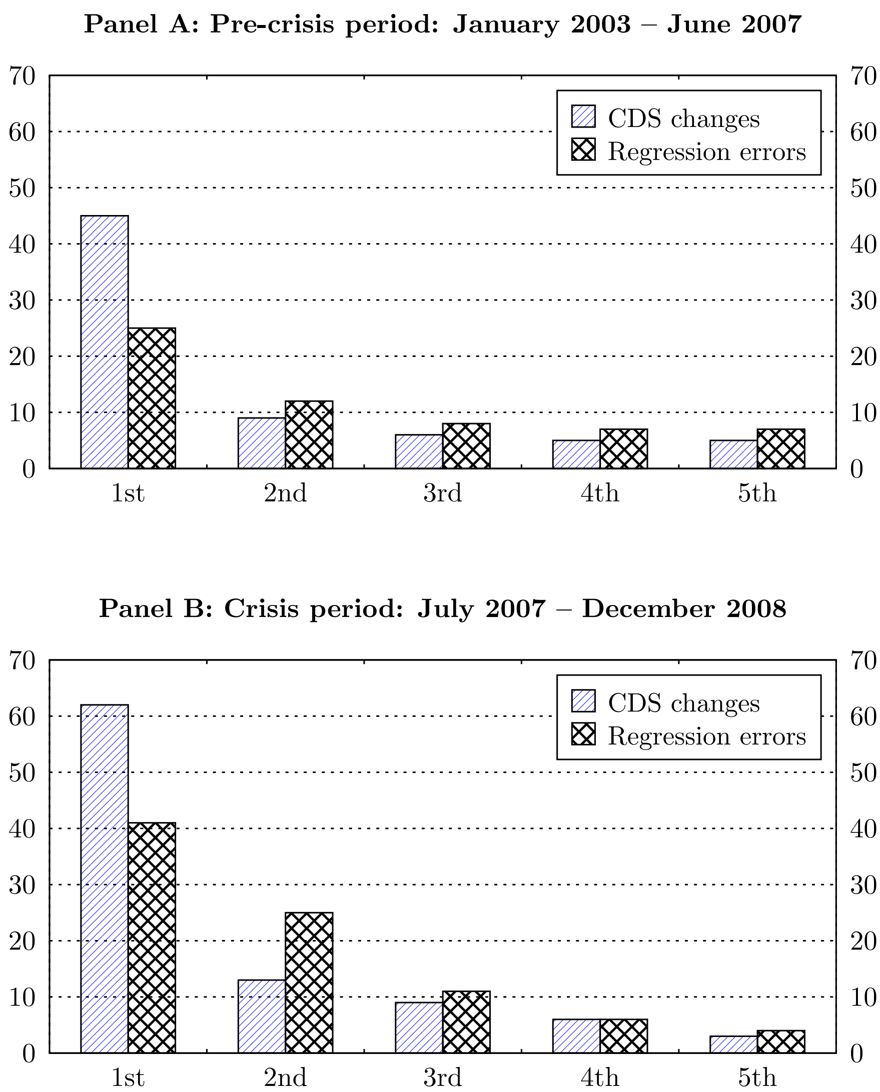


Figure 3. Principal component analysis

The principal component analysis has been conducted on a balanced sub-sample of 34 firms with complete data from January 2003 to December 2008 for the CDS changes and the regression residuals of Model 4. The explained variations by the first 5 components are expressed in percentages.

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