Credit Default Swaps: Theory and Empirical Evidence

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Credit derivatives are a specific class of financial instruments that allow users to manage credit risk by isolating such risk from the underlying financial assets. Although small compared to other derivatives and securities markets, the credit derivatives market has become one of the fastest-growing derivatives markets since the late 1990s.

The British Bankers Association's (BBA) survey in 2002 suggested that the global credit derivatives market had increased from around US$151 billion in 1997 to US$514 billion in 1999 (measured by notional amount outstanding). According to an International Swaps and Derivatives Association (ISDA) report in 2003, the outstanding notional amount of credit derivatives had grown to US$2.69 trillion by then. The Office of the Comptroller of the Currency [2003] showed that U.S. commercial banks and trust companies had notional credit derivatives outstanding worldwide of US$869 billion as of the end of September 2003. Given market participants' estimates of their market share compared to securities dealers and European banks, this is consistent with ISDA's survey.

Fitch's "Global Credit Derivatives Survey" [2004] estimates the notional size of the market at US$3 trillion. Market participants have estimated that the market continues to double in size each year, and it is predicted to hit US$10 trillion by 2007.[1]

Single-name credit default swaps (CDS) account for a large share of the market. According to the BBA's 2002 survey, around 50% of the market was in CDS, while Patel [2003] finds that CDS account for 72% of the market. In its latest credit derivatives market survey, FitchRatings suggests a portion of 64%. The Exhibit details the composition of the market.

With the rapid growth of the credit derivatives market and the important role of CDS in the market, much attention has been given to the pricing of this financial instrument. Current CDS pricing models can be classified into two groups: structural models and reduced-form models. In structural models, the default process is driven by the variability of the firm's asset value, and default occurs when the firm's asset value is below a certain threshold. In reduced-form models, default is linked to a stochastic jump process.

We review both structural and reduced-form models. Empirical studies of CDS pricing are relatively uncommon, so it is of interest to review their findings.

We make several contributions to the literature. First, there is to the best of our knowledge no previous review dedicated to pricing CDS with both structural and reduced-form approaches. Bielecki and Rutkowski [2000] review only reduced-form models. Second and more important, to the best of our knowledge this is the first review of empirical studies on CDS. Our comprehensive review of the empirical studies on recovery and CDS premium determinants forms a basis for future research on CDS.

Review of the overall performance of the theoretical pricing models reveals differences between theory and practice with regard to the pricing of credit risk. Moreover, review of the lead-lag relationship between the CDS market and other markets should inform future research on the interaction between these markets.

I. STRUCTURE AND TRADING MOTIVATION OF CDS

The protection seller in a credit default swap agrees to compensate the protection buyer upon the occurrence of any event as follows: bankruptcy (usually for corporate reference entities) or debt payment moratorium (usually for sovereign reference entities); repudiation; failure to pay; obligation acceleration or default; and restructuring. In return, the protection seller charges a fee, typically a constant quarterly fee paid until default or maturity, whichever is first. The annualized periodic fee is usually referred to as the CDS premium.[2]

In case of default, the accrued fee is also paid by the protection buyer. The default payment is either at par against physical delivery of a reference asset, known as *physical settlement*, or the notional amount minus the post-default market value of the reference asset determined by a calculation agent or through a dealer poll, known as *cash settlement*.[3]

Physical delivery is the prevailing form of settlement in the market (see Bowler and Tierney [1999]). CDS cover only the credit risk inherent in the asset, while risks arising from other factors such as interest rate movements remain with the originator.

Commercial banks, the most active participants in the market, use CDS to hedge their exposure to loans and bonds as well as to trade credit risk. To hedge credit risk, commercial banks are protection buyers in CDS, while they are protection sellers for trading credit risk. For example, there may be different expectations on the same credit risk due to information asymmetry. Commercial banks may sell protection on reference entities that they are familiar with. Commercial banks also play an important role in intermediating between protection buyers and sellers.

According to the Bank of England, corporate involvement in the credit derivatives market remains limited to a handful of large multinationals (see also Rule [2001]). Companies typically use CDS to buy protection against credit extended to customers or suppliers.

Insurance companies are net protection sellers; they use CDS only to trade credit risk. Typically, they have collateralized debt obligations (CDO) on the asset side of their balance sheet and CDS on the liabilities side. Most of the large securities houses have developed the capacity to buy and sell protection in the CDS market in order to provide liquidity to customers and trade on their own accounts.

II. PRICING OF CDS USING STRUCTURAL MODELS

Instead of directly deriving a valuation for CDS premiums, most researchers focus on modeling the credit risk on the underlying debt instruments for which CDS premiums are paid.

First-Generation Structural Models

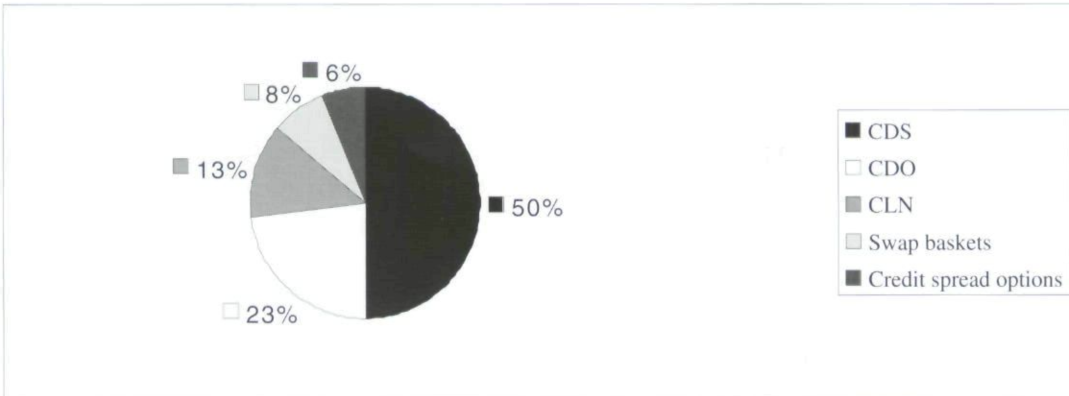
The first generation of credit risk models is based on a framework developed by Merton [1974], using the principles of option pricing (see also Black and Scholes [1973]). The generic structure of this class of models is as follows:

1. Firm value is assumed to follow a diffusion process with a constant volatility plus (possibly) a jump.
2. The default boundary, which is determined by policy decision within the firm such as leverage ratio and strategic default, is derived endogenously.
3. The recovery rate is an endogenous variable that is not treated explicitly in these models. It is a function of the residual value of the defaulted firm's assets.

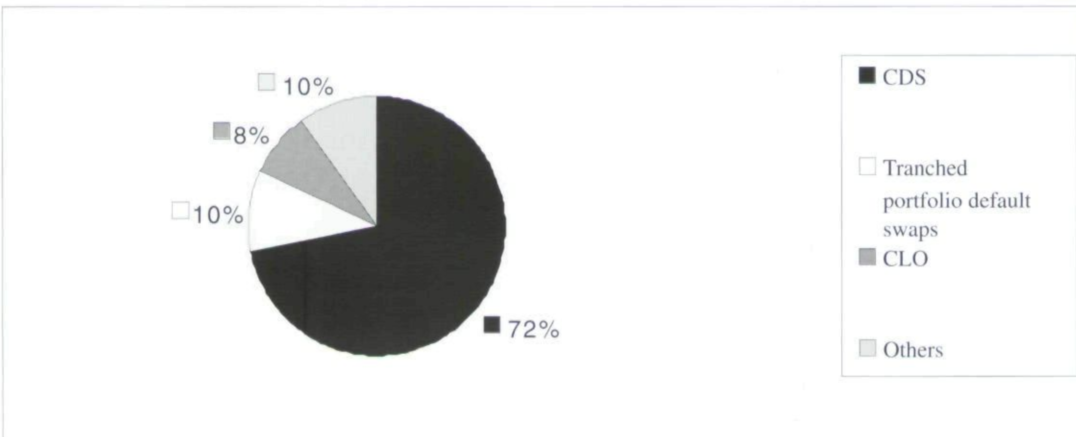
The basic intuition behind this model is relatively simple. Default occurs when the value of a firm's assets (usually the book value of debt plus the market value of equity) falls below the value of its liabilities. The payoff at maturity to the bondholder is therefore equivalent to the face value of the bond minus the premium of a put option on the value of the firm's assets, with a strike price equal to the face value of the bond and a maturity equal to the life of the bond.

Leland [1994] and Leland and Toft [1996] have extended Merton's model to link the default boundary to changes in taxes, bond covenants, bankruptcy costs, and payout ratios. Anderson, Sundaresan, and Tychon [1996] and Mella-Barral and Perraudin [1997] develop approaches (known as AST-MBP models), which assume that in an

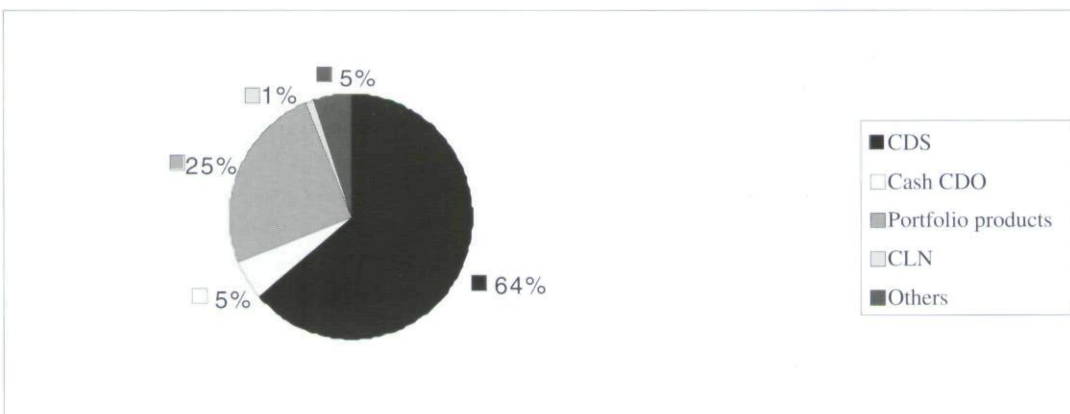
EXHIBIT
Composition of Credit Derivatives Market



Source: BBA 2001/2002 market survey.



Source: *Risk* 2003 market survey.



Source: FitchRatings 2004 market survey.

CDS = credit default swaps; CDO = collateralized debt obligations;

CLN = credit-linked notes; CLO = collateralized loan obligations.

environment of positive bankruptcy costs, equityholders default strategically to extract concessions from bondholders. They show that if equityholders have all the bargaining power, then at the endogenously determined default boundary, the payoff for bondholders, bounded above by the face value of the bond, will be equal to the firm asset value minus the bankruptcy costs.

Second-Generation Structural Models

The second generation of structural models is constructed as follows:

1. The firm value process is very similar to that of structural models with endogenous default boundary.
2. The default boundary is determined by factors other than firms' policy decisions, such as features of debt contracts.
3. Recovery rate processes are specified.

The second-generation structural models were developed by Black and Cox [1976]. Default is allowed to take place at any time in the term of the debt when firm asset value reaches a lower threshold level, which is exogenously specified.

Kim, Ramaswamy, and Sundaresan [1993] focus on the valuation of coupon-paying defaultable bonds. Nielsen, Saà-Requejo, and Santa Clara [1993] develop a model allowing the default boundary to be stochastic and the randomness of the boundary to be tied to the interest rate process.

Longstaff and Schwartz [1995] explicitly allow for deviations from absolute priority and incorporate both default risk and interest rate risk into their model. They assume that the short-term risk-free interest rate follows the process:

$$dr = (\alpha - \beta r)dt + \gamma dZ_2$$

where α, β, and γ are constants, and Z_2 is a standard Wiener process correlated with Z_1, the standard Wiener process in the firm value process.

The value of the firm is independent of capital structure and recovery of treasury (RT). This model is marked by the ability to value risky debt (fixed- or floating-rate) when the capital structure of the firm is very complex or when there are many coupon payment dates.

Following Longstaff and Schwartz's [1995] framework, Cathcart and El-Jahel [1998] develop a variant structural model that is characterized by a signaling process:

$$dX = \alpha Xdt + \sigma_x dZ$$

where α and σ_x are constants, and Z is a standard Wiener process.

Default occurs when the signaling variable X, a state variable that is allowed to follow other stochastic processes, is below the default boundary X_1. Incorporation of a signaling process enables capture of the impact on default of changes in factors other than firm value (such as the liquidity of firm assets).

Ericsson and Renault [2003] attempt to improve structural models by introducing the additional feature of liquidity shocks. They assume that liquidity premiums (compensation for liquidity shocks) are driven by the probability of default, but they do not take into account other liquidity factors such as demand and supply.

Tudela and Young [2003a, 2003b]) describe the Bank of England's structural model to assess credit risk. Its key feature is the asset-liability ratio k, which is allowed to be random. Default occurs when k falls below the default threshold *k*, which is defined as the point where assets equal half of the firm's long-term liabilities plus total short-term liabilities.[4]

Finger [2003] describes CreditGrades, developed jointly by J.P. Morgan, Deutsche Bank, and Goldman Sachs, which implements a set of techniques widely used by broker-dealers. The model uses an approximation to bypass the unobservable variables in the structural framework. Apart from relating the value and volatility of the firm's assets to those of the firm's equity, the model also assumes that the default boundary is random and follows a lognormal distribution with mean of 0.5 and percentage standard deviation of 0.3. This results in a jump-like default event.[5]

Under these models, the recovery rate in the event of default is exogenous and independent of the firm's asset value. It is generally defined as a fixed ratio of the outstanding debt value, and is therefore independent of the probability of default. This approach simplifies the original structural models both by exogenously specifying the cash flows to risky debt in the event of bankruptcy, which occurs when the value of the firm's underlying assets hits some exogenously specified boundary, and by clarifying the bankruptcy process.

Advantages and Disadvantages of Structural Models

The advantages of structural models are mainly practical. First, they can be used to impute estimated default probabilities from market equity prices, as seen in commercial applications. This is useful in risk measurement for bank loan departments and corporate bond portfolio managers. Commercial users of structural models include KMV (now KMV Moody's), whose model relies almost exclusively on equity market information (see Crosbie [1999]). Second, according to Guha and Sbuelz [2003, p. 3], "in principle these models supply information on how one could hedge the default risk in corporate bonds using the securities of the firm, say, its equity."

Despite the improvements and their increasing popularity, structural models suffer from three main drawbacks. First, they still require estimates of the parameters of the firm's asset value, which is unobservable. The use of proxies for firm asset value remains open to debate. Second, they cannot incorporate credit rating changes, which occur relatively frequently for default-risky corporate debt, and empirical studies suggest that rating changes are the most important determinant of CDS premiums.

Finally, most structural models assume the value of the firm is continuous over time, which overlooks jumps in firm values. In practice, the firm's asset value is proxied by the value of equity plus the value of debt. As there are jumps in share prices, jumps in the firm's asset value are therefore likely. Consequently, it is very difficult to generate reasonable levels of short-term bond yields from structural models. It follows that short-term CDS transactions are very likely to produce positive value for the protection sellers.

III. PRICING OF CDS USING REDUCED-FORM MODELS

Reduced-form models define defaults as exogenous rare events that can be modeled by a jump process. The term *reduced-form* is first used in Duffie and Singleton [1999]. This class of models is also referred to as *intensity-based models* (e.g., Bielecki and Rutkowski [2000]), *instantaneous risk of default models* (e.g., Blauer and Wilmott [1997]), and *hazard rate models* (e.g., Madan and Unal [2000]). Like the recovery schemes in structural models, the recovery rates in reduced-form models can also be either endogenously or exogenously derived.

Credit Rating-Based Markov Models

These models use a Markov process to model the migration between rating grades.[6] To set up a tractable model that accounts for migration between rating grades, Jarrow, Lando, and Turnbull [1997] make rather stringent assumptions to develop a discrete-time model that takes into account the migration of a defaultable bond in the finite set of credit rating classes and the continuous-time counterpart (see Bielecki and Rutkowski [2000] for more detail). Hull and White [2001] consider counterparty risk, and allow non-stationarity of the default boundary that is linked to the drift of the short rate. Other credit rating-based Markov models are Madan and Unal [1998] and Duffie and Singleton [1999].

Under the assumption that the spot martingale measure and risk-free term structures are given, Lando [1998] modifies the Jarrow, Lando, and Turnbull [1997] approach by introducing a conditional Markov migration process, which accounts for both the underlying state variables and different rating classes.

Arvanitis, Gregory, and Laurent [1999] assume that transition from one rating class to another is driven by a deterministic credit migration matrix. They use Moody's historical credit migration matrix, which effectively includes historical credit rating changes, credit spread volatility, and mean reversion.

Credit Spread-Based HJM Models

A second class of models is based on the term structure model of Heath, Jarrow, and Morton [1990] (HJM). In this case, Schönbucher [1998, 2000a], Das and Sundaram [2000], and Acharya, Das, and Sundaram [2002] start with given default-free and defaultable term structures, represented by a series of defaultable instantaneous forward rates. The aim is to use an associated family of default times defined on a suitable expansion of the underlying probability space, to support an exogenously given defaultable term structure.

Duffie and Singleton [1999] assume recovery of a fraction of market value. They use the forward rate process associated with a default-adjusted short rate to develop a *defaultable version of the HJM model*. Using a survival measure for probability of default, Schönbucher [2000b] develops a model to value default risk as well as other risks, including spread risk, interest rate risk, and recovery risk based on a LIBOR market model for default-free interest rates.

Das and Sundaram [2004] model the joint process of interest rate and equity price to develop another defaultable HJM model that has features in common with structural models because it also uses equity market information. Other credit spread-based HJM-type models are developed by Brace, Gatarek, and Musiela [1997], Jamshidian [1997], and Miltersen, Sandmann, and Sondermann [1997].

IV. EMPIRICAL LITERATURE ON CDS

A number of empirical studies focus on estimating the parameters of the credit spread process, the hazard process, and the risky short rate process. The first approach directly estimates the spread process. Nielsen and Ronn [1998] use cross-sectional data and non-linear least squares to estimate a lognormal spread model. Taurén [1999] estimates the spread dynamics as a Chan-Karolyi-Longstaff-Sanders process using the generalized method of moments (GMM).[7] Dülmann and Windfuhr [2000] and Geyer, Kossmeier, and Pichler [2001] use maximum-likelihood (ML) with Kalman filtering for the instantaneous spread.

A second approach focuses on estimating the parameters of the hazard process. Cumby and Evans [1997], Duffee [1998], Madan and Unal [1998], Janosi, Jarrow, and Yildirim [2000], Keswani [2000], Driessen [2001], and Frühwirth and Sögner [2002] use a number of methods such as ML and GMM for the estimation (see also Houweling and Vorst [2003]).

Duffie and Singleton [1997] use a third approach, i.e., considering the sum of the spread and the default-free rate, to estimate the swap rate as a two-factor Cox-Ingersoll-Ross process using ML.

Recovery Forms

Three basic recovery forms are commonly used in structural and reduced-form models. First, recovery of face value (RFV) is defined by Longstaff and Schwartz [1995] and Saà-Requejo and Santa-Clara [1999] as receiving at default the same fractional recovery of par (possibly random) for bonds issued by a particular company, regardless of maturity. Second, recovery of treasury (RT) is defined by Collin-Dufresne and Goldstein [2001] as receiving a fixed fraction of a default-free bond with the same coupon and maturity as the defaultable bond. Third, in the recovery of market value (RMV) case, Delianedis and Lagnado [2002] assume the recovery amount is a fraction of a non-defaulted risky bond of similar credit quality and maturity as the defaultable bond.

Hu and Perraudin [2002] test the relationship between recovery rate and default probability in response to the assumption that recovery rate and default probability are independent. The results show evidence of a negative correlation (around –0.2) between recovery rate and default probability, which is particularly pronounced in a U.S. subsample.[8]

There have been a variety of studies on the market belief that the choice among the three recovery forms is irrelevant to the pricing of CDS. Bakshi, Madan, and Zhang [2001] investigate the implications of the choice of recovery forms, following Jarrow and Turnbull [1995], Lando [1998], and Duffie and Singleton [1999]. They find model performance is sensitive to the choice of recovery form, and the RT model performs significantly better than the RFV and RMV models.

Delianedis and Lagnado [2002] use simulation to investigate the sensitivity of CDS premiums to the choice of recovery form. They apply a model similar to Hull and White's [2000] and find that the choice of recovery form is particularly sensitive to pricing CDS with non-investment-grade reference entities and long maturities.

When Skinner and Diaz [2003] test the performance of theoretical CDS pricing models, they find the RMV assumption underlying Duffie and Singleton [1999] generates higher premiums and default values for CDS than the RT assumption underlying Jarrow and Turnbull [1995]. To date, there is no similar empirical study using other theoretical frameworks, so the overall implications of the choice of recovery form are still unknown.

Pricing Determinants, CDS Premiums, and Credit Spreads

Hull, Predescu, and White [2004] test the relationship between credit spreads and CDS premiums, and find that the theoretical relationship between CDS premiums and credit spreads holds fairly well; the average difference is 10 basis points. Houweling and Vorst [2003] find consistent results, except that when they divide the sample according to rating classes, the relationship between the two diverges considerably, with absolute deviations increasing for lower credit ratings. In the subsample of AAA to A reference entities, bond spreads are higher than CDS premiums; in the subsample of BBB to B reference entities, CDS premiums are substantially higher than bond spreads.

Houweling and Vorst [2003] assume that bonds have exactly the same maturity as CDS (gaps are bridged by a matching method and an interpolation method), and that default-free bonds and defaultable bonds are priced at par, so that their yields are equal to the coupon rates. Apart from these assumptions, mean pricing error (MPE) and mean average pricing error (MAPE) methods are capable of estimating only an approximate relationship between the two. These three features make the results somewhat less robust.

Zhu [2003] uses a cointegration test to examine the relationship between CDS premiums and bond spreads. He finds that CDS premiums and credit spreads are cointegrated in the long run—market forces eliminate the arbitrage opportunity between the two markets over time.

Aunon-Nerin et al. [2002] use linear regression to explore the determinants of CDS premiums. They investigate the relationship between CDS premiums and 1) credit ratings; 2) interest rates; 3) slope of the yield curves; 4) time to maturity; 5) share prices; 6) volatility of firm assets; 7) leverage; 8) index returns; and 9) idiosyncratic factors. They find the credit rating is the most important determinant; U.S. interest rates influence reference entities from all countries; the slope of the U.S. yield curve matters for U.S. companies, and other local yield curves influence non-U.S. companies; share price changes are positively linked to CDS premium changes and still influential even adjusted for returns on indexes; and leverage has a significant influence on CDS premium.

Skinner and Townend [2002] apply option pricing theory to justify the put option nature of CDS. In accordance with their view that CDS are equivalent to American-style put options, they use linear regression to test the relationship between CDS premiums and: the risk-free interest rate; the yield on defaultable bonds (promised yield on reference bonds); volatility proxied by one-year interest rate cap volatility; maturity (time to maturity of CDS agreements); and exercise price (the amount payable on default) proxied by the notional amount underlying the CDS contract divided by the amount specified by the default amount clause.

Skinner and Townend find that changes in the risk-free interest rate are negatively related to changes in CDS premiums, while both changes in the yield on defaultable bonds and volatility are positively related to changes in CDS premiums. Maturity has an unexpectedly negative sign, which is explained as traders' manipulation of maturity to customize credit exposure.[9]

The validity of the assumption that CDS are equivalent to American-style put options remains open to debate. For example, put option holders can determine when to exercise, while default payment in CDS is not triggered by protection buyers. Moreover, option premiums are up-front, while CDS premiums are paid periodically. Skinner and Townend, however, argue that early exercise of American puts depends on realizations of the stochastic process of the price of the underlying assets instead of the option holder's decision.

Blanco, Brennan, and Marsh [2003] analyze the relationship between investment-grade bonds and CDS, and explore the determinants of CDS premiums. They find that the theoretical relationship linking credit spreads and CDS premiums holds reasonably well for most of the investment-grade reference entities. They also find that increases in interest rates and equity prices reduce CDS premiums; firm-specific implied volatility has a significant impact on CDS premiums; a steeper-sloping yield curve increases CDS premiums; and changes in liquidity matter for CDS.

Ericsson, Jacobs, and Oviedo-Helfenberger [2004] examine the theoretical relationship between changes in CDS premiums and the so-called structural determinants, namely, the parameters in structural models. They find the link between CDS premiums and leverage, equity volatilities, and risk-free interest rates is very significant. They suggest that these three structural determinants are important CDS premium determinants.

Berndt et al. [2004] examine the relationship between CDS premiums and estimated default frequency. Moody's KMV EDFs are conditional probabilities of default, which are fitted non-parametrically from the historical default frequencies of other firms with the same estimated distance to default as the targeted firm. The distance to default is the number of standard deviations of annual asset growth by which current assets exceed a measure of book liabilities. Berndt et al. find a positive link between five-year EDFs and five-year CDS premiums. That their sample includes only North American companies in three industries means this result may not be representative of the entire market.

Overall Model Performance versus Market Premiums

Skinner and Díaz [2003] compare the expected value of the CDS premium with the expected value of payments in default as generated by the Jarrow and Turnbull [1995] and Duffie and Singleton [1999] models, and find that both models overestimate the hazard rate and underestimate the value of the payment to the sellers of CDS;

they typically produce positive economic values for the protection buyers of CDS transactions. Skinner and Díaz [2003] view CDS as American-style put options and apply the binomial option pricing approach with parameters specified as in the Jarrow and Turnbull [1995] and Duffie and Singleton [1999] models.

Houweling and Vorst [2003] test the empirical performance of models that are mathematically equivalent to Aonuma and Nakagawa [1999], Brooks and Yan [1998], Jarrow and Turnbull [1998], Scott [1998], and Duffie [1999]. The signs of mean prediction error and mean average pricing error statistics for these models are either negative or positive, implying that the model premiums are on average either too high or too low, so the models overestimate or underestimate the credit risk.

Zhang [2003] uses data for CDS on Argentina to test the performance of a model similar to Duffee's [1999]. The model fits the data well (the MAPE range from 10 to 20 basis points), except for contracts of short maturities (one or two years). Zhang also finds that the model consistently underprices short-maturity contracts and overprices medium-maturity contracts.

Longstaff, Mithal, and Neis [2003] test the performance of a model similar to Lando [1998] and Duffie and Singleton [1999]. They conclude that the CDS premiums implied are significantly higher than the CDS market prices.

Eom, Helwege, and Huang [2004] test the performance of models by Merton [1974], Geske [1977], Longstaff and Schwartz [1995], Leland and Toft [1996], and Collin-Dufresne and Goldstein [2001]. They find that the credit spreads predicted by Merton [1974] and Geske [1977] are too low; and the spreads predicted by Longstaff and Schwartz [1995], Leland and Toft [1996], and Collin-Dufresne and Goldstein [2001] are too high. All the models have systematic errors related to leverage.

Lead-Lag Relationships Between the CDS Market and Other Markets

Zhu [2003] discusses the role of the CDS market in price discovery. Using vector autoregression (VAR), he finds that in the short run the results are slightly in favor of the hypothesis that the CDS market leads the bond market, thus contributing more to price discovery.

Longstaff, Mithal, and Neis [2003] also use VAR to examine the lead-lag relationship between CDS and equity and bond markets. They find that changes in both CDS premiums and stock returns often lead changes in corporate bond yields. In Zhang's [2004] investigation of the intra-industry credit contagion effect in the CDS market and the stock market, the CDS market is found to lead the stock market in capturing the contagion effect.

V. CRITIQUE OF EMPIRICAL STUDIES OF CDS

Our criticisms of these empirical studies relate to both data and methodology.

Data

As the CDS market is in its infancy, and CDS transactions are over-the-counter, available CDS data are not of as good quality as exchange-based transaction data. Exchange-based transactions are normally automatically recorded, while OTC transaction data are subject to recording omissions or error by those who collect them.

The main sources of CDS data are the trading desks of large investment banks and professional data vendors. Large investment banks record only the data of the CDS transactions they are involved in. Although professional data vendors have more comprehensive databases, their databases still have several pitfalls:

1. Data prior to 1999 are very limited (see Zhu [2003]).
2. Low frequency is more due to infrequent trading. CDS data are recorded infrequently. Even the most liquid reference entities have only daily prices. The results of estimated lead-lag relationships are thus not as robust as could be estimated using high-frequency data.
3. CDS premium data are usually quotes instead of trades, so they are not always an accurate reflection of transaction prices.
4. Most CDS data are for five-year contracts with notional amounts of $5 million or $10 million, providing little information on CDS of other maturities and notional amounts.
5. There are missing and spurious observations in the time series.

For further discussion of the quality of CDS data, see Blanco, Brennan, and Marsh [2003] and Hull, Predescu, and White [2004].

There are several problems with bond data as well. First, after filtering out bonds with special features, the remaining data may not include bonds that match the CDS data. Second, there are missing observations in bond series too. These problems are usually addressed by using econometric techniques to estimate the missing values.

Methodology

Comparisons of credit spreads and model premiums with market premiums typically use MPE and MAPE. When these measures are combined, it is possible to capture the degree and direction of pricing discrepancies. They cannot capture the patterns of pricing discrepancies, such as any industry-specific features, unless subsamples are used.

A linear regression approach is normally employed to explore the determinants of CDS premiums. Insignificance of a factor does not necessarily mean it is irrelevant, because it might not have an exact linear relationship with CDS premiums. Models may also suffer from misspecification of the functional form. The major dilemma is that it is difficult to decide what non-linear relationships are to be tested.

All the empirical studies we know of use VAR to examine the lead-lag relationship between the CDS market and the stock and bond markets. Sometimes all three prices depend on the previous prices of another two. The results are thus open to interpretation.

VI. CONCLUSIONS

From the first generation to the second generation, there have been huge improvements in structural models for pricing credit default swaps. Unrealistic assumptions have been relaxed (such as that default can occur only at maturity), and additional features have been added, making the modeling of credit risk closer to reality. Many more reduced-form models have been developed in the past ten years. Because of the problem of parameter estimation, the improvements in reduced-form models lie mainly in linking theoretical parameters to accessible data. In general, there have been significant improvements in both structural models and reduced-form models, so neither approach has become dominant.

The empirical literature on CDs is much more scarce, but there has been considerable growth in published research in the last four years. The implications of recovery forms for model performance, comparison of CDS premiums and credit spreads, determinants in pricing CDS, overall model performance, and the lead-lag relationship between the CDS market and other markets have attracted a variety of studies. In many cases, problems with data or methodology mean the empirical results are not always as robust as we might want.

These problems need to be addressed in future research and more empirical evidence is needed. There is considerable scope for research on undiscovered determinants of CDS premiums, the efficiency of the CDS market, and interaction between the CDS market and the equity market, the bond market, and credit ratings.

ENDNOTES

The authors are grateful for the comments of Frank Skinner and participants at the University of Wales Accounting and Finance Conference in 2004.

[1]According to Deutsche Bank's global head of integrated credit trading. See also Kentouris [2004].

[2]An up-front fee applies in the case of a short-maturity CDS.

[3]A CDS contract normally identifies a third party to calculate the market value of the reference asset when default occurs.

[4]$dk = (\mu_A - \mu_L)kdt + \sigma_A kdz$

where μ_A and μ_L are the drift in the asset and liability value processes, σ_A is the volatility of asset value, and dz is a standard Wiener process.

[5]The model defines the default barrier as the amount of the firm's assets that remain after default, effectively, the recovery value. The mean and standard deviation are based on analysis of S&P default data.

[6]A Markov process is a random process whose future probabilities are determined by its most recent values.

[7]$dc(t) = [u + kc(t)]dt + \sigma c(t)\gamma dW^P(t)$

where u is the long-run mean expected loss rate; k is the rate of mean reversion; c(t) is the probabilistic behavior of the expected loss rate; τ is the level elasticity of variance of c(t); and $W^P(t)$ is the differential of a standard Wiener process under the actual probabilities.

[8]The entire sample is divided into the U.S., emerging market countries, non-U.S. OECD countries, and off-shore banking centers.

[9]Asian CDS have shorter average maturities than non-Asian CDS, while their average premium is higher. This produces a negative relationship.

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