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Application of Structural Credit Risk Models in the Thai Corporate Bond Market[א]

[ABSTRACT]

FOR investments in corporate bond markets throughout the world, credit risk models calibrated to equity markets are often relied upon to quantitatively assess risk and return tradeoffs of investment decisions. This is especially true in a developing market such as Thailand, where the corporate bond market lacks the breadth and depth of more developed financial markets, and other credit risk assessment methodologies cannot be applied. In Thailand, breadth and depth of the equity market does all the use of structural credit risk models which are calibrated to equity prices. Structural credit risk models use an option-pricing approach with the analogy of equity as a call option on the value of the assets of the firm. Structural credit risk models have been the subject of many empirical studies and commercial applications for both pricing and default prediction of corporate securities. However, prior empirical research on the Thai corporate bond market has shown the performance of the models to be inconsistent with that which has typically been observed in more developed capital markets. Hence it is not clear that the degree of linkage between the equity and credit markets in Thailand is sufficient for this methodology.

In this study, we look at pricing performance of two structural credit risk models, the Merton (1974) and down-and-out call barrier option. This study utilizes the maximum likelihood calibration methodology that avoids bias in the parameter estimates of the models and allows for statistical inference of the results even in a limited sample study. This study will focus the pricing errors in actively traded bonds in the period following the post-Asian financial crisis of 1997, from 2000 to 2005. The pricing errors are tested for other influencing factors in the risky bond credit spreads. After screening for anomalies in the Thai corporate bond market data, results here show a credit-equity linkage that is more in line with prior empirical research such as has been done in the U.S. The noted anomalies in the Thai bond market can offer an explanation for prior studies that have conflicted with the more typical results.

[א] *The paper is adapted from the author's thesis at the Master in Finance (International Program), Faculty of Commerce and Accountancy, Thammasat University*

1. Introduction

ONE of the barriers to increasing the acceptance of corporate bonds as a financing alternative in Thailand has been the inability to accurately gauge the risk/return tradeoffs of corporate debt subject to default risk. Modern, theoretical approaches to credit risk modeling offer increased functionality to modeling credit risk, such as default prediction and pricing, yet have proven to be a bit more difficult to implement. These theoretical models of credit risk differ widely in their assumptions, formulations, as well as their methodologies and sources of market data for calibration, making comparisons of models also difficult. In Thailand, the equity market is the financial market with the most breath and depth. This fact compels the use of structural credit risk models which are calibrated to equity prices. Structural credit risk models use an option-pricing approach with the analogy of equity as a call option on the value of the assets of the firm. Data requirements of an equity-based approach include only the risk-free term structures, equity market capitalization and liability data of the firm.

However appealing and convenient structural credit risk models might be, they have proven difficult to implement successfully. Typical empirical investigations of structural credit risk models on the U.S. market and data, such as that by Eom, Helwege, and Huang (2004), have found that credit spreads of risky bonds tend to be under-estimated. Two previous studies of the Thai corporate bond market are those by Vayakornvichitre (2002) and Tirawannarat (2004). Both studies used primary market data based on the premise that the secondary market for corporate debt securities in Thailand is illiquid. Contrary to results on U.S. markets and data, both Vayakornvichitre (2002) who focused his study on the Merton (1974) and Tirawannarat (2004) who investigated the Longstaff and Schwartz (1997) model found that yields of risky bonds were over-estimated significantly.

The source of the discrepancies between the U.S. and Thai markets in these studies is not readily apparent. It is not entirely clear that risk models for corporate debt developed using assumptions, conditions, and data from the U.S. market are applicable to non-U.S. credit markets such as Thailand. For the U.S. and more developed capital markets, attempts have been made to reconcile the shortcomings of the structural approach to credit risk modeling. Considerations have been given to both the theoretical and practical aspects of the models leading to a plethora of different modeling approaches. These advances have addressed the definitions and assumptions of the default/bankruptcy event, recovery and risk process as well as calibration of the model.

For example, consideration of the default event and process has led to the development of the barrier option structural credit risk models. The typical default event assumption includes the concept of the absolute priority rule which guarantees senior creditors are paid in full before more junior creditors. However, default is not a consistent concept across countries due to the differences in laws and financial institutions. Many bankruptcy codes prevent bondholders from triggering liquidation immediately, impacting many net-worth covenants[1]. From a practical perspective, a firm's capital structure is typically much more complicated than that assumed in the original Merton model. Typically, there will be many issues of debt, of different seniority, with the publicly traded corporate bonds just one component. Reducing a complicated capital structure into

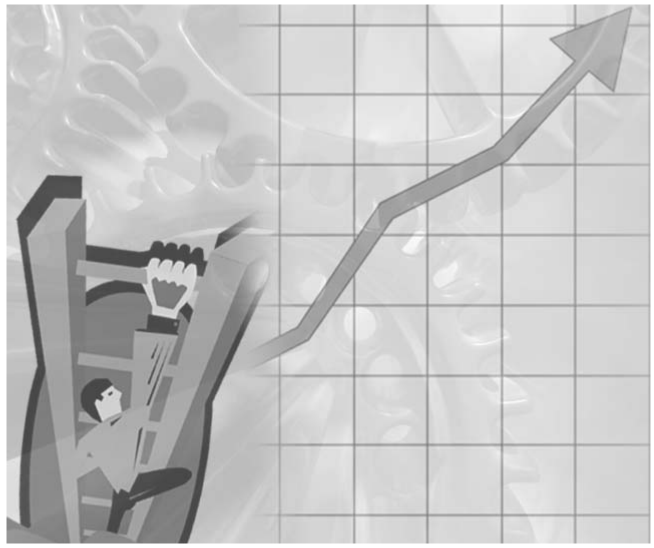
[1] *Nagano (2003), for example, notes that until the bankruptcy law in thailand was reformed in 1998, no listed firm had failed for 57 years.*

zero-coupon bond to fit within the framework of the Merton (1974) model is not necessarily straightforward. Barrier option credit risk models are one type of structural model that might be able to address these complications as the model can allow for early default as well as incorporate the effects of different bankruptcy codes and capital structures (Brockman and Turtle 2003).

The calibration of credit risk models, often overlooked, is another important component of providing useful quantitative assessment of credit risk. The data for calibration usually includes firm-level data such as historical balance sheets and income statements. Even in developed capital markets sources of data for calibration are not entirely reliable and may be of limited usefulness. Firm financial data is updated sporadically and subject to interpretation.

Even in light of the limitations in the actual data, some more recent approaches have tried to address the impact of the calibration methodologies employed. Wong and Li (2004) assert that the poor empirical performance of the Merton (1974) model is a direct result of the use of the calibration methodology typically used for structural credit risk models. Wong and Li (2003) show how the use of a common proxy for a key parameter in the Merton (1974) model automatically infers bias in the estimates. Ericsson and Reneby (2004) further find that another common calibration methodology performs poorly for highly-leveraged companies. Both groups of researchers make the case for the use of the maximum likelihood estimation (MLE) method of Duan (1994, 2000) for structural credit risk models. The MLE methodology is theoretically unaffected by firm leverage and can also be used to provide statistical inference of the model estimators.

The study here reviews and assesses both the formulation and calibration of the Merton (1974) and the barrier option structural credit risk model approaches to quantifying credit risk. A key objective of this study will be to determine the degree of linkage between the equity and credit markets within Thailand. The MLE methodology will be used for calibration as it has proven



to be unbiased in assumptions and in the level of firm leverage. Maximum likelihood also yields sampling distributions of the estimates, allowing statistical inference of the estimates for individual firms. Instead of specifying default barriers subjectively or based on historical interpretations, the maximum likelihood statistical framework is used to estimate the barrier value. In addition, whereas most empirical studies of default in Thailand have focused on the period around the Asian fiscal crisis, this study will focus on the period following the post-Asian financial crisis of 1997, from 2000 to 2005, as it is more applicable for future work. Although the Asian financial crisis period offers significantly more credit market mortality data, Wiwattanakantang, Kali, and Charumilind (2003) found that typical firm characteristics used in analyzing credit quality played almost no role in explaining allocation of long term credit in the Thai market during the Asian financial crisis.

The results of this study finds that after screening for anomalous data, the characteristics Thai corporate bond market as explained by structural credit risk models are more closely in line with prior studies on U.S. markets and data. Credit spread pricing tends to be under-estimated on average as in the U.S., which conflicts with prior empirical studies of the Thai market (Vayakornvichitre, 2002 and Tirawannarat, 2004). The difficulty of decomposing credit spreads is well noted in the literature. For example, Collin-Dufresne, Goldstein, and Martin (2001) conclude that credit spreads are primarily driven by local demand and supply shocks. Analysis of the credit spread residuals from this study show factors associated with liquidity to have significance, albeit small explanatory powers. Given the lack of depth in the Thai bond market, this is entirely plausible as one potential explanation of the difficulties in applying structural credit risk models to the Thai corporate bond market.

This paper is written as follows. In the second section, the theoretical background of structural credit risk models is overviewed, and the rationale for the approach is reviewed. The third section discusses the data used and specific results. Finally, conclusions are drawn and recommendation for further research is discussed.

2. Structural Credit Risk Models

STRUCTURAL credit risk models of risky debt were pioneered by Merton (1974) using Black and Scholes (1973) option theory[2]. The structural approach to modeling default risk relies on the dynamics of the value of the firm's assets, in order to determine the arrival of a default event. This, in effect, establishes an economic significance to default for the firm. The Merton (1974) model then allows us to derive a relationship for the pricing of a defaultable bond.

In the Merton (1974) structural credit risk model framework, default occurs only at bond maturity. Black and Cox (1976) were the first to extend the Merton approach into a barrier option framework to allow for default to occur at any time prior to debt maturity. In the barrier option framework, an absorbing barrier[3] is used to reflect the presence of net worth or safety covenants in the bond issue. As in a bond indenture agreement, the bondholders can force bankruptcy whenever the value of the firm drops below the barrier. This is equivalent to pricing equity as a down-and-out call (DOC) barrier option on the assets of the firm.

In both the Merton (1974) and DOC structural credit risk models, the firm's asset process is assumed to follow a standard log-normal Gaussian process. The dynamics of the asset path for both models is illustrated in Figure 1 below for both defaulting and non-defaulting asset value paths. For the Merton (1974) model, the firm goes into default if the value of the assets drops below the face value of the debt at maturity. Viewed this way, the equity holders are long a standard European call option on the assets of the firm with a strike price equal to the face value of the debt. In the DOC model framework, the firm defaults anytime the asset value of the firm breaches the barrier. In this example, the barrier height H, for the DOC model, is the face value of the debt.

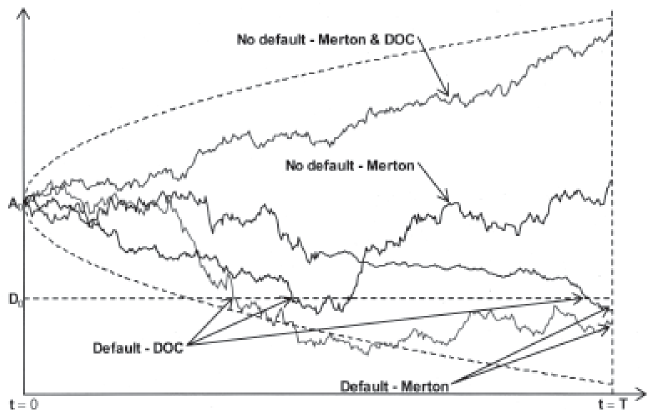


Figure 1. The asset process and default for the Merton (1974) and DOC structural credit risk models.

The primary assumptions of the Merton (1974) include the following:

- The risk-free rate is constant.
- There are no transaction costs or taxes
- The value of the assets of the firm follows a lognormal diffusion process:

$$\frac{dA}{A} = \mu_A \, dt + \sigma_A W, \; A_0 > 0$$

Where W is a standard Brownian motion, σ_A is the asset volatility, and μ_A is the asset drift

- The total liabilities of the firm consist of equity, E, and one zero-coupon non-callable debt contract, D, maturing it time T with face value F

[2] *Because of this, the Merton (1974) approach is commonly referred to as the contingent claims analysis (CCA) approach.*

[3] *The barrier can be considered as exogenous being due to safety covenant(s) found in the bond contract or endogenous being due to optimizing a decision policy by the management of the firm. Only exogenously - defined boundaries are considered here.*

$$A_t = E_t + D_t \tag{1}$$

This relationship relies on the Modigliani-Miller theorem in which the total firm value is invariant to its capital structure.

- Until debt maturity, the firm cannot issue additional debt or equity, nor pay dividends or retire equity.
- The absolute priority rule cannot be violated.

Using these assumptions, we can determine the value of the equity in terms of both the Merton (1974) and DOC frameworks. For the Merton (1974) model, the payoff to equity at maturity of the debt is the maximum of the assets of the firm less the liabilities or zero. This is equivalent to the payoff for a European call option on the assets of the firm with strike F and maturity T.

$$E_0 = A_0 N(d_1) - Fe^{-rT} N(d_2) \tag{2}$$

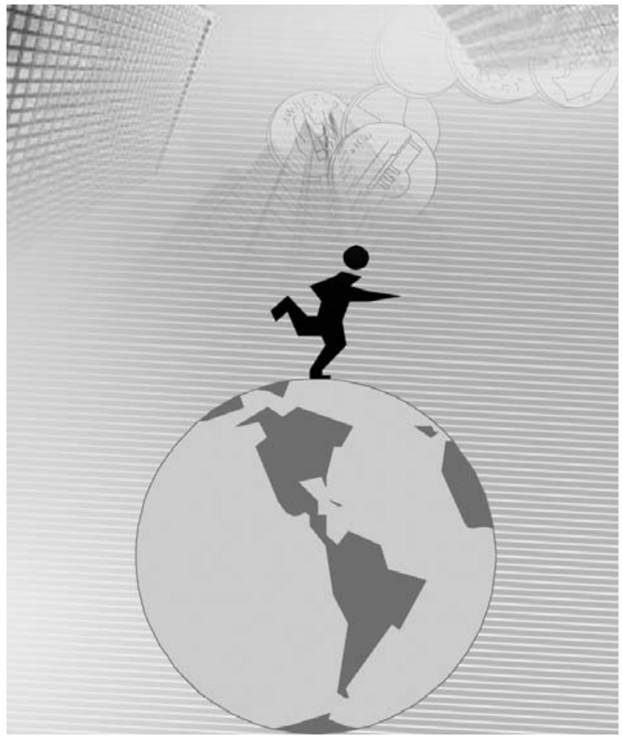
where $N(\cdot)$ is the standard normal cumulative density function and d_1, d_2 are defined,

$$d_1 = \frac{\ln(A_0 / F) + (r_f + 0.5\sigma_A^2)\,T}{\sigma_A \sqrt{T}}$$

$$d_2 = d_1 - \sigma_A \sqrt{T}$$

In applying DOC barrier option models to credit risk applications, there are two scenarios to consider with respect to the location of the barrier relative to the face value of the debt. The barrier can be viewed as the value of firm assets above which creditors cannot force dissolution. The case of interest is when the face value of debt is greater than the barrier, or $F \geq H$ as it is also the only scenario in which the bond holders are exposed to risk. Here we also assume a constant level for the default barrier[4] in order to utilize closed-form equations for the distribution of asset returns (Reiner and Rubinstein 1991). Assuming risk-neutrality, the equity option value can be then derived as:

$$E_0 = A_0 \left[N(x_1) - (H/A_0)^{2\lambda} N(y_1) \right] - F_E^{-r_f T} \left[N(x_1 - \sigma_A \sqrt{T}) - (H/A_0)^{2\lambda - 2} N(y_1 - \sigma_A \sqrt{T}) \right] \tag{3}$$



where x_1 and y_1 are:

$$x_1 = \frac{\ln(A_0/F) + (r_f + 0.5\sigma_A^2)\,T}{\sigma_A \sqrt{T}}$$

$$y_1 = \frac{\ln(H^2/A_0 F) + (r_f + 0.5\sigma_A^2)\,T}{\sigma_A \sqrt{T}}$$

In the DOC barrier option approach, bonds are worth at least as much those evaluated with the Merton (1974) model because of the knock-out feature which protects the bond holders in the case the firm defaults before the maturity T.

The credit spread, CS(T), is the premium demanded by bond holders as a compensation for bearing default risk and is the difference between the yield on the risky corporate bond of the firm and the yield on an equivalent risk-free bond. In deriving the value of the risky bond of the firm, the Modigliani-Miller relationship of equation (1) is used and evaluated at t=0.

$$\mathbf{D_0} = \mathbf{A_0} - E\,(\mathbf{A_0}, F, T, \mathbf{r_f}, \sigma_A) \tag{4}$$

[4] *In the original Black and Cox (1976) model, the barrier used was a risk-free bond.*

Where E() is either the equity relationship for the Merton (1974) or DOC models (equations (2) or (3) respectively). The value of an equivalent risk-free bond is $Fe^{-r_f T}$. The credit spread, CS(T), as the spread of the risky bond over the risk-free bond can then be evaluated as:

$$CS(T) = -\frac{1}{T}\ln\left(\frac{D_0}{Fe^{-r_f T}}\right) \tag{5}$$

2.1 Model Calibration

IMPLEMENTING structural credit risk models requires estimation of the firm's asset value process for A_t and volatility σ_A (both unobservable), as well as transforming the debt structure of the firm into an equivalent zero-coupon bond of face value F and maturity T. While equity prices are easily observed for public companies, the total asset value of the firm and its volatility, are not. Balance sheet data on the firm's capital structure values exists, but it is available at most on a quarterly basis, and often only annually. Thus for all practical purposes, the asset value of a firm is latent or unobserved. The unobserved nature of the firm value asset process requires it be estimated from market data.

MLE is a statistical approach for characterizing the unobserved asset process which results in both estimators and their standard errors. In application to structural credit risk models, the equity prices serve as a transformed data set of the unobserved asset value by an equity pricing formula, such as equation (2) for Merton's (1974) model or equation (3) for the DOC structural credit risk model. The advantage of MLE derives from the fact that the estimators have desirable properties of consistency, asymptotically unbiased, efficient, and are asymptotically normal with known variance. The later properties allow the standard error of a maximum likelihood estimator to be determined.

The standard MLE formulation assumes independent random variables with a given probability density function. For n independent random variables, the joint density of N independent observations becomes:

$$\phi(y \mid \Theta) = \prod_{i=1}^{N} \phi_i(y_i \mid \Theta) = L(\Theta \mid y) \tag{6}$$

where $L(\Theta \mid y)$ is the likelihood function for the unknown parameter set Θ given the data y. Because is a joint probability, The MLE method finds the parameter set Θ that maximize the likelihood of the data occurring, e.g., the Θ in which the sample is most likely. For a sufficiently large sample size, the distribution of the maximum likelihood parameter estimates can be approximated by a normal distribution.

$$(\hat{\Theta}^2_{ML} - \Theta^2) \xrightarrow{A} N(0, H_n^{-1})$$

$$H_n = -\frac{1}{n}\begin{bmatrix} \frac{\delta^2 L(\hat{\mu}, \hat{\sigma})}{\delta\mu^2} & \frac{\delta^2 L(\hat{\mu}, \hat{\sigma})}{\delta\mu\delta\sigma} \\ \frac{\delta^2 L(\hat{\mu}, \hat{\sigma})}{\delta\sigma\delta\mu} & \frac{\delta^2 L(\hat{\mu}, \hat{\sigma})}{\delta\mu^2} \end{bmatrix}$$

Where Θ notes the true parameter value and H_n is the Hessian matrix. The Hessian matrix is the negative of the second derivative of the log of the likelihood function given by equation (6) wrt Θ. The inverse of the Hessian matrix provides an estimate of the variance-covariance matrix from which we can determine standard errors of the estimators.

The distribution of the estimators can be used to infer the distribution of functions of those estimates. Lo (1986) examined a procedure which allows for the test of an option pricing model in a classical statistical sense in which the underlying asset can be observed. Lo (1986) notes that since the MLE of any well-behaved non-linear function of a given parameter is simply the non-linear function of the MLE of that parameter. Since option prices are monotone function of volatility, confidence intervals for the option price also exist. The general form of the asymptotic distribution of a function X of an estimator $\hat{\Theta}$ using MLE is:

$$(\hat{X}_{ML} - X) \xrightarrow{A} N(0, G' \cdot H_n^{-1} \cdot G)$$

Where $\xrightarrow{A}$ indicates that this is an asymptotic relationship. Here, G is any differentiable transformation of the MLE estimates such as the credit spread (equation 5) determined by the Merton (1974) and DOC structural models. Through this asymptotic properties of MLE, the distribution of the credit spread can be estimated by,

$$CS_t(\hat{\sigma}_A) - CS_t(\sigma_A) \xrightarrow{A} N(0, G^{'} \cdot H_n^{-1} \cdot G)$$

from which confidence intervals of the model estimates can be derived and used to qualify the model to the empirical bond prices.

3. Empirical Application and Results

ONE ultimate objective of this study is to determine the degree of linkage between the equity and credit markets in Thailand utilizing structural credit risk models. For evaluating the pricing performances of the models, the figure of merit to evaluate for pricing is the ability of models capture changes in credit spread over time. Residuals of the market and model credit spreads can then be tested for systematic influences. The MLE methodology will be used to calibrate both the Merton (1974) and DOC structural credit risk model parameters, which include the market value of assets A, asset volatility σ_A. For the barrier option model, the default barrier H is also extracted and is assumed to be less than the total liabilities of the firm.

The models and calibration methodologies are implemented in the R/S-plus statistical programming language.[5] The problem of maximizing the log of the likelihood function (equation 6) is an optimization problem. In the R/S-plus package, the "optim" optimizer is employed for implementing the MLE methodology, which uses a quasi-Newton unconstrained optimization. The derivatives for the log-likelihood function are computed numerically. The "optim" package also outputs an estimate of the Hessian matrix for use in statistical inference of the estimators. Constraints and scaling of parameter values are encoded within the log-likelihood function.

3.1 Firm and Market Data

FIRMS of actively traded issues are selected from the Thai Bond Market Association (Thai BMA) bond market transaction database[6] within the period of 2000-2005 in order to minimize the affects of structural changes that had occurred per- and post-Asian financial crisis. In addition, bonds with embedded options and/or amortization features are avoided. Market capitalization and balance sheet liability data were extracted from the SET market database. Consolidated reports are used when appropriate. The equity (market capitalization) data is daily, while the liability data is quarterly as reported. The models are estimated using the prior three year's market capitalization and liability data via MLE methodology as previously described. The three years of data represents a recognized trade-off between the length of the time series to minimize estimation error against the need to avoid the effects of structural changes in volatility over longer time periods.

It is important that the sample selection focus on firms with as large amount of consecutive monthly bond market pricing observations as possible. Define monthly bond market observations as transactions spanning no more than 30 calendar days as in the table below. Screening the bonds in the Thai BMA database based on activity, with remaining maturity of greater than one year and whose issuing firms are those without implicit or explicit third-party guarantees, results in eight bond issues for the sample. These eight issues are from firms within the communications, agriculture, property, and energy sectors and are listed in Table 1 below.

For empirical analysis of credit spread of the corporate bonds, we need to determine the difference between the weighted average transaction yield[7] as reported in the Thai BMA database for the transaction date less the risk-free rate for a bond of an equivalent maturity on that date. Since there are typically no

[5] *http://www.r-project.org*

[6] *http://www.thaibma.or.th*

[7] *The weighted average yield as reported by the Thai BMA is used. Details of the exact calculations used by Thai BMA are not provided*

Table 1 : Metrics on actively traded corporate bonds in the Thai BMA database.

Name	Iss.	Mat.	Amount (MB)	Coupon	Rating	# Trades	Cont. Days Trade
AISO73A	2002	2007	3000	5.250%	AA	66	99
AISO93A	2002	2009	2450	6.250%	AA	69	96
APO75A	2004	2007	1000	4.250%	BBB	5	55
BCP06NA	2001	2006	3000	4.800%	-	11	55
CPF07NA	2004	2007	2500	4.250%	A	25	107
CPF09NA	2004	2009	3500	5.500%	A	12	33
CK07OA	2004	2007	2000	4.625%	A-	5	21
NMG072A	2004	2007	1000	4.500%	BBB	8	25
QH064A	2004	2006	584	3.500%	BBB+	6	29
QH074A	2004	2007	917	4.250%	BBB+	5	21

observations of government bond yields of the same maturity on the same date of a transaction, the Nelson-Siegel-Svensson (Svensson 1994) (NSS) model is used to estimate the risk-free rate of intermediate maturities at any date. Using the NSS model provides us with a term structure of default-free zero coupon rates for the Thai market; credit spreads on corporate bond yields can be determined at any point in time for any given maturity.

3.2 Preliminary Analysis

IT is useful to examine a cross-section of the market versus model yields, as shown in Figure (2) below. Two issues in the sample, BCP06NA and CK07OA, do not trend well with the model predictions. If these two issues are excluded from the sample, the overall performance of the structural credit risk models is to under-estimate yields versus what is seen in the market which is similar to the experience in more developed markets. The CK07OA issue trades at yields approximately equal to it's coupon yield and apparently independent of any other risk factors. It is not readily apparent what might be driving the yields on the BCP06NA issue as it trades consistently below its coupon yield during the sample period.

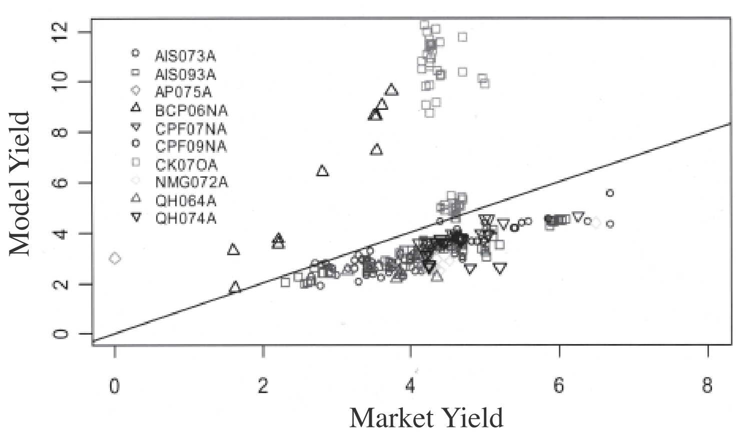


Figure 2. Market versus model yield for actively traded issues.

3.3 Credit Spread Pricing Performance

FOR the actively traded corporate bonds in the sample, the time-series behavior of the market and model yields are examined over the periods in which sufficient market activity is present. The reported market yields, which are the weighted average yields as reported in the Thai BMA database, are compared to the predicted model yields and the corresponding 99% confidence intervals. The confidence intervals of the yield model are calculated as previously described and shown for the Merton (1974) model (results are similar for the DOC barrier option model).

Similar to empirical results on U.S. markets and data, this application of structural credit risk models in the Thai market consistently underestimates credit spreads. As previously noted, for the majority of sample issues excepting BCP06NA and CK07OA, there is a clear direct correlation between the trends of the market and model yields. The absolute difference between the market and model yields is most likely attributed to the presence of other components of yield not accounted for in structural credit risk models. The analysis of two of the bonds issued by Charoen Pokphand Foods PLC (CPF) is used to illustrate the analysis and results. The results illustrated for CPF are representative of other firms in the sample of Table (1).

CPF is a major producer in Thailand's agribusiness sector. CPF has two bond issues that are actively traded in the secondary market during 2005, CPF07NA and CPF09NA, maturing in 2007 and 2009 respectively. CPF is a fairly active issuers' in the corporate debt market, currently with six issues outstanding, all maturing in different fiscal years. During the sample period, approximately 60% of the liabilities in the capital structure of CPF were classified as short term (due in less than one year) with very little variation in this ratio through the sample period of both bond issues. The Table (2) summarizes the model estimates for the two issues over the sample period:

Table 2 : Parameter estimates for CPF bond issues over the sample periods[8]

	CPF07NA '05/06-'05/12	CPF09NA '05/01-'05/11
Merton		
$\hat{\mu}$ $se_{\hat{\mu}}$	0.1988 0.4456	0.1519 0.0681
$\hat{\sigma}$ $se_{\hat{\sigma}}$	0.1760 0.0082	0.1863 0.0099
DOC barrier		
$\hat{\mu}$ $se_{\hat{\mu}}$	0.1755 0.0428	0.1390 0.5466
$\hat{\sigma}$ $se_{\hat{\sigma}}$	0.1755 0.0428	0.1772 0.0007
$\hat{\alpha}$ $se_{\hat{\alpha}}$	0.5874 0.2314	0.4274 0.0047

Of note is the different estimate of asset volatility between the two models, and that this difference is consistent between the two bonds. The empirical market and model yields for the issue CPF07NA maturing in 2007 is shown in Figure (3) for transactions in 2005. The agreement between model and predicted market yields are also good in relative terms. Other characteristics of the market versus model errors are consistent with the AIS issues. The issue, maturing in about two years, is a relatively short maturity.

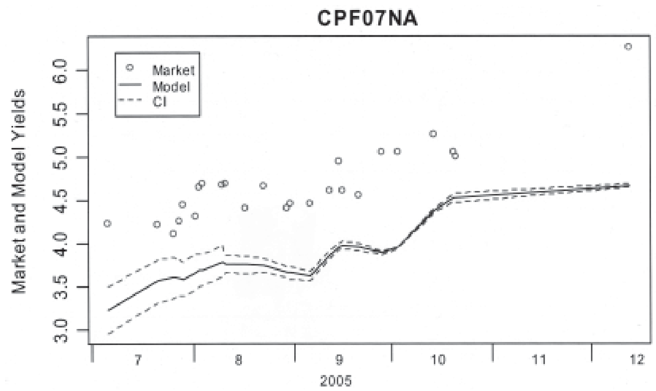


Figure 3. Market-model spread time-series for CPF07NA

The market-model spreads for CPF09NA issuance maturing in 2009 is shown in Figure (4). There is a large degree of correlation between model and predicted market yields, particularly in relative terms. The absolute difference between the market and model spreads can be attributed to the low volatility regime, or again by the presence of other components of yield not accounted for in structural credit risk models (similar to other bond issues).

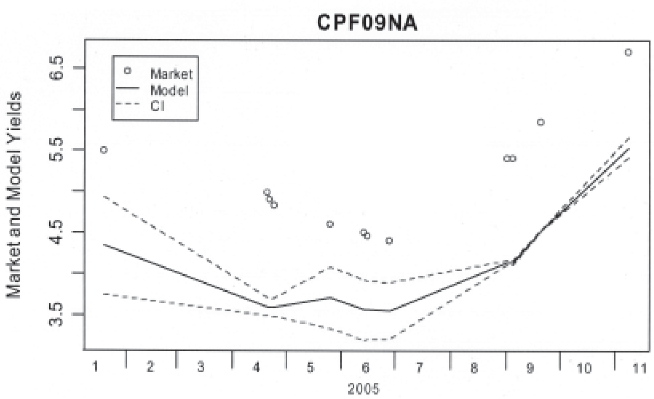


Figure 4. Market-model spread time-series for CPF09NA

8 *It is more efficient to estimate the barrier height, H, as a ratio of the barrier height to the outstanding liabilities, or alpha. Alpha estimates for the barrier of most samples were close to the expected value of 0.5 which is what is found in historical records of defaults in other countries such as the U.S. This is supported by the Moody's KMV (Crosbie 2003) model which uses 0.5 as the empirical estimate of the barrier*

3.4 Analysis of Credit Spread Pricing Errors

VISUAL inspection of market versus model yields appears to indicate a clear relationship between market and model yields for the actively traded corporate bonds in the Thai bond market[9]. However, we should also be interested in understanding what is not accounted for by the models. To do this, we specify a regression model to explain the difference in spreads between market and model[10]. Some explanatory factors might not be captured within structural credit risk models, or might not have the correct functional dependence. Some factors worth investigating as influencing bond yields include:

- Liquidity of the bond (proxied by the total size of the issue).
- Liquidity of the transaction (proxied by the size of transaction as a percent of the total issue size).
- Risky-ness of the issue (proxied by the current leverage (D/A) of the issue).
- Time to maturity effects (proxied by remaining maturity).
- Size of issuer (proxied by the total asset value of the firm).

It is expected that the factor for the liquidity of the bond will be negative on credit spread error as larger issues will garner more participants and hence more efficient pricing. Liquidity of the transaction size could go either way - and could be an indicator of supply and demand effects. Risky-ness of the issuers' is incorporated to determine if this factor is not being properly accounted for in the models. Time to maturity can reflect influences from the term structure of both the risk free index as well as the corporate spread. The size of the issuer would be expected to be negative as larger firms would be considered to be less risky.

Because many factors typically have nonlinear influences on the dependent variable, both linear and log relationships are considered. The results of the estimated regression for the issuers, excepting the issues BCP06NA and CK07OA for reasons previously discussed are given in Table (3) below:

Table 3. Full factor regression on credit spread pricing errors

Factor	Linear	Log
Intercept	- 1.149* (-2.576)	- 4.009*** (15.05)
Issue size	2.44e-4* (3.240)	0.403* (2.058)
Transaction size	8.568*** (4.166)	0.527* (2.318)
Asset	-4339e-7 (-0.400)	0.0016 (0.014)
Leverage	-6.901e-01 (-1.068)	-0.0797 (-0.516)
SET volatility	-1.078 (-1.450)	0.0626 (0.527)
Time to maturity	-9.044e-3 (-0.319)	-0.24 (-1.838)
Adj-R^2	0.1496	0.0792
DW	1.499	1.493

level of significance : *** (0.001), ** (0.01), * (0.05)

Overall explanatory performance of the model on the yield errors is low. For both the linear and log formulations of the model, only the two proxies for the liquidity (issue size and the transaction size) in the linear formulation show any definitive significance, and only the issue size in the log formulation of the model. The coefficient for the issue size factor, although small and positive, is a large influence on the residuals. This result would seem to indicate that transactions on the larger issues are susceptible to more model error. For the transaction size factor,

[9] The exception being bond CK07OA whose reported yields were independent of changes in firm risk.

[10] The data set actually represents panel data, but since we are interested in approximate effects and the more problematic issues have been eliminated from the sample standard OLS can be employed.

this positive relationship between market and model spread error is expected, and is confirmed by a coefficient of larger magnitude. Other factors show no significant influence on market versus model errors.

Conclusion

A PRIMARY objective of this study is to determine the degree of linkage between the equity and credit markets in Thailand implied through structural credit risk models. The lack of breadth and depth of data within the Thai corporate bond market was considered the main methodological obstacle in this study. But not only is the lack of bond market data an issue, but the anomalies in the available data present a challenge for testing the applicability of the models. Closer examination of the data indicates that during initial placement, many corporate bond issues were traded at yields below the equivalent risk-free government yield which may lead one to the conclusion that pricing may not be rational in the primary market. These yield differences are greater than that which can be attributed to underwriting fees as reported in issuers' prospectus. This anomaly occurs even for some actively traded corporate issues, such as noted for issues CK07OA and BCP06NA. This in part, supports a methodology in which credit risk models are applied at the firm-level in order to screen out such effects.

Quality of data factors most likely had a bearing on previous applications of structural credit risk models to the Thai market which concluded that models typically over-estimated spreads contrary to empirical studies on U.S. markets and data. When examining the Thai bond market yields as reported, anomalies in the data can explain the conflicting results in those studies. After screening for anomalies in the Thai corporate bond market data, results here show a credit-equity linkage that is more in line with prior empirical research such as has been done in the U.S.. As has been found in the U.S. markets, bond spreads are typically under-priced, and the difference between empirical and model spreads is fairly constant for a number of issues over periods of relatively active trading. The market yields are outside of the confidence intervals of the yields as predicted by the models. The constant magnitude of these differences indicates other components of yield that are not being priced by the structural models. Statistical inference of the estimators show that only a small percentage of the predicted yields fall within confidence limits indicating additional influences on credit spreads.

These results are consistent for both the Merton (1974) and barrier option structural credit risk models. This study also demonstrated the use of the MLE methodology for extracting the barrier level in the barrier option model from equity market data. In general, the financial distress barrier level extracted is consistent with empirical estimates of the barrier level based on historical defaults from the U.S. and other markets. However intuitively appealing the barrier option approach is, it is not clear that even with a efficient estimation methodology, the use of this model can account for the primary pricing influences in the market.

The residuals of the market versus model predictions were regressed against common factors in order to identify potential influences. Overall explanatory power was relatively low, with only factors related to issue liquidity statistically significant. Clearly more additional investigation is required in the decomposing the components of credit spreads with the Thai corporate bond market.

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