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Rating, Credit Spread, and Pricing Risky Debt: Empirical Study on Taiwan's Security Market

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This paper focuses on evaluating the credit risk of corporate bond in the fixed income market of Taiwan. We apply Vasicek (1977) model into Merton's (1974) option framework and obtain a closed-form solution of the options model. The solution algorithm employs the Newton-Raphson method in combination with the inverse quadratic interpolation and bisection technique of Dekker (1967) to find out the roots and calculate the credit spread. The result shows that the average credit spread is 1.346%, and the credit spread of TSE (Taiwan Stock Exchange) listed firm is higher than that of OTC firms, while the one with bank guarantee is higher than the one without. We find negative correlation between VaR rating, TEJ (Taiwan Economic Journal) rating and credit spread, implying that the higher the market risk is, the lower the required premium is by the bondholders, and credit spread is expected to be lower. Testing the hypothesis of Duffee (1998), we find a negative correlation between the Taiwan Stock weighted index and credit spread. It implies that the term structure of interest rate is an upward type. As firm's equity value rises, the index return follows suit. While the bond default probability decreases, and the credit spread is expected to decrease.

Key Words: Credit spread; Default risk; Interest rate risk; Market price of risk; Put-call parity; VaR (Value at Risk).
JEL Classification Numbers: C61, C63, G12, G13.

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1. INTRODUCTION

Recently, the focus of study in the securities of fixed income has been on interest rate behavior and valuation on fixed income securities from the viewpoint of options. Among them, the research of credit risk of fixed income securities is of primary importance, and becomes a focal point of comprehensive study for researchers. Therefore, we apply the options model to the securities market of fixed income in order to observe the credit risk exposure of the bond market in Taiwan.

In general, what kind of financial products in fixed income securities are deemed most important in Taiwan? It hinges upon market participants' investment allocation among government bonds and corporate bonds. As government deficit is reduced and corporate capital structure moves toward debt financing, corporate bond market becomes ever more important nowadays. Since the development of fixed income securities in Taiwan is still in its infancy, trading activities and volumes are still much less than those of the equity market.[1] As shown in Table 1, the total bond trading value was only $414.40 billion in 1988. Yet, the total bond trading value reached $118,968.40 billion in 2001 with a 285 fold increase. On the contrary, there is no considerable growth in equity market in terms of total transaction value during the past ten years. For sure, Taiwan bond market growth potential can be expected in the coming decade.

There are numerous kinds of bond issuance in Taiwan. The bond price disclosure depends on the yield to maturity (YTM). The yield to maturity reflects the market risk that a firm faces. Since there is not much trading volume of bonds, it is practically difficult, if not impossible, to observe the market risk data. To the participants in fixed income securities market, there is not enough information to understand the intrinsic value and credit risk of an issuing firm. Many researchers attempt to tackle the issue from the direction of corporate finance and accounting. Early studies employ financial statement analysis coupled with econometric methods, linear, nonlinear, and neural network models, for historical financial data. However, these methods fail to evaluate corporate credit risk and explain clearly the risk exposure of an underlying asset.

The credit risk can be decomposed into default risk and interest rate risk encountered by the bond participants. The valuation of default risk may be carried out by two methods. One can estimate an expected loss based on the default probability. Default risk may also be translated into adjusted discount rate, referred as the reduced-form model. As pointed

[1] In Taiwan, more than 90% of bond trade is completed in OTC market of which, financial institution accounting for more than 60% of the trading volume is the primary dealer. In addition, levying a high bond trade tax, special offer system, and failure to perform credit rating for the underlying firm, etc. all contribute to the unsound operation of bond market in Taiwan.

TABLE 1.

ISSUES AND TRADING VALUES OF CORPORATE BOND IN TAIWAN

	Issue of corporate bonds					Trading value (NT$ billion)					
	Common		Convertible		Total	ROSE			TSE		
year	Issues	Outstanding (NT$ billion)	Issues	Outstanding (NT$ billion)	amount	Stock	Bond (Common)	Total bond	Stock	Common	Convertible
1990	39	48.78	2	25.00	51.28	11.8	0.97	1,592.32	190,312.9	0.26	5.68
1991	36	522.00	10	6.79	58.99	4.6		3,743.49	96,827.4	0.18	5.91
1992	35	50.11	20	12.56	62.67	6.7	1.90	10,734.63	59,170.8	0.04	3.78
1993	29	37.14	20	10.65	47.79	6.5		13,155.83	90,567.2	0	2.59
1994	23	22.71	18	9.32	32.03	5.7		15,972.91	188,121.1	0	7.58
1995	28	41.79	16	6.95	48.74	27.9	2.75	20,821.36	101,515.4	0	1.87
1996	95	108.34	17	15.99	124.33	4,535.1	24.07	28,287.49	129,075.6	0	10.03
1997	188	177.21	44	419.00	219.11	23,106.6	27.1	40,372.21	372,411.5	0	19.80
1998	487	298.61	70	85.18	383.79	11,981.6	71.63	54,959.31	296,189.7	0	40.92
1999	907	386.17	79	655.00	451.67	18,999.0	98.12	52,180.75	292,915.2	0	54.23
2000	1,206	443.34	86	78.28	521.62	44,796.6	203.08	68,920.57	305,265.7	0	51.28
2001	1,487	516.90	97	81.82	598.70	23,269.6	263.86	118,968.47	183,549.4	0	24.04

by Duffee (1998), if the empirical result of valuation model verifies the independence of interest rate and default risk, then the valuation model has no predictive power. However, the reduced-form model takes event as a stochastic process in which bankruptcy comes as a surprise, that is, the correlation between interest rate and default risk is not decisive. Therefore, relative to other models, the reduced-form model is less appropriate. S&P and Moody's Company also employ the expected loss method of default probability to evaluate the default risk. Furthermore, the firm valuation model of Merton (1973, 1974) is frequently applied by researcher. Its concept is that of a valuation method based on the options valuation model of Black and Scholes (1973) to set up a theory of the risk structure of interest rate, and thereby derive bond value. This model taking financial structure factor into consideration is also referred to as a structural valuation model.

However, both models of Black and Scholes (1973) and Merton (1974) are weakened by assuming constant interest rate. In fact, interest rates fluctuate in a real world. Hence, many researchers study interest rate behavior. Some incorporate an interest rate model into the structural valuation model. Nonetheless, most of them deal with the issue theoretically with no practical value. A few can be used or applied but restricted by complicated numerical methods to find solutions.

Rabinnovitch (1989) derives an options pricing model with a closed-form solution by embedding the interest rate stochastic process configuration method of Vasicek (1974) into the corporate bond valuation model of Merton (1973). Since the correlation coefficient between interest rate and the underlying market price of risk is introduced into the model, this valuation model has the mechanism capable of adjusting to the change of time and the uncertain interest rates in market. It is equipped with the mechanism to evaluate default risk and interest rate risks. However, the valuation model of Rabinnovitch (1989) is also a simulation result with assumed or pre-set parameters without any explanation or justification: a weakness. Therefore, we employ the valuation model of Rabinnovitch (1989) to derive credit risk about the common corporate bond issued in the bond market of Taiwan. By separately evaluating the model parameters in accordance with the underlying firm and applying them in order to evaluate the corporate risk exposure through the credit spread, the weakness of the Rabinnovitch (1989) model can be remedied. Next, in order to compare the evaluated credit spread to market risk, the same underlying firm is employed in VaR estimation. The correlation between the model-evaluated credit risk and market risk is investigated by including the TEJ credit rating information on listed firms. Lastly, in order to verify whether the model satisfies Duffee's (1998) hypothesis, we employ OLS (ordinary least square) method to estimate and verify regression coefficients, and the applicability of the model.

Section I of the paper is introduction; Section II discusses theoretical models; Section III describes sample and valuation technique; Section IV reports simulation and valuation results, and the last section concludes the paper.

2. THEORETICAL MODELS

The Pull-Call Parity of Black and Scholes (1973) can be shown as follows:

$$P_t + S_t = C_t + Ke^{-r_f^{\tau}} \tag{1}$$

where S_t, C_t, P_t, K, r_f, and τ are the underlying asset, the call options value, the put options value, the exercise price, the risk-free rate and the maturity date, respectively.

Merton (1973) considers all out-circulating bond to be a contingent claim[2] of the corporate value. Therefore, to equity holders, the underlying asset is the firm value (V_A), its exercise price with the maturity value of debt (F). The options structure of its assets and liabilities shall be $V_A = V_E + F$, in which V_E is the market value of shareholders' equity. On the other hand,

[2]The law of application deems the relationship between a debtor and creditor as a kind of contingent claim; therefore, whether credit risk of firm should occur depends on the relative strength between corporate asset and liability values.

the call options value upon maturity shall be $V_E = \max(V_A - F, 0)$. Therefore, shareholders, upon the maturity of corporate bond, use F as the striking or exercise price to repay the debt. The market value of equity is just like a kind of contingent claim of corporate debt holders; that is call options. Exercise value is F with the underlying corporate asset value (V_A).

Assuming V_A follows the following stochastic process:

$$dV_A = uV_A dt + \sigma V_A dz_1 \tag{2}$$

where u is the drift term, σ is standard deviation of asset value, dz_1 is a standard Wiener process. Then the familiar call options pricing model to us is:

$$V_E = V_A N(d_1) - Fe^{r_f^\tau} N(d_2) \tag{3}$$

where $d_1 = (\ln(V_A/F) + (r_f + \sigma^2/2)(\tau))/\sigma\sqrt{\tau}$, $d_2 = d_1 - \sigma\sqrt{\tau}$, in which r_f denotes risk-free rate and $N(\cdot)$ is the cumulative normal density function. Therefore, value of risky bond (V_D) is put options:

$$V_D = V_A N(h_1) + Fe^{r_f^\tau} N(h_2) \tag{4}$$

where $h_1 = (\ln(Fe^{r_f^\tau}/V_A) - (\sigma^2\tau/2))/\sigma\sqrt{\tau}$, $h_2 = -h_1 - \sigma\sqrt{\tau}$, and the current yield of holding risky bond (r_D) is:

$$r_D = -\frac{l}{\tau} \ln\left(\frac{V_D}{F}\right) \tag{5}$$

Under the hypothesis of default probability for firms, a risk averse investor holding risky bonds must require a yield compensation for not holding risk-free bonds. Credit spread (cs) is then the difference between the return of risky bonds and that of risk-free bonds. It is the risk premium to compensate an investor for holding risky bonds as shown in the following equation:

$$cs = r_D - r_f \tag{6}$$

However, Merton's (1973) model implies a constant short-term interest rate and a term structure of interest rates at horizontal level which are not being empirically relevant. Therefore, recent studies mainly attempt to set up a dynamic model of interest rate. The interest rate model can be divided into two kinds; one is equilibrium models and the other no-arbitrage models. It is known from the empirical results of many researchers that the problem of no-arbitrage models is its inability to guarantee the existence of a best equilibrium relation in economic behaviors. After all, the theoretical equilibrium models are most persuasive. Cox, Ingersoll and Ross (CIR, 1985) and Vasicek (1977) models both assume the instant volatility of short-term interest rate as a state variable. In addition, CIR model further assumes the interest rate behavior to be free from any negative situation which conforms to the real world. However, in the inference process, we cannot employ the CIR model since it yields a stochastic variance for the price of the default-free discount bond that is incompatible with Merton's model. Compared with CIR equilibrium models, the application of Vasicek (1977) model seems more appropriate.

Vasicek model assumes the stochastic process of short-term interest rate to be as follows:

$$dr = q(m - r)dt + \nu dz_2 \tag{7}$$

where r denote the short-term risk-free interest rate; q is the adjustment speed of the instant interest rate to long-term means m; ν is the standard deviation of the instantaneous interest rate, dz_2 is also a standard Wiener process. Then, through the estimation of the following parameters, the price of zero-coupon bond can be obtained:

$$P(r_f, t, T) = A(t,T) \times e^{-B(t,T)r_f} \tag{8}$$

where $A(t,T) = \exp(k(B-\tau)-(\nu B/2)^2/q)$, $B(t,T) = (1-\exp[-q\tau])/q$, $k = m+\nu\lambda/q-(\nu/q)^2/2$, $\lambda = (\gamma-r_f)/\delta$, γ and δ are the instantaneous expected return and volatility of bond respectively and λ is market price of risk. Therefore, applying Itô's lemma with the stochastic process assumption, a risky bond value (V_D) shall satisfy the following partial differential equation (PDE)

$$Q_t+\frac{1}{2}Q_{VV}V^2\sigma_V^2+\frac{1}{2}Q_{rr}\sigma_V^2+Q_{rV}\rho\nu\sigma_V V+Q_r[q(m-r)-\lambda]-rQ+rQ_\nu V = 0 \tag{9}$$

The boundary condition is $V_D = \min(V_A-F, 0)$, in which $Q = V_D$, $V = V_A$, $r = r_f$ and $\delta(\tau) = \nu B(\tau)$. Furthermore, we can obtain a closed-form solution of risky bond value:

$$V_D = V_A - V_A N(k_1) + Fe^{r_f^{\tau}} N(k_2) \tag{10}$$

where $k_1 = (\ln(V_A/FP(r,\tau)) + T/2)/\sqrt{T}$, $k_2 = k_1 - \sqrt{T}$

$$T = \sigma^2\tau + (\tau - 2B + (1 - \exp[-2q\tau])/2q)(\nu/q)^2 - 2\rho\sigma(\tau - B)\nu/q \tag{11}$$

$$dz_1 dz_2 = \rho dt \tag{12}$$

Note that the composition elements in the equations (10) to (12) differ from those by Merton (1973). Three kinds of effects are added into the adjusted model: the volatility effect, the interest rate effect, and the Delta value effect. The first is the volatility effect. Including interest rate volatility and the instantaneous correlation (ρ) between dz_1 and dz_2 makes the model adjustable to changes. The second is the interest rate effect. In the equation, present value of bond (P) is implied. Therefore, options value is calculated through the bond value with stochastic process of interest rate, which agrees more to the actual situation. The third one is the Delta value effect. The value of options is adjusted in accompany with the volatility of Delta value[3]. The improved model is used for valuation in this paper.

TABLE 2.

ESTIMATED PARAMETERS FOR THE VASICEK MODEL

Risk-free rate AR(1) process		Vasicek model
	Coefficient	Parameter estimate
Intercept	0.002272	$q = 0.004683249$
t-stat	(0.993588)	$m = 0$
$r_{f(-1)}$	0.945351***	$v = 0.020829592$
t-stat	(20.919640)	
MSE	0.0000181	
F-stat	437.6312***	
R-square	0.824737	

***, **, * Significant at the 0.01,0.05, and 0.1 levels, respectively.

3. SAMPLE AND VALUATION TECHNIQUE

3.1. Sample

The research sample covers the corporate bonds issued by listed firms in Taiwan from January 1, 1995 to December 31, 2001 for a period of seven years. A sample firm must be listed in equity market six months before its first bond issuance. The total effective sample size in this study is 335. The data sources are Securities and Futures Commission (SFC), ROC Over-the-Counter Securities Exchange (ROSE[4]), Taiwan Economic Journal (TEJ), and AREMOS database of the Ministry of Education, ROC.

The share's average market value one year prior to the underlying corporate bond issuance date is used as the equity market value of call options in the model. In estimating the liability (face value) of an exercise, because the issuance quota that an issuing firm may have in the corresponding year, and that repeated issuance may occur, the total liability amount on the is-

[3]Delta is the proportion of change of options value to the underlying value.

[4]ROSE was renamed GreTai Securities Market (GTSM) now.

suance date[5] is adopted. In order to better describe the implication of an instantaneous stochastic process for the risk-free rate, we adopt the interest rate of one to ten day maturity for government-bond of Repurchase-Resale agreement. The maturity date is that approved by SFC for the bond issuance.

3.2. Parameter Estimation

The asset value volatility (σ_A) can be accurately estimated by the implied volatility derived from the options pricing model. A corresponding options product[6] in Taiwan in our research sample cannot be found. Also, observing such information from market is nearly impossible. Therefore, we employ Cox and Rubinstein (1985) method to estimate the volatility of equity, by converting the adjusted share's rate of return to the continuously compounded interest rate of return with the yearly standard deviation. King's (1986) method is used to adjust the share volatility (σ_E) through financial leverage ratios. The asset value volatility (σ_A) is obtained as shown in the following equation:

$$\sigma_A = \sigma_E \times \frac{V_E}{V_A} \tag{13}$$

We adopt the interest rate of government bonds with Repurchase-Resale Agreement maturing in one to ten days to describe the interest rate behavior for the parameter estimation of the Vasicek model. The estimation can be carried out after converting the continuous interest rate into discrete interest rate. Since the instantaneous interest rate follows the Ornstein-Uhlenbeck Process, we can solve Equation (7). Its conditional expected mean and variance are:

$$E(r_s|r_t) = r_t e^{-q(s-t)} + m(1 - e^{-q(s-t)}) \tag{14}$$
$$V(r_s|r_t) = \sigma^2(1 - e^{-q(s-t)})/2q \tag{15}$$

when a conditional probability density function (pdf) for a future maturity interest rate obeys a normal distribution.

From Equations (7), (14) and (15), we can convert the stochastic process of interest rate to an autoregression (AR) series function in a discrete form, to obtain the parameter values of q, m and ν in the equations.

Since no benchmark index is available in the bond market of Taiwan for reference, market price of risk (λ) cannot be obtained from the capital asset

[5]The data are observed from the quarterly financial report after the issuance date, in order to indicate the total debt amount of the corporate bond after issuance.

[6]In Taiwan, except for the warrants certificate from underlying stocks and the TSE weighted index options issued initially in December 2001, no other options products are available yet.

pricing model (CAPM) under the perfect market hypothesis. Therefore, we employ the average monthly return of corporate bond for one to ten years maturity during 1991 and 2001 to estimate the market price of risk of the bond market in Taiwan; that is, to estimate with $\lambda = (\gamma - r_f)/\delta$. One year data of the daily equity returns and government-bond interest rates prior to the corporate bond issuance date is used to calculate as a proxy the correlation coefficient (ρ) between short-term interest rate and equity return.

3.3. Nonlinear Roots Solution of the Model

Since options pricing model is an nonlinear equation, in which the integral calculus of normal distribution contains unknown parameters V_A and σ_A, we employ the Newton-Raphson method, in conjunction with the inverse quadratic interpolation and bisection technique of Dekker (1967) to find out the firm's market value and volatility. We then calculate the market value of corporate debt, derive the credit spread, and further evaluate the credit risk of firms.

3.4. Value at Risk (VaR)

The VaR[7] valuation method is a set of econometric model of evaluating asset adequacy developed by Capital Adequacy Directive Committee of European Union under Basle Capital Accord (BCA) and later J.P. Morgan Financial Service Co. developed a RiskMetrics model to serve as the basis for VaR. Bank of International Settlement (BIS) further requires its sectors to adopt VaR system to evaluate risks since 1998. It is recommended that the firms employ VaR to disclose market risk quantitatively in the draft of Financial Accounting Standards Communique (Taiwan). In other words, the importance of VaR can not be overemphasized.

VaR models basically can be divided into two major types; one is parametric, and the other is nonparametric (also referred to simulation model). The RiskMetrics model proposed by Morgan (1996) belongs to the parametric model. General parametric models assume the rate of return distribution is stochastic and is an independent joint normal distribution. However, Duffie and Pan (1997) and Hull and White (1998) report that actual data exhibit fat-tailed distributions.

At present, the frequently employed methods of VaR include Variance-Covariance, Historical Simulation[8] and Monte Carlo Simulation. Since

[7]Value at risk (VaR) indicates, "an asset investment portfolio, in a specific period, with a level of confidence, and under the worst situation of market, the market price occurs with variation, while the said asset market value may produce the maximum expected loss."

[8]Jorion (1997) refers it to Quantile-based Approach.

Monte Carlo Simulation is restricted by frequency and time, therefore, we employ Variance-Covariance and Historical Simulation in this research.

(1) Variance-Covariance Method

The characteristic of this method is its assumption that the probability distribution of the future investment portfolio value (r) is normal. This simplifies the VaR estimation greatly. The following equation under confirmed level of significance (α),

$$Z_\alpha = (r - \mu\Delta t)/\sigma\sqrt{\Delta t} \tag{16}$$

can be obtained for the rate of return (r) where $Z \sim N(0.1)$ is a standard normal variable Z_α with standard normal density function $\Phi(Z)$.

We can write Equation (17) to express $(1 - c)\%$ probability that the investment portfolio value or rate of return would be less than r^*.

$$1 - c = \int_{-\infty}^{r^*} f(r)dr = \int_{-\infty}^{Z_\alpha} \Phi(z)dz \tag{17}$$

In the above equation, this method attempts to find out the minimal critical value r^*. That is, relative to the finding of a standard normal variable Z_α, its left-tail cumulative probability is $(1 - c)\%$. Where Δt indicates the holding period., the VaR shall be:

$$Value - at - Risk = -r \times Z_\alpha \times \sigma\sqrt{\Delta t} \tag{18}$$

This method assumes the rate of return to be serially independent, without autocorrelation, and uses the estimated variances from past data. Also, this study deals with linear product — stocks. Therefore, a linear method of equally weighted moving average (EWMA) method is used in estimation.

(2) Historical Simulation

Many study results recommend using Historical Simulation method for a more stable risk valuation. When it is difficult to obtain historical data of product, Historical Simulation provides good calculation functions. This method of VaR is not to estimate from the product itself, but from the risk factor[9] of the product. Risk factors such as return rate ($r_{i,t}$) and the weight (w_i, T) of current investment portfolio are used to simulate the past return rates of the investment portfolio, $R_{p,t} = \sum_{i=1}^{n} w_{i,T} \times r_{i,t}$. We arrange the simulated return rates in ascending order from small to large to form a frequency distribution chart. At any given level of significance, VaR can be read off easily.

[9]The risk factor is the factor that influences the value of the product, while the risk factor of bond is interest rate.

Efron (1979) proposes another kind of Historical Simulation, called bootstrap, as a non-parametric stochastic technique, by employing a small period of historical data as sample, to continuously and repeatedly use sample data for the construction of statistical distribution for the simulated historical data. The most prominent difference between Historical Simulation and Geometric Brownian Motion (GBM) is that GBM shall assume a known distribution. On the contrary, no assumption of distribution shape and serial independence of variance term is needed for Historical Simulation. It overcomes the fat-tail problem, the weakness of the Variance-Covariance method.

In order to ensure the VaR calculation and options valuation result to be consistent, the daily data of the year prior to the issuance date are used for the underlying asset's market risk at the date of issuance.

4. EMPIRICAL RESULT

With respect to the parameter estimation of the Vasicek model, we employ OLS method to evaluate the stochastic process of interest rate. It can be known from Table 3 that AR(1) coefficient test result is significant, and the regression coefficient is stable and positive. Therefore, parameters q, m and ν can be estimated from equations (14) and (15). Since the intercept of the model is statistically insignificant, the estimated value of parameter m is zero.

TABLE 3.

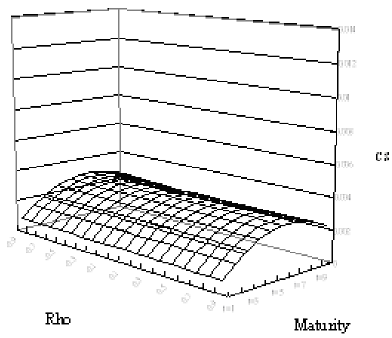
RESULT OF ESTIMATED CREDIT SPREAD FOR LISTED FIRMS

Credit Spread		N	Means	Std Dev	Minimum	Maximum	
Total		335	0.0134600	0.0039900	0.0033100	0.0333900	
	1995	6	0.0123077	0.0036074	0.0065351	0.0151945	
	1996	122	0.0133253	0.0038504	0.0033532	0.0268378	
	1997	52	0.0126848	0.0035972	0.0049555	0.0201574	
Year	1998	66	0.0130746	0.0038390	0.0033132	0.0201284	$F = 2.35^{**}$
	1999	42	0.0135477	0.0035395	0.0096100	0.0270107	
	2000	32	0.0148292	0.0052513	0.0096078	0.0333892	
	2001	15	0.0161330	0.0041660	0.0096825	0.0269903	

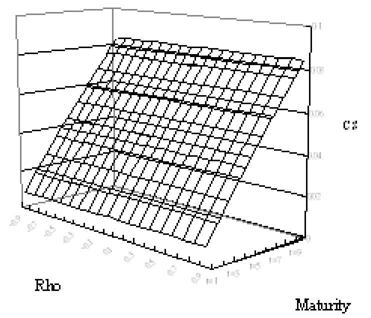
N is the number of observation, Std Dev is standard deviation and ***, **, * denote 0.01,0.05, and 0.1 significant levels, respectively.

We average interest rates of the corporate bonds of different maturity dates from 1991 to 2001. The result shows, risk premium $(r - r_f)$ equals 1.4982% and the standard deviation (δ) is 4.3997%; therefore, market price of risk (λ) equals 33.985%. It is the same method that Pindyck (1993) employs in estimating NYSE market price of risk. We then substitute the above mentioned parameter values into the valuation model, solve for nonlinear equation roots, and derive credit spread.

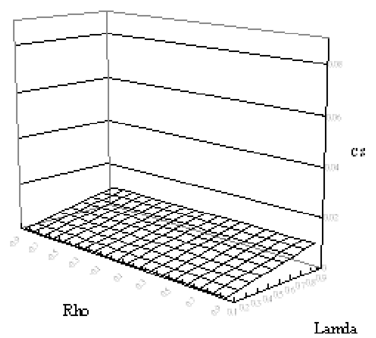
Panel A: $\lambda = 0.1$



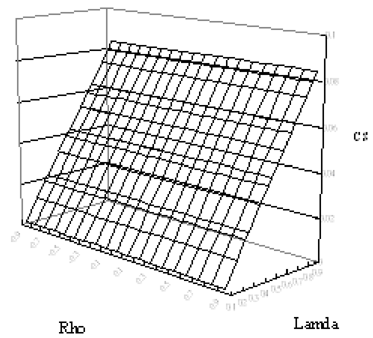
Panel B: $\lambda = 0.9$



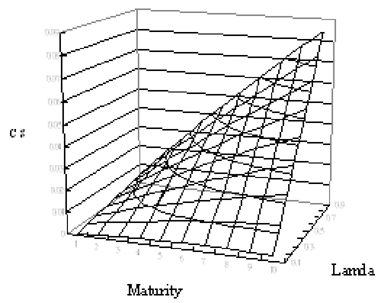
Panel C: Maturity = 1



Panel D: Maturity = 10



Panel E: $\rho = -0.9$



Panel F: $\rho = 0.9$

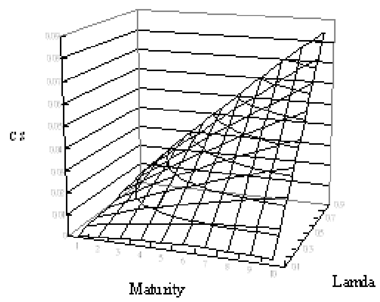


FIG. 1. SENSITIVITY ANALYSIS. The Lamda (λ), Rho (ρ), Maturity (τ) and CS are market price of risk, correlation, maturity and credit spread, respectively.

In order to understand the influence of maturity (τ), market price of risk (λ) and correlation coefficient (ρ) on credit spread, we employ a sensitivity analysis on parameters. From Figure 1, we can realize, as λ equals 0.1, under any ρ value, credit spread and maturity show a parabola relation. With increasing λ, they exhibit a pure positive correlation. The higher λ and τ are, the larger the credit spread will be. It means that the higher the market price of risk and the maturity are, the larger the credit spread will be. Yet the influence of ρ on credit spread is relatively smaller, and ρ has no effect on credit spread when τ equals one. On the other hand, if τ is longer[10], the negative correlation influence of ρ on credit spread would be more pronounced. It shows that as equity return and interest rate exhibit negative correlation, the longer the maturity term is, the larger the credit spread will be.

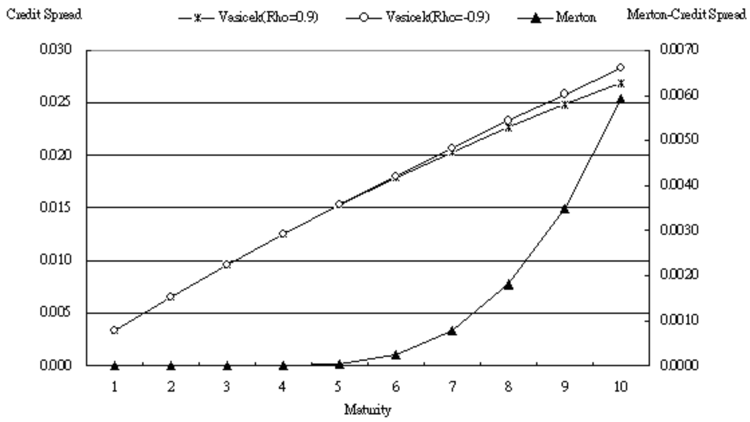


FIG. 2. A COMPARISON OF OUR MODEL WITH MERTON'S MODEL

Figure 2 provides a comparison of the credit spread in Merton's model and that in this paper. As can be seen from the diagram, since Merton's model is under the assumption of constant interest rate, its credit spread tends to be undervalued. This bears out the claim that Merton's model fails to respond to the change of interest rate risk.

Table 3 shows the statistical summary of credit spread. From the table, we know the means of credit spread for the listed firm is 1.346% in Taiwan, indicating that the risk premium is relatively low. If observed on annual basis, the credit spread tends to rise year after year since 1995 with the highest value of 1.6133% in 2001. One-factor analysis of variance (ANOVA) tests whether the annual means of credit spread are equal. The result indicates that the credit spreads of various years are statistically different

[10]When τ equals 10.

at 5% significant level with the F-statistic of 2.35. Among various industry groups, pulp and paper industry has the highest credit spread at 1.77%, while the financial industry has the lowest value at 0.65%.

In Table 4, we divide credit spread into two clusters as TSE and OTC, bank-guaranteed bonds and not bank-guaranteed bonds, and long-term and short-term, etc., to separately test whether the means of different groups are equal. The result shows an interesting phenomenon: the average credit spread of TSE is higher than that of OTC and the average credit spread of bank-guaranteed bonds is higher than that not guaranteed by bank. This finding is quite unique in the bond market.

TABLE 4.
TESTING THE DIFFERENCES BETWEEN PAIRWISE MEANS OF CREDIT SPREAD.

Cluster		N	Credit Spread	difference	T-statistic
Trading location	OTC	23	0.0114	−0.002	-2.54^{**}
	TSE	312	0.0136		
Bank guarantee	No	185	0.0128	−0.001	-3.47^{***}
	Yes	150	0.0143		
Maturity	Long-term	193	0.0163	0.0067	27.3^{***}
	Short-term	142	0.0096		
Debt ratio	High-debt	145	0.0126	−0.001	-3.41^{***}
	Low-debt	190	0.0141		
Market value	High-MV	66	0.0152	0.0022	4.16^{***}
	Low-MV	269	0.0130		

***, **, * Significant at the 0.01,0.05, and 0.1 levels, respectively.

To understand the correlation between credit spread and market risk, we perform a correlation analysis of the estimated VaR and the TEJ rating[11] with credit spread. The result in Table 5 shows, credit spread and VaR and TCRI[12] valuation grade are negatively correlated, while the total rating score and magnitude score[13] are in positive correlation with credit spread. It indicates, the lower VaR is, the better TEJ rating is, the larger the credit spread of the firm will be. It shows the credit spread of bond market in Taiwan reflects the yield rate of market risk, that is, the lower the market

[11] The year of TEJ rating and the year when financial report is applied in credit spread is the same.

[12] TCRI is the rating of the listed firms performed by TEJ. For its rating methods, one can refer to Money Watching & Credit Rating: A Bi-monthly Review.

[13] The magnitude score is the scoring conducted by TEJ concerning the operational revenue and total asset of the listed firms.

risk[14] a firm faces, the higher the corporate bond yield is, and the larger the credit spread will be.

TABLE 5.

TEST OF THE PEARSON CORRELATION COEFFICIENTS

Pearson Correlation Coefficients Prob $> \|\rho\|$ under $H_0 : \rho = 0$					
Variable	CS	VaR_eq	VaR_his	score	TEJ-TCRI
CS	1	−0.12746	−0.12260	0.28406	−0.30341
p-value		0.0381	0.0462	< .0001	< .0001
VaR_eq		1	0.91698	−0.03463	0.15585
p-value			< .0001	0.5865	0.0138
VaR_his			1	−0.02762	0.15460
p-value				0.6644	0.0146
score				1	−0.82593
p-value					< .0001
TEJ-TCRI					1

The CS is credit spread. VaR_eq is value at risk using Equally Weighted Moving Average Approaches and VaR_his is Historical Simulation Approaches: BootStrap Method. TEJ is the Taiwan Economic Journal and it is Taiwan's database company. TEJ-TCRI is the rating of the listed firms performed by TEJ.

In order to verify the correlation between credit spread and 5 variables in Merton model, we employ OLS method to validate regression coefficients using the cross-sectional data. Since credit spread implies the concept of puts, a positive correlation should exist among the volatility of underlying security, the maturity term, the debt ratio and credit spread. The result of Table 6 shows the following: coefficient tests are all positively significant indicating the higher the volatility, the longer the maturity term, the higher the debt ratio, the higher the default possibility will be and the larger the credit spread is expected. Next, the asset market value and risk-free rate are negatively correlated with credit spread. As the coefficient is negative, it follows that the higher the underlying value is, the lower its default possibility and the smaller the credit spread will be. However, the test result on asset market value is statistically insignificant.

Finally, in order to verify the finding of Duffee (1998) that a certain level of correlation should exist between an adequate pricing model and bond market as well as equity market, Longstaff and Schwartz (1995a, b) builds a regression model using credit spread, Treasury bond yield, and the equity market return. They use the annual data from 1977 to 1992 to fit

[14] VaR calculation basis is conducted by means of the value valuation in equity market, to evaluate the maximum possible loss risk in equity market, as the market risk.

TABLE 6.

REGRESSION ANALYSIS

PANEL A: REGRESSION COEFFICIENT OF MERTON'S MODEL.

Intercept	V_A	D_ratio	τ	r_f	σ_E	Rsquare	F
0.00182***	$-4.3E-11$	0.000263*	0.00271***	−0.01213***	0.00118**	0.9916	7738.15***
(9.7)	(−0.31)	(1.55)	(187.65)	(−5.02)	(2.31)		

PANEL B: REGRESSION COEFFICIENT OF DUFFEE'S HYPOTHESIS.

	Intercept	$\triangle Structure$	slope	I	Rsquare	F
Full	0.01379***	−0.06066*		−0.03729***	0.0281	4.8***
	(40.86)	(−1.64)		(−2.7)		
	0.01336***		−0.00145	−0.0348**	0.0224	3.81**
	(61.08)		(−0.87)	(−2.49)		
Not	0.01341***	−0.10241**		−0.05514***	0.0546	5.26***
Guaranteed	(27.080)	(−1.89)		(−2.71)		
by Bank	0.01266***		−0.00175	−0.05223**	0.0397	3.76**
	(40.88)		(−0.83)	(−2.54)		
	0.01429***	−0.0076		−0.01707	0.0065	0.48
Guaranteed	(33.09)	(−0.16)		(−0.97)		
by Bank	0.01423***		−0.000696	−0.01605	0.0067	0.5
	(48.78)		(−0.25)	(−0.9)		
	0.01402***	−0.06973*		−0.03464**	0.028	4.44**
TSE	(39.61)	(−1.82)		(−2.44)		
	0.01352***		−0.00151	−0.03191**	0.0201	3.17**
	(60.00)		(−0.9)	(−2.22)		
	0.01173***	−0.09494		−0.07357	0.1057	1.18
OTC	(11.34)	(−0.7)		(−1.4)		
	0.01124***		−0.00331	−0.07024	0.0853	0.93
	(13.08)		(−0.19)	(−1.31)		

***, **, * Significant at the 0.01,0.05, and 0.1 levels, respectively.

the following regression model:

$$\triangle CS_t = \beta_0 + \beta_1 \Delta Yield_t + \beta_2 I_t + e_t \quad (19)$$

where $\triangle CS_t$ is the change of credit spread, $\triangle Yield_t$ denotes the change in 30-year Treasury yield rate, I_t denotes index return of equity market, β_0, β_1 , β_2 and e are regression coefficients and the error term. The resulting coefficients are significantly negative, indicating an inverse correlation between corporate bond yield and Treasury bond as well as securities yield. Duffee (1998) employs the grade classification of American bond market to verify the relationship between credit spread and term structure of interest rate slope of Treasury bond; and the relationship is also negative. In addition, the lower the grade is (Baa grade), the larger the effect will be. That is, the larger the credit spread is, the greater the coefficient's negative influence will be.

According to the studies of Litterman and Scheinkman (1991) and Chen and Scott(1993), the majority of risk-free rates and term structure of interest rates can be substituted by the level and slope of bond interest rates. Therefore, in order to verify whether the bond market of Taiwan is provided with such a correlation, the term structure of interest rates is represented by the long-term and short-term interest rate difference of the bond with Repurchase-Resale agreement ($\triangle Structure$) and the slope of long term bond interest rate (slope) measuring government-bond yield rate variation. The weighted index return rate is applied to the listing firm in TSE or ROSE market as the equity market index (I).

$$CS_{t_i} = \beta_0 + \beta_1 \triangle Structure_{t_i} + \beta_2 I_{t_i} + e_{t_i} \quad (20)$$

$$CS_{t_i} = \beta_0 + \beta_1 Slope_{t_i} + \beta_2 I_{t_i} + e_{t_i} \quad (21)$$

Theoretically speaking, as the risk-free and term structure of interest rate is of the upward type, the asset value of firm is expected to rise, but the default possibility of the firm is expected to decrease, and the credit spread of credit risk would reduce, implying coefficient $\beta_1 < 0$. Secondly, as the equity value of firm rises, its default possibility would reduce as would the credit spread. Therefore, it represents a negative correlation between the share price of weighted index and credit spread of equity market (coefficient $\beta_2 < 0$).

The result of Table 6 shows that negative regression coefficients suggest the upward bond yield curve. The higher the rate of equity return is, the smaller credit spread will be. However, the regression coefficient of variable *Slope* is statistically insignificant. From the table, we also observe, in the regression analysis, TSE group and the not-guaranteed by bank group are statistically significant, while the others are statistically insignificant.

5. CONCLUSION

The focus of the paper is to evaluate the risks faced by the listed firms in issuing ordinary corporate bond in the fixed income market of Taiwan, along with interest rate risk and the implied or contingent claim of equity holders. We imbed the Vasicek (1977) model into the valuation model of Merton (1973) and employ the Newton-Raphson numerical method together with the inverse quadratic interpolation and bisection technique of Dekker (1967) to obtain nonlinear roots, and finally derive the credit spread of firms. Meanwhile, we also apply the VaR technique for the valuation on the market risk of firms and compare to TEJ rating information for further analysis of the credit spread.

In our model, we assume that two factors, asset value and short term interest rate, follow stochastic processes. The parameters in stochastic processes are estimated first by OLS method before calculating credit spread together with market price of risk (lambda) and correlation coefficient (rho). A sensitivity analysis is conducted to understand the impact of parameters on credit spread. It is found that the higher the market price of risk and the longer the maturity (tau) is, the larger credit spread will be. As the maturity date becomes longer, the influence of market price of risk on credit spread becomes larger too. There is a negative correlation between correlation coefficient (rho) and credit spread. As the maturity (tau) becomes shorter, there is no correlation between correlation coefficient (rho) and credit spread. Therefore, we can realize that, as the market price of risk (lambda) faced by each firm becomes higher, the correlation coefficient (rho) is smaller, the maturity (tau) longer, the larger the credit spread is expected to be.

It is found that the average credit spread of the listed firms in Taiwan is relatively low at 1.346%. Perhaps investors in Taiwan consider corporate bonds equivalent to bank saving accounts that are paid at risk-free interest rate. During our sample period, the credit spread in 2001 is the highest. Credit spread of firms listed in TSE is higher than those listed in OTC. Credit spread of firms with bank guarantee is higher than those without. It is ironic that investors tend to require a higher premium for corporate bonds of firms listed on a well-known exchange and with bank guarantee. It seems that investors in Taiwan perceive bond risk exposure situations differently from investors in advanced markets.

Next, the correlation coefficients of both VaR and TCRI with credit spread are negatively and statistically significant, while that between VaR and TCRI is positive, indicating the existence of negative correlation between credit spread and market risk in the bond market of Taiwan.

The empirical research of cross-sectional regression coefficient supports that the long-term and short-term interest rate deviation of government-bond (yield curve) and credit spread are negatively correlated. The index return of equity market and credit spread are also negatively correlated. This result not only agrees to the conclusion of Longstaff and Schwartz (1995a, b) and Duffee (1998), but also conforms to Duffee's hypothesis about a good valuation model. However, no verification can be obtained in long-term government-bond interest rate deviation. In testing clusters of regression coefficients, the TSE group and the guaranteed by bank group are statistically significant.

This paper incorporates interest rate risk into the valuation foundation of contingent claim, successfully performs a comprehensive valuation for the debt risks encountered by the listed firms in Taiwan. It also addresses the weakness of the models with only theoretical interest in the past or simulations done with assumed parameter methods. We apply available market information in estimating parameters. Thus, the valuation model proves to be more applicable for policy implementation.

REFERENCES

Black, F. and M. Scholes, 1973. The pricing of options and corporate liabilities. *Journal of Political Economy* **81**, 637-659.

Chen R.R. and L. Scott, 1993. Maximum likelihood estimation for a multifactor equilibrium model of the term structure of interest rates. *Journal of Fixed Income* **3**, 14-31.

Cox, J.C, J.E. Ingersoll, and S.A. Ross, 1985. A theory of the term structure of interest rates. *Econometrica* **53**, 385-407.

Cox, J.C. and M. Rubinstein, 1985. *Options Markets.* Englewood Cliffs, N.J., Prentice Hall.

Dekker, T.J, 1967. Finding a zero by means of successive linear interpolation. *Constructive Aspects and Fundamental Theorem of Algebra.* John Wiley & Sons Ltd.

Duffee, G.R., 1998. The relation between treasury yields and corporate bond yield spreads. *Journal of Finance* **53**, 2225-2241.

Duffie, D. and J. Pan, 1997. An overview of value at risk. *Journal of Derivatives* **4**, 7-49.

Efron, B., 1979. Bootstrap methods: Another look at the jackknife. *Annals of Statistics* **7**, 1-26.

Hull, J. and A. White, 1998. Value at risk when daily changes in market variables are not normal distribution. *Journal of Derivatives* **Spring**, 9-19.

Jorion, P., 1997. Value at risk: The new benchmark for controlling market risk. IRWIN.

King, R., 1986. Convertible bond valuation: An empirical test. *Journal of Financial Research* **9**, 53-69.

Litterman, R. and J. Scheinkman, 1991. Common factors affecting bond returns. *Journal of Fixed Income* **1**, 54-61

Longstaff, F.A. and E.S. Schwartz, 1995a. A simple approach to valuing risky fixed and floating rate debt. *Journal of Finance* **50**, 789-819.

Longstaff, F.A. and E.S. Schwartz, 1995b. Valuing credit derivatives. *Journal of Fixed Income* **5**, 6-12.

Merton, R.C, 1973. Theory of rational option pricing. *Bell Journal of Economics and Management Science* **4**, 141-183.

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

Morgan, J.P., 1996. *Risk Metrics TM-Technical Document.* 4th ed. Morgan Guaranty Trust Company. New YorkJ. P. Morgan bank.

Pindyck, R., 1993. Investments of uncertain cost. *Journal of Financial Economics* **34**, 53-76.

Rabinovitch, R., 1989. Pricing stock and bond options when default-free rate is stochastic. *Journal of Financial and Quantitative Analysis* **24**, 447-457.

Vasicek, O.A, 1977. An equilibrium characterization of the term structure. *Journal of Financial Economics* **5**, 177-188.