การประเมินโอกาสในการไม่จ่ายหนี้ของบริษัทในตลาดหุ้นกู้ของประเทศไทย

นางสาวกมลวรรณ สุชาตานนท์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาการเงิน ภาควิชาการธนาคารและการเงิน

คณะพาณิชยศาสตร์และการบัญชี จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2551

ASSESSING PROBABILITIES OF DEFAULT IN
THAI CORPORATE BOND MARKET

Miss.Kamonwan Sujatanond

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Finance
Department of Banking and Finance
Faculty of Commerce and Accountancy
Chulalongkorn University
Acadamic Year 2008

Thesis Title	ASSESSING PROBABILITIES OF DEFAULT IN THAI CORPORATE BOND MARKET
By	Miss. Kamonwan Sujatanond
Field of study	Finance
Thesis Advisor	Associate Professor Sunti Tirapat, Ph.D.

Accepted by the Faculty of Commerce and Accountancy, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

....Dean of the Faculty of Commerce and Accountancy
(Associate Professor Annop Tanlamai, Ph.D.)

THESIS COMMITTEE

....Chairman
(Anant Chiarawongse, Ph.D.)

....Thesis Advisor
(Associate Professor Sunti Tirapat, Ph.D.)

....Committee
(Ruttachai Seelajaroen, Ph.D.)

นางสาวกมลวรรณ สุชาตานนท์ : การประเมินโอกาสในการไม่จ่ายหนี้ของบริษัทในตลาดหุ้นกู้ของประเทศไทย (ASSESSING PROBABILITIES OF DEFAULT IN THAI CORPORATE BOND MARKET) อ. ที่ปรึกษา: รศ.ดร. สันติ ถิรพัฒน์, 64 หน้า.

วิทยานิพนธ์นี้ได้นำตัวแบบโครงสร้าง (Structural form) ซึ่งประกอบไปด้วย ตัวแบบของ Merton ตัวแบบของ Black และ Cox ตัวแบบของ Longstaff และ Schwartz และตัวแบบลดรูป (Reduced-form) ของ Jarrow และ Turnbull ซึ่งสามารถแยกออกเป็น ฟังก์ชัน Hazard คงที่ (Constant Hazard Function) ฟังก์ชัน Hazard แบบเส้นตรง (Linear Hazard Function) และ ฟังก์ชัน Hazard แบบเส้นโค้ง (Quadratic Hazard Function) มาประเมินโอกาสในการไม่จ่ายหนี้ของบริษัทในตลาดหุ้นกู้ของประเทศไทย การทดสอบนี้ได้ใช้ราคาหุ้นกู้ของบริษัทที่จดทะเบียนในตลาดพันธบัตรและตลาดหลักทรัพย์แห่งประเทศไทย ระหว่างปี ค.ศ.2001-2006 แล้วนำโอกาสในการไม่จ่ายหนี้นั้นมาทำนายราคาหุ้นกู้ในอีก 1 เดือนและ 3 เดือนข้างหน้า เทียบกับราคาในตลาด จากนั้นหาการกระจายตัวของความผิดพลาดของราคา ซึ่งผลที่ได้จากการเปรียบเทียบโอกาสในการไม่จ่ายหนี้ของบริษัทของทั้ง 6 ตัวแบบ ปรากฏว่า ค่าเฉลี่ยของโอกาสในการไม่จ่ายหนี้ที่ได้จากตัวแบบโครงสร้างมีค่าต่ำกว่าที่ได้จากตัวแบบลดรูป โดยตัวแบบของ Mertonให้ค่าต่ำที่สุด และค่าเฉลี่ยของโอกาสในการไม่จ่ายหนี้ที่ได้จากตัวแบบลดรูปที่มีฟังก์ชัน Hazard คงที่มีค่าสูงที่สุด ส่วนการเปรียบเทียบค่าเฉลี่ยการกระจายตัวของความผิดพลาดของราคาในอีก 1 เดือนข้างหน้าปรากฏว่า ตัวแบบลดรูปที่มีฟังก์ชัน Hazard คงที่ให้ค่าต่ำที่สุด ตามมาด้วยลำดับดังต่อไปนี้ ตัวแบบลดรูปที่มีฟังก์ชัน Hazard แบบเส้นตรง ตัวแบบลดรูปที่มีฟังก์ชัน Hazard แบบเส้นโค้ง ตามมาด้วยตัวแบบโครงสร้างของ Merton ตัวแบบของ Black และ Cox ส่วนค่าที่ได้จากตัวแบบของ Longstaff และ Schwartz มีค่าสูงที่สุด สำหรับการเปรียบเทียบค่าเฉลี่ยการกระจายตัวของความผิดพลาดของราคาในอีก 3 เดือนข้างหน้าปรากฏว่า ผลที่ออกมาก็เป็นไปในทางเดียวกันกับการเปรียบเทียบค่าเฉลี่ยการกระจายตัวของความผิดพลาดของราคาในอีก 1 เดือนข้างหน้า คือ โอกาสในการไม่จ่ายหนี้ที่คำนวณได้จากตัวแบบลดรูป มีความสามารถในการทำนายราคาหุ้นกู้ในอนาคตได้ดีกว่าโอกาสในการไม่จ่ายหนี้ที่คำนวณได้จากตัวแบบโครงสร้าง

ภาควิชา การธนาคารและการเงิน ลายมือชื่อนิสิต กมลวรรณ สุชาตานนท์

สาขาวิชา การเงิน ลายมือชื่ออาจารย์ที่ปรึกษา สันติ

ปีการศึกษา 2551

4882502026: MAJOR FINANCE

KEYWORD: STRUCTURAL MODEL/ REDUCED-FORM MODEL / CREDIT RISK

KAMONWAN SUJATANOND: ASSESSING PROBABILITIES OF DEFAULT IN THAI CORPORATE BOND MARKET. THESIS ADVISOR: ASSOC. PROF. SUNTI TIRAPAT, PH.D., 64 pp.

This study employs the structural models i.e. Merton, Black and Cox, Longstaff and Schwartz, and reduced-form models, i.e. Jarrow and Turnbull; Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model to assess the probabilities of default in the Thai corporate bond market. The study covers corporate bonds listed on Thai Bond Market Association (ThaiBMA) and Stock Exchange of Thailand (SET) from January 2001 to June 2006. We then compare the accuracy of default probabilities of each model by using probabilities of default to predict corporate bond price in next 1-month and 3-months. Thus, calculate the value of Mean Absolute Percentage Error (MAPE). Of all the result comparing probability of default value from six models, the average probabilities of default from structural form is lower than from reduced-form in Merton Model which gives the lowest value. For average probabilities of default from reduced-form models: Constant Hazard Function model has highest range of all. Comparing MAPE, forecast price in the next 1- month shows that MAPE from reduced-form: Constant Hazard Function model gives lowest value followed by MAPE from reduced-form: Linear Hazard Function model, reduced-form: Quadratic Hazard Function Model, Merton model, The Black and Cox model. For MAPE from Longstaff and Schwartz model has highest value. In MAPE in order to forecast price in the next 3-months, the results correspond with the forecasted price in the next 1-month. Since the mean of MAPE obtained from reduced-form model has lower value than the mean of MAPE obtained from structural form model for all firms. This infers that the probability of default from the reduced-form model is more effective in predicting the bond price than calculated from the structural model.

Department of Banking and Finance | Student's signature..............................

Field of study Finance | Advisor's signature..............................

Academic year 2008

Acknowledgements

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. I want to thank the Associated Professor Dr. Sunti Tirapat, for giving me permission to commence this thesis in the first instance. I have furthermore to thank Dr. Anant Chiarawongse and Dr. Ruttachai Seelajaroen, my project committees for their worthy suggestion and criticism.

I would like to give my special thanks to my friend especially Chaipakorn J. Kunopakorn for supporting in my technical field and valuable advise. Thanks to my old-friends Suchada Chatturaputpitak and Nitsinee Siritatsawas for generous help and encouragement in all time of research. My former colleagues in MSF program, Thammasat Univeristy, and from Market Risk Department at Kasikorn Bank whose help, stimulating suggestions, patient and valuable advice enabled me to complete this work.

Lastly, I would like to give my deepest gratitude to my beloved parents and my older sister for their inspiration, encouragement and dedicated supports given to me throughout my study.

Table of Contents

List of Tables

CHAPTER I

INTRODUCTION

1.1 Background and Problem Review

The most important risk in corporate bond is credit risk. Credit risk is composed of three major parts; Exposure at default (EAD), Probability of default (PD), and Loss given default (LGD). Probability of default is the most important component to measure credit risk. There are two ways to measure the probability of default, via usage of structural model and reduced-form model. There have been many arguments from both academicians and practitioners to find the most appropriate model in measuring the probability of default. This, therefore, becomes the main motivation of this research.

In structural model, structural or endogenous variable are used to determine the time of default. The first structural model was developed by Merton. The Merton's Model (1974) states that firm should default only when the firm's asset value is below outstanding debt. Later, Black and Cox (1976) introduced another approach for structural model which states that a firm defaults if the firm's asset value is below a certain threshold. This implies that default can occur at anytime. In addition, interest rate is a significant basis for structural models including non-stochastic processes (Black and Cox (1976), Geske (1977), and Leland and Toft (1996)), and stochastic processes (Ronn and Verma (1986), Kim, Ramaswamy and Sundaresan (1993), Nielsen et al. (1993), Longstaff and Schwartz (1995), Briys and de Varenne (1997), and Hsu, Saà-Requejo and Santa-Clara (2004)). On the other hand, the reduced-form model uses risk-neutral pricing of contingent claims. The model also has exogenous random variables in the form of time of default or other credit events. The process is done by parameterizing the amount where the owner of a defaulted claim receives upon default. Then the model is calibrated to market data. Finally, credit derivatives can be priced by using calibrated model. Artzner and Delbaen (1995), Jarrow and Turnbull (1995), Madan and Unal (1995), and Duffie, Schroder and Skiadas (1996) are the first to develop reduced-form models. Duffie and Lando (1995) show that with incomplete accounting information, a reduced-form model can also be obtained from a structural model. The simplest form among several types of reduced-form models contains intensity for the arrival of default or credit migration, and recovery is an exogenous process. Jarrow, Lando and Turnbull (1997) assume constant intensity for credit migration, while Litterman and Iban (1991) use a Markov chain model of credit migration. Duffie et al. (1999) and Lando (1998) apply a random process for the intensity of default.

The difference between the two models is that structural models are closer to models that use fundamentals for pricing, while the reduced-form models are closer to models that depend on relative pricing. The structural model is most applicable and useful for practitioners in the credit portfolio and credit risk management fields. The model, in economic interpretation, facilitates consistent discussion according to different credit risk exposures. However, it should be noticed that credit risk modeling researches mostly focus on reduced-form models of default because they are less complicated. Moreover, given its mathematical tractability, many of the credit trading practitioners have tended to gravitate towards the modeling approach. Apart from not compromising with the theoretical issue of complete information, the reduced-form model also has insufficient economic rationale to define the nature of the default process. In another way, reduced-form models are characterized by flexibility in their functional form. However, the flexibility can be either good or bad. It can help narrowing collection of credit spreads. On the other hand, this flexibility can result in a poor out-of-sample predictive ability in a model with strong in-the-sample fitting properties. Since the reduced-form models do not explain clearly why firm defaults, it is challenging to scrutinize a way to develop performance of these models.

The main objective of this paper is to compare the probabilities of default from four different models; the Merton, the Black and Cox, Longstaff and Schwartz structural model, and a reduced-form. The original quantitative structural approach for credit risk modeling is represented by the Merton model. Meanwhile, the Black and Cox model developed the Black and Cox Models, which is an extension of the Merton's model but with assumption that firms may default at any time instead of at the maturity date of the debt only. Longstaff and Schwartz structural model extends Black and Cox by using Vasicek stochastic interest rates model. A reduced-form approach is represented by Jarrow and Turnbull model, addressing the problems of parameter stability.

As a result, my research question is, given the four models, which model is the best model, for academicians and practitioners, for discrimination of defaulters from non-defaulters and for investigation of the relative value.

1.2 Statement of Problem / Research Questions

This study employs the structural models and the reduced-form models to estimate probabilities of default in the Thai bond market. Which model is appropriate to evaluate probabilities of default in Thailand?

1.3 Objective of the Study

- To apply three structural models, i.e. Merton (1974), Black and Cox (1976), Longstaff and Schwartz (1995), and reduced-form models, i.e. Jarrow and Turnbull (1995) to assess probabilities of default from Thai equity markets and bond markets.

- To compare the accuracy of default probabilities of each model.

1.4 Scope of the Study

The study covers corporate bonds listed with the Thai Bond Market Association (ThaiBMA) from January 2001 to June 2006, and of which the issued firm in the Stock Exchange of Thailand (SET).

1.5 Contribution

In Thailand, there has been no research about the probability of default and no research in comparing between structural and reduced-form model. Comparison between structural and reduced-form model in this paper can generate the best model suitable for Thai corporate bond market in order to assess the probability of default. If each model gives no different result, the investors should the use the reduced-form model since it is easier to evaluate than the other one.

In addition, from prior literature, the best model it tested on data of developed markets (for the example, Arora, Bohn, and Zhu (2005)). However, since the emerging markets are different from developed markets in many views e.g. the limited credit derivatives data, the model that is claimed to be the most suitable model for developed markets may not appropriate for emerging markets. Consequently, this study attempts to find the most suitable model for emerging markets. It should be the basis for further study about credit risk and practitioner in emerging market.

CHAPTER II

LITERATURE REVIEW

This section discusses related empirical studies of each structural model and reduced-form model.

2.1 Empirical Study from Structural Model

Huang and Huang (2002) use several structural models to predict yield spreads. The certain target variables which are leverage, equity premium, recovery rate, and cumulative default probability at a single time horizon, are matched by calibrating inputs, including asset volatility for each model. In base case, they use ten-year horizon; however, they also consider a four-year horizon separately. Consequently, inputs such as asset volatility vary across the models in the research, even though the observed default frequencies over a common time period are matched. Given this calibration, the study shows that the models result fairly comparable predictions on yield spread. The conclusion is that additional factors; for instance, illiquidity and taxes are significant in describing market yield spreads.

Cooper and Davydenko (2004) also applied Merton’s (1974) approach. Given information on leverage, equity volatility, and equity risk premium, on the contrary to the Huang and Huang, they forecast expected default losses on any corporate bond based on its current yield spread rather than calibrate on past default probability to predict yield spreads. They concluded that the proper measure of a bond’s yield spread for calibrating asset volatility must be the spread between that bond and an otherwise-similar AAA-rated bond in order to derive realistic numbers, instead of the yield spread between that bond and a Treasury bond of the same maturity.

Leland (2004) compared several structural models' abilities to predict observed default rates on corporate bonds. Each model does predict different value of default probabilities when maturity, asset volatility, or default costs are changed, ceteris paribus. At short time horizons, both endogenous and exogenous models underestimated the observed yield spread because of liquidity differences. However, there is no explanation of the underestimated predicted default frequencies.

2.2 Empirical Study from Reduced-Form Model

Janosi, Jarrow, and Yildirim (2003) estimate default probabilities implicit in equity prices by using a reduced-form credit risk model. The study covers the period from May 1991 to March 1997. For a cross-section of firms, a time-series regression of monthly equity returns is estimated. It is possible to infer the firm's probability of default implicit in equity returns, they conclude. Nevertheless, the existence of price bubbles and the annoyance in modeling equity price risk premium confound the estimation of these default probabilities, generating potentially biased estimates with large standard errors. The result is confirmed by comparing the default intensities with those obtained from historical data or implicitly from debt prices.

In empirical study of Andritzky (2003), Argentine US-Dollar Eurobonds during the Argentine crisis from 2000 to 2002 are used to calculate implied recovery rates and implied default probabilities in a risk neutral setting. His model relates to Jarrow and Turnbull (1995) (Reduced-form model) in the sense that the hazard rate is modeled as risk neutral probability using the Gumbel probability distribution. He concludes that implied probabilities roughly take five levels, allowing the time frame to be cut and analyzed into five periods. Jumps between the levels are associated with rating cuts in most cases. In 2000, the estimated location parameter of the Gamble distribution makes a default event appear most probable after four to five years.

Berardi, Ciraolo, and Trova (2004) studied two main areas, 1) the computation of risk neutral default probabilities implicit in emerging markets bond prices and 2) the impact on portfolio risks and returns of expected changes in default probability. By using a reduced-form model for the pricing of bonds that can default, they extracted the default probabilities from global bond prices of twelve countries. The estimated default probabilities exhibit the relationship between actual crisis observed in the market and the sample period.

2.3 Empirical Study from Comparing Two Models

Jarrow and Protter (2004) compare the two different model approaches that will be referred to as the structural models and the reduced-form credit risk models, derived from information based perspective. Furthermore, they present the differences between these two models. These can be characterized in terms of the assumed information which is commonly known by the modeler. Beginning with the structural models, they assume that the modeler has the same information set as the firm's manager who has complete information of all the firm's assets and liabilities. In most situations, this information leads to the predictable default time. In contrast, the reduced-form models assume that the modeler has the same information set as the market which has incomplete information of the firm's condition. In most cases, this imperfect information results in the inaccessible default time. As such, they argue that the key distinction between structural and reduced-form models is not predictability or inaccessibility of default time, but whether information set is observable by the market or not. Consequently, the reduced-form models are the preferred methodology for pricing and hedging.

Arora, Bohn, and Zhu (2005) compare two structural models of credit risk, which are basic Merton and Vasicek-Kealhofer (VK), with reduced-form model (Hull-White (HW)) of credit risk. To compare these three models, firstly, they test the Merton and VK models' ability to discriminate defaulters from non-defaulters based on default probabilities initiated from information available in the equity market. Secondly, they test the ability of the HW model to discriminate defaulters from non-defaulters; and the default probabilities are initiated from information in bond market. Finally, they test whether each model has ability to predict spreads in the credit default swap (CDS) market, which can be an indication of each model's strength as a relative value analysis tool. The goal of this paper is to help participants in the market determine the most useful model based on their objectives. They conclude that a basic Merton model is not good enough on the structural side. However an appropriate modification to the framework will make a difference. For reduced-form side, the quality and quantity of data make a difference.

Yalm Gunduz and Marliese Uhrig-Homburg (2005) study the structural form model and reduced-form model. In order to decide for the best credit risk modeling framework, this study computes pricing error of Credit Default Swap. The study uses out-of-sample method for both cross-sectional and time series to prediction error. With their results, first regard with the default time, the study shows that Merton model, the structural form model, estimates the higher default probabilities on average than from the reduced-form model. Second regard with the interest rate, the study shows that Merton model includes interest rate variable in estimating the probability of default but the reduced-form model exclude this variable. As their studies show that of all four cases with cross-sectional method, Merton model reveals lower absolute prediction errors only one case. While in next 1 day time series method, reduced-form model reveals three out of four cases. Moreover, in the next 5 day and next 10 day prediction, only two out of six cases that Merton is matched while the reduced-form model is better with three cases, leaving one in insignificant with neither models. Another highlight from this paper is the resource of data. Gunduz and Uhrig-Homburg uses CDS data in out-of-sample prediction and the estimation because it benefits in predicting the probability of default that concentrate only on credit risk not liquidity or other non-default premium.

CHAPTER III

DATA AND METHODOLOGY

3.1 Data

The bond data is collected from the Thai Bond Market Association (ThaiBMA) since January 2001 to June 2006. There are only monthly quoted prices available due to the low liquidity of Thai bond market. The stock data is collected from Stock Exchange of Thailand (SET) from January 2001 to June 2006. The type of the data matches with that of the bond data. For the risk-free interest rates, we use zero coupon yield curve from the Thai Bond Market Association (ThaiBMA) since 2001 to 2006

3.2 Research Hypotheses

Among the four estimations of probabilities of default in Thai Corporate bond market, the reduced-form model provides the most accuracy.

3.3 Methodology

In this section, we first define and estimate parameters for these models. There are several parameters required from structural models. Coupon rate (c) and maturity (T) are observable. We cannot observe firm value (V), face value (F) and recovery rate (ω) but these can be implied from total liabilities and market value of equities. The other parameters, asset return volatility (σ_{υ}), risk free rate (r), correlation between V and r (ρ), have to be estimated. The estimation process will be described as following.

From the empirical study in U.S. bond market of Keenan, Shtogrin, and Sobehart (1999), the average bond recovery rate is equal to 51.31% of face value. Because there is no such empirical study in Thai bond market that could help us determines the recovery rate, we also use recovery rate at 51.31% in base case even though it can vary to any value.

3.3.1 Parameter Estimation

Asset Return Volatility

Although the asset return volatility is unobservable, we can imply it from historical equity return volatility (σ_e). So, σ_v can be estimated by using the relationship $\sigma_e = \sigma_v \cdot \frac{V_t}{S_t} \cdot \frac{\partial S_t}{\partial V_t}$, where σ_e base on historical 60-days volatility, S_t denotes the market value of equity at time t. The $\partial S_t / \partial V_t$ can use $N(d_1)$ as proxy,

where
$$d_1 = \frac{\ln\left(\frac{e^{r(T-t)}V_t}{D}\right) + \frac{1}{2}\sigma_v^2 (T-t)}{\sigma_v \sqrt{T-t}}$$

Then, numerical method is used to find σ_v by iteration σ_v and makes the equation equally.

Interest Rate Parameters

Let $y\,(t, T; \Theta_r)$ denote the spot rate at time t with term equal to $T - t$ characterized by parameter set $\Theta_r = (\alpha, \beta, \sigma_r, r_t)$ in Vasicek model. To fit the model to interest rates on day t, one chooses parameters in Θ_r to minimize the sum of errors squared, where the error is measured as the deviation between the model price and the market price

In the Vasicek (1977) model,

$$y(t, T, \Theta_r) = \frac{-\ln(A(t,T)) + r_t B(t,T)}{(T-t)} \qquad (6)$$

$$A(t,T) = \exp\left[(B(t,T) - T + t)\left(\frac{\alpha}{\beta} - \frac{\sigma_r^2}{2\beta^2}\right) - \frac{(\sigma_r B(t,T))^2}{4\beta}\right] \qquad (7)$$

$$B(t,T) = \frac{1}{\beta}(1 - e^{-\beta(T-t)}) \tag{8}$$

where $\Theta_r = (\alpha, \beta, \sigma_r, r_t)$. The Vasicek model will be applied in the Longstaff and Schwartz model.

<u>Choice of hazard rate</u>

Three different hazard processes are contemplated and deterministic. One of them is constant and the other two are time-dependent.

	Hazard rate $\Lambda(t,T)$
Constant	λ_0
Linear	$\lambda_0 + \lambda_1 t$
Quadratic	$\lambda_0 + \lambda_1 t + \lambda_2 t^2$

3.3.2 Merton Model

In Merton's models, the firm's capital structure is assumed to be contained with equity and a zero-coupon bond that has maturity T and face value of debt D. Value of equity and value of zero-coupon bond at time t are denoted by E_t and $z\ (t,T)$ respectively, for $0 \leq t \leq T$. The asset value (V_t), by definition, is the sum of equity and debt values. Due to these assumptions, equity is demonstrate a vanilla European call option on the assets with maturity T and strike price of D. To calculate, if at maturity the asset value is equal to the face value of debt value, then there is no default and shareholders would receive V_t -D. On the other hand, if the asset value is less than the face value of debt, then default occurs and the shareholders lose their money, whereas the bondholders take control of the firm.

The asset value of firm is assumed to follow a diffusion process given by

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

Where σ_v is the (relative) asset volatility and W_t is a Standard Brownian Motion. Since we are working under the risk neutral probability measure, the drift term of the asset value process is given by the risk-free instantaneous interest rate *(r)*.

The payoffs to equityholders and bondholders at time T under the assumptions of this model are respectively, $\max\{V_t - D, 0\}$ and $V_t - E_t$, i.e.

$$E_t = \max\{V_t - D, 0\} \tag{2}$$

$$z(T,T) = V_t - E_t \tag{3}$$

Applying the Black-Scholes pricing formula, the value of equity at time t ($0 \le t \le T$) is given by

$$E_t(V_t, \sigma_v, T-t) = V_t N(d_1) - De^{-r(T-t)} N(d_2) \tag{4}$$

Where *N(.)* is the distribution function of a standard normal random variable, d_1 and d_2 are given by

$$d_1 = \frac{\ln\left(\frac{e^{r(T-t)}V_t}{D}\right) + \frac{1}{2}\sigma_v^2 (T-t)}{\sigma_v \sqrt{T-t}} \tag{5}$$

$$d_2 = d_1 - \sigma_v \sqrt{T-t} \tag{6}$$

The probability of default at time T is given by

$$\mathrm{P}[V_t < D] = N(-d_2) \tag{7}$$

Therefore, the value of the debt at time t is $z(t,T) = V_t - E_t$.

The disadvantage of using the Merton's model is that there is limitation in the default time to maturity of debt. This could make the possibility of an early default inconsistent either the value of firm is before the maturity of the debt. If the values of firm fall below the minimal levels before maturity of debt but recover and meet the payment at maturity, there is no appropriate solution from Merton's model. Moreover the structure of firm's liabilities is actually more complicated than a zero-coupon bond. Thus, it is difficult to do any transformation on the model.

3.3.3 Black and Cox Model

In 1976, Black and Cox developed the First Passage Model which is an extension of the Merton's model. In this new model, the firms may have default at any time instead of at the maturity date of the debt only.

Consider, as in the previous section, that the dynamics of the firm's asset value under the risk neutral probability are given by the diffusion process

$$dV_t = rV_t dt + \sigma_v V_t dW_t \tag{8}$$

And that there exists a lower level of the asset value so that the firm defaults once it reaches this level. Although Black and Cox consider a time dependent default threshold, we assume K as a constant default threshold and $K > 0$. If we are at time $t \geq 0$ and default has not been triggered yet and $V_t > K$, then the time of default τ is given by

$$\tau = \inf\left\{ s \geq t \mid V_s \leq K \right\} \tag{9}$$

where for $0 < s < T$.

Using the properties of the Brownian motion, in particular the reflection principle, we can infer the default probability from time *t* to time *T*:

$$P[\tau \leq T | \tau > t] = N(h_1) + \exp\left\{2\left(r - \frac{\sigma_v^2}{2}\right)\ln\left(\frac{K}{V_t}\right)\frac{1}{\sigma_v^2}\right\}N(h_2) \tag{10}$$

where

$$h_1 = \frac{\ln\left(\frac{K}{e^{r(T-t)}V_t}\right) + \frac{\sigma_v^2}{2}(T-t)}{\sigma_v\sqrt{T-t}} \tag{11}$$

$$h_2 = h_1 - \sigma_v\sqrt{T-t} \tag{12}$$

3.3.4 Longstaff and Schwartz Model

Longstaff and Schwartz extend the Black and Cox Model by issuing stochastic interest rates. The correlation between asset value and Vasicek process for the interest rates is stated by Nielsen et al. (1993), and Longstaff and Schwartz (1995). This can be written as the set of equations below.

Let V_t be the total value of the firm's assets. The dynamics of V_t are given by

$$dV_t = \mu V_t dt + \sigma_v V_t dW_t, \tag{13}$$

where W_t is a standard Wiener Process.

Let r_t denote the risk-free interest rate. The dynamics of r_t are given by

$$dr_t = (\alpha - \beta r_t)dt + \sigma_r d\overline{W_t} \tag{14}$$

where a and b are constants and $\overline{W_t}$ is also a standard Wiener Process.

The relationship between dW_t and $d\overline{W_t}$ can be described as follow

$$d\overline{W_t}\, dW_t = \rho\, dt \tag{15}$$

The correlation coefficient ρ between asset returns and interest rates in this model is approximated by the correlation between equity return and changes in interest rates (3-month T-Bill).

Longstaff and Schwartz also refer the level of default threshold in their analysis, using the ratio of V_t to K instead of the actual value of K. This method, however, provides a more complexity with no additional useful analysis for the valuation of risky debt.

Let $Q(t_0,T)$ denote the probability under the risk neutral measure that a default occurs. The term $Q(t_0,T)$ is the limit of $Q(t_0,T,n)$ as $n \to \infty$. However, the convergence is quite rapid. Numerical simulations show that setting n = 200, the result in value of $Q(t_0,T)$ and $Q(t_0,T,n)$ are virtually indistinguishable. The resultant formulas are shown as below.

$$Q(t_0,T,n) = \sum_{i=1}^{n} q_i \tag{16}$$

for $q_1 = N(a_1)$, $q_i = N(a_i) - \sum_{j=1}^{i-1} q_j N(b_{ij})$; $i = 2,3,\ldots,n$ and $j = i-1$

where

$$a_i = \frac{-\ln X - M(iT/n,T)}{\sqrt{S(iT/n)}} \tag{17}$$

$$b_{ij} = \frac{M(jT/n,T) - M(iT/n,T)}{\sqrt{S(iT/n) - S(jT/n)}} \tag{18}$$

and where

$$S(t)=\left(\frac{\rho\sigma_v\sigma_r}{\beta}+\frac{\sigma_r^2}{\beta^2}+\sigma_v^2\right)t-\left(\frac{\rho\sigma_v\sigma_r}{\beta^2}+\frac{2\sigma_r^2}{\beta^3}\right)(1-\exp(-\beta t))+\left(\frac{\sigma_r^2}{2\beta^3}\right)(1-\exp(-2\beta t)) \quad (19)$$

$$\begin{aligned}M(t,T)=&\left(\frac{\alpha-\rho\sigma_v\sigma_r}{\beta}-\frac{\sigma_r^2}{\beta^2}-\frac{\sigma_v^2}{2}\right)t+\left(\frac{\rho\sigma_v\sigma_r}{\beta^2}+\frac{\sigma_r^2}{2\beta^3}\right)\exp(-\beta T)(\exp(\beta t)-1)\\&+\left(\frac{r_t}{\beta}-\frac{\alpha}{\beta^2}+\frac{\sigma_r^2}{\beta^3}\right)(1-\exp(-\beta t))-\left(\frac{\sigma_r^2}{2\beta^3}\right)\exp(-\beta T)(1-\exp(-\beta t))\end{aligned} \quad (20)$$

where $\Theta_r=(\alpha,\beta,\sigma_r,r_t)$ from the Vasicek (1977) model

3.3.5 Reduced-Form Model

This model follows on Houweling and Vorst (2004), which also based on Jarrow and Turnbull (1995) model. In reduced-form model, defaults are supposed to occur unexpectedly.

Let $\tilde{Q}$ denote the equivalent martingale measure that is associated with the numeraire *B*(*t*) (see Harrison and Pliska (1981)). $\tilde{Q}$ is the risk-neutral measure. Let *D*(*t*,*T*) and *v*(*t*,*T*,*c*) denote the discount factor from time *t* to *T* and a defaultable bond with coupon rate *c*, maturity *T* and face value *F = 1* respectively. Default which occurs at a random time τ is independent from *r*(*t*) but under $\tilde{Q}$. $\tilde{P}(t,T)$ represents the risk-neutral survival probability, i.e. $\tilde{P}(t,T)=\tilde{E}_t\left[1_{\{\tau>T\}}\right]$ and $1_{\{A\}}$ the indicator function of event A. We assume the existence of a non-negative, bounded and predictable process $\lambda(t)$, which represents the default intensity or hazard rate for τ under $\tilde{Q}$. Then,

$$\tilde{P}(t,T) \quad = \quad \tilde{E}_t\left[\exp(-\int_t^T\lambda(s)ds)\right] \quad = \quad \tilde{E}_t\left[\exp(-\Lambda(t,T))\right] \qquad (21)$$

where $\Lambda(t,T)$ denotes the integrated hazard function:

$$\Lambda(t,T) = \int_t^T \lambda(s)ds$$

$$\begin{aligned} v(t,t,c) &= \sum_{i=1}^{n} D(t_0,t_i)\tilde{E}_t\left[c1_{\{\tau>t_i\}}\right] + D(t,t_n)\tilde{E}_t\left[1_{\{\tau>t_n\}}\right] + \tilde{E}_t\left[D(t_0,\tau)\omega 1_{\{\tau\le t_n\}}\right] \\ &= \sum_{i=1}^{n} D(t,t_i)c\tilde{P}(t,t_i) + D(t,t_n)\tilde{P}(t,t_n) + \int_t^{t_n} D(t,s)\omega f(s)ds \end{aligned} \tag{22}$$

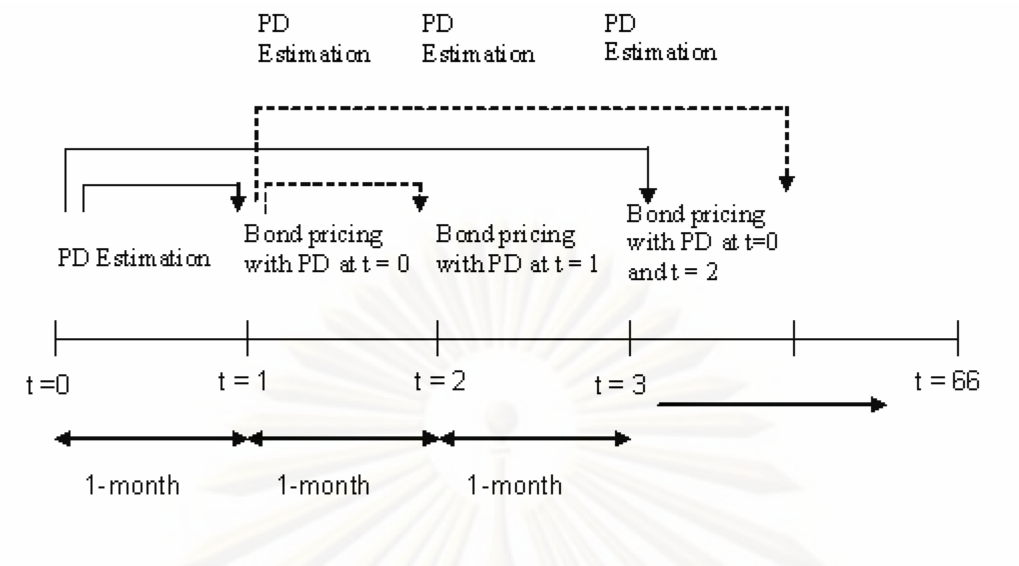
Where $f(t)$ denotes the probability density function associated with the intensity process $\lambda(t)$. In our empirical application, we replace the integral in Equation (22) by a numerical approximation: we define a weekly grid of maturities $s_0,...,s_m$, where $s_0 = t$ and $s_m = t_n$ and set

$$\int_t^{t_n} D(t,s)\omega f(s)ds \approx \sum_{i=1}^{m} D(t,s_i)\omega(\tilde{P}(t,s_{i-1}) - \tilde{P}(t,s_i)) \tag{23}$$

The interpretation of expression (23) is as follows. $\tilde{P}(t,s_{i-1})$ is the risk-nuetral survival probability till time s_{i-1} and $\tilde{P}(t,s_i)$ is the probability of no default till time s_i. The difference is between the two is simply the risk neutral probability of default of month i, conditional on no earlier defaults.

3.4 Hypothesis Testing

After obtaining monthly probabilities of default estimations by using in-the-sample data and applying with the four models used in this study, we test whether there are pricing errors of the bond prices between actual and predicted prices. Then, we predict the bond prices in the two out-of-sample periods, next 1-month and 3-months, by using reduced-form model. After that, bond prices can be compared with the observed market price to identify pricing errors. This procedure is repeated in the same manner for the next-month probabilities of default estimation.



The standard error of measurements such as mean absolute percentage error (MAPE) of each model are then calculated and compared. In this study, the forecast error means percentage difference or percentage error between predicted prices (P_{it}^{*}) from model *i* and real trading price (P_t).

Mean absolute percentage error (MAPE) is calculated as

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|P_{it}^{*} - P_t\right| / P_{it}^{*}$$

The model that generates the least Mean Absolute Percentage Error (MAPE) in prices is the most appropriate model for Thai bond market.

CHAPTER IV

RESULTS

4.1 Descriptive of Firms

Table 1 shows each firm's average firm value (Value), average equity value (Equity), average debt-to-equity ratio (D/E), average volatility of firm value (SigmaV), average volatility of equity value (SigmaE) and average correlation coefficient between asset returns and interest rates (Rho). The result shows PTT as the firm with highest average firm value and average equity with 880,124.86 MB and 585,823.05 MB respectively. NVL has the lowest average firm value and average equity with 3,191.91 MB. and 721.24 MB respectively. For debt-to-equity Ratio, the indication of the size of leverage of the firm, TRUE is in the highest range with 4.29. The firm with lowest range of average D/E ratio is AP which has only 0.43

Comparing in term of average volatility of firm value (SigmaV), we can see that AP has highest average volatility of firm value with 34.24%. PL has lowest average volatility of firm value with 5.20%. In the average volatility of equity value (SigmaE), TRUE has the highest range with 56.33% and MBK has the lowest range with 18.26%. For the average correlation coefficient between asset returns and interest rates (Rho), MBK has the highest percentage with 11.59% and BANPU has the least average correlation coefficient between asset returns and interest rates with only 0.40%

4.2 Comparing the Probabilities of Default from the Structural Form and Reduced-Form Models

The comparison of 1-year probabilities of default that obtained from structural form models (The Merton model, The Black and Cox model, The Longstaff and Schwartz model) and the reduced-form models (Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model) is shown in Table 2. The table contains the average 1-year probabilities of default of each company, the standard deviation, the grand mean and standard deviation of the 1-year probabilities of default of all companies. Results show that the average 1-year probabilities of structural form model are lower than those of reduced-form model. The Merton model has the lowest average value of 0.63%. The average probabilities of default of the Quadratic Hazard Function model have the highest value of 5.30%. Generally, the reduced-form model calibrated average probabilities of default from corporate bond price, assuming that credit spread of corporate bond will reflect company's credit risk. However, Thai corporate bond market is still in the emerging market which has liquidity problem. This lead the credit spread of corporate bond reflects the company's credit risk and liquidity risk. Hence, the probabilities of default obtained from reduced-form model are higher than those obtained from structural form model.

Among the average 1-year probabilities of defaults of the three structural form models, the Merton model has the lowest value with the grand mean of 1-year probabilities of default of 0.63% followed by the Black and Cox model with 1.04% and the Longstaff and Schwartz model with 1.34%. This result is consistent with the theories which stated that the probabilities of default of Merton model should be less than those of the others since the Merton model treats equity as a vanilla European call option and thereby calculate the probabilities of default only at maturity. However, the other two models treat equity as American call option and therefore including the probabilities of default before maturity. Though the difference between the Black and Cox model and The Longstaff and Schwartz model is the assumption of interest rate; the Black and Cox model assumes constant interest rate while the Longstaff and Schwartz model assumes stochastic interest rate. The Vasicek model is used to capture the movement of interest rate. Of all the average 1-year probabilities of defaults of the three reduced-form models, the Constant Hazard Function model has the lowest value with the grand mean of 1-year probabilities of default of 3.6% followed by the Linear Hazard Function model with 4.09%, and the Quadratic Hazard Function model with 5.30%.

Table 3 shows the comparison between credit rating and 1-year probabilities of default from each firm. In credit rating we divide into five different rates: AA+, A+, A, A- and BBB. Among the sample, the only firm with AA+ rating is PTT. Three firms with A+ rating: AIS, BANPU and SCC. Firm with A rating is LH. Under A- rating, there are eight firms: AEON, ATC, CK, KK, KTC, MBK, MINT and PL. Firm with BBB rating has four firms: AP, NMG, NVL and TRUE

Table 4 shows the average 1-year probabilities of default under the same rating. From this table, it shows that the default probability value of each model is consistent with credit rating categories; that is in the lower rating group, the higher default probability value of every model can be found. For example, in A- and BBB (in which the credit of A- is better than of BBB), the default probability value of Merton model under BBB is higher than of the A-.

4.3 Sensitivities to Model Parameters

4.3.1 Effect of Grid Points in Reduced-Form Model

Table 5 shows the sensitivity of grid points in reduced-form model and compares the 1-year probabilities of default obtained from those models. Since the reduced-form model separates the time to default, the grid points in the table then can be divided into three values: 12, 52 and 252 which mean monthly, weekly, and daily default respectively. The result shows that no matter what the grid point value is, the 1-year probabilities of default of the Quadratic Hazard Function model will always be higher than those of the

Linear Hazard Function model and the Constant Hazard Function model. For example, the grid points 12 has the grand mean of 1-year probabilities of default from the Quadratic Hazard Function model of 5.18% followed by the Linear Hazard Function model with 3.97%, and the Constant Hazard Function model with 3.47%. The grid points 52 has the grand mean of 1-year probabilities of default from the Quadratic Hazard Function model of 5.27% followed by the Linear Hazard Function model with 4.08%, and the Constant Hazard Function model with 3.60%. Grid points 252 has the grand mean of 1-year probabilities of default from the Quadratic Hazard Function model of 5.30% followed by the Linear Hazard Function model with 4.09%, and the Constant Hazard Function model with 3.60%.

4.3.2 Effect of Equity Price and Volatility in Probabilities of Default

Table 6 shows the sensitivity of number of historical data in structural form model and compares the 1-year probabilities of default obtained from those models. The numbers of historical data are divided into three groups: 30, 60 and 90 days. The table shows that the numbers of historical data increase as the 1-year probabilities of default obtained from the three models decrease because volatilities of equity will decrease when the numbers of historical data increase. For example, the number of historical data 30 days has the grand mean of 1-year probabilities of default from Merton model of 1.29%, the Black and Cox model of 2.19% and Longstaff and Schwartz model of 2.56%, respectively. The number of historical data 60 days has the grand mean of 1-year probabilities of default from Merton model of 0.63%, Black and Cox model of 1.04% and Longstaff and Schwartz model of 1.34% respectively. The number of historical data 90 days has the grand mean of 1-year probabilities of default from Merton model of 0.60%, Black and Cox model of 0.99% and Longstaff and Schwartz model of 1.28%.

As a result, the 1-year probabilities of default using historical data 30 days have the highest value, followed by the probabilities of default using historical data 60 days. The 1-year probabilities of default using historical data 90 days have the lowest value. However, the 1-year probabilities of default using historical data 60 days and historical data 90 days do not differ much

4.3.3 Sensitivity of Grid Points in Longstaff and Schwartz Model

Table 7 shows the 1-year probabilities of default obtained from various grid points value in Longstaff and Schwartz model. Since the Longstaff and Schwartz model separates the time to default, the grid points in the table can be divided into four values: 12, 52, 200 and 252 which mean monthly, weekly, and daily default respectively. The result in this study is consistent with the empirical results from investigating Longstaff and Schwartz (1995): the probabilities of default will converge when using grid points 200 or higher. For example, the grid points 12 has the grand mean of 1-year probabilities of default of 5.18%. The grid points 52 has the grand mean of 1-year probabilities of default of 5.27%. The grid points of 200 have the grand mean of 1-year probabilities of default of 5.27%. The grid points 252 have the grand mean of 1-year probabilities of default of 5.30%.

4.4 Mean Absolute Percentage Error (MAPE)

4.4.1 Mean Absolute Percentage Errors_Forcast 1 Month

Table 8 compares the mean of mean absolute percentage error (MAPE) obtained from structural form model and the reduced-form model. After obtaining monthly probability of default estimations by using in-the-sample data and applying with the 6 models used in this study, we test whether there are pricing errors of the bond prices between actual and predicted prices. Then, we predict the bond prices in the out-of-sample period, next 1-month, by using reduced-form model. After that, bond prices can be compared with the observed market price to identify pricing errors. The MAPE of each company is then used to calculate the mean of MAPE. The mean of MAPE in Quadratic Hazard Function model has the lowest value of 2.10% followed by Linear Hazard Function model with 2.12%, Constant Hazard Function model with 2.15%, Longstaff and Schwartz model with 3.83%, Black and Cox model with 3.88% and Merton model which has the highest value of 3.90%.

4.4.2 Mean Absolute Percentage Errors_Forcast 3 Month

Table 9 compares the mean absolute percentage error (MAPE) obtained from the structural form models and reduced-form models using the same procedure as described above but this time the probabilities of default is used to predict bond prices in the next 3-months instead of 1-month. The result shows that Quadratic Hazard Function model has the lowest value of 2.17% followed by Linear Hazard Function model with 2.18%, Constant Hazard Function model with 2.21%, Longstaff and Schwartz model with 3.98%, Black and Cox model with 4.02% and Merton model which has the highest value of 4.05%.

Table 10 and Table 11 compare the mean absolute percentage error (MAPE) of 1-month and 3-months of structural form models and reduced-form model. The table shows that, with any model, the MAPE obtained from predicted bond price in the next 1-month is always lower than the MAPE obtained from predicted bond price in the next 3-months. This implies that the probabilities of default are able to reflect bond price in the next 1-month better than bond price in the next 3-months. Because the probability of default has been priced in the bond price by the market in the previous period already so when we use this value to forecast bond price in 3-months period, it would be inappropriate and lead to high forecasting error.

In conclusion, most results correspond with the stated hypothesis: among the four estimations of probabilities of default in Thai corporate bond market, the reduced-form model provides the most accuracy. The mean of MAPE obtained from reduced-form model has lower value than the mean of MAPE obtained from structural form model for all firms, for instance. This infers that the probability of default from the reduced-form model is more effective in predicting the bond price, either with the next 1-month or 3-months prediction. The reason is that the input of reduced form is taken from bond prices not from stock price and financial statement of firm. So there is high correlation of the probability of default with bond prices in the market. In other words, the probability of default reflects the perception of investor onto the firm in bond market rather than reflect the value of firm from financial statement and the perception of the investor in equity market onto firm which would have lower correlation to the bond market. Generally, the perception of the investor from both equity market and bond market should go along within the same firm. However, in the emerging market such as Thai corporate bond market still has the liquidity problem. This makes the bond prices reflect not only the credit risk of the firm, but also the liquidity risk. The liquidity problem in Thai bond market is shown by the frequency of trading in Table 12.

Table 12 shows number of trading days within one month of the samples. Referred from ThaiBMA, the table shows minimum, maximum, and average trading days within one month of each bond. From the table, we can infer that Thai corporate bonds have high liquidity problem. Within one month, there are many bonds with no trading volume at all; moreover, the highest average day is only 10 days. In contrast with the developed market, the trading is always active and high in volume.

Table 1
Descriptive of Firms

This table shows samples from descriptive subscription of firms which contains each firm's average montly firm value (Value), equity value (Equity), debt-to-equity ratio (D/E), volatility of firm value (SigmaV), volatility of equity value (SigmaE) and correlation coefficient between asset returns and interest rates (Rho).Sample period cover 2001 to 2006.

	Value (MB)	Equity (MB)	D/E	SigmaV	SigmaE	Rho
AEON	19,843.36	7,532.95	1.73	17.19%	45.37%	2.97%
AIS	124,547.69	52,925.00	1.57	16.24%	39.14%	-1.86%
AP	14,746.47	10,732.91	0.43	34.24%	46.08%	0.60%
ATC	71,275.73	44,180.68	0.77	27.23%	45.65%	1.30%
BANPU	45,771.85	31,387.97	0.60	21.23%	32.43%	0.40%
CK	33,325.91	12,569.25	1.77	12.79%	33.41%	1.63%
KK	48,205.14	14,785.55	2.41	13.47%	41.75%	0.91%
KTC	20,334.58	5,938.88	2.69	14.57%	38.85%	0.40%
LH	84,086.19	68,853.05	0.23	28.68%	35.13%	-11.59%
MBK	16,887.68	9,305.88	0.84	10.07%	18.26%	-5.91%
MINT	15,818.09	9,637.16	1.00	18.00%	32.21%	-5.45%
NMG	6,626.91	2,295.42	1.96	9.43%	26.79%	4.46%
NVL	3,191.91	721.24	3.51	9.50%	39.09%	8.32%
PL	4,734.17	1,285.98	2.81	5.20%	19.25%	-9.31%
PTT	880,124.86	585,823.05	0.52	15.97%	24.04%	-6.15%
SCC	412,170.01	280,965.47	0.48	16.92%	24.93%	-5.35%
TRUE	111,316.67	23,009.54	4.29	12.12%	56.33%	-1.40%
VNG	16,091.38	11,259.99	0.49	25.49%	36.77%	6.57%

Table 2
Average of Probability of Default (1-Year)

This table compares the monthly grand mean of 1-year probabilities of default for each company from 2001 to 2006 by using structural form models (The Merton model, The Black and Cox model, The Longstaff and Schwartz model) and the reduced-form models (Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model). The data of 18 listed companies is obtained from the Stock Exchange of Thailand and Thai Bond Market.

	Structural Form			Reduced-Form		
	Merton	Black-Cox	Longstaff	Constant	Linear	Quadratic
AEON	0.88%	1.46%	1.78%	5.44%	5.82%	6.23%
Stdev	1.14%	1.93%	2.29%	6.45%	6.31%	5.92%
AIS	0.17%	0.25%	0.36%	8.95%	9.69%	11.14%
Stdev	0.31%	0.48%	0.69%	13.69%	13.50%	12.58%
AP	0.06%	0.11%	0.12%	0.15%	0.59%	2.32%
Stdev	0.11%	0.19%	0.20%	0.12%	0.28%	0.71%
ATC	0.44%	0.74%	0.87%	0.46%	1.01%	2.32%
Stdev	0.65%	1.14%	1.22%	0.52%	1.03%	0.98%
BANPU	0.05%	0.08%	0.09%	0.88%	1.41%	2.61%
Stdev	0.12%	0.19%	0.23%	1.40%	1.68%	1.48%
CK	0.18%	0.28%	0.41%	2.41%	2.99%	3.64%
Stdev	0.52%	0.85%	1.08%	2.40%	2.50%	2.02%
KK	0.93%	1.51%	1.93%	1.51%	2.21%	4.14%
Stdev	1.09%	1.84%	2.17%	2.94%	3.13%	2.92%
KTC	0.65%	1.11%	1.29%	9.19%	8.62%	8.67%
Stdev	1.37%	2.39%	2.65%	19.71%	18.12%	17.99%
LH	0.00%	0.00%	0.00%	4.41%	4.64%	5.04%
Stdev	0.01%	0.01%	0.01%	3.76%	3.65%	3.21%
MBK	0.00%	0.00%	0.00%	4.51%	4.86%	5.59%
Stdev	0.00%	0.00%	0.00%	6.45%	6.27%	5.79%
MINT	0.50%	0.87%	0.94%	2.95%	3.54%	5.06%
Stdev	1.46%	2.53%	2.68%	4.99%	5.06%	4.47%
NMG	0.03%	0.05%	0.08%	14.08%	13.93%	14.39%
Stdev	0.07%	0.10%	0.14%	23.50%	20.86%	20.40%
NVL	0.88%	1.39%	1.98%	4.15%	5.24%	7.08%
Stdev	2.16%	3.51%	4.80%	7.20%	7.25%	6.47%
PL	0.98%	1.51%	2.34%	3.04%	3.84%	4.27%
Stdev	2.40%	3.69%	5.70%	2.46%	2.35%	1.90%
PTT	0.00%	0.00%	0.00%	0.04%	0.22%	1.15%
Stdev	0.00%	0.00%	0.00%	0.02%	0.13%	0.65%
SCC	0.00%	0.00%	0.00%	1.34%	1.94%	2.75%
Stdev	0.00%	0.00%	0.00%	1.85%	2.08%	1.67%
TRUE	5.60%	9.38%	11.93%	0.97%	2.29%	6.89%
Stdev	6.09%	10.80%	12.04%	1.19%	1.48%	2.40%
VNG	0.04%	0.06%	0.07%	0.39%	0.83%	2.07%
Stdev	0.11%	0.19%	0.21%	0.47%	0.79%	0.87%
Average	0.63%	1.04%	1.34%	3.60%	4.09%	5.30%
Stdev	1.29%	2.17%	2.76%	3.80%	3.61%	3.42%

Table 3
Comparing between Rating and 1-Year Probabilities of Default by Firms

This table shows comparison between credit rating and 1-year probabilities of default from each firm from 2001 to 2006 by using structural form models (The Merton model, The Black and Cox model, The Longstaff and Schwartz model) and the reduced-form models (Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model). The data of 18 listed companies is obtained from the Stock Exchange of Thailand and Thai Bond Market.

		Structural Form			Reduced Form		
Firms	Rating	Merton	Black-Cox	Longstaff	Constant	Linear	Quadratic
PTT	AA+	0.00%	0.00%	0.00%	0.04%	0.22%	1.15%
AIS	A+	0.17%	0.25%	0.36%	8.95%	9.69%	11.14%
BANPU	A+	0.05%	0.08%	0.09%	0.88%	1.41%	2.61%
SCC	A+	0.00%	0.00%	0.00%	1.34%	1.94%	2.75%
LH	A	0.00%	0.01%	0.01%	2.90%	3.21%	3.73%
AEON	A-	0.88%	1.46%	1.78%	5.44%	5.82%	6.23%
ATC	A-	0.44%	0.74%	0.87%	0.46%	1.01%	2.32%
CK	A-	0.18%	0.28%	0.41%	2.41%	2.99%	3.64%
KK	A-	0.93%	1.51%	1.93%	1.51%	2.21%	4.14%
KTC	A-	0.65%	1.11%	1.29%	9.19%	8.62%	8.67%
MBK	A-	0.00%	0.00%	0.00%	4.51%	4.86%	5.59%
MINT	A-	0.50%	0.87%	0.94%	2.95%	3.54%	5.06%
PL	A-	0.98%	1.51%	2.34%	3.04%	3.84%	4.27%
AP	BBB	0.06%	0.11%	0.12%	0.15%	0.59%	2.32%
NMG	BBB	0.03%	0.05%	0.08%	14.08%	13.93%	14.39%
NVL	BBB	0.88%	1.39%	1.98%	4.15%	5.24%	7.08%
TRUE	BBB	5.60%	9.38%	11.93%	0.97%	2.29%	6.89%

Table 4
Comparing between Rating and 1-Year Probabilities of Default by Rating

This table shows the average 1-year probabilities of default under the same rating. From this table, it shows that the default probability value of each model is consistent with credit rating categories; that is in the lower rating group, the higher default probability value of every model can be found.

	Structural Form			Reduced Form		
Rating	Merton	Black-Cox	Longstaff	Constant	Linear	Quadratic
AA+	0.00%	0.00%	0.00%	0.04%	0.22%	1.15%
A+	0.07%	0.11%	0.15%	3.72%	4.35%	5.50%
A	0.00%	0.01%	0.01%	2.90%	3.21%	3.73%
A-	0.57%	0.93%	1.19%	3.69%	4.11%	4.99%
BBB	1.64%	2.73%	3.52%	4.84%	5.51%	7.67%

Table 5

Sensitivity of Grid Points in Reduced-Form Model

This table shows the sensitivity of grid points in reduced-form model and compares the 1-year probabilities of default obtained from the reduced-form model which consist of Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model. Since the reduced-form model separates the time to default, the grid points in the table are divided into three values, 12, 52 and 252. Grid Points 12 means monthly default. Grid points 52 means weekly default. And grid 252 means daily default.

	Grid Points = 12			Grid Points = 52			Grid Points = 252		
	Constant	Linear	Quadratic	Constant	Linear	Quadratic	Constant	Linear	Quadratic
AEON	3.52%	3.94%	4.43%	5.44%	5.82%	6.23%	5.44%	5.82%	6.23%
AIS	8.95%	9.69%	11.14%	8.95%	9.69%	11.14%	8.95%	9.69%	11.14%
AP	0.15%	0.59%	2.32%	0.15%	0.59%	2.32%	0.15%	0.59%	2.32%
ATC	0.46%	1.01%	2.32%	0.46%	1.01%	2.32%	0.46%	1.01%	2.32%
BANPU	0.46%	1.01%	2.32%	0.88%	1.41%	2.61%	0.88%	1.41%	2.61%
CK	2.41%	2.99%	3.64%	2.41%	2.99%	3.64%	2.41%	2.99%	3.64%
KK	1.51%	2.21%	4.14%	1.51%	2.21%	4.14%	1.51%	2.21%	4.14%
KTC	9.19%	8.62%	8.67%	9.19%	8.62%	8.67%	9.19%	8.62%	8.67%
LH	4.41%	4.64%	5.04%	4.41%	4.64%	5.04%	4.41%	4.64%	5.04%
MBK	4.51%	4.86%	5.59%	4.41%	4.64%	5.04%	4.51%	4.86%	5.59%
MINT	2.95%	3.54%	5.06%	2.95%	3.54%	5.06%	2.95%	3.54%	5.06%
NMG	14.08%	13.93%	14.39%	14.08%	13.93%	14.39%	14.08%	13.93%	14.39%
NVL	4.15%	5.24%	7.08%	4.15%	5.24%	7.08%	4.15%	5.24%	7.08%
PL	3.04%	3.84%	4.27%	3.04%	3.84%	4.27%	3.04%	3.84%	4.27%
PTT	0.04%	0.22%	1.15%	0.04%	0.22%	1.15%	0.04%	0.22%	1.15%
SCC	1.34%	1.94%	2.75%	1.34%	1.94%	2.75%	1.34%	1.94%	2.75%
TRUE	0.97%	2.29%	6.89%	0.97%	2.29%	6.89%	0.97%	2.29%	6.89%
VNG	0.39%	0.83%	2.07%	0.39%	0.83%	2.07%	0.39%	0.83%	2.07%
Average	3.47%	3.97%	5.18%	3.60%	4.08%	5.27%	3.60%	4.09%	5.30%
Stdev	3.79%	3.60%	3.43%	3.80%	3.61%	3.42%	3.80%	3.61%	3.42%

Table 6
Sensitivity of Number of Historical Data

This table shows the sensitivity of number of historical data in structural form model and compares the 1-year probabilities of default obtained from the structural form models which consist of Merton model, The Black and Cox model (Black&Cox Model) and Longstaff and Schwartz model. The number of historical data that was used to obtain the volatility of equity can be divided into three groups, 30, 60 and 90 days.

	30 days			60 days			90 days		
	Merton	Black-Cox	Longstaff	Merton	Black-Cox	Longstaff	Merton	Black-Cox	Longstaff
AEON	0.78%	1.30%	1.58%	0.88%	1.46%	1.78%	0.66%	1.08%	1.35%
AIS	0.95%	1.58%	1.84%	0.17%	0.25%	0.36%	0.12%	0.17%	0.26%
AP	0.10%	0.18%	0.19%	0.06%	0.11%	0.12%	0.05%	0.08%	0.09%
ATC	0.69%	1.16%	1.38%	0.44%	0.74%	0.87%	0.40%	0.68%	0.82%
BANPU	0.11%	0.19%	0.22%	0.05%	0.08%	0.09%	0.02%	0.04%	0.05%
CK	0.12%	0.17%	0.29%	0.18%	0.28%	0.41%	0.39%	0.63%	0.83%
KK	1.20%	2.03%	2.38%	0.93%	1.51%	1.93%	0.71%	1.13%	1.48%
KTC	0.95%	1.64%	1.85%	0.65%	1.11%	1.29%	1.22%	2.08%	2.29%
LH	0.01%	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MBK	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MINT	0.70%	1.18%	1.25%	0.50%	0.87%	0.94%	0.59%	1.02%	1.10%
NMG	0.08%	0.13%	0.17%	0.03%	0.05%	0.08%	0.02%	0.03%	0.05%
NVL	0.96%	1.52%	2.12%	0.88%	1.39%	1.98%	0.58%	0.88%	1.33%
PL	0.00%	0.00%	0.00%	0.98%	1.51%	2.34%	0.58%	0.81%	1.58%
PTT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SCC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRUE	5.56%	9.45%	11.61%	5.60%	9.38%	11.93%	5.49%	9.12%	11.83%
VNG	0.04%	0.06%	0.07%	0.04%	0.06%	0.07%	0.02%	0.03%	0.03%
Average	0.68%	1.15%	1.39%	0.63%	1.04%	1.34%	0.60%	0.99%	1.28%
Stdev	1.29%	2.20%	2.69%	1.29%	2.17%	2.76%	1.27%	2.11%	2.73%

Table 7
Sensitivity of Grid Points in Longstaff and Schwartz Model

This table shows the 1-year probabilities of default obtained from various grid points value in Longstaff and Schwartz model. Since the Longstaff and Schwartz model separates the time to default, the grid points in the table are divided into four values, 12, 52, 200 and 252. Grid Points 12 means monthly default. Grid points 52 means weekly default. And grid points 252 means daily default.

	Grid Points = 12	Grid Points = 52	Grid Points = 200	Grid Points = 252
AEON	1.41%	1.65%	1.78%	1.71%
AIS	0.29%	0.35%	0.37%	0.37%
AP	0.09%	0.11%	0.12%	0.12%
ATC	0.70%	0.84%	0.87%	0.88%
BANPU	0.07%	0.09%	0.09%	0.09%
CK	0.33%	0.39%	0.41%	0.41%
KK	1.59%	1.86%	1.93%	1.93%
KTC	5.54%	5.79%	5.84%	5.85%
LH	0.00%	0.00%	0.00%	0.00%
MBK	0.00%	0.00%	0.00%	0.00%
MINT	0.81%	0.91%	0.94%	0.94%
NMG	0.06%	0.07%	0.08%	0.08%
NVL	1.71%	1.92%	1.98%	1.98%
PL	2.08%	2.29%	2.34%	2.34%
PTT	0.00%	0.00%	0.00%	0.00%
SCC	0.00%	0.00%	0.00%	0.00%
TRUE	10.79%	11.73%	11.93%	11.95%
VNG	0.05%	0.07%	0.07%	0.07%
Average	1.42%	1.56%	1.60%	1.60%
Stdev	2.70%	2.91%	2.96%	2.96%

Table 8

Hypothesis Testing: Mean Absolute Percentage Errors_Forcast 1 Month

This table compares the mean of mean absolute percentage error (MAPE) obtained from structural form model which consist of the Merton model, The Black and Cox model (Black&Cox model) and The Longstaff and Schwartz model, and the reduced-form model which consist of Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model. After obtaining monthly probability of default estimations by using in-the-sample data and applying with the 6 models used in this study, we test whether there are pricing errors of the bond prices between actual and predicted prices. Then, we predict the bond prices in the two out-of-sample periods, next 1-month, by using reduced-form model. After that, bond prices can be compared with the observed market price to identify pricing errors. The MAPE of each company is then used to calculate the mean of MAPE.

	Pricing Error_Forcast 1 M					
	Structural Form			Reduced Form		
	Merton	Black-Cox	Longstaff	Constant	Linear	Quadratic
AEON	2.84%	2.71%	2.56%	1.34%	1.34%	1.34%
AIS	2.89%	2.73%	2.72%	2.29%	2.31%	2.36%
AP	4.00%	3.94%	3.74%	3.58%	3.57%	3.55%
ATC	3.47%	3.45%	3.40%	2.29%	2.28%	2.26%
BANPU	2.76%	2.70%	2.57%	2.28%	2.15%	2.04%
CK	2.45%	2.35%	2.03%	1.49%	1.49%	1.48%
KK	3.54%	3.53%	3.48%	1.86%	1.84%	1.82%
KTC	5.10%	4.63%	4.60%	1.61%	1.61%	1.60%
LH	2.02%	1.94%	1.88%	1.73%	1.73%	1.73%
MBK	2.50%	2.47%	2.40%	2.17%	2.15%	2.12%
MINT	3.40%	3.34%	3.25%	3.36%	3.29%	3.24%
NMG	4.00%	3.87%	3.53%	2.19%	2.19%	2.18%
NVL	3.62%	3.30%	2.64%	1.23%	1.24%	1.25%
PL	4.42%	4.41%	4.26%	2.19%	1.86%	1.94%
PTT	2.43%	2.41%	2.13%	2.22%	2.21%	2.20%
SCC	1.80%	1.75%	1.62%	1.40%	1.34%	1.34%
TRUE	16.54%	17.96%	19.96%	3.76%	3.71%	3.62%
VNG	2.44%	2.28%	2.15%	1.78%	1.77%	1.77%
Average	3.90%	3.88%	3.83%	2.15%	2.12%	2.10%
Stdev	3.27%	3.61%	4.11%	0.74%	0.73%	0.72%

Table 9
Hypothesis Testing: Mean Absolute Percentage Errors_Forcast 3 Month

This table compares the mean absolute percentage error (MAPE) obtained from all models, the structural form models and reduced-form models using the same procedure as described Table 8. However, the probabilities of default are used to predict bond value in the next 3-month instead of 1 month.

	Pricing Error_Forcast 3 M					
	Structural Form			Reduced Form		
	Merton	Black-Cox	Longstaff	Constant	Linear	Quadratic
AEON	2.79%	2.65%	2.49%	1.28%	1.28%	1.27%
AIS	3.13%	2.92%	2.86%	2.39%	2.42%	2.48%
AP	4.78%	4.77%	4.61%	4.36%	4.35%	4.33%
ATC	3.58%	3.54%	3.46%	2.36%	2.36%	2.34%
BANPU	3.05%	2.98%	2.86%	2.26%	2.15%	2.04%
CK	2.63%	2.51%	2.18%	1.72%	1.72%	1.71%
KK	4.11%	4.07%	3.97%	1.45%	1.44%	1.42%
KTC	5.26%	4.77%	4.74%	1.66%	1.66%	1.66%
LH	2.14%	2.05%	1.99%	1.83%	1.83%	1.83%
MBK	2.68%	2.66%	2.63%	2.23%	2.21%	2.19%
MINT	3.44%	3.35%	3.27%	2.98%	2.92%	2.87%
NMG	3.90%	3.78%	3.45%	2.03%	2.03%	2.02%
NVL	3.85%	3.56%	2.92%	1.39%	1.40%	1.40%
PL	4.74%	4.72%	4.58%	2.23%	2.11%	2.18%
PTT	2.78%	2.76%	2.50%	2.49%	2.48%	2.47%
SCC	1.83%	1.77%	1.66%	1.53%	1.43%	1.43%
TRUE	16.03%	17.44%	19.46%	3.72%	3.64%	3.54%
VNG	2.19%	2.03%	1.96%	1.90%	1.89%	1.89%
Average	4.05%	4.02%	3.98%	2.21%	2.18%	2.17%
Stdev	3.14%	3.48%	3.97%	0.81%	0.80%	0.78%

Table 10

Comparing between MAPE 1 M and MAPE 3 M (Structural Form Model)

This table shows comparing the mean absolute percentage error (MAPE) of 1-month and 3-month of structural form models by using the same procedure as described Table 8.

	Pricing Error_Forcast 1 M			Pricing Error_Forcast 3 M		
	Merton	Black-Cox	Longstaff	Merton	BlackCox	Longstaff
AEON	2.84%	2.71%	2.56%	2.79%	2.65%	2.49%
AIS	2.89%	2.73%	2.72%	3.13%	2.92%	2.86%
AP	4.00%	3.94%	3.74%	4.78%	4.77%	4.61%
ATC	3.47%	3.45%	3.40%	3.58%	3.54%	3.46%
BANPU	2.76%	2.70%	2.57%	3.05%	2.98%	2.86%
CK	2.45%	2.35%	2.03%	2.63%	2.51%	2.18%
KK	3.54%	3.53%	3.48%	4.11%	4.07%	3.97%
KTC	5.10%	4.63%	4.60%	5.26%	4.77%	4.74%
LH	2.02%	1.94%	1.88%	2.14%	2.05%	1.99%
MBK	2.50%	2.47%	2.40%	2.68%	2.66%	2.63%
MINT	3.40%	3.34%	3.25%	3.44%	3.35%	3.27%
NMG	4.00%	3.87%	3.53%	3.90%	3.78%	3.45%
NVL	3.62%	3.30%	2.64%	3.85%	3.56%	2.92%
PL	4.42%	4.41%	4.26%	4.74%	4.72%	4.58%
PTT	2.43%	2.41%	2.13%	2.78%	2.76%	2.50%
SCC	1.80%	1.75%	1.62%	1.83%	1.77%	1.66%
TRUE	16.54%	17.96%	19.96%	16.03%	17.44%	19.46%
VNG	2.44%	2.28%	2.15%	2.19%	2.03%	1.96%
Average	3.90%	3.88%	3.83%	4.05%	4.02%	3.98%
Stdev	3.27%	3.61%	4.11%	3.14%	3.48%	3.97%

Table 11

Comparing between MAPE 1 M and MAPE 3 M (Reduced Form Model)

This table shows comparing the mean absolute percentage error (MAPE) of 1-month and 3-month of reduced-form models by using the same procedure as described Table 8.

	Pricing Error_Forcast 1 M			Pricing Error_Forcast 3 M		
	Constant	Linear	Quadratic	Constant	Linear	Quadratic
AEON	1.34%	1.34%	1.34%	1.28%	1.28%	1.27%
AIS	2.29%	2.31%	2.36%	2.39%	2.42%	2.48%
AP	3.58%	3.57%	3.55%	4.36%	4.35%	4.33%
ATC	2.29%	2.28%	2.26%	2.36%	2.36%	2.34%
BANPU	2.28%	2.15%	2.04%	2.26%	2.15%	2.04%
CK	1.49%	1.49%	1.48%	1.72%	1.72%	1.71%
KK	1.86%	1.84%	1.82%	1.45%	1.44%	1.42%
KTC	1.61%	1.61%	1.60%	1.66%	1.66%	1.66%
LH	1.73%	1.73%	1.73%	1.83%	1.83%	1.83%
MBK	2.17%	2.15%	2.12%	2.23%	2.21%	2.19%
MINT	3.36%	3.29%	3.24%	2.98%	2.92%	2.87%
NMG	2.19%	2.19%	2.18%	2.03%	2.03%	2.02%
NVL	1.23%	1.24%	1.25%	1.39%	1.40%	1.40%
PL	2.19%	1.86%	1.94%	2.23%	2.11%	2.18%
PTT	2.22%	2.21%	2.20%	2.49%	2.48%	2.47%
SCC	1.40%	1.34%	1.34%	1.53%	1.43%	1.43%
TRUE	3.76%	3.71%	3.62%	3.72%	3.64%	3.54%
VNG	1.78%	1.77%	1.77%	1.90%	1.89%	1.89%
Average	2.15%	2.12%	2.10%	2.21%	2.18%	2.17%
Stdev	0.74%	0.73%	0.72%	0.81%	0.80%	0.78%

Table 12
Number of Trading Days within One Month

This table shows number of trading days within one month of the samples. Referring from ThaiBMA, the table shows minimum, maximum, and average trading days within one month of each bond.

Firms	Number of Trading Days (per 1-month)		
	Min	Max	Average
AEON	0	7	2.42
AIS	1	15	6.11
AP	0	6	1.80
ATC	1	17	4.43
BANPU	1	10	3.40
CK	1	9	3.07
KK	0	6	1.94
KTC	2	15	7.13
LH	0	2	1.67
MBK	1	12	4.83
MINT	0	4	2.00
NMG	0	4	2.18
NVL	0	4	2.27
PL	0	5	1.82
PTT	1	5	2.36
SCC	1	21	9.12
TRUE	5	20	7.31
VNG	1	10	3.32

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study employs the structural models i.e. Merton (1974), Black and Cox (1976), Longstaff and Schwartz (1995), and reduced-form models, i.e. Jarrow and Turnbull (1995); Constant Hazard Function model, Linear Hazard Function model and Quadratic Hazard Function model to estimate probabilities of default in the Thai corporate bond market. The study covers corporate bonds listed with the Thai Bond Market Association (ThaiBMA) from January 2001 to June 2006, and of which the issued firm in the Stock Exchange of Thailand (SET). We then compare the accuracy of default probabilities of each model by using probabilities of default to predict corporate bond price in next 1-month and 3-months then calculate the mean absolute percentage error (MAPE).

The results from comparing 1-year probabilities of default of all six models show that the average 1-year probabilities of default from structural form is lower than from reduced-form by Merton model which itself already has lowest value. The average 1-year probability of default from Quadratic Hazard Function model has highest value due to its assumption which stated that the credit spread of corporate bond would show the company's credit risk. In reality, in emerging market like Thai corporate bond market still has liquidity problem. This makes the credit spread of corporate bond show not only the company's credit risk but also company's liquidity risk. Therefore, the value of 1-year probabilities of default from reduced-form model is higher than from structural form model.

The probabilities of default from Merton model is lower than from Black and Cox model and Longstaff and Schwartz model because Merton model treats equity as a vanilla

European call option which would calculate the probabilities of default at maturity only. For the other two models that treat equity as American call option and also include the probabilities of default before maturity in the model.

Comparing the mean absolute percentage error (MAPE) of forecasting bond price in the next 1-month from structural form models and reduced-form models show that mean of MAPE from reduced-form model: Quadratic Hazard Function Model has the lowest value followed by reduced-form model: Linear Hazard Function model, reduced-form model: Constant Hazard Function model, The Longstaff and Schwartz model, The Black and Cox model. The result of mean of MAPE from The Merton model has highest value of all.

Comparing the mean absolute percentage error (MAPE) of forecasting bond price in the next 3-months shows same result as comparing the mean absolute Percentage Error (MAPE) of forecasting bond price in the next 1-month. The mean of MAPE from Quadratic Hazard Function model still has the lowest value followed by Linear Hazard Function model, Constant Hazard Function model, Merton model, and Black and Cox model. The result of mean of MAPE from Longstaff and Schwartz model also has highest value of all.

There is a different in value of mean absolute percentage error (MAPE) between using probabilities of default in forecasting bond price in the next 1-month and in the next 3-months in which MAPE of forecasting bond price in the next 1-month is lower than of the next 3-months which is explained by the probabilities of default. It reflects bond price better in the period of 1-month and the period of 3-months is considered to be too long for forecasting which make the results not accurate as it should be.

This corresponds with the stated hypothesis: among the four estimations of probabilities of default in Thai corporate bond market, the reduced-form model provides the most accuracy. Since the mean of MAPE obtained from reduced-form model has lower value than the mean of MAPE obtained from structural form model for all firms. This infer that the probability of default from the reduced-form model is more effective in predicting the bond price than calculated from the structural model, either with the next 1-month or 3-months prediction.

In conclusion, the appropriate model for Thai bond market in order to find probability of default is reduced-form model because it provides least MAPE.

5.2 Limitation

There are only 18 companies that are listed in the stock market and bond market from 2001 to 2006. This number is considerably low when compared to developed market. In addition, the liquidity of Thai corporate bond is low. The market maker can easily control the price to mark the price up or down. Although the flag does not increase much, the amount that will not be flag is only 10 million baht. This value is relatively low. Therefore, the result from this study might be distorted by the unreliable bond price.

REFERENCES

Andritzky, J. 2003. Implied Default Probabilities and Default Recovery Ratios: An Analysis of the Argentine Crisis 2000 – 2002. University of St. Gallen, available via the internet at *http://www.vfs.unizh.ch/papers.htm*.

Arora, N., Bohn, J., and Zhu, F. 2005. Reduced-Form vs. Structural Models of Credit Risk: A Case Study of three models. *Journal of Investment Management* 3, 4 (2005): 43–67.

Artzner, P., and Delbaen, F. 1995. Default Risk Insurance and Incomplete Markets. *Journal of Mathematical Finance* 5: 187-195.

Berardi, A., Ciraolo, S., and Trova, M. 2004. Predicting Default Probabilities and Implementing Trading Strategies for Emerging Markets Bond Portfolios. *Emerging Markets Review* 5: 447-469.

Black, F., and Cox, J. 1976. Valuing Corporate Securities: Some Effects of Bond Indenture Provisions. *Journal of Finance* 31: 351-367.

Briys, E., and de Varenne, F. 1997. Valuing Risky Fixed Rate Debt: An Extension. *Journal of Financial and Quantitative Analysis* 31: 239-248.

Cooper, I., and Davydenko, S. 2004. Using Yield Spreads to Estimate Expected Returns on Debt and Equity. *LBS Working Paper*.

Duffie, D., and Singleton, K. 1999. Modeling Term Structures of Defautable Bonds. *The Review of Financial Studies* 12: 687-720.

Duffie, D., and Lando, D. 2001, Term Structure of Credit Spreads with Incomplete Accounting Information. *Econometrica* 69: 633-664.

Duffie, D., Schroder, M., and Skiadas, C. 1996. Recursive Valuation of Defaultable Securities and the Timing of Resolution of Uncertainty. *Annals of Applied Probability* 6: 1075–1090.

Elizalde, A. 2005a. Credit Default Swap Valuation: An Application to Spanish Firms. Available at *www.abelelizalde.com.*

Eom, H., Helwege, J., and Huang, Z. 2004. Structural Models of Corporate Bond Pricing: An Empirical Analysis. *Review of Financial Studies* 17: 499-544.

Geske, R.1977. The Valuation of Corporate Liabilities as Compound Options. Journal *of Financial and Quantitative Analysis* 12: 541-552.

Gunduz, Y., and Uhrig-Homburg, M. 2005. An Empirical Comparison of Structural and Reduced-Form Frameworks: Evidence from the Credit Default Swap Market. *Working Paper.*

Harrison, M., and Pliska, S. 1981. Martingales and Stochastic Integrals in the Theory of Continuous Trading. *Stochastic Processes and Their Applications* 11: 215-260.

Houweling, P., and Vorst, A. 2004. Pricing Default Swaps: Empirical Evidence. *Journal of International Money and Finance*.

Hsu, J., Saá-Requejo, J., and Santa-Clara, P. 2004. Bond Pricing with Default Risk. *UCLA Working Paper*.

Huang, Z., and Huang, M. 2002. How Much of the Corporate-Treasury Yield Spread is Due to Credit Risk? Results from a New Calibration Approach. *Working Paper*.

Janosi, T., Jarrow, R., and Yildirim, Y. 2002. Estimating Expected Losses and Liquidity Discounts Implicit in Debt Prices. *Journal of Risk* 5: 1-38.

Jarrow, A., and Protter, P. 2004. Structural versus Reduced-Form Models: A New Information Based Perspective. *Journal of Investment Management* 2: 1-10.

Jarrow, R., Lando, D., and Turnbull, S. 1997. A Markov Model for the Term Structure of Credit Risk Spreads. *The Review of Financial Studies* 10: 481-523.

Jarrow, R., and Turnbull, S., 1995. Pricing Derivatives on Financial Securities Subject to Credit Risk. *Journal of Finance* 50: 53-86.

Kim, J., Ramaswamy, K., and Sundaresan, M. 1993. Does Default Risk in Coupons Affect the Valuation of Corporate Bonds?: A Contingent Claims Model. *Financial Management* 22: 117-131.

Keenan, C., Shtogrin, I., and Sobehart, J. 1999. Historical Default Rates of Corporate Bond Issuers, 1920-1998. *Moody's Investor's Service*.

Lando, D. 1998. On Cox Process and Credit Risky Securities. *Review of Derivatives Research* 2: 99-120.

Leland, H., and Toft, K. 1996. Optimal Capital Structure, Endogenous Bankruptcy, and the Term Structure of Credit Spreads. *Journal of Finance* 51: 987-1019.

Leland, H. 2004. Predictions of Default Probabilities in Structural Models of Debt. University of California, Berkeley.

Litterman, R., and Iben, T. 1991. Corporate Bond Valuation and the Term Structure of Credit Spreads. *The Journal of Portfolio Management* 17: 52-64.

Longstaff, F., and Schwartz, E. 1995. Valuing Risky Debt: A New Approach. *Journal of Finance* 50: 789-820.

Madan, D., and Unal, H. 1998. Pricing the Risks of Default. *Review of Derivatives Research* 2: 121-160.

Mello, A., and Parsons, J. 1992. Measuring the Agency Cost of Debt. *Journal of Finance* 47: 1887-1904.

Merton, R. 1974. On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. *Journal of Finance* 29: 449-470.

Nielsen, T., Saá-Requejo, J., and Santa-Clara, P. 1993. Default Risk and Interest Rate Risk: The Term Structure of Default Spreads. *Working Paper*.

Ronn, I., and Verma, K. 1986. Pricing Risk-Adjusted Deposit Insurance: An Option Based Model. *Journal of Finance* 41: 871-895.

Vasicek, O. 1977. An Equilibrium Characterization of the Term Structure. *Journal of Financial Economics* 5: 177-188.

APPENDICES

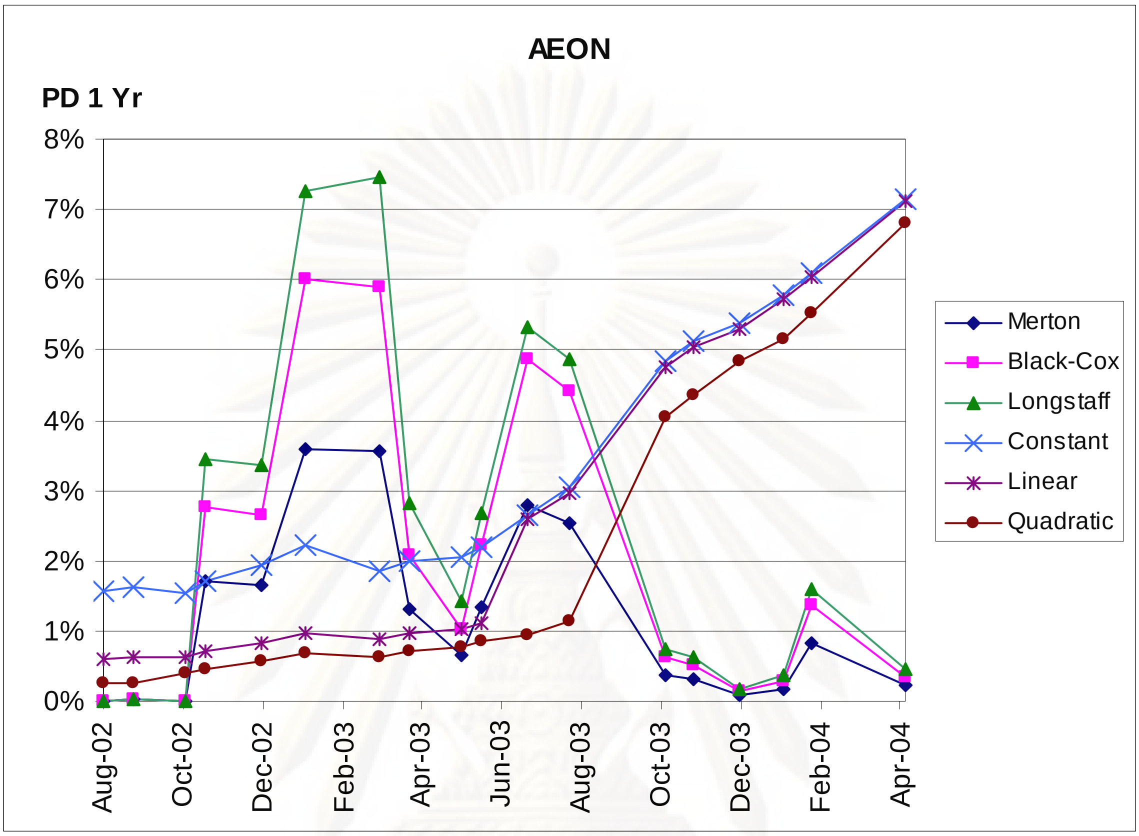
APPENDIX A

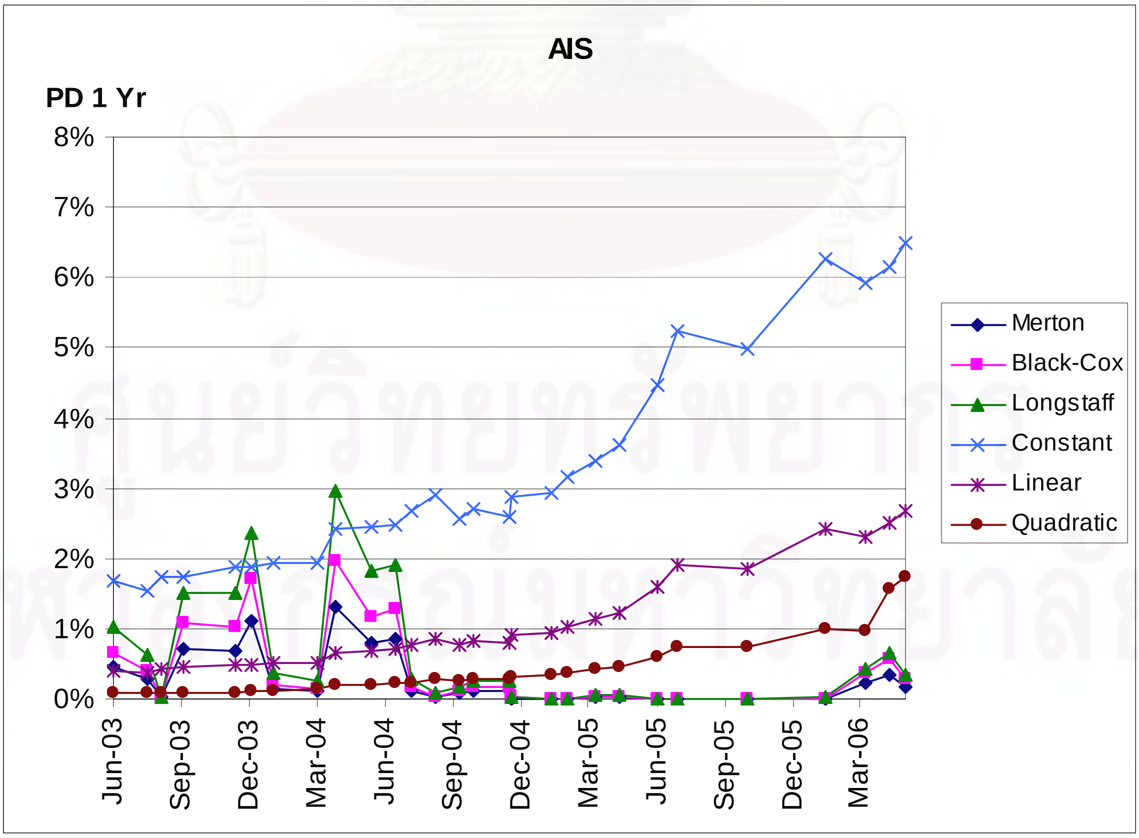
All bond data lists in this study are available in this section.

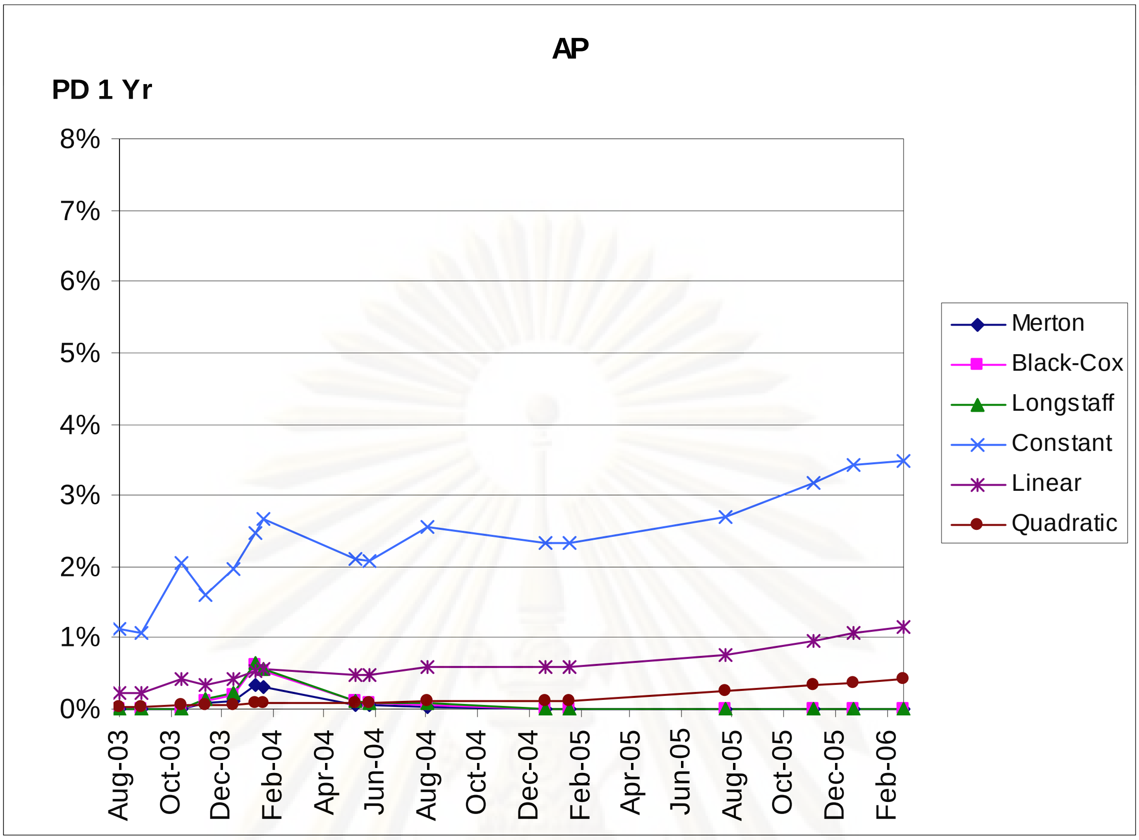
Industry:	Bond Name:
Banking	KK079A
Construction Materials	SCC07NA, VNG086A
Energy & Utilities	ATC086A, BP082A, PTTC125A
Finance and Security	AEON057A, KTC064A, NVL063A, PL079A
Food & Beverage	MINT078A
Information & Communication Technology	AIS06NA, TRUE087A
Media & Publishing	NMG055A
Property Development	AP097A, CK07OA, LH073A, MBK081A

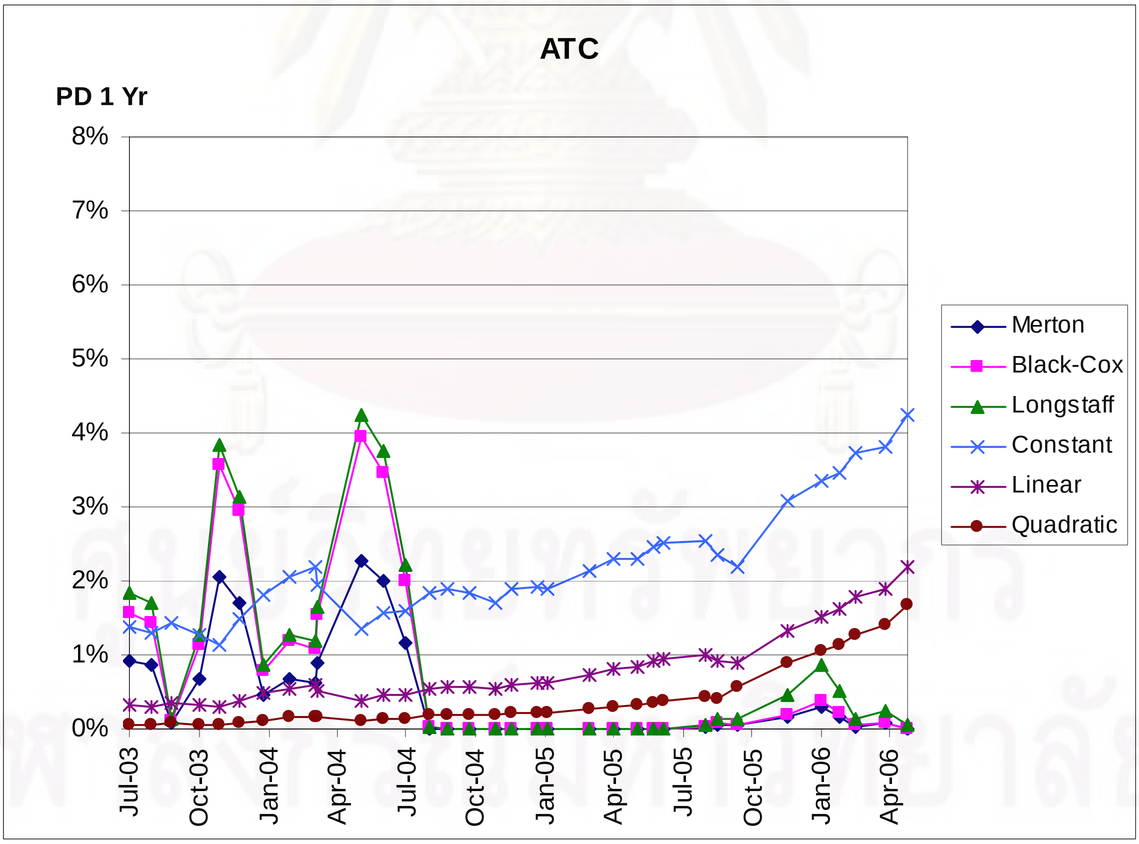
APPENDIX B

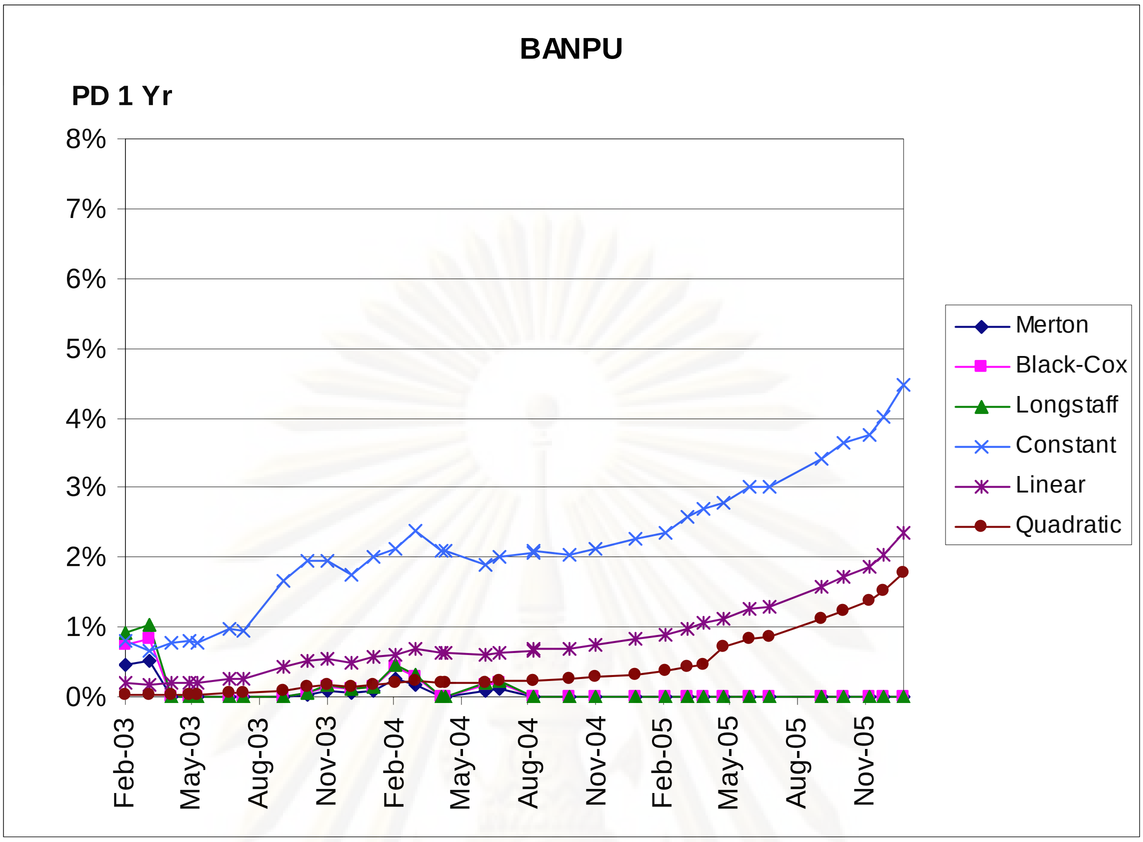
This section shows all firms' time-series of 1-year probabilities of default.

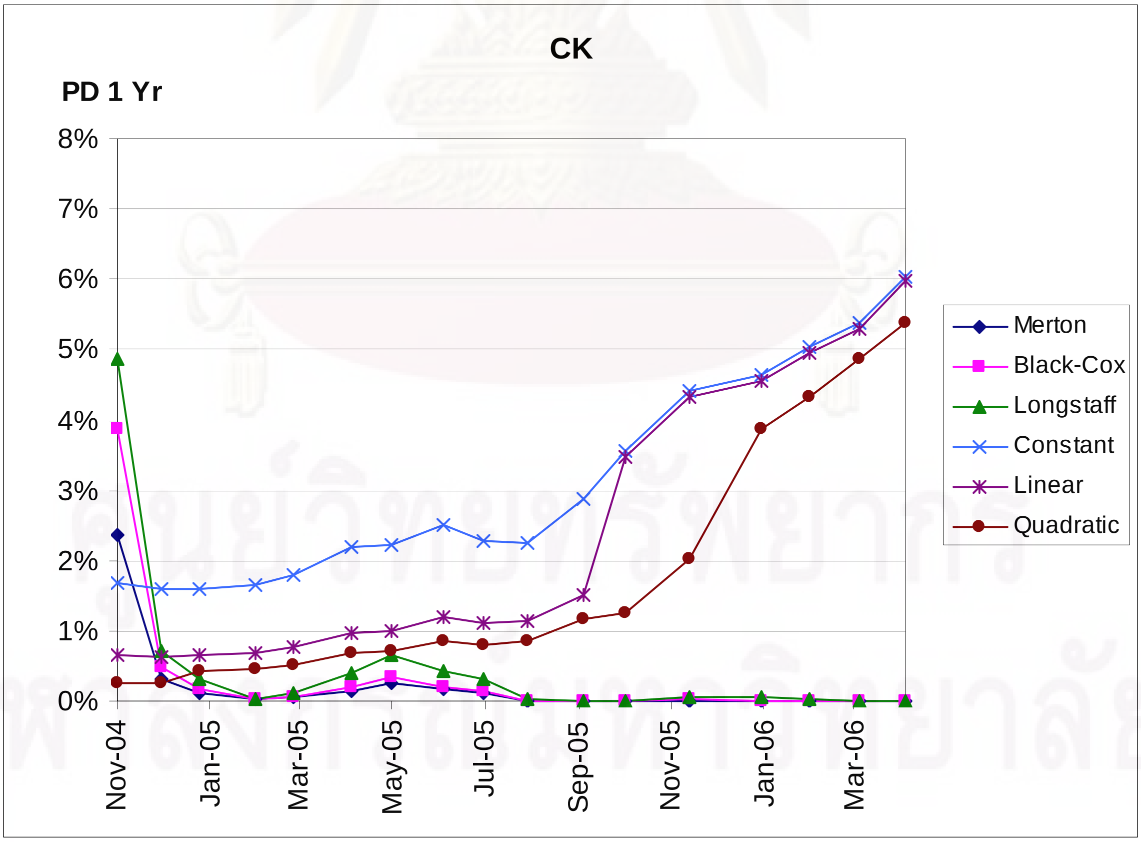


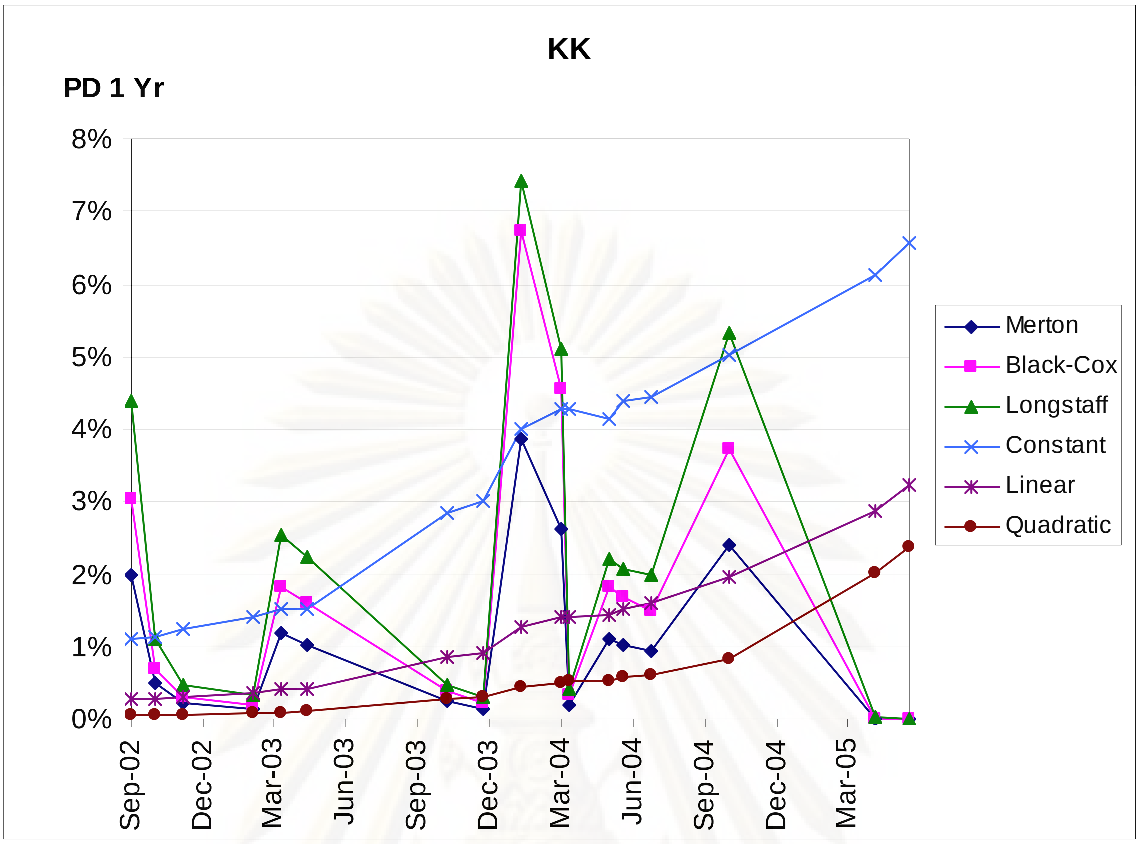


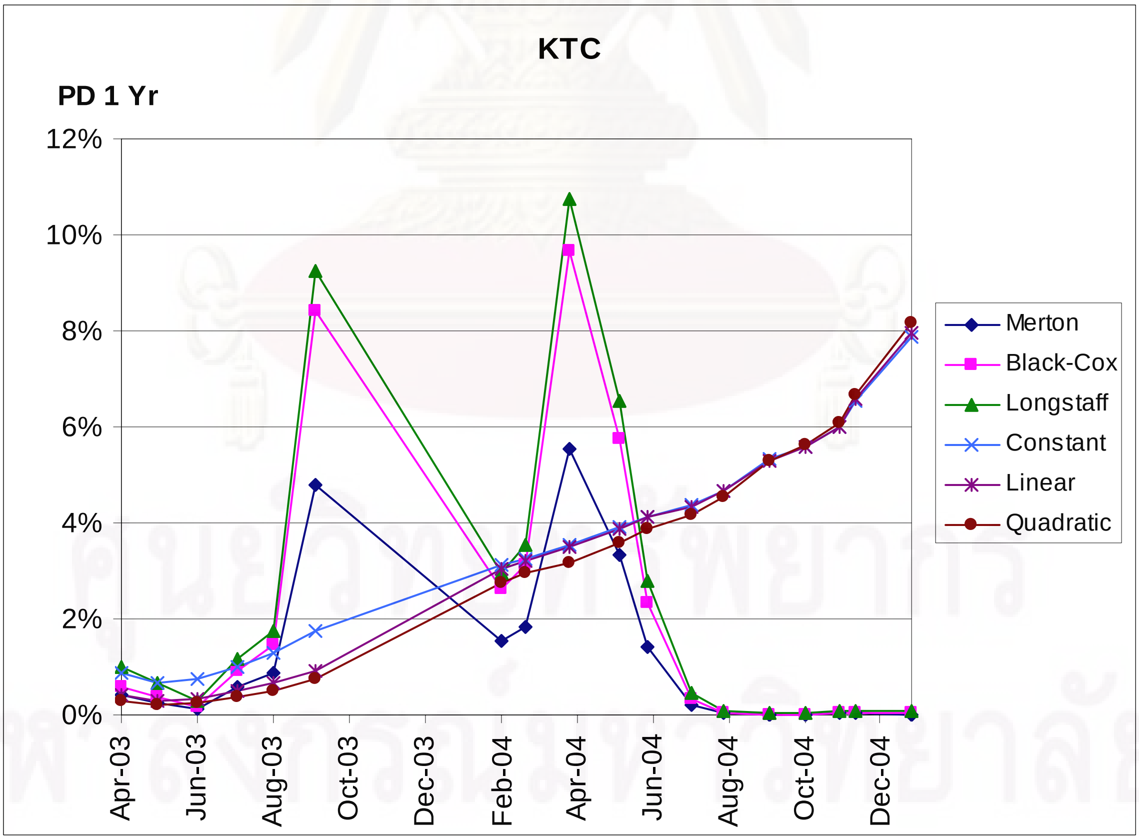

AP
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

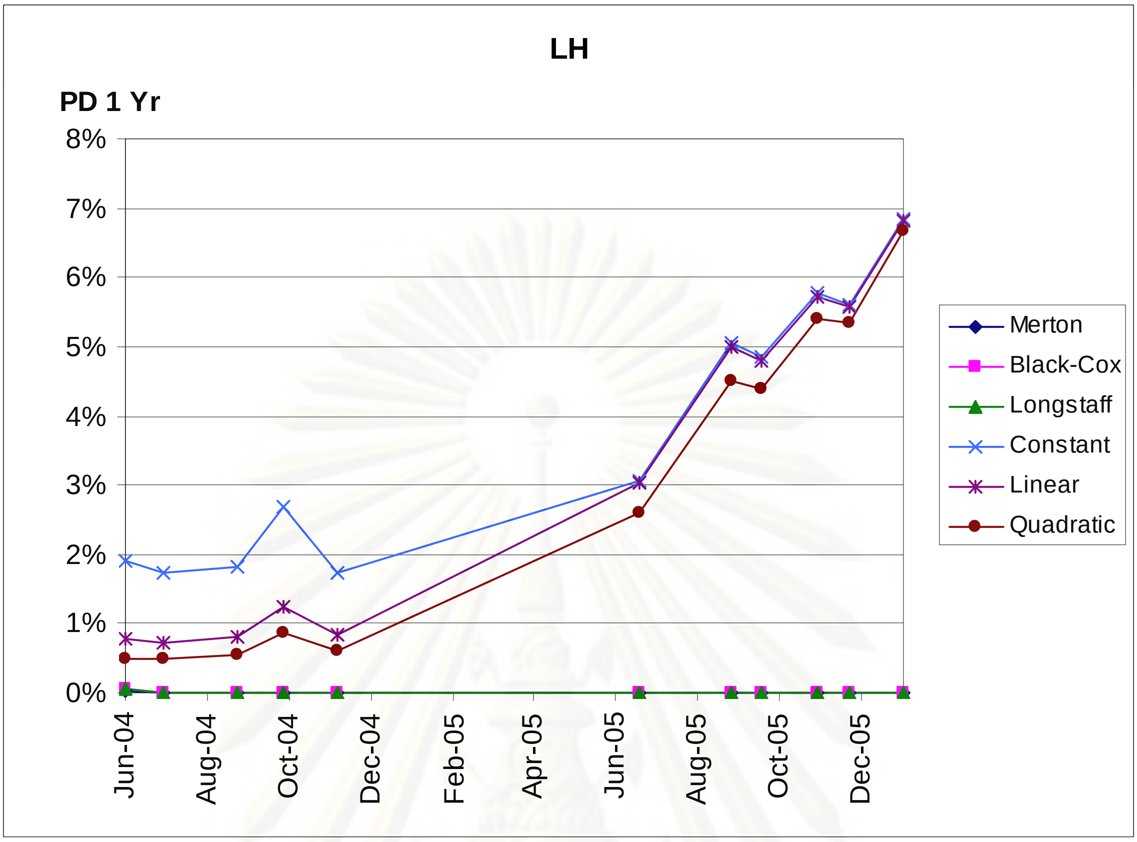

ATC
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

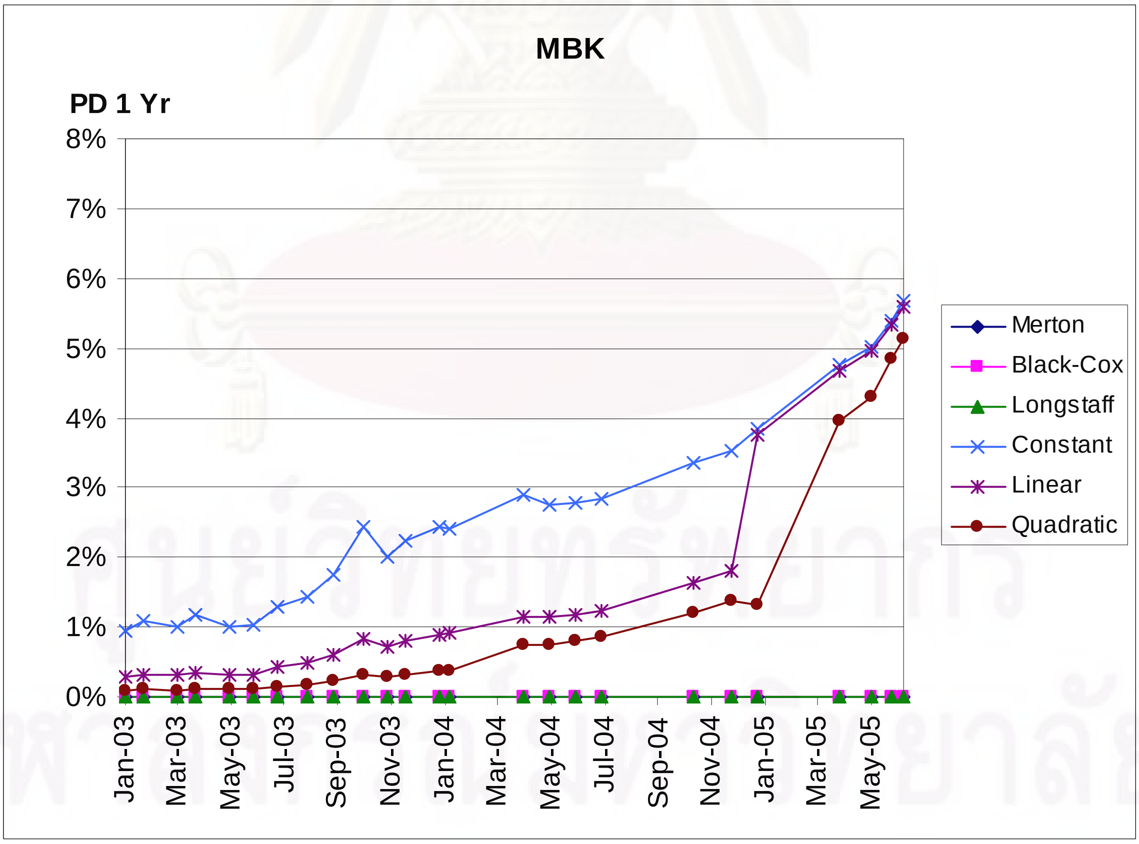

BANPU
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Feb-03
May-03
Aug-03
Nov-03
Feb-04
May-04
Aug-04
Nov-04
Feb-05
May-05
Aug-05
Nov-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

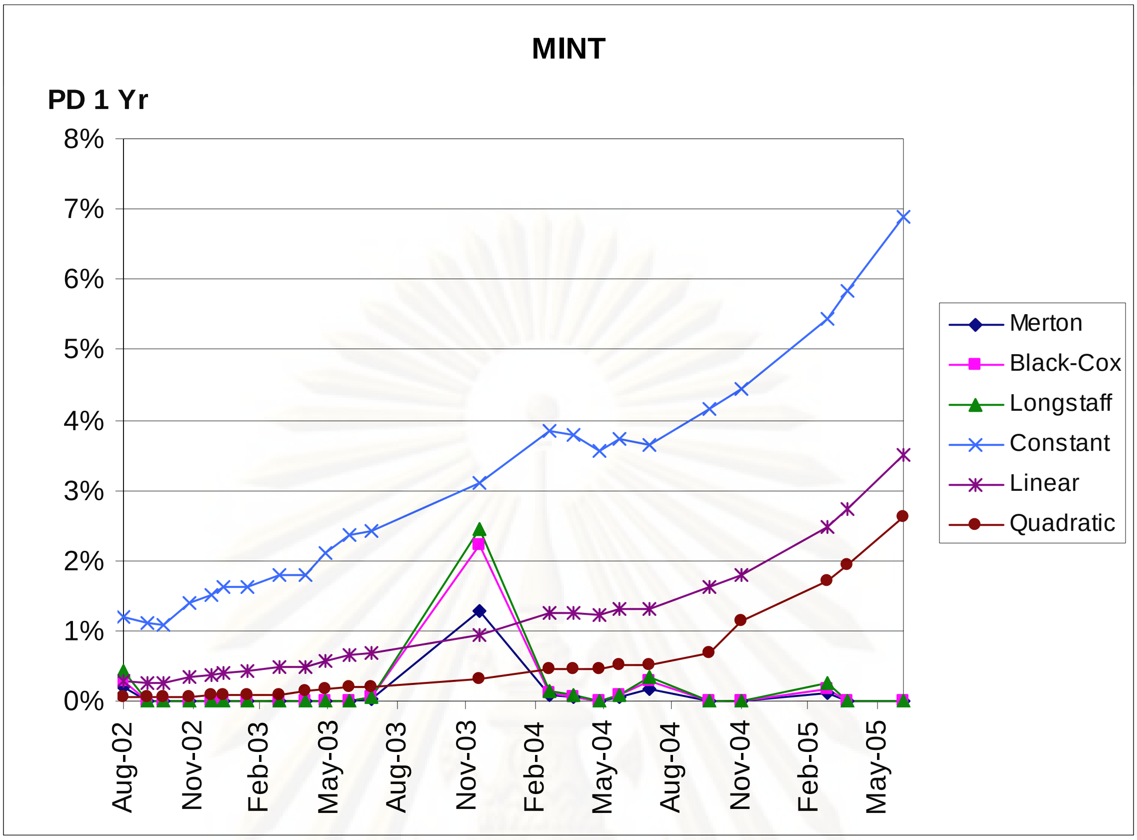

CK
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

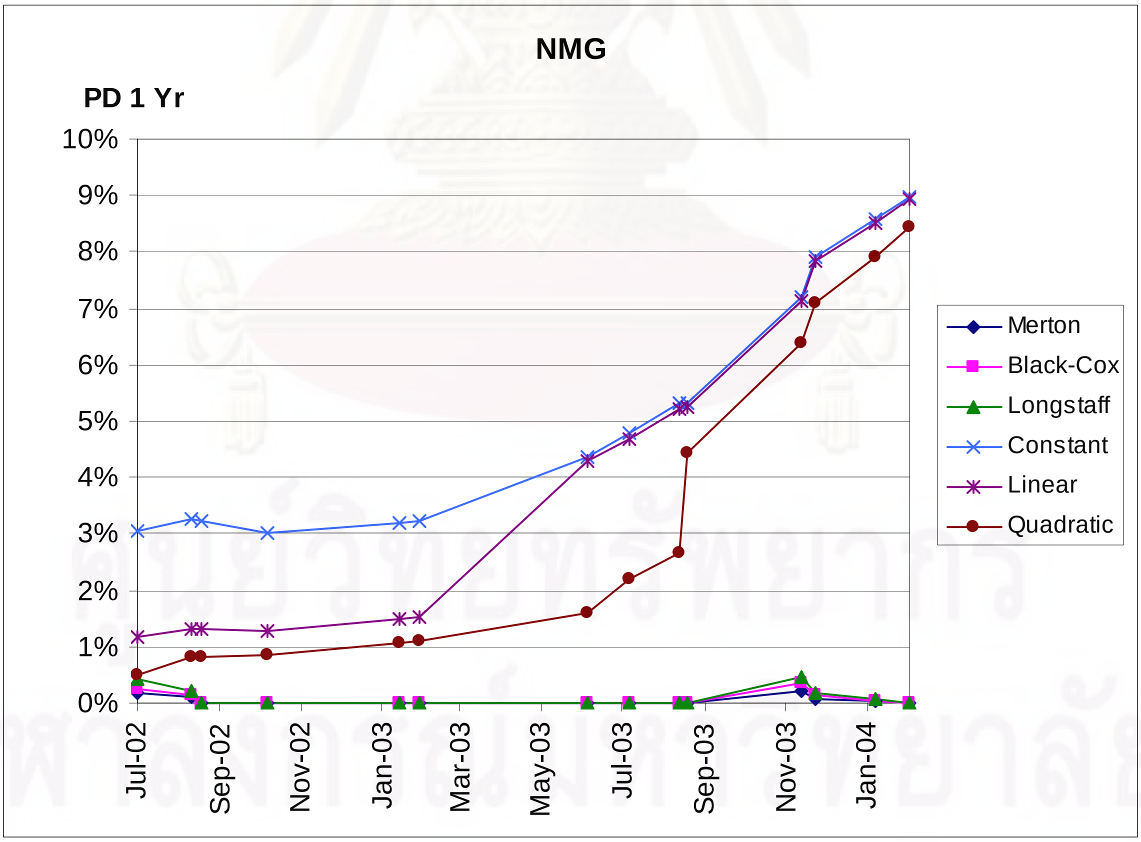

KK
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

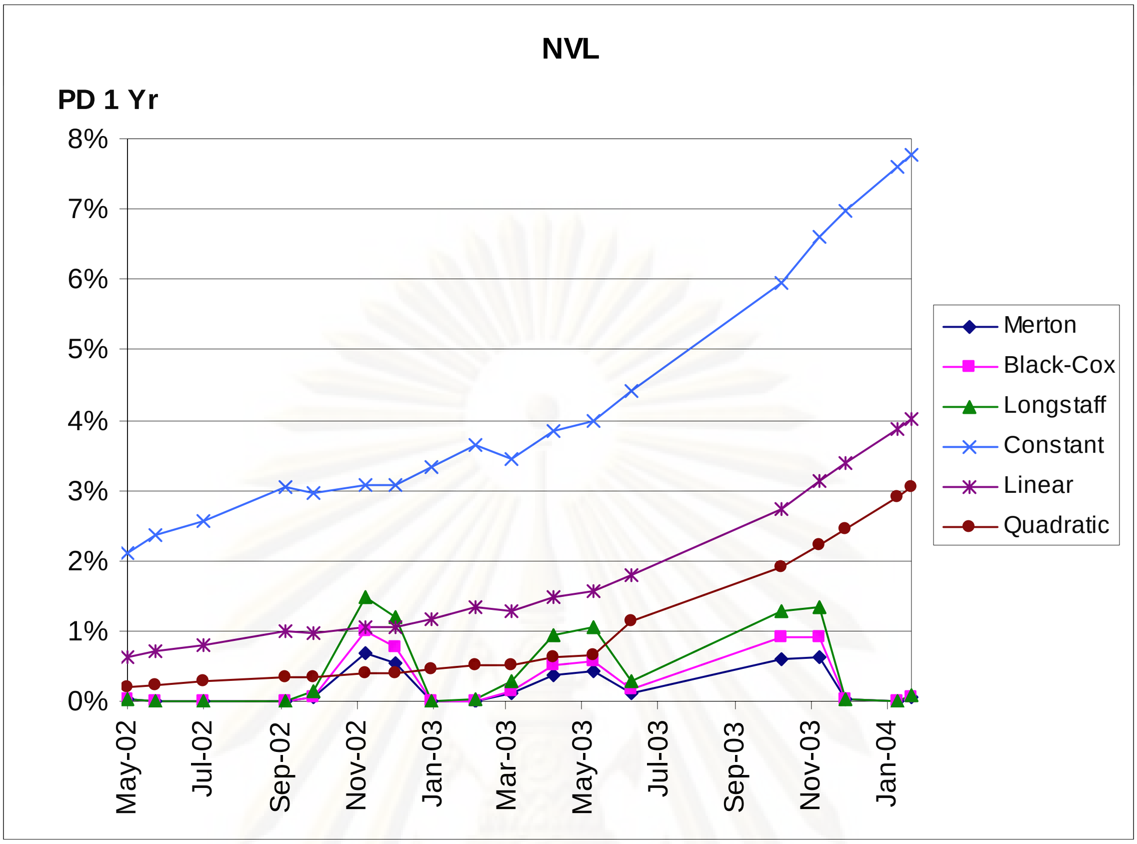

KTC
PD 1 Yr
12%
10%
8%
6%
4%
2%
0%
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

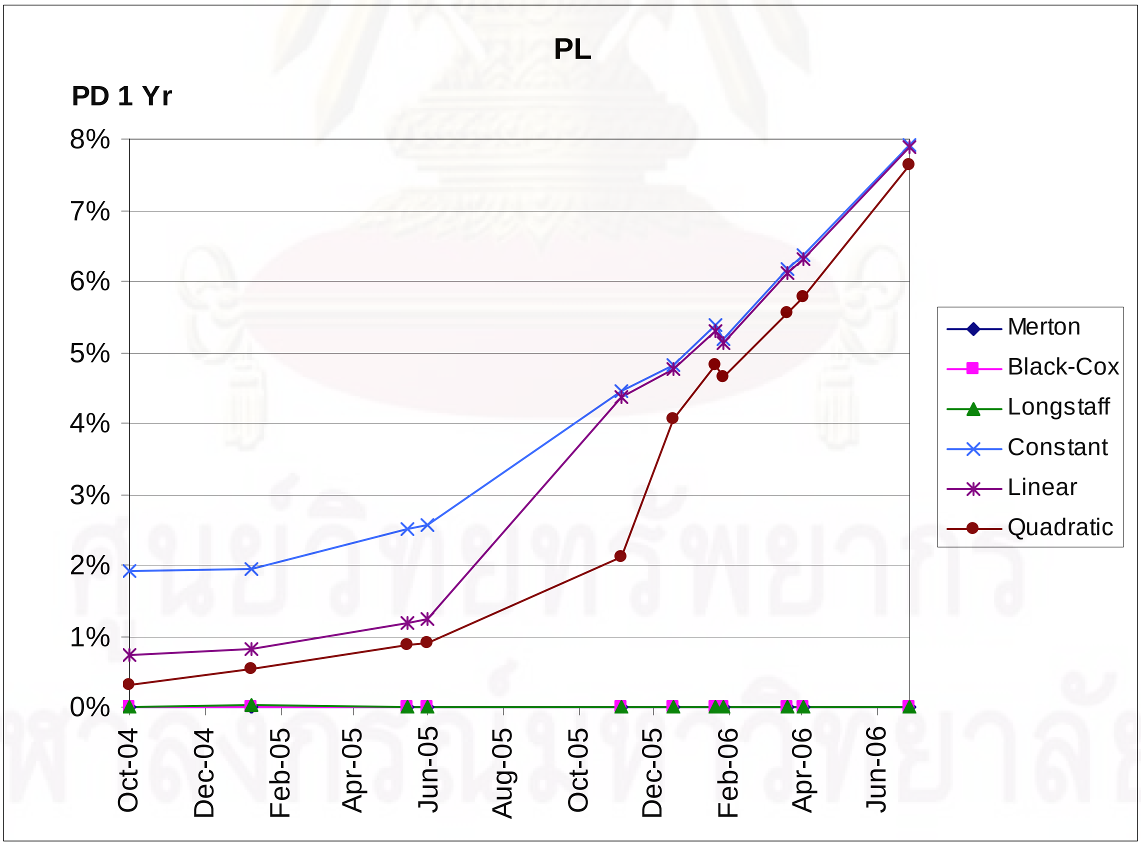

LH
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

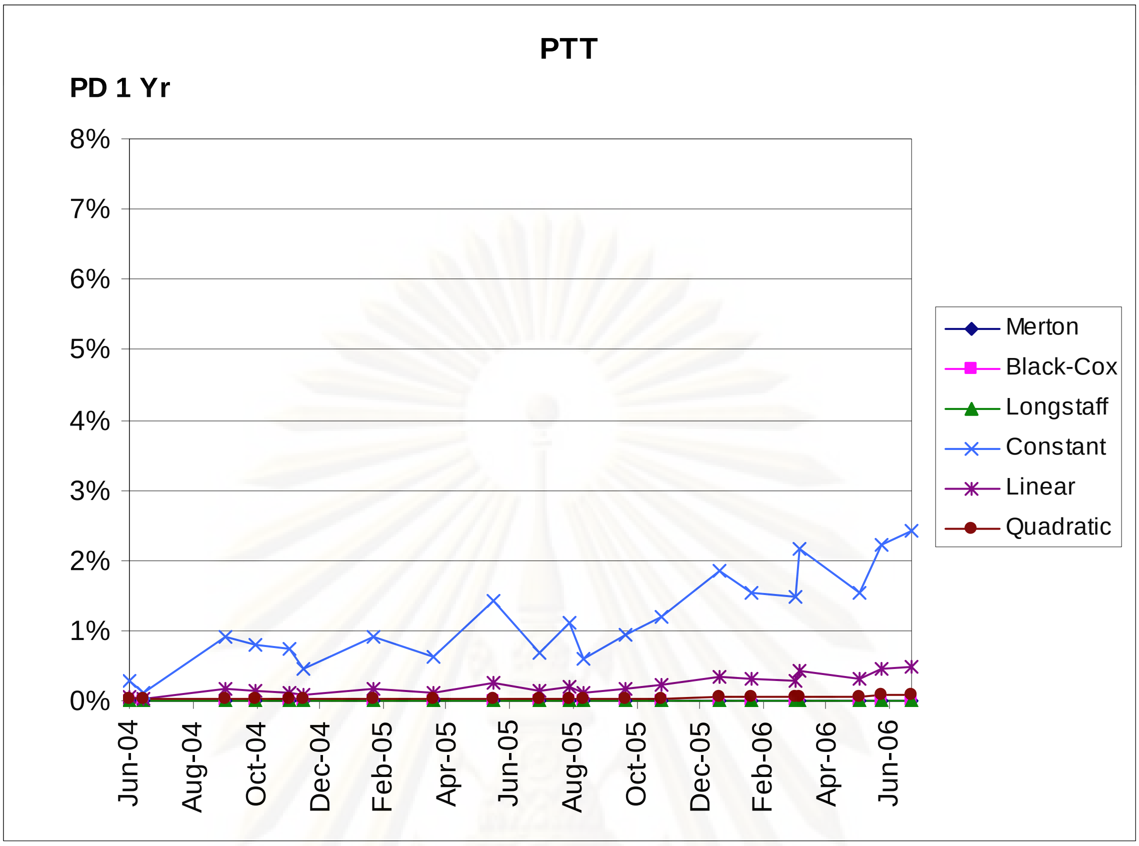

MBK
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

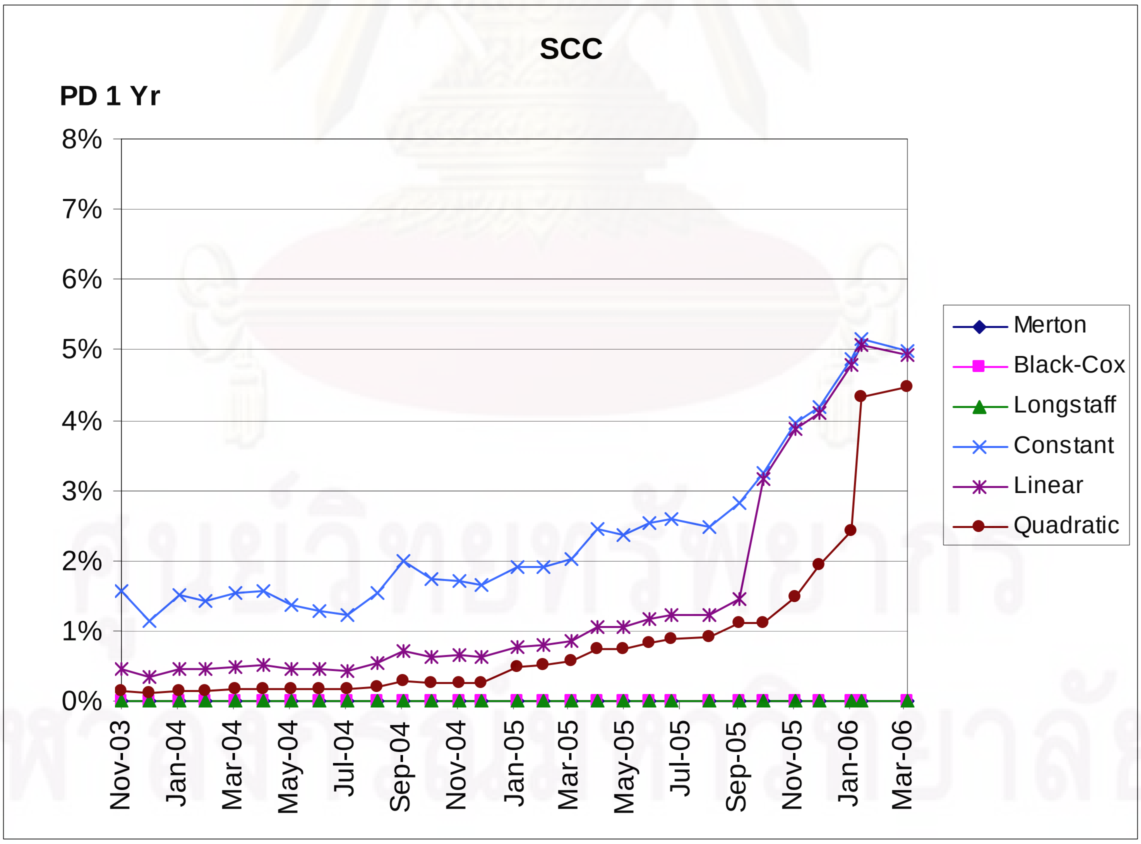

MINT
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Aug-02
Nov-02
Feb-03
May-03
Aug-03
Nov-03
Feb-04
May-04
Aug-04
Nov-04
Feb-05
May-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

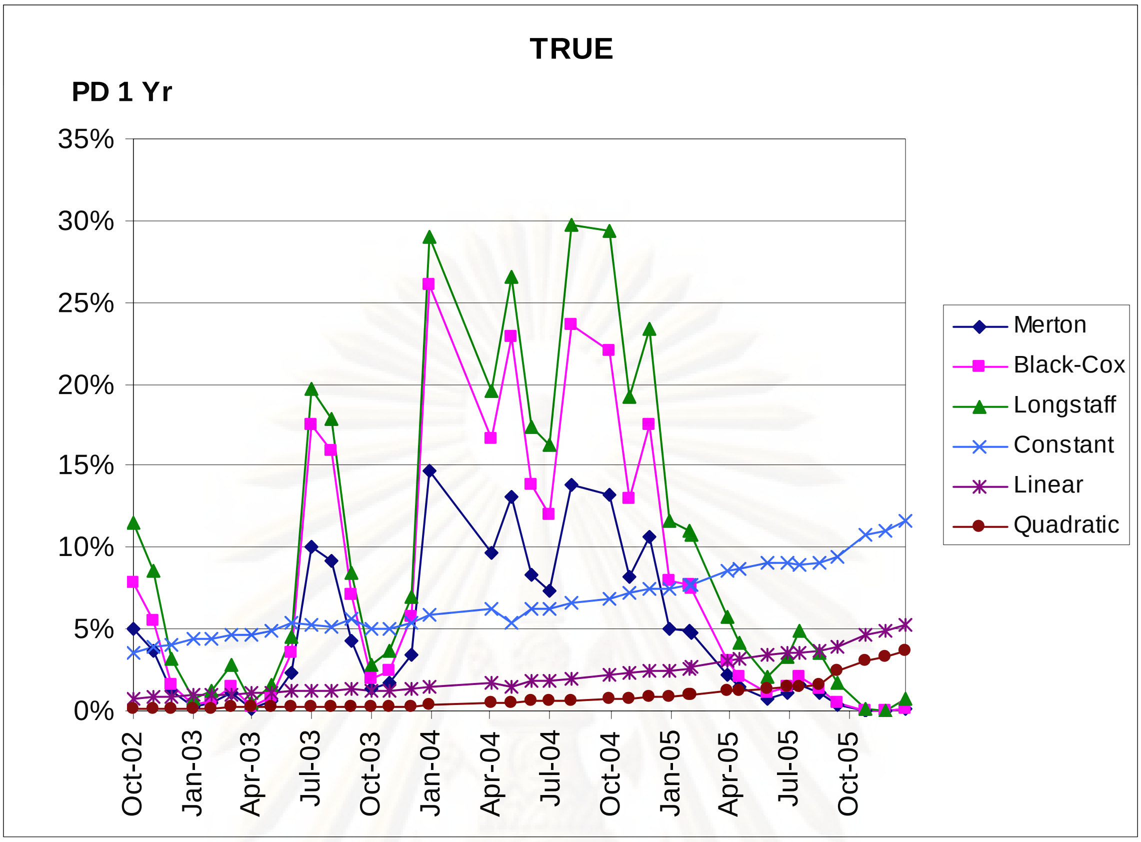

NMG
PD 1 Yr
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

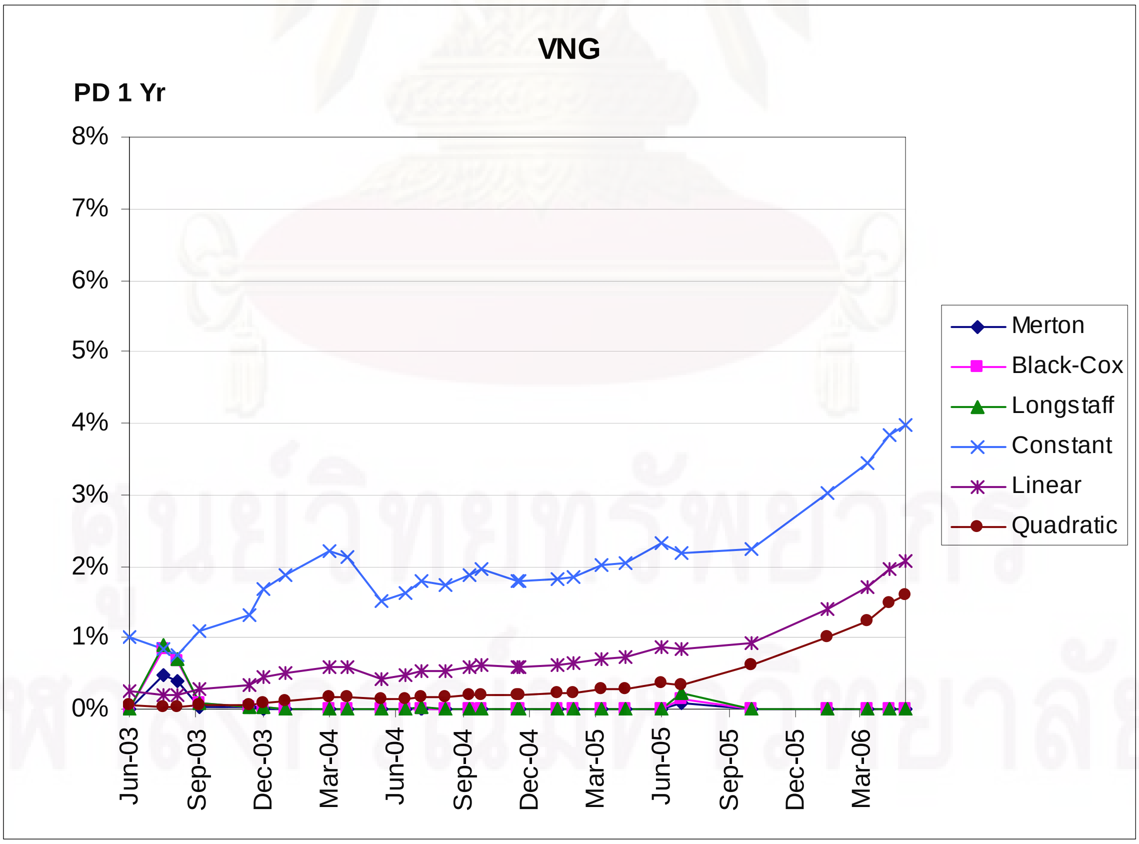

NVL
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic


PL
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic


PTT
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

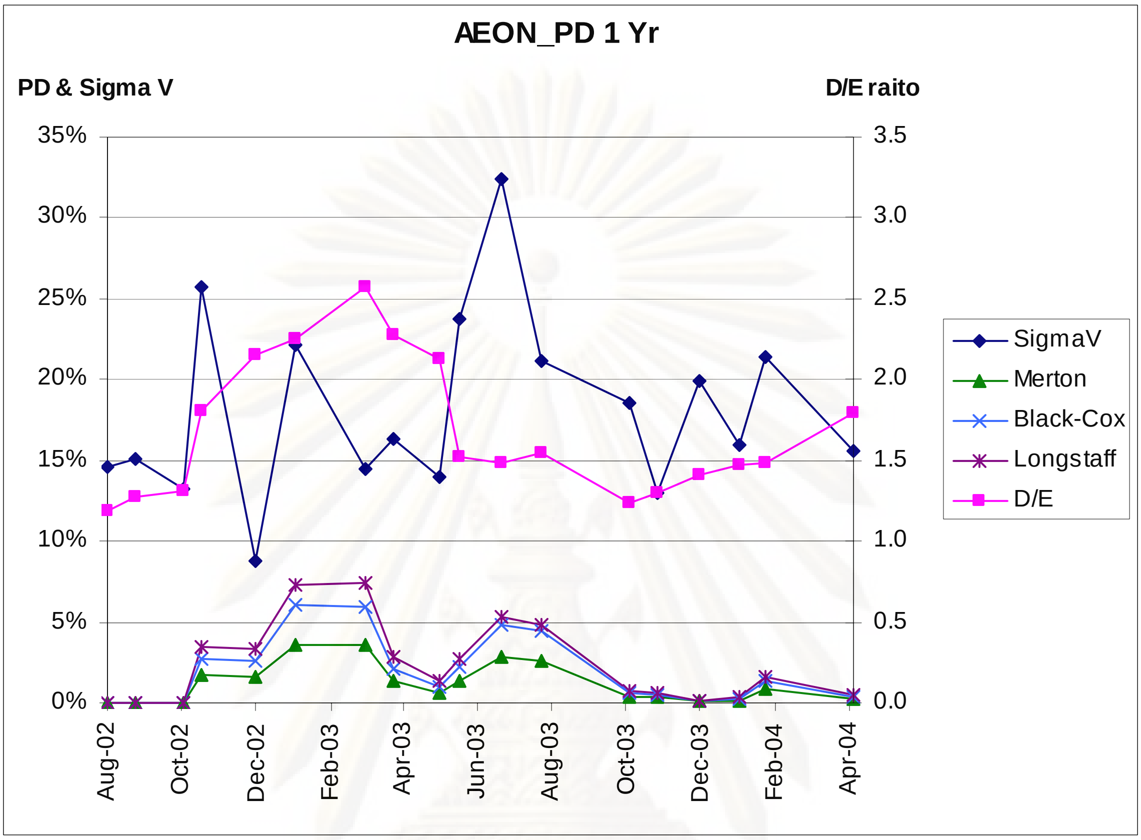

SCC
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

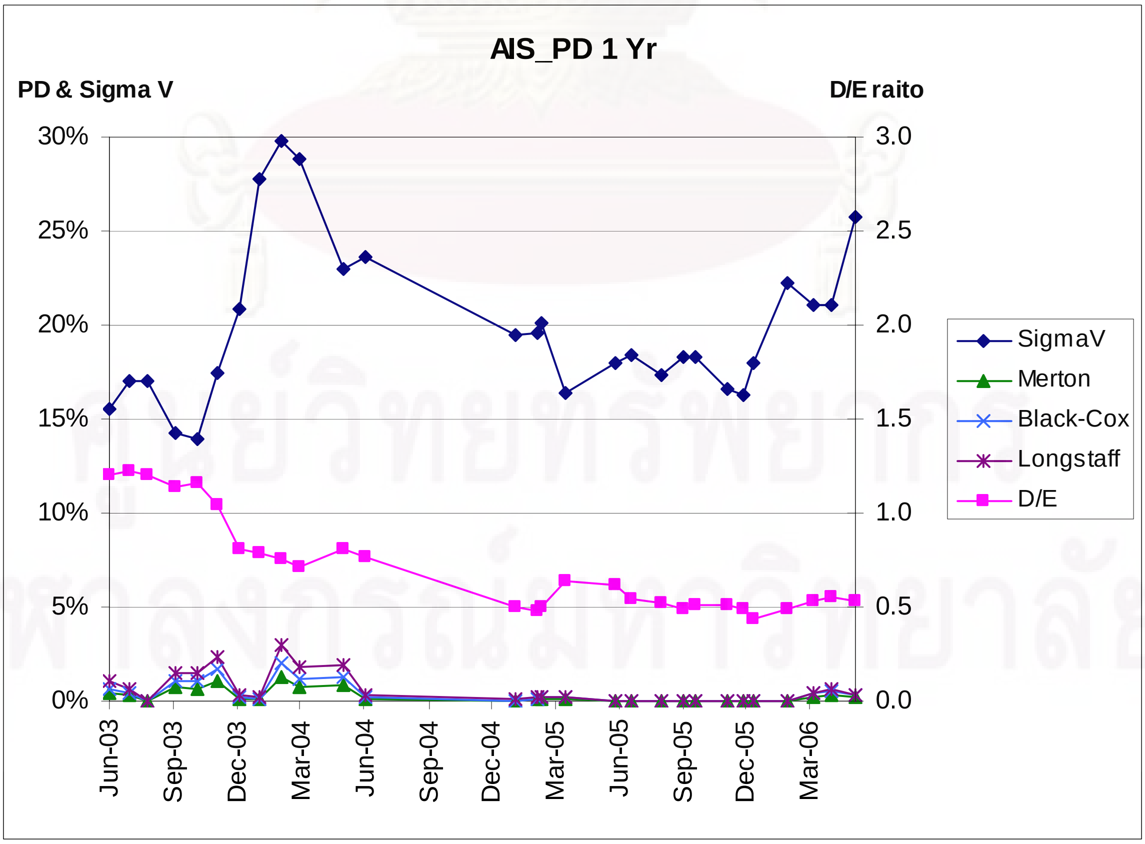

TRUE
PD 1 Yr
35%
30%
25%
20%
15%
10%
5%
0%
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

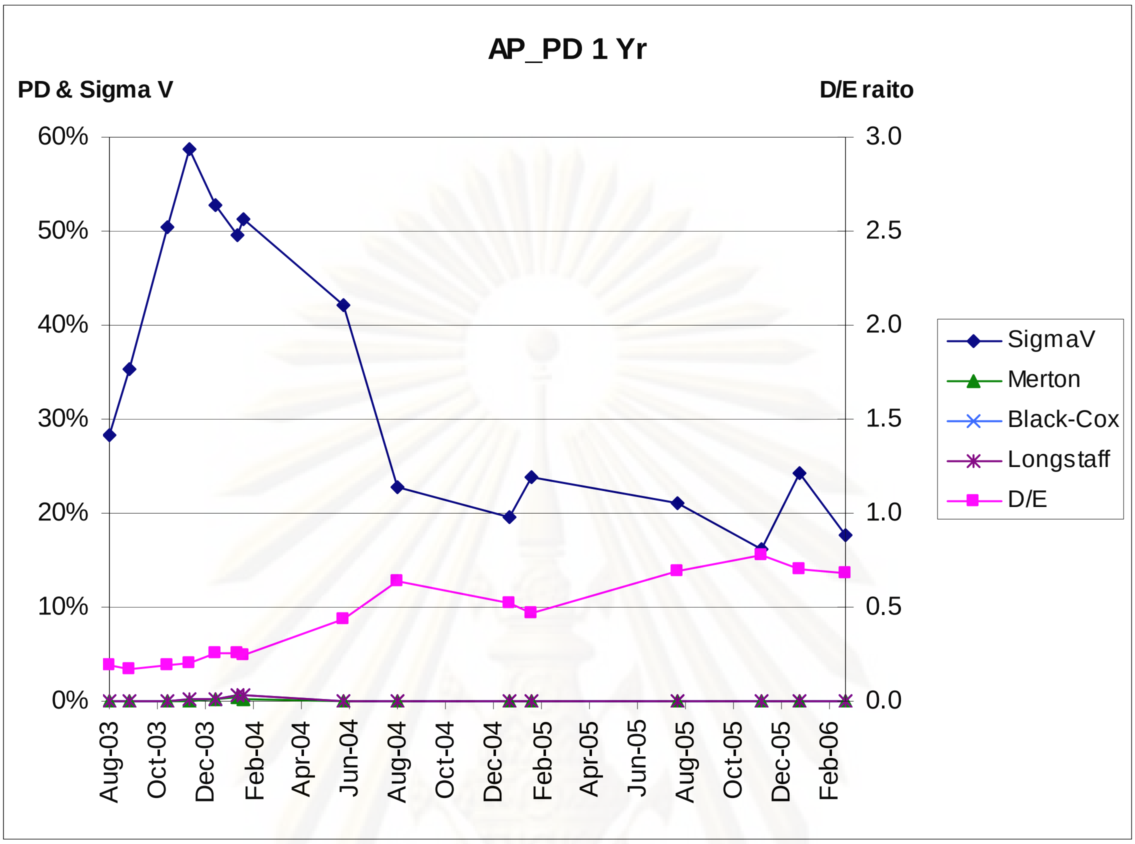

VNG
PD 1 Yr
8%
7%
6%
5%
4%
3%
2%
1%
0%
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
Sep-05
Dec-05
Mar-06
Merton
Black-Cox
Longstaff
Constant
Linear
Quadratic

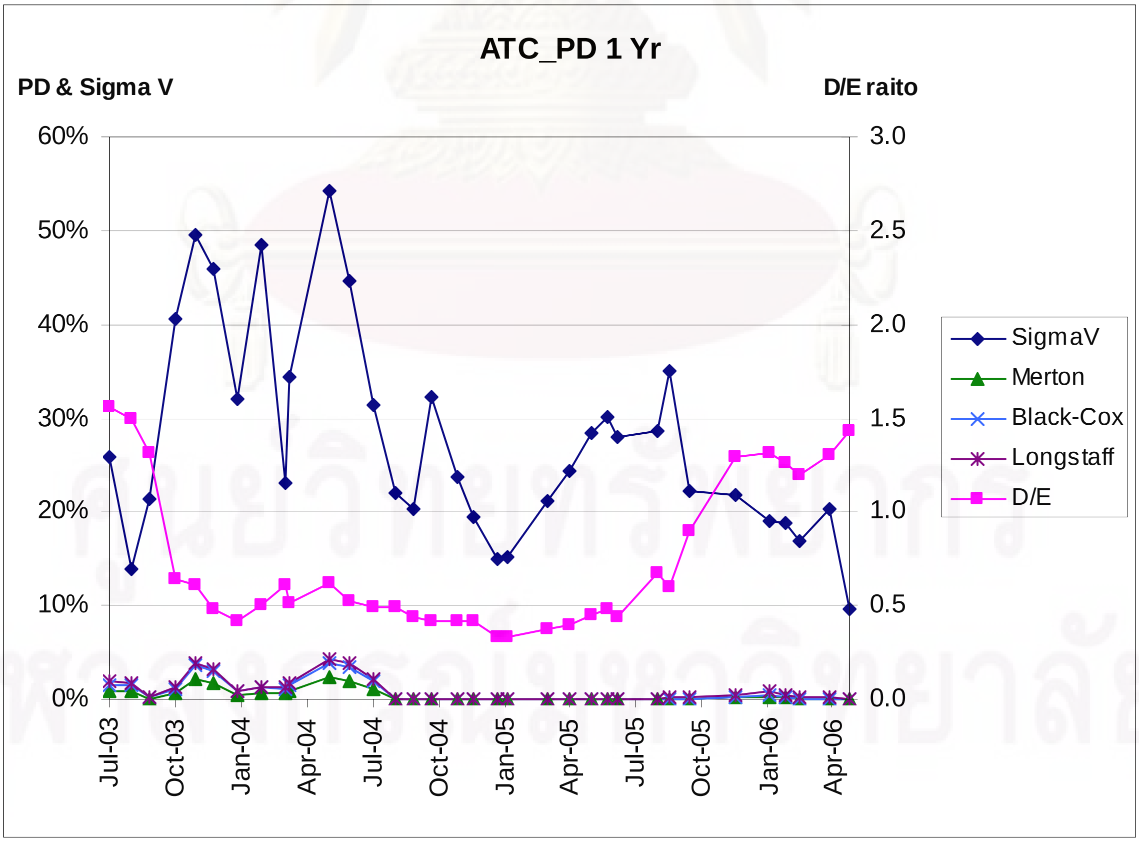
APPENDIX C

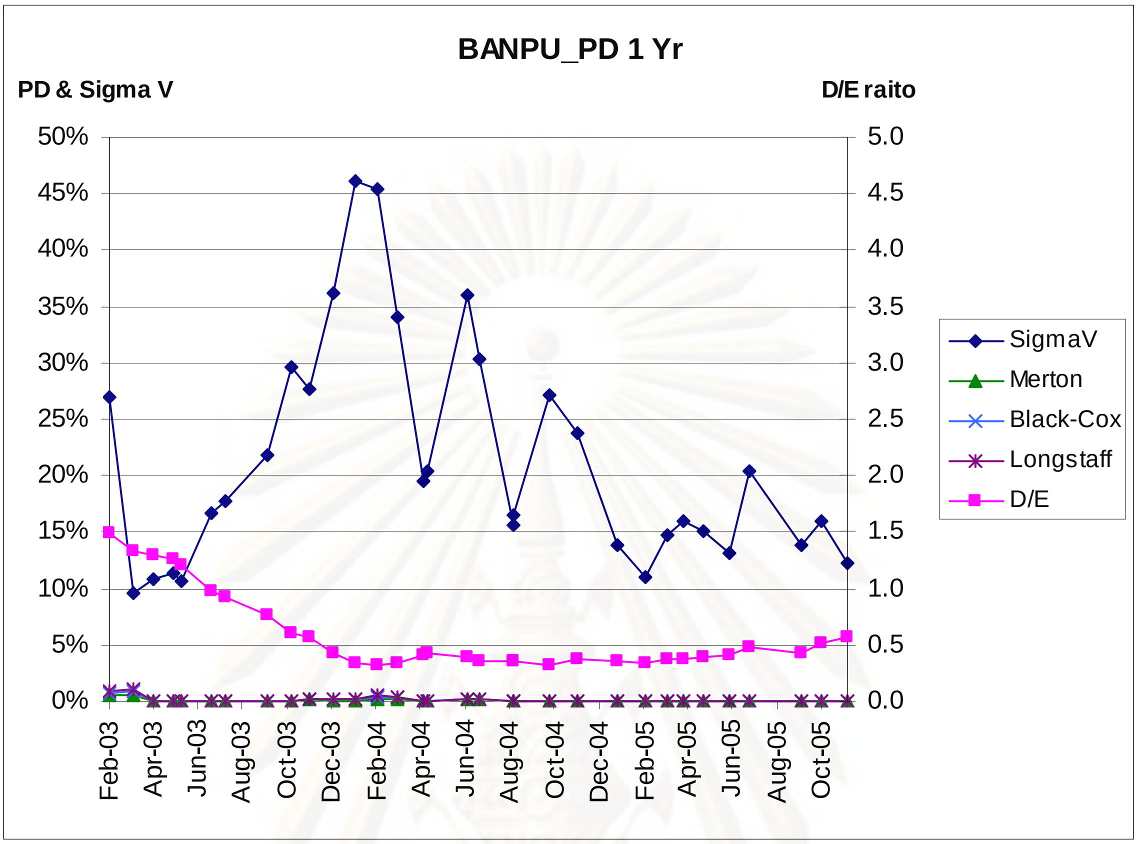
This section shows comparing between descriptive subscription of firms and 1-year default probability which using structural model

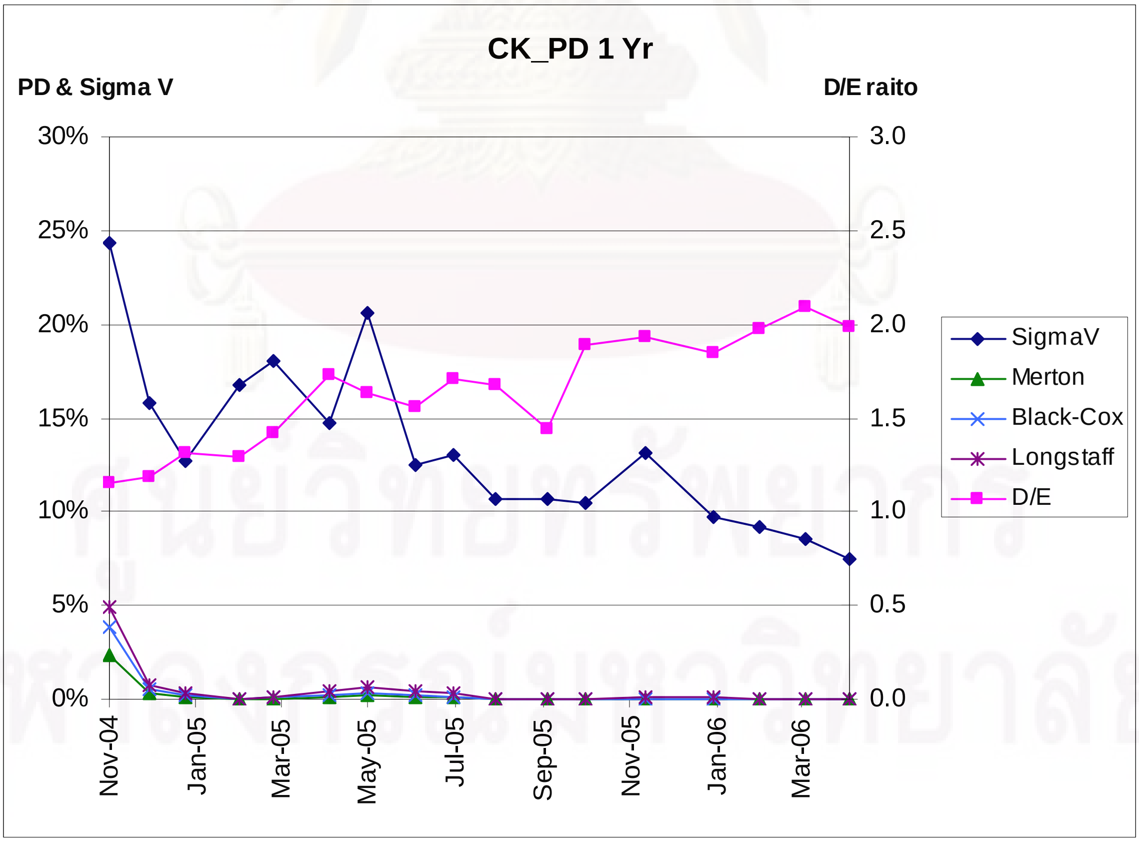


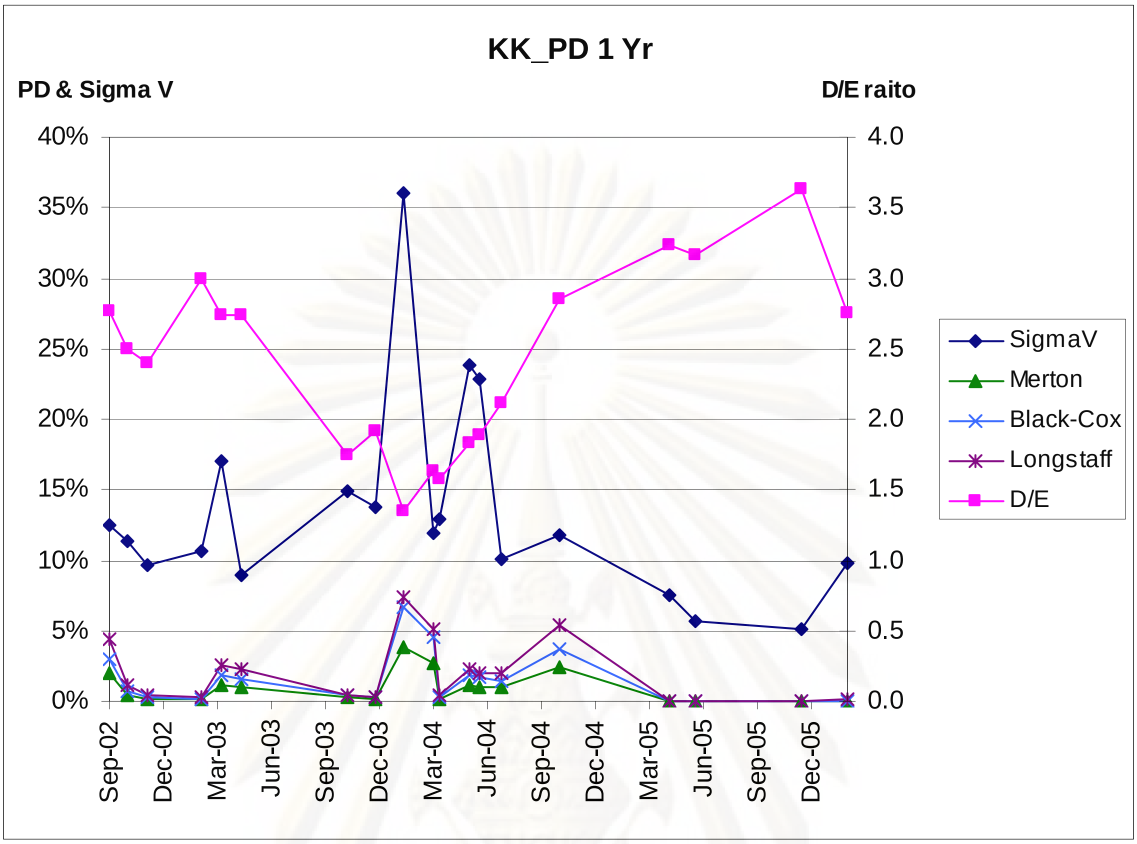


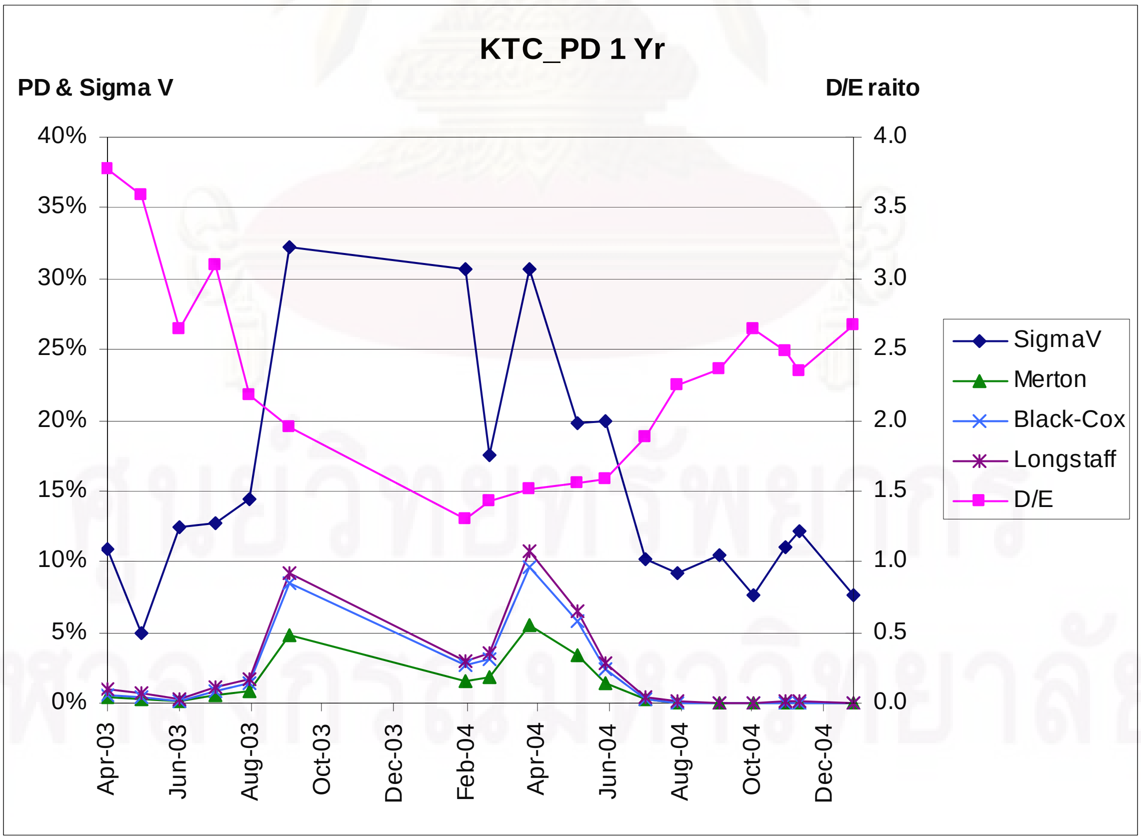

AP_PD 1 Yr
PD & Sigma V
D/E raito
60%
50%
40%
30%
20%
10%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
SigmaV
Merton
Black-Cox
Longstaff
D/E

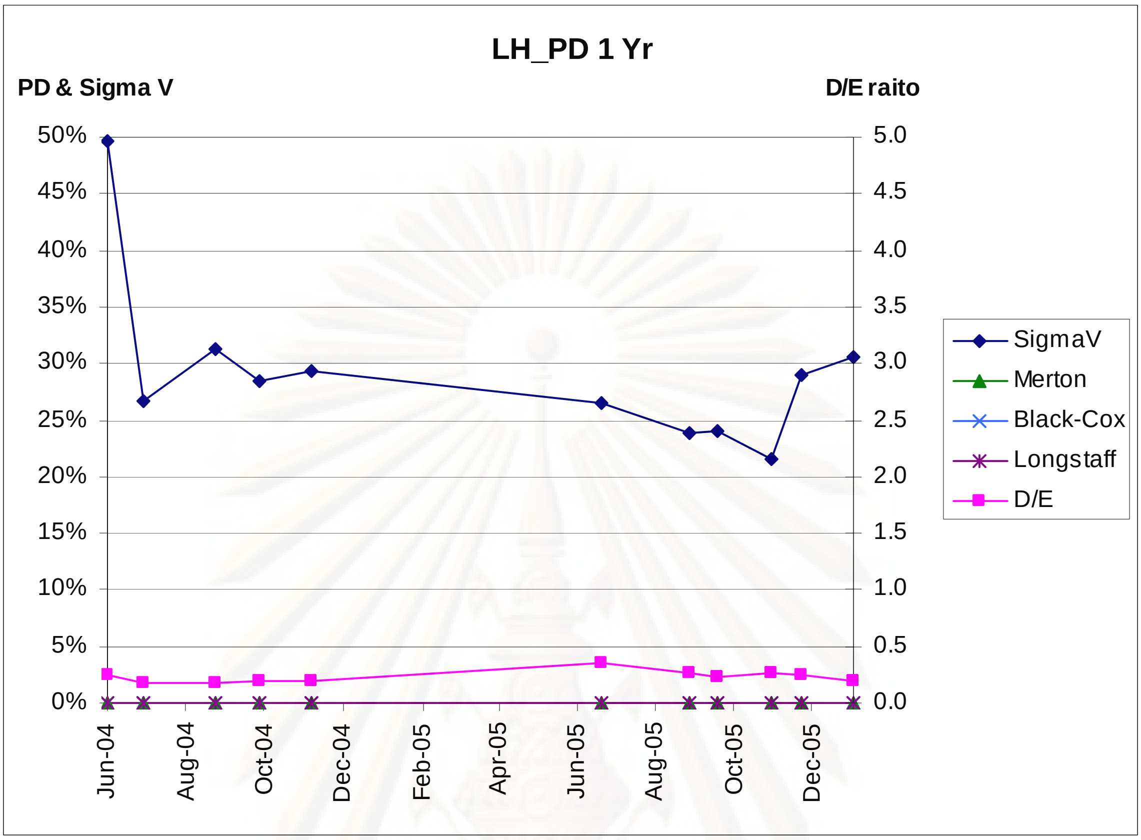

ATC_PD 1 Yr
PD & Sigma V
D/E raito
60%
50%
40%
30%
20%
10%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
SigmaV
Merton
Black-Cox
Longstaff
D/E

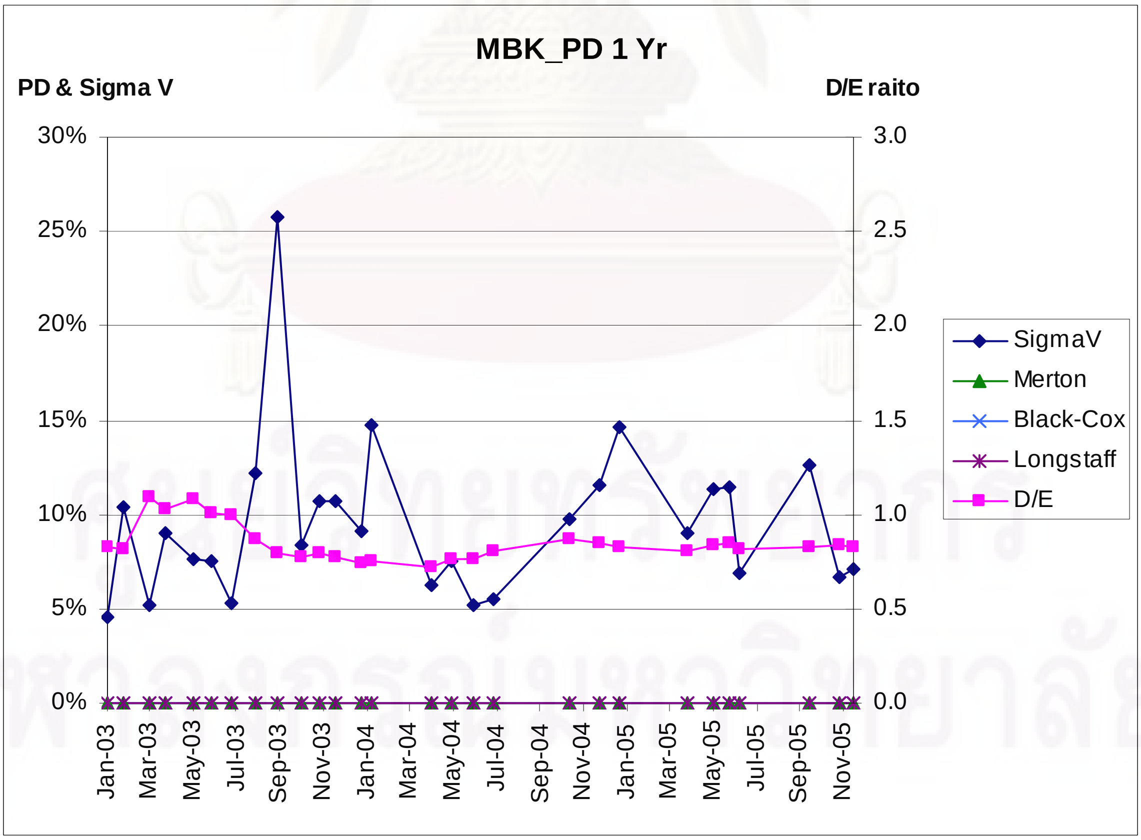

BANPU_PD 1 Yr
PD & Sigma V
D/E raito
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Feb-03
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
SigmaV
Merton
Black-Cox
Longstaff
D/E

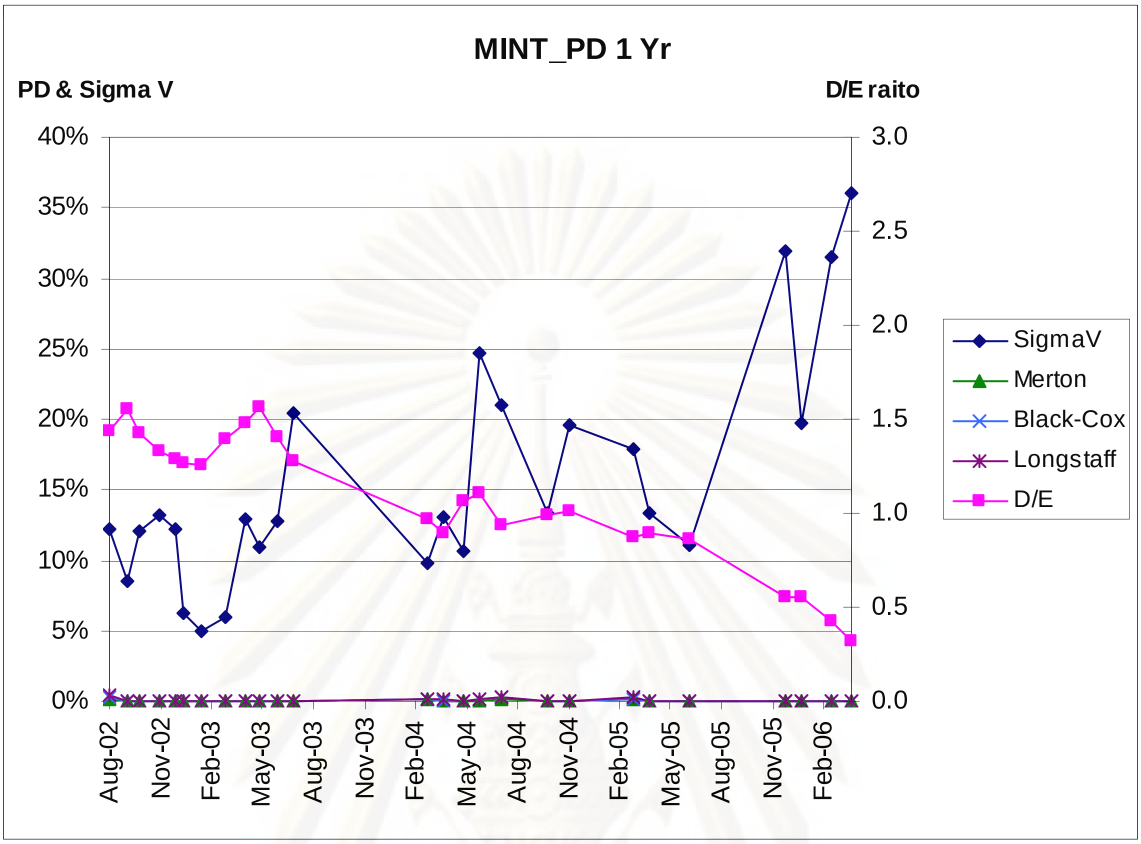

CK_PD 1 Yr
PD & Sigma V
D/E raito
30%
25%
20%
15%
10%
5%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
SigmaV
Merton
Black-Cox
Longstaff
D/E

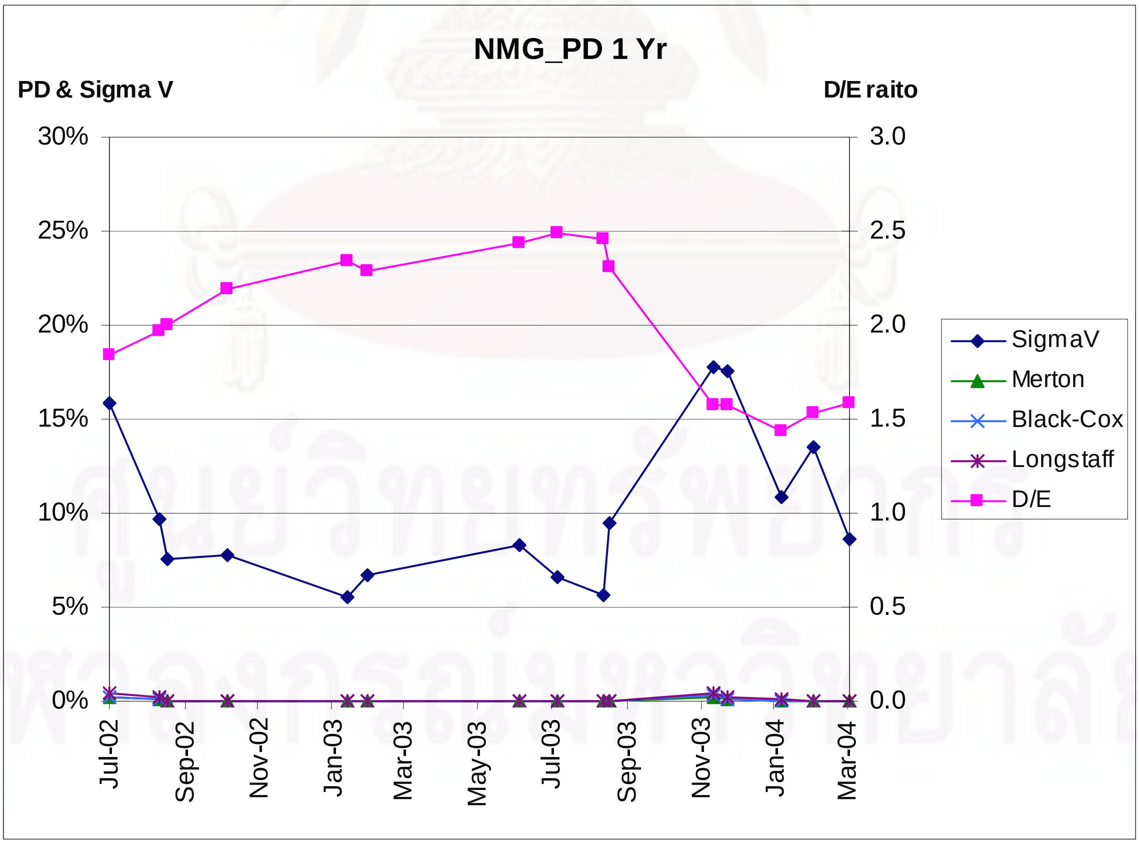

KK_PD 1 Yr
PD & Sigma V
D/E raito
40%
35%
30%
25%
20%
15%
10%
5%
0%
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
Sep-05
Dec-05
SigmaV
Merton
Black-Cox
Longstaff
D/E

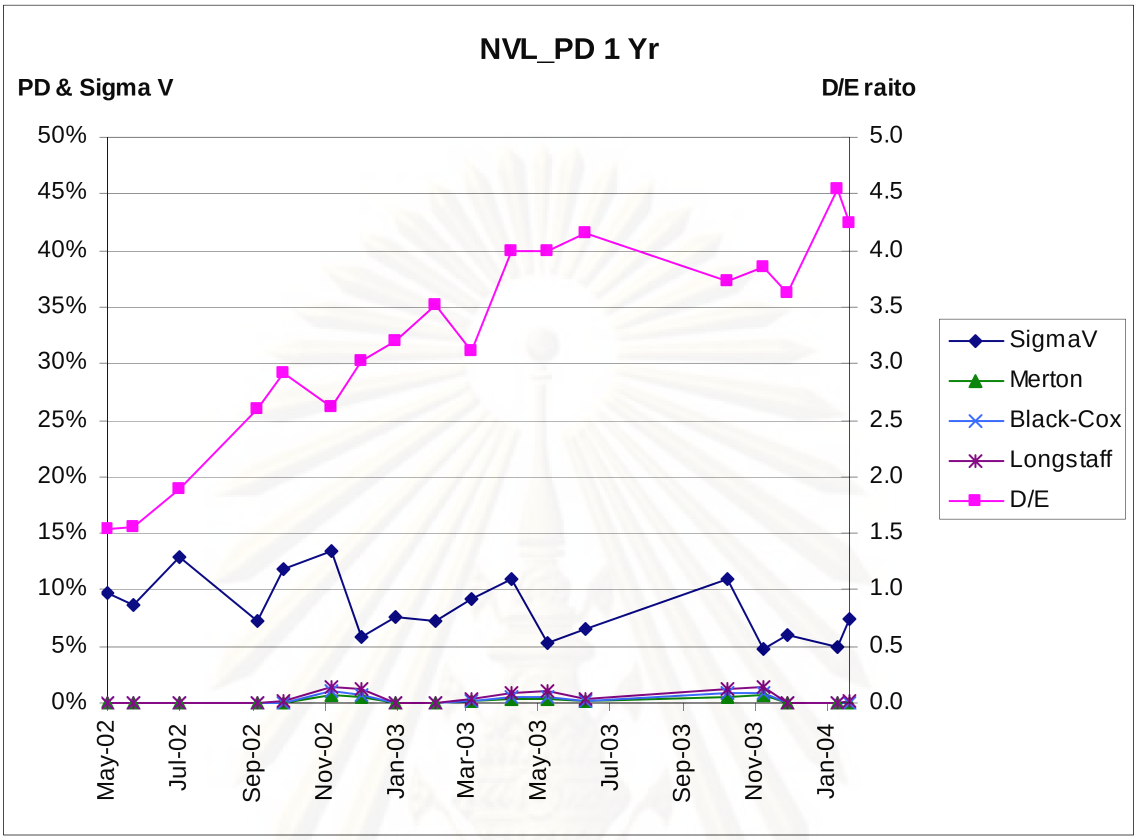

KTC_PD 1 Yr
PD & Sigma V
D/E raito
40%
35%
30%
25%
20%
15%
10%
5%
0%
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
SigmaV
Merton
Black-Cox
Longstaff
D/E

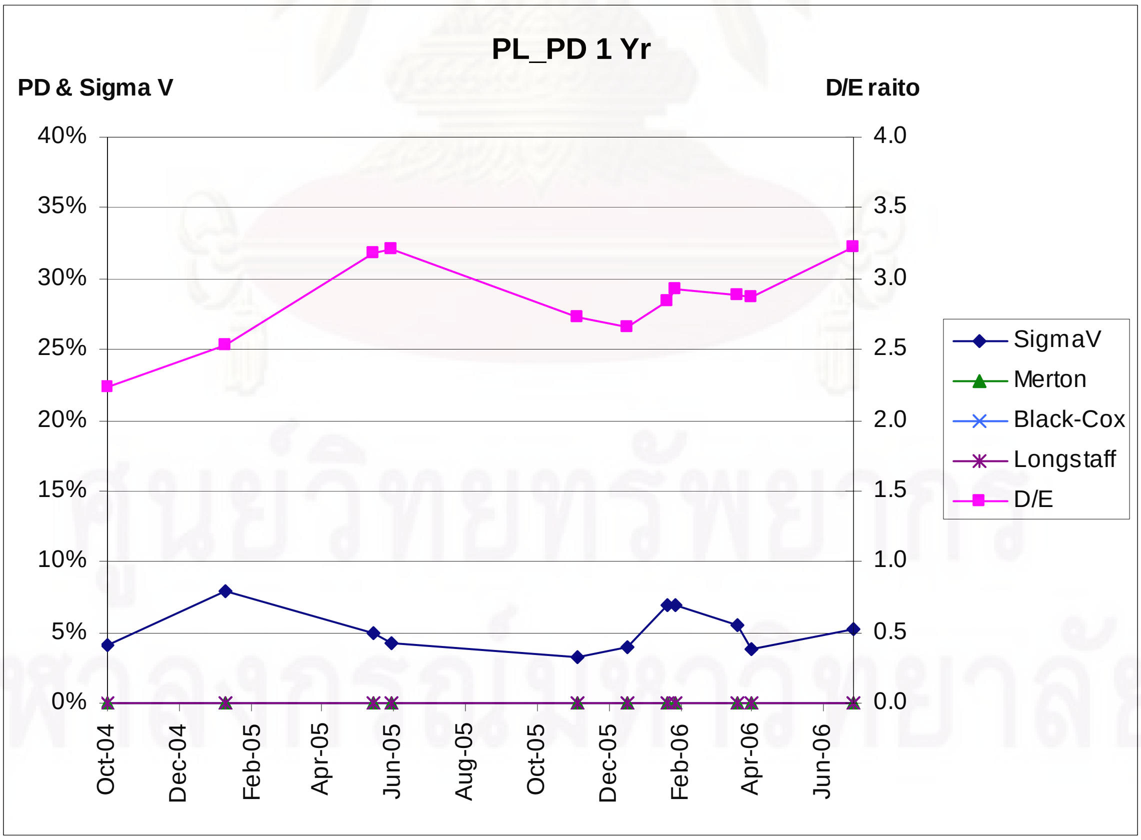

LH_PD 1 Yr
PD & Sigma V
D/E raito
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
SigmaV
Merton
Black-Cox
Longstaff
D/E

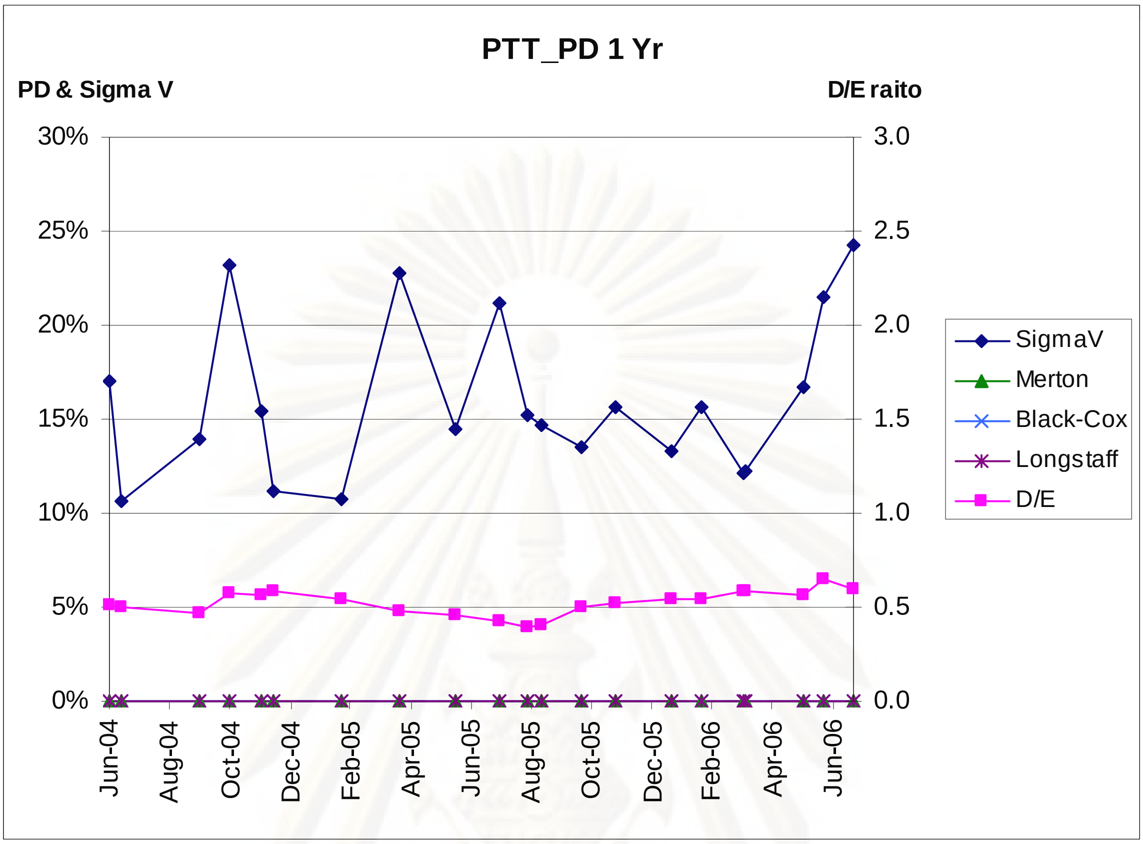

MBK_PD 1 Yr
PD & Sigma V
D/E raito
30%
25%
20%
15%
10%
5%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
SigmaV
Merton
Black-Cox
Longstaff
D/E

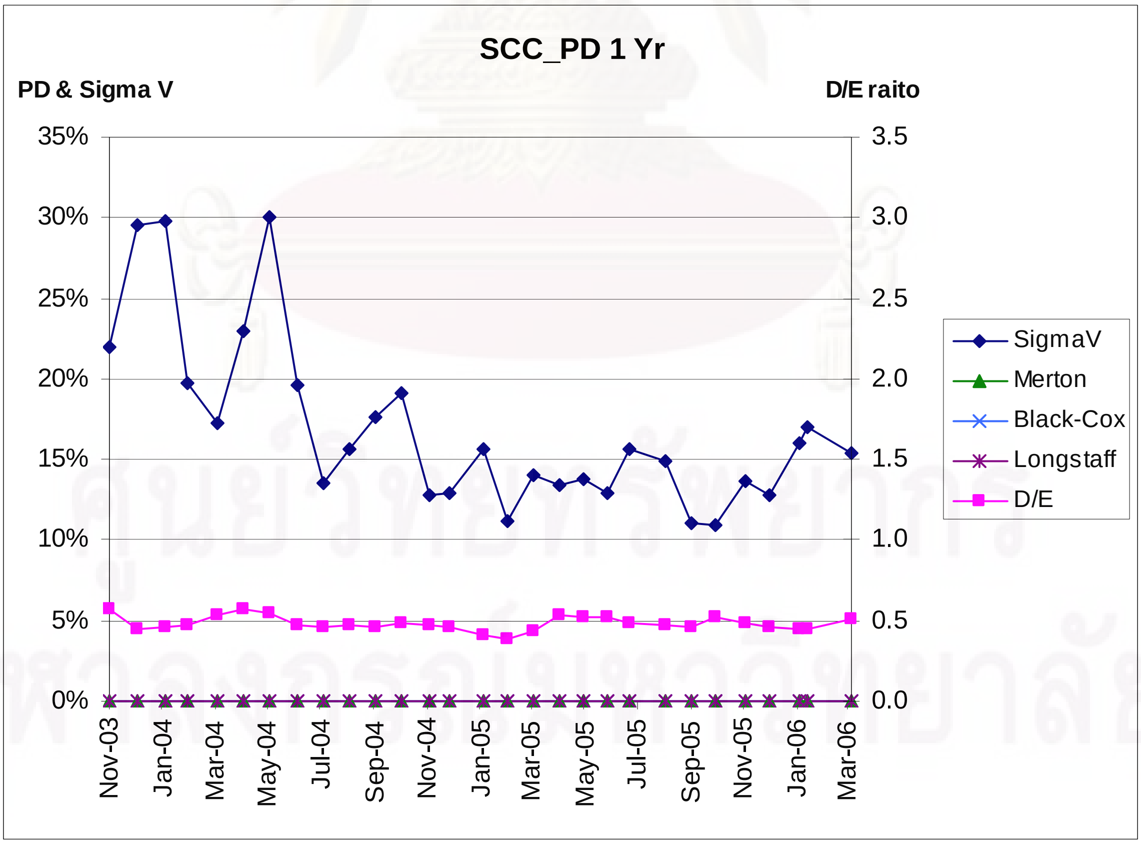

MINT_PD 1 Yr
PD & Sigma V
D/E raito
40%
35%
30%
25%
20%
15%
10%
5%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Aug-02
Nov-02
Feb-03
May-03
Aug-03
Nov-03
Feb-04
May-04
Aug-04
Nov-04
Feb-05
May-05
Aug-05
Nov-05
Feb-06
SigmaV
Merton
Black-Cox
Longstaff
D/E

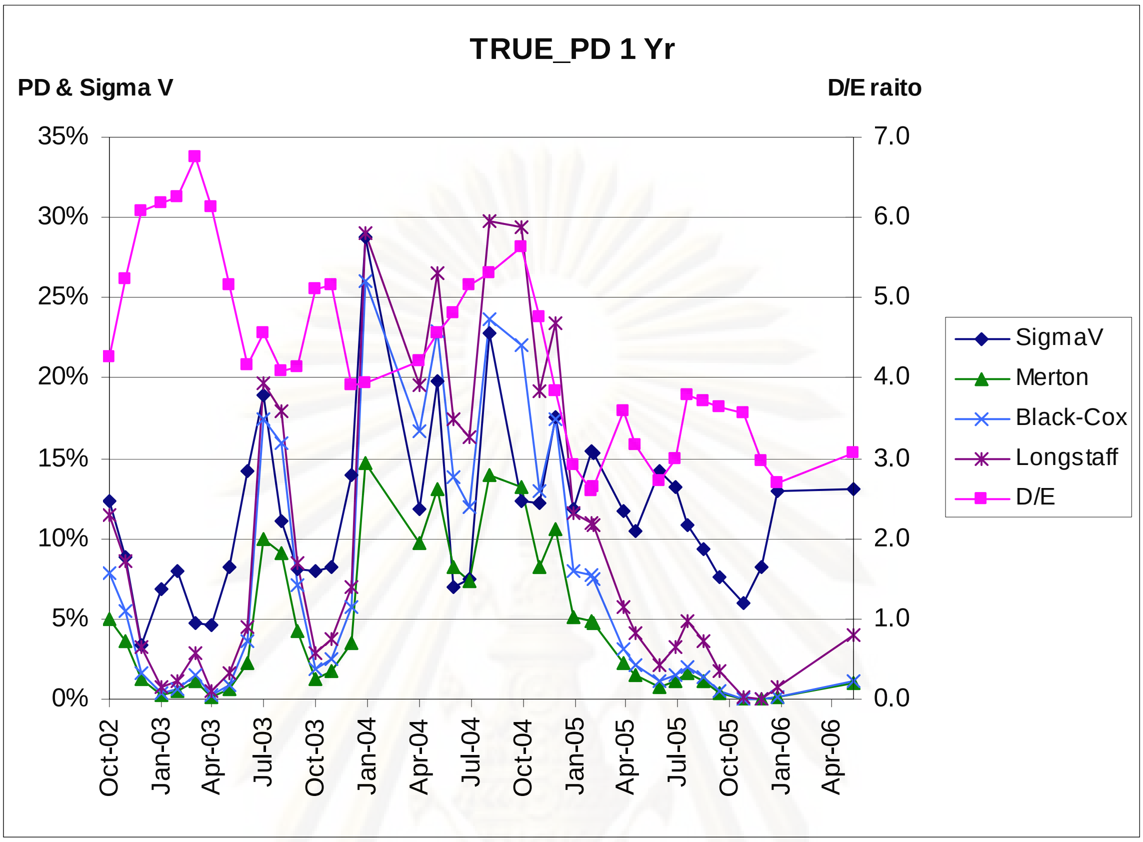

NMG_PD 1 Yr
PD & Sigma V
D/E raito
30%
25%
20%
15%
10%
5%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
SigmaV
Merton
Black-Cox
Longstaff
D/E


NVL_PD 1 Yr
PD & Sigma V
D/E raito
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
SigmaV
Merton
Black-Cox
Longstaff
D/E

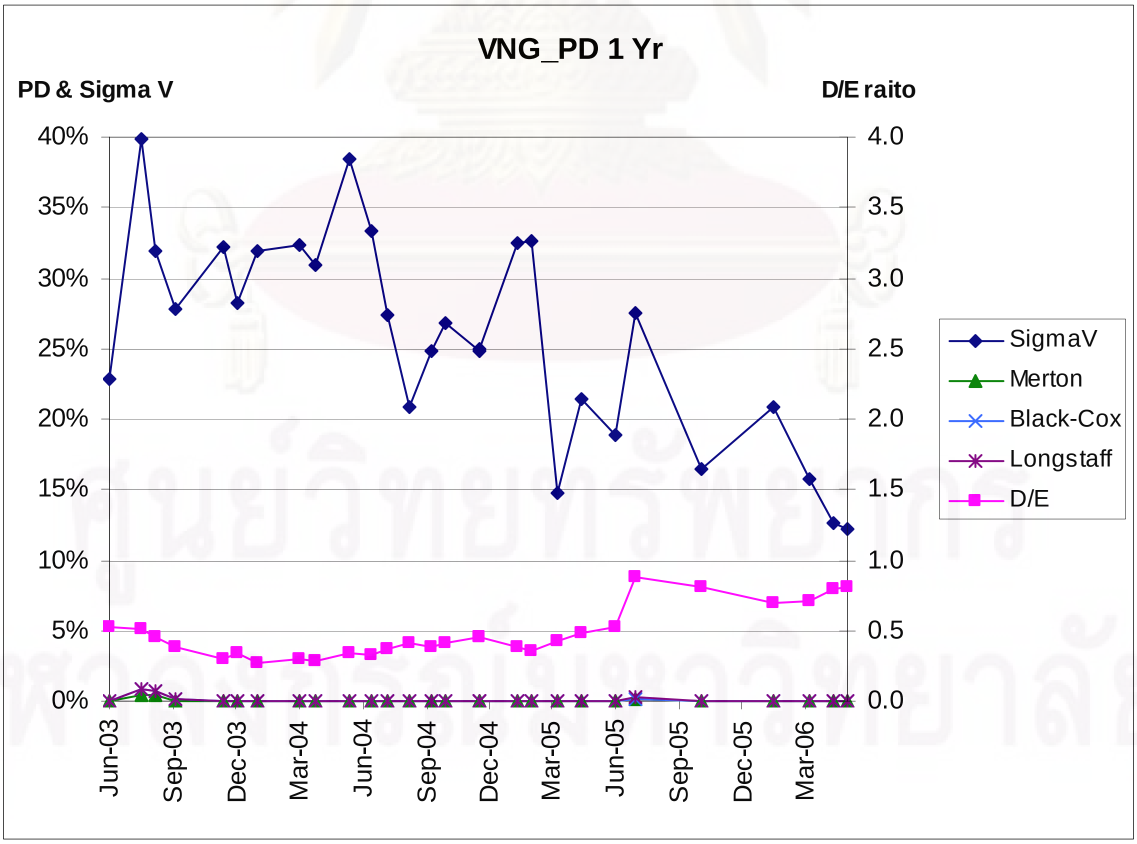

PL_PD 1 Yr
PD & Sigma V
D/E raito
40%
35%
30%
25%
20%
15%
10%
5%
0%
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
SigmaV
Merton
Black-Cox
Longstaff
D/E


PTT_PD 1 Yr
PD & Sigma V
D/E raito
30%
25%
20%
15%
10%
5%
0%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
SigmaV
Merton
Black-Cox
Longstaff
D/E


SCC_PD 1 Yr
PD & Sigma V
D/E raito
35%
30%
25%
20%
15%
10%
5%
0%
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
SigmaV
Merton
Black-Cox
Longstaff
D/E



TRUE_PD 1 Yr
PD & Sigma V
D/E raito
35%
30%
25%
20%
15%
10%
5%
0%
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
SigmaV
Merton
Black-Cox
Longstaff
D/E



VNG_PD 1 Yr
PD & Sigma V
D/E raito
40%
35%
30%
25%
20%
15%
10%
5%
0%
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
Sep-05
Dec-05
Mar-06
SigmaV
Merton
Black-Cox
Longstaff
D/E

BIOGRAPHY

Ms. Kamonwan Sujatanond was born in Feb 10, 1983. At the primary school and secondary school, she graduated from Suanbua School and Samsen Wittayalai School, repectively. At the undergraduate level, she graduated from the Faculty of Economics, Thammasat University in September 2004 with a Bachelor of Arts degree; First Class Honours, majoring in Econometrics. She joined the Master of Science in Finance program, Chulalongkorn University in June 2005.