The Asset Value Volatility Improvement of Merton KMV Credit Model: the Case Study of Thailand Listed Companies

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Abstract **- This paper applies asset volatility input of Merton KMV model using conditional volatility processes: GARCH EGARCH IGARCH (ACVG) to eliminate the effect of external stock volatility in calculating distance to default measure of the company. This study based on Thai listed companies in the stock exchange of Thailand (SET). The ACVG model distance to default imply more robust result than original Merton KMV model. The ACVG exhibit significant improvement in the distance to default value in term of consistency, reliability and it could be more forward indicator than Merton KMV model. The external volatility effect original Merton KMV model has been diluted.**

Keywords **- Merton Model, Distance to Default, Risk Nature, Probability of Default, GARCH, EGARCH, IGARCH, Credit Risk**

I. INTRODUCTION

The growth of Thai bond market has back drop in lower yield curve. The government bond yield curve in 2017 has shift down ward, particularly short term which its yield lower than interest policy at 1.5% from special issue that Bank of Thailand has decrease number of short term bond issue to limit fund inflow for protecting currency from appreciation in value. 10 years government yield lower from 2.6% at the end 2016 to 2.5% at the end 2017.

Corporate bond market also get benefit from the lower yield curve. The market has expanded sharply especially in recent year. The total bond outstanding is increasing from 3.08 Trillion Baht in 2015 to 3.83 Trillion Baht (include government bond which has rating) in 2017 the cumulative annual growth rate (CAGR) is 26%. Most portion of bond outstanding in the market is investment grade bond 93.3% while the rest number are non-investment grade and unrated bond (low grade bond). Trading value of corporate bond is also increase from 4.33 Billion average trading volumes per day in 2016 to 5.09 Billion average trading volume per day in 2017.

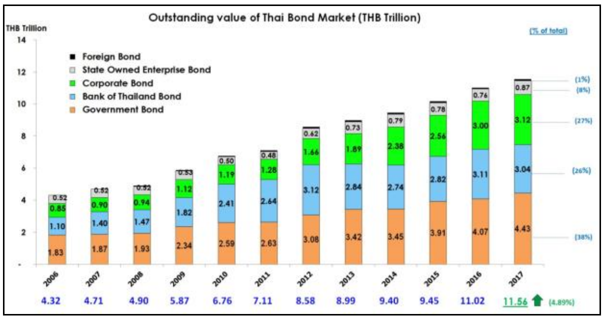

Fig. 1 Value of Bond Outstanding of Thai Bond Market
Data From: Thai Bond Market Association 2018

However, the growth rate in 2017 seem to be obstacle, the total bond outstanding increase only 1.4% due to the bill of exchange default event in the late 2016. Which may interfere low grade bond market sentiment as in fig. 2. The lowest investment grade bond yield has increased 36 bps. since the beginning of 2017. This could represent the worst event in low grade bond. The problem did not affect on the yield which represent the cost of funding but also the total number of issuer of low grade bond decrease by 31.8%.

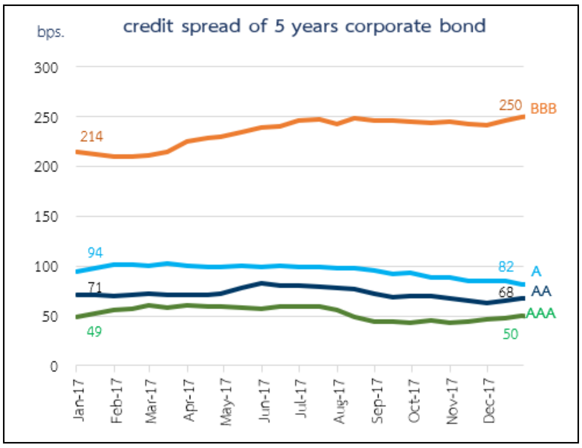

Fig. 2 Credit Spread Classify by Rating in 2017 After Default Event

Therefore, under the theme of growing in the bond market overall, the low-grade bond has been run dry by the specific event. Investor made decision without acknowledgment of how worst the low-grade bond was. When the default event happened even in a few part of the market, investor lost confidence and putting away of all class of low-grade bond. The case of low grade bond show that credit risk assessment is one of the key important issue not only for investor itself to concern of their loss, but also affect to the market and all related participant.

The popular model to forecast credit risk using available daily data from public source is Merton KMV model. The model use stock price as one of the input. However, the distance to value from Merton model exhibit effect of volatility in stock price and cause result of credit risk measure unreliable. This study focuses on the improvement of asset value volatility in Merton Model using GARCH, IGARCH, EGARCH to eliminate the effect of external factor volatility from stock.

II. RISK NATURE PROBABILITY OF DEFAULT

The credit risk can be indicated through risk nature default probability with stock price. Many studies Shumway (2001), [1] Bharath and Shumway (2008), [2] show strong relationships between default probability and stock price which already include an agreement of investor. The model helps business to warn its credit conditions of counterparty earlier through the possibility of credit deterioration. It is evident that Bohn, Arora and Korablev (2005), [3] this model quantifies credit risk in present time. Moreover, literatures indicated that the market value of stock price in can represent credit risk better than the accounting value. This method for valuing the credit can be regarded as the ways used to analyze the credit traditionally.

The pricing of stock has been done by the all investor in which analyzes both present and expected. The price is determined by market mechanism at a value of equilibrium through matching demand-supply approach. However, the evaluation might not be precise; therefore, the implication of prediction of business through stock price will be considered factors. Therefore, it is assumed that either individuals or institutions might not reach the better valuation. The claim is primarily involved with the fairness of the business properties. In case the business incomes tend to be either better or worse, the first which will be reflected is the stock price on its changing. Hence the suitable interpretation of the changing stock prices is challenged. Firm does not have to determine the payment of cash flow for its debts or interests in order to estimate if the business can afford. The market value is considered as the main point; it depends on the market value of the firm's assets. In case the market value of the firms is enough, then the firm will be able to provide its desired cash, or firm could sale their assets to meet obligation. If the transfer is hard to be managed through the assets, then they have to be sold in another way, which is, either added equity or debt has to be issued. The market value has more interesting the competency of the firms than the potential cash position.

One of the most useful model to quantify the probability of default for a company which based on stock price is Merton (1974), Kealhofer McQuown and Vasicek (KMV). Since the foundation of risk nature model' credit risk being considered from the stock price can be compared as a call option for the firm's properties. The default probability calculated from models are risk nature which based on market instrumental: equity. Merton (1974), [4] incorporate the view of credit risk in to firm's structure. Their model assumes that firm asset value follows a lognormal process of diffusion with a constant volatility. The model assume that firm has issued debt D that matures at time T. Market prices of stocks are considered as the critical factor used for health measurement toward firms. The Structural Defaulting Model founded by Merton in 1974 categorized the value of stock as a call option premium on the firm asset value. However, Merton model has the limitation on the properties in the real time due to the movement of stock. So, the model has been revised by Vasicek (1984), [5] and Crosbie and Bohn (2003), [6] (KMV-model) in terms of using stock price to measure the financial health of firm and predict statistical distance of how far asset value is away from its debt level called distance to default. The uncertainty of the firms' properties is also taken in to account through volatility. Such estimation helps indicate that how many standard deviations far away from its default point. In the work of Campbell et al. (2008), [7] claimed that although Merton's Model seems to be useful, it is obvious that the Model has reduced form models so far. The stock prices and structural models which provide accounting facts and estimation as well as Distance to Default Model. It is necessary to use the Model application to try out, estimate, and validate the data. The fair market prices are stated that they enhance the effectiveness statement through the financial health of the enterprises and credit risk assessment. In addition, both market prices of stock and debt level data are used to evaluation the financial health in the context of timeliness rather than credit scoring. These processes normally require equity data and strictly assumption that asset value follow lognormal diffusion process. However, study about an option pricing have observed implied volatility smile in option pricing which does not consistent with the assumption of constant volatility model in the Merton model. This study will investigate further in asset value volatility process which act as the main contribution of the model and relax the assumption of KMV-Merton to achieve the closer realistic character of asset value volatility.

III. METHODOLOGY

Let assume E_0 and A_0 to be the value of today Equity and Asset, E_T and A_T at time T. σ_A is the volatility of asset value, and r is the risk free rate. In Merton (1974) model, volatility and risk free rate are assumed to be constant. At time T, shareholder will be paid that: $\mathrm{E}_T = \max[A_T - D, 0]$ The assumption of the model expresses that equity of firm is an European call option on firm assets with maturity at T and the par value of firm zero coupon bond is considered as the debt obligation at time T. Therefore, holding equity of investor is analogous as holding a call option on the firm's asset which embed obligation on its debt payment at maturity date as option's strike price.

According to Black and Scholes (1973) the value of equity today provide as:

Where

$$\mathrm{E}_0 = A_0 N(d_1) - De^{-rT} N(d_2)$$

$$\mathrm{d}_1 = \frac{\ln(\frac{A_0 e^{rT}}{D})}{\sigma_A \sqrt{T}} + 0.5\sigma_A\sqrt{T}$$

$$\mathrm{d}_2 = \mathrm{d}_1 - \sigma_A\sqrt{T}$$

The debt has been shown in present value type as $D = De^{-rT}$ let L stand for leverage of firms. $L = D/A_0$. Therefore, the equity value is defined as:

Where

$$E_0 = A_0(d_1) - LN(d_2)$$

$$d_1 = \frac{-ln(L)}{\sigma_A\sqrt{T}} + 0.5\sigma_A\sqrt{T}$$

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

It's lemma could be used to quantify the instantaneous volatility of the equity from asset volatility.

$$E_0\sigma_E = \frac{\partial E}{\partial A} A_0 \sigma_A$$

Where

σ_E is the instantaneous volatility of equity.

$$\sigma_E = \frac{\sigma_A N(d_1)}{N(d_1) - LN(d_2)}$$

The Merton model, the underlying asset volatility can not be observed directly like option pricing model. Thus, solving from volatility and option price to implied back asset value and volatility of firm. Equation number (1) and (2) let us to E_0 and σ_E which can be observed from firm's public equity prices to get the unobservable A_0 and σ_A by taking L and T in to account. The probability of default at time T will be that the probability of shareholders cannot exercise the call option to buy asset for D at time T $\pi_Q = N(-d_2)$. The probability depends only on L (leverage) and the asset volatility.

A. The KMV-Merton Distance to Default

The model calculates from following function:

$$DD_{it} = f(A_{it}(E_{it}, \sigma_{it}^E), \sigma_{it}^E, E_{it}(E_{it}, \sigma_{it}^E), D_{iq(t)}(n\#_t), T, r_{it})$$

Where

D_{it} is the Distance-to-Default T periods ahead in data, subscript i represent individual stock, and subscript t is day. The definition of the inputs in the model are:

- $A_{it}(E_{it}, \sigma_{it}^E)$ asset value is implied from programing iteration technique under assumption that investor price equity based on firm asset value.

- σ_{it}^E is stock i volatility which calculate from standard diviation during T period.

- E_{it} is stock price at day t.

- $D_{iq(t)}(n\#_{it})$ is total debt per stock for stock i at latest quarter near day t. It has be devided by number of stock in order to find total debt per stock.

- $n\#_{it}$is number of stock.

- $T$is period of forecasting distance to default.

- r_{it} is expected growth rate of return for stock i.

B. The KMV-Merton Distance to Default with Applied Volatility Process

The model calculates from following function:

$$DD_{it} = f(A_{it}(E_{it}, \sigma_{it}^E(\sigma_{it-1}^E, u_{it-1}^E)), \sigma_{it}^E(\sigma_{it-1}^E, u_{it-1}^E), E_{it}(E_{it}, \sigma_{it}^E(\sigma_{it-1}^E, u_{it-1}^E)), D_{iq(t)}(n\#_t), T, r_{it})$$

Where

D_{it} is the Distance-to-Default T periods ahead in data, subscript i represent individual stock, and subscript t is day. The definition of the inputs in the model are:

- $A_{it}(E_{it}, \sigma_{it}^E)$ asset value imply from programing iteration technique under assumption that investor price equity based on firm asset value.

- $\sigma_{it}^E(\sigma_{it-1}^E, u_{it-1}^E)$ asset volatility follow GARCH (1,1), EGARCH (1,1), GJR-GARCH (1,1) process.

- σ_{it}^E is stock i volatility which calculate from standard diviation during T period.

- E_{it} is stock price at day t.

- $D_{iq(t)}(n\#_{it})$ is total debt per stock for stock i at latest quarter near day t. It has been divided by number of stock in order to find total debt per stock.

- $n\#_{it}$is number of stock.

- T is period of forecasting distance to default.

- r_{it} is expected growth rate of return for stock i.

C. The Data Set and Testing Period

The study calculates the distance to default of Merton KMV and the applied asset volatility process: KMV-Merton-GARCH, KMV-Merton-EGARCH, KMV-Merton-IGARCH of firms in stock exchange of Thailand which were listed before October 2015. The rest listed firms has been cut out due to the limitation of data. The number of stocks used in this study is 461 firms. The condition of the calculation in this study are that: 1) the period of volatility in Merton KMV is standard deviation of rolling 120 working days, 2) an assumption of 5 percent of large business lending rate use as risk free rate, and 3) the total debt of firm has been used to represent the debt outstanding which is called from latest available quarter of announcement. The one-year distance to default has calculate weekly from March 2010 to April 2018. For conditional volatility model, individual firm data of 500-days (2-years) period during March 2008 to March 2010 (429 period) is used to estimate conditional assets volatility using; GARCH, EGARCH, GJR-GARCH model. During the testing period (March 2010 to April 2018) estimated model of individual stock is used as an input to calculate conditional asset volatility in the week of estimate to replace constant volatility in (1) and calculate distance to default of each conditional volatility model.

IV. RESULT

This study show that ACVG model has more robust result in term of statistic and moderate correlated with Merton KMV model, however ACVG may change in different direction to Merton model. The causality test confirmed that ACVG model lead Merton KMV model. The reason that ACVG model has more conservative result and the signal lead Merton model is because of the asset value volatility process which implement in ACVG model has their own volatility process. The new coming data would be an input for the process. Unlike Merton KMV model that the new coming data would exhibit the new volatility estimation. Therefore, the result is more volatile due to the volatility measurement of the model.

A. Distance to Default Value

TABLE I
CROSS SECTIONAL STATISTIC
OF DISTANCE TO DEFAULT

Factor	Distance to default (average)	
	Merton KMV	M-GARCH
Mean	1.5789	1.2770
SD	3.9581	3.9006
Skewness	2.6428	0.5502
Kurtosis	9.8940	31.3490

ACVG-Merton model has lower mean value meaning that on average most of stock probability of default measured by ACVG is higher. It is conservative measure. The high Kurtosis mean that most the distance to default distribution of all stock peak around mean. Consistence SD confirm that ACVG in this study preform the same range of distribution. The cross-sectional ACVG data illustrate that ACVG-EGARCH has highest distance to default mean, SD, kurtosis. The second is ACVG-IGARCH and the third is ACVG model. The reason behind this is because ACVG-EGARCH exhibit leverage term more freely than ACVG-IGARCH and ACVG. This feature of EGARCH and IGARCH can gain more leverage effect in the volatility structure to improve distance to default in term of credit risk measure. Therefore, using leveraged estimator of GARCH model effect the value of distance to default.

TABLE II
CROSS-SECTIONAL STATISTIC
OF ACVG MODEL

Factor	Distance to default (average)		
	M-GARCH	M-EGARCH	M-IGARCH
Mean	1.2770	1.9703	1.2721
SD	3.9006	37.6542	4.7166
Skewness	0.5502	3.8021	2.7052
Kurtosis	31.3490	131.2310	57.7953

TABLE III
CROSS-SECTIONAL CORRELATION MERTON KMV AND ACVG MODEL OF THAI LISTED FIRMS

Correlation	Merton KMV		
	q1	mean	q4
M-GARCH	0.2970	0.5044	0.7217
M-EGARCH	0.2970	0.4818	0.7217
M-IGARCH	0.2856	0.8168	0.7173

Cross-section correlation (Table III) show that Merton-KMV and ACVG GARCH-EGARCH-IGARCH has highly correlate with IGARCH the first at mean 0.8168 and moderate correlation with GARCH, the second, at mean 0.5044, and EGARCH the third at mean 0.4818. However, quantile 1 and quantile 4 show large band of correlation distribute from 0.2970 to 0.7217. While they have highly correlate among ACVG class model. According to 461 sample firms, 89.7-94.3% of firm Merton KMV and ACVG are correlated at percent confidence level.

TABLE IV
CROSS-SECTIONAL CORRELATION STATISTIC AVERAGE OF THE DISTANCE TO DEFAULT CHANGE OF MERTON KMV AND ACVG MODEL

Change Correlation	Merton KMV		
	q1	mean	q4
M-GARCH	0.1617	0.2695	0.3758
M-EGARCH	0.1617	0.2405	0.3758
M-IGARCH	0.1360	0.2661	0.3940

B. Distance to Default Change

Merton KMV and ACVG model have low distance to default change correlation the highest is 0.2695 between Merton KMV and ACVG-GARCH, the lowest is 0.2405 between Merton KMV and Merton-EGARCH. The band of change correlation is between 0.1360 to 0.3940. On the other side, the change correlation among ACVG are at high level, the highest is between ACVG-GARCH and ACVG-IGARCH with high band from 0.4897 to 0.9271. This positive change correlation illustrates that the signal from Merton KMV and ACVG change in the same way, but it might be different magnitude. Reason behind is because volatility is main contribution to the signal.

C. Cointegration Test

First order cointegration test table show that mostly firm distance to default Merton KMV have significant level at 99% cointegration with IGARCH and has moderate cointegration to ACVG-EGARCH, ACVG-GARCH, ACVG-GARCH and ACVG-EGARCH, ACVG-GARCH and ACVG-IGARCH consecutively. On the other hand, ACVG-GARCH has highly number of stocks cointegration at 99%. Results from this table show that both Merton KMV and ACVG are cointegrated in both ways.

TABLE V
CROSS-SECTIONAL DISTANCE TO DEFAULT COINTEGRATION TEST RESULT (1)

From >To v	Merton KMV		
	90%	95%	99%
M-GARCH	0.07084	0.17166	0.59945
M-EGARCH	0.07629	0.15531	0.52588
M-IGARCH	0.06811	0.155313	0.54495
GARCH-EGARCH	0.09809	0.190735	0.43051
GARCH-IGARCH	0.10081	0.15803	0.39237
G-E-IGARCH	0.12261	0.16893	0.34059

TABLE VI
CROSS-SECTIONAL DISTANCE TO DEFAULT COINTEGRATION TEST RESULT (2)

From >To v	M-GARCH		
	90%	95%	99%
Merton	0.01362	0.0163	0.8855
M-EGARCH	0	0.0054	0.9128
M-IGARCH	0	0.0027	0.9209
IGARCH	0	0	0.9237

D. Granger Causality Test

TABLE VII
CROSS-SECTIONAL DISTANCE TO DEFAULT CAUSALITY TEST RESULT (1)

From >To v	Merton KMV		
	90%	95%	99%
M-GARCH	0.5994	0.5204	0.3542
M-EGARCH	0.5525	0.4804	0.2972
M-IGARCH	0.5778	0.4970	0.3413

TABLE VIII
CROSS-SECTIONAL DISTANCE TO DEFAULT CAUSALITY TEST RESULT (2)

TO >From v	Merton KMV		
	90%	95%	99%
M-GARCH	0.9509	0.9291	0.8719
M-EGARCH	0.9729	0.9519	0.9069
M-IGARCH	0.9550	0.9311	0.8832

Granger causality show statistic cross-sectional first order causality test result. It shows that half of stock in Thai stock market has parameter that Merton KMV Granger cause ACVG-GARCH, ACVG-EGARCH, ACVG-IGARCH and one fourth of stock has parameter that Merton KMV Granger cause ACVG-GARCH, ACVG-EGARCH, ACVG-IGARCH at 99% confidence level. On the other size, result show that every ACVG model has Granger cause Merton KMV. 90.6%, 88.5%, 87.1% of number stock in ACVG-EGARCH, ACVG-IGARCH, ACVG-GARCH has granger cause significant at 99% confidence level to Merton KMV consecutively. This show the implication of this study and confirm that using conditional volatility has lead measure feature to credit risk.

E. Example of Default Company

The case of Energy Earth Public Company Limited is a good example of using the ACVG model compare with Merton model. The result of ACVG enhance the predicting power of the distance to default as shown in fig. 3. The default event occurred in Jun 2017 when the company announce to the bill of exchange holder to extend their debt. Prior to that event, the distance to default (DD) from Merton model show excellent sign of its value. One month before the default, DD rose up to 20 which should be a good signal for company and represent very low chance to default in one year ahead. However, DD was suddenly drop and the value was lower than zero which significantly rose chance to default.

On the other hand, ACVG model DD show sign of higher default during a year before. The ACVG DD was lower for all of year 2016 and sudden drop two weeks prior to default event as Merton model. Even though, during the period of near default, the value of ACVG DD model did not low as Merton model DD was, It is enough to represent the jump up in higher change of default.

Altman z-score is one of a good indicator, prior to default the z-score was reach the lowest value at 0.6 which was the lowest since 2015. The z-score 0.6 mean to have the high chance to default. However, Altman z-score was lower than 1.8 which is the border line to be high chance of default for 4 years prior to default. Therefore, using Altman z-score could only represent the chance of default.

The example of Energy Earth company gives overview of how ACVG model DD have more consistent sing than Merton model DD, and over Altman z-score and financial ratio. Finally, it can be concluded that there is no all in one solution for monitoring credit risk since all the model could not tell exact default event will be. So using many instruments and take appropriate weight would be the best solution for dealing with credit risk.

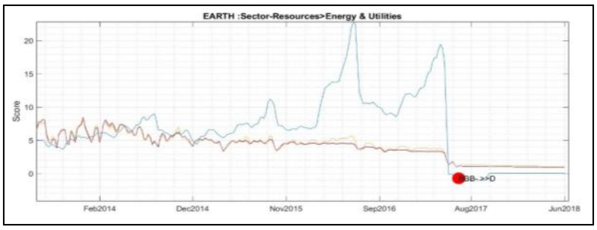

Fig. 3 The Distance to default of Energy Earth Public Company Limited which has default event in the red marked (blue line = Merton KMV, red line = ACVG-GARCH, purple line= EGARCH, yellow line = IGARCH).

V. CONCLUSION

This paper study the different and its implication between risk nature probability of default (Merton KMV model) and applied conditional volatility risk nature probability of default (Applied Conditional Volatility GARCH family model ACVG) based on Thai firms that listed in the stock exchange of Thailand (SET). Result show that in some dimension ACVG model post greater result and more conservative to use as credit risk measure. The ACVG model deduct the external volatility problem by using the conditional volatility process for asset value.

VI. ACKNOWLEDGMENT

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