CHAPTER IV

DATA AND METHODOLOGY

4.1 Data

- This study uses the data from the DataStream. All the warrants listed on the Stock Exchange of Thailand and registered from 2001 to 2006 are considered[1]. There are 291 warrants listed during that period. In this study, we are only interested in warrants that are issued as multiple series, that have about 20 series from firms in the market. The data set includes daily prices of warrants and stocks, number of outstanding warrants and stocks, time-to-maturity, and exercise price. The features of the studied warrants are shown in table 4.1.
- Interest rate data is obtained from www.thaibma.or.th. The government bond yield curve is used as the representative of risk-free rate of interest.

4.2 Research Hypotheses

4.2.1 Hypothesis 1: Testing Pricing Error of Each model

From all cases that have been tested by multiple warrants papers, omitting the dilution effects across warrant series may result in overpricing the value of warrant. Ignoring either cross-dilution effect or subtle slippage effect leads to an overestimation on the value of the firm and therefore overprices the value of warrant. Hence, our first hypothesis is that the market price is lower than the model price.

H0: The market price $\geq$ the model price.

H1: The market price $<$ the model price.

4.2.2 Hypothesis 2: Testing Pricing Error of the Model In Each Situation

The data used to test this hypothesis is categorized into 3 cases, in-the-money, at-the-money, and out-of-the-money. The warrants are in-the-money when $v/K > 1.15$

[1]This is due to the lack of risk-free rate of interest before year 2001.

Table 4.1: Features of the Studied Warrants

			A						B					
	Start	End		Exercise	Dilution	Observation				Exercise	Dilution	Observation		
	Date	Date	Maturity	Price	Ratio	ITM	ATM	OTM	Maturity	Price	Ratio	ITM	ATM	OTM
APC	7/10/03	30/11/06	4.9096	1.00	0.294	316	79	7	6.9068	1.00	0.294	336	92	7
BTC	16/3/04	30/11/06	2.9057	1.00	0.233	551			4.9507	1.82	0.622	459	103	
ESTAR	10/3/04	30/11/06	7.9041	0.42	0.158	534	95		7.9068	1.00	0.283	11	97	538
JAS	2/3/04	30/11/06	4.8247	0.50	0.610	552	44		5.4137	0.33	0.140	673	7	
QH	8/11/01	16/4/03	1.4384	1.18	0.059	286	44		4.9342	1.00	0.228	321	451	
QH2	5/9/03	16/10/06	3.0548	1.00	0.156	628	83		4.9534	1.20	0.188	223		
SICCO	20/11/03	21/9/04	2.4575	6.00	0.040	517	49		4.4603	5.00	0.094	558		
SPORT	6/7/04	30/11/06	3.1096	1.00	0.086	302			6.9233	5.50	0.343	2	48	495
STEC	3/5/05	30/11/06	2.0685	1.00	0.002	26			2.9562	8.50	0.148	232	29	127
SPALI	21/9/05	14/6/06	0.7370	1.50	0.017	159			2.9342	1.50	0.113	163		

The warrants are classified into two series, series A and B, based on the maturity. The warrant series that expires first is classified as series A. The warrant series that expires later is classified as series B. Start date is the date that two warrants series begin to overlap. End date is the date that series A warrants expire or the end of study date that is 30 November 2006. Maturity is the time-to-maturity at the start date. ITM, ATM, and OTM stand for in-the-money, at-the-money, and out-of-the-money, respectively.

and out-of-the-money when $v/K < 1.15$. For each case, each model should be significantly different from each other.

H0: Model price$_i$ = Model price$_j$

H1: Model price$_i$ $\neq$ Model price$_j$

4.2.3 Hypothesis 3: Testing Pricing Error Between Models

Since Galai-Schneller model does not take into account the cross-dilution effect and the subtle slippage effect. It should be the most biased model. Therefore, forecast error statistics of Galai-Schneller model is likely to be higher than forecast error statistics of each multiple warrants model. Additionally, the Darsinos-Satchell model considers only for the cross-dilution effect. Thus, the forecast error statistics of this model should be greater than the forecast error statistics the other two models. Let us denote that GS, LT, DS, and DR represent Galai-Schneller, Lim-Terry, Darsinos-Satchell, and Dennis-Rendleman, respectively.

- H0: Forecast error statistics of GS model $\leq$ Forecast error statistics of each multiple series warrants model
  H1: Forecast error statistics of GS model $>$ Forecast error statistics of each multiple series warrants model
- H0: Forecast error statistics of DS model $\leq$ Forecast error statistics of LT model
  H1: Forecast error statistics of DS model $>$ Forecast error statistics of LT model
- H0: Forecast error statistics of DS model $\leq$ Forecast error statistics of DR model
  H1: Forecast error statistics of DS model $>$ Forecast error statistics of DR model
- H0: Forecast error statistics of DR model $\leq$ Forecast error statistics of LT model
  H1: Forecast error statistics of DR model $>$ Forecast error statistics of LT model

4.3 Methodology

4.3.1 Parameter Estimation

4.3.1.1 The Value of Firm and Firm Volatility Estimation

All the variables in the warrant pricing formula can be observed in the market except for the value of the firm and firm volatility. However, as Thai market is an emerging market, obtaining volatility from other methods such as from market price (implied volatility) and from historical stock volatility might have some biases in pricing. The method to obtain the value of the firm and the firm volatility used in this study is expected to reflect the true value of the firm and true value of firm volatility more than other methods. The procedures to find the two unknown values are as follows. Recall that the value of the firm per share is defined in chapter 3 as

$$v = S + \sum_{i=1}^{q} \lambda_i W_i$$

Therefore, the stock price becomes

$$S = v - \sum_{i=1}^{q} \lambda_i W_i \tag{4.1}$$

It is well known that

$$\begin{aligned} \sigma_S &= \sigma_v \times \varepsilon_{S,v} \\ &= \sigma_v \times \left(\tfrac{\partial S}{\partial v}\tfrac{v}{S}\right) \end{aligned}$$

where σ_S is 1-year historical stock volatility. Substitute S from 4.1, the stock volatility can then be obtained

$$\sigma_S = \left(1 - \sum_{i=1}^{q} \lambda_i \frac{\partial W_i(S)}{\partial v}\right) \sigma_v \frac{v}{S} \tag{4.2}$$

The value of the firm and the firm volatility are obtained by solving 4.1 and 4.2 simultaneously.

4.3.1.2 Up and Down Factor of the Dennis-Rendleman model

As was pointed out by Dennis and Rendleman (2006), the binomial model will be normally distributed when the mean return equals the continuously compounded risk-free rate per binomial period minus half the variance of the logarithmic return per binomial period. Therefore, the value of u and d can be defined as $u = e^{ln(1+r)-\frac{1}{2}\sigma^2+\sigma}$ and $d = e^{ln(1+r)-\frac{1}{2}\sigma^2-\sigma}$,where r is the risk-free rate of interest per binomial period and σ is an estimation of the standard deviation of the daily logarithmic return to total equity.

4.3.1.3 Interest Rate Interpolation

The linear interpolation is used to obtain the interest rate at required maturity. For maturity less than one month, a linear line through one-month interest rate and three-month interest rate is plotted. The intercept point and the one-month interest rate point are then linearly interpolated to find the the needed rate.

4.3.2 Model Performance

4.3.2.1 Forecasting Error Statistics

This study employs two types of data, time series data and pooled data. Time series data is used to compare the general performance of each model . Pooled data is used to analyze further the model performance in the situation which warrants are in-the-money, at-the-money, and out-of-the-money. Pooled data is also used to examine the pricing errors with the model parameters.

For time series data of each company, the forecast errors generated from each model are compared by using the mean absolute error (MAE), the mean absolute percentage error (MAPE), and the root mean squared error (RMSE), which are defined as follows.

$$MAE = \frac{1}{n}\sum |MarketPrice - ModelPrice|$$

$$MAPE = \frac{1}{n}\sum \left(\frac{|MarketPrice - ModelPrice|}{MarketPrice}\right)$$

$$RMSE = \left(\frac{1}{n}\sum (MarketPrice - ModelPrice)^2\right)^{\frac{1}{2}}$$

For pooled data, only the MAPE is chosen to compare the performance of each model since it is normalized by the market price.

4.3.2.2 Test of Pricing Errors

Followed by the method that Huang and Chen (2002) use, two tests are performed as follows. Paired t-tests are applied to see if there is significant difference between the market price and the model price. They are also used to analyze the model performance for each moneyness situation. The Wilcoxon Sign-Rank test is conducted to test whether the forecast error statistics, which are MAE, MAPE, and RMSE, generated from each model are significantly different. The hypothesis testing for each test is as described in section 4.2.

4.3.2.3 Regression Analysis of Pricing Errors

To understand further the relationship between the pricing errors and the model input parameters, the percentage pricing errors are regressed on degree of moneyness, time-to-maturity, firm volatility, and risk-free rate of interest. The regression equation is given below

$$\frac{P_t^{mkt} - P_t^{mod}}{P_t^{mkt}} = \beta_0 + \beta_1 \left(\frac{v_t - K}{K}\right) + \beta_2 \tau_t + \beta_3 \sigma_{v,t} + \beta_4 r_t + \varepsilon_t$$

where P_t^{mkt} is the market price on day t, and P_t^{mod} is the model-based price on day t. If the models can capture all the input parameters, the coefficients ($\beta_0 - \beta_4$) should be insignificantly different from zero. If there is any pricing bias but it is not related to the model inputs, the intercept (β_0) should be significantly different from zero.