EMPIRICAL STUDY OF

BLACK-SCHOLES WARRANT PRICING MODEL

ON THE STOCK EXCHANGE OF MALAYSIA

by

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ABSTRAK

Kajian ini adalah untuk mengenalpasti setakat manakah ketepatan model penentuan nilai harga waran/ opsyen yang terkenal – model Black-Scholes – di bursa saham Malaysia. Dapatan kebanyakan kajian terdahulu (Rubinstein, 1981; Geske, Roll, & Shastri, 1983; Scott, 1987) terhadap model Black-Scholes adalah positif dan mendapati model ini berupaya meramalkan harga pasaran waran dengan tepat. Walau bagaimanapun, didapati ada juga kajian yang memaparkan kegagalan model ini (Macbeth & Merville, 1980; Lauterbach & Schultz, 1990). Model ini didapati terlebih menilai waran yang 'in-the-money' dan sebaliknya didapati terkurang menilai waran yang 'out-of-the-money'. Tujuan kajian ini adalah untuk menguji ketepatan and kegunaan model Black-Scholes ini di pasaran waran yang lebih kecil dan kurang cair – Bursa Saham Kuala Lumpur (BSKL). Kajian ini juga menimbangkan pelbagai kecondongan penentuan harga ke atas harga guna hak waran, tempoh matang waran, kemeruwapan harga, sebelum dan selepas krisis kewangan Asia. Kajian ini dijalankan dengan memerhatikan harga harian dari 74 waran sampel dalam tahun 1994-2003. Keputusan kajian ini medapati bahawa harga model adalah jelas sekali lebih kurang daripada harga pasaran dan seterusnya memaparkan kedua-dua harga model dan harga pasaran adalah berbeza secara bersistematik ke atas pelbagai kecondongan penentuan harga tersebut. Sebagai kesimpulan, pengguna model Black-Scholes perlu berhati-hati dan memerhatikan corak perbezaan harga secara bersistematik ini apabila memilih sesuatu waran untuk tujuan pelaburan di bursa saham Malaysia.

ABSTRACT

This paper addresses the question of how well the best-known warrant/ option pricing model – the Black-Scholes model – work in the stock exchange of Malaysia. Results of most studies (Rubinstein, 1981; Geske, Roll, & Shastri, 1983; Scott, 1987) have been positive in that the Black-Scholes model generates warrant values fairly close to the actual prices at which warrants trade especially for shorter term maturity warrants. Nevertheless, some regular empirical failures of the model have been noted (Macbeth & Merville, 1980; Lauterbach & Schultz, 1990). The Black-Scholes model tends to overvalue 'in-the-money' warrants and undervalue 'out-of-the-money' warrants. The objective of this paper is to test the warrant market behavior in relation to the application of Black-Scholes model to a relatively small and less liquid market – Kuala Lumpur Stock Exchange (KLSE). This study considered various pricing biases related to warrant strike price, time to maturity, volatility, and pre- and post-Asian financial crisis period. This paper has tested the model using daily prices of 74 sample warrants in the year 1994-2003. The results revealed that overall model prices were significantly below market prices and further indicated both the model and market prices deviate in certain systematic patterns as for the above various pricing biases. It was concluded that users of Black-Scholes model should carefully observe the systematic pattern of deviation when choosing an investment of warrants in the Malaysian stock exchange.

Chapter 1

INTRODUCTION

1.1 General Introduction

A warrant is an investment where the warrant issuer offers an option to the warrant holder, the right but not the obligation, to buy new ordinary shares from the issuer at a predetermined price at any point within this given time period. The definition of warrant is very close to that of a call option especially in term of valuation of its fair price where it is common to value warrants using option pricing models, such as Black-Scholes model. There are enormous empirical studies of Black-Scholes (BS) warrant pricing model that include Galai and Schneller (1978), Macbeth and Merville (1980), Rubinstein (1985), Geske, Roll, and Shastri (1983), Leonard and Solt (1990). The results in these studies regarding the applicability of the Black-Scholes model to warrant pricing are mixed. The Black-Scholes model is commonly found to perform as good as and is often more accurate than other warrant pricing model (Leonard & Solt, 1990). Nevertheless, some empirical failures of the model have been noted (Macbeth & Merville, 1980). General empirical findings revealed that the model tends to overvalue in-the-money warrants and undervalue out-of-money warrants. Somehow, the model probably brings forward a great impact to Malaysian equity warrant investors since it is widely used as equity warrant evaluator by local investment analysts. In order to answer the questions as to its applicability and reliability, this paper focuses on examining the market pricing behavior of listed warrants against fair value produced by the model. The empirical result of this study shall serve as evidence as to what extent the Black-Scholes model has performed on the stock exchange of Malaysia.

1.2 Problem Statement

Warrant is relatively more volatile as compared to its underlying share. To a certain extent, warrants offer better upside potential and tend to rise faster, in percentage terms, than their underlying share – the higher the gearing, the faster the price increases. However, in a bear market, everything works in reverse. Furthermore, the market for warrants in Malaysia is still small, hence warrants may be volatile and become targets for artificial rallies (Ariff, Chan, & Johnson, 1995).

Warrants is more complex as pertaining to its exercise price, conversion ratio, maturity date, exercise procedures, etc. The complex nature of warrants raise an important problem statement – what is the fair pricing of warrants? As for many uneducated investors, these are their principal disadvantages. Without a fairly workable warrant pricing model, investors may view this as an obstacle and stay away from warrant market.

Investors who have little grasp and understanding of the nature of warrants can rarely make good profit. Malaysian traded warrants are relatively new (since 1994) and many retail investors are not really well equipped with knowledge of warrant investment. As a result, retail investors can hardly make good profit or achieve their respective level of expected return.

Black-Scholes model is widely used by local researchers in Malaysia. Investors may over-relied solely on this model without referring to other common ratio and financial indicators. Wrong decision can be made while choosing a warrant investment.

Retail and institutional investors may also desire to find out whether the Black-Scholes model can provide a fairly accurate estimation for warrants with different length of maturity and degree of riskiness (volatility) of respective underlying shares, and for in-the-money versus out-of-money warrants. Moreover, investors may be interested to grasp the recent performance of the model after the Asian financial crisis (high-interest period) as compared to period before the crisis (low-interest period). This is to assist investors in making detail evaluation prior to choosing an investment.

1.3 Research Questions

From the above, general research question is raised as to whether the prices paid by investors in the market were fair prices should they be valued by the Black-Scholes model. The specific research questions can be summarized as follows:

1) Is the Black-Scholes model appropriate for pricing of the warrants traded on the KLSE?
2) Is the Black-Scholes model reasonably accurate for in-the-money versus out-of-the-money warrants pricing?
3) Is the Black-Scholes model more appropriate to value long-maturity warrants against near-maturity warrants?
4) Can the Black-Scholes model provide a fairer price for warrants with high underlying volatility, or low underlying volatility?
5) Does the Black-Scholes model work better during post-Asian financial crisis period compared to pre-Asian financial crisis period, particularly in Malaysia?

1.4 Research Objectives

The objective of this study is to address the above research questions. The questions are addressed by performing empirical testing on the performance of Black-Scholes model that commonly used for warrants traded in developed markets as applied to those traded on the KLSE. This focus of this empirical study is to compare the differences between actual market prices and BS model prices. Should the model performs poorly, this study will analyse all probable pricing biases rather than look into other alternatives. Probable pricing biases include warrant strike price, time to maturity, volatility of respective underlying share, and risk-free interest rate. The Black-Scholes model may over or under perform based on respective probable pricing biases. As a result, this study will find out whether the model and observed market prices deviate in certain systematic patterns as for the pricing biases.

1.5 Definition of Terms

For the purposes of this research, the following terms need clarification.

An Option. The right but not an obligation, to buy or sell a particular good at an exercise price, at or before a specified date.

Call Option. The right but not an obligation to buy a particular good at an exercise price.

Put Option. The right but not an obligation to sell a particular good at an exercise price.

Warrants. A long-term call options written on a specified number of ordinary shares by issuer company and traded on an organized exchange.

Call Warrants. A relatively new type of financial instrument introduced to the KLSE. A short-term call options (not more than 2 years) that can be issued by a

third party entity specified in the Security Commission guidelines based on existing shares.

Exercise Price or *Strike Price*. The fixed price at which the good may be bought or sold.

In the money. Gain from immediate exercise. Positive intrinsic value.

Out of the money. An option that is not worth exercising. Zero intrinsic value.

At the money. Where the share price is equal to the exercise price.

American Option. An option that can be exercised on any day up until its expiry date.

Pseudo-American Option. An option that can be exercised on a future specified date up to its expiry date.

European Option. An option that can be exercised on the last day of the option.

Premium. The cost of an option.

Black-Scholes Model. An option pricing model developed by Fischer Black and Myron Scholes to produce an expected value of a stock option, taking into account various factors like underlying share price and volatility, warrant exercise price and time to maturity, and risk-free rate.

1.6 Significance of the Study

The applicability of the Black-Scholes model to warrant pricing is an empirical issue. Although the model postulated by Black and Scholes (1973) has been widely tested in developed countries of the West and Japan, studies of the Black-Scholes model in emerging markets have been relatively scarce. Price inefficiency exists probably because of the market is under-researched, and not only because of the market is small, less developed, and less liquid (Ariff et al., 1995).

To date, these research questions pertaining to the performance of the model on KLSE remain unanswered. It is hoped that this study would contribute to the empirical literature on the valuation of warrants traded at the emerging markets, as well as stimulate further investigation in the valuation of warrants and other derivatives traded on KLSE.

According to Restaino and Andrew (2001), directors should understand the Black-Scholes model in order to determine the economic value of stock option in assessing and calibrating their own organization's stock compensation programs. In view of this, it is also hoped that the results of this study will be of value to directors and investors to understand the acceptability of Black-Scholes model in determining the economic value of stock option in Malaysia. As a result, warrant investors will not follow the model value blindly, as commonly advised by local financial analysts. In a nutshell, this study is expected to educate investors to have a better understanding of warrants as hedging, arbitraging, investing or speculative vehicle, in case of mispricing.

1.7 Organization of Remaining Chapters

The chapters in this study are organized in the following sequence. Chapter 1 provides the introduction, states the nature of problem and research questions that lead to research objectives. Chapter 2 reviews the relevant previous empirical research and highlights research gap in some warrant pricing biases, and describes the theoretical framework of this study and hypotheses to be tested. Chapter 3 explains the research methodology and statistical procedures in the study. Chapter 4

reports and analyzes the empirical findings for this study. Last but not least, Chapter 5 sums up the conclusion, states the limitation of the study as well as suggestions for future research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

A review of related literature is conducted to compare the knowledge of financial economists, compensation professionals, option traders, academics and other experts in the area of warrant pricing model evaluation, and assessment of BS model as to pricing of warrants. The review will serve as a method of comparing and contrasting the views of experts in the field, and to provide a conceptual framework for the study.

2.2 Practical Review

Warrants were first listed and traded on the Kuala Lumpur Stock Exchange (KLSE) in 1994. As at 31st June 2003, there are 183 warrants traded on the KLSE. Referring to *Figure 2.1* below, warrants have grown rapidly in terms of market capitalization and number of warrants listed.

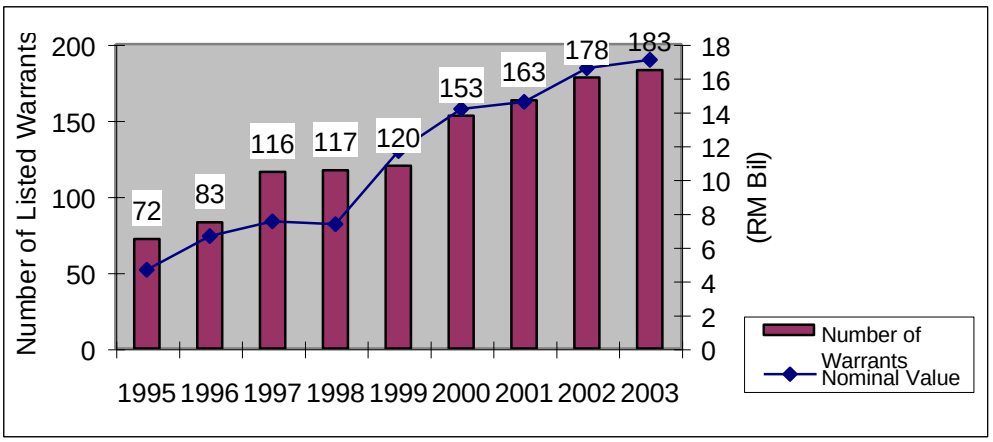

Figure 2.1. Growing number of warrants (Year 1995-2003).

(Source: *KLSE Daily Diary*)

The increasing popularity raises an important issue – what is the fair pricing for warrants? The Malaysian market is now in demand of a workable pricing model to guide investor in warrants investment.

2.2.1 Significance of the Model – Literature Context

Black and Scholes (1973) claimed that in many cases their famous model could be used as an approximation to give an estimate of the warrant value. The Chicago Board Options Exchange (CBOE), the first public options exchange, began trading in April 1973, and by 1975, traders on the CBOE were using the model to price and hedge their option positions. Since then, "thousands of traders and investors use the formula everyday", noted by the Nobel committee (Marsh & Kobayashi, 2000). It was widely used in those personal computer days that Texas Instruments sold a handheld calculator specially programmed to produce Black-Scholes options prices and hedge ratios.

Merton (1998) remarked that the influence of the Black-Scholes option theory on finance practice has not been limited to financial options traded in markets or even to derivatives generally. It is also used to price and evaluate risk in a wide array of applications, both financially and non financially. He further remarked that the publication of the option model in 1973 surely helped the development and growth of the listed options and over-the-counter (OTC) derivatives markets.

2.2.2 Significance of the Model – Malaysian Context

In the Malaysian context, Malaysia Derivatives Exchange Bhd (MDEX) and KLSE-RIIAM Information System (KLSE-RIS) has inserted a Black-Scholes

Option Pricing Model Calculator in their respective website for investors convenience in checking out BS price. KLOFFE (before MDEX) has become the first exchange to provide Black-Scholes Model calculator over internet in Southeast Asia, beginning 16th April 2001. Table 2.1 shows a list of local institutions that often apply the Black-Scholes Model to value Malaysian warrants and advise investors. The model brings forward a great impact to Malaysian equity warrant investors since it is widely used as equity warrant evaluator by local research institutions and securities firms.

Table 2.1

List of Local Institutions/ Publications that Apply Black-Scholes Model

TA Securities	RHB Research Institute
Kenanga Research	Affin Securities
AmSecurities	iCapital.biz
GK Goh Research	Malaysian Business
AMS Research	Dynaquest's Monthly Digest

(Source: *The Edge* and other local research articles)

One of the conditions for Securities Commission's (SC) approval for proposed replacement warrants is that the replacement warrants to be issued must be at a fair value based on the Black-Scholes valuation model. This has been done to Naluri Bhd and Minho (M) Bhd replacement warrants. As a whole, the application of the

Black-Scholes model in Malaysia is significance and hence the research questions pertaining to the applicability of the model should not be overlooked.

2.3 Empirical Test on Different Markets

There have been an enormous number of empirical tests on the Black-Scholes model. The size of the warrant or option market, and especially the difference in size between the U.S., Japan as well as emerging markets in Asia, and Malaysia in particular is interesting from the viewpoint of researchers. Empirical researches on call options traded on developed market in the U.S. include Macbeth and Merville (1980), Rubinstein (1985), Lauterbach and Schultz (1990), Leonard and Solt (1990), and Hauser and Lauterbach (1997). Macbeth and Merville (1980) and Rubinstein (1985) reported actual call option prices on the U.S. market tend to trade above their Black-Scholes values when the options are out-of-the money and below their Black-Scholes values when the options are in-the-money.

Kuwahara and Marsh (1992) investigated how well the prices of Euro-equity warrants issued by Japanese companies can be explained by the Black-Scholes model. They found similar pattern of discrepancies between Japanese equity warrant prices and Black-Scholes values to that was reported in previous studies (Macbeth & Merville, 1980; Rubinstein, 1985) of the performance of the Black-Scholes model in pricing U.S. stock options, at least over selected periods of time.

On the other hand, Huang and Chen (2002) have examined the performance of the Black-Scholes model applied to the valuation of covered warrants traded on the

Taiwan Stock Exchange (TSE) while Duan and Yan (1999) have investigated the market pricing of derivative warrants written on the HSBC common stock traded on the Hong Kong Stock Exchange. Interestingly, both Huang and Chen (2002) and Duan and Yan (1999) have empirically shown that the model underpriced the warrants in respective market. The conclusion reached in both of their papers seems inconsistent with the general empirical findings about the Black-Scholes model.

Empirical research on warrants traded on emerging markets in Southeast Asia include the work of Shastri and Sirodom (1995), who concluded that a constant elasticity of variance model outperformed Black-Scholes model in pricing Thailand warrants. Santoso (2000) has investigated empirically the relative performance of pricing models for warrants traded at the Jakarta Stock Exchange (JKX) and found out that the Black-Scholes and Dividend-adjusted Black-Scholes are doing equally well. For the most part, the results of the studies have been positive in that the Black-Scholes model generates option values fairly close to the actual prices at which options are traded. Nevertheless, different test results could have been produced in different markets.

2.4 Black-Scholes Model Assumptions

The version of Black-Scholes model is predicated based on a few simplifying assumptions (Black & Scholes, 1973).

I. The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus the distribution of possible stock price at the end of any finite interval is log-normal. The variance rate of the return on the stock is constant.

II. The short-term interest rate is known and is constant through time.

III. The option is "European", that is, it can only be exercised at maturity.

IV. The stock pays no dividend or other distributions.

V. There are no transaction costs in buying or selling the stock or the option.

VI. It is possible to borrow any fraction of the price of a security to buy it or to hold it, at the short-term interest rate.

VII. There are no penalties to short selling. A seller who does not own a security will simply accept the price of the security from a buyer, and will agree to settle with the buyer on some future date by paying him/her an amount equal to the price of the security on that date.

2.4.1 Do Black-Scholes Model Assumptions Hold?

Central to the Black-Scholes model is the assumption that the underlying stock price moves randomly, following a geometric Brownian motion process (Ariff et al., 1995). Kim, Oh, and Brooks (1994) argued that this would allow the price of an option to be computed from an estimation of the price variances of the underlying asset that can be readily obtained from the sample. However, Merton (1976) and Fortune and Peter (1996) found that the stock price distribution did not conform strictly to the normality assumption.

Fortune and Peter (1996) commented that the Assumption No II was adopted for convenience and not strictly true. However, this assumption was common to finance theory, for example it was one of the assumptions of the Capital Asset Pricing Model. Malaysian short-term risk-free interest, which is obtainable using 3-months Malaysian Treasury Bills yield, was reasonably flat since May 1999 until June 2003

(after Asian financial crisis) at the range of 2.65%-2.96%. However, the rate may fluctuate exceeding the range under certain market conditions.

Even though Malaysian equity warrants are pseudo-American where it can be exercised at any point within the time period or future period (as set out in Deed Poll) prior to its maturity, the European option assumption serves as the foundation in most of all options formula used today. Fortune and Peter (1996) explained the ability to focus on an European-style option for which the Black-Scholes model was designed would allowed us to ignore the potential influence of probable early exercise.

Some of the underlying shares do pay dividend or distribute bonus. However, prices of warrants and underlying shares, that are applied in Black-Scholes computational model, will be adjusted on ex-dividend dates by the amount of dividends paid, bonus issues or share splits in order to meet Assumption No IV and assist in price comparison.

Furthermore, the transaction costs in buying or selling the stocks or the warrants in Malaysia is very minimal. Referring to Table 2.2, KLSE clearing fees for on-market transaction (buying or selling) is only at 0.04% of transaction value. Also, there is no tax charged on any capital gains made upon the disposal of derivatives or securities in Malaysia. These have made the empirical study of Malaysian equity warrants pricing by using Black-Scholes model feasible.

Table 2.2

KLSE Clearing Fees

On-Market	0.04% of transaction value (payable by both buyer and seller) with a maximum of RM200.00 per contract. No minimum.
Direct Business	0.04% of transaction value (payable by both buyer and seller), with a maximum of RM200.00 and a minimum of RM10.00.
Institutional Settlement Service	RM25.00 - Non-Trading Clearing Member who issues an ISS Confirmation/Affirmation.

(Source: *KLSE Website, http://www.klse.com.my/website/trading/settlement.htm.*)

The Black-Scholes model is derived under the usual perfect-market assumptions, such as the securities are perfectly divisible and continuously tradable without transactions costs, taxes and restriction on short sales. Guo (1999) commented that should none of these assumptions were accepted, most of the finance theories would have to be rejected. Hence, the only possibility to challenge the Black-Scholes model is to argue the validity of its assumption on the underlying process.

The results in these studies regarding the applicability of the Black-Scholes model to warrant valuation are mixed. Leonard and Solt (1990), and Kremer and Roenfeldt (1993) concluded that the Black-Scholes model was commonly found to perform as well as more complicated alternative models for warrant pricing. On the other hand, Lauterbach and Schultz (1990), followed by Shastri and Sirodom (1995), and Hauser and Lauterbach (1997) presented empirical evidence that suggested the Black-Scholes model was outperformed by a model that assumed a constant elasticity of variance (CEV) diffusion process for stock price. However, Guo (1999) has commented the existing literature has not been conclusive on whether the Black-Scholes model, including all the alternative solutions, is wrong. Any theory

that gives best prediction consistently is the best theory, regardless of the assumptions required to generate them (Fortune & Peter, 1996).

2.5 Striking Price Bias

Black (1975) defined forward price equal to the strike price for at-the-money warrants and assumed that the current market price is the present value of the forward price. Nevertheless prior researches (Galai & Schneller, 1978; Hull & White, 1987) have suggested that the Black-Scholes model is a poor predictor of in-the-money and out-of-money options while it is a highly effective predictor of at-the-money options. Lauterbach and Schultz (1990) documented that the Black-Scholes model, as adopted for warrants, consistently misprices warrants – particularly out-of-money warrants. Black (1975) reported that the model systematically underpriced deep out-of-money options while it overpriced deep in-the-money options during the 1973-1975 period. Macbeth and Merville (1980) confirmed the existence of a striking price bias but contrary to Black's (1975) findings. Macbeth and Merville (1980) and Shastri and Sirodom (1995) reported the Black-Scholes model underpriced in-the-money options, overpriced out-of-money options, and gave an approximate and proper price for options at-the-money when the stochastic process that generating the stock price was a constant elasticity of variance process. Kuwahara and Marsh (1992) noticed the same pattern of discrepancies for Nikkei 225 options with those reported by Black earlier.

Shastri and Sirodom (1995) outlined the possible reasons for the model to underprice in-the-money warrants and overprice out-of-the-money warrants in that it did not properly incorporate the fact that market participants were not allowed to

short sell securities in Thailand. Otherwise, these discrepancies may be an indicator of an underlying stochastic process (volatility of the rate of return of the firm value) that differs from lognormal (Lekkas, 2002).

2.6 Time To Expiration Bias

Since warrants have much longer maturity than options, greater mispricing may be resulted from an incorrect assumption that stock price volatility is constant at historical level, and interest rate is known and constant over the life of the warrants. A distant expiration challenges the reasonableness of the Black-Scholes model. Perhaps Black and Scholes did not detect this longer maturity "bias" because in their study they used options at time of issue, when there were 6 months until expiration (Geske et al., 1983).

While Leonard and Solt (1990) analysed valuation errors for warrants, they categorized those warrant with time to expiration less than 2 years, between 2-4 years, and more than 4 years. They reported the Black-Scholes model tends to systematically undervalue out-of-money warrants with less than two years maturity. However, Ariff et al. (1995) investigated one of the very liquid call contract – Sime Darby of Stock Exchange of Singapore (SES) and found that the tests on difference between model and market prices were not highly significant throughout the period irrespective of the maturity or year of trading.

2.7 Variance Bias

Black and Scholes (1972) found that the market appeared to underestimate the effect of differences in variance rate on the value of an option. They reported the difference between the price paid by option buyers and the value given by the formula is greater for options on low-risk (variance) stocks than for options on high-risk (variance) stocks. They further found that using past data to estimate the variance has caused the model to overprice options on high variance stocks and underprice options on low variance stocks. Geske et al. (1983) demonstrated that these systematic "biases" should be expected when using the Black-Scholes model to value relatively shorter-term over-the-counter (OTC) options. Geske and Roll (1984) believed that non-stationary of stock volatilities could be a possible source for the variance bias.

2.8 Bias Reported in Different Time Period

Rubinstein (1994) found that strike price biases using the Black-Scholes model were statistically significant but the direction of the observed biases changed from one period to another. Black (1975) reported that the model underpriced deep in-the-money options using Chicago Board Options Exchange (CBOE) during the 1973-1975 period. Using CBOE data, MacBeth and Merville (1980) confirmed the existence of a striking price bias for the 1975-1976 period, but found that it was the reverse of the bias reported by Black (1975). Rubinstein (1985) also found that the striking price bias had reversed in the 1976-1977 period. Nevertheless, Rubinstein (1985) and MacBeth and Merville (1980) reported that the original striking bias observed by Black (1975) had reestablished itself in late 1977 and 1978. Using same market data, Whaley and Gray (1997) also found striking price,

time-to-maturity and variance biases for the period 1975-1978 but did not report on the reversal of the striking price bias.

The Asian financial crisis began in 2nd July 1997 when Thailand announced a managed float of the baht after using up $33 billion in defending the currency. Since then, Malaysian stock markets crumbled into a Composite Index level near 260 and appeared turbulence after the crisis (refer to *Figure 2.2*). Also, the yield on 3-month Malaysian treasury bills had been reduced from 6.76% (1997) to a low of 2.71% (1999). Duan and Yan (1999) divided their sample into two sub-periods with the data before and after 14th August 1997, to study the attributes of Black-Scholes model caused by the Asian financial crisis. They have found that the mean percentage errors (MPE) and mean absolute percentage errors (MAPE) after the financial crisis were particularly high. Furthermore, Ariff et al. (1995) considered the first 3 years since call options were introduced in the Stock Exchange of Singapore (SES) as learning period and found out that after the learning period (post-learning period) the market prices appeared to have converged to fair prices.

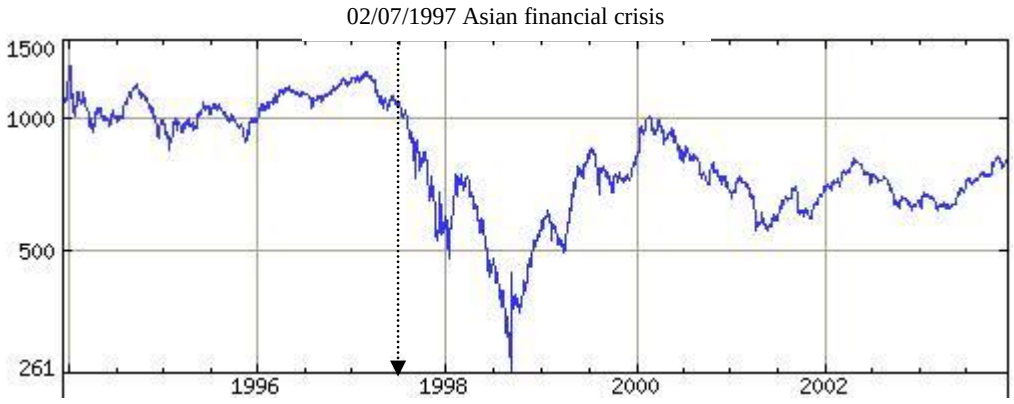

Figure 2.2. KLSE Composite Index showing turbulent market after 1997 Asian financial crisis (Year 1994-2003).

2.9 Theoretical Framework

Financial economists searched for years for a workable option-pricing model before the now famous Black-Scholes formula for valuing options published in 1973 by two financial academics, the late Fischer Black and Myron Scholes and co-developed by Robert Merton. Scholes and Merton shared the 1997 Nobel Prize in economics for their accomplishment. It is now widely used by options market participants.

2.9.1 Variables Affecting the Price of Warrants

The Black-Scholes model views the price of a warrants as a function of the time to expiration, the price of the underlying security, the exercise price, the risk-free rate of return, and the instantaneous variance of the security's return. The five main variables that influence the value of warrants are outlined in Table 2.3.

Table 2.3

Changes in Warrant Price against Variables Based on BS Model

Increase in	***Changes in Warrant Price***
Underlying Share Price	Increase
Exercise Price	Decrease
Volatility – σ	Increase
Time To Expiry	Increase
Risk-free Rate	Increase

The impact of the above variables on the value of the warrant can be seen by examining each variables of the Black-Scholes model. An increase in stock price today always increases the value of a warrant. Given that the exercise price of a warrant is fixed, any increase of the underlying share price should accommodate with an increase of the warrant price as a warrant's value in layman sense is equal to the share price minus the exercise price. On the other hand, if the share price is down under the exercise price and it is almost certain to expire without being exercised, its value will be near zero and effectively worthless.

Exercise price is fixed and does not change throughout the warrant lifespan unless it has a provision of step-up exercise price as set out in Deed Poll. A high (low) exercise price will reduce (increase) the fair value of a warrant. Volatility is a standard measurement of risk on the underlying shares and is the price movement of the underlying stock. Higher volatility indicates higher movement of the underlying share price (i.e. higher risk) and this potential upward price movement would induce higher prices for warrants.

The shorter the time to expiry, or called time decay, the lower the value of warrants. When the expiry date is soon approaching, the value of the warrants that approximately equal to the stock price minus the exercise price shall be near zero if out-of-money. This is because the warrant has less time to perform to breakeven or move into-the-money.

An increase in the interest rate or risk-free rate increases the value of a warrant. This is because an increase in interest rate will eventually increase the cost of fund carry and the warrants price must increase to cover the increased cost of carry.

2.10 Development of Hypotheses

There have been an enormous number of empirical tests of the Black-Scholes model. For the most part, the results of the studies have been positive in that the Black-Scholes model generates warrants values fairly close to the actual prices at which warrants trade. Nevertheless, some regular empirical failures of the model have been noted. Prior research (Galai & Schneller, 1978; Hull & White, 1987; Lauterbach & Schultz, 1990) have suggested that the Black-Scholes model is a poor predictor of in-the-money and out-of-money options while it is a highly effective predictor of at-the-money options. While Geske et al. (1983) demonstrated there are systematic variance biases when using the Black-Scholes model to value OTC options. Thus, the study is to test the applicability of the model to warrant pricing in Malaysia market. It can be examined by comparing the means of both market value and Black-Scholes value generally and re-grouped it according to different degree of moneyness, length of maturity, high-low variances, and pre- and post-Asian financial crisis to test its effectiveness respectively. As a result, the following alternate hypotheses are developed.

$H_{1,A}$: *The observed market value on all warrants ≠ The BS value on all warrants*

$H_{2(i),A}$: *The market value for in-the-money warrants ≠ The BS value for in-the-money warrants*

$H_{2(ii),A}$: *The market value for out-of-money warrants ≠ The BS value for out-of-money warrants*

$H_{3(i),A}$: *The market value for near-maturity warrants ≠ The BS value for near-maturity warrants*

$H_{3(ii),A}$: *The market value for far-maturity warrants ≠ The BS value for far-maturity warrants*

$H_{4(i),A}$: *The market value for warrants with high-variance underlying stocks ≠ The BS value for high-variance underlying stocks*

$H_{4(ii),A}$: *The market value for warrants with low-variance underlying stocks ≠ The BS value for low-variance underlying stocks*

$H_{5(i),A}$: *The market value on all daily price observations before Asian financial crisis ≠ The BS value on all daily price observations before Asian financial crisis*

$H_{5(ii),A}$: *The market value on all daily price observations after Asian financial crisis ≠ The BS value on all daily price observations after Asian financial crisis*

2.11 Summary

Results in these studies regarding the applicability of the Black-Scholes model to warrant pricing is mixed. Experts in the field of financial economics have acknowledged the importance of Black-Scholes model. The model is well known to be able to price at-the-money warrants quite fairly or about equal to the market prices especially for shorter-term maturity warrants. Leonard and Solt (1990), Kremer and Roenfeldt (1993) concluded that the model performs as good as alternative more complicated models for warrant pricing. On the other hand, there are some regular empirical failures and limitations of the model have been noted.

MacBeth and Merville (1980), Rubinstein (1985), Whaley and Gray (1997), and even Black (1975) himself have acknowledged the existence of striking price, time-to-maturity and variance biases in this model. From the above, the general null hypothesis is: There is no significant difference between the market value of warrants and the Black-Scholes value of warrants.