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行政院國家科學委員會專題研究計畫成果報告

模型誤差與市場不完美性對金融機構發行選擇權之影響:新興市場之分析

The impacts of model errors and market imperfections on the risk and return of financial institution writing options

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一、中文摘要

由於衍生性商品十分依賴理論模式來進行訂價及風險管理，發行選擇權之金融機構暴露於模式風險中，造成模式風險的主要因素包含模式定式錯誤，如報酬不符合常態分配，輸入參數(如波動性)之不可觀測性及因波動性預測錯誤而造成的避險誤差等等。本計劃針對台灣股票市場的電子、金融保險、塑膠等產業類股指數來進行模擬分析，模擬台灣認購權證發行環境以及發行券商可採行的因應策略，藉以瞭解認購權證之標的股票產業效應，對於發行環境限制及因應策略，與市場及模式風險之間的抵換關係。本研究亦將結果運用至匯率選擇權之發行。在模擬環境限制上，考慮發行失敗情境、交易成本與避險策略等重要市場特性因素；而因應策略包括：波動性加成、發行期間長度、到期日長度與發行時機。由於新興市場股票報酬有過於肥尾現象，且新興市場波動性誤差很大，探討在這些地區發行權證之模式風險是非常重要的。本研究對波動性加成、發行期間長度與發行時機等降低模式風險的可行方法在不同產業的標的物中的效用亦提出解析。本研究並提出一無母數迴歸之方法，運用局部線性核心迴歸(Local Linear Kernel Regression，LLKR) 來模式化模型誤差，進而提出並分析一個有降低模式誤差效能的半參數(semi-parametric)選擇權評價模式。

關鍵字：權證市場、模式風險、波動性預測、Up-and-out call

Abstract

This research uses the historical simulation approach to investigate the effects of market imperfections and model errors on financial institutions writing derivative warrants. The research undertakes specific exploration of the effects of particular market imperfections such as transaction costs and the primary market process. An understanding of model risk in the valuation and trading of derivative securities is particularly important for emerging markets. Simulation evidence shows that model risk is extremely significant for issuers of derivative warrants in emerging markets such as Taiwan. Whilst exploring possible remedial strategies for market imperfections and model errors, simulation evidence suggests that a search for a better pricing model for the Taiwan derivative warrants market is called for. This research model the error in BS model by applying a nonparametric regression function to further capture pricing error of call warrants in Taiwan. This research applied the local linear kernel regression (LLKR) method to estimate non-parametric regression function of the model error and a semi-parametric option pricing model is proposed.

Keywords: Model risk; Derivative warrants; Market Imperfections; Up-and-Out Call, Local Linear Kernel Regression

二、緣由與目的

Whilst derivative risks can be classified in terms of market risk, credit risk, operational risk and legal risk, the heavy use of theoretical models in the derivative industry inevitably involves an important new type of risk, model risk. The term 'model risk' relates to the risks arising from the use of a mis-specified model, incorrect inputs, or the misapplication of models due to an incomplete understanding of the limitations associated with a particular model (Figlewski, 1998; Simons, 1997). As financial institutions' derivative activities expand with the addition of further contracts and more complex derivative instruments, model risk can, in many circumstances, be substantial. In particular, derivative losses that are attributable to the misapplication of either derivative pricing or hedging models have been increasing in recent years. Falloon (1998) and Paul-Choudhury

(1997) provide many such examples of derivative losses arising from the improper application of models and challenges to market regulators. Derivative warrants have been traded successfully in the Taiwan stock markets recently, with the warrants being issued by independent financial institutions and listed on the Taiwan stock exchange (TAIEX). As noted by Crouhy, Gailai and Mark (1998) and Figlewski (1998), important sources of model risk for financial institutions writing options include model misspecification, unobservable input parameters and hedging risk. Model misspecification occurs when the underlying model for derivative trading is applied incorrectly, and model risk may be considerable if there are large estimation errors in terms of volatility.

The purpose of this research is to measure the effects of model errors and market imperfections on financial institutions issuing derivative warrants in emerging markets, where an understanding of model risk in the valuation and trading of derivative securities is of particular importance. Empirical evidence usually indicates that actual returns in emerging markets are too fat-tailed to be lognormal and volatility estimation errors tend to be considerable. In addition, market imperfections, such as transaction costs and issuance costs, induced by regulatory rules may also affect the risks and returns involved in writing warrants.

While the various sources of potential model risk and the effects of market imperfections are relatively easy to determine, their quantitative impacts are unknown. This research provides an extensive and systematic study of several aspects of the effects of Black-Scholes model error for financial institutions writing derivative warrants. First of all, simulation evidence is obtained on the risks and returns for financial institutions writing derivative warrants in Taiwan; this task is particularly important for the Asia-Pacific financial markets, because of the growing popularity of the derivative warrants market. Secondly, stock markets are largely characterized by frequent, sudden changes in variance. Model error stemming from the inaccurate estimation of volatility contributes significantly to overall risk, and since the option writer is exposed to the risk of losses that can greatly exceed the initial premium received, our results have important implications for risk management in emerging derivative markets. Thirdly, our historical simulation setup covers many important aspects of the derivative warrants market; for example, we include the effects of transaction costs and issuing failure effects in the primary market. Although the issuing failure effects not included in the traditional option pricing model are difficult to measure, the simulation evidence presented in this research provides their possible quantitative impacts. Furthermore, the simulation results provide useful information to support the design of strategies for volatility markup in pricing warrants for different maturities and degree of moneyness.

三、結果與討論

The simulation results show that the unhedged strategy is simply to sell the option at its model values, invest the proceeds at the risk-free interest rate, and hold the short position without hedging until maturity. Delta hedging is performed on a daily basis using the Black-Scholes model delta over the lifetime of the option. The results therefore reflect model error stemming from both inaccurate volatility inputs and model errors. Since there is no hedging, the theoretical mean return of writing call options should be negatively related to the expected return of the underlying stock index. Thus, a call-writing strategy without hedging should, in general, lose money. The standard deviation of the return on the one-year at-the-money (ATM) MSCI Taiwan stock index falls from 249.98% to 41.63%, and in the case of the electronics industrial index falls from 849.9% to 40.14%. Hedging not only reduces risk, but also the magnitude of the mean returns and the extent of the worst-case results. An interesting result is that the delta-hedged standard deviations of the four different indices are very close.

Whilst the option buyer's liability is limited to the amount invested, the option writer is exposed to the risk of losses that can greatly exceed the initial premiums received. The column labeled 'worst case' gives the figures for cases of extremely serious loss. These quantitative measures are thus useful for understanding stressful market conditions on the profit and loss of option writing. Without hedging, the worst case scenario in writing a one-year ATM call on the MSCI Taiwan index is a loss of 1243% of the initial premiums received, whilst delta-hedging limits the greatest loss to 221% of the initial premiums. The maximum loss of the at-the-money call on the electronics industrial index without hedging is 4829%, whilst that for a delta-hedged case is only 157%. The losses from writing call options on the electronics industrial index were exacerbated by the high-tech boom of recent years. In sum, the results demonstrate that extreme losses in call writing on a fast growing underlying asset can be severe if they are undertaken without hedging. Issuing call options on the electronics industrial index without hedging will generally produce serious losses with standard deviations equal to 2 to 4 times those of other underlying assets.

In general, the simulation results illustrate that option writing and delta-hedging positions using the most common valuation models involve exposure to considerable model risk. Hedging is much better than not hedging, although considerable risks remains. Even with delta hedging, the maximum loss is 220% of the initial premium received for the one-year ATM call option of the MSCI Taiwan Index. In the case of an out-of-money call, the situation is even worse. Model risk due to inaccurate volatility estimation contributes significantly to the overall risk. The recent 'value at risk' (VaR) risk management concept emphasizes the value of providing a single number summarizing the total risk in a portfolio of financial assets. Hence, in order to limit the maximum loss, an up-and-out call, which provides a stop-loss mechanism, may be issued instead of the plain vanilla call.

The Effects of Market Imperfections and Volatility Markup

Derivatives warrant issuers face the risk of issuing failure. Financial institutions are exposed to significant issuing risk; the risk that a sudden decline in underlying asset price causes loss in the initial hedge position. Clearly, there should be a higher proportion of issuing failures in out-of-money calls than in at-the-money calls.

The effects of primary market issuing failure on the risks and returns of writing warrants can be examined. Simulation results show that the probability of issuing failure decreases as the maturity of the contract lengthens. A comparison with the basic case shows that as the issuing process is included in the simulation design, the mean returns decrease for all cases whilst the standard deviations increase.

In general, at least 2% of the expected return of writing derivative call warrants is due to issuing costs. Since the simulation design includes the primary market process in this case, the differences in average returns and standard deviations represent the effects attributable to the primary market issuing process. Warrant issuers start their hedging at the time that they register for the issuance. Hence, the maximum loss is different from that of the basic case. In practice, the continuous rebalancing of a hedged portfolio is impossible because of transaction costs. The impact of transaction costs on the issue might be more severe when the underlying asset becomes bearish, because issuers have to sell off some of their delta-hedged positions. However, call writing may be profitable if the market is bearish, because of the high proportion of out-of-money expiration.

The results indicate a significant reduction in mean returns from writing derivative warrants when transaction costs and issuing costs are considered. The reduction in mean returns is close to 20% in the case of the daily delta-hedged method. Although positive average returns are observed for the basic model, the average returns are negative for all the underlying assets if the issuing risk and transaction costs are considered. Standard deviations increased, on average, by 10%. When transaction costs and issuing costs are considered, in the delta-hedge cases, the maximum loss is 290% of the initial premiums received for the one-year ATM call option on the MSCI Taiwan Index. The results are worse for shorter-maturity contracts.

In order to compare the risks and returns from issuing different warrant maturities, we presents the simulation results from writing 3-month, 6-month and one-year call warrants. We report the cases where transaction costs and the effects of failure in the issuing process are included in the simulation. A comparison across different maturities for a given underlying asset shows that writing shorter maturity contacts exposes the writer to higher risks and lower returns. Similar results hold for the three industrial indices, and for all indices, extreme loss is larger for shorter maturity period (three-month) contracts.

A practical procedure for writing a derivative warrant is to obtain the best available volatility estimation and increase it by a suitable amount to price the option. An appropriate volatility boosting strategy clearly enhances the mean returns of writing call options. At the same time, an increase in the volatility markup induces a higher probability of issuing failure. We also presents the average returns and standard deviation of writing call options on the MSCI Taiwan index for different volatility markup strategies. The simulation results thus provide useful information for designing a strategy for volatility markup. Comparing across maturities, we find that the number of issuing failures was highest for the short maturity contracts. Comparing the effects of volatility markup across different moneyness, we find that a higher percentage volatility markup is required for out-of-money calls. In general, writing short maturity contracts such as 3- and 6-month contracts tends to result in a higher proportion being in-the-money, indicating a general overreaction in the market index over 3- to 6-month periods. Hence, writing long maturity contracts with suitable volatility markup tends to produce sizable positive returns. Finally, this research applied the local linear kernel regression method to estimate non-parametric regression function of the model error and a semi-parametric option pricing model is proposed. The results show that substantial pricing errors was reduced by using the semi-parametric option pricing model.

四、計畫成果自評

This research contributes to the understanding of risk and return in writing warrants in emerging markets. We document the importance of the primary market process in warrant writing process.

Reliance on models to price derivatives, and to hedge and manage risk carries its own risks. An understanding of model risk in the valuation and trading of derivative securities is particularly important in the emerging markets. This research applies a historical simulation approach to investigate the quantitative impacts of model risk and market imperfections in the writing of warrants in emerging markets. Empirical simulation evidence drawn from the Taiwan stock market shows that model error can be quite high and can be expected to lead to significant risk in derivatives pricing and risk management.

The simulation results show that writing options and delta-hedging the positions using the common valuation models involves exposure to considerable model risk. Writing derivative warrants in emerging markets involves greater risk than those in developed markets, because volatility input error tends to be high in emerging markets. A key feature in the Taiwan stock market is that annual volatility of high-tech stocks is about 20% to 40% higher than that of other stocks. Although the volatility of different industrial groups in Taiwan tend to be different, if delta-hedged, the standard deviations of the returns of writing options on these indices are very close. Hedging is much better than not hedging; even so, considerable degree of risk remains. The maximum loss still accounts for two to five times the initial premiums received.

The simulation results also provide useful information for designing a strategy for volatility markup. In general, volatility mark up only increases the average return but not the risk of using it. One way to limit the loss is to issue an up-and-out call in which a stop loss mechanism is embedded. Chung and Lee (2000) investigated various strategies for reducing the model risk and market risk, for example, shortening the issuing period and issuing timing.

This research provides insights on the risk and return of writing options in emerging markets.

Researchers in the project have benefited from the understanding of derivative risk and the ability of applying the historical simulation methodology is enhanced.

The main research results were rewritten as two academic papers. One of the papers was presented in an international conference and was accepted to be published in an academic journal.

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